GENETIC EVALUATION OF GROWTH PERFORMANCE OF THE SAHIWAL CATTLE IN SEMI ARID KENYA

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A Thesis submitted to the Graduate School in partial fulfilment of the requirement for the Master of Science in Animal Production (Animal Breeding option) of Egerton University.

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DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not, wholly or in parts, been presented for the award of a degree in any other University.

Ms. S. A. Migose

Signed.....

Date.....06/10/2011.....

APPROVAL

This thesis has been approved for final submission with our approval as the University supervisors.

Prof. Dr. A. K. Kahi

Signed.....

Date.....06/10/2011.....

Dr. W. B. Muhuyi

Signed.....

Date.....06/10/2011.....

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DEDICATION

I dedicate this thesis to son Caleb; parents James and Jane; and siblings Sammy, Dan, Pauline and Mary.

Performance is a factor of both genetics and environment!

ABSTRACT

The Sahiwal breed has greatest potential for growth, milk production and reproductive efficiency in the tropics compared to other *Bos indicus* breeds. In Kenya, a breeding programme for improving productive and reproductive performance has been implemented at the National Sahiwal Stud (NSS). Data from NSS were used to genetically evaluate growth performance of the Sahiwal cattle through determination of environmental factors influencing growth, estimation of (co)variance components, genetic and phenotypic parameters and genetic, phenotypic and environmental trends for growth traits. The (co)variance components, genetic and phenotypic parameters were estimated using various univariate and multi-trait animal models based on a restricted maximum likelihood procedure (REML). The growth traits considered were: birth weight (BW, kg); weaning age at 42kg-weight (WA1, days; d), weaning age at 55kg-weight (WA2, d) and overall weaning age combining data from both weaning at 42kg and 55kg (WA, d); branding age at 125kg-weight (BA, d); preweaning daily gain to WA1 (DG1, g/d), preweaning daily gain to WA2 (DG2, g/d) and overall preweaning daily gain combining data from DG1 and DG2(DG, g/d); post weaning daily gain to BA(PDG, g/d); average daily gain to from birth to BA(ADG, g/d); and mature weight (24W, kg). Various environmental factors influenced growth performance at NSS. Direct heritability estimates from univariate animal model were, low. Heritability estimates from multivariate model were higher when compared to those from univariate analyses, the highest being BA. Genetic correlations between growth traits were high indicating that selection based on early growth performance measures would result in improved growth performance later as well. There was a decline in genetic, environmental and phenotypic trends for all growth traits except 24W over the years reflecting suboptimal selection and management decision. Although no substantial genetic progress has occurred, partly due to drought effect on performance, there is a strong genetic correlation between traits and multi-trait selection based on BA would lead to genetic improvement. Moreover, supplementary feeding during drought would cushion against the adverse environmental effects and allow for expression of full genetic potential.

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LIST OF ABBREVIATIONS AND ACRONYMS

18W	Weight at 18 months
24W	Mature weight at 24 months
ADG	Average daily gain from birth to branding age
AFC	Age at First Calving
AM	Animal Model
AMM	Animal Maternal Model
AMP	Animal Maternal model with Permanent environmental effects
ASAL(s)	Arid and Semi Arid Land(s)
BA	Branding Age
BLUP	Best Linear Unbiased Prediction
BV	Breeding Value
BW	Birth Weight
DFREML	Derivative Free Restricted Maximum Likelihood
DG	Preweaning daily gain
DG1	Preweaning daily gain to weaning age at 42kg
DG2	Preweaning daily gain to weaning age at 55kg
DPPW	Dam Post *Partum* Weight
EBV	Estimated Breeding Value
FAO	Food and Agricultural Organisation of the United Nations
KARI	Kenya Agricultural Research Institute
LR	Log Likelihood Ratio Test
MTM	Multi-trait models
NAHRC	National Animal Husbandry Research Centre
NSS	National Sahiwal Stud
PDG	Post weaning daily gain
PHS	Paternal half sib correlation
PROC GLM	Procedures of Generalised Linear Model
REML	Restricted Maximum Likelihood
RRM	Random Regression models
SAS	Statistical Analysis Systems

SEAZ	Small East African Zebu
SM	Sire Model
UM	Univariate Models
WA	Weaning Age
WA1	Weaning age at 42kg-weight
WA2	Weaning age at 55kg-weight
WW	Weaning Weight
YW	Yearling Weight
YA	Yearling Age

CHAPTER ONE

INTRODUCTION

The Sahiwal breed of cattle plays an important complementary role to other *Bos indicus* and small ruminants in the utilizations of available feed resources and acts as one of the practical means of utilizing rangelands; regions where crop production is almost impractical. In most tropical countries, sustainable breeding programmes cannot be guaranteed without the use of the adaptive indigenous cattle breeds, such as the Sahiwal (Trail and Gregory, 1981b; Cunningham and Syrstad, 1987; Islam and Bhuiyan, 1997; Muhuyi, 1997; Kahi et al., 2000a, b). Utilization of the Sahiwal in various pure breeding and crossbreeding programmes will continue to be important and this calls for maintenance of such programmes for evaluation, conservation and genetic improvement. Breeding strategies are therefore necessary to increase and sustain the productivity of this breed in such areas.

Genetic manipulation would be one of the most effective ways of improving productivity of the Sahiwal cattle because the resultant changes are permanent and transmittable to future generations. To effectively achieve this, a well-designed breeding programme is an important prerequisite. Development of such programmes should follow several logical and systematic steps that include definition of breeding objectives, development of selection criteria, performance and pedigree recording and genetic evaluations, selection of animals and design of appropriate mating systems (Kahi et al., 2004). Breeding objectives for various livestock species have been developed (Kosgey et al., 2003; Kahi and Nitter, 2004; Gicheha et al., 2005; Rewe et al., 2006; Bett et al., 2007). This has to be followed by genetic evaluation of these breeding objective traits (Ilatsia et al., 2007; Wasike et al., 2009). However, quantified genetic parameter estimates using appropriate analytical models are still scarce and selection of breeding animals is still based on phenotypic measures of performance and visual appraisal rather than more objective procedures such as Best Linear Unbiased Prediction (BLUP) estimates of breeding values.

Breeding programmes designed to improve the Sahiwal cattle have often included growth as one of the traits of economic importance whose genetic parameters would form an integral part of the selection index in addition to other productive and fertility traits (Ilatsia et al., 2007). During genetic evaluation, it is important to account for both direct additive and maternal effects and their interaction. This enhances the precision and accuracy of parameter estimates and ultimately improves on selection efficiency (Maniatis and Pollot, 2002; Rumph et

al., 2002; Campelo et al., 2004). Appropriate analytical models, such as the Animal model (AM), which have the capability of accounting for all sources of variations, would be ideal in such evaluations (Khan et al., 1999; Maiwashe et al., 2002; Mrode, 2005). However, breeding opportunities to improve productive performance of the Sahiwal breed may be limited because of inadequate information on the genetics of performance traits and lack of functional breeding and selection schemes. An efficient breeding programme for the Sahiwal breed would be one in which animals are selected for traits that influence profitability based on accurately estimated performance parameters.

Estimates of genetic parameters for growth performance of Sahiwal cattle have previously been presented (Rege et al., 1992). In that study a Sire model (SM) that assumed no relationship between the dams and that the sires were mated randomly to the dams was fitted. However, with regard to the mating structure at the National Sahiwal Stud (NSS), sires are usually assigned to particular dams. Furthermore, a SM cannot allow for estimation of maternal effects, a fact that would lead to potential overestimation of (co)variance components and ultimately genetic parameters (Wasike et al., 2009). Recently Ilatsia et al. (2007) presented genetic parameters for milk and reproductive performance of the Sahiwal cattle. However, the selection process at the NSS has traditionally been based on both milk and growth performance and therefore estimate of (co)variance components and genetic parameters for growth traits is equally important in order to design a selection programme that reflects the dual purpose role of this breed. Knowledge on genetic aspects of performance traits of Sahiwal cattle is important in development of sound and effective breed improvement programmes. In estimation of these parameters, the emphasis should be on making the best use of available data to enhance accuracy of estimation and use of appropriate analytical models.

1.1 Objectives

The main objective of this study was to genetically evaluate growth performance of the Sahiwal cattle under semi arid conditions in Kenya. The specific objectives were;

1. To determine factors influencing growth traits in Sahiwal cattle and obtain performance estimates for these traits.
2. To estimate (co)variance components, genetic and phenotypic parameters for growth traits in the Sahiwal cattle using various univariate and multi-trait animal models.

3. To estimate annual genetic, environmental and phenotypic trends for growth performance.

1.2 Hypotheses

H_0: Genetic and environmental factors do not influence growth performance of Sahiwal cattle.

H_0: Analysis models for estimating genetic, phenotypic and environmental parameters for growth trait in Sahiwal cattle are comparable.

H_0: Annual genetic, environmental and phenotypic trends for growth performance of the Sahiwal cattle at the NSS have been progressive over the implementation period of 40 years.

CHAPTER TWO
LITERATURE REVIEW

2.1 The Sahiwal cattle in Kenya

Attempts to develop an improved indigenous Small East African Zebu (SEAZ) for dairy production in a number of livestock improvement centres came to an unsuccessful end in 1939 when several Sahiwal bulls and cows were imported by the British colonial government from India and Pakistan (Meyn and Wilkins, 1974; Muhuyi et al., 1999). This marked the beginning and formation of the National Sahiwal Stud (NSS), a closed Nucleus herd, at Naivasha in 1962 and the start of a breeding programme for a Sahiwal dual purpose breed managed under extensive pasture conditions. Various other nucleus farms (mainly private, communal and government farms) and Maasai pastoral herds in Kajiado, Narok and Transmara districts act as conservation units where Sahiwal genetic resources are used for both commercial and subsistence purposes (Muhuyi et al., 1999). It was envisaged that genetic progress should be generated and transmitted from the nucleus herd. Pastoralists mainly use Sahiwal bulls for up grading of the SEAZ. The resulting progenies are mainly used as dam line due to their generally good maternal attributes which enhances calf growth and survival. The NSS is the main sources of breeding stock for these herds.

The Sahiwal stud also operates a crossbreeding programme where F1 Friesian x Sahiwal crossbreds are sold to smallholder farmers mainly in the high potential areas for dairy production. The breeding programme has been designed with the NSS as the top tier. In this set up, genetic gain is generated at the NSS and the resultant breeding bulls sold to the commercial ranches and pastoralists for both pure and crossbreeding. There is no movement of genetic material from the commercial herds into the NSS, although there is exchange of breeding animals among the other nucleus farms and pastoral herds. Details of the breeding plan have been described (see Mwandotto, 1985; Muhuyi et al., 1999). Initial selection of breeding bulls and replacement heifers is based on aggregate index combining dam's milk performance and own growth performance. A progeny testing programme is also in place where outstanding breeding bulls are selected based on milk and growth performance of their daughters managed under extensive grazing conditions with minimal supplementation.

2.2 Breeding, utilisation and conservation

2.2.1 Production systems

It is important to have a good understanding of production systems and the relative importance of the different constraints prior to initiating any genetic improvement programme. Characterisation of the production systems in which Sahiwal cattle are utilised and detailed economic comparison of these systems have been described (Muhuyi, 1997). In this study, three main systems were identified based on level of input and output, and on operational scale as; low input extensive beef and dual purpose production systems, where only beef and both milk and beef are the main production objectives, respectively. Low input extensive pastoral production systems where Sahiwal cattle and their derivatives are kept mainly for beef and subsistence milk production. Examples of herds where both milk and beef are the main production objective include the NSS, Olosentu farm, and government farms mainly owned by Kenya Agricultural Research Institute (KARI). Extensive beef production is mainly practiced at El'Karama ranch in Laikipia and Ilkerin group ranch both located in the semi arid parts of Rift Valley province.

There are a number of other Sahiwal herds with relatively smaller herd sizes which mainly specialise in production of Sahiwal crossbreds for sale to smallholder dairy farmers. These include Kilifi Plantation Estate in the low land coastal regions and various farms managed by KARI. There is some genetic relationship among these herds since most of them obtained their foundation stock from the NSS and have occasionally been using bulls from the stud. Unlike the NSS, most of the herds are characterized by inconsistent pedigree and performance recording which make joint evaluation of breeding stock difficult. This is attributed to the use of natural mating which makes pedigree recording difficult, and also due to the generally high costs associated with performance recording.

2.2.2 Conservation of Sahiwal cattle genetic resources

Sahiwal cattle genetic resources have evolved in harsh and diverse tropical environments and carry unique combinations of genes that define their productive and adaptive capabilities, which contribute to sustainable productivity in low input production systems. Policies in most developing countries have been aimed at promoting *Bos taurus* breeds and crossbreds because of their high production potential (Kahi et al., 2000a, b). However, such improved breeds often do not have the attributes required to enable them to fulfil the multifaceted roles they are

allocated in these systems. Concentration upon exotic breeds is likely to result in loss of such desired gene combinations that have enabled this breed to survive and produce under extreme circumstances. Conservation and sustainable development of these breeds would require a shift towards a broad focus on the many adapted breeds, such as the Sahiwal, that survive well in the low external input systems typical of the tropics (FAO, 1992). Therefore, Sahiwal cattle conservation strategies should involve deliberate human activities such as strategic planning and management, policy formulation and actions to be undertaken in order to ensure that the diversity of Sahiwal genetic resources is maintained so as to guarantee sustainable productivity.

