ON – FARM EVALUATION OF PERFORMANCE OF SUKUMA AND MALYA GOATS AND THEIR CROSSES IN MASWA DISTRICT, TANZANIA

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EXTENDED ABSTRACT

Goat production is an integral component of small holder agriculture in Tanzania but farmers have been keeping indigenous goats which have poor genetic potential for growth and have small mature body size. Goat keepers can improve mature body size by crossing with improved breeds. However, in Tanzania there is paucity of information on performance of crossbreds in comparison to their parents. The effects of breed, sex, birth type, season of birth, year of birth and dam weight class on growth performance of kids born, twinning rate of dams, genetic parameters and finally farmers' preference on crossbreds and indigenous Sukuma goats were investigated. Sixty participating farmers were trained on basic meat goat management. Does of either breed i.e. Sukuma or Malya goats to be used in breeding program were dewormed and unwanted bucks in the herds were castrated. Breeding bucks were kept separately by chosen farmers. Dams were initially weighed then were mated to bucks in a such a way that Malya bucks were allowed to mate with Malya does and Sukuma does while Sukuma bucks were allowed to mate with Sukuma does only. Goats were allowed to free graze on natural vegetation within each household's farmland without supplementing them. Kids born of pure Malya, Sukuma and crossbred (Malya x Sukuma) goats were monitored for over two years. Data on growth traits from birth to one year and some reproduction traits were recorded. The results showed that all growth traits of Malya kids were highest, which were 2.37±0.03 kg for birth weight, 11.08±0.19 kg for weaning weight, 13.04±0.22 kg for 32 weeks' weight, 25.91±0.41 kg for yearling weight, 75.67±2.63 g/day for pre-weaning growth rate, 57.79±2.56 g/day for post-weaning growth rate and 63.29±1.70 g/day for birth to yearling growth rate followed by crossbred kids which had 2.18±0.05 kg, 7.22±0.26 kg, 9.60±0.30 kg, 21.99±0.55 kg, 47.90±2.94 g/day, 55.60±2.86 g/day and 53.23±1.90 g/day of corresponding growth traits. Sukuma kids were the least with 1.66±0.06 kg for birth weight, 5.13±0.34 kg for weaning weight, 7.53±0.38 kg for 32 weeks' weight, 14.22±0.71 kg for yearling weight, 30.19±3.81 g/day for pre-weaning growth rate, 35.45±3.70 g/day for post-weaning growth rate and 33.83±2.45 g/day for birth to yearling growth rate. Sex of the kids affected all weights at different ages at $P<0.001$ for birth weights, 32 weeks weight and yearling weight and at $P<0.01$ for weaning weight. Birth type statistically influenced birth weights, weaning weights, 32 weeks weight and pre-weaning growth rate. Single born kids (birth weights of 2.15±0.03 kg, weaning weights of 8.25±0.17 kg, 32 weeks weight of 10.54±0.20 kg and pre-weaning growth rate of 55.37±1.91 g/day) performed better than twin born kids with 1.99±0.04 kg, 7.37±0.22 kg, 9.58±0.25 kg and 47.14±2.28 g/day for corresponding growth traits, respectively. Weaning weights (8.81±0.23 kg), 32 weeks weights (10.62±0.26 kg), yearling weights (21.46±0.48 kg) and pre-weaning growth rate (59.79±2.32 kg) for kids born in year 2010 were higher compared to 6.81±0.19 kg, 9.50±0.21 kg, 19.96±0.39 kg and 42.71±1.98 g/day for kids born in year 2011 for respective growth traits. Pre-weaning growth rate was affected by sex of kids ($P<0.05$), birth type ($P<0.01$) and year of birth ($P<0.01$) but not season of birth ($P>0.05$). Overall twinning rate of does that kidded was 34.47% and was significantly influenced by breed in which Malya does had higher (46.48%) twinning rate than that of Sukuma does (20.49%). Genetic parameters were computed based on Malya sires. Heritability estimates for 32 weeks weight, yearling weight, pre-weaning growth rate, post-weaning growth rate and birth to yearling growth rate were low ranging from 0.11±0.02 to 0.18±0.02. However, moderately high heritability estimates were found for birth weight (0.43±0.04) and slightly lower for weaning weight (0.23±0.03). Genetic correlations between weights at different ages were positive and ranged from 0.17 between weaning weight and yearling weight to 0.49 between weaning weight and 32 weeks weight. Phenotypic correlations were low to moderate. Genetic correlations between growth rates at different stages were positive and negative ranging from -0.39 between pre-weaning gain and post-weaning gain to 0.90 between post-weaning weight gain and birth to yearling weight gain. Corresponding phenotypic correlations ranged from -0.38 between pre-weaning and post-weaning growth rate to 0.89 between post-weaning and birth to yearling growth rate. Heterosis from crossbred (Malya x Sukuma) goats were positive for birth weight (8.19%), yearling weight (9.59%), post-weaning weight gain (19.26%) and birth to yearling weight gain (9.62%). However, heterosis for weaning weight, 32 weeks weight and pre-weaning gain were negative. Farmers preferred crossbred goats as they performed better with many more good attributes (large body size, 94%; premium price, 92%; high growth rates, 80%) than bad attributes (prone to diseases, 16%; perform poorly in drought conditions, 8%) and they had superior body measurements (body length, 60.58±0.46 cm; heart girth, 77.59±0.58 cm; height at withers, 66.35±0.42 cm and body weight, 35.07±0.52 kg) compared to body measurements of Sukuma goats (body length, 49.58±0.42 cm; heart girth, 65.07±0.54 cm; height at withers, 56.74±0.39 cm and body weight, 21.56±0.48 kg). From the study, it was concluded that mature body size of Sukuma can be improved by crossing them with Malya goats under farm condition with extensive system of management. Pre-weaning weight gains are influenced by maternal environment. Moderate heritability for birth and weaning weight suggest that selection based on these traits will improve genetic progress. Most of growth traits are moderately correlated, so indirect selection can result into moderate correlated response. And lastly is that farmers appreciated the crossbreeding program.

DECLARATION

I, **Boaz Charles Chavala,** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work done within period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Boaz Charles Chavala — Date

MSc. Candidate

The above declaration is confirmed by:

Prof. George C. Kifaro — Date

(Supervisor)

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DEDICATIONS

This dissertation is dedicated to my lovely mother, Magreth Mohammed Chunga and my son Harris Boaz Chavala.

TABLE OF CONTENTS

EXTENDED ABSTRACT .... **ii**

DECLARATION .... **v**

COPYRIGHT .... **vi**

ACKNOWLEDGEMENTS .... **vii**

DEDICATIONS .... **viii**

TABLE OF CONTENTS .... **ix**

LIST OF TABLES .... **xii**

LIST OF FIGURES .... **xiv**

LIST OF APPENDICES .... **xv**

LIST OF ABBREVIATIONS AND ACRONYMS .... **xvi**

CHAPTER ONE **1**

1.0 INTRODUCTION **1**

1.1 Background 1

1.2 Problem Statement and Justification 2

1.3 Objectives 3

1.3.1 General objective 3

1.3.2 Specific objectives 4

1.4 Organization of the Dissertation 4

REFERENCES 5

CHAPTER TWO **7**

2.0 Growth performance of Malya and Sukuma goats and their crosses in Maswa District, Tanzania 7

2.1 Abstract 8

2.2 Introduction 9

2.3 Materials and Methods 10

2.4 Results 14

2.5 Discussion 22

2.6 Conclusions 28

REFERENCES 29

CHAPTER THREE 35

3.0 Genetic parameter estimates for growth traits of Malya goats and heterosis from crossbreds of Malya and Sukuma goats 35

3.1 Abstract 36

3.2 Introduction 37

3.3 Materials and Methods 38

3.4 Results 42

3.5 Discussion 45

3.6 Conclusions 49

REFERENCES 51

CHAPTER FOUR 56

4.0 Breed preference by farmers and morphometric characteristics of Sukuma and Malya x Sukuma goats in Maswa district, Tanzania 56

4.1 Abstract 57

4.2 Introduction 58

4.3 Materials and Methods 59

4.4 Results 62

4.5 Discussion 68

4.6 Conclusions 71

REFERENCES 72

CHAPTER FIVE 76

5.0 CONCLUSIONS AND RECOMMENDATIONS 76

5.1 Conclusions 76

5.2 Recommendations 77

APPENDICES 78

LIST OF TABLES

TABLES IN CHAPTER TWO

Table 2.1: Least squares means for effect of breed, sex, birth type, season and year of birth on weights at different ages 17

Table 2.2: Least squares means for effect of breed*sex interaction on weights at different ages 18

Table 2.3: Least squares means for effect of breed, sex, birth type, season, dam weight and year of birth on growth rates at different age intervals 20

Table 2.4: Least squares means for effect of breed*sex interaction on growth rates at different age intervals 21

Table 2.5: Influence of genotype, season and year of kidding on twinning rate 22

TABLES IN CHAPTER THREE

Table 3.1: Heterosis estimates for different growth traits in crossbred (Malya x Sukuma) goats 43

Table 3.2: Heritability estimates for different body weights and growth rates of Malya goats.. 43

Table 3.3: Estimates of genetic (below diagonal) and phenotypic (above diagonal) correlations between weights at different ages 44

Table 3.4: Estimates of genetic (below diagonal) and phenotypic (above diagonal) correlations between growth rates at different stages 44

TABLES IN CHAPTER FOUR

Table 4.1: Total, average and range of herd structure in 50 households 63

Table 4.2: Good and bad attributes for Sukuma and crossbred goats 65

Table 4.3: Least squares means for effect of breed, sex and breed*sex interaction on body length, heart girth, height at withers and body weight 67

LIST OF FIGURES

FIGURES IN CHAPTER TWO

Figure 2.1: The mating plan that was used in the breeding program 11

FIGURES IN CHAPTER THREE

Figure 3.1: The mating plan that was used in the breeding program 39

LIST OF APPENDICES

Appendix 1: Data handling 78

Appendix 2: Summary of ANOVA table for birth weights of the kids 79

Appendix 3: Summary of ANOVA table for weaning weights of the kids 79

Appendix 4: Summary of ANOVA table for 32 weeks weights 79

Appendix 5: Summary of ANOVA table for yearling weights 80

Appendix 6: Summary of ANOVA table for pre-weaning growth rate 80

Appendix 7: Summary of ANOVA table for post-weaning growth rate 80

Appendix 8: Summary of ANOVA table for birth to yearling growth rate 81

Appendix 9: Questionnaire on farmers' preference on crossbreds and Sukuma goats 81

Appendix 10: Summary of ANOVA table for body length of mature goats 83

Appendix 11: Summary of ANOVA table for heart girth of mature goats 83

Appendix 12: Summary of ANOVA table for height at withers of mature goats 84

Appendix 13: Summary of ANOVA table for body weights of mature goats 84

LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
BL	Body Length
BW	Body Weight
F1	First Filial generation
GLM	General Linear Model
HG	Heart Girth
HW	Height at Withers
i.e.	That is
Ma	Malya
MLFD	Ministry of Livestock and Fisheries Development
REML	Restricted Maximum-Likelihood
SAS	Statistical Analysis System
SEA	Small East African
Su	Sukuma
TALIRI	Tanzania Livestock Research Institute
URT	United Republic of Tanzania
VARCOMP	Variance Component

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Tanzania is one of the largest ruminant producers in Africa, ranked fourth in goat production after Nigeria, Sudan and Ethiopia (Kanani, 2009). On the basis of the latest estimates, Tanzania has 20.0 million goats of which 98% are indigenous (MLFD, 2019). The indigenous goats are bred mainly for meat and belong to the Small East African (SEA) goats. Other indigenous strains include Newala, Ujiji, Masai, Gogo, Sonjo, Pare and Sukuma (Das and Sendalo, 1990; Nguluma *et al.*, 2018).

Goat keeping forms an important and integral part of small holder agriculture in Tanzania and it is undertaken mainly by agro-pastoralists, pastoralists and farmers engaged in mixed farming. The value of goat keeping in Tanzania's economy has for a long time been acknowledged. Goats are known to be potential genetic resources for meat, milk, skin, fibre and manure, however in Tanzania goats are mainly kept for meat production. They are source of income and also play an important role in social cultural life such as ceremonies and religious festivals (Safari *et al.*, 2005). Apart from those important roles, goats have a highest off-take rate of 18%. Given the importance of indigenous goats in various communities and in the economy of Tanzania in general, there is a need to establish a national conservation and improvement program for the various populations of the SEA breed (Nguluma *et al.*, 2018).

Despite the significant contribution of goat farming in enhancing the food security of the poorest households, reducing the livelihood vulnerability and insecurity, the overall productivity of indigenous goats is low compared to exotic and or improved breeds in terms of meat and milk production (Safari *et al*., 2005; Chenyambuga and Lekule, 2014). Apart from their low genetic potential, other major constraints to small ruminant productivity in the traditional sector, especially in the semi-arid areas of Tanzania, include poor nutrition, animal diseases, and water shortage. Nevertheless, use of improved production technologies and interventions that would help in boosting performance of indigenous goats have been very low in Tanzania due to negligence of the small ruminant sub sector. As a result, this has lead to underuse the currently increasing potential of goat production. This experience could be the cause to its un proportional contribution (relative to their huge population) to the livelihood improvement and national economy at large.

In view of climatic change, coupled with increasing human population, goat rearing is becoming an important livestock enterprise especially in the villages. Goats have low water turnover rate, can feed on a wide spectrum of forages and are efficient in converting marginal feed resources thus are less vulnerable to climate change than other ruminants (Silanikove, 2000; Njombe and Msanga, 2011). In addition to their adaptability to various environments, goats require low initial investment cost, have rapid turnover rate (short reproductive cycle) and require small area of land to keep due to their comparatively small size thus deserve to be promoted in the course of increasing population accompanied by climate change.

