Institute of Animal Production in the Tropics and Subtropics

Breeding Strategies for Sahiwal Cattle Genetic Resources in Kenya

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Breeding Strategies for Sahiwal Cattle Genetic Resources in Kenya

Dissertation

submitted in fulfilment of the requirements

for the degree of "Doktor der Agrarwissenschaften"

(Dr.sc.agr./PhD in Agricultural Sciences)

to the

Faculty of Agricultural Sciences at the University of Hohenheim

Presented by:

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born in Vihiga County, Kenya.

Stuttgart-Hohenheim, 2011

This thesis was accepted as a doctoral dissertation in fulfilment of the requirements for the degree “Doktor der Agrarwissenschaften, Dr.sc.agr” by the Faculty of Agricultural Sciences at the University of Hohenheim on the 27th of July 2011.

Date of oral examination: 27th of July 2011

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ACKNOWLEDGMENTS

The successful completion of this thesis has been made possible by endless assistance of several individuals and institutions that endured my relentless questions and inquisitiveness seeking answers that resulted in the knocking in and out volumes of knowledge. I recognise that many people, directly or indirectly, contributed to the achievement of this work but cannot all be mentioned here. Their understanding in this regard is highly appreciated.

I had the privilege of working with an experienced team on the material content of this thesis. I would therefore want to thank my major supervisor, Prof. Dr. Valle Zárate for her guidance and support from the initial conception of the research project to the final preparation of the thesis. She immensely shaped this thesis through a thorough conceptualisation of the scientific content and critique. Prof. Valle also played a central role in shaping my thinking towards pragmatic research methodologies and approaches that will forever guide me in my future professional endeavours. My deep gratitude and appreciation go to Prof. Dr. Alexander Kahi who, 10 years down the line, stands out to be my mentor in my academic and professional life. He inducted me to the world of scientific thinking and writing, shaped and transformed my perception with regard to critical and exploratory thinking. I would also like to offer sincere thanks to Prof. Dr. Hans-Peter Piepho for his thoughtful suggestions in the analytical stages of my work. I also thank him for agreeing to be a co-reviewer of this PhD thesis. I wish to acknowledge my resident supervisor Dr. Regina Roessler for her relentless involvement in the whole process of my doctoral study. She was always willing to spend time in discussions; she effectively coped with my enormous and voluminous manuscripts and ensured that I remained focused to the end. I would like to thank my fellow graduate students at the Institute of Animal production in the Tropics and Sub tropics, University of Hohenheim for their constant encouragement and moral support.

I gratefully acknowledge the financial support by the German Academic Exchange Service (DAAD) to undertake my study. The fieldwork was supported with funds from the Kenya Arid and Semi Arid Lands (KASAL) project through the Kenya Agricultural Research Institute (KARI). Logistical support from the Ministry of Livestock Development personnel and the field enumerators during the fieldwork is highly appreciated. The cooperation of pastoralists and ranch managers is highly appreciated. I would like to specifically thank Mr. Richard Ole Pulei of KARI-Naivasha who played a central role in coordinating the entire fieldwork and in breaking language barriers by offering translation services. The staff of the National Sahiwal Stud (NSS) KARI-Naivasha, records office for their continued assistance during secondary data collection. My study was possible while I was on study leave from KARI. I very much appreciate the contribution of Dr. Lanyasunya and Dr. Murage of KARI-Naivasha, Prof. Kosgey of Egerton University, Dr. Wasike and Dr. Rewe of Pwani University College, who through their experiences in a similar process, kept encouraging me to soldier on. The patience and immense moral support of Phylis and Alexander during the entire period was invaluable to this end.

While everything has been falling so well into place up to this point, it is not just a coincidence. I thank the Almighty God for this.

DEDICATION

to my late paternal grandfather, Zakaria Mukisira, for his philosophy that whoever cherishes hard work and has the determination will always fulfil his/her ambitions. This has come to pass, on his 26th anniversary.

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LIST OF ACRONYMS AND ABBREVIATIONS

27WT	Weight at 27 months
305MY	305 day adjusted milk yield
ADG	Average Daily Gain
AFC	Age at First Calving
AI	Artificial Insemination
AMM	Animal-Maternal Model
ASALs	Arid and Semi Arid Lands
BSWB	Body Size and Weight Basis
BWT	Birth Weight
CBK	Central Bank of Kenya
CI	Calving Interval
CMP	Consumable Meat Percentage
CN_{CROSS}	Closed Nucleus Crossbreeding strategy
CN_{PURE}	Closed Nucleus Pure breeding strategy
CSCB	Carcass Characteristic Basis
CWT	Cow Weight
DP	Dressing Percentage
EAZ	East African Zebu
EV	Economic Values
FAO	Food and Agriculture Organisation
FI	Feed Intake
GDP	Gross Domestic Product
HSD	Half Sib of Dam

HSS	Half Sib of Sire
ICC	Intra Class Correlation
IPCC	Intergovernmental Panel on Climate Change
ITK	Indigenous Technical Knowledge
KARI	Kenya Agricultural Research Institute
KMC	Kenya Meat Commission
KSB	Kenya Stud Book
LL	Lactation Length
LMY	Lactation Milk Yield
LRC	Livestock Recording Centre
MAM	Multivariate Animal Model
MAS	Marker Assisted Selection
MOET	Multiple Ovulation and Embryo Transfer
MOLD	Ministry of Livestock Development
MOLFD	Ministry of Livestock and Fisheries Development
MONPD	Ministry of National Planning and Development
NDRI	National Dairy Research Institute
NSC	Number of Services per Conception
NSS	National Sahiwal Stud
ON_{PURE}	Open Nucleus Pure breeding Strategy
PHS	Paternal Half-sib Correlation
PLT	Productive Life Time
PSR	Post weaning survival rate
PT	Progeny Testing

RCCSC	Research Centre for Conservation of Sahiwal cattle
SCBS	Sahiwal Cattle Breed Society
SM	Sire Model
SR	Pre-weaning Survival Rate
SWT	Sale Weight
TLU	Total Livestock Unit
UAM	Univariate Animal Model
WWT	Weaning Weight
YWT	Yearling Weight
ZPLAN	Computer Programme for evaluating livestock breeding programmes

CHAPTER 1

General Introduction

CHAPTER 1: General introduction

1.1 Background and research objectives

The livestock sector in Kenya accounts for approximately 42% of the agricultural Gross Domestic Product (GDP), which represents about 10% of the overall national GDP (MOLD, 2008). The sector is supported by various livestock species which include cattle, sheep, goats, poultry, camels, pigs, bees, rabbits and other emerging livestock species such as ostrich, quails, guinea fowls, guinea pigs, llamas and pigeons. Cattle are predominant and most important species in terms of biomass (73%) followed by sheep and goats (19%) and camels (6%) (MOLD, 2009). Cattle and small ruminants are reared under various production systems which vary in agro-ecological conditions, and production and husbandry objectives that range from extensive subsistence pastoral, to more developed productivity based intensive systems (Bebe et al., 2003; Mwacharo and Drucker, 2005; Kosgey et al., 2008). Over 60% of the cattle population are found in the arid and semi arid lands (ASALs) which are mainly characterised by pastoral production systems (MOLD, 2008). Local Zebu cattle breeds (mainly the East African Zebu and unimproved Boran) are predominant in this system where they fulfil socio-cultural, subsistence and economic needs of the pastoral communities (Mwacharo and Drucker, 2005; Ouma et al., 2007; Rewe et al., 2009). These breeds have evolved to adapt to the prevailing harsh environmental conditions and traditional husbandry systems. However their production potential is sometimes perceived to be relatively low and thus producers sometimes resorted to crossbreeding with both exotic *Bos taurus* and other introduced Zebu breeds in order to exploit the trade offs that exist in regard to production and adaption (Mwandatto et al., 1988; Muhuyi, 1997; Muhuyi et al., 2000; Mwacharo and Drucker, 2005; Roessler et al., 2010). The Sahiwal is one of the breed of choice in this regard because of its relatively high milk production and growth potential, as well as good reproductive ability (Rege et al., 1992; Mwandatto, 1994; Ilatsia et al., 2007; Ilatsia et al., 2011). Its suitability for the rangelands is also based on the fact that it has evolved and been reared under almost similar harsh agro-climatic conditions in its native home in the Punjab region of India and Pakistan (Meyn and Wilkins, 1974; Kimenye, 1978; Trail and Gregory, 1981; Muhuyi, 1997). Specifically the Sahiwal breed is used in an up-grading programme of the relatively well adapted East African Zebu (EAZ) for improved milk production and growth performance under the challenging rangeland conditions (Meyn and Wilkins, 1974; Trail and Gregory, 1981; Muhuyi et al., 1999). The Kenya Sahiwal is thus a product of several generation of this up-grading programme. The breed has also been utilised in crossbreeding with European cattle breeds for both, large scale and smallholder dairy production, but only on a limited scale (Kahi et al., 2000; Bebe et al., 2003).

Sahiwal bulls were first introduced in Kenya from India and Pakistan in the early 1930s because of the generally low response capability of the local EAZ cattle for both milk and beef production under rangeland conditions (Meyn and Wilkins, 1974; Gregory and Trail, 1981; Muhuyi et al., 1999). The Sahiwal breed was identified then by British colonial government officials as an ideal breed that could guarantee both milk and beef production especially in the ASALs through crossbreeding with local Zebu (Meyn and Wilkins, 1974; Gregory and Trail, 1981). Bulls imported were kept in various government livestock improvement centres across the country. Due to growing demand for Sahiwal bulls and increased importation costs, the government decided to centralise all breeding activities by collecting the best cows and bulls from the livestock improvement centres to form the National Sahiwal Stud at Naivasha, and an initial breeding programme set up to serve as a starting point (Meyn and Wilkins, 1974; Kimenye, 1978). The aim of the breeding programme was to select for improved milk and growth performance under conditions that are almost similar to the low-input production systems that characterise most of the pastoral areas. The NSS was stationed at Naivasha, which has semi arid climatic conditions that provide the ideal rangeland conditions similar to the target pastoral areas (KARI, 1994). The breeding programme at the NSS was supported by an elaborate performance and pedigree recording scheme and artificial insemination (AI) that allowed for a progeny testing scheme. The NSS remains one of the leading sources of Sahiwal bulls and semen as well as the main stakeholder in the Sahiwal cattle breeding and conservation programme. Several other private and government ranches were also established in the rangelands with similar objectives of producing a dual purpose breed suitable for low-input production systems.

Currently there are two types of producers who keep Sahiwal genetic resources: private and government ranches that collectively form the nucleus herds, and the Maasai pastoralists (Roessler et al., 2010; Ilatsia et al., 2011a). Sahiwal cattle producers have continued to interact through exchange of genetic material based on temporal breeding structures established over 45 years ago. These structures were envisaged to serve only on interim basis as more elaborate and systematic plans were contemplated to anchor a more inclusive and sustainable breeding programme. However, these structures remain in operation to date, notwithstanding lack of knowledge on their suitability as well as competitiveness when compared to other alternative breeding schemes. Before further considerations are made on whether to maintain the status quo, or explore other alternatives, it is imperative to have clear knowledge on the production conditions under which the programme will be implemented as well as factors that motivate continued interests of producers in the Sahiwal cattle genetic resources, a clear understanding of the existing stakeholder institutional arrangement and how the different breeding programmes technically compare with each other. Over the years most studies have only focused on on-farm and on-station performance and genetic evaluation (e.g. Mwandotto et al., 1988; Mwandotto, 1994; Rege et al., 1992; Muhuyi et al., 2000; Karimi et al., 2005; Ilatsia et al., 2007; Ilatsia et al., 2011b). There have been no systematic endeavours undertaken to understand the production systems under which Sahiwal genetic resources are raised, including the different constraints in these systems, as well as production objectives and breeding goals of the two categories of Sahiwal cattle producers. Moreover, there is lack of knowledge on the suitability of the existing breeding programme, as well as on how competitive it is when compared to other alternative programmes with regard to economic and genetic success. Such knowledge will be of particular interest because it will assist in developing breeding strategies that are sustainable and able to bring about general improvement in productivity and profitability. This study aimed at developing breeding strategies for Sahiwal cattle genetic resources in Kenya by systematically following important prerequisite steps. To achieve this general objective, the following specific objectives were pursued:

1. To critically examine breeding and conservation programmes for Sahiwal cattle in the tropics, highlighting shortcomings and strengths in existing strategies, and opportunities for improvement and conservation.
2. To understand the production conditions under which Sahiwal cattle genetic resources are raised, determine producers' production aims and assess the relative importance of breeding goals and production challenges.
3. To identify and define the structure and roles of various stakeholder institutions that are crucial in the implementation of practical and sustainable Sahiwal cattle breeding and conservation programme in Kenya.
4. To identify, based on genetic and economic merits, the optimal breeding programme for Sahiwal cattle genetic resources by evaluating the current and alternative breeding

programmes.

5. To discuss practical options for implementation of a sustainable Sahiwal cattle breeding and conversion programme in Kenya.

1.2 Structure of the thesis

Subsequent to chapter 1 that presents the general introduction, Chapter 2 of this thesis, accepted for publication in Animal Genetic Resources, is entitled ‘Breeding and conservation programmes for Sahiwal cattle genetic resources in the tropics. A review’. This chapter presents a review of breeding and conservation programmes for Sahiwal cattle genetic resources in the tropic. It mainly focuses on Pakistan, India and Kenya as the core regions for development and highlights strengths and shortcomings in existing breeding and conservation programmes. Chapter 3 of the thesis, ‘Production objectives and breeding goals of Sahiwal cattle keepers in Kenya and implications for a breeding programme’ published in Tropical Animal Health and Production, reports on the results of a field survey undertaken to understand the production systems under which Sahiwal cattle are raised and the reasons why producers prefer to keep Sahiwal cattle genetic resources. This chapter describes the production conditions and objectives and identifies the breeding goals of Sahiwal cattle producers using participatory approaches. Production constraints are also highlighted in this chapter. Chapter 4 is entitled ‘Evaluation of basic and alternative breeding programmes for Sahiwal cattle genetic resources in Kenya’ is published in Animal Production Science. This chapter presents results of an examination of the current basic and alternative breeding programmes based on findings in Chapter 2 and Chapter 3 and recently published pertinent findings on the breed in Kenya. The chapter specifically examines the roles of various stakeholder institutions supporting the existing Sahiwal cattle breeding programme, as well as its genetic and economic success. Chapter 5 integrates all results from the previous chapters, and other relevant information into general discussions and considerations for breeding and conservation of Sahiwal cattle genetic resources in Kenya. Chapter 5 also highlights the strength and shortcomings in the methodological approaches used in the previous chapters. The major findings in the thesis are summarised in Chapter 6.

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Breeding and conservation programmes for Sahiwal cattle genetic resources in the tropics. A Review

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CHAPTER 2: Breeding and conservation programmes for Sahiwal cattle genetic resources in the tropics. A review

Abstract

Studies on Sahiwal cattle genetic resources in the tropics have mainly concentrated on evaluating their performance levels, with only a few published reports describing the breed characteristics. The aim of this study was to critically examine the existing breeding and conservation programmes for Sahiwal cattle in the tropics, focussing on Pakistan, India and Kenya as the core regions of development. The study was based on review of both, published and unpublished literature highlighting shortcomings and strengths in existing strategies, and opportunities for improvement and conservation. The Sahiwal breed is utilised for dairy and beef production under smallholder dairy, pastoral extensive and ranching production systems, both as purebreds or crossbreds. The necessary components to strengthen the breeding programme such as performance recording, genetic evaluation and AI facilities exist to different degree. Breeding and conservation efforts benefit from the technical and financial support from government research institutions, which also provide incentives to enhance participation in the programmes. However, breeding goals are rather informal and only defined in terms of high production levels with functional traits largely ignored. There is need for participatory identification of breeding and production goals, and structured cooperation of the small herds, so as to accommodate the specific contributions of the breed in future breeding and conservation programmes.

Key words: Breeding programme, Conservation, Sahiwal cattle, Tropics

2.1 Introduction

The Sahiwal cattle belong to a group of large Zebu breeds that are generally classified as dual purpose. The breed is mainly utilised for milk and beef production because it has relatively high milk production and growth performance compared to other Zebu cattle breeds (Trail and Gregory, 1981; Muhuyi et al., 1999; Joshi et al., 2001). The Sahiwal breed has evolved in harsh and diverse tropical environments and carries unique adaptive capabilities that make it relatively competitive in terms of production and adaptation under low-input production systems (Muhuyi, 1997; Philipsson, 1999; Joshi et al., 2001). The breed has been spreading to various tropical regions and comes second to the Brahman in terms of distribution among the Zebu breeds of South Asian ancestry (FAO, 1992; Joshi et al., 2001; Mulindwa et al., 2006; Hatungumukama and Detilleux, 2009). Previous studies on the Sahiwal cattle breed have mainly focused on performance evaluation. Furthermore the existing reports mainly describe the breed characteristics, highlighting only the desirable attributes. There is no literature study that collates and critically examines information from the various countries on the strengths and shortcomings in the existing breeding and conservation strategies. This study was therefore designed to critically examine breeding and conservations programmes of Sahiwal cattle genetic resources in the tropics, focussing on Pakistan, India and Kenya as locations of main development and distribution. The purpose is to identify shortcomings and strengths in existing strategies, and opportunities for genetic improvement and conservation. In this paper, the term Sahiwal genetic resources is used to refer to both Sahiwal and its crosses with other cattle breeds.

2.2 Study methodology

This study was based on review of both published and unpublished literature concerning Sahiwal cattle breeding and conservation programmes in the tropics. The review mainly focused on the weaknesses and strengths of existing programmes, and identified opportunities that could enhance breed improvement, utilisation and conservation. Information was sourced from journal articles, project and institutional reports, and discussions with key resource persons. Specific information on use values and performance of Sahiwal cattle is highlighted. Breeding and conservation programmes in Pakistan, India and Kenya are specifically described, with emphasis on within-country improvement and conservation strategies. A general discussion is dedicated to identifying some of the strengths and opportunities within country strategies that would enhance sustainable utilisation and conservation efforts. It should be noted, however, that this review might not have captured all other breeding and conservation programmes for the Sahiwal breed in the tropics. This would be expected because breeding and conservation programmes may be existing in other regions but seldom reported through the conventional avenues. The difficulty in finding published information on livestock breeding programmes described in sufficient detail in the tropics has been acknowledged (Rege et al. 2001; Kahi et al. 2005).

2.3 Breed description, uses and performance of Sahiwal cattle in the tropics

The Sahiwal breed is commonly of reddish dun colour with more of a dark brownish colour around the hump and neck (Animal Genetics Training Resource (2006; Muhuyi et al., 1999). In the males the colour darkens towards the extremities (i.e. head, legs and tails), while the females maintain the reddish coat colour. Sahiwals have a characteristic large, long and drooping ears; skin coat is generally smooth and shiny especially during hot weather conditions. Males attain a wither height of about 140 cm with well developed thoracic hump that is normally perpendicular to the backline (Muhuyi et al., 1999). Females are about 120 cm at maturity, they have large udders compared to other *Bos indicus* breeds and large unevenly distributed teats. Compared to other Zebu cattle breeds, Sahiwal are generally docile and of low temperament a characteristics that allows them to be milked in the absence of the calf (Kimenye, 1978).

Some of the traits description and their corresponding attributes that have traditionally been considered important for Sahiwal cattle in the tropics are summarised in Table 1 while Table 2 shows performance estimates of various production and reproductive traits of Sahiwal cattle and other selected Zebu cattle breeds in the tropics. Sahiwal cattle generally posses attributes and characteristics that make them relatively competitive under highly challenging low-input production systems in the tropics. However, it is important to note that there are other indigenous Zebu cattle breeds that are relatively more adapted to specific production systems, a fact that demonstrates clear trade-offs between the Sahiwal genetic resources and such breeds with regard to productivity and adaptability. For example, in a recent study on the role of Sahiwal genetic resources in pastoral production systems in Kenya, Roessler et al. (2010) and Ilatsia et al. (2010) reported that pastoralists rated Sahiwal genetic resources highly in regard to production and fertility traits but were more apprehensive of their disease, parasite and drought tolerance relative to the local East African Zebu breed. Such trade-offs need to be taken into account when making consideration of the various options for designing breeding programmes, because cattle keepers in low-input production systems prefer mixed breed herds, attaching to each breed involved different trait profiles depending on their desired production objectives (Valle Zárate, 1996). Thus, the future breed planning and organisation should take comprehensive account of the breed attributes that capture the full array of contributions of Sahiwal genetic resources to producers’ livelihoods.

Table 1. Production and functional traits of Sahiwal cattle and some of their related attributes

Traits	Important attributes	Reference
Growth and meat quality	Low birth weights, high pre- and post-weaning gain, well marbled meat with a very high meat-to-bone ratio, Large loin muscle area, flat and wide. Highly developed rump for meat deposition, high live weight.	Khan et al. (1999), Muhuyi (1997), Mwandatto (1985) , Trail and Gregory (1981
Milk yield	Relatively high milk yield and lactation length, persistence, high butter fat, protein, and solid non fat content, large and well attached udder.	Kimenye (1978); Muhuyi (1997), Dahlin et al. (1998), Joshi et al. (2001)
Reproduction	High calving rate under natural mating, calving ease (few dystocia incidences), early onset of puberty, high weaning rate, short CI under natural mating.	Khan et al. (1999), KARI (2004), RCCSC (2010)
Temperament	Good milking ability in absence of calf, ease of handling, good mothering ability.	Muhuyi et al. (1999), KARI (2004)
Adaptability	Disease tolerance, parasite tolerance, long productive life, ability to dissipate heat, smooth and shiny skin coat to reflect heat, long and pendulous ears as fly and insect swatters, loose and pliable skin to dislodge insects and ticks (extra layer of muscle tissue just under the skin which enables them to shake their skin to remove or discourage parasites)	Kimenye (1978); Muhuyi (1997), Dahlin et al. (1998), Joshi et al. (2001)
Feed utilisation efficiency	Conversion of low quality feed into milk and beef, low maintenance requirement, ability to utilise poor quality pastures, ability to cope with feed and water scarcity, more efficient digestion	Kimenye (1978); Singh and Kumar (1997).

According to the livestock sector strategy of the Government of Punjab and the Agricultural Census Organisation in Pakistan, Sahiwal genetic resources are among the leading sources of milk in Pakistan, coming second to buffaloes in domestic milk supply in Punjab province which is home to nearly half of the Pakistan population (Agricultural Census Organisation, 2006; Khan et al., 2008; Government of Punjab, 2010). In Kenya, Sahiwal genetic resources are mainly kept by pastoralists, private and government ranches, and by a few smallholder dairy farmers for domestic milk production and revenue generation through sale of live animals and surplus milk (Muhuyi, 1997; Bebe et al., 2003; Roessler et al., 2010).

Sahiwal bulls and semen have been exported from Kenya to several other East and Central African countries for crossing with various local Zebu breeds for milk production as well as provision of farm power (KARI, 2004; Mulindwa et al., 2006; Hatungumukama and Detilleux, 2009). In India, Sahiwal and their crosses are raised by smallholder farmers, government and private nucleus farms mainly for dairy production (Joshi et al., 2001; Singh et al., 2005). Previous organised crossbreeding programmes involving the Sahiwal and mainly European breeds have been used to develop synthetic breeds in India. For example the Karan Swiss and Frieswal have been developed through several years of crossing the Sahiwal to the Brown Swiss and Friesian breeds, respectively (Singh and Gurnani, 2004; Gaur et al., 2006; NDRI, 2007). The synthetic breeds have shown the advantage of combining the high production levels of the European breeds and adaptation of the Sahiwal on a sustainable basis for dairy production under smallholder production conditions (Kahi et al., 2000; Singh and Gurnani, 2004; Gaur et al., 2006).

Table 2. Performance estimates for production and reproductive traits of Sahiwal cattle in the tropics

Trait[1]	Country	Mean	No of records	Reference
LMY (kg)	Pakistan	1395	9382	Dahlin et al. (1998)
	Pakistan	1537	5697	Zafar et al. (2008)
	Pakistan	1547	3434	Rehman et al. (2006)
	Pakistan	1475	2039	Bajwa et al. (2002)
	Kenya	1370	6365	Ilatsia et al. (2007)
305 MY (kg)	Kenya	1663	-	Rege et al. (1992)
	Pakistan	1363	9341	Dahlin et al. (1998)
	India	1760	1887	Singh and Nagarcenkar (1997)
	India	1504	1367	Banik and Gandhi (2006)
LL (days)	Pakistan	262	5697	Zafar et al. (2008)
	India	288	1887	Singh and Nagarcenkar (1997)
	Pakistan	268	3434	Rehman et al. (2006)
	Kenya	278	6324	Ilatsia et al. (2007)
BWT (kg)	Kenya	22.9	121	Mwandotto (1994)
	Pakistan	21.6	3299	Khan et al. (1999)
WWT (kg)	Kenya	170	187	Trail and Gregory (1981)
CI (days)	Pakistan	465	3545	Khan et al. (1999)
	Pakistan	437	4461	Zafar et al. (2008)
	Kenya	468	4441	Ilatsia et al. (2007)
NSC	Kenya	2.1	7211	Ilatsia et al. (2007)
AFC (days)	Pakistan	1323	4213	Khan et al. (1999)
	Kenya	1347	2894	Ilatsia et al. (2007)

[1]LL, lactation length; LMY, lactation milk yield; 305 MY, 305 day adjusted milk yield; CI, calving interval; AFC, age at first calving; NSC, number of services per conception; BWT, birth weight; WWT, weaning weight.

