GENETIC AND NON-GENETIC FACTORS AFFECTING SURVIVABILITY, GROWTH AND REPRODUCTIVE PERFORMANCE OF BOER AND CENTRAL HIGHLAND GOATS AND THEIR CROSSES REARED AT ATAYE FARM, NORTH SHOA, ETHIOPIA

MSc THESIS

AMINE MUSTEFA

HAWASSA UNIVERSITY

COLLEGE OF AGRICULTURE

HAWASSA, ETHIOPIA

OCTOBER, 2017

GENETIC AND NON-GENETIC FACTORS AFFECTING SURVIVABILITY, GROWTH AND REPRODUCTIVE PERFORMANCE OF BOER AND CENTRAL HIGHLAND GOATS AND THEIR CROSSES REARED AT ATAYE FARM, NORTH SHOA, ETHIOPIA

AMINE MUSTEFA

ADVISOR: MESTAWET TAYE (PhD)

CO-ADVISOR: SANDIP BANERJEE (PhD)

A THESIS SUBMITTED TO THE SCHOOL OF ANIMAL AND RANGE SCIENCES

HAWASSA UNIVERSITY

COLLEGE OF AGRICULTURE

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF THE MASTER OF SCIENCE IN ANIMAL AND RANGE SCIENCES

(SPECIALIZATION: ANIMAL BREEDING)

HAWASSA, ETHIOPIA

OCTOBER, 2017

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

ADVISORS APPROVAL SHEET

(Submission Sheet – 1)

This is to certify that the Entitled Genetic and non-genetic factors affecting survivability, growth and reproductive performance of Boer and Central Highland goats and their crosses reared at Ataye farm, North Shoa, Ethiopia submitted in partial fulfillment of the requirements for the degree of Masters in Animal and Range Sciences (Animal Breeding), the graduate program of the School of Animal and Range Sciences, Hawassa University, College of Agriculture has been carried out by Amine Mustefa ID No. SGS/039/08, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

………………………………..………… ………………………… …………………

(Major Advisor) Signature Date

…………………………………………. ………………………… ………………….

(Co-Advisor) Signature Date

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

EXAMINERS APPROVAL SHEET – 2

(Submission Sheet – 2)

As members of the Examining Board of the Final MSc Open Defense, we certify that we have read and evaluated the thesis prepared by Amine Mustefaentitled Genetic and non-genetic factors affecting survivability, growth and reproductive performance of Boer and Central Highland goats and their crosses reared at Ataye farm, North Shoa, Ethiopia and recommend that it be accepted as fulfilling the thesis requirement for the degree of

…………………………………………………………………………………………………..

……………………………… ..…………………….. …..……………….

Name of Chairman Signature Date

……………………………… ..…………………….. …..……………….

Name of Major Advisor Signature Date

……………………………… ..…………………….. …..……………….

Name of Co-advisor Signature Date

……………………………… ..…………………….. …..……………….

Name of Internal Examiner Signature Date

……………………………… ..…………………….. …..……………….

Name of External Examiner Signature Date

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the candidate's school.

I hereby certify that I have read this thesis prepared under my direction and recommend that it accepted as fulfilling the thesis requirement.

……………………………… ..…………………….. …..……………….

Name of Thesis Advisor Signature Date

I dedicate this thesis manuscript to my wife Hawa Yesuf and my mother Saediya Mohammed for their love and dedicated partnership in the success of my life.

ACKNOWLEDGEMENTS

ALHAMDULILLAHI RABBIL ALAMIN. I am highly indebted to my advisors Dr. Sandip Banerjee and Dr. Mestawet Taye as without their encouragement, insight, guidance, and professional expertise the completion of this work would not have been possible. My special appreciation also goes to Dr. Tesfaye Getachew who had advised me during proposing the work and data analysis.

I also takes this opportunity to thank my wife Hawa Yesuf, my mother Saediya Mohammed, my sister Emana Mohammed-nur , my father Mustefa Nuruhsen and my uncles Saud Nuruhsen and Aref Nuruhsen for their endless help, as their encouragement, insight, guidance, moral and financial support bring me be here. I also acknowledge the love and affection of my daughter Salina Amine who with her smile brought joy during the stressful days of my study.

A special word also goes to my friends and my work partners Mr. Aschalew Abebe, Mr. Shenkute Goshme, Mr. Ayele Abebe, Mr. Derib Aydefruhm, Mr. Shanbel Besufekad and Mr Alemnew Araya. I want to thanks the Head and staff of Debre Birhan Agricultural Research Center of Amhara Agricultural Research Institute for giving me the chance to attend my MSc study and for allowing me to work my thesis on the data collected.