1.2 Problem Statement and Justification

Shinyanga region is among the few regions in the country where farmers have been extensively involved in small ruminant development programs. They keep indigenous goats (Sukuma strain) which generally have low productivity for meat due to their poor genetic potential for growth and relatively small mature size which is lowering market value due to the tendency of buyers to set prices based on visual appraisal. This situation is a setback toward the improvement of farmers' income. In response to that, in 2010 Tanzania Livestock Research Institute (TALIRI) in collaboration with Lake Zone Research Development Fund initiated a community-based breeding program which aimed at improving the mature size of Sukuma strain by crossing with the Malya goats. The program aimed to improve living standards of the goat keepers by producing crossbreds of Malya x Sukuma goats which would have larger mature size and thus attract buyers to offer good prices. According to Mruttu *et al.* (2015), livestock genetic improvement programs in Tanzania would significantly help to reduce poverty by helping many farmers to upgrade their traditional subsistence livestock production systems to market-oriented, profit-making enterprises that directly improve livelihoods and reduce food insecurity.

Malya goats on the other hand are three way crosses (55% Kamorai, 30% Boer and 15% Indigenous), developed at Malya, Tanzania, in the late 1960s for both meat and milk production (Das and Sendalo, 1990). The Malya "composite" type of goats have a large size of the Kamorai, hardness of the indigenous (SEA) and meatiness of the Boer goats from South Africa (URT, 2003). Due to these advantages Malya goats have been used to improve other indigenous goats for meat production traits. Such attempts include crosses between Galla x Malya and Malya x Anglonubian (Das and Sendalo, 1990; Shirima, 2005). Therefore, this study was conducted to provide a baseline report on the performance of the Malya and Sukuma goats and their crosses in Maswa district, Tanzania.

1.3 Objectives

1.3.1 General objective

To evaluate the performance of Sukuma and Malya goats and their crosses.

1.3.2 Specific objectives

The specific objectives were:

i. To evaluate effects of genetic and non-genetic factors on body weights and growth rates of Malya goats, Sukuma goats and their crosses at different ages and on twinning rate of Malya and Sukuma does.

ii. To estimate genetic parameters (heritability, genetic and phenotypic correlations) for growth traits of Malya goats and heterosis from crossbreds of Malya and Sukuma goats.

iii. To assess farmers' preference on the performance of the two genetic groups i.e Sukuma and crossbred (Malya x Sukuma) goats.

1.4 Organization of the Dissertation

This dissertation is organized into five chapters. Chapter one consists of an introduction of the overall topic studied. Chapter two comprises paper one on "Growth performance of Malya and Sukuma goats and their crosses in Maswa district, Tanzania" while chapter three comprises paper two titled "Genetic parameter estimates for growth traits of Malya goats and heterosis from crossbreds of Malya and Sukuma goats". Chapter four covers paper three on "Breed preference by farmers and morphometric characteristics of Sukuma and Malya x Sukuma goats in Maswa district, Tanzania" and lastly chapter five presents the overall conclusions and recommendations of the entire study findings.

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CHAPTER TWO

2.0 Growth performance of Malya and Sukuma goats and their crosses in Maswa District, Tanzania

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2.1 Abstract

This study was conducted to evaluate growth performance of Malya goats, Sukuma goats and their crosses (Malya x Sukuma goats) in Maswa district. The study involved a total of 306 kids which were analyzed to get least squares means of birth weight, weaning weight, 32 weeks' weight, yearling weight, pre weaning growth rate, post weaning growth rate and birth to yearling growth rate. The overall least squares means for birth weight, weaning weight, 32 weeks' weight, yearling weight, pre weaning growth rate, post weaning growth rate and birth to yearling growth rate were 2.21±0.02 kg, 8.64±0.12 kg, 11.01±0.14 kg, 22.70±0.25 kg, 57.48±1.04 g/day, 55.40±1.02 g/day and 56.04±0.67 g/day, respectively. The overall twinning rate of all does which kidded during whole period of the study was 34.47%. Breed of the kids had a significant effect on all growth traits involved in this study. Further, sex, birth type, year of birth and dam weight had effect on weights at different ages and growth at different growth stages. Twinning rate was statistically ($p<0.001$) affected by breed of the does. Growth performance of Malya kids were the best followed by the crossbreds (Malya x Sukuma) while Sukuma kids were the last. Pre weaning growth rates of kids was largely dependant on maternal influence, due to the significant ($p<0.05$) effect of dam weight on pre weaning growth rate rather than on other growing stages.

Key words: Growth performance, crossbred goats, on farm, multiple births

2.2 Introduction

In developing countries livestock are an important and integral component of agriculture and they provide animal protein for the ever-growing human population. Small ruminants particularly goats are vital livestock for supporting food security and the economy of the farming communities in rural areas due to their high reproductive capacity and low initial investment (Braker *et al*., 2002; Deribe *et al*., 2015). Many rural people around the Lake Zone regions are involved in keeping goats. Most of them keep indigenous goats (Sukuma strain) which have very low productivity. Generally indigenous goats are characterized by small birth weights, low milk production, slow growth rates and small mature sizes (Ademosun, 1994). According to Nguluma *et al*. (2016) Sukuma and Sonjo goats are among of Tanzania indigenous strains which belong to Small East African goats having the lowest body measurements (mean body weight 22.3±0.50 kg, heart girth 65.6±0.52 cm, wither's height 55.8±0.43 cm, body length 48.4±0.52 cm for Sukuma and body weight 22.8±0.48 kg, heart girth 65.8±0.50 cm, wither's height 57.1±0.42 cm, body length 50.7±0.50 cm for Sonjo).

Malya goats is a breed with large size and meatiness characteristics (URT, 2003). The use of Malya goats for upgrading indigenous goats has been widely adopted as an alternative way of improving the low output in meat and milk. Despite efforts of improving indigenous goats, information on performance of crossbred progenies arising from crossing Malya and indigenous goats is generally lacking. This paper, therefore presents results of a crossbreeding program involving Malya goats and indigenous goats under on-farm conditions in Maswa district, Tanzania.

2.3 Materials and Methods

2.3.1 Description of study area

The study was conducted in Senani and Mwabayanda villages in Maswa district one of the five districts of Simiyu Region in Tanzania. The district is located on $03^{0}11'$S and $033^{0}47'$E latitude and longitude, respectively. The area has an average temperature of 22.1°C and receives an annual average of 878.8 mm of rainfall, raining from October to April

2.3.2 Experimental design and management of animals

Data used in this study were collected from a community based breeding program which was conducted by Tanzania Livestock Research Institute in Senani and Mwabayanda villages between 2008 and 2011. All goats were managed under uniform system which was extensive system throughout of the breeding program. Senani and Mwabayanda villages have the same type of land and vegetation, where the land is covered by grass and shrubs mainly of acacia species. The goats were released for free grazing on natural vegetation within each household's farmland each day at around 10:00 hrs in the morning to 17:00 hrs in the evening. No supplementary feeds were provided to these animals. Standard housing in a roofed house was provided as night shelters in each household.

Sixty (60) participating farmers were trained on basic goat husbandry practices like improved housing and group dynamics. Furthermore, two (2) farmers from each village were selected by their respective members to pursue a detailed training in basic animal health so as to provide services to his or her participating members within easy reach and at affordable cost. They were also meant to supplement technical services of the local extension staff. After the training session, does of either of the breed i.e. Sukuma or Malya goats to be used in breeding program were dewormed and weighed in each herd while unwanted bucks were castrated in each participating household. In addition, the two (2) farmers who were nominated to pursue a training in basic animal health from each village were also assigned to be bucks keepers and therefore they were responsible for managing the breeding bucks of either of the breeds (pure Malya or pure Sukuma bucks) to which all does involved in breeding program within a particular village were mated to produce pure Malya, pure Sukuma or their crosses (F1, Malya x Sukuma). The detailed mating plan is represented in Figure 2.1.

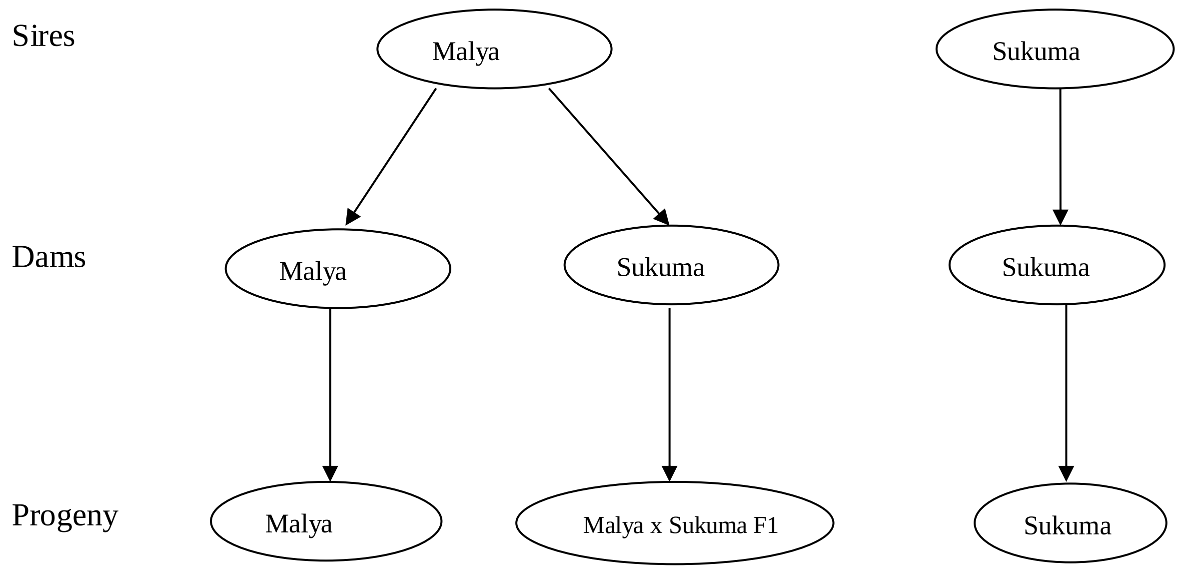

Figure 2.1: The mating plan that was used in the breeding program

2.3.3 Data collection

A sub-population of 60 flocks were monitored for over two years (2010-2011) for a number of production and reproduction traits. The current study reports on growth performance and twinning rate. Data collection for three genetic groups i.e Malya, Sukuma and crossbred goats (F1, Malya x Sukuma) was mainly on kid body weights, kidding dates, sex of the kid and type of birth. Birth weights were taken within 24 hours of kidding. Kid body weights and dates of weighing were used to calculate growth rates at different stages (Appendix 1). Further, kidding dates were used to establish the season of birth by months and year of kidding. Other body weights that were recorded included weights at 16 (weaning), 32 and 52 weeks of age. Data for animals involved in this study were those which had full records from birth to yearling age.

2.3.4 Data analysis

2.3.4.1 Effect of genotype, sex, birth type, season and year of birth on weights at different ages

Data on growth performance was analyzed using the General Linear Model Procedures of Statistical Analysis System (SAS, 2003). The dependent growth variables were birth weight, weaning weight (16 weeks), 32 weeks weight and one-year weight (52 weeks). The Least-Squares Means (LSM) and Standard Errors (SE) for growth traits in each level of the fixed factors i.e. genetic group, sex, birth type, season and year of birth were estimated.

The following model was used for statistical analysis:

$$Y_{ijklm} = \mu + S_i + G_j + T_k + Y_l + B_m + (G*S)_{ij} + b(X_{ijklm} - \bar{X}) + \varepsilon_{ijklm} \quad \text{(Equation 2.1)}$$

Where:

Y_{ijklm} = Observation (weight) from a kid of ith sex, jth genotype, kth season, lth year and mth type of birth

μ = Overall mean

S_i = Effect of ith sex (1=Male, 2=Female)

G_j = Effect jth genotype (1=Malya, 2=Sukuma, 3=F1 crossbreds)

T_k= Effect of kth season of birth (1=Wet, 2=Dry)

Y_l = Effect of lth year of birth (1=2010, 2=2011)

B_m = Effect of mth birth type (1 = Single, 2 = Twin)

$(G*S)_{ij}$ = Effect of interaction between i^{th} sex and j^{th} genotype

b = Regression of kid weight on dam weight

X_{ijklm} = Weight of individual dam

$\overline{X}$ = Mean of dam weights

ε_{ijklm} = Random error term

2.3.4.2 Effect of sex, genotype, birth type, dam weight, season of kidding and year of birth on growth rate during selected age intervals

Analyses were carried out to evaluate the effects of genetic group, sex, birth type, dam weight, season of kidding and year of kidding on growth rates at different age intervals i.e Birth to weaning, weaning to yearling and birth to yearling using the following model:

$$Y_{ijklmn} = \mu + S_i + G_j + B_k + DW_l + T_m + Y_n + (S*G)_{ij} + b(X_{ijklmn} - \overline{X}) + \varepsilon_{ijklmn} \quad \text{(Equation 2.2)}$$

Where:

Y_{ijklmn} = Observation (growth rate) from a kid of i^{th} sex, j^{th} genotype, k^{th} birth type, l^{th} dam weight, m^{th} season and n^{th} year

μ = Overall mean

S_i = Effect of i^{th} sex (1=Male, 2=Female)

G_j = Effect j^{th} genotype (1=Malya, 2=Sukuma, 3=F1 crossbreds)

B_k = Effect of k^{th} birth type (1 = Single, 2 = Twin)

DW_l = Effect l^{th} Dam weight (1=18-22, 2=23-27, 3=28-32, 4=>33Kg)

T_m = Effect of m^{th} season of kidding (1=Wet, 2=Dry)

Y_n = Effect of n^{th} year of kidding (1=2010, 2=2011)

$(S*G)_{ij}$ =Effect of interaction between i^{th} sex and j^{th} genotype

b = Regression of kid growth rate on birth weight

X_{ijklmn} = Birth weight of individual kid

$\overline{X}$ = Mean of birth weights

ε_{ijklmn} = Random error term

2.3.4.3 Influence of genotype, season and year of kidding on twinning rate

Statistical analyses were carried out to evaluate effects of genetic group, season and year of kidding on twinning rate using SAS procedure of frequency and chi – square.

Twinning rate was derived as:

$$\text{Twinning rate} = \frac{\text{Number of does kidded twins}}{\text{Total number of does kidded}} \text{ x } 100 \qquad \text{(Equation 2.3)}$$

2.4 Results

2.4.1 Weights of Malya, Sukuma goats and their crosses at different ages

Mean live weights of kids from birth to 52 weeks of age by genotype, sex, birth type, season and year are shown in Tables 2.1 and 2.2.