Sahiwal cattle have, alongside other indigenous livestock species, facilitated the use of marginal lands which would be of no value for crop agriculture. Apart from the stated output functions, Sahiwal cattle genetic resources play other important and significant socio-economic and socio-cultural roles which include savings, insurance, accumulation and diversification of wealth as well as other socio-cultural roles related to status (Muhuyi et al., 1999; Joshi et al., 2001; Rege and Gibson, 2003; Scarpa et al., 2003; Mwacharo and Drucker, 2005; FAO, 2007). This specifically refers to their roles as capital investments among the pastoral communities, small scale herders yielding interests in the form of milk and meat products, and draught power. Just like other indigenous animal genetic resources in developing countries, they represent the only sustainable way of storing wealth, particularly in circumstances where financial systems to perform these functions are scarce, as is the case with most of the small scale and pastoral communities in the rural areas (Joshi et al., 2001; Rege and Gibson, 2003; Mwacharo and Drucker, 2005; FAO, 2007).

Conservation and multiplication of animal diversity has an intrinsic value in its aesthetic desirability (Wagner and Hammond, 1999; Rege and Gibson, 2003; Scarpa et al., 2003; Mwacharo and Drucker, 2005). This implies that, as part of animal diversity, the Sahiwal breed makes an important cultural contribution as an integral part of the community's life, in celebrations and other day-to-day customs, which has sustained communities and their life style over time (FAO, 2007). Any conservation efforts should therefore be viewed in terms of these values to communities that depend on the breed. In view of the environmental and disease loads in the tropics, only adapted breeds such as the Sahiwal can guarantee such purposes. Sahiwal cattle genetic resources could be exploited to deliver new levels of production and adaptability. Conservation and sustainable development of animal genetic resources requires a shift towards a

broad focus on the many adaptive breeds that survive well in the low external input agriculture typical of the tropics (FAO, 1992).

The reasons for ideal conservation strategies for this breed in the tropics range from economic, ecological, scientific and socio-cultural considerations (Rege and Gibson, 2003; Scarpa et al., 2003; FAO, 2007). Economic arguments for conservation of and sustainable use of Sahiwal genetic resources become an effective tool of gathering the necessary public and political support, including development of appropriate policies. Rege and Gibson (2003) and Scarpa et al. (2003) have summarised some of the important task that need to be performed to ensure continuous utilisation and conservation of animal genetic resources. These recommendations would be extended for Sahiwal cattle in the tropics and should include assessing the economic contribution that the Sahiwal cattle make to various communities and provide economic arguments to help evaluate cost and benefits of conserving this important genetic resource; evaluation of alternative strategies and action plans that might be instigated in each of the countries to improve and conserve these valuable genetic resources; and developing economic incentive to support conservation by individual farmers or communities.

2.2.3 Constraints to conservation and genetic improvement of the Sahiwal cattle

Breeding opportunities to improve productivity and conservation efforts of the Sahiwal breed may be limited because of inadequate information on the population structures, lack of formal breeding objectives and lack of structured breeding and selection schemes. Most breeding programmes do not show clear evidence of selection decisions supported by formal breeding goals. This has the danger of resulting in little or no benefits from breeding efforts, suboptimal selection decisions and low economic returns which would eventually lead to wasted breeding opportunities and conservation efforts. The existing goals are more informal and ignore the functional traits that have defined the uniqueness of the Sahiwal breed under low input production systems. The need to have breeding goals that define the economic viability of the breed cannot therefore be overemphasised. Such breeding goals should be followed by performance evaluation of goal traits.

Efforts have been made to estimate genetic and phenotypic parameters for Sahiwal cattle in the tropics based on a wide range of models (Table 2). However, there are no well organised breeding schemes for dissemination of genetic superiority. Even in situations where various herds corporate, the technical details on the genetic efficiencies as well as the economic benefits

of such organisations are not clearly stated (Muhuyi et al., 1999). Financial support and appropriate expertise to run the genetic improvement programmes have also constrained the achievement of genetic gains and sustainable utilisation and conservation of the Sahiwal genetic resources. Lack of financial commitment of the government to support research, production and marketing of local breeds and their products in order to perpetuate the breeding and eventual conservation of the animal genetic resources in general is also lacking (Ojango et al., 2002).

2.3 Performance of the Sahiwal breed, other *B. indicus* breeds and their crosses

2.3.1 Traits of economic importance

Sahiwal cattle are generally classified as dual purpose where the production objectives are driven by milk output, growth and reproductive efficiency. Therefore most selection programmes strive to increase milk yield and high sale weights (Kimenye, 1978; Trail and Gregory, 1981a; Maule, 1990). Other than milk production and reproductive efficiency, high production depend on the growth productivity of the herd which are determined by weight of animal at a particular age (e.g. birth weight, weaning weight and mature weight or sale weight) as well as growth rates at particular periods during the growth trajectory. In some cases, ages at weighing rather than weights at certain ages have been used to describe growth.

Economically important traits will be determined by the breeding objective of the production system. In dual purpose production systems, fertility, growth and milk yield would form part of the traits of economic importance. While growth traits determine the overall calf crop from the herd and are good indicators of the quantity of beef that will be availed for sale or slaughter, birth weight and preweaning growth rate primarily determine calf survival (Rege et al., 2001). Low birth weight and preweaning gains lead to high preweaning calf mortality, slow preweaning growth rate and low subsequent weights due to the high genetic correlation. Other traits such as draught power which are highly correlated with growth and weight have also been used as guide in the culling process (Muhuyi et al., 1999). Moreover, correlated traits such as age at first calving (AFC) is highly influenced by growth rate and preweaning weights and faster growth rate and heavier preweaning weights would result to younger AFC. Survival traits such as survival rates are particularly important in small herds as witnessed for the Sahiwal. High survival rates would ensure regular supply of replacement heifers and also provide males for sale as breeding stock. Low survival rates leads to loss of good combination of desirable genes and reduction in intensities of selection and hence reduced annual genetic turnover.

Although the locally adapted *B. indicus* breeds in developing countries commonly show low absolute production figures, the Sahiwal is known to have the greatest potential for both milk and growth traits (Rege et al., 1992; Mwandotto, 1994; Singh and Nagarcenkar, 1997; Dahlin et al., 1998; Khan et al., 1999). Table 1 summarises mean performance estimates for various growth traits of some tropical breeds including Sahiwal cattle and its crosses in the tropics. There are differences in performance in most of the traits both within and between the breeds and the countries. The differences in estimates observed is a clear indication that there is phenotypic variation in most growth traits that can be exploited to increase performance. Low weaning weight is an indication of productive inefficiency. This would lead to wastage of breeding opportunities as a result of longer age at first calving and reduced productive life of the herd. Furthermore, most selection programmes for the Sahiwal cattle in the tropics put much emphasis on selection for milk yield with little consideration for optimal growth performance. This would result in sub optimal productive efficiency as a result of suspected negative correlation between growth and milk traits (Ilatsia et al., 2007). The need to include growth traits in the breeding objective is critical. Improvement in growth could also be achieved through culling of cows that fail to attain desirable weaning weight; herd management strategies such as proper feeding and disease control. A faster growth rate is usually required for increased productivity. For the Sahiwal cattle in the tropics, this would permit greater selection intensity because of more replacement stock and thus an increase in the annual rate of genetic gain.

Performance differences between countries is expected because of the inherent differences that exist in production circumstances, climatic conditions and management practices including quantity and quality of nutrient resources available (Rege et al., 1992; Dahlin et al., 1998; Khan et al., 1999; Ilatsia et al., 2007). The differences mainly result through nutrition, health related and management practices both within herds and across countries. The observed variation in mean performances on most of the production traits is due to great inter annual variation in climate resulting in poor pasture quality and availability and lack of feeding and high disease incidence which is typical of most tropical countries. Acceptable levels of management tend to increase performance on production traits. Therefore, any strategy targeted towards these areas should be able to realise substantial improvement. Furthermore, selection strategies for the Sahiwal breed differ among countries in the tropics; in essence, this would affect the responses to selection for growth traits, hence resulting in a variance of performances. To improve growth performance of Sahiwal cattle, there is a need for sound management and

genetic improvement strategies to be done concurrently rather than in isolation from one another.

Table 1. Growth performance of the *B. indicus* breeds and their crosses with European breeds in the tropics

Genotype[a]	Trait[b]							Country	Source
	BW	WA	WW	YW	18W	DG	PDG		
Sahiwal	22.7							Kenya	Meyn and Wilkins (1974)
"	24.7	240	170					"	Trail and Gregory (1981b)
"	22.9	90	56			340	410	"	Mwandotto (1985)
"		240	146		200			"	Mwandotto et al. (1988)
"	22.7	98	55	125				"	Rege et al. (1992)
"	29.5	128	92			492		"	Kahi (1995)
"	21.0		56			254	491	"	Muhuyi et al. (1999)
"	21.6			130				Pakistan	Khan et al. (1999)
"			228					South America	Cundiff (1984)
SXA	30.3		208					Kenya	Trail and Gregory (1981b)
"	29.6	127	92			496		"	Kahi (1995)
SXZ	19.2	240	92					"	Trail and Gregory (1981b)
"		240	123		177			"	Mwandotto et al. (1988)
"	20.4	365	121	121		281		"	Muhuyi et al. (2000)
SXH			181		271			Australia	Laing and Taylor (1982)
"			123					Australia	Deland and Rowe (1981)
"			177					Australia	Newman et al. (1990)
SXF		240	154		225			Kenya	Mwandotto et al. (1988)
SXB	31.2	127	92			484		"	Kahi (1995)
SXBXA	30.9	127	92			485		"	Kahi (1995)
SXP	21.4							Bangladesh	Bhuiyan et al. (1998)
Boran		240	170					Kenya	Trail and Gregory (1981b)
"		240	141		190			"	Mwandotto et al. (1988)
"	28.0		185	145	179			"	Wasike et al. (2009)
"	24.0	253	169	192				Ethiopia	Haile-Mariam and Kassa-Marsha (1995)
"	28.0	270	151					Kenya	Indetie et al. (2000)
"	27.0		114			415	262	Tanzania	Said et al. (2001)
"	25.0	180	98	138				Ethiopia	Demeke et al. (2003)
SEAZ		240	108		148			Kenya	Mwandotto et al. (1988)
Nelore	28.8		155	216				Brazil	Eler et al. (1995)
Brahman	30.0	205		269				Venezuela	Plasse et al. (2002)

[a]SXZ = Sahiwal-Zebu cross; SXA = Sahiwal-Ayrshire cross; SXP = Sahiwal-Pubna milking cow cross; SXH = Sahiwal- Hereford cross; SXB = Sahiwal-Brown Swiss cross; SXBXA = Sahiwal-Brown Swiss-Ayrshire cross, SXF = Sahiwal-Friesian cross

[b]BW = birth weight (kg); WA =weaning age (d); WW = weaning weight (kg); YW = yearling weight (kg); 18W = 18month weight (kg); DG =preweaning daily gain; PDG = post weaning daily gain

2.3.2 Environmental factors influencing growth performance in cattle

Production environment and its influence on growth performance are very important for the development of sound and effective management improvement programme. Differences in production environment in terms of management strategies in feeding and health contribute to variation in growth performance within a breed (Mwandotto et al., 1988; Lunstra and Cundiff, 2003). The environmental factors that affect production and can be classified into definite class levels are referred to as fixed effects (Mrode, 2005). They include differences in production requirement e.g. sex and environment such as year and seasons. Sex is normally included as fixed effect since the different physiological nature of the males and females requires that they be treated differently. Continuous effects are those sources of variation which vary continuously with the variable and cannot be put into definite class levels. They include dam and animal weights or ages at weighing among others. The significance of these effects however depends on the differences in classification of factors into class levels, data and population structure, which influence the distribution of the observations among the fixed effect classes (Maniatis and Pollot, 2003). The impact of environment and herd management on trait expression requires that these factors are corrected for by describing the environment from which the data originated (van Bebber et al., 1997).

Significant effect of sex has been reported for growth traits (Rege et al., 1992; Kahi, 1995; Khan et al., 1999; Wasike, 2006). The effect of sex on growth performance of calves is caused by the interplay of hormones in the different sexes resulting to differences in growth rates (Mwandotto, 1985). This phenomenon persists and is pronounced at puberty where the hormonal production is high (Mwandotto et al., 1988; Wasike, 2006). The difference in growth pattern by sexes is important when determining the feed intake especially for the preweaning of artificially reared calves. If not considered, heavier, fast growing male calves might be underfed thereby reducing their growth potential. Non-significant sex effect could only mean reduced growth rate of males due to inadequate feed availability (Mwandotto, 1985).

In tropical environments where production depends on pasture, year and season become important due to their direct and indirect influence on pasture and nutrient availability. Feeds are available during times of the wet season and scarce as the dry season nears its end. These lead to slow weight gain or even negative gain during the dry seasons with compensatory growth occurring during the wet season (Burrow, 2001; Demeke et al., 2003; Wasike, 2006). However,

disease and parasite increase coincides with wet season lowering the growth rate (Rege et al., 1992). The breed differences in their ability to utilise poor quality feeds, appetite, drought resistance and feed energy requirement for maintenance results into variation in performances with seasons (Lunstra and Cundiff, 2003). High year-season interaction significance and large influence on growth traits indicates lack of uniform seasonal effects across the year (Mwandotto, 1994). However, non significant effect of year- season on growth traits have been attributed to supplementation to buffer the effects of fluctuation in feed availability (Muhuyi et al., 2000). Besides, in artificial rearing, calves are fed uniform amount of milk thereby eliminating the effects of season (Rege et al., 1992).

Significant effect of dam age, sometimes considered as parity, on growth traits is due to the relationship between the nutritional demand for development and maintenance and the level of cow maturing and uterine development of the dam at calving (Rege et al., 1992). Mature cows with fully developed mammary glands normally give birth to heavier calves. Cow weights and maturity increase with parity reaching a maximum at seventh parity (Mwandotto, 1994). Lack of significant effect of dam age on post weaning traits could be due to the diminishing maternal influence post weaning. Dam weight post partum (DWPP), that is, the weight of the dam immediately after calving, normally indicate the nutritional condition of the dam during the last stages of pregnancy and at birth and this will have an effect on the weight of the calf at birth. Weight of dam however depends on the level of maturity.