Table 3. Heritability estimates for productive and functional traits of Sahiwal cattle in the tropics

Trait[1]	Heritability – Lactation 1	2	3	Heritability	Model[2]	Reference
LMY	0.32	0.45	0.41	0.16	AM	Ilatsia et al. (2007)
	0.15	0.12	0.17	0.17	AM	Dahlin et al. (1998)
	0.18				AM	Choudhary, et al. (2003)
				0.15	AM	Bajwa et al. (2002)
	0.27			0.32	AM	Kumar et al (2009)
	0.17	0.15	0.20		AM	Dahlin et al. (1998)
305MY	0.14	0.11	0.15	0.17	UAM	Dahlin et al. (1998)
	0.16	0.14	0.22		MAM	Dahlin et al. (1998)
				0.36	SM	Rege et al. (1992)
	0.35	0.47	0.31		PHS	Kimenye (1978)
LL	0.26	0.31	0.34	0.07	AM	Ilatsia et al. (2007)
	0.17	0.09	0.11	0.15	AM	Dahlin et al. (1998)
	0.14	0.14	0.17		AM	Dahlin et al. (1998)
	0.13				AM	Choudhary, et al. (2003)
	0.25			0.27	PHS	Singh and Nagarcenkar (1997)
CI	0.02	0.03	0.06	0.03	AM	Ilatsia et al. (2007)
	0.08			0.15	SM	Rege et al. (1992)
	0.07	0.04	0.05		AM	Khan et al. (1999)
	0.06	0.05	0.03		AM	Khan et al. (1999)
AFC				0.04	AM	Ilatsia et al. (2007)
				0.12	AM	Khan et al. (1999)
				0.29	SM	Rege et al. (1992)
NSC				0.01	AM	Ilatsia et al. (2007)
				0.02	SM	Rege et al. (1992)
BW				0.35	SM	Rege et al. (1992)
				0.21	AMM	Khan et al. (1999)
27WT				0.31	PHS	Mwandotto (1994)
YW				0.16	PHS	Mwandotto (1994)

[1]LL, lactation length; LMY, lactation milk yield; 305 MY, 305 day adjusted milk yield; CI, calving interval; AFC, age at first calving; NSC, number of services per conception; BW, birth weight; YW, yearling weight; 27MWT, weight at 27 months.
[2]UAM, univariate animal model; MAM, multivariate animal model; PHS, paternal half-sib correlation; SM, sire model; ICC, intra class correlation; AMM, animal-maternal mode

Performance and genetic parameter estimates for various production and reproductive traits of Sahiwal cattle are presented in Table 2 and Table 3 respectively. Differences in performance estimates reflect diversity in the gene pools and influence of environmental conditions and production circumstances. Most of these studies were, however, based on data collected from institutional herds, where production conditions might be quite different from the commercial herds. Furthermore, datasets used in the studies were very limited (Table 2), a fact that could cast doubt on the accuracy and reliability of some of the estimates. However, lack of proper recording systems is widely acknowledged as a major challenge in achieving comprehensive performance evaluation in developing countries (Wasike et al., 2011). Slow and undesirable genetic progress has been reported in the breeding goal traits of Sahiwal cattle in the tropics despite selection emphasis on these traits (Dahlin et al., 1998; Khan et al., 1999; Rehman et al, 2006; Ilatsia et al., 2007). This has been attributed to low selection intensities within the small herds, poor production conditions and high mortalities, inappropriate evaluation procedures and inbreeding depression that may emasculate genetic potential of breeding animals. Inbreeding depression has been reported on some performance traits in stationed maintained Sahiwal cattle populations in Kenya (Rege and Wakhungu, 1992) and Pakistan (Iaved et al., 2001).

2.4. Breeding and conservation programmes

Sahiwal genetic resources are distributed in 27 countries in Asia, Africa and the Caribbean (Joshi et al., 2001; FAO, 2007). Pakistan, India and Kenya are endowed with the majority of purebred Sahiwal cattle and have actively been involved in breeding and conservation programmes. This section will therefore focus on documented breeding and conservation programmes in these three countries. It should be noted, however, that other programmes might have been developed in other regions but have not been reported.

2.4.1 Pakistan

The Sahiwal breed originated in the arid subtropical Indus region of the Punjab province (Dahlin et al., 1995). It was raised in nomadic pastoral systems by the indigenous people for dairy production. However, increased irrigation activities in this region in the 1910s displaced the Sahiwal breed, as farming communities preferred Hissar and Haryiana breeds for draft power (RCCSC, 2007). Pakistan has a national database for various livestock species and breeds; however, there are huge disparities in reported population figures for the Sahiwal cattle breed. According to the country report submitted to the FAO, Pakistan has an estimated 0.35 million Sahiwal cattle (Government of Pakistan, 2003). This estimate is far below that of the recent livestock population census published by the Agriculture Census Organization, which indicates a population of approximately 2.7 million Sahiwal cattle, out of which approximately 80% (2.0 million) are found in the Punjab state province alone (Agricultural Census Organisation, 2006). The reasons underlying these huge discrepancies in the estimates cannot be discerned, however, it is possible that both estimates could have either included or excluded some non-descript breed types and other Sahiwal derivatives. It is possible that the population census results could include figures arising from inaccuracies and inconsistencies on the farmer's and enumerator's side in breed identification, especially where documented pedigree information is lacking.

Strategic breeding and conservation programmes have been operational in Pakistan for the last three decades. This could be traced to previous collaborative research programmes involving the FAO, the Pakistan Research Council and the Swedish University of Agricultural Sciences, which recommended the establishment of a genetic improvement and conservation programme for the breed in Punjab (FAO, 1992; Dahlin et al., 1995). This was in recognition of the economic contribution of the breed to rural livelihoods, as well as the threat posed to the future of the breed due to indiscriminate crossbreeding and changes in agricultural systems. This initiative culminated in the recent establishment of the Research Centre for Conservation of Sahiwal Cattle (RCCSC) by the Punjab state government (RCCSC, 2007). The RCCSC has the statutory mandate to register Sahiwal cattle, carry out performance recording and genetic evaluation and to conduct strategic research, in collaboration with national and international research organisations, for genetic improvement and conservation of the breed. Currently the centre has 24 sub-centres in Punjab which host more than 11,000 registered breeding cows. It also provides Artificial Insemination (AI) and extension services, and coordinates various disease and parasite control programmes as incentives to Sahiwal producers to participate in the breeding and conservation programme (RCCSC, 2007). The livestock sector strategy for the government of Punjab state has also prioritised the Sahiwal cattle breed among other indigenous livestock breeds for further genetic improvement and conservation (Government of Punjab, 2010).

Pure breeding is mainly implemented within government and private farms (Dahlin et al., 1998; Khan et al., 1999; Bajwa et al., 2002; Bhatti et al., 2007). The breeding programme depicts an open nucleus breeding system where the RCCSC coordinated nucleus herds are the main source of breeding animals for other medium and small holder livestock farms (RCCSC, 2007). Transfer of genetic superiority is mainly realised through AI where superiority of candidate breeding bulls for milk production is evaluated based on a progeny testing (PT) programme (RCCSC, 2007). Multiple ovulation and embryo transfer (MOET) is used to enhance reproductive rates of promising breeding cows (RCCSC, 2007). The RCCSC herds and other private herds form *in situ* conservation units. These farms are also the source of semen and embryos which are frozen and stored for future use.

Indiscriminate crossing remains a major challenge to conservation of the Sahiwal cattle breed in Pakistan (FAO, 1992; Dahlin et al., 1995; Government of Pakistan, 2003). To forestall this, the Pakistan government has formulated breeding policies and regulations that prohibit crossing of the Sahiwal cattle with exotic dairy cattle breeds (Government of Pakistan, 2003), but allows crossbreeding of non-descript populations with exotics breeds. However, enforcement of these regulations has not been fully achieved because of lack of clear mechanisms for their implementation. This could be because breeding and mating decisions are made by individual farmers targeting at the best genetic solution for their farm, which might not always coincide with conservation purposes, unless incentives are given. Further, it may be difficult for farmers to discriminate among which cattle breeds to use in crossing. The net consequence has been that illicit crossbreeding is further predominating leading to erosion of Sahiwal cattle genetic resources.

Both, private and government stakeholders are involved in the breeding programme at various levels. However, our study did not find evidence of the technical efficiency, in terms of economic and genetic sustainability, of the existing breeding programme organisation. Furthermore, formal breeding goals that reflect the production objectives and breeding aims of the various Sahiwal producers are not documented notwithstanding that Sahiwal genetic resources play different roles alongside other cattle breeds. In addition, the existing breeding programme prioritises lactation performance and fertility (as a proxy for adaptation) without clear evidence of how other important functional attributes are accounted for.

Nonetheless, the RCCSC could be regarded as a model conservation programme for the Sahiwal breed in the tropics where both human and financial capital has been concentrated to enhance breed conservation and utilisation. The expertise at the RCCSC, together with other collaborating institutions, provides a platform for consolidating efforts towards developing appropriate breeding schemes involving the various producers. The active involvement of the farmers and private farms in the genetic improvement and conservation programme also provides an opportunity to set up a more inclusive breeding programme and organisation with improved chances of sustainable success. The active Sahiwal cattle breed Society in Punjab regularly organises exhibitions aimed at promoting the breed among producers (RCCSC, 2007).

2.4.2 India

Unlike in Pakistan, our study did not find a national database indicating the population estimates of Sahiwal cattle in India. Nonetheless, there exist breeding and conservation programmes in the country. A pure breeding programme is implemented in 12 state-owned farms receiving technical support from the National Dairy Research Institute (NDRI) (Joshi et al., 2001; NDRI, 2007). The contributions of the NDRI in the breeding programme are similar to those carried out by the RCCSC in Pakistan and mainly involve coordination of performance recording, genetic evaluation and dissemination of genetic material to the farmers (Joshi et al., 2001; NDRI, 2007). The breeding goal mainly focuses on increased milk production. This is achieved through a performance testing programme based on recorded lactation milk yield of candidate bulls' daughters, supported by AI and a MOET programme (NDRI, 2007). There is no evidence of whether adaptation to local production conditions is also considered as important breeding goal. Furthermore, similar to the case of Pakistan, there was no clear evidence of how the breeding organisation involving the governmental herds is planned for sustainable genetic improvement and conservation.

In situ conversation is mainly concentrated in the 12 government maintained herds where less than 2000 breeding animals are hosted (Joshi et al., 2001; Government of India, 2003). There are also a few Sahiwal herds maintained on a religious basis referred to as '*Gaushalas*' given that cattle are sacred in the Hindu religion (Dr. D.K. Sadana, *personal communication*). There are two well maintained '*Gaushalas*' at Sirsa in Haryana and Gurudwara in Punjab, each with a herd of approximately 200 Sahiwal cows. Smallholder farmers also keep between 2-3 pure Sahiwal cows for milk production (NDRI, 2007). *Ex situ* conservation involve cryopreservation of frozen semen and embryos in national gene banks maintained by the NDRI.

Unlike in Pakistan where the breeding policy is prohibitive of crossing Sahiwal cattle with other breeds, various state breeding policies and regulations in India encourage crossbreeding of the breed with exotic breeds for dairy production (Government of India, 2003). Ironically, crossbreeding has been acknowledged as a major contributor to depletion of Sahiwal genetic resources in India (Joshi et al., 2001). This observation could be related to a lack of clear regulatory and monitoring mechanisms of these crossbreeding programmes especially at the farmer level, a situation that increases the tendency towards unplanned crossing.

2.4.3 Kenya

The history of Sahiwal cattle in Kenya dates back to the early 1930s when breeding bulls were imported from India and Pakistan for upgrading the local Zebu for higher milk production and enhanced growth performance under low-input production conditions (Meyn and Wilkins, 1974; Trail and Gregory, 1981). The promising results of the upgrading programme led to an increase in demand for Sahiwal bulls mainly by the Maasai pastoralists. A decision was taken in 1962 by the government to consolidate breeding activities by collecting the best Sahiwal cows and bulls from various livestock centres to create the National Sahiwal Stud (NSS) (Meyn and Wilkins, 1974). Other private Sahiwal ranches were also established to supplement the NSS (Muhuyi, 1997). Currently there are at least 18 ranch herds, which host approximately 7,000 purebred Sahiwal cattle with about 1500 breeding cows (KARI, 2004). Just like in India, there exists no national database showing breed specific population figures. However, some unpublished reports by field livestock extension officers in the pastoral areas estimate the Sahiwal population at 50,000 with about 170,000 Sahiwal x Zebu crossbreds (MOLFD, 2006).

Pure breeding and crossbreeding programmes are the main genetic improvement strategies for the Sahiwal breed in Kenya. Pure breeding programmes mainly involve 18 ranches, besides pastoral herds. Genetic gain is generated in the nucleus herds, mainly through male and to a lesser extent female selection; the transfer of genetic progress to the pastoral herds is realised exclusively through breeding bulls (Trail and Gregory, 1981; Muhuyi, 1997). The primary breeding goals of producers are high milk production, large body size, good fertility and adaptation to local production conditions (Roessler et al., 2010). However, the suitability as well as genetic and economic sustainability of the currently followed and alternatively suggested breeding schemes reflecting producers breeding goals have not been ascertained.

Conservation of Sahiwal genetic resources in Kenya involve both, *in-situ* and *ex-situ* strategies. Government and privately owned nucleus herds act as *in-situ* conservation units which produce breeding animals for the pastoral herds (Muhuyi, 1997). Pastoral herds also act as *in-situ* conservation units where Sahiwal cattle genetic resources are reared for both subsistence and commercial purposes. *Ex-situ* conservation takes place exclusively through preservation of frozen semen at the Central Artificial Insemination Station from superior bulls at the NSS (KARI, 2004). Unlike in the case of India and Pakistan, there is no national breeding policy in Kenya that governs use and development of specific livestock species and breeds. The yet to be operationalized animal breeding policy recently developed by the Ministry of Livestock Development (MOLD, 2009) describes conservation measures only in general terms and gives broader recommendations with no clear or specific policies accounting for the multiple roles that different livestock species and breeds play under various production systems. Nonetheless, there are strengths in the current set up that could form a basis for establishment of an expanded and more inclusive breeding programme. For example, all the nucleus herds keep some performance and pedigree records that could be joined into a basis for a coordinated joint selection programme among the nucleus herds. The NSS is a research facility under the Kenya Agricultural Research Institute. This offers an opportunity for effective mobilization of financial and human resources, and other infrastructure to provide the required technical support in implementation, monitoring and evaluation of the breeding programme. The existence of the Sahiwal Cattle Breed Society also offers an opportunity to enhance more coordinated breeding and husbandry activities involving the various producers. However, the current diversity of organisations and recording systems involved and the lack of co-ordination between them has to be regarded as a weakness, which may not be easily overcome.

2.5 General discussion

2.5.1 Breeding goals and breeding organisation

The success and sustainability of the breeding and conservation programmes for Sahiwal cattle genetic resources reviewed will depend not only on the technical quality of the selection process, but also on the structures of the breeding organisation and how the producers' desired breeding goals are accounted for. Except in the Kenyan case, this study did not find evidence of participatory definition of breeding goals that incorporate producers' production objectives. The existing breeding goals are either informal and narrow (i.e. based exclusively on production) or largely neglect the functional attributes that have defined the uniqueness of the Sahiwal breed under low-input production systems, by only addressing adaptation indirectly through selection on fertility. For the programmes to remain relevant and sustainable, compatibility with the socio-cultural and economic aspects of the producers needs to be ascertained and incorporated in future breed planning (Valle Zárate and Markemann, 2010). The present rather marginal and mostly informal involvement of producers in the breeding and conservation programmes in each of the three countries might form a basis for their formal incorporation into the organisation. Studies on participatory identification of production aims and breeding goals are already underway in Kenya (e.g. Roessler et al., 2010;

Ilatsia et al., 2010); similar or different approaches of farmer participation could be applied in the Indian and Pakistani cases.

The breeding systems reviewed in this study are based on a pyramidal management of the population with the breeders of nucleus herds at the top and participating herds at the lower levels. Performance recording and evaluation is confined in the nucleus herds as a basis for genetic evaluation and selection. However, evaluations are based on data obtained from either single or a few herds (see Table 2) with focus on production parameters while functional traits such as fertility and survival are seldom considered. Future performance evaluation should strive to better co-ordinate existing data sources, extend the traits to be monitored and augment data from the small herds and pastoralists to improve not only data amount and accuracy, but also account for possible genotype x environment interactions that might occur when animals are transferred from the stations to the production sector. According to our study, the organisation between the various herds and stakeholders is not well structured, transparent and may require substantial efforts to consider the organisational aspects towards achievement of optimal economic and genetic success. Professional planning and implementation will be critical in order to achieve optimal benefits from the breeding programmes and also make them more sustainable (Kahi et al., 2005).

2.5.2 Crossbreeding

The benefits of crossbreeding strategies involving the Sahiwal breed have sometimes been overstated to an extent that improvement of this breed has been regarded as synonymous to crossbreeding. Most of the crossbreeding programmes are not systematic, a scenario that is worsened by either lack of proper policies, or in case of their existence, there is lack of clear regulatory and enforcement mechanisms to ensure that such policies achieve the intended purpose. Strategies that support pure-breeding schemes that produce breeding animals to be used in crossbreeding in a systematic way may be most suitable to combine farmers' preferences with the purposes of breed conservation. This would particularly be important in curbing indiscriminate crossing that is largely blamed for rapid depletion of Sahiwal genetic resources in the tropics (FAO, 1992; Dahlin et al., 1995; Joshi et al., 2001). Crossbreeding programmes can be carried out in a way that supports and not replaces pure-breeding programmes. Kahi et al (2000) recommended crossbreeding systems for Kenya that are able to raise animal production from low to intermediate levels rather than programmes optimized for production, which are logistically difficult to implement and economically unsustainable. It would therefore be desirable that the Sahiwal crossbreds are not just evaluated in terms of their on-station performance (e.g. Mulindwa et al., 2006; Singh et al., 2005; Hatungumukama and Detilleux, 2009), but also on their resilience to physical environmental conditions in which they are to perform and including considerations for breeding organization and compatibility with conservation of the pure breed. More effective implementation of crossbreeding policies could also be achieved by use of ear notching or tagging where sanctions or penalties are preferred in cases where such identity marks are tampered with.

2.5.3 Future considerations

There are prospects for the three countries to cooperate in terms of exchange of genetic material and experiences in their Sahiwal breeding programmes. The difference in herd performances across the countries is an indication that there is some variance in the gene pools of the sub-populations which could be exploited through exchange of breeding material, although some of the differences could also be manifestation of different production environments. The active participation of the respective cattle keepers, the national research and training institutions offer an opportunity for the technical staff to share their experiences and contribute to the realisation of the programmes by conducting relevant research, monitoring and evaluation. This could also form the basis for a joint analysis of alternative genetic improvement and conservation strategies aimed at better utilization of Sahiwal cattle genetic resources. The cooperation will also be greatly advantageous in the use of shared infrastructure such as animal information systems and in the application of biotechnologies such as AI and MOET in the breeding and conservation programmes. However, there are logistical challenges that need to be addressed in order to realise the full potential of such a scheme. For instance farmer preferences may differ between the countries and each country might have Sahiwal cattle breed standards on which potential breeding animals are selected and allowed to join their nucleus stock. This was one of the reasons that an initial programme for semen importation from Pakistan into the Kenyan sub-population was suspended in 1992 over concerns of breed conformity and lack of evidence for genetic merit of the bulls (Muhuyi, *personal communication*). Furthermore, there are differences in the recording schemes among countries which would make direct comparison of bulls' breeding values a bit difficult and therefore the need to have a standardised basic recording system. The full benefits of the MOET could be realised subject to effective genetic evaluation and selection of female candidates for the scheme. There are also concerns about the financial sustainability of a co-ordinated programme, regarding financial support and cost-benefit sharing given that there would be specific issues within individual countries that would be of priority.

Acknowledgements

We thank the German Academic Exchange Service (DAAD) for funding the first author.

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Production objectives and breeding goals of Sahiwal cattle keepers in Kenya and implications for a breeding programme

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CHAPTER 3; Production objectives and breeding goals of Sahiwal cattle keepers in Kenya and implications for a breeding programme

Abstract

The Sahiwal breed has been used for upgrading the East African Zebu (EAZ) for improved milk production and growth performance in the southern rangelands of Kenya. Main users of this breed are Maasai pastoralists. Until now, there has been no deliberate effort to understand why these pastoralists specifically prefer to keep Sahiwal genetic resources as well as which traits are considered important by them and what is the underlying reason for this. However, this information is regarded vital for further development of the breed. A survey was conducted between May and October 2009 among Maasai pastoralists in Kajiado and Narok counties in the Southern part of Kenya, and private ranches and government farms to identify production objectives and breeding goals of Sahiwal cattle producers. Sahiwal genetic resources were mainly kept for domestic milk production and for revenue generation through milk sales and live animals. To a limited extent they were kept for breeding and also for multiple objectives that included social functions and insurance against risks. Production aims were influenced to varying extents by various household and farmer characteristics. Sahiwal cattle and their crosses were generally perceived to be better with respect to productive traits and fertility traits when compared to the EAZ. However, the EAZ was rated higher with respect to adaptation traits. The breeding objective traits of primary importance were high milk yield and big body size, good reproductive efficiency and relatively good adaptation to local production conditions. Performance and functional traits are important breeding goals that play a major role in fulfilling the multiple production objectives. This forms the basis for the optimisation of a breeding programme for sustainable utilisation to meet the needs of Sahiwal cattle producers.

3.1 Introduction

The Sahiwal cattle breed was introduced in Kenya by the British colonial government from India and Pakistan for crossing with local Zebu breeds to improve milk and growth performance. The Kenya Sahiwal is thus a product of several generations of crossing local East African Zebu (EAZ) cows with Sahiwal bulls. A decision was taken by the government to centralise the breeding and management of the breed at Naivasha, now the National Sahiwal Stud (NSS) which is currently a research facility of the Kenya Agricultural Research Institute (KARI) (Muhuyi, 1997). The establishment of the NSS and other private ranches marked the beginning of a breeding programme that aimed at improving milk and beef production under conditions that would be close to the low input pastoral production systems (Meyn and Wilkins, 1974). The NSS and private ranches currently form the nucleus stud herds and are the main source of breeding animals for the Maasai pastoralists who keep Sahiwal genetic resources both as purebreds and as crosses with the EAZ (Muhuyi, 1997).

The breeding programme implemented in 1962 was just to function on interim basis (Meyn and Wilkins, 1974). It was envisaged that prior to its full implementation, its suitability and sustainability would be ascertained in order to accommodate producers' production objectives and breeding goals. However, the programme is still operational to date, with the ascertains of its relevance in light of the producers' production aims and breeding goals still left pending. Breeding strategies that ignore production aims and breeding goals risk being ignored, being unsustainable or alienating the entire breeding programme from the producers (Ouma et al., 2007). Producers' interests can be captured through participatory approaches to gain insight into production aims, breeding goals, breeding practices and husbandry practices among pastoralists and ranchers who keep Sahiwal cattle genetic resources in Kenya. It is important, however to note that production aims could be influenced by socio-cultural and economic factors as well as differences due to geographical factors. These factors are expected to have pronounced effects on livelihood strategies which ultimately might affect the decision for keeping Sahiwal cattle genetic resources for particular reasons. Therefore a clear definition and understanding of the producers' multiple and often interactive production objectives and their contributions to the breeding goals are equally important considerations in order to optimise a breeding organisation as well as evaluate the suitability of the existing programme. The objective of this study was therefore to explore the reasons why producers keep Sahiwal cattle genetic resources and identify traits of perceived importance. In this paper, Sahiwal cattle genetic resources are used to refer to both pure Sahiwal and their crosses with the EAZ.