2.4.1.1 Birth weights

The overall mean birth weight of kids was 2.21±0.02 kg. There were significant (P<0.001) differences in birth weights between breeds and between (P<0.01) sexes (Appendix 2). The mean birth weight for Malya goats was higher (2.37±0.03 kg) than that of crossbreds (Malya x Sukuma) (2.18±0.05 kg) and Sukuma (1.66±0.06 kg). Average birth weight for male kids (2.16±0.03 kg) was higher than female kids (1.99±0.03 kg). But also there were significant (P<0.01) differences between birth types on birth weights (Appendix 2). Mean birth weight for kids born single was higher (2.15±0.03 kg) than those born multiple (1.99±0.04 kg). However, there were no significant (P>0.05) differences in birth weights between years, seasons and interaction between breed and sex (Appendix 2).

2.4.1.2 Weaning weights (kg) at 16 weeks of age

At weaning, kids had an average weight of 8.64±0.12 kg. Weaning weight differed significantly ($P<0.001$) between breeds, birth types and years of kidding (Appendix 3). Malya kids had higher weaning weight (11.08±0.19 kg) followed by crossbreds (7.22±0.26 kg) while Sukuma kids (5.13±0.34 kg) had the lowest. On the other hand, kids born single had higher weaning weight (8.25±0.17 kg) compared to kids born multiple (7.37±0.22 kg) and also kids born during year 2010 had higher mean weaning weight (8.81±0.23 kg) than those born during year 2011 (6.81±0.19 kg). Weaning weights differed significantly ($P<0.05$) between sexes (Appendix 3), where male kids had higher weaning weight (8.17±0.21 kg) than female kids (7.45±0.20 kg). There was a difference in weaning weight between seasons, however the difference was not significant ($P>0.05$). Further, interaction (breed*sex) did not influence significantly ($P>0.05$) weaning weights of the weaned kids (Appendix 3).

2.4.1.3 Weights at 32 weeks of age

The results show that overall mean for weights at 32 weeks of age was 11.01±0.14 kg. Significant differences on weights at 32 weeks of age were found to be between breeds, sexes and years of birth ($P<0.001$) and also between birth types ($P<0.01$) (Appendix 4). At 32 weeks of age Malya goats were heavier (13.04±0.22 kg) than that of crossbreds (Malya x Sukuma) (9.60±0.30 kg) and that of Sukuma (7.53±0.38 kg). Similarly, at this age males, were heavier with 10.73±0.24 kg live body weight than that of females (9.38±0.23 kg). Also single-born kids were found to be heavier (10.54±0.20 kg) than multiple born kids (9.58±0.25 kg). Kids born in year 2010 were heavier (10.62±0.26 kg) than those born in year 2011 (9.50±0.21 kg). The interaction between breed and sex was found to be significant ($P<0.01$) (Appendix 4) with the mean weight for Malya males being (14.05±0.29 kg) higher than Malya females (12.04±0.28 kg) and crossbred males had body weights of 9.63±0.40 kg being heavier only by 1.12 kg than that of crossbred females, and lastly Sukuma males were heavier (9.57±0.39 kg) than Sukuma females (6.55±0.49 kg).

2.4.1.4 Yearling weights at 52 weeks of age

The average weight of yearling goats was 22.70±0.25 kg. Significant ($P<0.001$) differences between breeds and sexes were observed on yearling live body weight (Appendix 5). Malya goats had higher body weight (25.91±0.41 kg) than crossbreds (21.99±0.55 kg) and Sukuma goats (14.22±0.71 kg). Male yearling goats had higher (21.719±0.45 kg) weights than female yearling goats (19.71±0.42 kg). Also year of birth had significant influence ($P<0.05$) on yearling weights (Appendix 5). Goats born in year 2010 had higher mean body weight (21.46±0.48 kg) compared to goats born in year 2011 (19.96±0.39 kg). However, birth type, season of birth and interaction (breed*sex) were found to have in-significant influence ($P>0.05$) on yearling weights (Appendix 5).

Table 2.1: Least squares means for effect of breed, sex, birth type, season and year of birth on weights at different ages

Source	N	Birth weights(kg)	Weaning weights(kg)	32weeks weight(kg)	52 weeks weight(kg)
Overall mean		2.21±0.02	8.64±0.12	11.01±0.14	22.70±0.25
Breed		***	***	***	***
Malya	165	2.37±0.03[a]	11.08±0.19[a]	13.04±0.22[a]	25.91±0.41[a]
Crossbred	90	2.18±0.05[b]	7.22±0.26[b]	9.60±0.30[b]	21.99±0.55[b]
Sukuma	51	1.66±0.06[c]	5.13±0.34[c]	7.53±0.38[c]	14.22±0.71[c]
Sex		**	*	***	***
Males	148	2.16±0.03[a]	8.17±0.21[a]	10.73±0.24[a]	21.71±0.45[a]
Females	158	1.99±0.03[b]	7.45±0.20[b]	9.38±0.23[b]	19.71±0.42[b]
Birth type		**	***	**	NS
Twins	133	1.99±0.04[a]	7.37±0.22[a]	9.58±0.25[a]	20.58±0.47
Singles	173	2.15±0.03[b]	8.25±0.17[b]	10.54±0.20[b]	20.84±0.36
Season		NS	NS	NS	NS
Dry	104	2.03±0.04	8.08±0.23	10.04±0.26	20.36±0.48
Wet	202	2.11±0.03	7.54±0.18	10.08±0.21	21.06±0.39
Year		NS	***	***	*
2010	111	2.08±0.04	8.81±0.23[a]	10.62±0.26[a]	21.46±0.48[a]
2011	195	2.06±0.03	6.81±0.19[b]	9.50±0.21[b]	19.96±0.39[b]

***P<0.001; **P<0.01; *P<0.05 [a,b,c] Means with different letters within same column and factor are significantly different at P<0.05; N: No. of observations; NS: Not significant.

Table 2.2: Least squares means for effect of breed*sex interaction on weights at different ages

Breed Sex	**N**	**Birth weight**	**Weaning weight**	**Weight at 32 weeks**	**Weight at 52 weeks**
		*	***	***	**
Malya male	82	2.44±0.05[a]	11.66±0.26[a]	14.05±0.29[a]	26.91±0.55[a]
Malya female	83	2.29±0.04[b]	10.50±0.25[b]	12.04±0.28[b]	24.92±0.52[b]
Combined mean	165	2.37±0.03	11.08±0.19	13.04±0.22	25.91±0.41
		**	NS	NS	NS
Crossbred male	43	2.31±0.06[a]	7.19±0.35	9.63±0.40	22.68±0.74
Crossbred female	47	2.05±0.06[b]	7.24±0.34	9.57±0.39	21.30±0.72
Combined mean	90	2.18±0.05	7.22±0.26	9.60±0.30	21.99±0.55
		NS	NS	**	*
Sukuma male	23	1.71±0.09	5.65±0.48	8.51±0.54[a]	15.55±1.00[a]
Sukuma female	28	1.61±0.08	4.62±0.43	6.55±0.49[b]	12.90±0.90[b]
Combined mean	51	1.66±0.06	5.13±0.34	7.53±0.38	14.22±0.71

***P<0.001; **P<0.01; *P<0.05 [a,b,c]Means with different letters within same column and factor are significantly different at P<0.05; N: No. of observations; NS: Not significant.

2.4.2 Growth rates for Malya, Sukuma and crossbred (Malya x Sukuma) at different age intervals

Growth rates from birth to weaning (16 weeks of age), weaning to yearling and birth to yearling (52 weeks of age) are shown in Table 2.3 and 2.4.

2.4.2.1 Growth rate from birth to weaning

The growth rate from birth to weaning differed significantly (P<0.001) between breeds, birth type and years of birth (Appendix 6). Malya kids had higher growth rate (75.67±2.63 g/day) compared to crossbreds and Sukuma kids which had growth rates of 47.90±2.94 and 30.19±3.81 g/day, respectively. From birth to weaning single-born kids exhibited higher growth (55.37±1.91 g/day) than the multiples (47.14±2.28 g/day) while kids born in year 2010 had higher growth rate (59.79±2.32 g/day) than those born in year 2011 (42.71±1.98 g/day). Effects of kid sex, dam weight and breed x sex interaction were found to be significant (P<0.05) (Appendix 6). Male kids grew faster (54.30±2.19 g/day) than female kids (48.21±2.11 g/day). Kids from dams with higher body weight (>33 kg) grew faster (59±5.55 g/day) than kids from lighter dams. At the same time Malya male kids showed to be growing faster (81.10±3.08 g/day) than Malya female kids (70.24±2.93 g/day), but these rates were higher than those for crossbred male kids, crossbred female kids, Sukuma male kids and Sukuma female kids, which had rates of 48.69±3.53, 47.11±3.58, 34.70±4.77 and 25.69±4.43 g/day, respectively. The effects of season of birth was not statistically significant (P>0.05) as shown in Appendix 6.

2.4.2.2 Growth rate from weaning to yearling

The overall least-squares mean of growth rate from weaning to yearling was 55.40 g/day as shown in Table 2.3. Breeds and seasons of birth had significant effects (P<0.001) and (P<0.05), respectively on growth rate from weaning to yearling (Appendix 7). However, sex of kids, birth type, year of birth, dam weights and breed x sex interaction were not important (P>0.05) sources of variation on post-weaning growth rate (Appendix 7).

Table 2.3: Least squares means for effect of breed, sex, birth type, season, dam weight and year of birth on growth rates at different age intervals

Factor	N	Pre-weaning growth rate (g/day)	Post-weaning growth rate(g/day)	Birth to yearling growth rate(g/day)
Overall mean	306	57.48±1.04	55.40±1.02	56.04±0.67
Breed		***	***	***
Malya	165	75.67±2.63[a]	57.79±2.56[a]	63.29±1.70[a]
Crossbred	90	47.90±2.94[b]	55.60±2.86[a]	53.23±1.90[b]
Sukuma	51	30.19±3.81[c]	35.45±3.70[b]	33.83±2.45[c]
Sex		*	NS	**
Males	148	54.30±2.19[a]	51.58±2.13	52.42±1.41[a]
Females	158	48.21±2.11[b]	47.65±2.05	47.82±1.36[b]
Birth type		***	NS	NS
Twins	133	47.14±2.28[b]	51.34±2.22	50.05±1.47
Singles	173	55.37±1.91[a]	47.89±1.86	50.19±1.23
Season		NS	*	NS
Dry	104	53.22±2.35	47.10±2.29[b]	48.99±1.52
Wet	202	49.28±1.93	52.13±1.88[a]	51.25±1.25
Dam weight(kg)		*	NS	NS
18 – 22	53	42.74±4.36[c]	55.74±4.25	51.74±2.81
23 – 27	153	52.79±1.68[ab]	50.77±1.64	51.39±1.08
28 – 32	75	49.90±3.20[cb]	50.51±3.11	50.32±2.06
> 33	25	59.58±5.55[a]	41.45±5.40	47.03±3.58
Year		***	NS	NS
2010	111	59.79±2.32[a]	47.65±2.26	51.39±1.50
2011	195	42.71±1.98[b]	51.58±1.93	48.85±1.28

***P<0.001; **P<0.01; *P<0.05 [a,b,c]Means with different letters within same column and factor are significantly different at P<0.05; N : No. of observations; NS : Not significant.

2.4.2.3 Growth rate from birth to yearling

Significant differences between breeds (P<0.001) and sexes (P<0.01) were observed on growth rate from birth to one year of age (Appendix 8). Malya goats had higher growth rate (63.29±1.70 g/day) than crossbred (53.23±1.90 g/day) and Sukuma goats (33.83±2.45 g/day) whereas male goats had higher growth rate (52.42±1.41 g/day) than female goats (47.82±1.36 g/day). As shown in Appendix 8, breed x sex interaction were found significant (P<0.05), Malya male goats showed to be growing faster (65.50±1.98 g/day) than Malya female goats (61.09±1.89 g/day), but these rates were higher than those for crossbred male goats, crossbred female goats, Sukuma male goats and Sukuma female goats, which had growth rates of 54.50±2.31, 51.97±2.28, 37.26±3.07 and 30.40±2.86 g/day, respectively (Table 2.4). However, there were no significant (P>0.05) differences between birth types, seasons, years of birth and dam weights (Appendix 8).

Table 2.4: Least squares means for effect of breed*sex interaction on growth rates at different age intervals

Breed	Sex	N	Pre-weaning growth rate(g/day)	Post-weaning growth rate(g/day)	Birth to yearling growth rate(g/day)
			***	NS	*
Malya	males	82	81.10±3.08[a]	58.56±3.00	65.50±1.98[a]
Malya	females	83	70.24±2.93[b]	57.03±2.85	61.09±1.89[b]
Combined mean		165	75.67±2.63	57.79±2.56	63.29±1.70
			NS	NS	NS
Crossbred	males	43	47.11±3.58	57.78±3.49	54.50±2.31
Crossbred	females	47	48.69±3.53	53.42±3.44	51.97±2.28
Combined mean		90	47.90±2.94	55.60±2.86	53.23±1.90
			NS	NS	*
Sukuma	males	23	34.70±4.77	38.40±4.64	37.26±3.07[a]
Sukuma	females	28	25.69±4.43	32.50±4.31	30.40±2.86[b]
Combined mean		51	30.19±3.81	35.45±3.70	33.83±2.45

***P<0.001; *P<0.05; [a,b]Means with different letters within same column and factor are significantly different at P<0.05; N: No. of observations; NS: Not significant.

2.4.3 Influence of genotype, season and year of kidding on twinning rate

Birth types of does by genotype, season and year are shown in Table 2.5. Results show that 264 does kidded during the period of 2010 and 2011. About 53.52% of Malya does produced single kids, 46.48% of Malya does gave birth to twin kids, 79.51% of Sukuma does delivered single kids and 20.49% of Sukuma does kidded twin kids. The overall twinning rate of does was 34.47%. There was significant (P<0.001) difference in twinning rates between breeds. The twinning rate for Malya does was higher (46.48%) than that of

Sukuma does (20.49%). Differences between seasons of kidding and years of kidding were not important (P>0.05) sources of variation on twinning rates.