I also takes this opportunity to thank the Head and staff of School of Animal and Range Sciences, College of Agriculture, Hawassa University for their encouragement and sharing their knowledge. I would specially like to acknowledge the teaching and help received from Dr. Yosef Teklegiorgis.

Statementof author

I declare that this thesis is my bonafied work and all sources of materials used for this thesis have been duly acknowledged. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Name: …………………………...…………………….Signature: ………..……………

Place: College of Agriculture, Hawassa University, Hawassa

Date of Submission: ………………………………………….

I. List of Abbreviation

6mW	Six Month Weight
6m-YADWG	Six month to yearling average daily weight gain
ARARI	Amhara Regional Agricultural Research Institute
BED	Breeding, Evaluations and Distribution
BW	Birth Weight
CHG	Central Highland Goat
DBARC	Debre-Birhan Agricultural Research Center
ESGPIP	Ethiopian Sheep and Goat Productivity Improvement Program
GARC	Gondar Agricultural Research Center
IBC	Institute of Biodiversity Conservation
LS	Litter size
LSB	Litter size at birth
LSW	Litter size at weaning
LW	Litter weight
LWB	Litter weight at birth
NCBG	Nigerian crossbred goats
PoWADWG	Post-weaning average daily weight gain
PrWADWG	Pre-weaning average daily weight gain
SDARC	Sekota Dry Land Agricultural Research Center
USAID	United States Agency for International Development
W-6mADWG	Weaning to six month average daily weight gain
WADG	West African dwarf goats
WW	Weaning Weight
YW	Yearling Weight

Table of contents

Contents page

II. List of Tables

III. List of Figures

IV. List of Tables in the Appendix

Tables Page

GENETIC AND NON-GENETIC FACTORS AFFECTING SURVIVABILITY, GROWTH AND REPRODUCTIVE PERFORMANCE OF BOER GOATS AND CENTRAL HIGHLAND GOATS AND THEIR CROSSES REARED AT ATAYE FARM, NORTH SHOA, ETHIOPIA

By AMINE MUSTEFA

ADVISOR: MESTAWET TAYE (PhD)
CO-ADVISOR: SANDIP BANERJEE (PhD)

ABSTRACT

This study was conducted at Ataye site of Debre-Birhan Agricultural Research Center. Data pertained to512 kids/ yearlings of Boer (B), Central Highland Goats (CHG), and F_1 (B X CHG), $F_{2\,(a)}$ (F1 X F1), $F_{2\,(b)}$ (B X F1), were collected from 381 kiddings, recorded between 2012 and 2017. The study was aimed to access the effects of genetic and non-genetic factors on growth, reproductive and survivability performances of the above genotypes. The data was analyzed using GLM of SAS (9.0) to investigate the effect of genetic and non-genetic factors (dam parity, sex, year, season and type of birth) affecting body weight and daily weight gain from birth to 1 year of age, litter size and weight at birth and at weaning. Non-parametric tests were used to investigate the genetic and non-genetic factors influencing the conception, kidding and abortion rates. Survival analysis study was carried out using Weibull proportional hazards models using Survival Kit version 6.0 and chi square sub-dividing analysis using SAS (9.0) was used to access the genetic and non-genetic factors influencing the survival of the kids from birth to yearling age. Similarly Animal model were used for the estimation of genetic parameters and sire ranking based on their breeding value estimates using WOMBAT®. The overall least-squares means for body weight (kg) at birth, at weaning, at six months and at yearling and body weight gain to weaning, weaning to six-months and six months to yearling (grams) were 2.68±0.04, 9.11±0.19, 11.69±0.26, 16.41±0.38, 69.73±1.89, 30.48±1.54 and 24.33±1.21 respectively. Genotype and all the studied non-genetic factors affected the body weight and weight gain from birth to yearling age. However, parity of the doe only influenced body weight gain six month to yearling. Weaning weights were not affected by sex of the kids. Yearling weights were not affected by breed and season of birth. Similarly season of birth did not affect six-month weight. The overall conception, kidding and abortion (%) of the does were recorded to be 48.75, 77.05 and 20.49 respectively. Genetic and non-genetic factors influence the studied traits but kidding and abortion percentages were not affected significantly by mating season similarly conception (%) were not affected by mating weight. The overall least-squares means for litter size at birth was (1.40±0.03), at weaning was (0.67±0.03), litter weight (kg) at birth was (3.63±0.07) and at weaning was (10.68±0.28) respectively. The traits were not affected by parity. Similarly litter size at birth and at weaning were not affected by breed of the doe and season of kidding. Litter size at birth was not affected by year of kidding while litter weight at weaning was not affected by type of birth. The overall least-squares means for body weight at mating and at kidding (kg) of the does were 26.52±0.40 and 28.04±0.39 respectively. These traits were affected by breed of the does and year of mating year but not by season of mating. The heritability estimates ranged were slightly over estimated due to small sample size. The h^2 among the (B and F_1) for body weight at birth, at weaning, at six-months and at yearling ages were (0.43±0.28 and 0.73±0.17), (0.78±0.50 and 0.67±0.27), (0.75±0.52 and 0.65±0.27) and (0.23±0.70 and 0.65±0.27). Similarly genetic and phenotypic correlations were also over estimated. Sires were also ranked based on their estimated breeding values for body weight from birth to yearling age among the B and F_1. The overall survival (%) of the kids at day 4, 90, 180 and 365 were 73.99, 53.57, 47.98 and 40.27 respectively. The above survivability traits were not influenced by sex and parity. Similarly survival at day 90 and 180 were not affected by genotype. Season of birth also influenced the survivability of the kids at the 4^{th} day (after birth). So from this study we can conclude that the overall growth, reproductive and survivability performances of all the studied genotypes were quit low which indicating their sub-optimal adaptability to the study area. Thus, evaluating the genotypes based on a large sample size reared across