3.2 Materials and methods

3.2.1 Study area

The study was conducted between the months of June to October 2009 and covered the counties of Kajiado and Narok, inhabited by the Maasai community, whose main source of livelihood is pastoral livestock keeping. Figure 1 shows a map of the study area. The counties were purposively selected because they have the highest concentration of Sahiwal cattle genetic resources in the country and represent the target area for the Sahiwal cattle breeding programme. The Kajiado County has a semi arid to arid tropical environment, conditions that favour pastoral livestock production. The EAZ is the predominant cattle breed, followed by Sahiwal and their crosses with EAZ, and unimproved Boran (MOLFD, 2006). Kajiado has approximately 440,000 heads of cattle, out of which approximately 39,000 are pure Sahiwal while approximately 130,000 are crosses of the Sahiwal breed and EAZ (MOLFD, 2006). Kajiado falls under the research mandate area of the NSS where Sahiwal breeding activities have actively been promoted, hence the relatively high concentration of Sahiwal genetic resources.

The Narok County has relatively favourable weather conditions (average annual rainfall of 1400 mm with temperature ranges of 18 ^{0}C to 28 ^{0}C in the North and West, while the southern part has a semi-arid climate). The weather conditions in Narok favour crop-livestock farming whereby crop production is practiced mainly on leasehold arrangements. Narok South is mainly semi-arid where pastoral livestock farming is the main activity. Sahiwal bulls were first introduced in Narok in the early 1980s for upgrading the local Zebu. Narok County has an approximate cattle population of 770,000, out of which 5000 are pure Sahiwal cattle while 69,000 are crosses of Sahiwal and the local Zebu (MOLFD, 2006).

3.2.2 Sampling and data collection

The sampling focussed mainly on pastoralists who kept Sahiwal cattle and their crosses with EAZ. A minimum of 10 respondents were randomly selected from a given administrative location in Narok County. However, this sampling procedure based on locations was not possible in Kajiado County due to the drought conditions. Thus, information was obtained from the Ministry of Livestock Development field officers on possible sites where the pastoralists had migrated to in search of pastures and water. These sites formed the sampling units. A total of 244 pastoralists were interviewed (152 from Narok, and 92 from Kajiado). In addition, interviews were conducted with managers of 18 ranches and other government farms that keep Sahiwal cattle genetic resources. The survey was conducted by way of structured interviews. The questionnaire was designed to obtain information from respondents on general household characteristics, purpose of keeping Sahiwal and their crosses, traits of importance, their selection criteria and culling decisions, feeding and breeding management, animal health, marketing and pricing. Government field officers with some knowledge of animal production and health, familiarity with the study areas and ability to speak the local language, were hired as enumerators.

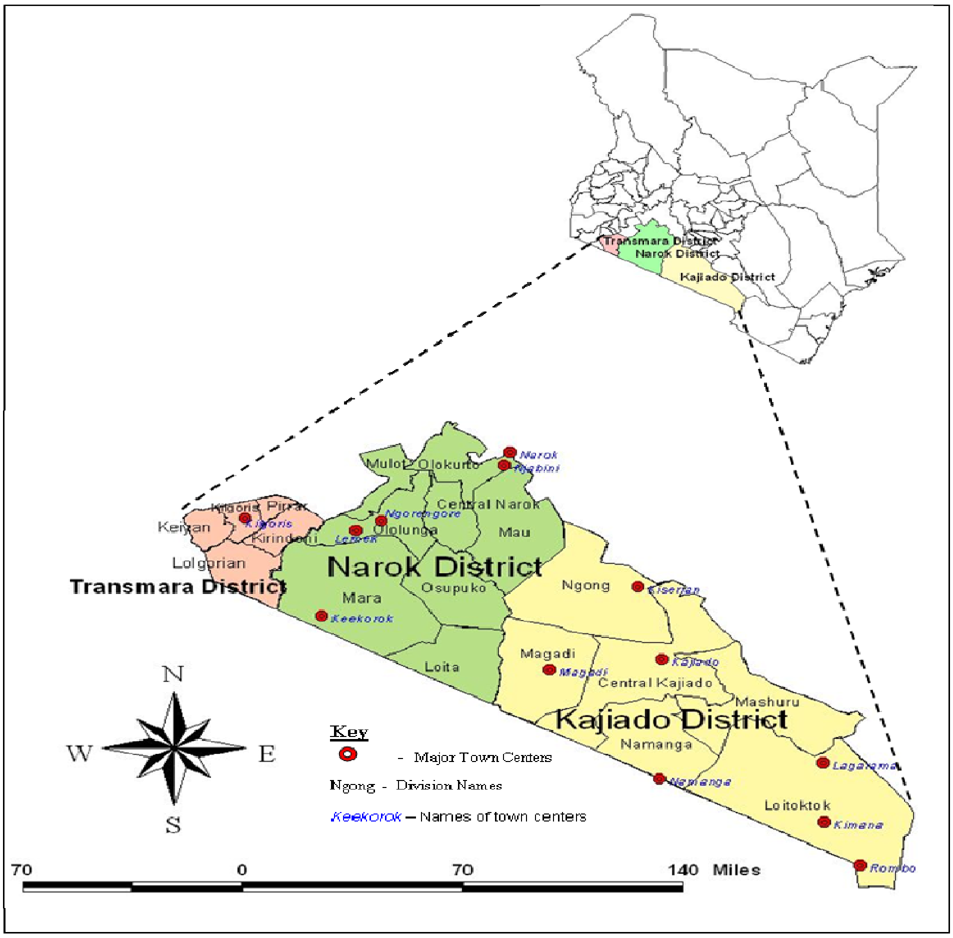

Figure 1. Map of the stud area. Transmara and Narok Districts constitute Narok County while Kajiado District is currently designated as Kajiado County

Seven group discussions with 7-10 key informants were held to crosscheck information obtained in personal interviews and to gain a deeper insight into some of the topics, namely breeding objective and selection traits, importance of the traits, general breeding management as well as major constraints and challenges in Sahiwal cattle breeding. The key informants were selected based on their experience in management of Sahiwal cattle genetic resources.

3.2.3 Data analysis

Descriptive statistics were calculated to evaluate general information collected on household and farmer characteristics. Indices were calculated to represent weighted averages of rankings for purposes of keeping Sahiwal genetic resources and culling criteria. Ranks were based on the first four choices of priority characteristic in order of importance by the respondent (i.e. 4=highest importance, 1=lowest importance) and were calculated as: Rank index= sum of [4 for rank 1+3 for rank 2+2 for rank 3+1 for rank 4 for a specific purpose or culling criteria] divided by the sum [4 for rank 1+3 for rank 2+2 for rank 3+1 for rank 4] for all purposes of keeping Sahiwal cattle genetic resources or culling criteria.

Logistical regression models were used to evaluate the effect of household characteristics on the purpose of keeping Sahiwal cattle genetic resources. The household characteristics considered were: household size, literacy level of the household head, age class of the head, land tenure system, the region and number of livestock. The age class of the head was used as a proxy for experience in livestock production and management. The literacy level of the head was fitted as a binary response, where zero (0) was assigned to those who could not read and write and one (1) to the literate. The household size was assumed to affect household's livelihood strategies (through e.g. labour availability, competition for resources) and was fitted as continuous variable. Livestock numbers measured in tropical livestock units (TLU) was used as a proxy for household wealth status. The land tenure (ownership) was included in the model as proxy for access to credit facilities, which would influence the level of investment in livestock activities. Since there were differences in climatic conditions and household characteristics between the counties, a term representing the two counties was included in the model to account for such differences. Gender was excluded from the model since there were very few female household respondents. Due to common grazing fields in pastoral areas, land size which would be expected to influence number of livestock was not considered in the final model. The logistical regression equation fitted was:

$$\log[p_i/(1-p_i)] = \beta_0 + \beta_1 X_{1i} + \alpha_2^T X_{2i} + \alpha_3^T X_{3i} + \alpha_4^T X_{4i} + \alpha_5^T X_{5i} + \beta_6 X_{6i}$$

where: p_i is the probability that the i^{th} respondent keeps Sahiwal genetic resources for a specified purpose; X_{1i}, X_{2i}, X_{3i}, X_{4i}, X_{5i} and X_{6i} represent household size, literacy level, age class, land tenure system, region and tropical livestock number (TLU) in the i^{th} household, respectively and β_1, α_2, α_3, α_4, α_5 and β_6 are regression parameters associated with each explanatory variable. For qualitative factors represented by dummy (0-1) variables in column vectors $X_{ji}(j=2,3,4,5)$ regression parameters α_j are vector-valued with number of elements equaling the number of categories minus one and α^T_j denotes the transpose of column vector α_j. Literate respondents, old respondents (>50 years), individual land ownership and Kajiado County were considered as reference for the respective class variable.

It was hypothesised that there could be differences in perception of various trait qualities among pure Sahiwal, crosses and the EAZ breed that would ultimately influence production objectives and breeding aims. A proportional odds model with terms for breed was therefore used to evaluate trait qualities as perceived by pastoralists. Trait quality levels were defined as good, average or poor. The traits were categorised into production (size and conformation, milk and growth performance), fertility (calving interval, age at first calving and calving ease) and adaptability (disease and parasite tolerance, drought and heat tolerance).

3.3 Results

3.3.1 General household and farmer characteristics

Table 4 summarises household and farmer characteristics in the two study sites.

Most household heads were male (94.7% and 96.7% in Narok and Kajiado, respectively), with 42 % of those interviewed in Narok falling in the middle aged bracket (31 to 40 years), while the majority in Kajiado were relatively older (> 40 years). The household sizes were larger in Narok (mean =13.4) compared to Kajiado (mean=10.8) (P>0.01). Literacy levels were higher in Narok (over 50%), while Kajiado County had more educated household heads (63%). Communal land ownership was more prevalent in Narok (34.9%) than in Kajiado (1.1%). Mixed livestock keeping was the main economic activity in both study sites; livestock species were sequentially ranked in order of importance as cattle, sheep, goats, donkey and poultry. The mean livestock numbers varied depending on the species. There were also large variations in flock and herd sizes in the two sites. Pastoralist in Narok had more cattle compared to their counterparts in Kajiado (means of 113 vs 87). However, those in Kajiado kept on average 15 more sheep, twice as many goats and 3 more donkeys compared to their counterparts in Narok. Although the mean number of Sahiwal females was higher in Narok (mean=62.0) compared to Kajiado (mean=55.6), the proportion of households with pure Sahiwal cattle in Kajiado (38%) was much higher compared to Narok (4.6%). Pastoralist in Kajiado also owned more Sahiwal breeding bulls (mean=7.6) in their herds compared to their counterparts in Narok (mean=2.0). However, the proportion and average number of Sahiwal crossbreds and EAZ females was high in Narok compared to Kajiado.

3.3.2 Use of Sahiwal cattle genetic resources by pastoralists compared to ranchers

Table 5 shows a summary of husbandry and breeding practices by pastoralists in contrast to stud herds (private ranches and government farms). All the stud herds (N=18) were commercially oriented, generating revenue mainly through sale of breeding animals, followed by milk and cull-for-age cows and steers. Pastoralists on the other hand kept Sahiwal cattle genetic resources for subsistence with surplus products sold mainly as milk and live animals. Free grazing on natural pastures was common to both producer groups with supplementary feeding only limited to mineral salt licks. However, most pastoralists (96.7%) practiced mixed grazing of Sahiwal cattle and their crosses with local Zebu cattle and small ruminants on communal grazing fields. All the pastoralists (N=244) interviewed indicated use of family labour with clear roles shared among family members. All the ranches employed skilled personnel for the overall ranch management while unskilled labour was used mainly in herding and milking. Most pastoralists (94.3%) and all stud herds take cognisance of the importance of ecto-parasite control, especially ticks, practicing routine spraying and dipping to prevent vector borne diseases. Both groups indicated to participate in public routine vaccination programmes against notifiable diseases; yet, most pastoralists (80%) relied more on para-veterinarians and local agro-veterinary shops for general disease and other prophylactic treatments. Sixteen of the 18 stud herds uniquely identify their animals by use of either alpha-numeric branding and/or ear notching. Among pastoralists, a combination of branding (96.2%), ear notching (60%) and matrilineal naming (54.7%) were used to differentiate their animals both within and among herds. None of the pastoralists interviewed kept pedigree or performance records. Natural group mating, where mate selection was practiced, was prevalent in both producer groups (97.5% for pastoralists, and all ranches except the NSS where AI was practised).

Table 4. General household and farmer characteristics in Narok and Kajiado counties

Characteristic		Narok			Kajiado		
		Respondents[1]	Percentage[1]	Mean (SD)	Respondents[1]	Percentage	Mean (SD)
Gender of household head	Male	144	94.7		89	96.7	
	Female	8	5.3		3	3.3	
Age of household head (years)	Less than 30	29	19.1		6	6.5	
	31 to 40	65	42.8		19	20.7	
	41 to 50	37	24.3		36	39.1	
	More than 50	21	13.9		30	32.6	
Education level of household head	Illiterate	82	53.9		34	37.0	
	Literate	67	46.1		56	63.0	
Land ownership	Own	99	65.1		90	97.8	
	Communal	53	34.9		1	1.1	
	Lease	0	0.0		1	1.1	
Household numbers		147		13.4	80		10.8 (8.3)
Livestock by species							
Cattle		152	100.0	113.9(107.1)	92	100.0	87.7 (81.1)
Sheep		136	89.5	103.2(104.5)	92	100.0	118.4 (149.8)
Goats		134	88.2	36.4(31.9)	85	92.4	74.5 (65.0)
Chicken		60	39.5	17.3(13.4)	34	37.0	16.4 (33.2)
Donkey		69	45.4	2.2(1.5)	62	67.4	5.2 (3.8)
Cattle by breed, sex and age class							
Sahiwal	Bulls	94	61.8	2.0(5.1)	75	81.5	7.6(14.2)
	Females[2]	7	4.6	62.0(90.8)	35	38.0	55.6(69.3)
	Young stock[3]	4	2.6	2.5(3.0)	35	38.0	19.9(32.6)
Sahiwal crosses	Steers	88	57.9	8.6(15.3)	44	47.8	21.3(24.3)
	Females[2]	145	95.4	41.3(62.1)	78	84.8	29.3(33.7)
	Young stock[3]	145	95.4	28.7(36.1)	75	81.5	16.5(19.1)
	Crossbred steers	101	66.4	15.3(17.0)	14	15.2	14.5(19.3)
EAZ	Bulls	12	7.9	13.3(27.5)	8	8.7	14.1(10.0)
	Females	86	56.6	26.4(38.1)	13	14.1	14.0(21.1)
	Young stock[3]	86	56.6	20.1(24.6)	13	14.1	8.1(13.2)

Source: Personal interviews with 244 pastoralists;
[1]within class percentages do not add up to 100% because of non responses; [2]Include both heifers and cows; [3]Include animals up to one year of age

Table 5. Comparison of husbandry and breeding practices of pastoralists with ranchers

Aspects	Sahiwal producers	
	Pastoralists	Private and government ranches
Production and breeding aims	Both subsistence and market oriented, multiple objectives,	Mainly commercial, multiple objectives
Main products	Milk, cull-for-age animals, and steers	Breeding bulls, milk, cull-for-age cows and steers
Feeding	Communal mixed grazing on natural pastures, mineral salts licks, no concentrates	Extensive grazing on natural pastures, mineral salts licks, no concentrates
Health management	Government vaccination programmes, private veterinary disease and prophylactic treatment programmes, communal dipping and individual hand spraying, ecto-parasite control for young stock	Private veterinary vaccination and disease treatment programmes, regular dipping, and de-worming up to weaning
Identification and recording	Branding for identifying herds, use of names within family lines, no performance records	Alpha-numerical branding to identify individual animals, unsystematic performance and pedigree recording
Selection and culling	Physical appraisal and performance of relatives ancestral information	Physical appraisal supported by some performance records and documented pedigree records
Breeding management	Natural mating based on family lines, sires replacement based on ancestry and time of service in the herd, no systematic exchange of breeding stock	Mostly natural mating and AI[1], breeding based on mate selection and family lines, sire replacement based on age and ancestry, no systematic exchange of breeding stock
Housing	Open enclosures with live thorny fences for protection against carnivores and theft, sometimes manned. Calves secured indoors	Fenced night sheds and paddocks, calf pens provided
Marketing	Direct sale to other pastoralists, local butcheries, auction centres and middlemen	Pastoralists, local butcheries and abattoirs
Labour	Mainly family labour	Hired skilled labour at management and casual labour for grazing and milking

Source: Personal interviews with 244 pastoralists and 18 ranch managers, 8 group discussions and field observations

[1]Only practiced at the National Sahiwal Stud

3.3.3 Reasons of pastoralists for keeping Sahiwal cattle genetic resources

The rankings for various purposes of keeping Sahiwal cattle genetic resources are shown in Figure 2. Pastoralists in the two counties mainly kept Sahiwal cattle genetic resources (in descending order of importance) for milk production, as a source of cash income (from sales of surplus milk and live animals), meat production, breeding and multi-purposes (risk management and socio-cultural functions). Sahiwal cattle genetic resources were mainly sold when cash was required for specific purposes such as investment in assets, buying of breeding animals, and to cover children educational expenses. Milk production was for home consumption and any surplus was sold for cash income to cater for immediate subsistence family needs, purchase of prophylactic drugs and treatment, and as savings to cover future financial obligations.

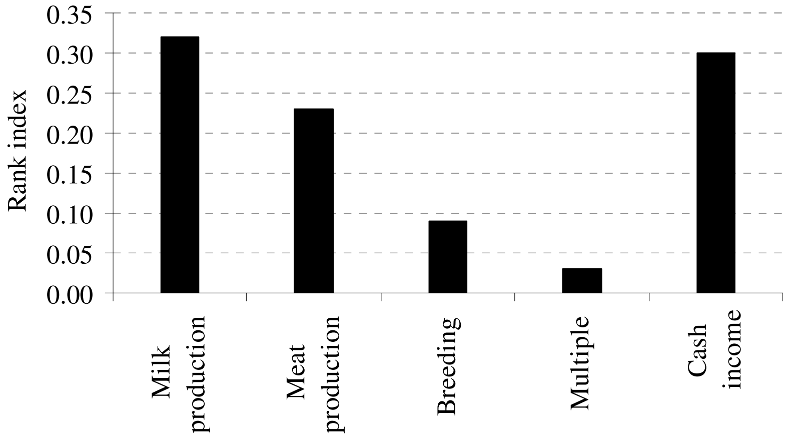

Figure 2. Ranking[1] for the various purposes[2] of keeping Sahiwal cattle genetic resources.
[1]Index based on rank weights of the first four choices of priority characteristics (i.e. 4=highest importance, 1=lowest importance).
[2]Multiple represents roles such as insurance against risks and socio-cultural functions.

Results of the logistical regressions show that the importance pastoralists attached to different purposes of keeping Sahiwal cattle genetic resources is influenced by various households characteristics (Table 6). Hence, milk production was likely to be ranked higher by young pastoralists (<30 years) than by older ones (>50 years) (P<0.01), and pastoralists >30 years but <50 years showed a high likelihood to indicate meat production as more important (31-40 years, p<0.05; 41-50 years, p<0.01). The impact of household size was positive and significant (p<0.05) for keeping Sahiwal for meat production. The middle age (41-50 years) household heads had also a high likelihood of keeping Sahiwal for income generation. When compared to their counterparts in Kajiado, pastoralists in Narok were less likely (p<0.01) to keep Sahiwal for meat production but would be more inclined (P<0.05) towards cash generation. Literate respondents were more likely to keep Sahiwal for cash generation compared to illiterate pastoralists (p<0.05). In contrast to other household characteristics, the land tenure system did not have any influence on farmers' reasons for keeping Sahiwal cattle genetic resources. There was no significant relation between the number of livestock units and the objective to keep Sahiwal cattle for cash income or breeding purposes.

Table 6. Objectives of keeping Sahiwal cattle and their crosses by pastoralists (coefficients and their corresponding standard errors (in parenthesis) of logistical regressions

Variable[1]	Purpose of keeping				
	Milk	Meat	Breeding	Multiple [2]	Cash income
Household size	-0.037(0.039)	0.040*(0.010)	-0.012(0.020)	0.004(0.002)	0.005(0.001)
Education level	0.487(0.350)	0.211(0.156)	0.202(0.165)	0.200(0.171)	-0.358*(0.164)
Age of head					
< 30 years	1.404**(0.596)	0.229(0.334)	-0.312(0.325)	-0.094(0.348)	-0.245(0.348)
31 to 40 years	-1.027(0.834)	0.609*(0.265)	0.092(0.267)	0.074(0.275)	-0.539*(0.278)
41 to 50 years	0.310(0.543)	-0.721**(0.257)	0.165(0.276)	-0.041(0.284)	0.575*(0.259)
Land tenure	0.104(0.500)	-0.053(0.194)	-0.235(0.205)	-0.379(0.211)	-0.034(0.204)
County	-0.665(0.423)	-0.492**(0.195)	0.059(0.195)	0.070(0.200)	0.439*(0.196)
TLU[3]	0.009**(0.003)	-0.004*(0.002)	0.004(0.002)	0.005*(0.002)	0.001(0.001)

*, **Mean coefficient statistically significant at 5% and 1% level probability, respectively
[1]Literate respondents, old age group (> 51 years), individual land ownership and Kajiado County are the reference group for the respective class variable
[2]Represents multiple roles such as insurance against risks and socio-cultural functions
[3]Tropical livestock unit, TLU, calculated as 0.7 TLU=1 head of cattle; 0.5 TLU=1 head of donkey; 0.1TLU=1 head of sheep or goat

However, higher numbers of livestock significantly increased the odds of keeping Sahiwal cattle genetic resources for milk ($p<0.01$), and multiple purposes ($p<0.05$), but decreased the odds of keeping them for meat production ($p<0.05$)

3.3.4 Breeding goals, trait perception and selection criteria

Table 7 shows a summary of pastoralists' stated breeding goal traits, their importance and corresponding selection criteria, while Figure 3 shows the main reasons for culling and their ranking in both, males and females. All respondents interviewed (N=244) preferred Sahiwal cattle with high milk production and big body size, while 86% and 79% stated a good reproductive ability and adaptability, respectively as their preferred breeding goal. Managers of all the stud herds (N=18) indicated high milk production, high growth rates and sale weights, and good fertility as their main breeding goals. Stud herd farms raised their animals under range conditions with minimal husbandry interventions as a way of ensuring adaptation of the animals to these conditions. Pastoralists mentioned high milk production as a breeding goal because that would guarantee sufficient supply for both domestic consumption and surplus for sale.

Table 7. Stated breeding goal traits, corresponding reasons and their selection criteria

Stated breeding goal	Reasons	Selection criteria
High milk yield	Increase calf growth and survival rates, domestic milk sufficiency, surplus for sale to buy minerals supplements and health management	Dam's own milk performance, body size, tail length, udder size and teat placement
Big body size	High sale prices, high milk yield in females	Size at birth, individual's growth rate, sire's growth performance, individual body frame
Good reproductive efficiency	High off-take, more replacement	Early estrus, high calving rate (one calf/year), low dystocia incidence
High adaptability	High off-take, low health costs, more replacements, long productive life	High growth rate, body condition, general health status of family lines

Source: Personal interviews with 244 pastoralists and 8 discussion groups

They also indicated that cows with high milk yield increased the growth and survival rates of their progeny. Big body size as breeding goal was manifested in the high ranking based on size as a selection and culling criterion in both males and females (see Figure 3). Breeding for big body size, according to a rapid appraisal of livestock markets during the study, was probably caused by market prices, since prices were mostly determined by body weight. The pastoralists preferred females with a large body because they believed body size was an indirect measure for high milk production ability. Good reproductive efficiency was mentioned as a breeding goal for female cattle. Most pastoralists (86%) viewed reproductive efficiency mainly in terms of one calving per annum. The reasons given for the importance of good reproductive efficiency were to increase their herd sizes by having more replacements. High adaptability was mentioned as desirable trait because of its influence on herd size and health costs hence one of the main reasons for culling was based on health in both sexes (Figure 3). All pastoralists interviewed relied on physical characteristics supplemented with pedigree information for making their selection decisions. For example, high milk producers were retained in the herd as bull dams and progeny of such cows were mostly selected as replacement heifers. Physical characteristics such as length of the tail, body frame, udder size and teat placement were guides in selecting for high milk and growth performance. Pastoralists used individual animal's growth performance and general health as indicators for the ability to withstand stress.