Table 2.5: Influence of genotype, season and year of kidding on twinning rate

Classes	N	Single births	Twin births		
Overall	264	173(65.53)	91(34.47)	χ^2	**P – value**
Breed of does				19.61	0.001
Malya	142	76(53.52)	66(46.48)		
Sukuma	122	97(79.51)	25(20.49)		
Season of kidding				1.41	NS
Dry	94	66(70.22)	28(29.78)		
Wet	170	107(62.94)	63(37.06)		
Year of kidding				0.69	NS
2010	96	66(68.75)	30(31.25)		
2011	168	107(63.69)	61(36.31)		

Figures in the blankets indicate percentages.
NS: Not significant

2.5 Discussion

2.5.1 Birth weights

The mean birth weight of Malya goats was slightly lower than 2.90 kg and 3.11±0.09 kg as reported by Das and Sendalo (1990) and Hyera *et al*. (2018), respectively for the same breed reared on station. This was probably because of difference in management systems practiced. In this study an extensive system was used with no concentrate supplementation. On the other hand, birth weights for crossbred goats (Malya x Sukuma) were similar to 2.01±0.05 kg for crossbred (Teso x Boer) goats as observed by Ssewannyana *et al*. (2004). However, the mean birth weight for crossbreds in the current study was slightly lower than 2.78±0.03 kg and 2.67±0.05 kg of crossbreds with 50% and 75% blood level (Boer x Central Highland goats of Ethiopia), respectively as reported by Deribe *et al*. (2015). The mean birth weight for Sukuma goats was nearly similar to

1.54±0.07 kg of pure Teso goats from Uganda (Ssewannyana *et al*., 2004) and 1.50 kg for Mid Rift Valley kids (Tucho *et al*., 2000). The value was lower than 1.91±0.03 kg of Arsi-Bale goats of Ethiopia (Bedhane *et al*., 2013), 1.91±0.04 kg of Abergele goats (Deribe and Taye, 2013a) and 2.98±0.21 kg of SEA goats (Ahuya *et al*., 2002). This may be due to differences in genetic makeup and mature size between Sukuma goats and other indigenous goats. In addition, differences in management and agro-ecology between the current study and other studies may have contributed to the disparities. The difference in birth weight between single born kids and those born multiple might be due to presence of intra-uterine nutritional and space competition between kids born multiple. This result is in conformity with what was reported by Deribe and Taye (2013a), Ahuya *et al*. (2009), Mohammadi *et al*. (2012) and Deribe *et al*. (2015). However, effect of birth type in this study is contrary to the result reported by Hyera *et al*. (2018) who found insignificant effect. Effect of sex on birth weight with male kids being heavier than female kids is in conformity to reports of various authors for various breeds of goats such as Ssewannyana *et al*. (2004), Duricic *et al*. (2012), Sankaran *et al*. (2012) and Deribe *et al*. (2015).

2.5.2 Weaning weights (kg) at 16 weeks of age

The weaning weight for Malya goats was slightly lower than 13.4 kg reported by Das and Sendalo (1990) for the same breed. It was slightly higher than 10.2±0.29 kg (Hyera *et al*., 2018) for the same breed. Mean weaning weight for crossbreds was comparable to 7.16±0.46 kg for Boer x Mubende but lower than 10.72±0.52 kg for Boer x Teso (Ssewannyana *et al*., 2004). On the other hand, the weaning weight of Sukuma goats was lower than 6.65±0.19 kg for Arsi-Bale goats of Ethiopia (Bedhane *et al*., 2013), lower than 8.27±0.28 kg for Mubende goats and 6.99±0.37 kg for Teso goats of Uganda (Ssewannyana *et al*., 2004) and lower than 7.51±0.32 kg for Pare White and 7.31±0.35 kg for Sonjo Red (Hyera *et al*., 2018). The low weaning weight of Sukuma goats might be due to the small body size of Sukuma goats which has an implication on maternal effects and thus produce low amount of milk for their young resulting in weaning lighter kids. Further, the management system of rearing goats used might have influenced weaning weights of kids. After birth, single born kids had an advantage over twins born kids as they did not compete for the milk from their dams. Thus, they were growing faster than those born multiple. Birth type effect is similar to findings in the literature (Dadi *et al*., 2008; Deribe *et al*., 2015). Male kids were also heavier at weaning than females. This may be due to sexual dimorphism. This result concurs with what is reported in the literature (Das and Sendalo, 1990; Dadi *et al*., 2008; Mioč *et al*., 2011; Mahammed *et al*., 2018; Nugroho *et al*., 2018). Weaning weights for kids born in 2011 were lower than those kids born in 2010. This might be related to the nutrition of their dams at kidding which in turn increased available milk for kids to suckle, and thus increased growth of kids. Dadi *et al*. (2008), Deribe *et al*. (2015) and Mahammed *et al*. (2018) reported similar effect of year on weaning weight which was related to the availability of grass for kids to eat.

2.5.3 Weights at 32 weeks of age

At 32 weeks of age, Malya goats were heavier followed by crossbred goats and Sukuma goats were the last. This is due to the good genetic potential of Malya goats for growth which in turn benefits the crossbreds by exploiting heterosis. It has not been possible to find literature of goats’ weights at 32 weeks of age because researchers have not preferred to measure weight at this age, thus weight at 36 weeks of age have been used for comparison. The values of weights at 32 weeks of age for all genetic groups in the current study were lower than 15.09±0.26 kg for Tellicherry goats weighed at 36 weeks of age (Thiruvenkadan *et al*., 2009). At 32 weeks of age, single born goats were heavier than multiple born goats. This might be due to advantage of higher weaning weight of single born kids than multiple born kids whereby single born kids had lower weaning stress compared to multiple born kids (Deribe *et al.*, 2015; Ssewannyana *et al.*, 2004). The variation in weights at this age due to year of birth can be explained by variations in amount of annual rainfall which influenced availability of pasture for does and kids after weaning. Similar results were observed by Das *et al*. (1994) and Deribe *et al*. (2015).

2.5.4 Yearling weight at 52 weeks of age

The yearling weight of Malya goats in this study was higher than 16.42±0.35 kg and 19.9 kg yearling weights of the same breed as reported by Das *et al.* (1994) and Das and Sendalo (1990), respectively. On the other hand, yearling weight for crossbreds was slightly higher than 19.60 kg for Malya x Galla goats and 20.40 kg for Kamorai x indigenous goats (Das and Sendalo, 1990). Mean yearling weight for Sukuma goats was comparable with 14.15±1.20 kg yearling weight of Abergele goats (Deribe and Taye, 2013a) and 13.96±3.04 kg yearling weight of Mubende goats reported by Oluka *et al*. (2004). Male goats were heavier than female goats due to difference in the sex hormones which influence growth of the skeletal muscles during postnatal period. Ballal *et al*. (2008) and Deribe and Taye (2013b) reported similar differences.

2.5.5 Pre-weaning growth rates

Pre-weaning growth rates differed between breeds. Malya goats grew faster than crossbreds and Sukuma goats. The pre weaning growth rate of Malya goats was lower than 94.30 g/day for the same breed reported by Das and Sendalo (1990). Pre-weaning growth rate of crossbreds was comparable to 47.15±3.83 g/day for Boer x Mubende crossbred goats (Ssewannyana *et al.*, 2004). In addition, pre-weaning growth rate of crossbreds was lower than 88.70 g/day for Malya x Galla and 82.70 g/day for Kamorai x indigenous crossbred goats (Das and Sendalo,1990) and lower than 78.67 g/day for Boer x Central highland goats of Ethiopia (Deribe *et al.*, 2015). On the other hand, the pre-weaning growth rate of Sukuma goats was lower than 47.15±3.28 g/day for indigenous Teso goats and 55.30±16.43 g/day for indigenous Mubende goats reported by Ssewannyana *et al*. (2004) and Oluka *et al*. (2004), respectively. The significantly higher pre-weaning growth rate of male kids than females in this study is similar to that reported by Zahraddeen (2008), Mohammadi *et al*. (2012) and Deribe and Taye (2013b). The influence of birth type on pre weaning growth rate concurs with results of Thiruvenkadan *et al*. (2009) and Deribe and Taye (2013b). The phenomenon that single kids grow faster than multiples is commonly observed mainly due to competition for the limited supply of milk per kid from their dams. Pre weaning growth rate was affected by year of kidding and dam weights. Dam weight effect on pre weaning growth rate is associated to maternal influence. Lighter dams produced lighter kids which had consequently low post-natal growth rates. One of the reasons is that such dams produce low amount of milk for their young. The effect of year of kidding might be due to dam nutrition which in turn was influenced by availability of green pastures. This result concurs with literature (Ssewannyana *et al*., 2004; Thiruvenkadan *et al*., 2009; Deribe *et al*., 2015).

2.5.6 Post-weaning growth rate

Post-weaning growth rate of Malya goats in the current study was nearly similar to 59.00±1.50 g/day of the same breed reported by Das *et al*. (1994). However, post-weaning growth rate of crossbred goats was higher than 34.94±1.76 g/day for Boer x Central Highland goats (Deribe *et al*., 2015). On the other hand, post weaning growth rate of Sukuma goats was higher than 20.14±0.68 g/day for West African Dwarf goats and 29.30±4.32 g/day for Abergele goats in Sekota district reported by Birteeb *et al*. (2015) and Deribe and Taye (2013a), respectively. Growth rate for Sukuma goats was lower than 42.80±2.90 g/day for Central highland goats in Sekota district (Deribe and Taye, 2013b). This might be due to differences between breeds and management of goats from other studies. The higher post-weaning growth rate among wet season born kids compared to dry season kids was influenced by the availability of more nutritious feeds in that season.

2.5.7 Birth to yearling growth rate

Birth to yearling growth rate differed among the breeds, whereby Malya goats grew faster than crossbreds and Sukuma goats in that order. Malya goats had higher birth to yearling growth rate than 46±10 g/day for same breed over two decades ago (Das *et al.*, 1994). Sex had a highly significant effect on growth rate for birth to yearling. During this stage of growth, the growth rate was higher for male goats compared to female goats. This is due to differences in the sex hormones which influence the skeletal growth and fetal development during pre and postnatal periods and subsequently affect the growth rate which attributed to the differences in the live body weights at birth and the following growth stages of age. There has been a paucity of matched literatures for birth to yearling growth rate for different breeds in the tropics.

2.5.8 Twinning rate

Twinning rates for Malya does and Sukuma does were high and moderate respectively. South African Boer goats had a higher (75.51%) twinning rate (Campbell, 2003) than that of Malya does in the current study. However, occurrence twinning among Malya goats was comparable to 40.9% for the same breed, but higher than 34.3% for Galla x Malya and similar to 43.5% for Kamorai x SEA as reported by Das and Sendalo (1990). Twinning rate of Sukuma does was comparable to 24.59% of Mid Rift Valley goats (Tucho *et al.*, 2000) and 25% of Mashona goats from Zimbabwe (Kusina *et al.*, 2001). However, it was higher than 10.52%±1.98 of Osmanabadi goats as reported by Sahare *et al.* (2009). The reason for the difference between Malya and Sukuma does is their difference in genetic makeup. Malya does showed higher multiple births than Sukuma does despite both being managed extensively. Therefore, Malya goats are more profitable than Sukuma goats, and can pass on this trait to their crossbred off springs. According to Sahare *et al*. (2009) twinning ability is not only the most important parameter in reproductive efficiency but also it is a measure of productivity and profit in goat farming.

2.6 Conclusions

Least squares means for birth weight, weaning weight, 32 weeks weight, yearling weight, pre weaning growth rate, post weaning growth rate and birth to yearling growth rate are higher for Malya goats, followed by crossbreds and Sukuma goats are the last. This means that Malya goats are an appropriate breed for improving indigenous goats since the performance of crossbred goats is superior to that of Sukuma goats. Effect of birth type on birth weight, weaning weight, 32 weeks weight and pre weaning growth rate was more pronounced than on yearling weight and post weaning growth rate. Further, effect of year of birth significantly influenced weaning weight, 32 weeks weight and yearling weight.

The twinning rate of does observed in the current study was moderate and was neither affected by season of birth nor by year of birth. However, breed/genetic group was the only factor that affected twinning rate. Malya goats had shown to have higher twinning rate than Sukuma goats.

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CHAPTER THREE

3.0 Genetic parameter estimates for growth traits of Malya goats and heterosis from crossbreds of Malya and Sukuma goats

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3.1 Abstract

Growth data for parent breeds and crossbred offsprings were used to estimate heterosis. Positive heterosis was observed for birth weight (8.19%), yearling weight (9.59%), post-weaning growth rate (19.26%) and birth to yearling growth rate (9.62%) while negative heterosis was found for weaning weight (-10.92%), 32 weeks weight (-6.66%) and pre-weaning growth rate (-9.50%). In addition, growth data (birth to 52 weeks of age) of 255 kids were analyzed for genetic parameter estimates. Heritability estimates from sire variance components were 0.43±0.04 for birth weight, 0.23±0.03 for weaning weight, 0.11±0.02 for 32 weeks weight, 0.18±0.02 for yearling weight, 0.18±0.02 for pre-weaning growth rate, 0.17±0.02 for post-weaning growth rate and 0.17±0.02 for birth to yearling growth rate. Genetic correlations between body weights ranged from 0.17±0.06 to 0.49±0.05 while the corresponding phenotypic correlations ranged from 0.10 to 0.61. Genetic correlations between growth rates at different stages ranged from -0.39±0.06 to 0.90±0.03 while the phenotypic correlations ranged from -0.38 to 0.89. Negative correlations were found between pre-weaning growth rate and post-weaning growth rate (genetic: -0.39, phenotypic: -0.38). Genetic and phenotypic correlations between body weights at different ages, pre-weaning growth rate vs birth to yearling growth rate and post-weaning growth rate vs birth to yearling growth rate were all positive. From the results on heterosis, it can be concluded that birth weight, yearling weight, post-weaning growth traits benefited from positive heterosis. Moderate heritability estimates for birth weight and weaning weight means that these traits could respond well to selection.