different locations under different management is desired to come to a definite conclusion. Similarly as the yearling weight were highly correlated with the weaning and six month weight then we can therefore consider them as indicator traits for yearling weight of the goats. The findings also showed variation across bucks (based on their EBV) for the growth traits.

1. Introduction

Small ruminants contribute significantly to the economy and food security of Ethiopia as they do for many other developing countries. They are better adapted to harsh environments, thereby help in utilisation of marginal, degraded, sloppy and other lands which are unsuitable for any meaningful agrarian activities (Misra and Singh, 2002; Degen, 2007). Studies have also indicated that rearing of small ruminants have several benefits as they are endowed with an inherent ability to efficiently digest feeds which have high-fibrous and high-tannin contents, have excellent grazing skill, with low body weight and ability to manipulate metabolism(Mestawet *et al.*, 2012; Silanikove, 2000). The small ruminants are economical to rear, produce and reproduce even under marginal conditions (Mestawet *et al.*, 2012; Morand-Fehr *et al*., 2007; Hassen *et al.*, 2012).

Like all parts of Ethiopia goats native to the Amhara region (including the Central Highland goats) generally have low body weight, have suboptimal growth, poor carcass yield and have low reproductive performance when compared to some tropical and temperate breeds (Moses, 2006; Dereje *et al.,* 2015).The chevon quality too have coarse muscles and hence have poor conformation (Moses, 2006). Birth weight for the indigenous goats ranges from 2.2 kg for Adillo goats to 3.4 kg for Begait goats (Getahun, 2008; Birhane and Eik, 2006 respectively). Similarly the weaning weight of the native goats too vary across the breeds and range from 6.7 kg, for Central Highland goats to 11.7 kg for the Somali goats (Tesfaye *et al.,* 2006; Zeleke, 2007). Findings of a study by (Berhane and Eirk, 2006; Tatek *et al.,* 2004) have also indicated that the pre-weaning weight gain too varied across the breeds with 39 g. for Abergelle goats to 72.2 g. for Arsi-Bale goats respectively. The hot carcass weight of the goats too indicated wide variation across the genotypes with values ranging from 5.7 kg for Sidama goats to 12.8 kg for Arsi-Bale goats (Wondwosen *et al.,* 2010; Mesfin, 2007).

The age at first kidding too indicated wide variation across the genotypes with the values ranging from 11.9 months for goats in Alaba to 28.5 months for Arsi-Bale goats (Deribe, 2009; Dadi *et al.,* 2008 respectively). Kidding interval too varied across the genotypes with values ranging between 7.9 months for Keffa goats to 12 months for Abergelle goats (Belete, 2009; Berhane and Eik, 2006 respectively). The prolificacy values too varied across the genotypes with values of 1.3 % for Abergelle goats to around 41% for Western lowland goats (Jemal, 2008; Farm Africa, 1996 respectively), while the litter size ranged from 1.07 for Afar goats to 1.34 for Arsi-Bale goats (Farm Africa, 1996; Mahlet, 2008).