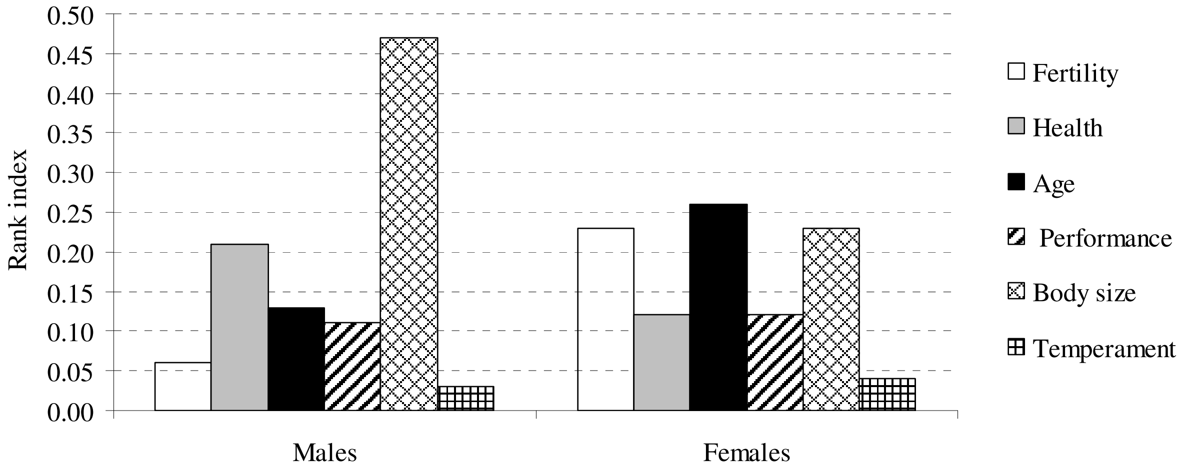

Figure 3. Main reasons for making culling decisions and their corresponding rankings[1] in males and females[2].
[1]Index based on rank weights of the first four choices of priority characteristics (i.e. 4=highest importance, 1=lowest importance)
[2]Growth performance was considered in males while both, milk and growth performances, were considered in females.

Table 8 shows the pastoralists' relative perception of various traits of Sahiwal and their crosses when compared to the EAZ. All trait categories were considered to be important for each breed category. In general, Sahiwal cattle and their crosses were perceived to be of good productive (milk production, body size and conformation) and reproductive (age at first calving, calving ease and calving interval) performance, but were seen to be less adapted to the local production conditions. On the other hand, the EAZ were perceived to be relatively inferior in regard to milk production, growth and fertility but were perceived to be more robust than the Sahiwal cattle and their derivatives in terms of drought and heat tolerance, and disease and parasite tolerance.

3.3.5 Production challenges

Although results of the herd structure (Table 4) indicate that most of the pastoralists in the two counties owned bulls, access to breeding bulls was identified as a major constraint in both study sites. The shortage was manifested in delayed replacement and longer retention of both existing breeding bulls, a fact that disrupted mating plans resulting in some cows remaining un-serviced for longer periods leading to wasted breeding opportunities.

Table 8. Pastoralists' perception[1] of various traits considered to be important, comparing pure bred and crossbred Sahiwals with EAZ

Trait	Breed			
	Sahiwal crosses		Sahiwal	
	Regression Coefficient[2]	Odds ratio (95% confidence limits)	Regression coefficient[2]	Odds ratio (95% confidence limits)
Size and conformation	3.18±0.23***	24.00(15.43, 37.73)	3.44±0.03***	31.00(17.24, 56.60)
Growth performance	2.57±0.23***	13.00(8.69, 19.51)	2.64±0.27***	13.97(8.12, 24.05)
Milk production	3.44±0.24***	31.22(19.49, 50.00)	3.21±0.30***	24.89(13.80, 44.88)
Age at first calving	2.91± 0.22***	18.34(11.92, 28.19)	3.30±0.30***	27.18(14.98, 49.28)
Calving interval	1.66±0.19***	5.27(3.64, 7.62)	3.35±0.34***	28.43(14.60, 55.37)
Calving ease	1.61±0.19***	4.99(3.45, 7.21)	1.74±0.27***	5.72(3.40, 9.64)
Disease resistance	-2.56±0.24***	0.08(0.05, 0.12)	-3.15±0.29***	0.04(0.02, 0.08)
Drought and heat tolerance	-2.62±0.25***	0.07(0.05, 0.12)	-3.43±0.34***	0.03(0.02, 0.06)

[1]Relative perception for a trait in pure Sahiwal or Sahiwal crossbred when compared to the native EAZ. There is no difference in perception if the confidence limits include one (1), a better perception when greater than one (1) and a lower perception when less than one (1).
[2]***statistically significant at 0.1% level probability

Moreover, most pastoralists preferred breeding bulls from the ranches because of their perceived genetic superiority compared to bulls from other pastoralists, a fact that could have also increased demand that could not be sustained by supply from the ranches. According to views by all the participants in the discussion groups, bureaucracies in the government ranches, poor communication between pastoralists and stud herds and high prices for breeding bulls were the main reasons that hampered access to breeding stock. Interviews with ranch managers also revealed no clear mechanism and criteria to ensure proper distribution of breeding bulls as all stud herds sold their stock on first-come-first-served basis. This practice, according to pastoralists, favoured those in proximity to the stud herds who were able to get timely information on availability of breeding animals hence resulting in skewed distribution of breeding bulls. Sometimes disease quarantines in the ranches, and the tendency of Maasai pastoralists not to freely share breeding bulls could also have contributed to the shortage. Inadequate feeds, according to all the respondents (N=92) and the two group discussions in Kajiado County, was a major constraint due to frequent droughts that influenced quality and quantity of feeds. However, feed availability was not mentioned as a major constraint in Narok County, possibly due to the favourable weather conditions. Extended drought conditions affected the growth and reproductive performance of the herds in Kajiado, and in some cases loss of promising genotypes. Outbreaks of disease such as foot and mouth were also mentioned as a constraint that hampered movement and marketing of animals. Insecurity that leads to theft of livestock by neighbouring ethnic communities was mentioned as a major challenge by participants in Narok County, but this was not raised as a major concern by their counterparts in Kajiado County.

3.5 Discussion

The number of female household heads was very low in both counties, a fact that could be attributed to the male dominance in livestock farming activities among the Maasai pastoral communities. This observation is consistent with what was reported in earlier studies (e.g. Mwacharo and Drucker, 2005; Ouma et al., 2007; Kosgey et al., 2008). Women roles are mainly restricted to duties such as milking and taking care of the young stock. The higher literacy level in Kajiado could be attributed to the long campaign by various non-governmental organisations and the church in promotion of basic education in this area. There has been a growing shift from communal to individual land ownership in the Southern rangelands. This has been occasioned by population growth and growing need to access credit facilities where land is mainly used as collateral (Ng'ethe, 1992; MONPD, 2005). However, communal grazing fields are still common where extended families pool their land allocations to form grazing areas for their livestock. This shift in land ownership is bound to have far reaching implication on resource availability and utilisation. Such changes, coupled with climate variability, will definitely influence herd/flock sizes and their composition in the near future. Therefore, such dynamics should be taken into account when evaluating current and planning future livestock breeding programmes.

The relatively high numbers of sheep, goats and donkeys in Kajiado shows pastoralists recognises the need to diversify their livestock species given that they are more disadvantaged in terms of climatic conditions compared to their counterparts in Narok. For example due to water scarcity in Kajiado, donkeys play a vital role in transportation of water from far flunked water points for other livestock and for domestic use. Pastoralists have been known to diversify their livestock activities by keeping multiple species and breeds as a risk coping strategy and to optimise on feed resource utilisation (Mwacharo and Drucker, 2005; Wurzinger et al., 2006; Kosgey et al., 2008). The higher proportion of pastoralists who own Sahiwal cattle genetic resources in Kajiado points to the long history of the breed in this area. Pastoralists in Kajiado adopted Sahiwal cattle genetic resources in earnest and have been actively involved in the Sahiwal x EAZ up-grading programme since the breed was introduced in the country. However, the numbers of Sahiwal cattle genetic resources in Narok is expected to increase given the focus by KARI in promotion of the breed in this area in the recent past. This was also evident during the survey where the number of pastoralists from Narok who purchase breeding bulls from the ranches was higher compared to those from Kajiado. However, it is important to note that the drought conditions during the field study in Kajiado could have affected herd and flock sizes, as most animals were hurriedly sold to avert losses and many succumbed to starvation.

Sahiwal cattle genetic resources are generally raised under low-input production systems with very limited husbandry intervention by both pastoralists and ranchers. This is consistent with the recommendation made at the start of the Kenya Sahiwal breeding programme for the stud herds to raise the breeding animals in conditions that are close to those of pastoral rangelands in Southern Kenya (Meyn and Wilkins, 1974). The commonality in production conditions between the two types of producers reduce influence of potential genotype by environment interactions which might arise when breeding animals are exchanged between production systems. However, the limited pasture and water availability, occasioned by semi-arid conditions characterised by frequent droughts disrupted grazing patterns and consequently increased animal movements in search of feed and water in Kajiado. This condition predisposed the herds to more disease and parasite challenges, and also affected the general herd performances. For example, more outbreaks of foot and mouth disease and lumpy skin disease were reported in Kajiado compared to Narok county, an observation that was directly linked to animal movement even where restrictions existed. These movements could have also interfered with endo- and ecto-parasite control schedules resulting in more parasitic loads.

The identified production and breeding goals of pastoralists keeping Sahiwal cattle genetic resources are a reflection of the multiple roles that livestock play in the livelihoods of pastoral communities. This multipurpose pattern is consistent with what has been reported in similar studies (e.g. Steglich and Peters, 2002; Musa et al., 2006; Mwacharo and Drucker, 2005; Ouma et al., 2007). Milk is a staple food and an important component of the daily diet among Maasai pastoralists. Sahiwal cattle produce on average 4.8 litres per day (Ilatsia et al., 2007) compared to the EAZ that hardly produces more than 2 litres (Muhuyi et al., 2000). Thus, the relatively high milk production of Sahiwal cattle may have favoured the high ranking of milk as a production aim. Meat production was also ranked highly despite the fact that most of the domestic meat demand is fulfilled through slaughter of sheep or goats (Kosgey et al., 2008). Group discussions revealed that pastoralists may have ranked meat production favourably because they anticipated more meat as a result of the relatively big body size of Sahiwal compared to the EAZ. Very few respondents in both counties indicated use of Sahiwal cattle as a form of insurance and risk management, as well as for other cultural functions, an observation that seemed contrary to what has been reported in other studies (e.g. Kosgey et al., 2008; Ouma et al., 2007). Introduced exotic breeds such as the Sahiwal are sometimes held in high regard and perceived to be of high value compared to the existing local breeds. Most producers would therefore be hesitant to use them for purposes that seem to be of little tangible benefit. In such cases small ruminants would be preferred to fulfil intangible roles and hence cushion large ruminants from such roles (Legesse et al., 2008; Kosgey et al., 2008). Active promotion of Sahiwal cattle by KARI would also influence the importance that pastoralists attach to this genetic resource and subsequently their willingness to dispose them for tangible benefits. It is important to note that some of the reasons for keeping Sahiwal and their crosses could be overlapping. Milk production, for example, was highly rated because of its dual benefits, home consumption and surplus for sale, although revenue was equally generated through sale of live animals. Similarly, revenue generated through daily milk sales increases disposable income and hence ability of households to manage risks and other emergencies that require instant cash remedies. Such purposes could therefore eclipse intangible roles such as risk management and other socio-cultural functions.

Various determinants influenced production goals to varying levels. The division of labour, which is mostly influenced by gender and age, had an influence on production objectives. For example, young people (less than 30 years) were inclined towards milk as a production goal, because, as alluded to earlier, milking and its marketing is mostly done by the youths and women while decisions about breeding, selling and purchase of cattle are a reserve of male household heads. Division of labour based on age and gender have been reported to have an influence on production goals of cattle keepers (Mwacharo and Drucker, 2005; Wurzinger et al., 2006). Pastoralists in Narok county were more inclined towards milk production because of the relatively good weather conditions that ensure adequate pasture and water supply which guarantee higher milk production compared to their counterparts in the semi arid Kajiado. Milk production in Kajiado is seasonal and households depend more on meat as a dietary component compared to their counterparts in Narok, explaining the tendency to state meat production as production goal. There was no significant relationship between the number of livestock and the tendency to keep Sahiwal cattle for cash income, a situation that seems contrary to what would be expected. The dual purpose role of Sahiwal cattle genetic resources guarantees revenue through sale of milk and live animals. Most producers therefore seem to assign a relatively high monetary value to this resource and a high likelihood of stating cash generation as a production goal, the number of livestock owned notwithstanding. A survey at local cattle auction centres during this study revealed that the Sahiwal breed and its derivatives attracted relatively higher prices compared to other local Zebu breeds, probably because of their large body size and milk production potential. In an empirical comparison of stated and revealed preferences value estimates of cattle keepers in Kenya, Scarpa et al. (2003) showed that market prices were strongly determined by the slaughter weight, which is correlated to body size. Notwithstanding some overlaps in various production goals, more educated producers have a high probability of stating cash generation than any other purpose of keeping Sahiwal cattle genetic resources. This group tend to specialise in a few production goals, have a better understanding of market dynamics and therefore explore markets that are more rewarding compared to the less educated pastoralists. This has the net effect of substantially increasing revenue they generate from Sahiwal genetic resources and therefore high probability of stating cash generation as a production goal. Similar observations were reported in a study of small ruminants in mixed farming systems in southern Ethiopia (Legesse et al., 2008). In this study educated farmers were less diversified in their production gaols and focused mainly on revenue generation compared to their less educated counterparts.

This study has presented knowledge on production and breeding goals of Sahiwal cattle producers that should be considered in future breeding programmes for sustainable utilisation of Sahiwal cattle genetic resources in Kenya. The experience gain and lesson learnt here could form the basis of initiating similar work in other tropical countries such as India and Pakistan to enhance utilisation and conservation of Sahiwal cattle genetic resources. Knowledge on producers' production objectives could be used as indicators of breeding goals. Keeping Sahiwal cattle for milk and meat production, for example, suggests that high milk yield and body size are considered important breeding goals. In addition, high ranking of revenue generation (Figure 2) through milk and live animals sales also suggests that producers regard milk yield and body size as important breeding goal traits. Similarly, knowledge on the relative perception of various traits (Table 8) could be an indication of producers' breeding goals. In this case, the favourable rating of productive and reproductive performance in the Sahiwal and its crosses imply that producers attach importance to these traits because of their direct effect on herd productivity. The relatively higher ranking for adaptation and disease resistance in the EAZ compared to Sahiwal cattle genetic resources shows that producers take cognition of adaptation as important breeding goals in their herds. However, adaptation traits are regarded as less important in higher yielding breeds like the Sahiwal compared to local breeds. Producers may assume that higher yielding breeds are receiving better care and attention because of higher valuation, thus conferring to them improved protection. Knowledge on reasons for making culling decisions (see Figure 3) can also be used to cross-check producers breeding goal traits and selection criteria. For example, culling of females based on their milk performance confirms breeding towards improved milk yield while culling based on body size and conformation confirms body weight is an important breeding goal trait. Longevity could be considered as a breeding goal trait by producers because cull-for-age among the females is given prominence. Exempting cows with persistently poor fertility from the herds reflects that producers take cognisance of good reproductive efficiency as a breeding goal. Culling based on an animal's health status and general growth rate is an indication that adaptability and tolerance to existing production conditions are important under limited possibilities for veterinary treatments.

Sahiwal cattle genetic resources were generally perceived to be of good productive and reproductive performance, however, it was not lost to the pastoralists that the EAZ remained competitive with regard to adaptation and disease tolerance. This demonstrates clear trade-offs between the Sahiwal and the EAZ with regard to productivity and adaptability. These trade-offs need to be examined more carefully with producers' participation when evaluating various options for the breeding programme. The strategy of pastoralists keeping both genetic resources in parallel might help them in coping with changing environmental conditions. Production traits (milk production and growth) in the Sahiwal have been reported to be moderately influenced by genetic effects hence it is feasible to make gains through appropriate selection programmes (Ilatsia et al., 2007; Ilatsia et al., 2011). The challenge is that selection would be less effective in regard to functional traits, which are not only difficult to measure, but are more influenced by environmental factors than genetic effects. Furthermore, formulation of breeding goals and selection schemes needs to be made simple and cost-efficient so as to be sustainable under the prevailing production and environmental conditions. Thus, the future breed planning and organisation should take comprehensive account of breed attributes that capture the full array of contributions of Sahiwal cattle genetic resources to producers' livelihoods, as identified in this study, considering at the same time that pastoralists prefer mixed breed herds, attaching to each breed involved different trait profiles.

Acknowledgements

This study was supported by funds from the Kenya Arid and Semi Arid Lands (KASAL) project through the Kenya Agricultural Research Institute (KARI). We are also grateful to the German Academic Exchange Service (DAAD) for financial support. We greatly acknowledge the support of the personnel of the Ministry of Livestock Development and the field enumerators for successful logistical support. Cooperation of pastoralists and ranch managers is highly appreciated.

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Evaluation of basic and alternative breeding programmes for Sahiwal cattle genetic resources in Kenya

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This chapter is published in Animal Production Science. Volume 51; Pages 682-694.

CHAPTER 4: Evaluation of basic and alternative breeding programmes for Sahiwal cattle genetic resources in Kenya

Abstract

The Sahiwal cattle breeding program in Kenya has been operational on an interim basis for over 45 years. However, there have been no systematic efforts undertaken to evaluate its suitability, or to examine how competitive it is compared with other alternative programs in terms of genetic and economic merit. The objective of this study was therefore to evaluate the genetic and economic success of the current basic and alternative Sahiwal cattle breeding programs in Kenya. The breeding programs examined were the current closed nucleus with two breeding strategies: a purebreeding (CN_{PURE}) and a crossbreeding system (CN_{CROSS}) involving Sahiwal sires and East African Zebu dams. An open nucleus with a certain proportion of pastoral-born Sahiwal bulls introduced into the nucleus herds to produce cows was simulated as an alternative breeding program. In this program only a purebreeding strategy (ON_{PURE}) was considered. The breeding strategies were evaluated under two breeding objective scenarios that addressed traditional markets where animals are sold on body size/weight basis and the Kenya Meat Commission where payment is based on carcass characteristics. Sensitivity analyses to changes in nucleus size and gene contribution were also performed. The annual monetary genetic gain and profit per cow for all investigated breeding programs varied within breeding objectives. The CN_{PURE} was the most attractive economically but less competitive in regard to genetic superiority compared with either CN_{CROSS} or ON_{PURE}. Returns and profits were generally higher for the carcass characteristic basis compared with the body size/weight basis for all evaluated breeding strategies. Expansion of the nucleus size was not attractive because of the associated reduction in genetic and economic benefits. However, gradual importation of pastoral-born sires into the nucleus

farms at the current nucleus proportion of 14% was both genetically and economically beneficial. The CN_{CROSS} plays a complimentary role of facilitating the exploitation of trade-offs that exist between the Sahiwal and the locally better adapted East African Zebu, it also represents an intermediate phase in the on-going upgrading program.

Keywords; Breeding programs, breeding objectives, Sahiwal cattle, Stakeholders

4.1 Introduction

The Sahiwal cattle breed has traditionally been used for milk and beef production in low-input production systems. It has evolved under harsh and diverse tropical environments and carries unique combinations of attributes that have made it competitive compared with other Zebu cattle breeds (Trail and Gregory, 1981; Muhuyi et al., 1999; Joshi et al., 2001). The breed has been spreading from its native origin in India and Pakistan to various tropical regions and comes second to the Brahman in terms of distribution among the Zebu breeds of South Asian ancestry (FAO, 1992; Joshi et al., 2001). The breed was introduced in Kenya to boost milk and beef production under the challenging pastoral rangeland conditions. Over the past 70 years, this has been achieved by crossing Sahiwal bulls with local East African Zebu (EAZ) cows in an upgrading program (Meyn and Wilkins, 1974; Muhuyi et al., 2000). The aim of the upgrading program is to exploit the differences that exist between the two breeds with regard to production potential in the Sahiwal and adaptation in the EAZ; thus Kenya Sahiwal is a product of several generations of crossing the two breeds.

In Kenya, pure Sahiwal cattle are mainly raised by private and government ranches, which collectively form the nucleus herds, and the Maasai pastoralists (Roessler et al., 2010). Two main breeding strategies are currently applied for genetic improvement: purebreeding and crossbreeding (Trail and Gregory, 1981; Muhuyi, 1997). Purebreeding is practiced in the nucleus herds to produce breeding bulls that are eventually used for both purebreeding and crossbreeding with EAZ cows in the pastoral herds. Nucleus herds are closed to animals born in the pastoral herds and therefore the current breeding system depicts a typical closed nucleus breeding program where performance recording and selection is confined to the nucleus, and the pastoral herds are the main recipients of the resultant genetic superiority generated in the nucleus herds. To simulate the low-input production systems in the pastoral areas, selection for high milk yield and growth performance and general herd management in the nucleus herds are done within the strenuous range conditions with minimal husbandry support (Muhuyi, 1997).

The breeding program was only to be operationalised on an interim basis (Meyn and Wilkins, 1974) pending more elaborate studies to determine its suitability for full implementation, or, where deemed necessary, to recommend alternatives. This undertaking is still pending to date notwithstanding the fact that both producers (pastoralists and nucleus herds) have continued to interact based on the temporal breeding structures initiated in 1962. Some of the fundamental elements that still need to be undertaken include understanding the production systems within which the breeding program is applied, as well as gathering knowledge on production and breeding aims that motivate the continued participation of Sahiwal cattle producers in the program. The production systems under which Sahiwal cattle genetic resources are raised, including producers' production and breeding aims, have recently been described (Roessler et al., 2010; Ilatsia et al., 2011a). According to this study (Roessler et al. 2010; Ilatsia et al. 2011a), Sahiwal cattle genetic resources are kept mainly for tangible benefits that include family subsistence and revenue generation through sale of surplus milk and live animals. This is reflected in the breeding goals that aim to increase milk production, big body size and high mature weight, good fertility and adaptation to local production conditions. The next endeavour is to ascertain the genetic and economic suitability of the existing breeding program design, and compare this with other alternatives in order to identify the optimum for possible adoption and enhancement. This should concurrently be accompanied by identification and definition of roles of various stakeholder institutions that are critical in the realisation of any promising and sustainable breeding program. The objective of this study was to identify, based on genetic and economic merits, the optimal breeding program for Sahiwal cattle genetic resources by evaluating both the current and alternative breeding programs.

4.2 Materials and methods

4.2.1 Identification of stakeholder institutional support

Stakeholder institutions that are crucial in the Sahiwal cattle breeding programme in Kenya were identified through personal interviews with Sahiwal producers (244 pastoralist and 18 managers of nucleus farms) and open discussions with 21 key resources persons in 10 stakeholder institutions. Details of how the interviews were conducted have already been reported (Ilatsia et al., 2011a). In brief, producers were required to state the most important institutions they interact with and the reasons why the said institutions were perceived to be of importance for the breeding of Sahiwal cattle genetic resources. This was followed by open discussions with key resource persons in the identified institutions where more detailed information was sought on the specific roles these institutions play in the Sahiwal cattle breeding programme. The discussions also focused on organisational development of the Sahiwal breed as well as the interactions among the various stakeholder institutions. The information collected was analysed qualitatively, and the interrelationship between the stakeholder institutions with respect to their contribution to Sahiwal cattle breeding evaluated to depict the organisational support available.

4.2.2 Description of production system

Sahiwal cattle genetic resources are raised under low-input production systems by both pastoralists and ranchers, a strategy that aims to minimise the potential effects of genotype by environment interaction when breeding animals are exchanged (Roessler et al. 2010; Ilatsia et al., 2011a). Their functions in low-input production systems are mainly related to family subsistence and revenue generation through sale of surplus milk and live animals. The primary breeding goals of both producer groups are to increase milk production, big body size and high mature weight, good fertility and adaptation to local production conditions (Ilatsia et al., 2011a). The breeding programs were therefore evaluated within the low-input pastoral production system where milk and meat are the important products. In this case the economic values for the breeding objective traits considered were re-calculated based on bio-economic functions developed for low-input dual-purpose pastoral production systems in Kenya (Rewe et al., 2006a and Rewe et al., 2006b).

4.2.3 Breeding objectives and marketing

Figure 4 shows the main market outlets for milk and live animals in the production system. Surplus milk is sold at local markets, to neighbours and middlemen based on volume, while live animals are sold at local livestock markets and butcheries (traditional markets) on a willing-buyer-willing-seller basis and prices are determined by visual appraisal of body size/weight. The recently revamped Kenya Meat Commission (KMC) is also a market outlet for live animals. The KMC buys slaughter animals from the pastoralists for processing into various meat cuts and other products for both specialised domestic and for export markets. Unlike the traditional markets, KMC market is based on a post-paid system where prices are determined on hot carcass weight basis. Sahiwal and their crossbred steers are the favourites for this market because of their relatively large body size and weight compared with the EAZ (Figure 4). Nonetheless, the traditional markets for live animals are more predominant.