Key words: Heritability, phenotypic, genetic, correlation, heterosis, growth.

3.2 Introduction

Malya goats are a dual purpose breed also known as Blended goats (URT, 2011). They are a composite breed formed by crossing three breeds namely Kamorai, Boer and indigenous goats i.e Small East African (SEA) goats (Das *et al*., 1994). It has a large body size of the Kamorai, higher multiple births, fast growth rate, good carcass quality of the Boer goats from South Africa and sound adaptation to the semi-arid tropical climate from indigenous (SEA) goats (URT, 2003; Shirima, 2005). It was developed as an alternative breed to SEA goats which generally have poor genetic potential for growth and mature body size. It is also known that goats are a tool for poverty alleviation (Faruque *et al*., 2010). This is due to their higher reproductive prolificacy (i.e. twinning ability and short gestation period), small size and can easily be disposed compared to the larger ruminants. Genetic parameters are important because genetic improvement is largely dependent on the heritability of the trait and its genetic relationship with other traits of economic importance upon which some selection pressure may be applied. Information on heritabilities is essential for planning efficient breeding programs, and for predicting response to selection (Falconer, 1989). A genetic correlation is the correlation between an animal's genetic value for one trait and the same animal's genetic value for the other trait. Phenotypic correlation, on the other hand, is the association between records of two traits on the same animal measured at different times or same time. Genetic correlation between different traits is important in indirect selection to estimate correlated response to selection while phenotypic correlation can be used to predict full records from part records or lifetime performance from early life records. This paper presents results of genetic parameters i.e. heritability, genetic and phenotypic correlations for body weights at various stages of growth from birth to fifty-two weeks of age and growth rate traits. In addition, heterosis has been estimated from crossbred (Malya x Sukuma) goats.

3.3 Materials and Methods

3.3.1 Description of the study area

Maswa district is one of the five districts of Simiyu region in Tanzania. The district is located on $03^{0}11'$S and 033^{0} $47'$E latitude and longitude, respectively. The area has an average temperature of 22.1°C and receives an annual average rainfall of 878.8 mm, raining from October to April. Maswa is an area of steppes with thorny species. There are widely spread seasonal grasses, and bushes of thorny acacia species.

3.3.2 Experimental design and management of animals

Data used in this study were collected from a community based breeding program which was conducted by Tanzania Livestock Research Institute (TALIRI) in Senani and Mwabayanda villages between 2008 and 2011. All goats were managed under uniform extensive system which was used throughout of the breeding program. Senani and Mwabayanda villages have the same type of land terrain and vegetation type, where its land is covered by grass and shrubs mainly of acacia species. The goats were released for free grazing on natural vegetation within each household's farmland each day around 10:00 hrs in the morning to 17:00 hrs in the evening. No supplementary feeds were provided to these animals. Thereafter, standard housing in roofed houses was provided as night shelters in each household.

According to the breeding plans, 60 participating farmers in the targeted areas were trained on basic goat husbandry practices like improved housing and group dynamics. Furthermore, two (2) farmers from each village were selected by their respective members to pursue a detailed training in basic animal health so as to provide services to his or her participating members within easy reach and at affordable cost. They were also meant to supplement technical services of the local extension staff. After the training session, does of either of the breeds i.e. Sukuma or Malya goats to be used in breeding program were dewormed and weighed in each herd and all unwanted bucks were castrated. In addition, the two (2) farmers who were nominated to pursue a training in basic animal health from each village were also assigned to be bucks keepers and therefore were responsible for managing the breeding bucks of either of the breeds (pure Malya or pure Sukuma bucks) to which all does within a particular village were mated to produce pure Malya, pure Sukuma or their crosses (F1, Malya x Sukuma). The detailed mating plan is represented in Figure 3.1.

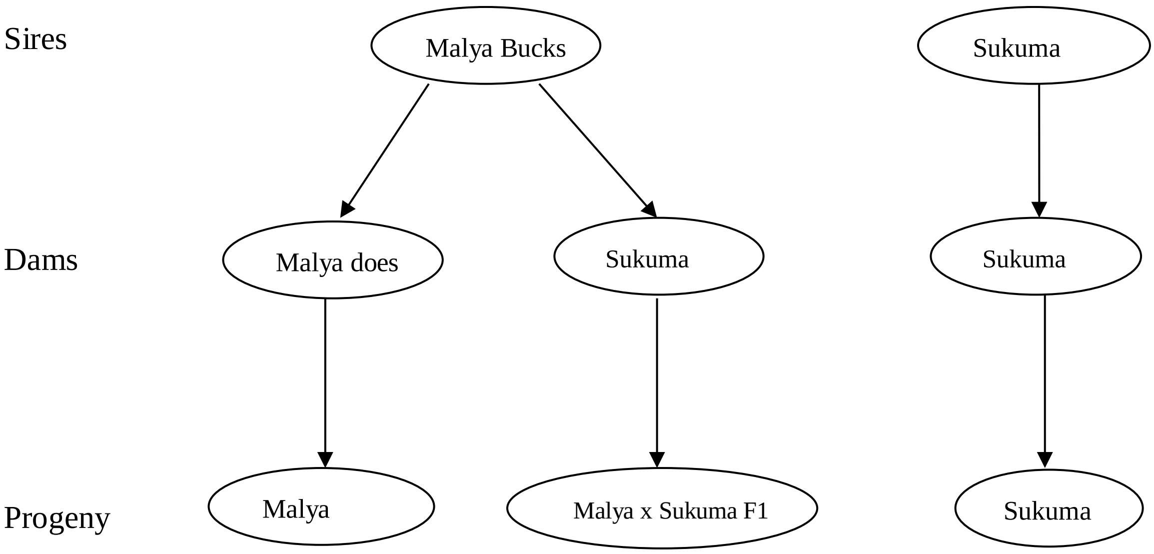

Figure 3.1: The mating plan that was used in the breeding program

3.3.3 Data collection for statistical analysis

About 255 kids progeny of 11 sires and 160 dams were produced. Each kid was weighed at birth and then at weaning, 32 weeks and 52 weeks. These weights were used to calculate growth rates for different intervals i.e. from birth to weaning, from weaning to yearling and from birth to yearling (Appendix 1) and were recorded during the wet and dry seasons and from year 2010 to 2011. Data were classified according to breed, sex, season, year, type of birth and dam weight.

3.3.4 Data analysis

3.3.4.1 Heterosis for growth traits

Heterosis was expressed in percentage for weights and for growth rates specified in section 3.3.3. It was calculated as follows:

$$\text{Heterosis} = \left(\frac{\text{F1 mean} - \frac{(\text{Malya}+\text{Sukuma})}{2}}{\frac{(\text{Malya}+\text{Sukuma})}{2}}\right) \text{x } 100 \qquad \text{(Equation 3.1)}$$

The F1 were not represented by reciprocal crosses but by progeny emanating from mating of Malya bucks to Sukuma does.

3.3.4.2 Heritability (h^2)

Data from offspring and their parents were used to estimate heritabilities (h^2) for weights at birth, weaning (16 weeks), 32 weeks and yearling and for growth rates at different age intervals. i.e. birth to weaning, weaning to yearling and birth to yearling. Thus, heritabilities were estimated from sire variance components according to Becker (1984) and as shown in equation 3.3 and their standard errors were approximated according to Malole *et al*. (2002). The variance components for calculating heritabilities were estimated using Restricted Maximum-Likelihood (REML) method from VARCOMP procedures of SAS (2003).

The linear model that was used is as follows: -

$$Z_{ijklmno} = \mu + T_i + Y_j + C_k + B_l + S_m + D_{mn} + \varepsilon_{ijklmno} \qquad \text{(Equation 3.2)}$$

Where:

$Z_{ijklmno}$ = record of o^{th} individual from i^{th} season of birth, j^{th} year of birth, k^{th} sex, l^{th} birth type and n^{th} dam mated to m^{th} sire

μ = General mean

T_i = Fixed effect of i^{th} season of birth

Y_j = Fixed effect of j^{th} year of birth

C_k = Fixed effect of k^{th} sex

B_l = Fixed effect of l^{th} birth type

S_m = Random effect of m^{th} sire

D_{mn} = Random effect of n^{th} dam mated to m^{th} sire

$\varepsilon_{ijklmno}$= Random effect peculiar to each individual (N,O,σ^2)

$$\text{Heritability} = \frac{4\delta^2 s}{\delta^2 s + \delta^2 d + \delta^2 w} \qquad \text{(Equation 3.3)}$$

$\delta^2 s$ = Sire variance component

$\delta^2 d$ = Dam variance component

$\delta^2 w$ = Error variance component

3.3.4.3 Genetic (r_g) and phenotypic (r_P) correlations among growth traits at different ages

Genetic and phenotypic correlations between growth traits were calculated from variance and covariance components. The variance components were estimated using the REML method of the VARCOMP procedures of SAS (2003) by using model in equation 3.2. Covariance components of two traits, a and b, for example, were calculated by using equation 3.4:

$$\text{cov}_{ab} = \frac{\text{var}_{a+b} - \text{var}_a - \text{var}_b}{2} \qquad \text{(Equation 3.4)}$$

Where var_{a+b} is the variance of the sums of the two individual traits while var_a and var_b are variances of trait a and b, respectively.

Genetic (r_g) and phenotypic (r_p) correlations of growth traits at different ages were estimated from variance and covarience components using the following formulae (Becker, 1984).

Genetic correlations (r_g):

$$r_g = \frac{\delta^2 Sxy}{\sqrt{\delta^2 Sxx * \delta^2 Syy}} \qquad \text{(Equation 3.5)}$$

Where:

$\delta^2 Sxy$ = Sire covariance of traits x and y

$\delta^2 Sxx$ = Sire variance of trait x

$\delta^2 Syy$ = Sire variance of trait y

Phenotypic correlations (r_p)

$$r_p = \frac{\delta^2 Pxy}{\sqrt{\delta^2 Sxx * \delta^2 Syy}} \qquad \text{(Equation 3.6)}$$

$\delta^2 Pxy$ = Phenotypic covariance of traits x and y

$\delta^2 Pxx$ = Phenotypic variance of trait x

$\delta^2 Pyy$ = Phenotypic variance of trait y

3.4 Results

3.4.1 Heterosis for growth traits

Heterosis estimates for birth weight, weaning weight, weight at 32 weeks, weight at 52 weeks of age, pre weaning growth rate, post weaning growth rate and growth from birth to yearling are shown in Table 3.1. There were positive heterosis for birth weight (8.19%), yearling weight (9.59%), post-weaning growth rate (19.26%) and growth rate from birth to yearling (9.62%). Negative heterosis were found in weaning weight (-10.92%), weight at 32 weeks of age (-6.66%) and in pre-weaning growth rate (-9.50%).

Table 3.1: Heterosis estimates for different growth traits in crossbred (Malya x Sukuma) goats

Trait	Heterosis	
Birth weight	0.17 kg	8.19%
Weaning weight (16 weeks)	-0.89 kg	-10.92%
Weight at 32 weeks age	-0.69 kg	-6.66%
Yearling weight	1.93 kg	9.59%
Pre-weaning growth rate (Birth to weaning)	-5.03 g/day	-9.50%
Post-weaning growth rate (Weaning to Yearling)	8.98 g/day	19.26%
Growth rate from birth to yearling	4.67 g/day	9.62%

3.4.2 Heritability for growth traits of Malya goats

Heritability estimates for growth rates and body weights are presented in Table 3.2. Heritability estimates for body weights varied from 0.11 to 0.43 which were low to moderate. Birth weight and weaning weight had moderate heritability (0.43±0.04 and 0.23±0.03, respectively). There were low heritability estimates for weight at 32 weeks (0.11±0.02) and yearling weight (0.18±0.02). Growth rates (Pre weaning, post weaning and birth to yearling) had low heritability estimates which had values of 0.18±0.02, 0.17±0.02 and 0.17±0.02, respectively.

Table 3.2: Heritability estimates for different body weights and growth rates of Malya goats

Traits	Heritability estimates
Birth weight	0.43±0.04
Weaning weight	0.23±0.03
Weight at 32 weeks age	0.11±0.02
Yearling weight	0.18±0.02
Pre-weaning growth rate (Birth to weaning)	0.18±0.02
Post-weaning growth rate (Weaning to Yearling)	0.17±0.02
Growth rate from birth to yearling	0.17±0.02

3.4.3 Correlations among growth traits of Malya goats

Genetic and phenotypic correlations for various growth traits are presented in Table 3.3 and 3.4. Generally, both genetic and phenotypic correlations between the weights at different ages were positive and ranged from low to moderate. The values of genetic correlations between birth weight and weaning weight, birth weight and weight at 32 weeks of age, weaning weight and weight at 32 weeks of age and weight at 32 weeks of age and weight at 52 weeks of age were 0.48±0.05, 0.43±0.06, 0.49±0.05 and 0.44±0.06, respectively.

Table 3.3: Estimates of genetic (below diagonal) and phenotypic (above diagonal) correlations between weights at different ages

Traits	Birth weight	Weaning weight	32 weeks' weight	52 weeks' weight
Birth weight	-	0.10	0.17	0.14
Weaning weight	0.48±0.05	-	0.37	0.11
32 weeks'weight	0.43±0.06	0.49±0.05	-	0.61
52 weeks'weight	0.32±0.06	0.17±0.06	0.44±0.06	-

The corresponding values for phenotypic correlations ranged from 0.10 for birth weight and weaning weight to 0.61 for 32 weeks weight and 52 weeks weight. There were negative genetic and phenotypic correlations between pre-weaning growth rate and post-weaning growth rate (-0.39±0.06 and -0.38, respectively).

Table 3.4: Estimates of genetic (below diagonal) and phenotypic (above diagonal) correlations between growth rates at different stages

Traits	Pre weaning growth rate	Post weaning growth rate	Birth to yearling growth rate
Pre weaning growth rate	-	-0.38	0.09
Post weaning growth rate	-0.39±0.06	-	0.89
Birth to yearling growth rate	0.14±0.06	0.90±0.03	-

Genetic correlation between post-weaning and birth to yearling growth rate and between pre-weaning growth rate and birth to yearling growth rate were 0.90±0.03 and 0.14±0.06, respectively. The corresponding phenotypic correlations were 0.89 and 0.09, respectively.