2.4 (Co)variance components

Genetic variation is an important aspect in any selection process (Falconer and Mackay, 1996). The actions of individual genes are largely unknown and hence the non discrete nature of genetic effects on growth traits has necessitated the use of quantitative methods to analyse and partition the phenotypic variance into three main components namely, direct additive variance, maternal additive variance and residual error variance (Mrode, 2005). (Co)variance components vary across populations and this depends on changes in gene frequency, previous selection, environment and past history of the population. Model specific genetic analysis is important to avoid overestimation of genetic parameter estimates (Gutierrez et al., 1997; Campelo et al., 2004; Meyer, 2005). Precise and accurate estimates of variance components are important in the planning of a sound breeding programme by improving the efficiency of selection thus enhancing optimum progress from a selection programme. Estimation of variance components

of growth traits by fitting different models has been conducted and results published (Eler et al., 1995; Gutierrez et al., 1997; Khan et al., 1999; Maiwashe et al., 2002; Demeke et al., 2003; Campelo et al., 2004; Wasike et al., 2009). However, estimates based on such recent models for Sahiwal cattle populations in the tropics are still limited.

2.4.1 Additive direct variance

This is the proportion of the genetic variance that is attributed to an individual's own genes (Falconer and Mackay, 1996). It determines the direct heritability estimate of a particular trait. Medium additive genetic variance suggests that selection from it will result to genetic gain (Mrode, 2005). Additive genetic variance is affected by breed, population history, environment, model as well as data structure and size (Falconer and Mackay, 1996). Breeds with higher phenotypic expression will automatically show higher additive genetic variance (Meyer, 1992). Small population have low heritability than large population while highly selected population will have low genetic variance compared to unselected population (van Dyk et al., 2001). More reliable environmental conditions reduce genetic variation while more measurements on individuals tend to increase the variance. Models that account for maternal effects reduce the component of variance that is due to direct additive effects (Maniatis and Pollot, 2002; Campelo et al., 2004). The data structure and pedigree information influences the correlation between direct and maternal genetic effects thus affecting the additive genetic variances (Maniatis and Pollot, 2003).

2.4.2 Additive maternal variance

These are the effects the animal derives from its dam (Mrode, 2005). Maternal variance is affected by similar factors as additive direct variance, in addition to individual age. Maternal variances are particularly important in early stages of growth but decline with age (Meyer, 1992; Khombe et al., 1995; Dodenhoff et al., 1998; Rumph et al., 2002). Accounting for maternal effects results in reduced direct variance because the maternal variance is lumped with the residual error variance thus increasing the phenotypic variance (Ferreira et al., 1999; Maniatis and Pollot, 2002; Campelo et al., 2004). Fitting models that account for maternal effects result in direct-maternal covariance which is due to the interaction of the two genetic effects. The direct-maternal covariance, if not accounted for, have a tendency of increasing the components of variance which is environmental thus lowering direct and maternal variance estimates (Ferreira et al., 1999; Maniatis and Pollot, 2002).

2.4.3 Residual error variance

All other factors whose sources of variation cannot be accounted for in the analysis are summed up as residual error variance. These include gene interactions (dominance and epistasis) and the random environmental effects (Mrode, 2005). This portion of variance is important since it indicates the accuracy and reliability of estimates and is however treated as heterogeneous since measurements are taken at different times (Mackinnon et al., 1991; Burrow, 2001). Residual variance is influenced by the model and structure of the data and its value will be inflated when the data has missing records and several outliers or if environmental effects are not accounted for (Ferreira et al., 1999; Maniatis and Pollot, 2003).

2.5 Genetic and phenotypic parameters

Genetic and phenotypic parameters are ratios of (co)variance components and they include heritability (direct and maternal), repeatability and correlation (genetic and phenotypic). These parameters are important animal breeding tools since they act as a guide in designing selection criteria and are used in prediction of expected genetic gain from a particular breeding programme. These estimates vary depending on population history, environment, method and model of analysis, breed, sex as well as data size and structure (Falconer and Mackay, 1996). Therefore it is important to get specific estimates that reflect these factors so as to help in enhancing accuracy of selection, prediction of response, and expected genetic gain from a selection programme.

Heritability is the proportion of phenotypic variance that is due to heredity. It is the regression of the genetic variance on the phenotypic variance (Falconer and Mackay, 1996). Knowledge of heritability is the basis of selection since it expresses the proportion of total variance attributable to genes and therefore determines the degree of resemblance. Heritability plays a major predictive role of reliability of the phenotypic values as a guide to the breeding value (Falconer and Mackay, 1996). It determines the performance of the next generation by measuring the degree of correspondence between phenotypic variance and breeding value. Productive traits like growth traits have low to medium heritability (Table 2). Response to selection depends on the magnitude of heritability and traits with high heritability are expected to have high response to selection. Potential for genetic improvement is largely dependent on the heritability of the trait and its genetic relationship with other traits of economic importance upon which selection pressure is applied.

Correlation is the degree of association between variables and is derived as the standardised covariance between two variances (Falconer and Mackay, 1996; Bourdon, 2000). Correlation is either positive or negative implying positive and negative relationship and it is further partitioned into phenotypic, genetic and environmental correlations to reflect the corresponding sources of the relationship (Mackinnon et al., 1991). Correlations are importance since they measure the relationship between animal performances among traits, the breeding values and management levels between environments thereby aiding in prediction of indirect response to selection in one trait due to selection in another. The correlation parameters are needed in order to determine the optimal weighting index of the breeding objective and response to multiple trait selection. Additive genetic correlation between traits (r_a) e.g. between BW and WW or WW and YW measures the degree of genetic association between the two traits while maternal genetic correlation (r_m) on the other hand measures the maternal influence on the relationships of the two traits. On the other hand, correlation between direct and maternal effects (r_{am}) measures the degree of association between individual direct gene effects and those from the dam. Phenotypic correlation (r_p), which is a between trait correlation, measures the relationship between animal performances among traits.

Table 2 shows some estimate of genetic parameters (heritability and repeatability) estimates obtained by fitting various models for indigenous cattle in the tropics. The efficiency of a Sahiwal cattle improvement programme will depend on selection based on accurate estimates of genetic and phenotypic parameters. Such estimates are important in prediction of genetic merit of breeding cows and bulls and are also determinants of genetic progress (Choudhary et al., 2003; Banik and Gandhi, 2006; Ilatsia et al., 2007). These parameters are also important for the identification of easily measurable biological characters in the animal that are strongly correlated to breeding objective traits and can be used as selection criteria. Population and environmental specific estimates obtained by appropriate analytical models are desirable and would be more appropriate in the design of future Sahiwal cattle breeding schemes in the tropics.

Differences in the parameters estimates are evident (Table 2). This would be expected because of differences in selection and herd management policies which vary greatly between herds; differences in environment and climatic conditions; and the type of models and structure of pedigree information used in the analyses. For example, while selection policies in Kenya put

emphasis on both improved milk and growth performance (Rege et al., 1992; Mwandotto, 1994; Ilatsia et al., 2007), the primary objective in India and Pakistan is improved lactation milk yield (Singh and Nagarcenkar, 1997; Dahlin et al., 1998; Joshi et al., 2001). This in essence would result in differences in the additive genetic variance for these traits. Nevertheless, the medium to high heritability estimates for growth traits offers opportunities to improve these traits through selection. The additive genetic variances for growth traits are generally low to medium resulting in low to moderate heritability estimates (Table 2.) This shows that growth performance is to a large extent attributed to high phenotypic variance arising from environmental and other herd management variations than genetic factors. Therefore improvement of these traits could be achieved through management intervention which includes proper feeding and disease control. Notwithstanding the low additive genetic variance for growth traits, more progress in these traits could also be achieved through selection policies such as culling cows that do not achieve the desired weaning weight, by culling heifers with extended AFC or by selecting for higher body weight at one year of age in heifers (Khan et al., 1999; Ilatsia et al., 2007). If this scheme is strictly followed, growth traits are expected to improve and this would prevent growth from decreasing when selection is for higher yields. In essence, estimate of genetic and phenotypic parameters for growth using accurate and precise models for Sahiwal cattle are rather scarce in literature. The ratios of variance and covariance components are what constitute the genetic and phenotypic parameters.

Table 2. Estimates of genetic and phenotypic parameters for growth traits of indigenous cattle in the tropics

Trait$_1$[a]	Trait$_2$	Breed	Model[b]	Parameter estimates[c]							Country	Source
(kg)	(kg)			h^2_2	m^2_2	c^2	$r_{a(1,2)}$	$r_{m(1,2)}$	$r_{p(1,2)}$	r_{am2}		
BW	BW	Sahiwal	PHS	0.21							Kenya	Mwandotto (1985)
"	WA	"	"	0.20							"	"
"	YW	"	"	0.16							"	"
"	BW	"	SM	0.35							"	Rege et al. (1992)
"	WA	"	"	0.35							"	"
"	BW	"	AMM	0.21	0.04					-0.14	Pakistan	Khan et al. (1999)
"	YW	"	"	0.08			0.09		0.85		"	"
"	BW	Boran	AM	0.26							Ethiopian	Haile-Mariam and Kassa-Marsha (1995)
"	"	"	AMM		0.09						"	"
"	"	"	AMM	0.14	0.07					0.47	"	Demeke et al. (2003)
"	WW	"	"	0.07	0.03		0.07				"	"
"	BW	"	AM	0.34							Kenya	Wasike et al. (2009)
"	WW	"	AMM	0.12	0.14	0.16				-0.25	"	"
"	YW	"	"	0.19	0.34	0.04				-0.58	"	"
"	BW	Bonsmara	"	0.32	0.13					-0.44	South Africa	Maiwashe et al. (2002)
"	WW	"	"	0.25	0.18		0.45	0.30		-0.54	"	"
"	YW	"	AM	0.12	0.01						"	"
BW	BW	Nelore	AMM	0.29	0.08					-0.38	Brazil	Eler et al. (1995)
"	WW	"	AMP	0.14	0.17		0.23	0.21	0.15	-0.13	"	"
"	YW	"	"	0.17	0.12		0.16	0.18	0.14	-0.13	"	"
WW	"	"	"				0.74	0.84	0.70		"	"

[a]BW = birth weight; WW = weaning weight; YW = yearling weight; 18W = 18 months weight.

[b]AM = Animal Model; AMM = Animal Maternal model; AMP = Animal Maternal model with Permanent Environmental effects; PHS = Paternal Half Sib model; SM = Sire Model.

[c]h^2_2 = additive direct heritability of trait 2; m^2_2 = maternal heritability of trait 2; c^2 = permanent maternal effects; $r_{a(1,2)}$ = additive genetic correlation between Traits$_1$ and Trait$_2$; $r_{p(1,2)}$ = phenotypic correlation between Traits$_1$ and Trait$_2$; $r_{m(1,2)}$ = maternal genetic correlation between Traits$_1$ and Trait$_2$; r_{am2} = additive-maternal correlation for Trait$_2$.

2.6 Models for genetic evaluation of growth performance

Growth data is generally composed of repeated traits. The characteristics of repeated traits are that they are functions of time where observations at each age point could be considered as distinct traits and traits measured at each age are highly correlated i.e. longitudinal traits or age dependent traits. Thus repeated observation or longitudinal data can be described by a curve or as a function of age. Mathematical models using non linear functions like Gompertz have been used to analyse growth curves (Lewis and Brotherstone, 2002). However, these models do not take into consideration the genetic relationship among animals and therefore it is problematic to quantify genetic merit between animals. Animal models have therefore been used to analyse growth performance in cattle, generally described as a series of traits each represented by weights at some predefined range of age resulting in landmark ages (Table 2). These are treated as single traits using univariate models (UM) or as multiple traits using multi-trait models (MTM). However, more recently advanced models like random regression models (RRM) have been used to adequately analyse longitudinal data with improved accuracy and precision (Nobre et al., 2003; Schaeffer, 2004; Meyer, 2005). Use of appropriate models results to accurate and precise genetic parameters thereby improving the expected genetic gain.

2.6.1 Univariate models

Univariate models analyses one trait at time without considering the relationship between them (Meyer, 1993; Meyer and Hill, 1997). Analyses of growth traits using UM trait models are preferred for their ease of manipulation and reduced computational time (Meyer, 1993; Lynch and Walsh, 1998). These models have been utilized to analyse growth traits in most tropical beef cattle. However, evaluation of growth parameters using UM gives estimates with lower accuracy due to their inefficiency in data utilisation and inability to account for trait correlation (Lynch and Walsh, 1998). Since use of these inaccurate parameters estimates creates selection bias which results in slow genetic progress and reduced expected genetic gain, MTM that account for trait correlation have therefore been employed.

2.6.2 Multi-trait models

Multi-trait models are preferred over univariate models since they analyse several traits simultaneously and consider the relationships among them (Lynch and Walsh, 1998; Nobre et al., 2003). Since it accounts for trait correlation, it is able to utilise the covariance structure by

fully adjusting for the residual covariance between traits and thereby reducing the error variance (Mrode, 2005). For example, overestimated results for correlation between direct and maternal genetic effects were reported using UM instead of MTM (Rumph et al., 2002). Better reliabilities have also been achieved when predicting genetic merit using MTM than UM due to their ability to use extra information from correlated traits (Strabel et al., 2001). The MTM therefore have improved accuracy of parameter estimates and have thus become the ideal model where selection is based on multiple traits (Khan et al., 1999; Maiwashe et al., 2002). The increased accuracy of estimates derived from the use of MTM has resulted to improved genetic progress in such selection programmes. For this reason, use of MTM in evaluation of growth traits has replaced the UM. However, in situations where recording is inconsistent as is common in tropical countries, the traits to be analysed are numerous resulting into overparametisation of the model which gives biased estimates resulting from increased sampling error of parameters and thus reduced accuracy (Nobre et al., 2003). Models that overcome the overparametisation problem would result into more accurate genetic parameter estimates (Schaeffer, 2004).