The breeding goals identified by producers were therefore extended into two breeding objectives to address the two market scenarios. The first breeding objective scenario was modelled to address the traditional markets where body size and weight are important price determinants (BSWB). The sale weight (SWT, kg) was considered as breeding objective trait besides lactation milk yield (LMY, kg), feed intake (FI, DM kg), age at first calving (AFC, days), cow weight (CWT, kg), calving interval (CI, days), pre-weaning (SR, %) and post-weaning survival rate (PSR, %) as well as productive life time (PLT, days). Productive life time was included in recognition of the fact that age was identified as an important culling criterion where good performing animals were retained longer in the herds (Ilatsia et al. 2011a). Feed intake was included as a breeding objective trait in order to accommodate the effect of correlated responses when improving growth and milk traits, in light of the fact that pasture availability is becoming more restrictive in the southern rangeland due to climate change manifested in reduced precipitation (Kaitho et al., 2007). In such circumstances, increasing FI would be undesirable and therefore the breeding objective that results in reduction of this trait would be most preferable (Kahi et al., 2003). The second breeding objective (CSCB) reflected KMC market scenario with carcass characteristics playing a great role in determining prices. In this case, dressing percentage (DP, %) and consumable meat percentage (CMP, %), as proxies for hot carcass weight, were included as additional breeding objective traits.

4.2.4 Definition of breeding programmes, selection criteria and information sources

Two two-tier nucleus breeding programs were considered; the first breeding program was a closed nucleus program with downward movement of young bulls from the nucleus to the pastoral herds to produce both sires and dams for this sector. Within this program, two breeding strategies exist: a purebreeding (CN_{PURE}) and a crossbreeding system (CN_{CROSS}) where nucleus- and pastoral-born sires are mated to EAZ dams to produce crossbred cows. In CN_{CROSS}, the Sahiwal is used as the sire line, while EAZ and the resultant crossbreds are the dam lines and crossbred males are castrated and therefore not used for mating. The second was an open nucleus breeding program with a certain proportion of pastoral-born Sahiwal bulls introduced into the nucleus herds to produce Sahiwal cows. Only the purebreeding strategy (ON_{PURE}) was modelled under the open nucleus breeding program. The closed nucleus breeding program represented the current basic breeding program, while the open nucleus breeding program was modelled as an alternative to be considered for adoption subject to its competitiveness when compared with the current program. The two breeding programs were also cross-examined with respect to the two breeding objective scenarios described earlier.

The breeding programs consist of a pyramid breeding scheme where pedigree and performance recording and selection are practiced in the nucleus herds to generate genetic gain; the transfer of the genetic gain from the nucleus to the pastoral herds is exclusively through breeding bulls. Figure 4 shows the structure of the Sahiwal cattle breeding program in Kenya and the important selection groups used in transmission of genes in the entire population. There is no pedigree or performance recording in the pastoral herds, however, pastoralists utilise indigenous technical knowledge and visual appraisal in making selection decisions on important traits of interests. The selection groups were defined respectively as; SS, SD, DS and DD, Sahiwal sires of sires, sires of dams, dams of sires and dams of dams in the nucleus; S_PD, pastoral-born sires to breed dams in the nucleus; SD_p and SS_p nucleus-born sires to breed dams and sires in pastoral herds, D_pS_p, S_pD_p, D_pD_p, and S_pS_p are pastoral-born

Table 9. Information sources and selection criteria for indices applied in the selection of sires and dams for the nucleus and pastoral herds

Information sources	Selection criteria[2]						
	LMY	ADG	BWT	WWT	YWT	AFC	CI
Sires for the nucleus herds (SS, SD)							
Individual	-	1	1	1	1	-	-
Sire	-	1	1	1	1	-	-
Dam	1	1	1	1	1	1	1
PHS, males	-	10	10	10	10	-	-
PHS, female	10	10	10	10	10	10	10
Sire's dam	1	1	1	1	1	1	1
Dam's dam	1	1	1	1	1	1	1
HSS, males	-	19	19	19	19	-	-
HSS, females	19	19	19	19	19	19	19
HSD, males	-	19	19	19	19	-	-
HSD, females	19	19	19	19	19	19	19
Dams for the nucleus herds (DD,DS)							
Individual	1	1	1	1	1	1	1
Sire	-	1	1	1	1	-	-
Dam	1	1	1	1	1	1	1
PHS, males	-	10	10	10	10	-	-
PHS, female	10	10	10	10	10	10	10
Sire's dam	1	1	1	1	1	1	1
Dam's dam	1	1	1	1	1	1	1
HSS, males	-	19	19	19	19	-	-
HSS, females	19	19	19	19	19	19	19
HSD, males	-	19	19	19	19	-	-
HSD, females	19	19	19	19	19	19	19
Sires for the pastoral herds (S_PS_p, S_PD_P, S_PD, S_PD_{PX})							
Individual	-	1	-	1	-	-	-
Dam	1	1	-	1	-	-	1
Dams for the pastoral herds (D_PS_P, D_PD_P, $D_{PX}D_{PX}$)							
Individual	1	1	-	1	-	-	1

[1] See section 4.2.4 for description of information sources, selection groups and selection criteria traits
[2] Number of available records is calculated from figures for cow to bull ratio, calving rate, pre- and post-weaning survival rate.

dams and sires to breed sires and dams for this sector; SD_{PX} and S_PD_{PX} nucleus- and pastoral-born Sahiwal sires mated to EAZ cows to produce crossbred cows, $D_{PX}D_{PX}$ are crossbred cows backcrossed to Sahiwal sires to produce crossbred cows. Based on the producers' stated breeding goals, culling criteria and nucleus herd recording systems, various traits were identified as selection traits. Table 9 shows the number of records and information sources used to select sires and dams for the nucleus and pastoral herds. In the pastoral herds for CN_{CROSS}, EAZ selection groups were selected on an index that was assumed to be uncorrelated with the breeding objective and so did not contribute to generating genetic gain and economic returns. Mating was considered entirely natural where young bulls were selected to produce cows and bulls in the nucleus and pastoral herds. Based on the field survey 65% of respondents used nucleus sires to mate cows in the pastoral herds, while the rest (35%) relied on pastoral sires. These proportions were therefore assumed to represent the current gene contributions of each of the two sire categories in the population.

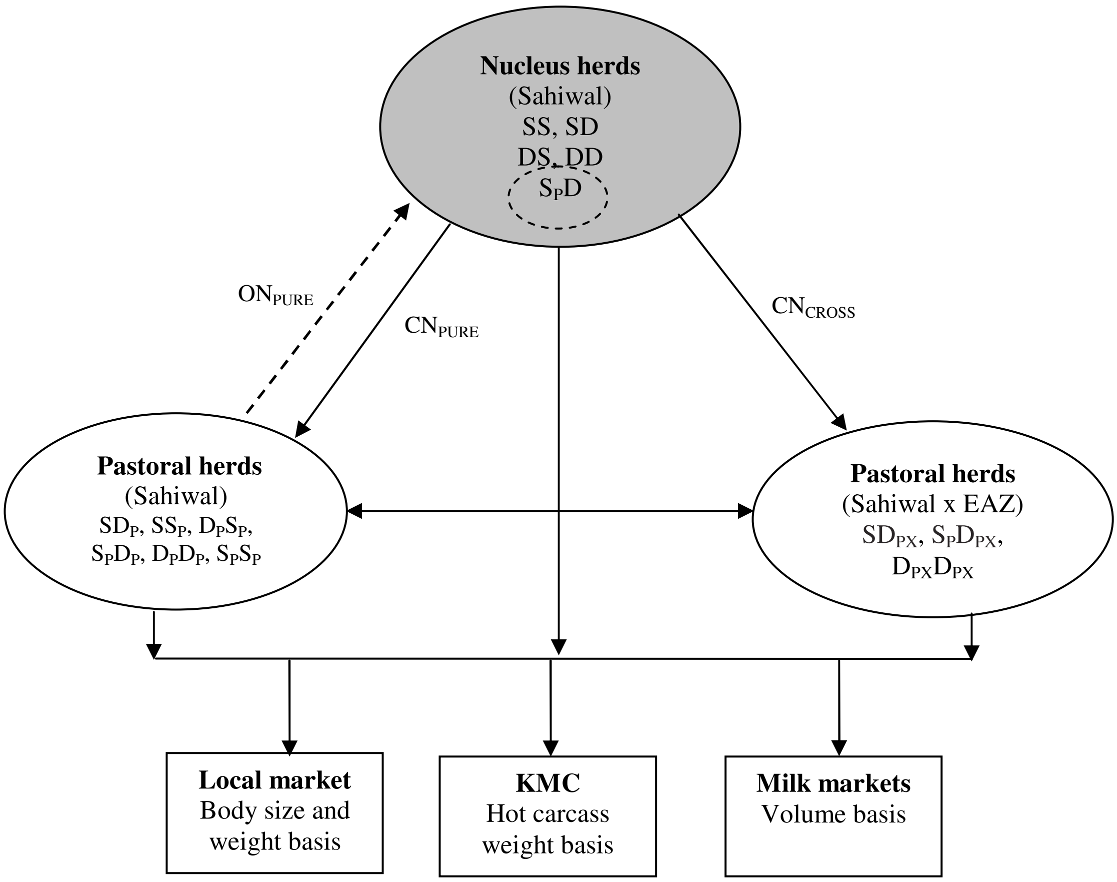

Figure 4. The breeding structure, main selection groups and market channels for milk and live animals. KMC, Kenya Meat Commission

4.2.5 Evaluation of the breeding programmes

The three breeding strategies were modelled and evaluated by a deterministic approach, using the computer program ZPLAN version z10 (Willam et al., 2008). Based on genetic, biological and economic parameters, the annual genetic gain for the breeding objective as well as for single traits and the discounted profit per cow in the entire population (nucleus and pastoral herds) were calculated for a 25-year investment period by obtaining the difference between discounted breeding costs and returns, using the gene flow method and selection index procedures (Hill, 1974). ZPLAN's main advantage lies in its ability to predict the economic performance of breeding programs based on given levels of investments and therefore provide alternative criteria, besides genetic response, in optimising breeding schemes (Willam et al., 2008). This was of interest in this study because costs and profitability of a breeding program are considered of priority by livestock keepers besides genetic efficiency when making decisions on which breeding scheme to adopt. However, only the effects of one round of selection on the performance of succeeding generations are taken into consideration, a fact that has been acknowledged as a major weakness of ZPLAN. The program does not account for decreased genetic variance due to further selection rounds and ignores the effect of inbreeding in predicting genetic gain. An overview of the population and technical parameters for the nucleus herds and the pastoral herds as well as variable and fixed costs that were directly related to identification, pedigree and performance recording in the nucleus herds are presented in Table 10. The costs were calculated based on economic data from the National Sahiwal Stud (NSS) and are expressed per cow and year basis. Variable costs were computed based on the amount of man-hours required to perform given recording task per animal as a function of the current market rates for labour cost per 1 man-hour. Other variable costs of consumables such as tattoo ink, individual animal pedigree cards, milk and weight sheets were also included. The returns were discounted at 4% and costs at 6% based on the Central Bank of Kenya monthly reviews of interest rates (CBK, 2010). The biological and technical parameters were obtained from field data (see Table 2) supplemented with selected literature from earlier population-specific studies (e.g. Mwandotto et al., 1988; Muhuyi et al., 2000; Karimi et al., 2005; Mwacharo and Drucker, 2005; Ilatsia et al., 2007).

Table 10. Population, biological and technical parameters describing the modelled herd structures in the nucleus and the pastoral unit

Variable	Nucleus herds	Pastoral herds		
	Sahiwal	Sahiwal	Sahiwal crosses[2]	EAZ
Population parameters[1]				
Total population	7,000	43,000	200,000	250,000
Number of breeding cows	1,500	13,000	40,000	50,000
Productive lifetime of bulls (years)	3.0	5.0	n.a.	3.0
Productive lifetime of cows (years)	6.0	7.0	7.0	7.0
Age at first service for sires (years)	3.3	3.5	n.a.	4.0
Age at first calving for cows (years)	3.7	4.0	4.0	4.5
Pre-weaning survival rate (%)	81.3	81.0	81.0	91.0
Post weaning survival rate (%)	93.0	93.0	93.0	93.0
Calving rate (%)	85.0	78.0	78.0	78.0
Male: female ratio	1:30	1:10	1: 20	1:20
Replacement rate (%)	81.0	78.0	78.0	78.0
Calving interval (years)	1.3	1.3	1.3	1.6
Average herd size	80	48	60	70
Investment parameters[3]				
Investment period (years)	25	-	-	-
Interest rate on returns (%)	6	-	-	-
Interest rate on costs (%)	4	-	-	-
Variable costs (US$)[4]				
Identification and pedigree recording (at 0 years)	2.08	-	-	-
Recording birth weight (at 0 days)	0.63	-	-	-
Recording weaning weight (at 6months)	0.63	-	-	-
Recording yearling weight (at 1 year)	0.63	-	-	-
Recording milk yield (at 3.7 years)	15.00	-	-	-
Recording calving interval (5 years)	0.88	-	-	-
Recording age at first calving (at 3.7years)	0.63	-	-	-
Fixed costs per year (US$)[1]				
Farm manager and office maintenance	12,813	-	-	-

[1]Source; Field survey data and related studies (e.g Mwandotto et al., 1988; Muhuyi et al., 2000; Mwacharo and Drucker, 2005, Karimi et al., 2005; Ilatsia et al., 2007)
[2] n.a., not applicable.
[3]Central Bank of Kenya average interest rates for the month of November 2010.
[4]Variable costs computed based on the amount of man-hours required to perform given recording task per animal as a function of the current rates of cost of labour per man-hour. Costs of consumables such as tattoo ink, individual animal pedigree cards, milk and weight sheets were also included in the costs. 1US$ = Kenya Shillings (Ksh) 80.0.

4.2.6 Genetic and phenotypic parameters

Genetic and phenotypic parameters for the selection criteria and the traits in the aggregate genotype are required in order to calculate the composition and the accuracy of selection indices. Population-specific parameters for tropical livestock species are generally scarce and most studies have relied on assumed literature estimates in evaluating breeding programmes (e.g. Gicheha et al., 2006; Kahi et al., 2004; Rewe et al., 2010; Rewe et al., 2011). However, in cases where performance records exist, efforts have to be made to estimate population-specific parameters so as to obtain more credible and realistic outputs when evaluating breeding programmes. Genetic and phenotypic parameters used in this study were obtained from studies that evaluated performance data at NSS (Ilatsia et al., 2007; Ilatsia et al., 2011b). The NSS is owned by Kenya Agricultural Research Institute (KARI) and is used as a research facility for development of appropriate husbandry and breeding practices for the Maasai pastoralists in the southern rangelands of Kenya (Muhuyi, 1997). Compared to other nucleus herds, NSS keeps relatively good performance and pedigree records and was therefore chosen because of the reliability of such data, as well as the resemblance in production conditions between NSS, other nucleus farms and in the pastoral herds. Table 11 shows the genetic and phenotypic parameters for the breeding objective and selection criteria traits that were used in evaluating the breeding programmes. Due to lack of some records at NSS, estimates for FI, DP, CMP and PLT were obtained form literature sources cited in Kahi et al. (2004) and Rewe et al. (2011).

4.2.7 Sensitivity analyses

Variations of the nucleus size, usage level of nucleus sires in the pastoral herds and level of sire importation from pastoral herds into the nucleus herds were examined for CN_{PURE} and ON_{PURE}. The aim was to determine the effect of such variations on the overall monetary genetic gain and profitability of the breeding programs. Preliminary evaluations showed that the trends were similar for the two breeding objectives and therefore variations runs were only performed for the BSWB.

.

Table 11. Heritabilities (h^2), phenotypic standard deviations (σ_p), economic values (EV), phenotypic correlations (above diagonal) and genetic correlations (below diagonal) among selection criteria and breeding objective traits

Trait[1]	LMY (kg)	SWT (kg)	DP (%)	CMP (%)	FI (kg DM)	AFC (days)	CWT (kg)	CI (days)	SR (%)	PSR (%)	PLT (days)	ADG (g/day)	BWT (kg)	WWT (kg)	YWT (kg)
h^2	0.33	0.21	0.30	0.45	0.30	0.04	0.21	0.03	0.03	0.02	0.11	0.17	0.23	0.39	0.28
σ_p	469.00	31.97	1.80	2.00	47.00	157.10	31.97	112.00	10.50	11.75	864.90	21.53	2.59	4.30	10.85
EV	5.03	5.69	72.40	54.60	-3.43	-1.56	8.80	-1.60	9.96	45.15	0.70	-	-	-	-
LMY		-	-	-	-	0.13	-	0.13	-	-	-	0.10	0.09	0.24	0.17
SWT	0.20		-	-	-	-	-	-	-	-	-	-	-	-	-
DP	0.00	-0.06		-	-	-	-	-	-	-	-	-	-	-	-
CMP	0.00	0.15	0.10		-	-	-	-	-	-	-	-	-	-	-
FI	0.00	0.12	-0.10	0.00		-	-	-	-	-	-	-	-	-	-
AFC	0.17	-0.17	0.00	0.00	0.00		-	0.10	-	-	-	0.00	0.00	-0.26	-0.26
CWT	0.22	0.40	0.11	0.15	0.12	-0.17		-	-	-	-	-	-	-	-
CI	0.17	-0.50	0.00	0.00	0.00	-0.10	-0.50		-	-	-	0.22	0.00	0.00	0.00
SR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		-	-	-	-	-	-
PSR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05		-	-	-	-	-
PLT	0.00	0.27	0.00	0.00	0.00	-0.13	0.00	0.10	0.00	0.00		-	-	-	-
ADG	0.11	0.38	0.00	0.00	0.20	0.00	0.33	0.00	0.05	0.03	0.10		0.11	0.11	0.17
BW	0.12	0.22	0.11	0.00	0.20	0.00	0.42	0.00	0.08	0.04	0.00	0.46		0.48	0.46
WWT	0.34	0.20	0.00	0.05	0.12	-0.22	0.31	0.00	0.10	0.11	0.00	0.40	0.63		0.48
YWT	0.21	0.49	0.00	0.09	0.12	-0.33	0.47	-0.03	0.01	0.00	0.00	0.32	0.65	0.59	

[1]LMY, lactation milk yield; SWT, sale weight; DP, dressing percentage; CMP, Consumable meat percentage; FI, feed intake; AFC, age at first calving; CWT cow weight; CI, calving interval; SR, pre-weaning survival rate; PSR, post weaning survival rate; PLT, productive life time; average daily gain, ADG; BWT, birth weight; WWT, weaning weight; YWT, yearling weight.

(Source; Kahi et al., 2004; Ilatsia et al., 2007; Ilatsia et al., 2011; Rewe et al., 2011)

The nucleus size was varied because the management of the nucleus farms expressed plans to expand their herds in response to the growing demand for breeding bulls by pastoralists. It was also assumed that in future some pastoralists would transform their herds to join the nucleus herds. In this case the size of the nucleus was gradually expanded at six levels from the current proportion of 14% to 44% of the total population. This increase in nucleus size would definitely result in a concomitant increase in the number of available breeding bulls for distribution to the pastoral herds; hence, the level of usage of nucleus sires in the pastoral herds was also varied at six levels from the current 65% to 90% of available sires. During the interviews, most nucleus farms expressed willingness to allow in a small fraction of pastoral sires into their herds to produce dams, however, only when such sires passed the threshold of Sahiwal cattle breed standards (Muhuyi et al. 1999). Consequently, the impact of varying the degree of usage of pastoral sires in the nucleus was investigated by gradually varying the proportion of sires imported into the nucleus from an assumed initial level of 5% to 30% of available pastoral-born sires.

4.3 Results and discussion

4.3.1 Stakeholder institutions supporting the existing Sahiwal cattle breeding programme

Figure 5 shows some of the stakeholder institutions identified by both pastoralists and ranchers, and their roles in the existing Sahiwal cattle breeding programme in Kenya. It is important to note that operations of the identified stakeholder institutions are not exclusively confined to the Sahiwal cattle breed, but also extend to other livestock breeds, e.g. Boran cattle breed society and other European cattle breeds (Rewe et al., 2010; Wasike et al., 2011a). The stakeholders included both government and private institutions. One of the private institutions is the Sahiwal Cattle Breed Society (SCBS), which draws its membership from the 18 nucleus farms, and the Kenya Stud Book (KSB), the latter acting as the secretariat to the SCBS. Its key functions include promotion of the Sahiwal breed in the country, and directly or through KSB, SCBS performs regulatory functions with regard to registration and maintaining breed standards. The KARI is a government institution and is actively involved in developing husbandry and breeding intervention strategies for Sahiwal cattle genetic resources for pastoralists in the Southern rangeland through the NSS and its Transmara sub-centre. KARI also sells breeding bulls to pastoralists at subsidised prices. In collaboration with the Livestock Recording Centre (LRC), KSB and SCBS, KARI also provides technical support to nucleus farms in form of free training in performance recording and evaluation. The Ministry of Livestock Development (MOLD) is mainly involved in provision of extension services to pastoralists and nucleus farms on husbandry practices and in disease control through highly subsidised vaccination programmes. Local veterinary stores and para-veterinarians supplement efforts of government veterinary officers to provide clinical services and prophylactic treatment. The KMC (government parastatal), private butcheries and abattoirs, as well as local markets provide market outlets for live animals and milk. Other 'producers' were also collectively classified as stakeholder institution because they are the main custodians of Sahiwal cattle genetic resources and are target beneficiaries of any proposed breeding programme. Therefore, their decisions in this regard will have far reaching implications on the adoption and sustainability of the breeding programme.

4.3.2 Basic selection parameters and overall annual monetary genetic gain in the two sire selection pathway

Selection intensities and selection accuracies were equal in all evaluated breeding programs for both sire selection pathways. Sires' sires were more intensively selected compared with the sires' dams (selection intensity of 2.20 versus 0.56);

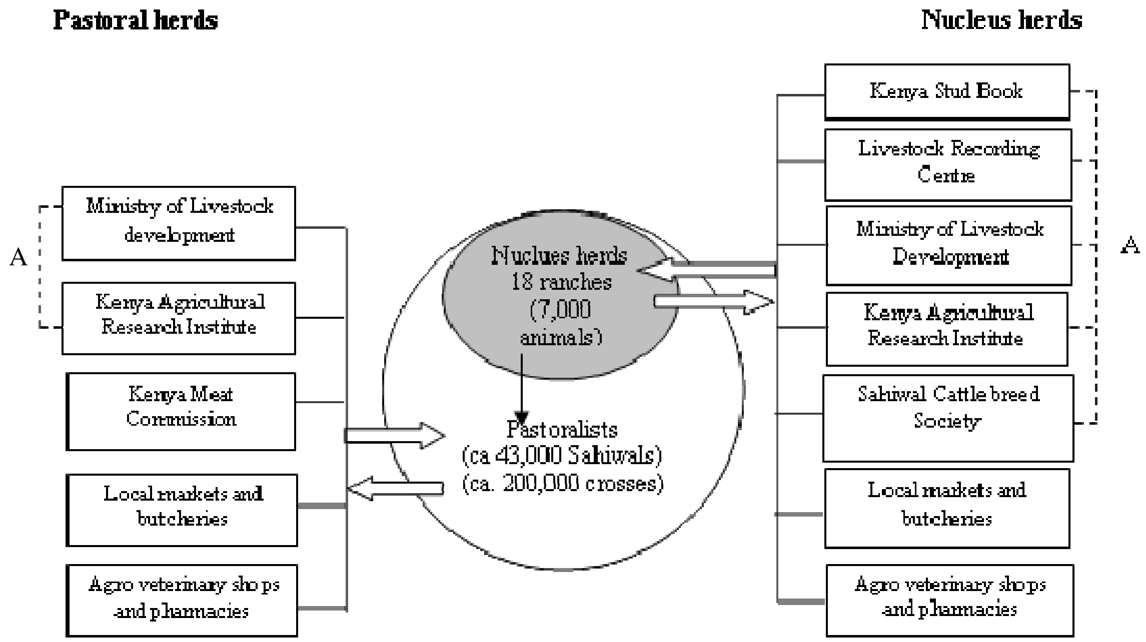

Figure 5. Stakeholder institutional organisation that support the Sahiwal cattle breeding programme in Kenya

Source: personal interviews with 244 pastoralists and 18 nucleus farm managers and discussion with 21 key resource persons.