3.5 Discussion

3.5.1 Heterosis for growth traits

The positive estimates of heterosis for birth weight, yearling weight, post weaning and birth to yearling growth rate and negative estimates of heterosis for weaning weight, 32 weeks weight and pre weaning growth rates found in this study are the similar to those reported by Mugambi *et al*. (2007). They reported positive heterosis estimates for birth weight (0.05 kg) and yearling weight (0.36 kg) and negative heterosis estimates for weaning weight (-0.21 kg) and pre weaning growth rate (-1.72 g/day) in crossbred kids between Small East African goats and improved breeds (Toggenburg, Anglo-Nubia and Galla). Heterosis estimate for birth weight was lower compared to 10.6%, 17.1%, 15.3% and 23.1% heterosis for birth weight of crossbreds of Nubia, Saanen, Toggenburg and Alpine sires with local goat does from Northern Mexico, respectively (Meza-Herrera *et al*., 2019). Present heterosis values are also lower than heterosis estimates for birth weight, weaning weight and pre weaning growth rate in crossbred kids between Aradi Saudi goats and Syrian Damascus goats which ranged from 7.8% to 14.5% (Khalil *et al*., 2010). Heterosis estimates for weaning weight (6.28%) and (5.66%) in crossbreds of Boer and Kiko goats and in crossbred of Boer and Spanish goats respectively were higher than the present result (Browning and Leite-Browning, 2011). In addition, the obtained heterosis for birth weight and weaning weight were lower than heterosis of corresponding traits (2.23 kg and 0.03 kg, respectively) of crosses between two indigenous Moroccan breeds (El Fadili and Leroy, 2001). The reason for lower estimates of heterosis in this study might be caused by loss of co-adaptive gene combinations in the crossbreds between different breeds or due to environmental conditions where the animals were reared as explained by Mugambi *et al*. (2007). Another reason for negative heterosis in pre weaning growth rate can be explained by the permanent maternal environmental and genetic effects. Dam weight and size affect the amount of milk available for kids which in turn affect kids' growth rates. Particular in this study was that Sukuma dams which were the mothers for the crossbred goats had small body size and thus low amount of milk.

3.5.2 Heritability for growth traits in Malya goats

Heritability estimates for growth traits ranged from 0.11±0.02 to 0.43±0.04. For those traits with low heritability estimates it indicates that environmental factors play a significant role in the performance of goats in the study area. The moderate estimates of heritability suggest that additive gene action was moderate for individual selection and that crossbreeding would improve birth weight and weaning weight. For the remaining traits, improvement of environment in terms of feeding and diseases control will help to improve goats' performance.

The heritability estimate recorded for birth weight is higher than 0.15±0.04 reported by Das *et al*. (1994) for the same breed, higher than 0.05±0.08 reported by Faruque *et al*. (2010) for Black Bengal goats, higher than 0.13±0.03 reported by Mugambi *et al*. (2007) for Kenya Dual Purpose goats and higher than 0.15 reported by Muhammed *et al*. (2018) for Ardi goats. However, current heritability for birth weight is similar to 0.43, 0.44±0.10, 0.47±0.12 and 0.41 reported by Hongping (2007) for Boer goats, Supakorn and Pralomkarn (2009) for goats raised for meat, Alade *et al*. (2010) for indigenous goats from Nigeria and Muhammed *et al*. (2018) for Damascus goats, respectively. The heritability estimate for weaning weight obtained in the current study was also moderate. This estimate of heritability is close to 0.22±0.08 for Boer goats, 0.28±0.11 for Black Bengal goats and 0.26 for Ardi goats found by Zhang *et al*. (2009), Faruque *et al.* (2010) and Mohammed *et al*. (2018), respectively. The current estimate is higher than those estimated by Mugambi *et al*. (2007) for Kenya Dual Purpose goats (0.16±0.01), Ahuya *et al*. (2009) for Toggernberg goats in Kenya (0.18±0.11), Alade *et al.* (2010) for indigenous goats in Nigeria (0.04±0.01) and Yousif *et al*. (2011) for Sudan desert goats (0.06±0.26). However, it was also lower than those estimated for Small East Africa goats (0.40±0.05), Sudanese Nubian goats (0.42 ±0.18.) and Damascus goats (0.35) by Malole *et al.* (2002), Ballal *et al*. (2008) and Mohammed *et al*. (2018), respectively.

Weight at 32 weeks of age, yearling weight, pre-weaning growth rate, post-weaning growth rate and birth to yearling growth rate were poorly heritable with heritabilities ranging from 0.11±0.02 to 0.18±0.02. The obtained values concur with a range of 0.10±0.04 to 0.15±0.05 for post-weaning weights and growth rates of Malya goats reported by Das *et al*. (1994). In addition, heritability for yearling weight in the current study was similar to 0.18±0.47 for Black Bengal goats (Faruque *et al.*, 2010), lower than 0.44±0.02 for Small East African goats and 0.33±0.07 for Nigeria crossbreed goats reported by Malole *et al.* (2002) and Otuma and Onu (2013), respectively. Estimated values of heritability for growth rate in this study were within the range of 0.03±0.01 to 0.39±0.08 for local goats of Nigeria found by Alade *et al*. (2010). Current estimated values for growth rate were lower than the range of 0.22±0.19 to 0.59±0.32 in Sudanese Nubian goats (Ballal *et al*., 2008). These differences between values in the current study and the literature may be due to the fact that heritability varies between breeds, places, sample size and method of estimation.

3.5.2 Correlations between growth traits

3.5.2.1 Correlations between weights at different ages

Genetic correlations between body weights at different ages were positive and moderate. The estimated genetic correlations in this research were lower than those reported by Zhou *et al*. (2015) for Hainan Black goats of southern China who reported genetic correlations between body weights to range from 0.35±0.13 to 0.91±0.13. But they accord well with the range of genetic correlations between body weights of 0.29 to 0.61 in Teddy goats (Kuntu *et al*., 2017). According to Beneh *et al*. (2012) genetic correlation between birth weight and weaning weight in Naeini goats was higher (0.61) than the corresponding genetic correlation in our study. However, Al-Shorepy *et al*. (2002) found a similar (r_g=0.45) genetic correlation between birth weight and weaning weight in Emirati goats as the one found in our study. The moderate positive genetic correlation between these weights indicate that the traits are somehow influenced by same genes and that selection for higher birth weight will result in higher weaning weight as a correlated response. Current phenotypic correlations between weights at different ages are almost similar to the range of 0.12 to 0.72 for Arsi-Bale goats of Ethiopia reported by Bedhane *et al*. (2013) and lower than a range of 0.52 to 0.65 for Teddy goats reported by Hyder *et al*. (2002). Also phenotypic correlations between birth and yearling weights and that of 32 weeks weights and yearling weights found in the current research were similar to the values of 0.12 and 0.62 in Markhoz goats respectively as reported by Rashidi *et al*. (2008).

3.5.2.2 Correlations between growth rates at different age intervals

The genetic and phenotypic correlations between the studied growth rate at different stages showed positive and negative values. Similarly, Alade *et al*. (2010) and Ghafouri-Kesbi *et al*. (2011) found positive and negative genetic and phenotypic correlations between pre weaning and post weaning growth rates for Nigerian indigenous goats.

However, the estimated genetic correlation between pre weaning and post weaning growth rate in the current study is lower than 0.73±0.44 reported by Ballal *et al*. (2008). Negative genetic correlation between pre weaning growth rate and post weaning growth rate is an indication that a faster pre-weaning growth rate which might be due to maternal influence, tended to be followed by a slower post weaning growth. This means that the advantage of maternal influence on kids decreases as age advances and hence after weaning growth rate was low. This might be due to high weaning stress for fast growers during pre-weaning stage and compensatory growth for slow pre-weaning growers. Positive genetic correlations between birth to yearling growth rate and post-weaning growth rate indicates that faster growing kids after weaning contributed much to the higher birth to yearling growth rate because the latter period is longer than the former. Thus selection for post weaning growth rate would have a considerable positive impact on birth to yearling growth rate.

3.6 Conclusions

It is concluded that, positive heterosis for birth weight, yearling weight and post weaning growth rate show achievements of crossbreeding program involving Malya sires and Sukuma does. However, negative heterosis manifested in weaning weight and pre weaning growth rate is due to poor maternal influence of Sukuma does who failed to supply enough milk for crossbred kids and thus lowering weaning weight and pre weaning growth rate compared to their genetic potential. Malya goats have moderate heritability for birth weight and weaning weight. Any crossbreeding program that will involve Malya goats with a poor performer breed, will result into improvement of birth and weaning weight. Heritability estimates for other growth traits are low and thus requiring manipulations of environmental factors to improve performance of those traits.

Genetic correlations among growth traits in this study are moderate to high, which indicates that selection for moderately and highly correlated traits will result into moderate and high correlated response, respectively. For negative genetic correlation it is an indication of poor management of kids after weaning, which should therefore be improved.

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CHAPTER FOUR

4.0 Breed preference by farmers and morphometric characteristics of Sukuma and Malya x Sukuma goats in Maswa district, Tanzania

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4.1 Abstract

This study was conducted in order to describe the farmers' preference towards crossbreds (Malya x Sukuma) goats and indigenous Sukuma goats. Good and bad attributes of each genotype and ranks of desired breed according to market price, mature body size and age of attaining mature size were assessed. Body weights and linear body measurement were taken on live goats. Household interviews were done using structured questionnaires administered to 50 respondents who were previously involved in the crossbreeding program. The survey and measurements results showed that the average herd size for all surveyed households was 20 goats (12 Sukuma goats and 8 crossbred goats). The most preferred breed was crossbred goats due to their high market price, large mature body size and early age of attaining mature size. Good attributes for Sukuma goats were disease resistance (98%) and drought resistance (94%) while bad attributes were low price in the market (88%), small body size (94%) and slow growth rate (72%). However, good attributes for crossbred goats were premium price in the market (92%), high growth rate (80%) and large body size (94%) and bad attributes for crossbred goats had low frequencies. Mature body measurements of crossbred goats for body length (60.58±0.46 cm), heart girth (77.59±0.58 cm), height at withers (66.35±0.42 cm) and body weight (35.07±0.52 kg) were higher than corresponding mature body measurements of Sukuma goats which were 49.58±0.42 cm, 65.07±0.54 cm, 56.74±0.39 cm and 21.56±0.48 kg. It was concluded that, crossbred goats were accepted by farmers due to the beneficial impact to the households' economy.

Keywords: Crossbreeding, mature body size, attributes of breeds, indigenous goats

4.2 Introduction

Goats play an important role in the food and nutritional security of the rural people especially in places where there is scarcity of pasture for rearing large ruminants. The role of goats in improving the income and livelihood of rural people has increased due to goats' ability to thrive by grazing on poor natural pastures in arid and semi-arid areas with no supplementary feeding (Ballal *et al.*, 2008). Thus, they are important to poor farming communities in the developing world because of their higher output as compared to inputs, small size and small space requirements.

People around many rural parts of Tanzania keep indigenous goats strains like Sukuma, Masai, Gogo, Pare, Newala, Ujiji and Sonjo (Nguluma *et al.*, 2016). Goats are multipurpose, producing a variety of products and by products, such as meat, manure, skin and can be utilized in various social functions such as paying of dowries (Malole *et al.*, 2002). Many people keep goats that originate from their locality because of their preference to certain traits such as tolerance to drought and heats, resistance to diseases, higher reproduction efficiency and appreciable growth performance traits (Chenyambuga *et al.*, 2012; Berhanu *et al.*, 2012). Despite people's preference to these strains of indigenous goats, local goats' productivity in terms of growth and reproduction performance has been poor (Malole *et al.*, 2002; Safari *et al.*, 2005; Chenyambuga and Lekule, 2014). Indigenous Sukuma goats are described to have smallest mature body size among all indigenous strains belonging to Small East African goat breed (Nguluma *et al.*, 2016). Due to higher demand of goat meat, the market value for goats has increased. However, small mature size of Sukuma goats has been lowering market value due to the tendency of buyers to set prices based on visual appraisal of body size.

In an effort to improve the market value of goats kept in Maswa district, Tanzania Livestock Research Institute in collaboration with Lake Zonal Research Development Fund initiated a community-based breeding program which aimed to improve preferred attributes such as growth rate, mature body size and ability to produce in extensive management system by crossing Malya with Sukuma goats. Information concerning the farmer's preference on crossbred goats which is a product of improved breed and indigenous breed have not been evaluated. The objective of this study was therefore, to assess herd structure, preferred breeds, good and bad attributes of each genetic group of goats from farmers and mature body measurements of crossbreds (F1, Malya x Sukuma) and Sukuma goats.

4.3 Materials and Methods

4.3.1 Description of the study site

The study was conducted in Maswa district one of the five districts of Simiyu Region in Tanzania. The district is located on $03^{0}11'$S and $033^{0}47'$E latitude and longitude, respectively. The area has an average temperature of 22.1°C and receives an annual average of 878.8 mm of rainfall, raining from October to April.

4.3.2 Data collection

4.3.2.1 Farmers' preference on breeds

Farmers' views on the performance of the two genetic groups were collected through individual interview by using a structured questionnaire (Appendix 9). The data collected included informations that describe the difference in mature size between indigenous goats (Sukuma goats) and crossbreds F1 (Malya x Sukuma), the market price of crossbreds (Malya x Sukuma) in comparison to pure Sukuma goats, the time taken by crossbreds (Malya x Sukuma) to reach the (mature size) market size in comparison to pure

Sukuma goats, the good and bad attributes of each genotype. Further, information about herd structure by sex and age class and farmers' preference for the breeds and ranks of each genotype were taken. About 30 open and closed questions were answered during a discussion with the farmer.

4.3.2.2 Measurements for mature size

Body measurements for mature size for the two genetic groups were taken to examine the difference in mature body size between Sukuma goats and crossbred (Malya x Sukuma) goats so that the farmers' responses can be compared with mature size measurements of the two genetic groups.