2.6.3 Random regression models

Random regression models are regression models based on covariance functions that are described by orthogonal polynomials. They contain linear functions of fixed and random coefficients and a set of covariables to describe longitudinal data (Jamrozik et al., 1997; van der Werf, 2001). Random regression models are more flexible and accurate and allow use of all available data without age pre-adjustments (Albuquerque and Meyer, 2001; Huisman, 2002; Lewis and Brotherstone, 2002; Nobre et al., 2003; Fischer et al., 2004; Meyer, 2005). They incorporate orthogonal polynomials that model data with few parameters and therefore reduce the problem of overparametisation (Meyer and Hill, 1997; Albuquerque and Meyer, 2001). Besides, the use of RRM has enabled the comparison of breeding values and variances across the trajectory allowing for more informed selection decisions (van der Werf, 2001; Nobre et al., 2003). The RRM are expected to increase the accuracy of selection compared to MTM and replacing MTM with RRM has been shown to improve the accuracy of genetic evaluation for growth of beef cattle in a field data by 5% by appropriately modelling the parameters (Huisman, 2002; Fischer et al., 2004; Meyer, 2004). However, computational demand, data structure and size available in the current situation would not allow for such models to be explored and thus univariate and multivariate are utilised in this study.

2.7 Annual genetic, environmental and phenotypic trends

Annual trends are indicators of change in the selection process and management practises which are used to evaluate the effectiveness of a breed improvement programme (Falconer and Mackay, 1996). Positive genetic trends are expected in any breed improvement programme where selection has been taking place as they reflect the level of genetic progress while negative genetic trends on the other hand are undesirable and indicate failure of the selection programme in place (Khan et al., 1999; Ebangi et al., 2000; Ojango and Pollot, 2001). Positive environmental trends are favourable as they indicate the level of herd management in feeding and disease control while negative environmental trends point to poor management within a herd (Rege and Wakhungu, 1992; Khan et al., 1999; Ebangi et al., 2000).

Genetic trends are estimated by regressing the animals' breeding values (BV) in that trait on the year while environmental trend are derived by regressing the solutions for year-season effects on each seasons of the year. Previous evaluation of annual trends at the NSS revealed negative genetic and environmental trends for growth traits; a fact that was tied to less emphasis being put on selection for growth (Rege and Wakhungu, 1992). However, the Sahiwal breed is utilised for both milk and beef production and undesirable trends would not be beneficial to the producers whose source of the breeding stock is the stud.

2.8 Conclusion

The performance of Sahiwal cattle is comparable to other *B. indicus* breeds in Kenya. However, there is still limited knowledge on performance estimates based on recent analytical procedures that could guarantee accuracy and reliability. Results from the literature indicate the existence of some maternal additive variance in Sahiwal cattle populations in other countries. There are no studies that have documented the extent of maternal influence on various growth parameters in the artificial calf rearing system in Kenya. There is need to ascertain this for Sahiwal cattle in Kenya by fitting a more robust animal-maternal model to the existing performance data at the NSS. To benefit from the Sahiwal improvement programme, it is also imperative to explore the possibility of multiple selections based on estimates from multivariate analysis. Based on these, various univariate and multivariate models fitting maternal effects and giving the best fit for growth data will be analysed in this study in order to estimate genetic and phenotypic parameters.

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CHAPTER THREE
MATERIALS AND METHODS

3.1 Data source

Growth performance data were collected from available performance records at the NSS. The stud is owned by National Animal Husbandry Research Centre (NAHRC) of KARI. It is located at an altitude of 1,829 - 2,330 metres above sea level in agro-ecological zone IV generally classified as semi arid (Muhuyi, 1997). The vegetation consists mainly of Kikuyu grass (*Pennisetum clandestinum*) and Star grass (*Cynodon plectostachyus)* with scattered trees of *Acacia* species. The bimodal rainfall distribution is characterised by long rains in April and short rains in November and the average annual rainfall is 680mm. Figure 1shows the rainfall distribution over the study period. The temperature ranges from 8°C to 26°C with relative humidity varying between 60 and 75% (Ilatsia, 2006).

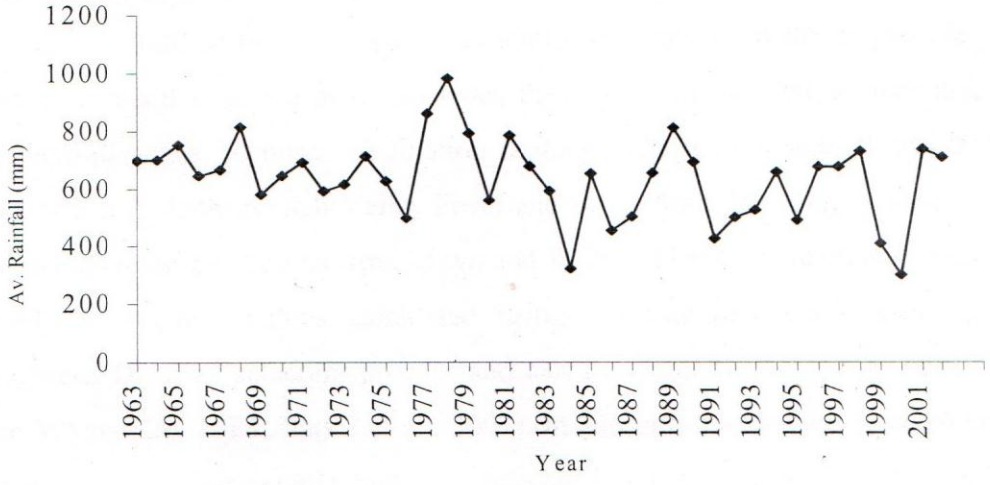


Figure 1. Rainfall distribution over the study period (adapted from Ilatsia, 2006)

3.2 Herd management and breeding

The herd is managed such that calves are immediately separated from their dams at birth, weighed and identified by ear tattooing method. They are bucket fed, receiving colostrum in the first 4 days, and whole milk before being weaned onto pasture and supplemented with concentrates when available. Subsequent weekly weighing follows to determine the amount of milk provided for the calves at 10% body weight. The age at weaning is weight dependent and

two weight criteria have been applied before. Initially, the calves were weaned at an average weight of 42kg. Due to the slow growth rate and high preweaning mortality that was experienced in the previous years, weaning weight was changed to 55kg in 1986. After weaning, the animals are periodically (weekly)weighed until they achieve an average weight of 125kg at which point they are branded and the bull and heifers are separated into different herds where they are managed differently. Grazing is generally based on natural pasture with no supplementation. Pasture availability is dependent on the rainfall pattern with favourable seasons (1978) expected to yield better pastures and hence better growth performance (Figure 1). During dry periods (1984 and 2000) when drought situations are critical, growth performance is lowered due to reduced feed availability and supplementation of pastures with hay would prevent reduction in growth and weight gain.

Bulls are weighed monthly while heifers are weighed at about 27 months and 270kg body weight (expected service age). Bulls are selected at two to three years of age either for progeny testing or for natural service in the pastoral areas. All dams are weighed immediately after calving to determine their post *partum* weight. Lactating cows are grazed on the best pastures and milked twice daily in mobile milking parlour. Water is provided to all groups *ad libitum*. Mineral licks are provided when they are available. All animals are treated for endo- and ecto-parasites. Routine vaccination is done against Foot and Mouth disease, Rinderpest, Black-quarter, Anthrax, Rift Valley Fever and Brucellosis. Breeding is based on a plan designed following recommendations from Meyn and Wilkins (1974). Selection of both sires and dams is based on breeding values calculated using contemporary comparison of performance of daughters. Detailed selection process and calculation of the selection index has been reported (see Mwandotto, 1985; Ilatsia et al., 2007). In addition females are selected based on their first lactation performance while bulls are selected based on the progeny test results of their first daughters' milk yield performance. The candidate bulls own weight at approximately 24 months of age is also included in the selection index.

3.3 Description of traits and data characteristics

Growth performance records of animals born from 1973 to 2004 were used in this study. Records from earlier years were not available since during the 1960's male calves were slaughtered at birth. Growth traits considered were; birth weight (BW, kg), weaning age at 42kg-weight (WA1, days; d), weaning age at 55kg-weight (WA2, d), overall weaning age

combining data from both weaning at 42kg and 55kg (WA, d), preweaning daily gain to WA1 (DG1, g/d), preweaning daily gain to WA2 (DG2, g/d), overall preweaning daily gain combining data from both DG1 and DG2 (DG, g/d), age at 125kg-weight (BA), post weaning daily gain to BA (PDG; g/d), average daily gain from birth to BA (ADG; g/d) and mature weight at 24 months (24W). Several DG measures were considered in this study to get appropriate parameters for selection since the current programme was based on contemporary comparison of daughters' performance and mature weight. Since the mature weight will be determined by daily gains, it was imperative to get the genetic parameters for the specific average daily gains from birth to weaning and then from weaning to yearling.

Table 3 presents the data structure and summary statistics for growth traits used in the final analyses. Three datasets were formed. The first dataset (D1) consisted of all records from 1973 to 2004 and included BW, WA, DG, BA, 24W, PDG and ADG. Dataset 2 (D2) and dataset 3 (D3) were generated by splitting dataset 1 into two, corresponding with the weight at weaning (at 42kg and at55kg respectively). The D2 and D3 had records from 1973 to 1986 and from 1986 to 2004, respectively. Records from D2 and D3 were used for the analyses of two traits each (i.e. WA1 and DG1 and WA2 and DG2, respectively). Records for the analysis of 24W were available only for males.

Table 3. Data structure for different data sets used in the analyses

	Trait[a]										
	D1							D2		D3	
	BW	WA	BA	24W	DG	PDG	ADG	WA1	DG1	WA2	DG2
Total records	10145	6448	2980	1251	6448	2980	2980	3571	3571	2877	2877
Sex											
Male	5336	3268	1210	1251	3268	1210	1210	1717	1717	1551	1551
Female	4809	3180	1770		3180	1770	1770	1854	1854	1326	1326
Season											
Primary dry	2242	1351	684	299	1351	684	684	759	759	592	592
Primary wet	2813	1865	780	332	1865	780	780	1054	1054	811	811
Secondary dry	2612	1682	756	325	1682	756	756	852	852	830	830
Secondary wet	2478	1550	760	296	1550	760	760	1717	906	644	644

[a]D1 =dataset 1; D2 = dataset 2; D3 = dataset 3. See section 3.3 for description of traits and datasets.

Data were edited for consistency of pedigree information and correct dates of birth, calving and weighing. Records with anomalies in pedigree information and dates were discarded. Records from still birth, birth weights of less than 13kg were not included in the final analysis. Only records with known BW were included in the final datasets. In D2, weights below 42kg and above 48kg were not considered for the analysis while in D3, weights below 46kg and above 61kg were deleted. There was inconsistency in weighing interval resulting in wide variation for BA hence 21% of the records were edited from the analysis. Birth records with corresponding dam post partum weight missing were also deleted.

3.4 Data analyses

3.4.1 Fixed effects and mean performance

Analyses of variance were conducted for different traits in order to assess the non-genetic traits included sex of calf, breed, year-season of birth/calving, and dam parity. A maximum of 9 parities were allowed in the analyses. Table 4 shows the type of fixed effects and covariates fitted for the various traits in the analysis. Dam age (years) and post *partum* weight

Table 4. Structure of the models used in the final analyses for growth traits

Factors	Type[a]	Trait[b]										
		BW	WA	BA	24W	DG	PDG	ADG	WA1	DG1	WA2	DG2
Sex	F	√	√	√	-	√	√	√	√	√	√	√
Season	F	√	√	√	√	√	√	√	√	√	√	√
Year	F	√	√	√	√	√	√	√	√	√	√	√
Year-season	F	√	√	√	√	√	√	√	√	√	√	√
DPPW	C	√	√	√	-	√	√	√	√	√	√	√
Dam age	C	√	√	√	-	√	√	√	√	√	√	√
BW	C	-	√	√	√	√	√	√	√	√	√	√
WW	C	-	√	√	√	√	√	√	√	√	√	√
WA	C	-	-	√	√	√	√	√	-	√	-	√
BRW	C	-	-	√	√	-	√	√	-	-	-	-
BA	C	-	-	-	√	-	-	√	-	-	-	-
Age at 24W	C	-	-	-	√	-	-		-	-	-	-
Direct genetic	A	√	√	√	√	√	√	√	√	√	√	√
Maternal genetic	A	√	√	√	-	-	√	√	√	√	-	-
Maternal Environmental	A	√	√	√	-	-	√	√	√	√	-	-
Direct-maternal	R	√	√	√	-	-	√	√	√	√	-	-

√Indicate where the effects were fitted.
[a]F=Fixed effects; C=Covariables; A=Additive; R=Correlation.
[b]See section 3.3 for description of traits.

(kg) were fitted as covariate where appropriate. The year of birth ranged from 1973 to 2004 while year of weaning ranged from 1973 to 2005. The season of birth or weaning was classified into; January to March for the primary dry season; April to June for the primary wet season; July to September and October to December for the secondary dry and wet seasons, respectively.

3.4.2 (Co)variance components and genetic parameters

(Co)variance components and genetic parameters for individual traits were estimated using single-trait animal models utilizing the DFREML programme (Meyer, 1998). Only significant fixed effects identified in section 3.4.1 were included in this analysis. To identify the best model, preliminary analyses were conducted using different univariate models each with different combinations of direct additive, maternal genetic and maternal environmental effects and covariance between additive direct and maternal genetic effects. Likelihood ratio tests were conducted to determine the most suitable model for each growth trait. Analyses were terminated when the change in variance of function values (-2log likelihood) fell below 10^{-4}.

The following six models were fitted.