[A]Strategic corporation among stakeholder institutions

however, the sires' dams were more accurately selected as compared with the sires' sires selection group (selection accuracy of 0.72 versus 0.58). As would be expected, generation intervals were higher for sires' dams compared with sires' sire selection pathway (6.86 versus 4.39 years). Other selection pathways were equally important in the transmission of genes; however, the discussion herein is focussed on the two sire selection pathways because they are considered to have the greatest genetic contribution in the breeding programs since the dissemination of genes from the nucleus to the pastoral herds was exclusively via sires.

The monetary genetic gain (in US$) for the two main bull parental selection groups (bulls' sires and bulls' dams) were 22.46, 22.71 and 22.43, and 7.03, 7.06 and 7.13 under CN_{PURE}, CN_{CROSS} and ON_{PURE}, respectively. In this context the monetary genetic gain is a function of the sum of genetic gain in individual breeding objective traits and their corresponding economic values. As would be expected, there were differences in the annual monetary genetic gain both within and between the two sire selection groups. The monetary genetic gain was markedly higher in the sires' sires compared with the sires' dams selection pathway, an observation that points to over-reliance on sires in transmission of genetic superiority in the population. The superiority of the sires' sires is associated with the higher selection intensities for this pathway given that just a few bulls from a pool of potential candidates are selected and retained in the herds. The higher selection accuracies in the sires' dams are attributed to more traits and information sources for selection in this group as compared with the sires' sires selection pathway. For example, in the selection of sires' dams, both individual and relatives' information are used to select for milk yield (MY), AFC and CI in addition to growth performance traits. For the sires' sires, selection for milk and fertility is only possible via information from relatives, hence fewer information sources. Furthermore, in the sires' dam selection group, MY, AFC and CI are selection criteria and breeding objective traits, a fact that is expected to considerably improve the accuracy of selection as compared with the sires' sires group where these traits are represented by female relatives only. Having traits in the breeding objective without corresponding selection criteria and measurement in the selection criteria especially on an individual has the potential to reduce the accuracy of selection, and ultimately the genetic gain for the breeding objective traits under consideration (Dickerson et al., 1974).

4.3.3 Overall performance of the breeding programmes

Table 12 shows the overall returns on investment, total costs and profits per cow after the whole investment period of 25 years, as well as the genetic gain for the three breeding strategies under the two breeding objective scenarios. There were differences among the breeding strategies within the two breeding objectives scenarios. Under both breeding objective scenarios, CN_{PURE} was the most attractive in terms of returns on investment and profits compared with ON_{PURE} and CN_{CROSS}. Returns and profits were generally higher for CSCB compared with BSWB. Costs were fairly similar for CN_{PURE} and ON_{PURE} but were far lower for CN_{CROSS} under both BSWB and CSCB scenarios (Table 12). The lower cost under CN_{CROSS} was due to the increased number of EAZ and Sahiwal x EAZ crossbred dams in the population, bearing in mind that costs were expressed per cow in the entire population after the whole investment period. The costs per cow did not differ markedly between the two breeding objectives (Table 12) because the selection criteria traits under recording were similar. The extra breeding objectives traits for CSCB (i.e. DP and CMP) had no accompanying selection criteria traits hence no additional recording costs were incurred.

Table 12. Returns, total costs, profit per cow after 25 years and genetic gain in the nucleus for different breeding strategies and breeding objectives

Component	Breeding objective[1]					
	BSWB			CSCB		
	CN_{PURE}	CN_{CROSS}	ON_{PURE}	CN_{PURE}	CN_{CROSS}	ON_{PURE}
Returns per cow (US$)	22.64	14.67	21.65	23.30	18.81	22.07
Total cost per cow (US$)	1.44	0.13	1.42	1.42	0.13	1.42
Profit per cow (US$)	21.21	14.54	20.23	21.88	18.68	20.65
Annual monetary genetic gain (US$)	2.52	2.77	3.32	2.62	2.70	3.38

[1] See section 4.2.3 for description of breeding objectives and 4.2.4 for description of breeding strategies. 1US$ = Kenya Shillings (Ksh) 80.0

A similar pattern was also evident for the annual monetary genetic gain where superiority was higher under CSCB compared with BSWB, except in CN_{CROSS} where the monetary genetic gain was slightly higher by US$0.07 under BSWB compared with CSCB. The main difference in profitability and monetary genetic gain between the two breeding objective scenarios is directly a result of including DP and CMP as breeding objective traits to accommodate the peculiarities of the CSCB market scenario. Differences in genetic and economic merit arising from variations in breeding objective scenarios or selection criteria modelled to address various peculiarities in given production and market systems have been reported (e.g. Kahi et al., 2003, 2004; Kahi and Hirooka, 2006; Herold et al., 2010). The open nucleus breeding programme was the most attractive with regard to the overall annual genetic gain (US$3.32 and 3.38, respectively), compared with CN_{PURE} (US$2.52 and 2.62, respectively) and CN_{CROSS} (US$2.77 and 2.70) under the BSWB and CSCB, respectively. The extra recording with concomitant improvement in selection accuracy that is normally associated with ON_{PURE} did not contribute to the profits, but rather to the monetary genetic gains. The relatively lower genetic gain in CN_{CROSS} when compared with CN_{PURE} or ON_{PURE} may be attributed to the low selection intensities in the EAZ and also fewer information sources in the EAZ subpopulation which resulted in low response to selection. As alluded to earlier the EAZ was selected on an index that was uncorrelated with the breeding objective and so did not contribute much to genetic gain. The low performance of CN_{CROSS} compared with CN_{PURE} and ON_{PURE} could be attributed to the relatively long generation intervals in the EAZ. This in essence increases the time lag which is detrimental to both the profits and the genetic gain, when compared with the purebreeding programs where the ages at first service for both males and females are relatively short.

Sires from the pastoral herds are born from pastoral dams which are more diverse genetically owing to the fact that these dams are products of the long-term upgrading program (Meyn and Wilkins, 1974). Introducing such sires in the nucleus herds is therefore expected to increase genetic variability, broaden the base for selection and consequently translate into high genetic performance. In addition, the high risks of inbreeding and reduction in genetic variance that are normally associated with CN_{PURE}, especially in small populations (e.g. Bosso et al., 2009) are reduced under ON_{PURE}. The superiority of allowing animals from the lower tiers to be used in the nucleus has widely been acknowledged. For example, in a study of the Boran beef cattle breed under semiarid conditions in Kenya, Rewe et al. (2011) reported high genetic superiority of open nucleus breeding systems as compared with closed nucleus systems for various types of Boran cattle producers. Similarly, open nucleus breeding systems were reported to be more attractive in terms of genetic gain compared with closed nucleus systems under various breeding objective scenarios in meat sheep (Gicheha et al., 2006) and in smallholder dairy cattle in Kenya (Kahi et al., 2004). The superiority of ON_{PURE} to CN_{PURE} in terms of response to selection has been reported to be in the range of between 10 and 15% depending on the population size, a fact that has been attributed to the use of relatively good sires from diverse lower tiers (Shepherd and Kinghorn, 1992; Bondoc and Smith, 1993).

4.3.4 Genetic and economic merits in individual breeding objective traits

Table 13 shows the annual natural genetic gains in individual traits of economic importance in the three breeding programs and under the two breeding objective scenarios. Of interest is comparison of genetic gain within breeding objective traits across the three breeding strategies. Annual genetic gains for individual traits largely varied depending on the breeding strategy and breeding objective scenario under examination. Genetic gain for LMY was highest in ON_{PURE} when compared with CN_{PURE} (50.83 versus 38.64 kg and 51.40 versus 39.86) and CN_{CROSS} (50.83 versus 28.06 and 51.40 versus 23.82) under BSWB and CSCB, respectively. Similarly, the natural genetic gain in SWT was highest in the ON_{PURE} compared with CN_{PURE} (0.69 versus 0.51 kg) and CN_{CROSS} (0.69 versus 0.49 kg) under the BSWB. The CN_{CROSS} was comparable to the ON_{PURE} (0.69 versus 0.68 kg) but better than the CN_{PURE} (0.69 versus 0.52 kg) under CSCB. Genetic gain in FI was favourable under the BSWB for the CN_{PURE} (–0.07 DM kg) and ON_{PURE} (–0.08DM kg) but was positive and undesirable in CN_{CROSS}. However, the genetic gains for FI under CSCB were positive and undesirable in all the breeding systems (Table 13).

Table 13. Annual natural genetic gain in individual traits of economic importance in the three breeding strategies and two breeding objectives trait scenarios

Trait[1]	Breeding objective[2]					
	BSWB			CSCB		
	CN_{PURE}	CN_{CROSS}	ON_{PURE}	CN_{PURE}	CN_{CROSS}	ON_{PURE}
LMY (kg)	38.64	23.82	50.83	39.86	28.06	51.40
SWT (kg)	0.51	0.49	0.69	0.52	0.69	0.68
DP (%)	-	-	-	0.01	0.02	0.02
CMP (%)	-	-	-	0.02	0.02	0.03
FI(DM kg)	-0.07	0.20	-0.08	0.05	0.20	0.06
AFC (days)	0.31	-0.04	0.38	0.67	-0.19	0.88
CWT (kg)	0.58	0.64	0.77	0.61	0.75	0.80
CI (days)	0.44	0.23	0.58	0.47	0.21	0.61
SR (%)	0.01	0.02	0.01	0.00	0.00	0.00
PSR (%)	0.01	0.02	0.01	0.00	0.00	0.00
PLT(days)	0.09	0.21	0.12	0.13	0.38	0.18

[1] See Table 11 for description of traits
[2] See section 4.2.3 for description of breeding objectives and 4.2.4 for description of breeding strategies. 1US$ = Kenya Shillings (Ksh) 80.0

Selection for short AFC was only favourable in the CN_{CROSS} (–0.04 versus –0.19 days) under the BSWB and CSCB, respectively, but was generally undesirable and higher under BSWB compared with CSCB for the CN_{PURE} (0.31 versus 0.67 days) and in the ON_{PURE} (0.38 versus 0.88 days), respectively. The trend was also similar for CI and in this case the genetic gain was positive and undesirable in all the breeding systems under the two breeding objective scenarios (Table 13). Genetic gain was generally low for SR and PSR under BSWB, and effectively zero under CSCB. Under BSWB, CN_{CROSS} was superior in SR and PSR (0.02 versus 0.01%) compared with CN_{PURE} and ON_{PURE}. Genetic gain in PLT was generally higher under CSCB compared with BSWB. In this case the CN_{CROSS} had highest genetic gain when compared with CN_{PURE} (0.21 versus 0.09 days and 0.38 versus 0.13 days) and ON_{PURE} (0.21 and 0.12 days and 0.38 versus 0.18 days) under BSWB and CSCB, respectively. Table 14 shows the monetary returns for the traits in the three breeding strategies and the breeding objective scenarios. Just like in the case of genetic gain, the highest returns were reported in LMY although this varied depending on the breeding objective and breeding strategy under consideration (Table 14). For example, the returns for LMY were more under CSCB compared with BSWB in CN_{PURE} (US$22.42 versus 22.00), ON_{PURE} (US$21.04 versus 21.25) and CN_{CROSS} (US$14.06 versus 17.10), respectively. The CN_{CROSS} had the highest returns in SWT and CWT compared with both CN_{PURE} and ON_{PURE} under both market scenarios. The monetary returns were also high for DP and CMP in CN_{CROSS} compared with CN_{PURE} and ON_{PURE}. Returns from FI, AFC and CI were generally negative, while those from SR, PSR and PLT were generally low but positive under both breeding objective scenarios and in the three breeding strategies (Table 14).

Table 14. Monetary returns (US$) in individual traits of economic importance in the three breeding strategies and under the two breeding objective scenarios

Trait[1]	Breeding objective[2]					
	BSWB			CSCB		
	CN_{PURE}	CN_{CROSS}	ON_{PURE}	CN_{PURE}	CN_{CROSS}	ON_{PURE}
LMY (kg)	22.00	14.06	21.04	22.42	17.10	21.25
SWT (kg)	0.35	0.36	0.35	0.37	0.53	0.35
DP (%)	-	-	-	0.11	0.13	0.11
CMP (%)	-	-	-	0.12	0.13	0.12
FI(DM kg)	-0.01	-0.12	0.00	-0.03	-0.10	-0.02
AFC (days)	-0.02	-0.01	-0.02	-0.05	-0.03	-0.05
CWT (kg)	0.32	0.38	0.29	0.36	0.45	0.33
CI (days)	-0.04	-0.02	-0.04	-0.04	-0.02	-0.04
SR (%)	0.01	0.02	0.01	0.00	0.00	0.00
PSR (%)	0.00	0.01	0.04	0.01	0.01	0.01
PLT(days)	0.04	0.01	0.00	0.01	0.02	0.01

[1]see Table 11 for description of traits
[2] See sections 4.2.3 for description of breeding objectives and 4.2.4 for description of breeding strategies. 1US$ = Kenya Shillings (Ksh) 80.0

The marginal genetic gains in SR and PSR are a reflection of the generally low heritability of these traits as well as lack of direct selection criteria and information sources to enhance their improvement. In our study, SR and PSR, normally considered as herd traits, were used as direct measure of the ability of animals to withstand various production challenges and other environmental stresses associated with the low-input pastoral production systems. While production can be measured in terms of quantity and quality of products, the greatest challenge is identifying selection criteria of adaptation and incorporating them into technically and economically feasible recording schemes. Previous studies included indirect measures such as tick counts, faecal egg count and pact cell volume as indirect measures for parasite and disease tolerance (e.g. Gicheha et al., 2007; Rewe et al., 2011). Such endeavours are theoretically attractive but their practicality remains remote owing to the fact that enormous financial and human resources would be required to operationalise such schemes especially in the already over-constrained livestock recording schemes in developing countries (Wasike et al., 2011b). Inclusion of such measures in evaluating alternative breeding schemes will only inflate the genetic gain, while at the same time diminishing the profits because of their associated high recording costs. Kahi and Graser (2004) suggested use of direct measures such as survival rate at various age categories, and the production levels under disease and parasite challenges as more feasible indicators of adaptation. Identification of markers linked to genes responsible for various adaptation traits could also holds the potential for genomic selection (van Arendonk, 2011), however, the application of such techniques in the near future would still be limited by cost and logistical factors already mentioned.

4.3.5 Cross evaluation of breeding programmes and sensitivity analyses

The impact on monetary genetic gain and profits per cow of varying the nucleus size at different usage levels of nucleus-born sires in the pastoral herds for CN_{PURE} are shown in Figure 6 and Figure 7, respectively. Expanding the nucleus size and increasing the number of nucleus-born sires to breed bulls and cows in the pastoral herd had no effect on the annual genetic gain (Figure 6), but diminished the profit margins (Figure 7). The optimal profitability of CN_{PURE} has already been achieved at the current level of 65% of nucleus-born sires that are transferred to the pastoral herds (Figure 6).

The size of the nucleus is an indirect measure of the number of animals available for recording; thus, increased recording results in high variable costs which consequently reduces the profit margins of the breeding program.

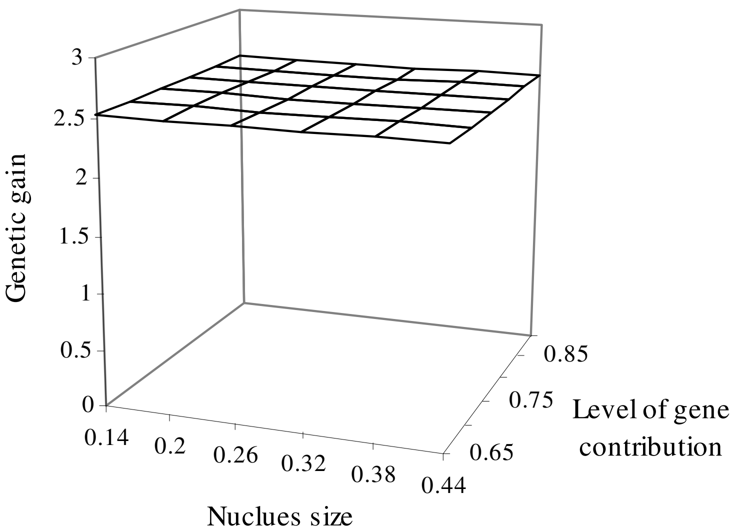

Figure 6. Impact on genetic gain of varying the size of the nucleus at different levels of usage of nucleus born sires in the pastoral herds for the CN_{PURE} of the breeding objective addressing the traditional local market (BSWB)

Various studies have reported initial increases in genetic gain and profitability due to nucleus expansion and increased gene transfer into the commercial units (e.g. Kasonta and Nitter, 1990; Kahi et al., 2004; Gicheha et al., 2006; Rewe et al., 2011), showing that increasing the proportions only resulted in positive changes in genetic gain and profitability up to when the most optimal levels are attained. Bosso et al. (2009) also reported a reduction in annual genetic gain for LMY under an increase in nucleus size in West African N'Dama cattle. Theoretically, increasing the nucleus is supposed to be genetically attractive (Shepherd and Kinghorn, 1992); however, in this case increased costs of recording arising from expansion of the nucleus seemed to surpass the genetic gains that are usually associated with the increase and thus diminishing the monetary genetic gain and profitability when the optimal nucleus and gene contributions are exceeded.

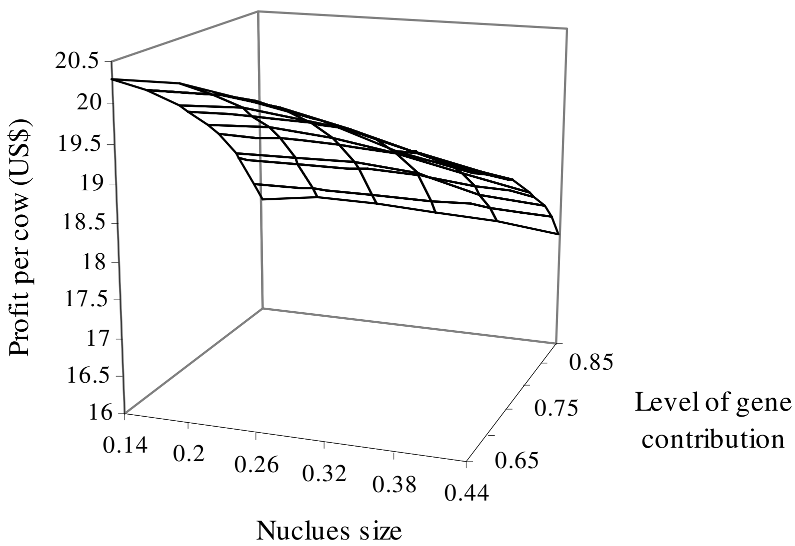

Figure 7. Impact on profit per cow of varying the size of the nucleus at different levels of usage of nucleus born sires in the pastoral herds for the CN_{PURE} of the breeding objective addressing the traditional local market (BSWB)

The static monetary genetic gain (Figure 6) could possibly result from the proportionate changes in the functions of the basic selection parameters (selection intensity, accuracy of selection and generation interval) when there is a concomitant expansion in nucleus size and level of gene contribution to the pastoral herds, which in essence would not influencing the magnitude of these basic parameters *per se*.

The effect of varying the level of importation of pastoral-born sires into the nucleus on monetary genetic gain and profit was investigated under ON_{PURE}, the results of these are shown in Figure 8 and Figure 9, respectively. Gradual importation of sires into the nucleus resulted in an upward trend in both monetary genetic gain (Figure 8) and profits (Figure 9) at any given nucleus proportion. Restricting the nucleus size at the current proportion of 14% and increasing gene importation into the nucleus resulted in the highest genetic and economic returns. However, simultaneous increase in the level of sire importation and nucleus size was associated with reduction in monetary genetic superiority (Figure 8). It would be expected that pastoral-born sires would result in more genetic advantage when introduced into the nucleus herds since they are sourced from a more diverse gene pool in the pastoral herds. However, Dekkers and Shock (1990) observed that the potential extra benefits that could be accrued from increasing the usage level of commercial-born animals in the nucleus is sometimes eclipsed by the high genetic superiority of the nucleus over the lower tiers.

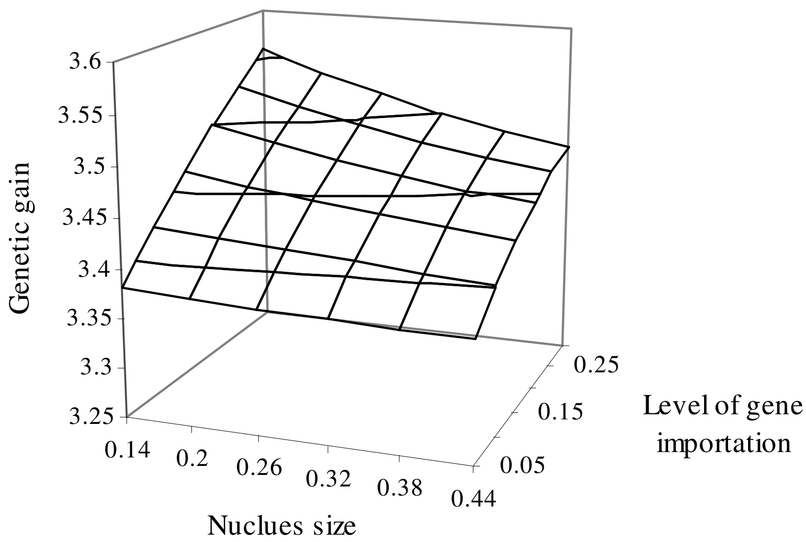

Figure 8. Impact on genetic gain of varying the size of the nucleus at different level of gene importation into the nucleus herds for the ON_{PURE} of the breeding objective addressing the traditional market (BSWB)

4.3.6 Choice of a breeding programme and practical applications

All the breeding strategies evaluated in this study showed positive genetic and economic gains, however, the difference was only in the margins of these benefits. At the current nucleus proportion of 14% of the total population, CN_{PURE} with 65% of nucleus-born sires transmitted to the pastoral herds was more attractive economically, however, relatively less competitive with regard to genetic merit. On the other hand, gradual opening of the nucleus was both genetically and economically beneficial, although the overall economic benefits were relatively lower compared with those in CN_{PURE} (Table 12).

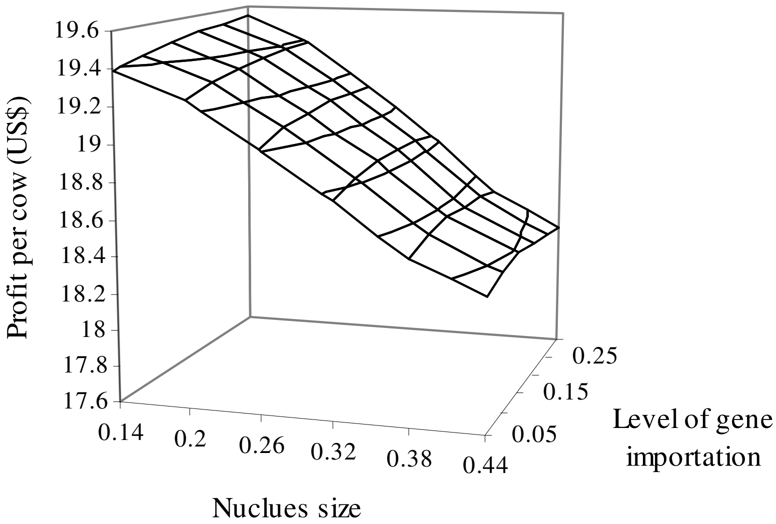

Figure 9. Impact on profit of varying the size of the nucleus at different level of gene importation into the nucleus herds for the ON_{PURE} of the breeding objective addressing the traditional market (BSWB)

While economic merits of a breeding program would have more influence on its adoption, it is important to take cognisance of the small population size of the Sahiwal breed and the associated risks of inbreeding which can substantially compromise the biological performance and ultimately affect the economic merit in the long run. This supports the case for ON_{PURE} because it will allow exploitation of the genetic diversity in pastoral herds by introducing sires from this sector into the nucleus herds and therefore increase the genetic base that would enhance selection. Crossbreeding is an important breeding strategy in the Sahiwal cattle breeding program because it represents an intermediate phase in the upgrading program towards obtaining the Kenya Sahiwal. In addition CN_{CROSS} is the medium through which the trade-offs that exist between the Sahiwal and EAZ in regard to production and functional traits are exploited; therefore, its relevance will prevail notwithstanding its genetic and economic performance in relation to the purebreeding programs.