The following body measurements were taken on mature animals, where by two breeds (Sukuma and crossbreds F_1 (Malya x Sukuma goats) and two sexes were involved. Selection of animals to be measured was based on ages and sexual activities in the herd.

Body weight (BW)

Body weights in kg were obtained by weighing live goats by using a spring balance weighing up to 100 kg.

Body length (BL)

Body lengths in cm were obtained by measuring the distance between the prominence of the shoulder and the hind edges of ischium (Length from the shoulder to the pin bone) using a tailor's measuring tape.

Heart girth (HG)

Heart girths were measured using a tailoring tape as described by Abegaz and Awgichew (2009). Each animal standing on its four legs was restrained, with head maintained in an upright position. Measuring tape was placed around the animal at the point with smallest circumference just behind the forelegs and measurements were taken in cm.

Height at withers (HW)

Heights at withers refer to the distance from the ground to the highest point of the withers using a calibrated ruler and were recorded in centimeters.

4.3.3 Data analysis

Data were coded, then frequencies and percentages of farmers' views on the performance of the two genotypes were computed. A multiple response analysis was also conducted on good and bad attributes describing the crossbreds and Sukuma goats.

The effects of breed, sex and interaction between breed and sex on body measurements (body weights, body length, heart girth and height at withers) of mature goats were analyzed by using General Linear Models of SAS (2003) using the following model:

$$Y_{ij} = \mu + B_i + S_j + (B*S)_{ij} + \varepsilon_{ij} \qquad \text{(Equation 4.1)}$$

Where:

Y_{ij} = Observation (Mature body measurements) from a goat of i^{th} breed and j^{th} sex.

μ = Overall mean

B_i = Effect of i^{th} breed (1=Crossbred, 2=Sukuma)

S_j = Effect j^{th} sex (1=Male, 2=Female)

$(B*S)_{ij}$ = Effect of interaction between i^{th} breed and j^{th} sex

ε_{ij} = Random error term

4.4 Results

4.4.1 Herd structure

Table 4.1 shows that the total number of goats in the 50 households were 961, of which 289 (30.10%) were males and 672 (66.90%) were females. Sukuma strain were 621 (64.60%) while crossbreds (Malya x Sukuma) were 340 (35.40%). The average herd structure for all 50 households shows that each household had only one Sukuma buck and one crossbred buck while the number of adult females were higher than the rest of categories which were five (5) for Sukuma strain and three (3) for crossbreds. Further, in each household the number of mature females were higher than other categories, with Sukuma mature females ranging from 0 to 15 and crossbred mature females ranged from 0 to 9.

Table 4.1: Total, average and range of herd structure in 50 households

Age class	Sex	Total herd structure			Average herd structure per household						Range	
		Su	MaxSu	Total	Su	SD	MaxSu	SD	Total	SD	Su	MaxSu
Kids	M	54	34	226	1	1.08	1	0.85	5	3.50	0 - 4	0 - 4
	F	91	47		2	1.70	1	1.38			0 - 6	0 - 6
Weaners	M	73	31	273	1	1.27	1	0.88	5	3.39	0 - 5	0 - 3
	F	113	56		2	1.94	1	1.52			0 - 7	0 - 5
Adult	M	53	44	462	1	0.99	1	0.83	10	4.75	0 - 4	0 - 3
	F	237	128		5	2.59	3	2.19			0 - 15	0 - 9
Total		621	340	961	12	6.13	8	5.74	20	9.98		

Su=Sukuma goats, Ma=Malya goats, MaxSu=crossbred goats, SD=Standard deviation

4.4.2 Description on the difference in goats' mature size, market price, age of attaining mature size and preferred breed

Findings show that all farmers (100%) involved in the breeding program ranked first the crossbred goats because of their large mature size, premium market price and early age of attaining mature size and as their preferred breed while Sukuma goats were ranked second.

4.4.3 Good and bad attributes of Sukuma and crossbred (Malya x Sukuma) goats

The two major good attributes of Sukuma goats were drought resistance and disease resistance (Table 4.2). The majority (98%) of respondents identified disease resistance and 94% of them identified drought resistance as the best attributes in Sukuma goats while other good attributes which were acknowledged by few farmers were high fertility and low management cost with 12% and 8% of all respondents, respectively. On the other hand, farmers indicated several bad attributes of Sukuma goats. About 88% of respondents identified low price in the market, 94% of respondents specified small body size and 72% of respondents listed slow growth rate as their bad attributes. However, a minority group of respondents remarked that dams of Sukuma goats produce small amount of milk, have poor fertility, small quantity of meat, small size of skin and are destroyers of crops as shown in Table 4.2

Three (3) main good attributes in crossbred (Malya x Sukuma) goats acknowledged by farmers were premium price (92%), fast growth rate (80%) and large body size (94%). In addition, a few farmers mentioned other good attributes which included high amount of milk produced by crossbreds does, resistance to diseases, high twinning rate, high fertility, attractiveness, large quantity of meat, large size of skin, habits of eating everything even kitchen swills and calmness of crossbred goats (percentages are shown in Table 4.2).

However, there were a few respondents who mentioned bad attributes of crossbred goats, and these were being prone to diseases (16%), crossbred goats perform poorly in drought condition (8%) and aggressiveness of bucks (6%).

Table 4.2: Good and bad attributes for Sukuma and crossbred goats (n = 50)

Sukuma goats			
Good attributes	**Frequency**	**Bad attributes**	**Frequency**
Diseases resistance	49 (98)	Low price in the market	44 (88)
Drought resistance	47 (94)	Small body size	47 (94)
High fertility	6 (12)	Slow growth rate	36 (72)
Have low management	4 (8)	Small amount of milk	15 (30)
		Poor fertility	2 (4)
		Low quantity of meat	6 (12)
		Small size of skin	8 (16)
		Destroy crops	8 (16)
Crossbred goats			
Good attributes		**Bad attributes**	
Premium price	46 (92)	Prone to diseases	8 (16)
High growth rates	40 (80)	Perform poorly in drought condition	4 (8)
Large body size	47 (94)	Aggressive especially bucks	3 (6)
Resistance to diseases	8 (16)	Expensive management	1 (2)
Have high amount of milk	15 (30)	Easily captured by predators	1 (2)
High twinning rate	5 (10)		
High fertility	7 (14)		
They are attractive	5 (10)		
Large quantity of meat	8 (16)		
Large size of skin	11 (22)		
Eats everything even kitchen swills	3 (6)		
They are docile	6 (12)		

NB: Numbers in brackets indicate percentages out of the 50 respondents

4.4.4 Morphometric characteristics of mature Sukuma and crossbred (Malya x Sukuma) goats

The results for body measurements of mature goats are presented in Table 4.3. They include body lengths, heart girths, height at withers and live body weights of Sukuma and crossbreed goats.

4.4.4.1 Body length (BL)

The overall mean body length was 53.62±0.25 cm. There were significant (P<0.001) differences between breeds, sexes and interaction between breed and sex on body length (Appendix 10). The body length for Sukuma goats was shorter (49.58±0.42 cm) than that of crossbreds (Malya x Sukuma) (60.58±0.46 cm). Mean body length for does was 53.41±0.29 cm while for bucks was 56.74±0.55 cm. The difference in body length between crossbred bucks and Sukuma bucks was bigger than the difference between crossbred does and Sukuma does. The body lengths for Sukuma bucks (49.81±0.76 cm) and Sukuma does (49.36±0.38 cm) were shorter than those of crossbred bucks (63.67±0.81 cm) and crossbred does (57.47±0.44 cm).

Table 4.3: Least squares means for effect of breed, sex and breed*sex interaction on body length, heart girth, height at withers and body weight

Factor	N	Body length	Heart girth	Height at withers	Body weight
Overall mean	278	53.62±0.25	69.47±0.32	59.39±0.23	26.19±0.29
Breed		***	***	***	***
Crossbreed	123	60.58 ± 0.46[a]	77.59 ± 0.58[a]	66.35 ± 0.42[a]	35.07 ± 0.52[a]
Sukuma	155	49.58 ± 0.42[b]	65.07 ± 0.54[b]	56.74 ± 0.39[b]	21.56 ± 0.48[b]
Sex		***	***	***	***
Male	60	56.74 ± 0.55[a]	73.56 ± 0.70[a]	64.61 ± 0.51[a]	31.01 ± 0.63[a]
Female	218	53.41 ± 0.29[b]	69.10 ± 0.37[b]	58.48 ± 0.26[b]	25.61 ± 0.33[b]
Breed x sex		***	***	***	***
Crossbred male	28	63.67±0.81[a]	81.32±1.03[a]	71.10±0.74[a]	39.98±0.92[a]
Crossbred female	95	57.47±0.44[b]	73.87±0.55[b]	61.60±0.40[b]	30.15±0.50[b]
Combined mean	123	60.58±0.46	77.59±0.58	66.35±0.42	35.07±0.52
		NS	NS	***	NS
Sukuma male	32	49.81±0.76	65.81±0.96	58.12±0.69[a]	22.04±0.86
Sukuma female	123	49.36±0.38	64.34±0.49	55.36±0.35[b]	21.08±0.44
Combined mean	155	49.58±0.42	65.07±0.54	56.74±0.39	21.56±0.48

***P<0.001; [a,b]Means with different letters within the same factor and column are significantly different at P<0.05; N : No. of observations; NS : Not significant

4.4.4.2 Heart girth (HG)

Heart girths differed significantly ($P<0.001$) between breeds and sexes. The interaction effect between breeds and sexes was also significant ($P<0.001$) as shown in Appendix 11. The mean heart girth for crossbreds was higher (77.59±0.58 cm) than for Sukuma (65.07±0.54 cm) and the heart girth for bucks (73.56±0.70 cm) was higher compared to the does (69.10±0.37 cm). The heart girth for crossbred bucks was higher (81.32±1.03 cm) than the crossbred does (73.87±0.55 cm) but these were higher than those of Sukuma bucks (65.81±0.96 cm) and Sukuma does (64.34±0.49 cm). Chest girths of crossbred bucks was wider than the chest girths of crossbred does, while the difference between chest girths of Sukuma bucks and chest girths of Sukuma does was small.

4.4.4.3 Height at withers (HW)

Withers height differed significantly ($P<0.001$) between breeds, sexes and the interaction was also significant (Appendix 12). Crossbred goats had a higher mean height at withers (66.35±0.42 cm) compared to Sukuma goats (56.74±0.39 cm). Further, bucks had a higher height at withers (64.61±0.51 cm) compared to does (58.48±0.26 cm). Height at withers for crossbred bucks was higher (71.10±0.74 cm) than the crossbred does (61.60±0.40 cm). Crossbred bucks were taller by 12.98 cm compared to Sukuma bucks while crossbred does were only taller by 6.24 cm compared to Sukuma does.

4.4.4.4 Body weight (BW)

Significant ($P<0.001$) differences between breeds, sexes and interaction between breeds and sexes were observed for body weight (Appendix 13). Crossbred goats had a higher mean body weight (35.07±0.52 kg) compared to Sukuma goats (21.56±0.48 kg). Also for sex difference, bucks had a higher mean body weight (31.01±0.63 kg) than does (25.61±0.33 kg). Moreover, the body weight for crossbred bucks was heavier by 17.94 kg over Sukuma bucks. At the same time, crossbred does were heavier by 9.07 kg compared to Sukuma does.

4.5 Discussion

4.5.1 Herd structure, goats mature size, market price, age of attaining mature size and preferred breed

Regarding the herd structure, the herd size of goats in the area of study was small with the mean herd size of 12 Sukuma goats and 8 crossbred goats. This finding is comparable with herd size of 10 – 40 reported by Németh *et al*. (2004) and that of 1 -22 reported by Ahuya *et al*. (2005). It was higher than the mean herd sizes of 8.8 and 11.6 reported by Akpa *et al*. (2010) and Boogaard *et al*. (2015), respectively. However, the obtained mean herd size was lower than 25 obtained by Engström (2016) in Chepareria, West Pokot, Kenya. Average herd size for crossbred (8) goats and Sukuma (12) goats in this study indicates that, the desire of transforming herds into crossbred goats was partially achieved despite the tendency of farmers to sell more crossbreds due to their large size. Also the number of males in each household herd was very low. This might be due to the fact that farmers prefer to sell them rather than females because of their large body size for fetching premium price and retention of only selected breeding male(s). This observation has also been reported by Chenyambuga and Lekule (2014). Results on farmers' response towards goats' mature size, market price, age of attaining mature size and preferred breed suggest that crossbred goats have been accepted by farmers due to their ability to perform better than indigenous goats. Preference for an improved breed in the current study is similar with that found in Bena-Tsemay district in Ethiopia as reported by Berhanu *et al*. (2012). However, it is contrary to that reported by Chenyambuga and Lekule (2014) who showed that farmers from Kongwa and Mvomero didn't prefer improved breeds due to low survival rate in the harsh local environment.

4.5.2 Good and bad attributes of Sukuma and crossbred goats

Good attributes for Sukuma goats as perceived by farmers were disease and drought resistance while bad attributes were slow growth rate, small body size and thus low price in the market. Similar observations were stated by Berhanu *et al*. (2012) for goats of South Omo of Ethiopia and Kosgey *et al*. (2009) for the Small East African goats that have slow growth rate, small body size and poor fertility. On the other hand, they had good attributes of tolerating drought, diseases and heat as professed by farmers in the extensive farming systems of Central and Western Kenya. Chenyambuga and Lekule (2014) reported that tolerance of indigenous goats to diseases and drought might be due to the fact that indigenous goats have been naturally selected, through continuous exposure to survive drought and diseases. In addition, Gunia *et al*. (2010) observed the same results on Creole goats and crossbred goats in a survey carried out in Guadeloupe, where they reported 75% of farmers said Creole goats were hardy and resistant and 10% identified good meat taste as a good attribute. Further, they stated that farmers specified good conformation (48%), high growth rate (24%) and good market price and profitability (10%) to be desired characteristics of crossbred goats in Guadeloupe. According to Abraham *et al*. (2018) farmers who keep Begait goats in North Ethiopia liked goats with large body size, high twinning ability and resistant to drought which are similar observations to those found in this study. The current farmers' opinions on good attributes toward crossbred goats had higher frequency than bad attributes. This suggests that farmers appreciated the performance of improved (crossbred) goats due to the greater role they play in their household economy.