Model 1 $$y = Xb + Z_1a + e \quad (1)$$

Model 2 $$y = Xb + Z_1a + Z_3c + e \quad (2)$$

Model 3 $$y = Xb + Z_1a + Z_2m + e \quad (3)$$

with $\text{cov}(a, m) = 0$

Model 4 $$y = Xb + Z_1a + Z_2m + Z_3c + e \quad (4)$$

with $\text{cov}(a, m) = 0, \text{Var}(c) = I_{NC}\sigma^2 e$ and $\text{Var}(e) = I_n\sigma^2 e$

Model 5 $$y = Xb + Z_1a + Z_2m + e \quad (5)$$

with $\text{cov}(a, m) = A\sigma_{am}$

Model 6 $$y = Xb + Z_1a + Z_2m + Z_3c + e \quad (6)$$

with $\text{cov}(a, m) = A\sigma_{am}$, $\text{Var}(c) = I_{NC}\sigma^2 e$ and $\text{Var}(e) = I_n\sigma^2 e$

where **y** is a vector of observations on the specific trait of the animal, **b, a, m** and **c** are vectors of fixed effects including covariables, direct additive genetic effects, maternal additive effects and

maternal permanent environmental effects, respectively, **X**, $\mathbf{Z}_1$, $\mathbf{Z}_2$ and $\mathbf{Z}_3$ are corresponding incidence matrices relating the effects to **y**, **e** is the vector of residual error, **A** is the numerator relationship matrix, **I** is the identity matrix, NC is the number of dams, n is the number of animals in the analysis including parents without records, σ_{am} is the direct additive genetic by maternal genetic covariance and σ^2_c and σ^2_e are the maternal permanent environmental and residual error variances, respectively.

Models differed from each other by either omission or inclusion of maternal additive, maternal permanent environmental effects and the correlation between direct and maternal additive genetic effects. For example, model 1only included direct additive genetic effects in addition to the fixed effects and the residual error while model 2 included maternal permanent environmental effects in addition to the effects fitted in model 1. Model 3 on the other hand fitted both direct and maternal additive effects but not maternal permanent environmental effects and did not include the correlation between direct and maternal effects. Model 4 included maternal permanent environmental effects in addition to the effects fitted in model 3. Model 5 and 6 were respectively similar to model 3 and 4 but included the correlation between direct and maternal effects.

Direct and maternal heritability estimates were calculated as the proportions of direct and maternal variances, respectively on the phenotypic variance (σ^2_a/σ^2_p; σ^2_m/σ^2_p). Permanent maternal environmental effect was calculated as the proportion of σ^2_c on phenotypic variance (σ^2_c/σ^2_p). Direct-maternal correlation was calculated as the covariance between direct and maternal effects divided by the product of their standard deviation ($\sigma_{am}/\sigma_a*\sigma_m$). The total heritability was calculated by summing all the genetic effects as a proportion of the phenotypic variance i.e., $(\sigma^2_a + 0.5\sigma^2_m + 1.5\sigma_{am})/\sigma^2_p$.

The number of records, pedigree structure and summary statistics are presented in Table 5. To obtain a global convergence, runs were restarted each time using the previous (co)variance estimates until there was no change in the function values. Log likelihood ratio tests (LR) were carried out to determine the best model to fit the growth data. Likelihood ratio was calculated as deviation from log likelihood of Model 1 and the other competing models. The likelihood ratio was compared with the tabulated chi-square statistics with differences in number of parameters between the two models taken as the degrees of freedom. A multivariate animal Model was used to estimate genetic and phenotypic correlations between various traits. The traits considered in

multivariate analysis were BW, WA, DG, BA, PDG and 24W. The model was similar to Model 1 but ignored additive maternal and maternal permanent environmental effects.

Table 5. Number of records, pedigree information and summary statistics for growth traits

	Trait[a]										
	BW	WA	BA	24W	DG	PDG	ADG	WA1	DG1	WA2	DG2
Animals in											
Pedigree	15034	15033	15027	15646	15033	15027	15027	15029	15029	15030	15030
Records	10145	6447	2950	1251	6447	2944	2950	3570	3570	2877	2877
Progeny records											
Sires	259	247	208	147	247	208	208	154	154	136	136
Dams	3332	2841	1830	889	2841	1827	1830	1711	1711	1310	1310
Grand Sire	363	351	317	261	351	317	317	199	199	252	252
Grand Dam	2140	1951	1445	833	1951	1443	1445	1189	1310	1009	1009

[a]See section 3.3 for description of traits.

3.4.3 Annual genetic, environment and phenotypic trends

Phenotypic, genetic and environmental trends were estimated for all traits. Genetic trends were estimated by averaging the predicted breeding values within the year. Year-season of birth solutions were averaged and regressed on year to obtain environmental trends. Phenotypic trends were calculated as deviations of LSM means for the year from the overall LSM mean. Phenotypic and environmental trends were expressed as deviations from the overall mean.

CHAPTER FOUR

RESULTS

4.1 Fixed effects and mean performance

4.1.1 Effects of non genetic fixed effects

Table 6presents the results from the analysis of variance for various effects on growth traits. Sex was significant ($P<0.01$) for all weight and age traits apart from DG1. Season influenced ($P<0.01$) all traits except WA1, PDG and 24W ($P<0.05$). Both year and year-season interaction were significant ($P<0.001$) for all traits. Dam post *partum* weight was important ($P<0.001$) for BW and WA2 while dam age at birth was important for only BA ($P<0.01$) and where dam weight was significant, dam age was not and *vice versa*. Both DPPW and dam age at birth were assumed non significant for 24W and were therefore not fitted for this trait. However, growth rate was not affected ($P<0.05$) by dam age or weight post partum except DG1. All weight/age covariables fitted were significant ($P<0.001$) and weight /age of the individual at weighing affected its growth rate both pre and post weaning and hence the actual weight except for WA1 and ADG. For example, BW was significant ($P<0.001$) as a covariable fitted for WA1, WA2, WA and 24W but not for BA ($P<0.5$). Covariable WW was equally significant ($P<0.001$) for all age and weight traits except WA1 ($P<0.05$).

4.1.2 Mean performance

The overall means and subclass least square means are presented in Table 6. The mean BW was 21.9kg and male calves were heavier than their female counterparts at birth while dams calving in primary dry season produced lighter calves compared to other seasons. However, there was no significant difference ($P<0.05$) in BW for calves born in primary and secondary wet season although calves born in primary wet season were lighter ($P<0.05$) than those born in secondary dry season. The weaning ages were classified into three traits according to the data (Table 3). From this classification, the mean estimates in days were 79.4, 144.0 and 108.2, respectively for WA1, WA2 and WA. Male calves weaned earlier than their female counterparts in all the cases. Season of birth was significant for all weaning traits except for WA1 and calves born in primary wet seasons weaned earlier than those born in the rest of the seasons (Table 6).

Table 6. Analysis of variance, levels of significance, means[a] and coefficient of variations for various growth and maturing traits

	Trait[b]										
Effect	BW, kg	WA, d	BA, d	24W, kg	DG, g/d	PDG, g/d	ADG, g/d	WA1, d	WA2, d	DG1, g/d	DG2, g/d
Overall mean	21.9	108.2	376.1	324.4	262	322	302	79.4	144	276.6	243.9
CV (%)	10.2	17.7	10.1	9.9	8.2	9.2	5	24.3	13	7.9	4.9
Sex	***	***	***	-	**	*	***	***	***	ns	**
Male	22.4±0.0[b]	114.1±0.4[a]	388.8±2.2[a]	-	261.4±0.5[b]	319.1±1.7[b]	301.4±0.9[b]	78.8±0.5[a]	145.5±0.6[a]	276.2±0.6[a]	244.8±0.4[b]
Female	20.9±0.0[a]	117.7±0.4[b]	399.3±2.1[b]	-	258.7±0.5[a]	315.1±1.6[a]	298.4±0.9[a]	82.8±0.5[b]	148.6±0.6[b]	274.9±0.6[a]	241.9±0.4[a]
Season[c]	***	***	**	ns	**	ns	***	ns	***	***	**
Primary dry	21.4±0.1[a]	112.8±0.6[a]	387.2±2.4[a]	317.3[a]	257.8±0.7[a]	322.1±1.8[b]	303.7±1.0[b]	81.6±0.7[a]	139.2±0.9[a]	276.3±0.8[b]	241.6±0.6[b]
Primary wet	21.7±0.0[bc]	112.5±0.5[a]	393.4±2.4[b]	324.8[b]	261.1±0.6[b]	320.4±1.8[b]	302.2±1.0[b]	79.9±0.6[a]	140.7±0.8[a]	277.1±0.7[b]	246.9±0.5[d]
Secondary dry	21.8±0.1[c]	118.4±0.6[b]	399.7±2.4[bc]	319.8[ab]	262.3±0.6[b]	313.2±1.9[a]	296.1±1.0[a]	80.8±0.7[a]	151.8±0.8[b]	275.6±0.8[b]	244.9±0.5[c]
Secondary wet	21.6±0.1[b]	120.0±0.6[c]	395.9±2.5[b]	315.5[a]	259.0±0.7[a]	312.7±1.9[a]	297.6±1.0[a]	80.9±0.7[a]	156.5±0.9[c]	273.3±0.8[a]	239.9±0.6[a]
Year	***	***	***	***	***	***	***	***	***	***	***
Year-season	***	***	***	***	***	***	***	***	***	***	***
DPPW	***	ns	ns	-	ns	ns	ns	ns	***	ns	ns
Dam age	ns	ns	**	-	*	ns	ns	ns	ns	***	*
BW	-	***	ns	***	***	ns	***	***	***	***	***
WW	-	***	***	***	***	***	ns	ns	***	***	***
WA	-	-	***	***	***	***	***	-	-	***	***
BRW	-	-	***	***	-	***	***	-	-	-	-
BA	-	-	-	***	-	***	-	-	-	-	-
Age at 24W	-	-	-	***	-	-	-	-	-	-	-

[a]Within column means followed by the same superscripts do not differ significantly (P< 0.05).

[b]See section 3.3 for description of traits.

[c]Season of weaning fitted for BA, PDG and ADG otherwise season of birth; *P<0.05, **P<0.01, ***P<0.001, ns, not significant.

CV; coefficient of variation.

The mean BA was 376.1d and male calves attained this weight 11d earlier than females. Calves weaned in primary dry season reached BA 6.2d earlier than the rest of the seasons which did not differ from each other. However, weaning in secondary dry season produced the oldest BA (400d). The mean 24W was 324.4kg with the mean age at weighing of 2yrs. There was no significant difference between the periods of weaning although animals weaned during the primary wet season attained the heaviest weight than the rest by 5kg.

Table 6 also shows the mean estimates for growth rates. The preweaning daily gains were estimated based on corresponding ages at weaning and the mean estimates in g/d for DG1, DG2 and DG were 276.6, 243.9 and 262.0, respectively. Males grew faster than their female counterparts except for DG1 where no significant ($P<0.05$) difference was realised between the sexes. Calves born in primary wet seasons grew faster and therefore weaned earlier than the rest of the seasons. The mean estimate for PDG was 322.0g/d and males grew faster than females by 4g/d while calves weaned in primary wet season grew faster than those weaned in the other seasons. The mean estimate for ADG was 302.0g/d and male calves grew faster than females by 3g/d. Calves weaned in primary dry season had a faster growth rate (7.6g/d) than those weaned in the secondary dry season. Similarly, calves weaned in primary wet season grew faster (4.6g/d) than those weaned in secondary wet season. Since growth increases with age, the preweaning growth rate was slower than post weaning growth rate (Table 6).

4.2 (Co)variance components, genetic and phenotypic parameters

4.2.1 Univariate analyses

The estimates of variance components and genetic parameters for each trait using various univariate animal models are presented in Table 7. Direct maternal effects were important for BW, WA2 and PDG and ignoring them substantially increased the direct additive genetic variance and hence direct heritability estimates. Permanent maternal effects were important for BW, WA2, DG2, DG and BA and fitting them substantially reduced direct heritability estimates for BW and WA2. Accounting for correlation between direct additive and maternal effects reduced and increased the proportion of variance that is due to direct additive and maternal genetic effects, respectively for BW, WA2 and PDG and hence direct and maternal heritability estimates.

From the log likelihood ratio tests (LR), fitting permanent maternal effects or accounting for direct-maternal correlation did not improve the LR for all traits. However, fitting direct maternal effects significantly ($P<0.001$) improved log likelihood for all traits even where maternal effects were not present (see Table 7). Therefore, Model 3 (with direct genetic and maternal effects) gave the best fit to estimate the genetic variance components and subsequently the genetic parameters for BW, WA2 and PDG while for the other traits Model 1 was adequate to estimate the genetic parameters since maternal effects were not important.

For BW, additive genetic effects accounted for a larger proportion of genetic variance than maternal variances and hence direct heritability estimates ranged from 0.13 to 0.34 in the various models (Table 7). From the best Model (Model 3), direct heritability estimate was 0.15 with direct maternal effects accounting for 10% of the total variation. Direct maternal heritability estimates were reduced when Model 6 was fitted. Similarly, estimates for permanent maternal effects were low ranging from 0.04 in Model 6 to 0.07 in Model 2. Correlation between direct additive and maternal genetic effects were positive and high ranging from 0.66 for Model 5 to 0.72 for Model 6.

For the weaning age traits, additive genetic variances were lower for WA1 than for WA and WA2 and accounted for larger proportion of genetic variance (Table 7). The estimates for direct heritability were 0.03, 0.10 and 0.06 for WA1, WA2 and WA, respectively using Model 1. Maternal effects were only evident in WA2 where estimates were 0.01 and 0.03, respectively for maternal heritability and permanent maternal effects. Model 3 best described the data for WA2. Accounting for direct-maternal correlation increased both h^2 and m^2 resulting into a negative correlation of -0.57. The estimate of direct heritability for BA (0.13) was higher than those estimated for WA. Permanent maternal effects were 0.02 for BA. For 24W, both direct and permanent maternal effects were assumed non significant and were therefore not fitted. The estimate for direct heritability for 24W was 0.21 (Table 7).