The open nucleus breeding programme can be implemented using the existing arrangement of CN_{PURE}, only that additional structures would be required to facilitate the upward movement of pastoral-born sires into the nucleus. Advanced mechanisms of vetting the pastoral-born sires to be transferred into the nucleus subject to the Sahiwal breed standards would also be required. The current nucleus proportion (14% of the population) seems to be optimal, and therefore its expansion might not be of immediate priority because of the associated genetic and economic disadvantages. The next endeavour should be to set up mechanisms that will ensure breeding bulls from both the nucleus and the pastoral herds are properly distributed and utilised in mating. This is because Ilatsia et al. (2011a) recently reported poor access to breeding bulls as a major constraint that has the potential to hamper smooth implementation of the breeding program.

Participation of the producers and relevant stakeholder institutions (Figure 5) would play a crucial role in ensuring that practical distribution mechanism exist to guarantee smooth operation of the breeding program. For example, SCBS together with KARI offer a platform where the nucleus herds can share information on availability of breeding animals. Given the strategic interaction between KARI and the Ministry of Livestock Development extension officers (see Figure 5), pastoralist interested in procuring bulls could be identified by the local livestock extension agents. The agents would then profile and create an inventory of such pastoralists based on details such as their location and information on previous bull purchases from the nucleus farms. This would then be used to form a specific group of pastoralists who are then linked to particular nucleus farms on need basis. Individual nucleus farms together with SCBS and KSB can also make use of the inventory created as the basis for recruiting candidate bulls from the pastoral herds so as to reduce the chances of recruiting progeny of bulls that were initially sourced from particular nucleus farms. In addition the inventory will ensure that breeding bulls, in future, are geographically dispersed to forestall unintended concentration of particular sire progenies within given geographical regions.

The economic and genetic performance of a given breeding program is influenced by market conditions which ultimately influence the selection of breeding objective traits. The methodological approach used in this study accounted for both traditional and KMC (see Figure 4) by defining two set of breeding objectives that addressed differences in pricing system. Market peculiarities with the potential to influence breeding objectives have been acknowledged in some studies in developing countries. For example, Kahi et al. (2004) evaluated dairy cattle breeding programs in Kenya taking into account milk quality (fat content) as a breeding objective trait that would influence future payment system. In another study, Herold et al. (2010) acknowledged the role of marketing channels in influencing breeding objective and breeding organisation for local pig breeds in North-west Vietnam. In a recent evaluation of Boran cattle breeding program in Kenya, Rewe et al. (2011) included carcass traits in the breeding objectives notwithstanding the fact that such traits have little influence on the market price of beef animals in the predominant traditional market set up where emphasis is only on body size/weight. Similarly, an evaluation of the efficiency of various small ruminant breeding programs in Kenya (Kosgey, 2004; Gicheha et al., 2006) focussed on the roles small ruminants play to the livelihood of livestock keepers, with no specific focus on how the existing and emerging markets and their corresponding price regimes could influence the overall profitability of the breeding programs.

Acknowledgements

The field study was supported by funds from the Kenya Arid and Semi Arid Lands (KASAL) project through the Kenya Agricultural Research Institute (KARI). We are also grateful to the German Academic Exchange Service (DAAD) for financial support. The cooperation of pastoralists, ranch managers and key resource persons is highly appreciated.

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General discussion and conclusions

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CHAPTER 5: General Discussion and Conclusions

5.1 Breeding and conservation programmes in the tropics

Existing breeding and conservation strategies for Sahiwal cattle genetic resources in the tropics were reviewed in Chapter 2. The results showed that there are active breeding and conservation programmes in Pakistan, India and Kenya. However breeding goals incorporating the immediate specific and long-term socio-economic and ecological conditions of all the Sahiwal producers are lacking. The selection programmes only emphasise increased production without clear evidence of how other important attributes and functions of the breed, from the cattle owners' perspective, are accommodated. Information on the functions and roles of Sahiwal cattle genetic resources and the relative importance of traits from the producers' point of view were scarce in literature. Such knowledge deficits have been acknowledged as one of the leading causes of dysfunction or failure of most livestock breeding programmes in the tropics (Sölkner et al., 1998; Kahi et al., 2005; Kosgey et al., 2006; Roessler et al., 2008).

Both within-breed selection (pure breeding) and crossbreeding are the main strategies used for improving performance of Sahiwal cattle genetic resources. Within-breed selection strategies are particularly important to preserve the functional traits of breeds that are well adapted to the traditional production system (Drucker and Scarpa, 2003). However, effective implementation of pure breeding schemes in the developing countries are constraint by small populations sizes, lack of systematic animal identification and performance recording, inadequate infrastructure and high illiteracy levels among livestock producers (Jaitner et al., 2001; Kosgey and Okeyo, 2007). Bondoc and Smith (1993) suggested use of nucleus breeding schemes to overcome the aforementioned constraints by optimising the little resources available, and enhanced interaction between the producers both in technical and socio-economic sense (Kosgey et al., 2006). Such possibilities for establishing optimal Sahiwal cattle breeding programmes were explored in Chapter 4 by incorporating the desires and wishes of the Sahiwal producers as target beneficiaries as highlighted in Chapter 3.

Crossbreeding has been widely proposed for genetic improvement of dairy cattle in the tropics to meet the ever increasing demand for dairy products in this region (Cunningham and Syrstad 1987). Rege (1998) reviewed results of over 80 crossbreeding programmes involving European and indigenous breeds in the tropics. The results showed that adopted and relatively productive Zebu cattle breeds are widely used in crossbreeding to support dairy production in production systems where high production levels of purebred European dairy cannot be sustainably maintain. Crossbreeding involving Sahiwal cattle and other Zebu and European breeds is particularly preferred because the Sahiwal breed is considered unequalled in terms of additive breed effects for milk and growth production compared to other Zebu breeds (Trail and Gregory, 1981; Kahi et al., 2000: Joshi et al., 2001). However, there are no formal breeding policies or organized programmes to provide the framework and standard for such crossbreeding programmes, a fact that is blamed for the shrinking population of the breed in the tropics (FAO, 1992; Dahlin et al., 1995; Joshi et al., 2001). Wollny (2003) attributed the loss of livestock biodiversity to unregulated crossbreeding programmes, lack of economic valuation (Rege and Gibson, 2003) and other factors such as political instability and warfare. This has necessitated measures for conservation that include systematic documentation of comparative biological and economic performance in harsh environments (Anderson, 2001), and programmes that support sustainable utilisation (FAO, 2007) through selection within local populations in low-input production systems (Smith, 1988) and organised crossbreeding schemes (Cunningham and Syrstad, 1987). The FAO Global Programme for the Management of Farm Animal Genetic Resources (FAO, 1998a) underlines the importance of indigenous domestic animals in global biodiversity. Utilisation of indigenous livestock populations depends, to a large extent, on the ability of communities to decide and participate in implementation of suitable breeding programmes (Drucker and Scarpa, 2003). It is gratifying that both private producers and government farms in Pakistan, India and Kenya still maintain purebred Sahiwal cattle populations as reported in Chapter 2. Such programmes should be accompanied by some economic incentive as suggested by Drucker and Scarpa (2003), and reflect the production objectives of the farmer (Chapter 3). The breeding schemes evaluated in Chapter 4 provide an opportunity for conservation by according Sahiwal producers a participatory role in breeding programmes that meet their production objectives and are economically and genetically beneficial.

5.2 Role of Sahiwal cattle genetic resources

5.2.1 Production objectives

Breeding programmes planning and should be preceded with clear knowledge on the production aims and breeding goals of the target beneficiaries (Valle Zárate, 1996; Sölkner et al., 1998¸ Jaitner et al., 2003). Previous efforts to design and evaluate breeding programmes in the tropics have collected such knowledge from secondary sources (e.g. Kasonta and Nitter, 1990; Gicheha et al., 2006; Bosso et al., 2009; Rewe et al., 2010; Rewe et al., 2011). These secondary information sources are still important, however, specific studies tailored to solicit for in-depth knowledge on production and breeding objectives and their implication for a breeding programme would be desirable in order to make the process more credible and realistic. This is particularly of interest to avoid situations where arbitrary assumptions are made about particular production systems, notwithstanding the fact that there exist inherent differences in such systems with regard to breed functions, biological and other economic variables (Olivier et al., 2002). There exist a few studies where preliminary field studies were specifically conceptualised to establish the state-of-the-art production conditions upon which recommendations for the design of breeding programmes were derived. For example, Roessler et al. (2008), using choice experiments, assessed smallholder farmers' preferences for pig breeding traits in North-western Vietnam; the results from this study formed the basis for a comprehensive analysis of smallholder pig breeding and recording programmes (Roessler et al., 2009; Herold et al., 2010). The design of small ruminant breeding programmes (Kosgey, 2004) was supported by a prior assessment of producers' production aims and constraints as well as stated breeding goals and selection criteria (Kosgey et al., 2008). The present study therefore adopted a similar approach in assessing use values of Sahiwal cattle genetic resources and the needs and desires of Sahiwal cattle producers' in Kenya. The study showed that Sahiwal cattle genetic resources were mainly kept for tangible roles (milk, revenue and meat production), and to a lesser extent for intangible goals (risk management and cultural values). The multifunctional role of livestock in traditional low-input systems such as the one considered in this study has widely been acknowledged (e.g. Rege et al., 2001; Anderson, 2003; Jaitner et al., 2003; Scarpa et al., 2003; Mwacharo and Drucker, 2005; Wurzinger et al., 2006; Kosgey et al., 2008). The importance which producers attach to Sahiwal cattle genetic resources suggest that genetic improvement and conservation strategies have a high chance of success when carefully planned, as observed by Kosgey et al. (2008) for small ruminant breeding programmes in Kenya.

5.2.2 Selection criteria and breeding goals

The challenging production conditions in the traditional low-input production systems require animals that are well adapted and reasonably productive to preserve the hardiness in order for those breeds to fulfil the multiple productions objectives of the livestock keepers (Olivier et al., 2002; Anderson, 2003). In Kenya, producers perceived Sahiwal cattle genetic resources to be of good production and fertility, but at the same time acknowledged the relative competitiveness of the local EAZ with regard to adaptation to the harsh rangeland conditions (Table 8). The perceived high production potential coupled with the high selection and culling emphasis on growth and body size (Table 7, Figure 3), as well as milk production reflects the key roles of the breed (milk production revenue generation and meat production) to the Maasai producers. The importance of adaptation traits, alongside production and fertility under traditional low-input production systems has been widely reported. For example using choice experiments and conjoint analysis, Ouma et al. (2007) reported that cattle keepers in East African take cognisance of increased costs of production due to disease and parasite challenges and therefore attached high economic values to adaptation traits. The mentioned study confirmed earlier findings by Mwacharo and Drucker (2005) by identifying adaptation traits (disease resistance, drought and heat tolerance, low feed and water requirement) as priority traits when making selection decision in the Maasai Zebu cattle in South East Kenya. Although adaptation was not directly mentioned by Ankole cattle keepers, Wurzinger et al. (2006) acknowledges that producers took cognisance of adaptation trait as an important attribute in the Ankole cattle breed in East and Central Africa. Unlike the results in Chapter 3 and others (e.g. Jaitner et al., 2003; Mwacharo and Drucker, 2005; Ouma et al., 2007) where several breed and breed combinations were involved, lack of a comparative assessment in the study by Wurzinger et al. (2006), which focused only on the Ankole breed, increased the likelihood that the relative suitability of the breed may have been understated by the producers. N'Dama cattle were preferred because of their relatively good health status to the large Gobra Zebu or their crossbreds in The Gambia, a fact that Jaitner et al. (2003) ascribed to the adaptability and well documented trypano-tolerance in the N'Dama breed.

Selection and culling by Sahiwal cattle producers mainly revolved around general growth, body size and milk performance, fertility and general health in both males and females (Table 7). Ancestral and relatives' information also played a crucial role in making informed decision on males with regard to milk production (Chapter 3, Table 7), an observation that could reveal the intrinsic knowledge of producers with regard to pedigree of their animals. Selection criteria related to an animal's health status and age (for females) could be taken as proxies for adaptation and productive lifetime, respectively. Jaitner et al. (2003) listed traits related to growth, pedigree and relatives' milk production as important traits when making selection decision for breeding bulls in N'Dama cattle; however, unlike in this study, N'Dama cattle producers did not fact in body size when making selection decisions. Males were considered more important in transmission of genes to next generations and therefore much of the emphasis was skewed towards male selection in both N'Dama cattle (Jaitner et al., 2003) and Ankole cattle in Uganda (Nakimbugwe and Muchinguzi, 2003). However, more extensive study of Ankole cattle producers in East and Central Africa revealed that producers took cognisance of the contribution of both male and female to genetic improvement by preferring certain selection criteria on both sexes (Wurzinger et al., 2006). In this study (Wurzinger et al., 2006), phenotypic characteristics such as coat colour and size and shape of horns were used as additional selection parameters in males, besides general growth, body size, and temperament and dams milk production. By contrast, colour did not influence selection or culling among Sahiwal cattle, while horns were not mentioned at all. This observation is probably directly linked to the more uniform and consistent dark red to brownish coat colour complexity of the Sahiwal breed and its crosses and the mandatory dehorning practices applied (*W.B. Muhuyi, personal communication*).

These breeding goals should closely be aligned with overall production objectives of the target group who form the critical link in the use of genetically improved animals (Amer et al., 1998). Wurzinger et al. (2006) concluded that such information should be shared with the relevant stakeholders and form part of the logical steps in participatory planning of future sustainable breeding and production strategies. The knowledge on production aims and breeding goals identified in Chapter 3 was therefore re-formulated into practical selection criteria and breeding objective traits used in evaluating the suitability of various breeding programmes in Chapter 4.

5.3 Optimisation of the breeding programme and organisational issues

Bondoc and Smith (1993) recommended the establishment of two tier open nucleus breeding schemes as opposed to unstructured populations in developing countries, to maximise genetic improvement, reduce inbreeding rates and reduce the total costs of recording. The current and alternative nucleus breeding programmes for Sahiwal cattle in Kenya and opportunities for their establishing were evaluated in Chapter 4. Open nucleus breeding schemes have been associated with high operational costs as compared to closed or unstructured breeding programmes. Bosso et al. (2009) recommended an open nucleus as opposed to a closed nucleus breeding scheme to enhance the genetic base and reduce the level of inbreeding in a small population of N'Dama cattle in The Gambia. Although opening the nucleus did not significantly translate in much genetic gains in the dual purpose Mpwapwa cattle in Tanzania, Kasonta and Nitter (1990) recommended its implementation to improve milk yield because of its high profits, better structures for utilisation of available breeding animals and reduced chances of inbreeding in the population. To the contrary an evaluation of alternative two-tier nucleus breeding systems for improvement of meat sheep in Kenya, utilisation of young rams in a closed nucleus systems was more efficient with regard to both genetic gain and profits when compared to an open nucleus system (Gicheha et al., 2006). There is no evidence of whether the modelled schemes in those studies (Kasonta and Nitter, 1990; Bosso et al., 2009) have been practically implemented.

In the present study, there were no significant differences in the cost of operating both the open- and closed-nucleus breeding (US$ 1.44 vs 1.42) (Table 12). This could be linked to the simple selection criteria applied in both cases (see Table 10) as compared to other studies where more selection criteria traits were considered (e.g. Gicheha et al., 2007; Rewe et al., 2011). In the case of the open-nucleus scheme modelled in this study, bulls were recruited into the nucleus based on physical appraisal on traits of interests with no extra recording costs incurred in the pastoral herds. The cost of operating an open nucleus for low-input Boran cattle breeding programme was found to be three times higher than that of implementing a closed nucleus of similar size (Rewe et al., 2011). The enormous recording costs in that study were a result of inclusion of measures of trypano-tolerance and tick count as a prerequisite for recruiting commercial born bulls into the nucleus. Similarly, in a study of meat sheep breeding programmes in Kenya, Gicheha et al. (2007) reported high recording costs due to screening of commercial born rams for faecal egg count prior to inclusion into nucleus flocks. While inclusion of such measures was associated with relatively higher accuracy of selection in those breeding programmes (Gicheha et al., 2007; Rewe et al., 2011), the high recording costs portrayed the breeding programme to be less economical, whilst more direct measures of adaptation such as survival rate could be co-opted in the breeding objective at relative lower costs and produce the desired outcome (Rege et al., 2001; Kahi and Graser, 2004). Rewe (2009) recommended several other austerity measures that included 1) cutting down of recording costs among commercial herds by restricting the number of animals participating in the breeding programme only up to the effective population sizes as earlier suggested by

Goddard and Smith (1990) for dairy cattle and Rege et al. (2001) for Zebu cattle in Kenya, and 2) co-opting external stakeholders' support in the implementation of the breeding programme, similar to earlier suggestions made by Dempfle (1991) for N'Dama cattle breeding programme in West and Central Africa. However, in a review of success and failures of small ruminant breeding programmes in the tropics, Kosgey et al. (2006) identified over-reliance on external support as one of the reasons for the unsustainability of breeding programmes, especially in cases where such support expires or is withdrawn before the realisation of project goals (Kahi et al., 2005).

The decision for setting up a certain breeding programme should not only be based on genetic and economic merit for its successful implementation and sustainability. Some other factors that have been identified are of organisational and logistical in nature (Kosgey and Okeyo, 2007). The closed nucleus modelled in Chapter 4 was economically more attractive compared to the open nucleus (

Table 12). As alluded to earlier in Chapter 4, the current basic closed-nucleus breeding programme for Sahiwal cattle genetic resources seems to restrict direct participation of pastoralists in the breeding programme, and thus an open nucleus offers a chance for their animals to contribute to genetic gain as wells as give cattle keepers a sense of ownership in the breeding programme. According to Bondoc and Smith (1993), an open-nucleus breeding programme provides a means through which livestock producers in the lower tier are integrated into the programme and encourages more producer participation.

Strong institutional framework and infrastructural network as well as farmer organisation are crucial in implementation of planned breeding programmes (Kahi et al., 2005; Rewe et al., 2008; Roessler, 2009). For instance, opening the nucleus will require elaborate capacity building of pastoralists to participate in the breeding programme because producers may be reluctant to relinquish some of their best animals to the nucleus, a decision that needs a lot of persuasion to achieve as observed by Kahi et al. (2004) in the case of establishing smallholder dairy cattle breeding programmes. In a review of sustainable community-based organisations for genetic improvement of livestock in developing countries, Kahi et al. (2005) recommended the use of incentives to encourage cooperation of producers such as temporal leasehold arrangements and profit sharing from leased animals to the nucleus. In the case of the Sahiwal cattle breeding programme in Kenya, the exchange of additional selected pastoral-born bulls with those from the nucleus farm in the form of ‘barter trade’ or ‘trade in’ contractual agreement could be considered.

Animal evaluation is important for management decision on the farms, between farm performance comparisons and selection purposes (FAO, 1998b, cited in Wasike et al., 2011). This can only be achieved in the presence of an efficient recording scheme (Groen, 2000). Genetic evaluation of the Sahiwal breed has mainly been based on performance data collected over the years at a single farm, the NSS (Rege et al., 1992; Ilatsia et al., 2007: Ilatsia et al., 2011). The proposed open nucleus breeding programme is expected to involve more herds in genetic evaluation and breeding value estimation, however the performance records from these farms are varied in terms of scope of recording, type of records kept and the extent of information utilisation (Muhuyi, 1997), a fact that has been identified as a major constraint in realisation of comprehensive genetic evaluation in large-scale livestock farms in Kenya (Wasike et al., 2011b). Provision of incentives such as free but provisional data processing and breeding advice to the nucleus herds as currently practices by the LRC and NSS has been suggested as a motivation to attract interest among the nucleus herds to take proactive role in the full realisation of the planned breeding programme.

The economic and genetic performance of a given breeding programme is influenced by market conditions which ultimately influence the selection of breeding objective traits. The methodological approach employed in Chapter 4 discriminated between two markets set-ups (traditional and KMC, see Figure 4) by defining two set of breeding objectives that addressed differences in pricing system. Some studies in developing countries have already taken cognisance of such market peculiarities in breeding programme planning and implementation. For example, Kahi et al. (2004) evaluated dairy cattle breeding programmes in Kenya taking into account milk quality (fat content) as factor that would influence future payment system. In another study, Herold et al. (2010) acknowledged the role of marketing channels in influencing breeding organisation for local pig breeds in Northwest Vietnam. In a recent evaluation of Boran cattle breeding programme in Kenya, Rewe et al. (2011) included carcass traits in the breeding objectives notwithstanding the fact that such traits have little influence on the market price of beef animals in the predominant traditional market set up where emphasis is only on body size/weight. Similarly, an evaluation of the efficiency of various small ruminant breeding programmes in Kenya (Kosgey, 2004; Gicheha et al., 2006) focused on the roles small ruminants play to the livelihood of livestock keepers, with no specific focus on how the existing and emerging markets and their corresponding price regimes could influence the overall profitability of the breeding programmes.

5.4 Methodological approach

This study was designed to systematically follow the important steps involved in developing breeding programmes. This was preceded by review of literature to identify strengths and limitations in breeding and conservation programmes for Sahiwal cattle genetic resources based on published and unpublished material (Chapter 2). Previous studies on evaluation of livestock breeding programmes in the tropics have been preceded by similar reviews to identify the broader production and breeding objectives of livestock producers prior to detailed analyses of breeding programmes (e.g. Bosso, 2006; Kosgey et al., 2006; Rewe et al., 2009). In the present study, however, the number of publications was relatively small which in essence limited the scope of coverage.

Structured questionnaires and group discussion were used to solicit information on producers' production objectives and constraints, as well as selection and breeding goals. Structured interviews were used to obtain information on specifics topics covering general household characteristics, purpose of keeping Sahiwal and their crosses, traits of importance, selection criteria and culling decisions, feeding and breeding management, animal health, marketing and pricing. Roessler (2009) noted that single-person interviews were more advantageous than group discussions because they eliminated the chances of cross-influences of interviewees on each other. Because of the limited time, this study used trained enumerators in conducting personal interviews in order to cover a wide area and increase the sample size. However, the use of different enumerators could have affected the flexibility of putting additional and in depth questions and as well as uniform scrutiny of some pertinent issues, as opposed to a case where only one enumerator (the researcher) conducts the interview making it more consistent. Due to a severe drought in Kajiado county the sampling procedures applied were not uniform in the two counties. Pastoralists in Kajiado could not be sampled using the administrative units as was the case with Narok county, but rather on 'clusters' formed around watering and grazing points. This situation affected the area covered by the study as well as the balance in sample size achieved in Kajiado (n=92) compared to Narok (n=152). Furthermore, the livestock numbers were also affected by the drought since most pastoralists lost there animals or sold them in haste to avoid further losses. This would be expected to have an effect on the ideal mean herd and flock sizes and ultimately have an influence on regression co-efficiencies in the logistical regression applied in Chapter 3. However, this was not expected to influence the overall outcome of the study since Maasai community is culturally homogenous and the two counties only differed in agro-climatic conditions.

The group discussions aimed at bringing together participants who shared some insight knowledge or understanding of the topics covered during the personal interviews as observed by Bryman (2004). In this study the group size was limited to a maximum of 10 participants so as to enhance individual participation and for ease of management. The focused group discussions provided a platform for self-learning on the participants' side as well as in depth coverage of discussion topics and cross-check whether patterns of information found in the households were validated by the focused group, observed earlier by Chambers and Jiggins (1986). In a study to characterise small ruminant genetic resources in Northern Kenya, Warui (2009) observed that focus group discussion resulted in a two-way sharing of knowledge that supplemented information from more subject-focused personal interviews. However, group discussions have a tendency to allow over-dominance of some participants in the discussion as well as fear that comes with providing some sensitive information, which might be of interest to the researcher, but seldom revealed as experienced by Roessler (2009) during field study to identify functions of pigs among smallholder producers in Vietnam. Language, as reported elsewhere (Warui, 2009), could also affect the smooth flow of the discussions and therefore some information may not be well captured during translation.