4.5.3 Morphometric characteristics

Crossbred (Malya x Sukuma) goats had a larger mature body size than indigenous Sukuma goats. Das and Sendalo (1990) had observed that improved breeds have larger mature body size than indigenous breeds. Current findings reveal that all mature body measurements for crossbred goats were higher compared to Sukuma indigenous goats. Mature body measurements (body length, heart girths, height at withers and body weight) for Sukuma goats in the current study were comparable to those reported by Nguluma *et al*. (2016) for the same breed, but were slightly lower than those measured by Chenyambuga and Lekule (2014) for Iramba and Kongwa local goats. Crossbred mature body measurements were almost similar to those obtained from crossbreds of Creole x Nubian as stated by Vargas *et al*. (2007). Body measurements of Kalahari Red goats measured by Hifzan *et al*. (2015) were heavier in body weight (52.90±1.05 kg) and had longer body length (75.70±2.24 cm) than in current study, while height at withers was similar to that of crossbred goats and higher than withers height of Sukuma goats. Body measurements of crossbred goats in the current study were in line with body measurements of Western lowland goats of Ethiopia while body measurements of Sukuma goats were in good agreement with body measurements of Abergele goats of Ethiopia (Abagaz *et al*., 2013). However, Chanyambuga *et al.* (2012) reported higher mature body measurements for Malya goats than all measurements in this study. In addition, effect of sex in all body measurements may be due to sexual dimorphism, bucks were superior to does in all body measurements. Morphometric results in the current study shows that crossbreds of Malya and Sukuma goats had bigger size due to the advantage of exploiting heterosis from their parents. Heterosis was higher because genetic differences between the Malya and Sukuma goats was big. Also this finding reveals that farmers' preference on the crossbred goats is valid since there is statistical evidence of difference between mature body measurements of Sukuma goats and that of crossbred goats.

4.6 Conclusions

The present study reveals that farmers in the study area appreciated the performance of crossbred goats due to their ability to grow faster and attain bigger mature size which in turn results into getting premium price. This has lead them to rank crossbred goats as their preferred breed.

The crossbreds out-performed Sukuma goats in all body measurements. Also bucks of both breeds excelled their respective does in all body measurements while the difference in body measurements between breeds within sex was larger among males than among females. Thus, mature body measurements of crossbreds have proven to be superior to those of Sukuma goats which matches with the responses of farmers in describing performance of the crossbreds.

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CHAPTER FIVE

5.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

i. It is concluded that breeds had significant influence on weights at different ages, growth rate at different stages and on twinning rate. This imply that, the crossbreeding program in the study area succeeded because crossbred (Malya x Sukuma) goats had better growth performance than that of Sukuma goats. Thus mature body size of indigenous goats was improved under extensive farm management system. However, pre-weaning growth traits were more affected by maternal environment, so any factor that affected does as maternal environment also affected pre weaning growth traits of kids.

ii. Birth weight, yearling weight and post-weaning growth rate had positive heterosis. However, weaning weight and pre-weaning growth rate had negative heterosis due to poor maternal influence of Sukuma dams which had small body size, low weight and thus produced low milk for their crossbred kids which affected growth traits. Birth weights and weaning weights had moderate heritabilities whereas, other growth traits require maneuvering of environmental factors (feeding management, diseases control) to improve their performance.

iii. Genetic correlations among growth traits were positive or negative and ranged from moderate to high. Positive correlations among traits means that selection for correlated traits can result into positive correlated response. On the other hand, negative genetic correlation was an indication of poor management of kids after weaning. Low phenotypic correlations among many growth traits was an indication that association among these traits was low. Further, high phenotypic correlations between yearling weight and at 32 weeks weight indicates high association between these traits. So 32 weeks weights can be used to predict yearling weights.

iv. Farmers in the area of study accepted the crossbreeding program and they preferred crossbred goats as an alternative breed due to their remarkable growth performance and low age of attaining mature size. Further, crossbreds have larger mature body size compared to that of Sukuma goats.

5.2 Recommendations

i. It is recommended that farmers who are involved in indigenous goat production should cross their indigenous goats with improved goats for market at the same time conserve the indigenous Animal Genetic Resources. This will help them to use crossbred goats for income generation activities.

ii. Also it is recommended to scale up crossbreeding by providing Malya goats and guide mating approach so as to ensure genetic improvement and avoid in-breeding.

iii. Further, management (feeding management and diseases control) and extension services in crossbred goats should be improved in order to allow them to exhibit their genetic potential for production traits.

APPENDICES

Appendix 1: Data handling on growth rate

The growth rate from birth to weaning, weaning to yearling and birth to yearling were calculated as average daily gain (ADG) in gram per day, using equations below. But before calculation data of weights were adjusted for age.

$$ADG1 = \frac{Wt1 - Bw}{T2 - T1}$$

Where:

ADG1 = Average daily gain from birth to weaning at 112 days

Wt1 = Weight at 112 days of age (weaning)

Bw =Birth weight

T2-T1 = Time interval from birth to weaning (112 days)

$$ADG2 = \frac{Wt2 - Wt1}{T3 - T2}$$

Where:

ADG2 = Average daily gain from weaning to yearling

Wt2 = Yearling weight

Wt1 =Weaning weight

T3-T2 = Time interval from weaning to yearling (252 days)

$$ADG3 = \frac{Wt2 - Bw}{T3 - T1}$$

Where:

ADG3 = Average daily gain from birth to yearling

Wt2 = Yearling weight

Bw =Birth weight

T3-T1 = Time interval from birth to yearling (364 days)

Appendix 2: Summary of ANOVA table for birth weights of the kids

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Breed	2	14.22326301	7.11163151	40.00	<.0001
Sex	1	1.65218340	1.65218340	9.29	0.0025
Birth type	1	1.95473313	1.95473313	10.99	0.0010
Season	1	0.34308882	0.34308882	1.93	0.1658
Year	1	0.04086580	0.04086580	0.23	0.6320
Breed*Sex	2	0.24844804	0.12422402	0.70	0.4980
Dam weight	1	0.02427167	0.02427167	0.14	0.7120
Error	296	52.62459211	0.17778578		
Corrected Total	305	74.34376634			

R-Square	Coeff Var	Root MSE	BWT Mean
0.292145	19.03147	0.421647	2.215523

Appendix 3: Summary of ANOVA table for weaning weights of the kids

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Breed	2	1133.642592	566.821296	119.93	<.0001
Sex	1	30.455059	30.455059	6.44	0.0116
Birth type	1	53.265420	53.265420	11.27	0.0009
Season	1	17.559422	17.559422	3.72	0.0549
Year	1	227.932629	227.932629	48.23	<.0001
Breed*Sex	2	22.356756	11.178378	2.37	0.0957
Dam weight	1	0.051342	0.051342	0.01	0.9171
Error	296	1398.964940	4.726233		
Corrected Total	305	3305.340074			

R-Square	Coeff Var	Root MSE	WK16 Mean
0.576756	25.15136	2.173990	8.643627

Appendix 4: Summary of ANOVA table for 32 weeks weights

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Breed	2	954.6962748	477.3481374	79.44	<.0001
Sex	1	108.7019872	108.7019872	18.09	<.0001
Birth type	1	63.5336713	63.5336713	10.57	0.0013
Season	1	0.1076144	0.1076144	0.02	0.8936
Year	1	72.3012529	72.3012529	12.03	0.0006
Breed*Sex	2	59.5479590	29.7739795	4.95	0.0076
Dam weight	1	0.0002634	0.0002634	0.00	0.9947
Error	296	1778.690436	6.009089		
Corrected Total	305	3429.238603			

R-Square	Coeff Var	Root MSE	WK32 Mean
0.481316	22.26213	2.451344	11.01127

Appendix 5: Summary of ANOVA table for yearling weights

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Breed	2	3852.491284	1926.245642	94.45	<.0001
Sex	1	241.594055	241.594055	11.85	0.0007
Birth type	1	4.733892	4.733892	0.23	0.6303
Season	1	29.360114	29.360114	1.44	0.2312
Year	1	130.359832	130.359832	6.39	0.0120
Breed*Sex	2	13.356000	6.678000	0.33	0.7210
Dam weight	1	0.005429	0.005429	0.00	0.9870
Error	296	6036.58463	20.39387		
Corrected Total	305	12027.12765			

R-Square	Coeff Var	Root MSE	WK52 Mean
0.498086	19.88770	4.515957	22.70729

Appendix 6: Summary of ANOVA table for pre-weaning growth rate

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Breed	2	25454.16980	12727.08490	37.86	<.0001
Sex	1	2142.83557	2142.83557	6.37	0.0121
Birth type	1	4466.80761	4466.80761	13.29	0.0003
Season	1	880.66139	880.66139	2.62	0.1066
Year	1	16277.48536	16277.48536	48.42	<.0001
Dam weight class	3	2615.31425	871.77142	2.59	0.0502
Breed*Sex	2	2251.56667	1125.78334	3.35	0.0365
Birth weight	1	1949.90530	1949.90530	5.80	0.0166
Error	293	97492.7619	336.1819		
Corrected Total	305	231793.0336			

R-Square	Coeff Var	Root MSE	GRBtW Mean
0.579397	31.89771	18.33526	57.48144

Appendix 7: Summary of ANOVA table for post-weaning growth rate

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Breed	2	10666.66202	5333.33101	16.75	<.0001
Sex	1	892.36062	892.36062	2.80	0.0952
Birth type	1	785.27007	785.27007	2.47	0.1175
Season	1	1431.45167	1431.45167	4.49	0.0349
Year	1	860.05495	860.05495	2.70	0.1014
Dam weight class	3	1284.76687	428.25562	1.34	0.2601
Breed*Sex	2	233.53285	116.76642	0.37	0.6934
Birth weight	1	1221.91028	1221.91028	3.84	0.0511
Error	293	92364.6872	318.4989		
Corrected Total	305	126568.3269			

R-Square	Coeff Var	Root MSE	GRWtY Mean
0.270239	32.21041	17.84654	55.40611

Appendix 8: Summary of ANOVA table for birth to yearling growth rate

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Breed	2	12913.21800	6456.60900	46.12	<.0001
Sex	1	1219.15227	1219.15227	8.71	0.0034
Birth type	1	1.35230	1.35230	0.01	0.9218
Season	1	290.97574	290.97574	2.08	0.1504
Year	1	358.97478	358.97478	2.56	0.1104
Dam weight class	3	247.85732	82.61911	0.59	0.6219
Breed*Sex	2	149.17442	74.58721	0.53	0.5875
Birth weight	1	112.61174	112.61174	0.80	0.3705
Error	293	40594.49486	139.98102		
Corrected Total	305	80299.17903			

R-Square	Coeff Var	Root MSE	GRBtY Mean
0.494459	21.11056	11.83136	56.04474

Appendix 9: Questionnaire on farmers' preference on crossbreds and Sukuma goats

Name of interviewer......................... Date.......................Questionnaire No...............

1. **Household identification**

Name of respondent...

Name of household head...

Education level of respondent...

Village...

Telephone No..

2. **Herd structure**

Number of goats within herd

Age class	Sex	Breed		Total
		Sukuma goats	Crossbred goats	
Kids	M			
	F			
Weaners	M			
	F			
Adults	M			
	F			
Total				

3. Description on the difference in goats' mature size, market price and age of attaining mature size

Mark (1) for genotype group that rank first and (2) for genotype group that rank second in (mature size, market price and age of attaining mature size)

Genotype group	Mature size	Market price	Age of attaining mature size
Sukuma goats			
Crossbred goats			

4. Preference for the breeds

Between these two genotype groups which group do you prefer to keep? Rank them according to preferences (Sukuma goats and Crossbred goats)

Rank No	Preferred breeds
1	
2	

5. Good and bad attributes of each genotype

a. Sukuma goats

S/No	Good attributes	S/No	Bad attributes
1		1	
2		2	
3		3	
4		4	
5		5	

b. Crossbred goats

S/No	Good attributes	S/No	Bad attributes
1		1	
2		2	
3		3	
4		4	
5		5	

6. Measurements of mature animals

Animal No	Breed	Sex	Body weight(kg)	Heart girth(cm)	Body length(cm)	Height at withers(cm)
1						
2						
3						
4						
5						
6						

Thank you very much for your cooperation in this research

Appendix 10: Summary of ANOVA table for body length of mature goats

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Breed	1	5643.609905	5643.609905	307.98	<.0001
Sex	1	517.995400	517.995400	28.27	<.0001
Breed*Sex	1	386.165738	386.165738	21.07	<.0001
Error	274	5020.92652	18.32455		
Corrected Total	277	11963.09353			

R-Square	Coeff Var	Root MSE	BL Mean
0.580299	7.982558	4.280718	53.62590

Appendix 11: Summary of ANOVA table for heart girth of mature goats

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Breed	1	7323.687935	7323.687935	246.43	<.0001
Sex	1	929.035497	929.035497	31.26	<.0001
Breed*Sex	1	417.201016	417.201016	14.04	0.0002
Error	274	8143.12489	29.71943		
Corrected Total	277	17581.37050			

R-Square	Coeff Var	Root MSE	HG Mean
0.536832	7.846398	5.451553	69.47842

Appendix 12: Summary of ANOVA table for height at withers of mature goats

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Breed	1	4312.810392	4312.810392	277.30	<.0001
Sex	1	1757.307297	1757.307297	112.99	<.0001
Breed*Sex	1	531.827772	531.827772	34.19	<.0001
Error	274	4261.51516	15.55298		
Corrected Total	277	10612.67986			

R-Square	Coeff Var	Root MSE	HW Mean
0.598451	6.639350	3.943726	59.39928

Appendix 13: Summary of ANOVA table for body weights of mature goats

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Breed	1	8521.780637	8521.780637	356.82	<.0001
Sex	1	1359.721292	1359.721292	56.93	<.0001
Breed*Sex	1	916.555455	916.555455	38.38	<.0001
Error	274	6543.73933	23.88226		
Corrected Total	277	17125.11871			

R-Square	Coeff Var	Root MSE	BW Mean
0.617886	18.65401	4.886948	26.19784