For preweaning growth rate, additive genetic components of variance were low resulting in low direct heritability. The heritability estimates were 0.04, 0.03 and 0.04 for DG1, DG2 and DG, respectively (Table 7). Permanent maternal effects were low, present only for DG2 (0.01) and DG (0.02). The genetic variance for PDG was low, in this case heritability estimate ranged from 0.02 to 0.04.

Table 7. Estimates of (co)variance components, genetic and phenotypic parameters for growth traits using different models in univariate analysis

Trait[a]	Model[a]	(Co)variance components and genetic parameters[b]										
		σ^2_a	σ^2_m	σ^2_c	σ_{am}	σ^2_p	h^2	m^2	r_{am}	c^2	h^2_T	Δ log L[c]
BW	1	1.68				4.98	0.34				0.34	0.00
	2	1.05		0.35		4.81	0.22			0.07	0.22	-24.40
	3	0.72	0.48			4.82	0.15	0.10			0.2	1472.36***
	4	0.79	0.22	0.23		4.78	0.16	0.05		0.05	0.19	1467.35
	5	0.63	0.27		0.27	4.85	0.13	0.06	0.66		0.24	1465.35
	6	0.67	0.13	0.18	0.21	4.81	0.14	0.03	0.72	0.04	0.22	1461.75
WA	1	20.81				367.09	0.06				0.06	0.00
	2	20.94		0.00		367.11	0.06			0.00	0.06	-0.07
	3	19.88	1.22			367.05	0.05	0.00			0.06	1495.27***
BA	1	202.85				1505.81	0.13				0.13	0.00
	2	193.03		36.63		1504.97	0.13			0.02	0.13	-0.35
	3	202.93	0.00			1505.83	0.13	0.00			0.13	1494.78***
24W	1	211.11				1022.14	0.21				0.21	0.00
DG	1	19.26				463.56	0.04				0.04	0.00
	2	17.29		6.95		463.37	0.04			0.02	0.04	-0.69
	3	19.47	0.00			463.59	0.04	0.00			0.04	1495.41***
PDG	1	12.86				667.98	0.02				0.02	0.00
	2	13.36		0.46		668.02	0.02			0.00	0.02	-1.09
	3	10.10	6.68			667.93	0.02	0.01			0.02	1496.27***
	5	28.64	21.66		-19.74	668.81	0.04	0.03	0.79		0.01	1499.81
ADG	1	3.42				231.07	0.01				0.01	0.00
	2	3.45		0.00		231.07	0.01			0.00	0.01	0.00
	3	3.46	0.00			231.07	0.01	0.00			0.01	1494.78***
WA1	1	9.94				372.43	0.03				0.03	0.00
	2	10.07		0.00		372.45	0.03			0.00	0.03	0.00
	3	9.93	0.00			372.43	0.03	0.00			0.03	1495.13
WA2	1	36.03				353.00	0.10				0.10	0.00
	2	30.49		9.04		352.29	0.09			0.03	0.09	-0.84
	3	33.16	3.38			352.86	0.09	0.01			0.10	1494.62***
	4	30.72	0.00	8.90		352.32	0.09	0.00		0.03	0.09	1493.93
	5	43.31	12.83		-13.42	353.18	0.12	0.04	0.57		0.08	1493.70
DG1	1	17.68				483.38	0.04				0.04	0.00
	2	17.68		0.00		483.38	0.04			0.00	0.04	0.00
	3	17.87	0.00			483.41	0.04	0.00			0.04	1495.12***
DG2	1	4.73				142.97	0.03				0.03	0.00
	2	4.36		1.57		142.95	0.03			0.01	0.03	-0.14
	3	4.79	0.00			142.98	0.03	0.00			0.03	1494.78***

[a]See section 3.3 and 3.4 for description of traits and models respectively

[b]σ^2_a = direct additive variance; σ^2_m = maternal additive variance; σ^2_c = maternal permanent environmental variance; σ_{am} = direct-maternal genetic covariance; σ^2_p = phenotypic variance; h^2 = direct genetic heritability; m^2 = maternal heritability; c^2 = ratio of maternal permanent environmental effect; r_{am} = direct-maternal genetic correlation; h^2_T = total heritability.

[c]Δ log L, the deviations in log likelihood of competing models; ***, P<0.001.

Direct maternal effects were also low (0.01), however allowing for a correlation between direct and maternal genetic effects resulted in higher estimates for direct and maternal heritability and a negative correlation of -0.79. Additive genetic variance for ADG was low resulting in low direct heritability estimate (0.01) with no maternal influence.

4.2.2 Multivariate analyses

The estimates of variance components, heritability, genetic and phenotypic correlations from MTM are presented in Table 8. When compared with results from UM, the variance estimates from MTM were substantially higher and hence the direct heritability estimates from multivariate analysis were increased except for PDG which did not change. The heritability estimates for BW, WA, BA, DG and PDG from MTM were 0.34, 0.07, 0.05, 0.15 and 0.02 respectively.

The direct genetic correlation estimates were low to medium ranging from -0.04 between BW and BA to 0.47 between BW and DG. Genetic correlation between BW and age traits were negative, being moderate for WA (-0.39) and low for BA (-0.04) while the genetic correlation between BW and growth rate traits were moderate, being positive (0.47) between BW and DG but negative between BW and PDG (-0.33). The estimate of genetic correlation between WA and other traits were also moderate, being negative between WA and DG (-0.34) but positive between WA and BA (0.42) and WA and PDG (0.33). Genetic correlation was positive between DG and BA (0.22) and negative between DG and PDG (-0.40) while the genetic correlation between BA and PDG was 0.12. Phenotypic correlations followed the same direction but of low magnitude ranging from 0.01 to 0.06.

Table 8. Variance components and genetic and phenotypic parameters estimates (±SE) for growth traits using multivariate models

Trait[a]	Variance components[b]			Trait[c]				
	σ^2_a	σ^2_e	σ^2_p	BW	WA	BA	DG	PDG
BW	1.67	3.31	4.98	0.34±0.02	-0.06	-0.01	0.06	-0.02
WA	25.65	343.45	369.10	-0.39±0.10	0.07±0.02	0.04	-0.02	0.01
BA	225.02	1287.30	1512.40	-0.04±0.09	0.42±0.15	0.15±0.04	0.02	0.01
DG	22.63	443.03	465.66	0.47±0.12	-0.34±0.18	0.02±0.02	0.05±0.02	-0.01
PDG	10.64	657.44	668.08	-0.33±0.29	0.33±0.43	0.12±0.37	-0.40±0.44	0.02±0.02

[a]See section 3.3 for description of traits
[b]σ^2_a = direct additive variance; σ^2_e = error variance; σ^2_p = phenotypic variance
[c]Heritability on the diagonal, genetic correlation below and phenotypic correlation above diagonals

4.3 Annual genetic, environmental and phenotypic trends

Phenotypic, genetic and environmental trends for BW, WA, BA, 24W, DG and PDG are presented in Figures 2, 3 and 4. The genetic trends were generally undesirable in overall for all traits considered in this study except for 24W where there was a positive and desirable genetic trend. Regression analysis indicated that genetic trends were significant ($P<0.01$), although there were wide fluctuations in the mean annual estimated breeding values (EBVs), resulting in general negative genetic trends.

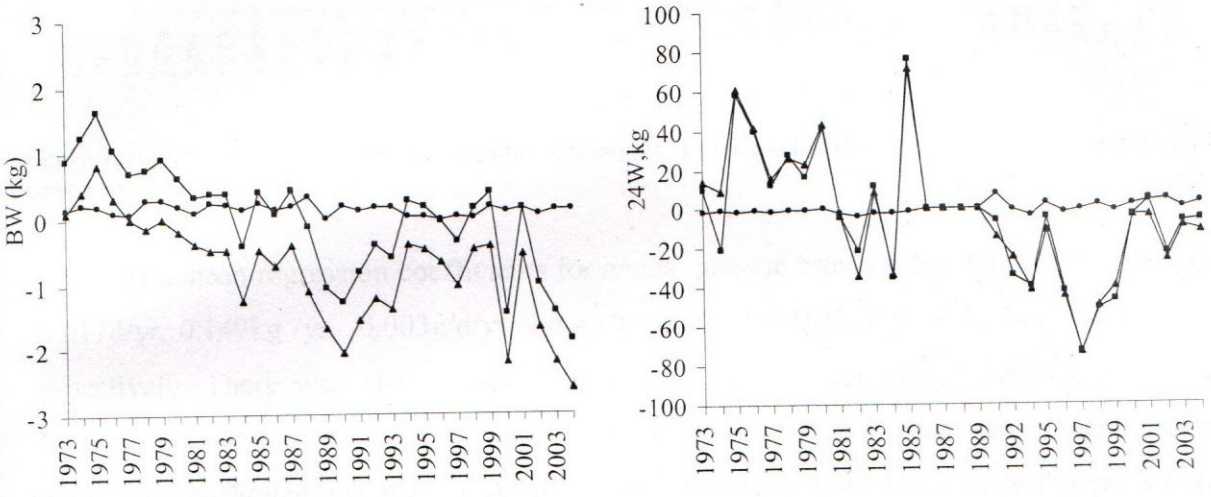


Figure 2. Genetic (•), environmental (▲) and phenotypic (■) trends for BW (birth weight) and 24W (weight at 24 months) using data set 1

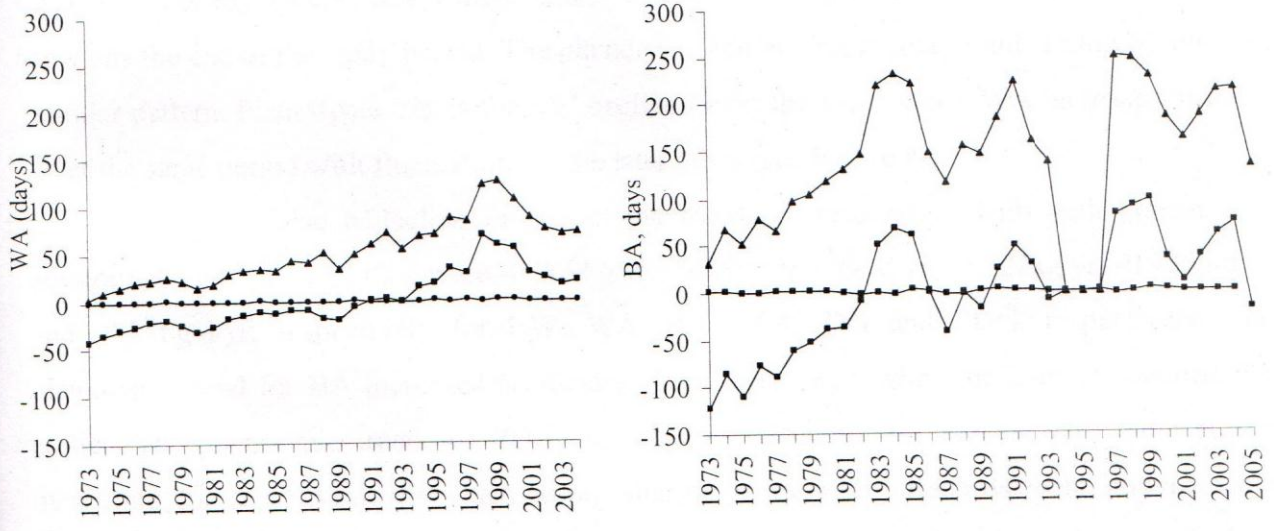


Figure 3. Genetic (•), environmental (▲) and phenotypic (■) trends for WA (weaning age) and BA (branding age)

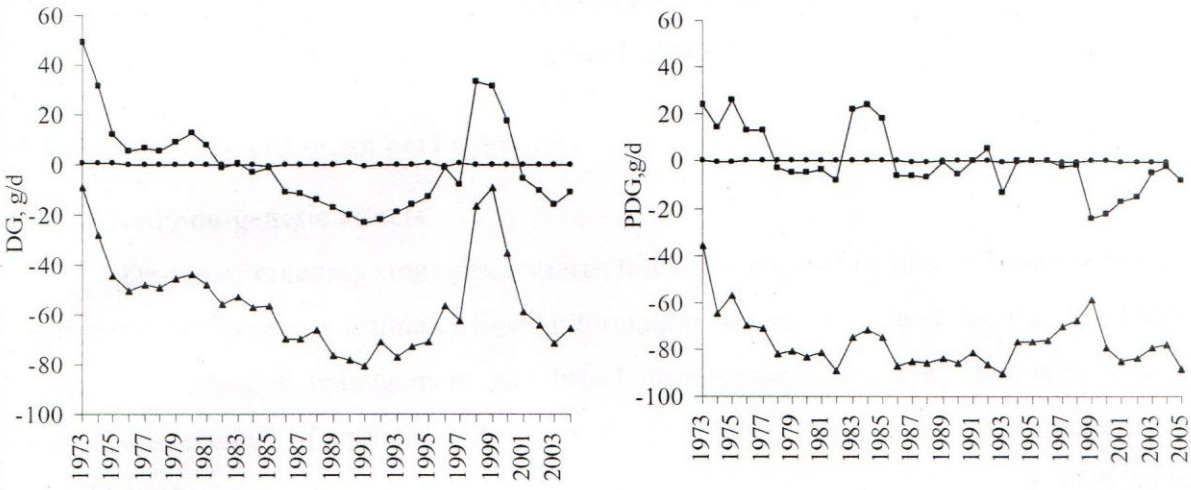


Figure 4. Genetic (•), environmental (▲) and phenotypic (■) trends for DG (preweaning daily gain) and PDG (post weaning daily gain)

The mean regression coefficients for annual genetic trends were -0.004kg/yr, -0.016d/yr, -0.017d/yr, 0.149kg /yr, -0.003g/d/yr and -0.001g/d/yr for BW, WA, BA, 24W, DG and PDG, respectively. There was also a general decline in the environmental trends over the years (Figures 2, 3 and 4. which translated into a general deterioration in herd management. The mean regression coefficient for BW, WA, BA, 24W, DG and PDG were -0.064kg/yr, 3.111d/yr, 4.242d/yr, -2.671kg/yr, -0.613g/d/yr and -0.437g/d/yr, respectively. There was environmental instability in the study period as depicted by wide fluctuations in solutions of fixed effects for growth traits except for WA which tended to increase in a steady trend with a sharp drop towards the end of the study period. The phenotypic and environmental trends followed almost a similar pattern. Phenotypic trends for BW declined over the years while WA increased steadily over the same period with fluctuations in the later years (see Figure 2).