Breeding programmes are long term investments (Smith, 1988), and their outcome is realised many years after their establishment. Their future genetic and economic responses can be determined through predictions based on current scenarios and realistic assumptions about the future. Deterministic modelling was used is this study to evaluate the current and alternative Sahiwal cattle breeding programmes by comparing their genetic and economic efficiencies using ZPLAN computer programme (Willam et al., 2008). The programme computes the annual genetic gain for the aggregate breeding value and for each selection and correlated trait, the returns from investment of a breeding system and the profit per cow by subtracting breeding costs from returns (Willam et al., 2008). It has been used widely in design and evaluation of various livestock breeding programmes and selection schemes in tropical countries (e.g. Kasonta and Nitter, 1990; Kahi et al., 2004; Gicheha et al., 2006; Roessler, 2009; Herold et al., 2010; Rewe et al., 2011). Whilst the alternative simulation programme SelAction has been credited for taking account of the potential influence of inbreeding and reduced genetic variance in the modelled populations (Rutten et al., 2002), ZPLAN's main advantage lies in its ability to predict the economic performance of breeding programmes based on given levels of investments and therefore provides an alternative criterion, besides genetic response, in optimising breeding schemes (Willam et al., 2008). This was of interest in this study because costs and profitability of a breeding programme are considered of priority by livestock keepers besides genetic efficiency when making decision on which breeding scheme to adopt (Groen, 2000). Although levels of inbreeding are expected to accumulate over the years given the small Sahiwal population in the country, ultimately affecting the response to selection and genetic gain in the long run, the effect of inbreeding could not be considered in ZPLAN due to inherent incapabilities of the programme (Willam et al., 2008). ZPLAN is the only programme that has the ability for simultaneous comparison of genetic and economic merits of given breeding and selection strategies and thus allowing for decisions to be made on the optimal breeding programme for adoption and implementation. Because of the deterministic approach, the results in Chapter 4 are entirely determined by the input parameters (i.e. genetic biological and economic input variables) and therefore the potential usefulness of the study is limited by the validity of these variables. Only the effects of one round of selection on the performance of succeeding generations are taken into consideration; this is a major weakness of ZPLAN since parameters cannot be held constant in a changing production environment. In developing countries such as Kenya, production and marketing conditions are in most cases unstable, interests and inflation rates are always high and therefore changes in economic weights, selection criteria and other aspects may change considerably during the planned investment period; however, such risks, as noted by Nitter et al. (1994), cannot be accommodated within the deterministic modelling adopted here.

As alluded to earlier, evaluation of most livestock breeding programmes in the tropics have been based on arbitrary assumptions on some biological and other technical issues (e.g. Kasonta and Nitter, 1990; Gicheha et al., 2006; Kahi et al., 2004; Rewe et al., 2011). As noted by Roessler (2009), alternative assumptions could also be justified, which in essence could have an influence on the outcome of the breeding schemes under investigation. In the present study, however, endeavours were made to limit the level of assumptions so as to make the outcome of analyses of the breeding schemes more realistic. This was achieved by restricting information sources on biological and technical parameters on tailored field survey supported by additional sources from publications related to the current study (e.g. Ilatsia et al., 2007: Ilatsia 2011).

Evaluation of alternative breeding programmes in sub Saharan Africa mainly focused on either pure bred populations (e.g. Kasonta and Nitter, 1990; Bosso et al., 2009; Rewe et al., 2010; Rewe et al., 2011) or mixed populations where contributions from each breed were not defined (e.g. Kahi et al., 2004; Kosgey et al., 2004; Gicheha et al., 2006;). Such approaches have the tendency to either under- or over-estimate the potential genetic and economic benefits of the planned breeding programme since specific contributions of the crossbred populations were either lumped together or taken for granted. This study recognised the significance of crossbred populations in the overall genetic and economic performance of a breeding programme. This was particularly of interest given the fact that livestock keepers prefer to keep mixed cattle breeds and more often crossbreeding is practiced to fulfil their multiple production objectives (Olivier et al., 2002; Jabbar and Diedhiou, 2003). In addition, different breeds might serve different functions and also show different biological and economic performance in given production systems hence blanket assumptions about their functionality should be exercised with caution to avoid under- or over-rating the contribution of such breeds in planned breeding programmes. Roessler (2009) recently documented the contribution of local and exotic pig breeds and showed how the various crossbreeding strategies involving these breeds influenced the genetic and economic performance of planned pig breeding programmes in Vietnam.

5.5 General conclusions

The potential for genetic improvement and conservation of Sahiwal genetic resources in the tropics exists given their economic contribution to people's livelihoods, and the active role played by both private and government stakeholders in initiatives in this regard. Sahiwal cattle genetic resources are kept for tangible benefits because of their perceived high production potential compared to the native Zebu breed. These tangible roles are influenced by various household and farmer characteristics which should be taken into account when formulating breeding strategies. Given the different roles cattle play in low-input production systems, especially under the traditional systems, future assessment should take cognisance of intangible roles and other non-market traits on the genetic and economic merit of the breeding programme. The major contribution of this study lies in the use of first-hand information from the producers' perspective and other production system specific technical parameters in evaluating the suitability of breeding programmes for improvement of Sahiwal cattle and their crosses in Kenya. In addition, the present study specifically accounted for and documented the contribution of Zebu crossbreds in the overall efficiency of cattle breeding programmes under low-input production systems, a component that previously had largely been ignored. This could serve as an example and form the basis to illicit similar efforts in countries such as Pakistan and India where suitability of such programmes for Sahiwal are yet to be ascertained. Implementation of the proposed breeding programme would require full participation of the relevant stakeholders, technical support and financial resources. In this regard, it is important to emphasize that the modelled programme only provides the blue-print that should be used as basis to support further activities and decision making during execution, a process that is expected to be gradual.

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CHAPTER 6

GENERAL SUMMARY

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6.1 Summary

The Sahiwal breed is an important cattle genetic resource in the tropics where it is vital for subsistence and economic development among various communities. The breed has widely been utilised in pure and crossbreeding in various production systems in the tropics, hence, sizes of purebred sub-populations are declining. Therefore, appropriate conservation and genetic improvement programmes are required to guarantee its sustainable use. There is no literature study that collates and critically examines information from the various countries on the strengths and shortcomings in the existing breeding and conservation strategies. In Kenya a breeding and conservation programme has been in existence for over 45 years with the ascertains of its relevance in light of the producers' production aims and breeding goals still left pending. Moreover, there have been no systematic efforts undertaken to evaluate the suitability of the existing breeding programme or to examine how competitive it is compared to other alternative programmes in terms of genetic and economic merit. This thesis focused on understanding the breeding strategies for improvement of Sahiwal cattle genetic resources in Kenya. Specific objectives were; 1) to critically examine the existing breeding and conservation programmes for Sahiwal cattle genetic resources in the tropics focussing mainly on the strengths and weaknesses in Pakistan, India and Kenya as the core regions of development, 2) to understand the production conditions under which Sahiwal cattle genetic resources are raised, determine producers production aims and assess the relative importance of breeding goals and production challenges, 3) to identify and define the roles of various stakeholder institutions that are crucial in the realisation of a promising and sustainable Sahiwal cattle breeding programme, 4) to identify based on genetic and economic merits the optimal breeding programme for Sahiwal cattle genetic resources by evaluating the current and alternative breeding programmes, and 5) to analyse and discuss organisational options for implementation of promising breeding and conversion programmes.

The methodological approach entailed review of both published and unpublished literature highlighting shortcomings and strengths in existing strategies and opportunities for improvement and conservation. A survey was conducted between May and October 2009 among Maasai pastoralists in Kajiado and Narok counties in the Southern part of Kenya, on private ranches and government farms to identify production objectives and breeding goals of Sahiwal cattle producers. A total of 244 pastoralists (152 from Narok and 92 from Kajiado) and 18 private ranches and other government farm managers were interviewed. Descriptive statistics were used to evaluate general information collected on household and farm characteristics. Indices were computed to represent weighted averages of rankings for purposes of keeping Sahiwal genetic resources and culling criteria. Logistical regression models were used to examine the effect of household characteristics on the purpose of keeping Sahiwal genetic resources. A proportional odds model with terms for breed (the Sahiwal, Sahiwal x East African Zebu (EAZ) crosses and the EAZ) was used to evaluate trait qualities as perceived by pastoralists. Stakeholder institutions that are crucial in the Sahiwal cattle breeding programme in Kenya were identified through personal interviews with Sahiwal producers and discussion with key resource persons. The information collected was analyzed qualitatively and the interrelationship between the stakeholder institutions with respect to their contribution to Sahiwal cattle breeding evaluated to depict the organizational support available. Genetic and economic successes of the nucleus breeding programmes were assessed using computer programme ZPLAN. The study was limited to private and government ranches, which collectively form the nucleus herds that supply breeding bulls to the Maasai pastoralists who mainly raise pure Sahiwal and their crosses with EAZ. Two two-tier nucleus breeding programmes were considered: The first breeding programme was a closed nucleus programme with downward movement of young bulls from the nucleus to the pastoral herds to produce both, sires and dams for this sector. Within this programme two breeding strategies exist: a pure breeding (CN_{PURE}) and a crossbreeding system (CN_{CROSS}) where nucleus and pastoral born sires are mated to EAZ dams to produce crossbred cows. The second was an alternative open-nucleus breeding programme with a certain proportion of pastoral-born Sahiwal bulls introduced into the nucleus herds to produce Sahiwal cows. Only the pure breeding strategy (ON_{PURE}) was modelled under the open-nucleus breeding programme. The breeding objectives and selection criteria traits, selection groups as well as their reproduction performance parameters were defined based on results of the field study. The breeding goals identified by producers were formulated into two breeding objectives to address two market scenarios. The first breeding objective scenario was the traditional markets where body size and weight are important price determinants (BSWB). The sale weight was considered as breeding objective trait besides lactation milk yield, feed intake, age at first calving, calving interval, pre- and post-weaning survival rate and productive life time. The second breeding objective (CSCB) reflected the Kenya Meat Commission (KMC) market scenario with carcass characteristics playing a great role in determining prices. The costs of the breeding programme included fixed costs and costs of animal recording calculated from economic data at the National Sahiwal Stud (NSS). Information sources in the nucleus included the individual, its parents and grand parents, half sibs and half sibs of parents. Sires in the pastoral herds were selected based on information on their won growth performance as well as milk performance and calving interval of their dams. Dams in this sector were selected based on their own milk performance and calving frequency. The interest rates for returns and costs were 4% and 6% per year, respectively, while the investment period was set at 25 years.

The results from the literature review study show that most studies on Sahiwal cattle genetic resources in the tropics have mainly concentrated on evaluating their performance levels with only a few published reports describing other breed characteristics. The Sahiwal breed is utilised for dairy and beef production under smallholder dairy pastoral extensive and ranching production systems both as purebreds or crossbreds. The necessary components to strengthen the breeding programme such as performance recording genetic evaluation and AI facilities exist albeit at different degree. Breeding and conservation efforts benefit from the technical and financial support from government research institutions, which also provide incentives to enhance participation in the programmes. However, breeding goals are rather informal and only defined in terms of high production levels with functional traits largely ignored.

Field data analysis revealed that Sahiwal genetic resources were mainly kept for domestic milk production and for revenue generation through sales of milk and live animals. To a limited extent they were kept for breeding and also for multiple objectives that included insurance against risks and social functions. Production aims were influenced to varying extents by various household and farmer characteristics. Sahiwal cattle and their crosses were generally perceived to be better with respect to productive traits and fertility traits when compared to the EAZ. However, the EAZ was rated higher with respect to adaptation traits. The breeding objective traits of primary importance were high milk yield and big body size, good reproductive efficiency and relatively good adaptation to local production conditions. Performance and functional traits are important breeding goals that play a major role in fulfilling the multiple production objectives. This forms the basis for the optimisation of a breeding programme for sustainable utilisation to meet the needs of Sahiwal cattle producers.

All the breeding programmes evaluated in this study showed positive genetic and economic gains, however, the difference was only in the margins of these benefits. Given the small population of the Sahiwal breed, an open-nucleus breeding programme is economically and genetically optimal because it will allow for efficient utilisation of the existing genetic base by allowing participation of more diverse pastoral born sires in the nucleus. The CN_{CROSS} will continue to play an important role of facilitating the exploitation of trade-offs that exist between the Sahiwal and the EAZ with regard to production and adaption, as well as an intermediate phase in the up-grading programme. However, the full benefits of the open-nucleus breeding programme can only be realised in the presence of proper logistical organisation to facilitate exchange of breeding bulls between the pastoral herds and the nucleus farms and ensure equitable distribution. Co-operation between producers and relevant stakeholder institutions is necessary to ensure the requisite structures for implementation and sustainable execution of the breeding programme.

6.2 Zusammenfassung

Die Sahiwal-Rinderrasse ist eine wichtige genetische Ressource der Tropen, die entscheidend für die Subsistenz und ökonomische Entwicklung vieler Bevölkerungsgruppen ist. Die Rasse wird stark in verschiedenen Produktionssystemen sowohl in Rein- als auch in Kreuzungszucht genutzt. Um den nachhaltigen Nutzen dieser Rasse weiterhin gewährleisten zu können, bedarf es geeigneter Erhaltungs- und Zuchtprogramme. Bisher gibt es keine Literaturstudien, die die Stärken und Schwächen existierender Zucht- und Erhaltungsstrategien verschiedener Länder zusammengefassen und kritisch untersucht haben. In Kenia besteht seit mehr als 45 Jahren ein Zucht- und Erhaltungsprogramm, dessen Relevanz in Bezug auf die Produktions- und Zuchtziele der Nutzer noch unklar ist. Außerdem gibt es bisher keine systematischen Versuche, bestehende Zuchtprogramme bezüglich ihrer Eignung bzw. ihrer genetischen und ökonomischen Konkurrenzfähigkeit im Vergleich zu anderen Programmen zu untersuchen.

Im Fokus dieser Arbeit steht daher das Verständnis von Zuchtstrategien zur Verbesserung der genetischen Ressource Sahiwal-Rind in Kenia. Besondere Ziele waren:

1) die bestehenden Zucht- und Erhaltungsprogamme für Sahiwal-Rinder in den Tropen kritisch zu untersuchen, mit besonderer Berücksichtigung der Stärken und Schwächen der Programme in den Hauptentwicklungsregionen Pakistan, Indien und Kenia;
2) die Produktionsbedingungen zu verstehen, unter denen Sahiwal-Rinder gehalten werden und die Produktionsziele der Halter zu bestimmen, und die relative Bedeutung der Zuchtziele und Herausforderungen in der Produktion zu bewerten;
3) die Rollen der verschiedenen beteiligten Institutionen zu identifizieren und zu definieren, die für die Umsetzung eines vielversprechenden nachhaltigen Zuchtprogramms für Sahiwal-Rinder in Kenia entscheidend sind;

4) durch die Bewertung der bestehenden und alternativen Zuchtprogramme das optimale Zuchtprogramm für Sahiwal-Rinder zu identifizieren, basierend auf dem genetischen und ökonomischen Gewinn;
5) und die praktischen Möglichkeiten der Implementierung aussichtsreicher Zucht- und Erhaltungsprogramme zu diskutieren.

Der methodische Ansatz umfasst eine Übersicht veröffentlichter und unveröffentlichter Literatur, welche sowohl Schwachstellen und Stärken bestehender Strategien aufzeigt, als auch Möglichkeiten zur Verbesserung und zum Erhalt liefert. Zwischen Mai und Oktober 2009 wurde eine Befragung von 244 Maasai-Pastoralisten in Kajiado (152 Pastoralisten) und Narok (92 Pastoralisten) im südlichen Teil von Kenia durchgeführt. Zeitgleich wurden auch Manager von 18 privaten und weiteren staatlichen Großbetrieben befragt, um Produktions- und Zuchtziele diverser Sahiwal-Rinderzüchter zu ermitteln. Beschreibende Statistik wurde angewandt, um allgemeine Farm- und Haushaltsmerkmale zu ermitteln. Gewichtete Mittelwerte der Rankings von Verwendungszweck und Keulungskriterien von Sahiwal-Rindern wurden als Indizes dargestellt. Modelle der logistischen Regression wurden angewandt, um die Effekte von Haushaltsmerkmalen auf die Verwendung von Sahiwal-Rindern zu berechnen. Ein Proportional-Odds-Modell mit Sahiwal, Sahiwal x EAZ Kreuzungen und EAZ als Rassen wurde benutzt, um die Qualität von Zuchtmerkmalen aus Sicht der Pastoralisten zu beurteilen. Beteiligte Institutionen, die für die Umsetzung von Sahiwal-Zuchtprogrammen in Kenia entscheidend sind, wurden in persönlichen Interviews mit Sahiwal-Rinderproduzenten und in Diskussionen mit Schlüsselpersonen identifiziert. Die erhaltene Informationen wurden qualitativ ausgewertet und die Beziehung zwischen den beteiligten Institutionen mit Bezug auf ihren Beitrag zur Sahiwal-Zucht beurteilt, um die verfügbare organisatorische Unterstützung darzustellen. Der genetische und ökonomische

Erfolg des bestehenden Nukleus-Zuchtprogramms wurde mit dem Computerprogramm ZPLAN ermittelt. Die Studie war auf private und staatliche Betriebe begrenzt, die gemeinschaftlich die Nukleus-Herde bilden. Diese Herden stellen Zuchtbullen für die Maasai-Pastoralisten, die hauptsächlich reine Sahiwal und Kreuzungen von Sahiwal und EAZ halten. Zwei zweistufige Nukleus-Zuchtprogramme wurden betrachtet: das erste Zuchtprogramm war ein geschlossenes Nukleus-Programm, in dem junge Zuchtbullen aus dem Nukleus an Herden der Pastoralisten abgegeben werden, um in der Produktionsstufe männliche und weibliche Zuchttiere zu erstellen. Inneralb des Programms gibt es zwei Zuchtstrategien: Reinzucht (CN_{PURE}) und Kreuzungszucht (CN_{CROSS}). In der Kreuzungszucht werden Zuchtbullen aus der Nukleus-Herde und aus der Herde der Pastoralisten mit weiblichen EAZ-Zuchttieren angepaart, um Kreuzungskühe zu erhalten. Die andere Strategie ist ein alternatives offenes Nukleus-Zuchtprogramm mit einem festgelegten Anteil an Sahiwal-Bullen, die im pastoralen System geboren sind, aber in die Nukleus-Herde aufgenommen werden, um Sahiwal-Kühe zu produzieren. Nur die Reinzuchtstrategie (ON_{PURE}) wurde für das offene Nukleus-Zuchtprogramm modelliert. Die Zuchtzielmerkmale, Selektionskriterien, Selektionsgruppen sowie Parameter der Reproduktionsleistung wurden anhand der Ergebnisse der Feldstudie definiert. Die von Rinderhaltern genannten Zielvorstellungen wurden in zwei breit aufgestellte Zuchtziele gefasst, die zwei verschiedenen Vermarktungsstrategien entsprechen. Das erste Zuchtziel-Szenario stellt die traditionelle Vermarktung dar, bei der die Körpergröße und das Gewicht wichtige Preisdeterminanten darstellen (BSWB). Zuchtzielmerkmale sind neben dem Verkaufsgewicht die Laktationsleistung, die Futteraufnahme, das Erstkalbealter, die Zwischenkalbezeit, die Überlebensrate und die funktionale Nutzungsdauer. Das zweite Zuchtziel (CSCB) reflektiert die Vermarktungsstrategie der *Kenya Meat Commission* (KMC), bei dem die Schlachtkörpermerkmale eine wichtige Rolle in der Preisfindung spielen. Die

Kosten der Zuchtprogramme umfassen Fixkosten und Kosten der Leistungsprüfung, die anhand ökonomischer Daten des *National Sahiwal Stud* (NSS) errechnet wurden. Die Informationen der Leistungsprüfung im Nukleus stammen neben dem Einzeltier von dessen Eltern und Großeltern, seinen Halbgeschwistern und den Halbgeschwistern der Eltern. Die Selektion der Zuchtbullen in den Herden der Pastoralisten basiert auf Informationen zur eigenen Wachstumsleistung, sowie auf der Milchleistung und Zwischenkalbezeit ihrer Mütter. Bullenmütter wurden in diesem Sektor anhand ihrer Abkalbe- und Milcheigenleistung selektiert. Der Gewinn wurde mit 4% pro Jahr verzinst, die Kosten mit 6%, wobei mit einer Investitionsperiode von 25 Jahren gerechnet wurde.

Ergebnisse der Literaturstudie zeigten, dass sich die meisten Studien über die genetische Ressource des Sahiwal-Rindes in den Tropen hauptsächlich auf die Leistungsbewertung konzentrieren, die sich auf nur wenige veröffentlichte Berichte zur Beschreibung der Rasse stützt. Das Sahiwal-Rind wird zur Milch- und Fleischproduktion in kleinbäuerlichen und pastoralen Milchvieh- und Weidesystemen verwendet, wobei sowohl Reinzucht-, als auch Kreuzungstiere eingesetzt werden. Notwendige Voraussetzungen zur Verbesserung der Zuchtprogramme, wie zum Beispiel die Leistungserfassung, die genetische Bewertung und Besamungseinrichtungen existieren, sind jedoch unterschiedlich stark vorhanden. Bemühungen der Zucht und des Erhalts können durch technische und finanzielle Hilfe staatlicher Forschungsinstitutionen unterstützt werden, die auch Anreize zur Teilnahme an den Programmen geben. Jedoch sind die Zuchtziele eher informell und nur auf hohem Produktionsniveau definiert, während funktionale Merkmale größtenteils unberücksichtigt bleiben.

Die Auswertung der im Feld gesammelten Daten zeigte, dass Sahiwal-Rinder hauptsächlich zur Milchproduktion für den Eigenbedarf und dem Einkommenserwerb durch den Verkauf von überschüssiger Milch und lebendes Tiere gehalten werden. Zu einem geringen Teil werden sie auch zur Zucht gehalten oder dienen anderen mannigfachen Zwecken, unter anderem der Risikoabsicherung und sozialen Funktionen. Produktionsziele werden dabei unterschiedlich stark von Farm- und Haushaltseigenschaften beeinflusst. Sahiwal-Rinder und ihre Kreuzungen werden in den Produktions- und Fruchtbarkeitsmerkmalen im Allgemeinen besser angesehen als EAZ. EAZ hingegen werden besser beurteilt in Bezug auf Adaptationsmerkmale. Die wichtigsten Merkmale für Pastoralisten sind eine hohe Milchleistung und ausgeprägte Körpergröße, hohe Reproduktionsleistung und eine gute Anpassung an die örtlichen Produktionsbedingungen. Leistungs- und Funktionsmerkmale sind wichtige Zuchtziele, die zum Erreichen verschiedener Produktionsziele beitragen. Sie formen daher die Basis für die Optimierung der Zuchtprogramme zur Sicherstellung Befriedigung der Bedürfnisse der Sahiwal-Rinderhalter.

Alle Zuchtprogramme, die in dieser Arbeit evaluiert wurden, zeigten einen positiven genetischen und ökonomischen Gewinn, wenn auch mit unterschiedlichen Gewinnspannen. Aufgrund der geringen Populationsgröße der Sahiwal-Rasse ist ein offenes Nukleus-Zuchtprogramm ökonomisch und genetisch optimal, denn es erlaubt einen effizienten Nutzen der vorhandenen genetischen Basis, die durch die zusätzliche Aufnahme diverser Zuchtbullen aus den Herden der Pastoralisten in die Nukleusherde erweitert wird. Kreuzungstiere werden jedoch weiterhin von Bedeutung sein, da sie die Vorteile beider Rassen (Sahiwal und EAZ) vereinen und so ein wichtiger Zwischenschritt im Zuchtprogramm sind. Es braucht allerdings geeignete logistische Strukturen für den Austausch von Bullen zwischen den Herden der Pastoralisten und den Nukleusfarmen, sowie für die ausgewogene Verteilung der Tiere, um den vollen Nutzen eines offenen Nukleuszuchtprogramms zu realisieren. Eine aktive Teilnahme der Produzenten und der relevanten Institutionen könnte außerdem die notwendigen Strukturen für die Implementierung und den reibungslosen Ablauf der Zuchtprogramme sicherstellen.

Curriculum Vitae

1. Personal information

Date of birth	2nd June 1976
Place of birth	Vihiga County
Nationality	Kenyan
Marital status	Married

2. Educational background

B.Sc. Agricultural extension	Egerton University, 2001.
M.Sc Animal Production	Egerton University, 2007.

3. Languages

Kiswahili	Written and Spoken
English	Written and Spoken
German	Basic

4. Research experience

April 2008 to date	PhD candidate, Institute of Animal Production in the Tropics and Subtropics, University of Hohenheim, Stuttgart, Germany.
June 2006 to date	Senior Research Scientist, Animal breeding and genetics, National Animal Husbandry Research Centre, Kenya Agricultural Research Institute.
2003 to 2006	Graduate assistant, department of Animal Sciences, Egerton University. Involved in various projects on database management and genetic evaluations of various livestock species In Kenya.

5. PUBLICATIONS

5.1 Submitted manuscripts

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Erklärung

Hiermit erkläre ich, daß ich die vorliegende Dissertation selbständig angefertigt habe in Übereinstimmumg mit den Vorgaben der Promotionsordnung. Alle verwendeten Quellen und Hilfsmittel sowie wörtlich oder inhaltlich übernommene Stellen sind als solche gekennzeichnet.

Die vorliegende Arbeit wurde bei keiner anderen Prüfungskommission als Dissertation zur Eröffnung eines Promotionsverfahrens eingereicht, weder in Teilen noch als ganze Arbeit.

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