The overall productivity of goats (as in any other livestock species) is influenced both by the genotype of the animals, the environment where they are reared besides the interaction between the two (Falconer, 1989). In order to optimize the production from the flocks both the genotype (of the flock) and the environment (where they are reared) need to be improved. According to Horst (1983) the concept of 'productive adaptability', suggests that phenotypic performance is the result of an animal's true genetic performance and the animals ability to cope with environmental stresses, including the burden of common diseases/parasites and heat load.

The environment (where the goats are reared) can be improved through proper nutrition, veterinary care and management (von Kaufmann and Peters, 1990). If larger, faster growing and early reproducing animals are imported to any country, adequate feed resources commensuration to their need, have to be made available to the producers (Ademosun, 1990; Moses, 2006).

The genotype of the flock can be improved either through within breed selection or through crossbreeding using exotic breeds (Falconer, 1989). Improving the genotype through within breed selection can be sustainable when compared to crossbreeding viz. adaptation, stable genetic gain and others. However, such schemes are usually time consuming process with genetic progress/generation being as low as <5% (McDowell, 1972, 1988). However, long-term production goals are therefore usually best met by within breed selection (Moses, 2006).

Therefore, in order to bring about within breed improvement of small ruminants there were initiation of village (community) based small ruminant improvement projects in the country. In continuation with the same, goat genetic resource improvement projects was also initiated at Sekota Dry Land Agricultural Research Center (SDARC), Gondar Agricultural Research Center (GARC) and Debre-Birhan Agricultural Research Center (DBARC) on Abergelle, Western Low Land and Central Highland goats respectively under Amhara Regional Agricultural Research Institute (ARARI) (Alemu, 2015).

Crossbreeding of goats can lead to their rapid improvement by enhancing their genetic performance (Cunningham and Syrstad, 1987). In order to rapidly improve the growth and reproductive performance (of the native goats) crossing them with some improved goat breeds can be useful and an option of choice (Ethiopia LMP, 2015). However, the exotic breeds need to be such which are well adapted to the climate of the region where they are expected to perform (Ademosun, 1990; Mestawet *et al.*, 2014).

Introduction of exotic goat breeds (for cross-breeding purposes) have been carried out in the past by both researchers and non-government agencies alike. However, desirable results were not observable and the footfalls of the schemes have since been lost in oblivion, primarily because of lack of follow up and improper records of the achievements (Ayalew *et al.,* 2003, Mestawet *et al.,* 2014).Lessons from the history are rarely taken into account one such study was by Davendra and Burns (1983) who had reported that the Boer goats do not adapt to East African conditions.

Technically the process of crossbreeding needs to be initiated only after understanding the different productive and reproductive parameters of both the breeds involved in the process of cross breeding including their nicking for productive, reproductive and adaptive traits including traits pertaining to disease tolerance traits and the producers breeding objectives. The nicking of the breeds (for the traits of interest) need to be assessed before large scale dissemination of the crossbreds (Cunningham and Syrstad, 1987). Introduction of the exotic genotypes need to be carefully assessed for the adaptive traits prior to initiation of any crossbreeding experiments (Moses, 2006).

Over the years several goat breeds including Saanen, Anglo-Nubian, Toggenburg and Boer goats have been introduced in the country under some project or the other (Alemu and Merkel, 2008). These goat breeds were introduced under donor driven projects and were of both dairy and chevon types. All projects were initiated for improving the milk and carcass yield keeping in mind the effects of heterosis (Alemu and Merkel, 2008).

Among the recently conceived crossbreeding project, ESGPIP (Ethiopia Sheep and Goat Productivity Improvement Program) was initiated under USAID program. This project had aimed at improving the carcass yield from the native goat breeds by crossing them with Boer bucks which were imported from South Africa (Alemu and Merkel, 2008). Besides the same semen of the Boer bucks were also imported from USA from Langston University (Oklahoma).

The collaborative Ethiopian Universities under the project were Haramaya and Hawassa Universities (IBC, 2004).

In addition to this, Boer goats (bucks and does) were imported under the project at different locations in the country which also included certain locations in the Amhara region. There were different breeding, evaluations and distribution (BED) sites in Amhara region where these Boer goats were introduced. One of the sites in Amhara region where the Boer goats were introduced in 2011 was at Ataye site of Debre-Birhan Agricultural Research Center under Amhara Regional Agricultural Research Institute in 2011.