There was also a decline in phenotypic trends corresponding with both genetic and environmental trends and they were -0.069kg/yr, 2.649d/yr, 4.599d/yr, -2.522kg/yr, -0.735g/d/yr and -0.258g/d/yr, respectively for BW, WA, BA, 24W, DG and PDG, respectively. The phenotypic trend for BA increased erratically; there were years when the animals attained BA earlier. The phenotypic trend for PDG was negative although the means were quite erratic increasing for some years then decreasing sharply in between. Records were not available between 1994 and 1996 for PDG thus phenotypic trends for this period could not be estimated.

CHAPTER FIVE
DISCUSSION

5.1 Fixed effects and mean performance

5.1.1 Fixed non-genetic effects

Design of breeding strategies requires full knowledge of factors influencing performance and mean performance estimate. Such information would be critical for the development of sound and effective management and breed improvement strategies that take into account extraneous sources of variation (Rewe et al., 2006). Therefore objective selection decisions should be based on evaluation procedures that can effectively account for such sources of variation in order to obtain unbiased ranking of breeding stock. In this study, various sources of variation on mean performance estimates for growth and maturing characteristics have been determined (Table 6).

The results show that various environmental and fixed factors influence performance of Sahiwal cattle to varying levels. This is in agreement with other studies which have reported significant non genetic effects on performance of Sahiwal cattle in the tropics (Mwandotto, 1985; Rege et al., 1992; Mwandotto, 1994; Khan et al., 1999; Ilatsia, 2006) and other tropical beef cattle (Indetie et al., 2000; Wasike, 2006). Year-season effects are closely associated with availability of pastures and therefore would be expected to largely affect performance (Lunstra and Cundiff, 2003). During favourable years and season where there is adequate rainfall, growth performance is enhanced unlike during unfavourable condition such as drought where performance is largely depressed. For example, in this study, favourable growth performance was reported between 1997 and 2001 where there was increased growth rate. This period coincided with *El Nino* rains which resulted in good pastures (Figure 1; Figure 4). In addition, there was increased growth rate during primary wet seasons due to adequate pasture which extended to some parts of secondary dry season.

Management interventions during adverse periods such as drought will be able to cushion animals against the adverse climatic conditions. Measures such as production and preservation of fodder and pastures should be observed. Profits accrued from sale of milk and breeding bulls should be used to finance pasture production and preservation. The NSS is a central nucleus herd and therefore financial resources should be committed in providing the best

production environment to the herd so that the full genetic potential of promising genotypes could be realised. This also makes it possible to discriminate superior genotypes from the rest, since unfavourable environmental effects would obscure genetically superior animals if an evaluation procedure does not effectively adjust for these effects. Poor production circumstances will always adversely affect the good performing animals because of their high metabolic requirement. If suitable animals are not accurately selected based on their genetic merit then genetic progress would be slowed down and result in genetic decline.

Evaluation procedures that account for such sources of variation should be adopted to obtain accurate and reliable genetic merit and discriminate superior cows and bulls while accounting for variations that arise due to systematic environmental effects. With regard to Sahiwal cattle improvement in Kenya, a decline in performance has been attributed to sub optimal selection decisions, which have been occasioned by evaluation procedures that do not accurately correct for these factors (Ilatsia et al., 2007). Similar observations have also been witnessed in some Sahiwal herds in Pakistan (Khan et al., 1999) although most evaluations are now based on the more robust BLUP, which is capable of handling such discrepancies.

5.1.2 Mean performance

Although the locally adapted *B. indicus* breeds in developing countries commonly show low absolute production figures, the Sahiwal is known to have the greatest potential for both production and functional traits (Rege et al., 1992; Mwandotto, 1994; Singh and Nagarcenkar, 1997; Dahlin et al., 1998; Khan et al., 1999). This study has presented mean performances estimates for various growth traits and maturing characteristics of Sahiwal cattle under semi arid conditions in Kenya. The results reveal some differences and similarities in mean estimates for various traits compared to previous studies both within and between countries. For example, most of the estimates presented in this study are lower than those reported in previous studies using a subset of the current data (Mwandotto, 1985; Rege et al., 1992), a fact that could be attributed to data structure and models of analysis. The observed differences could also be due to differences in editorial restriction on data, classification of fixed effects and inclusion of dam post partum weight.

Mean performance estimates for BW and YW reported in this study are comparable to what has been reported for Sahiwal in Pakistan (Khan et al., 1999). The similarity in estimates could be attributed to almost similar management practises between the NSS and the herds in

Pakistan. For example in both countries calves are weaned at approximately three months under bucket feeding systems with occasional concentrate supplementation (Khan et al., 1999; Ilatsia et al., 2007). Generally the mean performance estimates in the current study were lower than has been reported for other Zebu breeds in the tropical countries e.g. Boran, Nelore and Brahman (Table 1). This would be expected considering the differences in the calf rearing system. The bucket feeding system at the NSS denies the calf the requisite environmental maternal influence, a fact that would largely result in relatively low growth performance as compared to most tropical beef cattle production system where the cow-calf management is dominant. However, in a comparative study between Sahiwal and Boran in cow-calf system, the Sahiwal were reported to have higher WW than the Boran (Mwandotto et al., 1988), a fact that was attributed to more milk provided to Sahiwal calves because of the high milk production of their dams compared to Boran dams. It should be noted however that even with the bucket feeding systems, the growth performance of Sahiwal at the NSS was higher than what has been reported for other tropical breeds (Mwandotto et al., 1988; Said et al., 2001).

The early age at weaning and artificial rearing of calves also requires that the calves be supplemented during adverse period to reduce the post weaning stress and thus improve growth performance. In most production systems where calves are artificial reared, concentrate supplementation before weaning to pasture have resulted to improved growth (Khan et al., 1999; Demeke et al., 2003).Estimates for 24W reported in this study was higher than 222 kg reported for same breed in Pakistan (Khan et al., 1999) and 220 kg for Boran cattle in Kenya (Wasike et al., 2009). The higher mean estimate in this study could be attributed to the inconsistency in weighing dates such that weights were not taken close to 24 month age point. The average daily growth rates reported in this study are generally lower than what has been reported for Sahiwal and other tropical beef cattle (Kahi, 1995; Muhuyi et al., 2000; Said et al., 2001). The preweaning growth rate was slightly higher for DG1 than DG2 and this coincides with the periods when calf feeding and housing management was favourable at the stud in earlier years (between 1973 to 1986). The PDG, although low, is comparable with results from some literature on indigenous cattle breeds (Talib et al., 1998; Muhuyi et al., 2000). However, most beef cattle in cow-calf systems are weaned much later (around eight months) and therefore the post weaning gains are not directly comparable. The slow post weaning growth rate is typical of indigenous breeds reared under the harsh tropical condition of poor nutrition.

Differences in herd management, the definition of fixed effects and varying climatic factors between countries could also explain the differences in mean estimates. Furthermore, selection strategies for the Sahiwal breed differ among countries in the tropics: in essence, this would affect the responses to selection for production and reproductive traits, hence causing disparities in performance. To improve on growth performance of Sahiwal cattle, there is a need for sound management and genetic improvement strategies. Prospects to improve performance of the Sahiwal through selection exist, given the considerable coefficients of variation in most of the traits studied (Table 6).

5.2 (Co)variance components and genetic parameters

5.2.1 Estimates of (co)variance components

The (co)variance components for the various traits varied across models (Table 7). A model that included both direct and maternal effects (Model 3) gave the best fit and was only fitted for BW where maternal effects were considered important. Fitting direct maternal variance where they are not important slightly increases the additive direct and phenotypic variance with a subsequent reduction in error variance (Maniatis and Pollot, 2002; Wasike et al., 2009). As for those traits where maternal effects were not significant, it was appropriate to fit only additive direct effects (Model 1). Several studies have reported the importance of fitting maternal effects in estimation of (co)variance components (Gutierrez et al., 1997; Ferreira et al., 1999; Khan et al., 1999; Demeke et al., 2003; Wasike et al., 2009), including cases where artificial calf rearing has been practiced (Demeke et al., 2003).

The presence of direct maternal variance for BW exhibited in this study concurs with results from other studies (Eler et al., 1995; Haile-Mariam and Kassa-Marsha, 1995; Gutierrez et al., 1997; Khan et al., 1999; Maiwashe et al., 2002; Demeke et al., 2003), although absence of maternal effect on BW has also been reported for Boran (Wasike et al., 2009). The absence of maternal effects on both WA1 and WA differs from results found in other studies where the calves were separated from their dams immediately at birth (Khan et al., 1999; Demeke et al., 2003). The absence of maternal effects could be attributed to the fact that the calves are weaned at relatively younger age. However, there is low maternal variance (0.01) for WA2 (Table 7) which could have been due to over reliance on carryover maternal effects from BW. These calves are reared under adverse condition with minimal supplementation, probably the harsh

environmental effects enhances the over reliance on maternal effects for survival. In a related study, Demeke et al. (2003) reported minimal maternal variance for WW of artificially reared mixed population of purebred *B. indicus* and crosses weaned at 180 days. In tropical beef and dual purpose production systems, little information is available on the effect of maternal genes on early growth traits of artificially reared calves. However, several studies have indicated maternal influence (attributed to dams' milk and mothering ability provided to the calves) on WW of most beef cattle in the tropics (Eler et al., 1995; Gutierrez et al., 1997; Maiwashe et al., 2002; Demeke et al., 2003; Wasike et al., 2009).

Absence of direct maternal effects on preweaning growth rate was expected. As alluded to earlier, maternal effects are attributed to the dam pre and post natal environment, minimal maternal influence is expected in artificially reared calves and this coupled with the early weaning (42 and 55kg) explains the absence of maternal effects for most of the preweaning growth traits. Presence of maternal effects, albeit minimal, on preweaning gains has been reported in bucket fed calves (Demeke et al., 2003). In cow-calf system, persistent of maternal effects to post weaning up to one year have also been reported (Mackinnon et al., 1991; Eler et al., 1995; Wasike et al., 2009). Other authors using more accurate models to analyse growth calves, e.g., RRM, indicate that maternal effects diminish with age but persists even up to maturity (Nobre et al., 2003; Fischer et al., 2004). The decline is expected to coincide with the time maternal environment is withdrawn and some studies have therefore omitted fitting maternal effects when estimating genetic parameters for YW (e.g., Meyer, 1992; Burrow, 2001). Permanent maternal effects for BA were lower than estimates reported by Meyer (1992) for dam nursed Hereford and Angus in tropical environment and the low effects were because the maternal environment was withdrawn when the calves were relatively younger.

5.3.2 Genetic parameters from univariate models

Direct heritability estimate for BW is within the range of those reported in literature (Eler et al., 1995; Gutierrez et al., 1997; Maiwashe et al., 2002; Wasike et al., 2009). Higher direct heritability estimates than found in this study has however been reported for Sahiwal herds in Pakistan (Khan et al., 1999). In that study, a heritability estimate of 0.21 and negative genetic correlation of 0.14 were reported. Maternal heritability estimate for BW from the best model was however higher than those reported in other studies for *B. indicus* breeds (Eler et al., 1995; Haile-Mariam and Kassa-Marsha, 1995; Khan et al., 1999; Demeke et al., 2003) and some

exotic breeds (Angus and Hereford) in the tropics (Meyer, 1992). For example, in the study by Demeke et al. (2003), maternal heritability estimate for BWwas0.09 while Khan et al. (1999) and Eler et al. (1995) reported estimates of 0.04 and 0.08 respectively. The differences in these studies could be attributed to genetic variations between breeds and populations, structures of the pedigree and selection policies (Falconer and Mackay, 1996).

Permanent maternal heritability for BW is low and consistent with literature findings for artificially reared *B. indicus* calves (Khan et al., 1999; Demeke et al., 2003). However, permanent maternal effects accounted for very little variation suggesting minimal effects of uterine environment provided by the dams to their offspring during embryonic development. Permanent maternal effects did not improve the log likelihood (Table 7). Direct-maternal genetic correlation for BW was higher than reported elsewhere (Koots et al., 1994b; Demeke et al., 2003). This was however contrary to the negative estimates reported for most beef breeds in tropics (Table 2). Differences in direction and magnitude of direct-maternal correlations for BW have been associated with data structure and pedigree information (Gutierrez et al., 1997; Maniatis and Pollot, 2003). In the present study however, the pedigree structure was sufficient to guarantee adequate estimate of direct-maternal correlation for BW (Table 5). The positive genetic correlations between these effects imply that simultaneous selection is feasible.

Several weaning ages are considered in this study and direct heritability estimate for WA2 is higher than what has been reported for Boran weaned at the same weight (Demeke et al., 2003). Results for weaning ages are however not directly comparable to most of the results reported in literature (Table 2) since in most studies, weaning is based on age rather than weight and hence the trait of importance is WW. On the other hand, most beef production systems differ in calf rearing and management. For example, calves in present study were artificially reared and weaned at weights of 42kg or 55kg while most beef producers practice cow-calf system where dams suckle their calves and wean later in life at an age of between 7-9months of age (Table 1). Direct-maternal genetic correlation for WA2is consistent and within the range reported in literature (Table 2). This antagonism is attributed to the fact that data is not sufficient to allow for a cubic approximation of sampling variance when maternal effects are fitted for WA2 thus providing limited information to allow separation of direct additive and maternal genetic effects. The implication of antagonism between direct and maternal genetic effects is

that selection for increased maternal effects would result in depressed direct genetic potential of the animals.

Direct heritability estimate for BA is within range for tropical beef cattle (Table 2) but slightly higher than other estimates (Lôbo et al., 2000). For example, Khan et al. (1999) and Maiwashe et al. (2002) have reported heritability estimates of 0.08 and 0.12 for Sahiwal cattle in Pakistan and Bonsmara population in South Africa, respectively. The differences in these studies have been attributed mainly to genetic variations between breeds and populations. Low heritability estimates for YW in tropical climates have been attributed to environmental stresses and inadequate energy provided by the tropical pastures that suppresses full expression of genetic potential for growth (Lôbo et al., 2000; Lunstra and Cundiff, 2003). Considering the higher direct heritability estimate for BA than WA, selection based on BA would result in more genetic progress. Direct heritability estimate for 24W is higher than reported for some *B. indicus* breeds (Khan et al., 1999; Wasike et al., 2009) but lower than summarised estimates for *B. indicus* beef cattle breeds (Lôbo et al., 2000). The relatively higher heritability for 24W is as a result of using only a few selected bulls that were used for breeding while the wide age range considered could have contributed to the higher estimates. It has been noted that additive genetic effects for growth traits increase with age (Nobre et al., 2003; Fischer et al., 2004).

Direct heritability estimate for DG2 is lower than for DG1 and DG. This could be explained probably by the fact that in the earlier years, management was favourable for feeding and health care allowing the calves to express their full genetic potential. It has been reported that where environmental variation is minimized, direct heritability estimates tend to be higher (Koots et al., 1994a). In general, estimates for direct heritability for preweaning growth rates (0.03-0.04) reported in this study are lower than what has been reported for tropical beef cattle (Maiwashe et al., 2002; Demeke et al., 2003) although close to estimates (0.06) for artificially reared Boran calves weaned at six months (Demeke et al., 2003). The low estimates are partly due to restricted feeding regime where calves are given fixed amount of milk based on weight. The unfavourable environment could have led to the low parameter estimates exhibited in the two studies. In cow-calf systems, the unlimited access to dam milk has resulted to calves obtaining more milk from the dams thus improving their performance and hence genetic parameters. Besides, the calves in the current study weaned barely 4 months and since growth rate is calculated as a ratio of weaning weight, weight at which weaning occurred would

subsequently determine the growth rate period and hence influence estimates of genetic parameters.

The heritability estimates for PDG are found to be lower (0.02) than for preweaning daily gain. However, like most estimates in this study, these results are lower than reported for tropical Zebu cattle (Mackinnon et al., 1991; Burrow, 2001). However, the post weaning period considered in the current study (from four months to one year) is earlier than reported for most tropical Zebu following the artificial calf feeding system and early weaning. Growth rate increases with age and therefore the magnitude of phenotypic variation is expected to increase with increase in growth rate. However, lower genetic variance for PDG than DG reported in this study could be probably due to the fact that after weaning the calves are subjected to the harsh tropical stresses of heat, poor nutrition as well as disease and parasite challenges without supplementation and optimal health care. These could have resulted to the suppressed expression of genetic potential for growth of the bucket fed calves that are consequently weaned earlier in life. Minimal maternal effects are present for PDG and this could be related to prenatal dam care carryover effects. Similar findings have been reported for a mixed population of beef cattle in Ethiopia (Demeke et al., 2003).

In general, the differences in estimates could be attributed to levels of genetic variation between populations; effect of data structure; selection policies; and models used. For example, the NSS has been a closed nucleus structure for over thirty years and levels of inbreeding are suspected to be high which could have result in reduced additive genetic effect (Rege et al., 1992). At the same time, the partitioning of the fixed effects and covariables especially fitting post *partum* dam weight could have contributed to the very low values for preweaning genetic parameters. The high direct heritability estimates for BA would be preferable for selection for direct genetic effects.

5.3.3 Genetic and phenotypic parameters from multivariate models

There is a similarity in variance and heritability estimates for BW considering both MTM and UM. This agrees with literature findings (Meyer, 1993; Wasike et al., 2009). However, the study shows differences in estimates for other traits considering the two models. This is also in agreement with other studies (Khan et al., 1999; Van Dyk et al., 2001; Demeke et al., 2003; Wasike et al., 2009). Generally lower estimates are obtained when fitting UM than MTM and this could be attributed to the fact that biases arise when selection is based on a single

trait. It should however be noted that in MTM analyses, the maternal effects are not fitted due to computational inadequacies and the fact that maternal effects were generally minimal for most pre and post weaning traits. Nevertheless, comparing results from MTM and those from UM using Model 1, the estimates from MTM are still inflated. It is therefore imperative to conclude that MTM models adequately analyse growth data considering the relationship between traits. Due to higher estimates from MTM, selection based on multiple traits would result in a faster genetic response. At the same time, use of MTM allows for simultaneous improvement of correlated traits which would also result in to faster genetic response (Mrode, 2005).

Results on genetic correlation between BW and WA are moderate and negative (Table 8). This is comparable to results from another study on crosses of the Sahiwal with exotic breeds (Kahi, 1995). The moderate and negative genetic correlation between BW and WA indicate that the genes acting at birth are similar to those acting at weaning of the Sahiwal calves. This is desirable since selection for earlier WA would result in improved BW. However, caution should be taken to avoid cases related to dystocia and increased BW. Under normal circumstances, BW for Sahiwal cattle is low and cases of dystocia are low. Very low and negative genetic correlation between BW and BA indicate that genes that determine BW are different from those affecting BA and selection for BA would result in very minimal improvement in BW.

Positive and moderate correlation between DG and BW and WA implies similarity in the effects of genes and thus selection for improved preweaning growth rate would result in improved BW and reduced age WA. Similarly, moderate correlation between WA, DG and BA would result in improved performance when selection is based on one of the traits. However, there is a strong antagonism between genes for PDG and other traits and selection for improved post weaning gain would result in reduced BW, increased WA, reduced preweaning gain and increased BA. Based on these findings, improvement in growth performance of the Sahiwal to one year would be achieved if selection were based on BA.

In this study, the genetic parameters generated when fitting maternal models are more accurate implying that such results need to be incorporated into the evaluation programme of the NSS to replace the previous results. Similarly, the minimal or complete absence of maternal effects for most traits of the artificial reared Sahiwal cattle implies that the maternal effects need not necessarily be selected for and selection for growth traits could be purely based on additive

genetic effects. Moreover, the high genetic correlation between growth traits reflects the need to concentrate on multiple trait selection based on age at one year (BA).

5.3 Annual genetic, environmental and phenotypic trends

The negative genetic trends for BW, DG and PDG indicate that there has been rather slow genetic progress at the NSS despite selection for improved growth performance. Similarly, positive trends for WA and BA depicted that there has been an increase in age at which Sahiwal cattle attained WW, which is still undesirable. Increased age at weaning reflects slow average weight gain. In the present growth improvement programme at the stud, females are not selected for growth and breeding bulls are selected based on weight at 24 months. An analysis of data on 24W indicated a positive genetic trend indicating that there has been some genetic progress in the herd for weight at 24 months. However, the negative phenotypic trend for this trait indicate the negative impact of environment on performance such that even with the increasing genetic merit for 24W, the environment is too demeaning to allow full genetic expression. The low daily weight gain has an implication on reproductive efficiency of females. Age at first services is weight depended and the rather slow weight gains would result in delayed onset of oestrus in females which ultimately translates in delayed age at first calving. This was noted in a recent study on genetic trends in age at first service (Ilatsia et al., 2007).

The negative environmental trends illustrate that there has been deterioration in management practices over the years. The impact is pronounced especially for post weaning growth traits which indicate post weaning stress that the animals at subjected to. The declining trend for growth traits is not desirable since weak and very light calves are normally culled early. High BW could be achieved by proper feeding management of pregnant cows at the stud. Although high BW is normally undesirable due to high incidences of dystocia, Sahiwal cattle are generally known to have few dystocia incidents even in case where the calf BW is high. The increasing phenotypic and environmental trend for WA could also be ascribed to differences in herd management strategies over the years. The overall environmental trend shows seasonal fluctuation in BA that reflects rainfall pattern. For example, there was good management in earlier years (in the 1970s up to mid 1980s) which resulted in reduced weaning age and higher weight gains and compared to other years when the general management shifted to a rather low input systems. Fluctuations in annual trends as result of poor climatic conditions with limited

management interventions are common in most tropical countries (Rege and Wakhungu, 1992; Khan et al., 1999; Plasse et al., 2002).

Increase in growth rate around late 1980's corresponds with increase in annual rainfall during that time (Figure 1). Similarly, the sharp drop in growth rate from 1998 coincides with post *El Nino* rains that drastically affected pasture availability in late 1990's. The annual trends reflect a decline in growth rate and seasonal variation in growth rate follows similar trends as for pre- and post weaning daily gains. The general implication is that growth rate of the Sahiwal calves at the stud increased slightly before 1998 but declined sharply thereafter. Declining annual genetic and environmental trends are also a reflection of the selection decisions at the NSS.

In general, the undesirable trends points out the weaknesses in both management and selection policy. In particular, grazing Sahiwal cattle purely on pasture without supplementation during drought would lead to a reduction in growth performance and this will further deter any genetic improvement accrued due to selection. Therefore, readjustment of the breeding plan and management strategies to incorporate more emphasis on growth traits and supplementation during drought, respectively, would enhance rapid genetic improvement for both growth and milk. Similarly, a multi-trait selection involving various growths, milk and reproductive traits and their possible correlation could be more appropriate for holistic genetic improvement of the Sahiwal cattle breed. Since the extent of this correlation is not known, an immediate research is required to determine the magnitude of these effects and their ultimate effect on the selection process.

5.4 Implications to the Sahiwal cattle breeding programme

The aim of genetic evaluation in a breeding programme is to help design appropriate breeding strategies and change the already existing breeding and management policies. Results in Chapter 4 indicate that management factors, in particular, adequate feeding in the dry season should be addressed for optimum performance. Therefore both existing management and breeding strategies in place need to be adjusted for the success of the breeding programme.

The aim of Sahiwal keepers is to improve performance of future generation of animals by making use of parents that outperform their contemporaries. Utilisation of such superior genetics in a population would therefore require the development of organised animal population structures to optimise response to selection. Recording and breeding schemes would

define how Sahiwal cattle populations will be structured for purposes of genetic improvement through the dissemination of superior genetics to the whole population. When implementing these schemes appropriate breeding structures are required in order to facilitate movement of genes in the population (Bondoc and Smith, 1993). This would involve two activities; the generation of desired genetic gain through selection of individuals based on accurately determined genetic merit; and the dissemination of the resultant improved genotypes to the entire population. The former would require the development of a selection index that combines all the desirable traits and assigning an aggregate breeding value. In order to achieve these, accurate estimates of genetic and phenotypic parameters for the economically important traits is a prerequisite.

This study has provided some estimates for growth traits for Sahiwal cattle that compliment those recently presented by Ilatsia et al. (2007) for milk production and reproductive performance. The first step would be to increase the weight of growth trait in the selection index by including BA for both males and females instead of the exclusive 24W currently being used for bulls. Secondly, the nucleus breeding scheme would offer practical means in which the population and the nucleus herds would benefit from each other. Pastoralist and smallholder Sahiwal keepers, as well as other commercial ranchers have shown interest in participating in the open nucleus breeding systems (Muhuyi, 1997; Mwacharo and Drucker, 2005). A decision therefore has to be made on the most efficient selection scheme involving these herds for genetic improvement.

5.5 Conclusions

In this study, environmental factors affected growth traits and especially the effect of year-season (seasonal fluctuation of rainfall and hence feed availability) resulted in reduced growth performance of the Sahiwal cattle. In addition, after fitting maternal univariate models for growth traits for Sahiwal cattle, the results indicate that maternal effects were very minimal for most traits and only significant for BW. Therefore, fitting maternal effects in genetic analysis especially for pre- and post-weaning traits would result to increased direct additive variance thus increased direct heritability hence biased estimates. Using inflated heritability estimates in calculating genetic progress would reflect inaccurate results hence introducing some bias to selection. Moreover, when comparing the appropriateness of using univariate to MTM models in analysis of growth traits of Sahiwal cattle, the results indicate that MTM models

significantly inflate the genetic parameter estimates. Multivariate model results give higher heritability estimates and BA presents a higher heritability estimates compared to other traits in the analysis. Finally, the study further evaluated the progress of the stud over the years and the results show both declining genetic and environmental trends probably due to minimal selection pressure for growth traits and suboptimal management strategies to cushion the effects of drought.

5.6 Recommendation

This study has revealed that environmental effects plays a significant role in growth of young Sahiwal cattle and addressing seasonal fluctuation of feed availability by adopting management policies that cushion the animals, especially young stock, during drought would improve early growth performance. Particularly, calf supplementation and pasture preservation techniques (like hay bulking for use during dry periods) should be considered. In addition, the absence of maternal effects on other traits implies that use of maternal models only on analysis of BW and animal models on other growth traits would be appropriate for evaluation of growth of Sahiwal cattle at the NSS. Furthermore, use of multivariate analysis basing selection on BA which corresponds with yearling age would result to faster genetic progress and hence improved growth rate. Besides, the declining genetic and environmental trends could be reversed by redesigning the current selection and management policies at the NSS in order to realise faster genetic progress in growth of Sahiwal cattle. In the redesigning of the breeding plan, the closed nucleus herd should be opened for it to participate in a breeding scheme where progeny tested bulls can be sourced from other ranches. Finally, given that the Sahiwal cattle is maintained as a dual purpose breed, further research need to be conducted to provide information on the correlation between milk production (milk and growth), reproduction and adaptive traits.

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