1.1 Justification of the study

Over the years since the Boer goats were introduced to Ataye site, it was recorded that their production, reproduction and survivability (irrespective of their sexes) were suboptimum and much below values reported from the native area of the breed. The differences in the production and reproduction traits as observed might be ascribed to the genotype by environment interaction. Thus, the present study was aimed to estimate some genetic and non-genetic effects influencing the production, reproduction and survivability traits of Boer, Central highland goats and their crosses.

1.2 Objectives of the study

General objective:-

The overall objective of this study was to evaluate the performances of Boer, Central Highland Goats and their crosses reared at Ataye farm.

Specific objectives:-

- To estimate some genetic parameters such as heritability, genetic and phenotypic correlations influencing the growth traits of Boer and their crosses with CHG.
- To estimate the effects of the genotypes on some growth, reproductive and survivability traits.
- To develop sire ranking based on their estimated Breeding values
- To estimate the effect of some non-genetic factors on the growth, reproductive and survivability traits.

2. Literature review

2.1 Goat genetic resources of Ethiopia

Based on differences in physical characteristics and genetic differences at the DNA level, four families and 12 breeds of goats have been identified in Ethiopia (Tesfaye, 2004) .The families and breeds are named after their geographical location, the ethnic communities maintaining them, or based on some identifying physical features (Gizaw, 2009).. Thus, the goats in Ethiopia are classified into Nubian family (Nubian), Rift Valley family (Afar, Abergelle, Arsi-Bale and Woito-Guji), Somali family (Hararghe Highland, Short-eared Somali and Long-eared Somali) and Small East African family (Central Highland, Western Highland, Western Lowland and Keffa) (Gizaw, 2009).

2.2 Central highland goats

The Central Highland goats (Brown goat) belong to the Small East African family and are medium-sized, broad-faced, have thick horns and are predominantly reddish-brown in colour. Other features of the breed include facial profile straight (71%) or concave (29%). The bucks are horned, with around 82% having straight horns which are pointed backwards, while 13% of them have curved and 5% spiral horns. Their coat type is short and smooth with 51% of them exhibiting the plain colour, 42% of them have patchy while 7% exhibited spotted colour. Their predominant colour is red-brown (41%), the rest being black, white and grey. Beard is present in 82% of the bucks, while 99% of them had ruffs and 6% had wattles.The breeding tract of Central Highland goats extend from many parts of Tigray, Eastern Amhara and Central Ethiopia region. These goats are the source of Bati Genuine skin. They are moderately prolific with adult body weight of 30.1 kg (Gizaw, 2009).

2.3 Boer goats

Although the exact origin of Boer goats is not clear, it is believed to be the result of a genetic pooling of African indigenous goats, Jamunapari and Angora goats, and with some influence of European dairy goats (Boer Goat News, 1998). The present day Boer goats appeared in the early 1900's when the Eastern Cape ranchers started selection for a meat type goat (Casey and Van Niekerk, 1988).

There are five types of Boer goats recognized in South Africa according to South African Boer Goat Breeders' Association (http://studbook.co.za/boergoat/stand.html). These are the ordinary Boer goats, the long hair Boer goats, the polled Boer goats, the indigenous Boer goats and the improved Boer goat. The improved Boer goats are the primary line/s which breeders have been selecting for (Boer Goat News, 1998).

Boer goats are considered to be one of the most desirable mutton type breeds globally with the highest mature weight of (100-110 kg). It has been reported that the Boer goats can improve productive performance of many indigenous breeds where the crossbreds have outperformed the native breeds at many aspects (Erasmus, 2000; Lu and Potchoiba, 1988; Casey and Van Niekerk, 1988; Lu, 1989). The traits which showed significant improvement among the crossbreds were birth weight, and growth related traits (weaning weight, weight at mating, mature body weight), prolificacy and fecundity besides the carcass quality (Cameron *et al*., 2001). Boer doe also reach puberty at an early age (Greyling, 2000).

It has also been reported that the Boer goats are less susceptible to heat stress and tolerate heat better than many of the other temperate goat breeds (Lu, 1989). They are moderately tolerant to drought and tannins, are efficient fiber digesters and they can adapt to various ambient temperature and have lower water turnover rate (Erasmus, 2000). Because of their browsing habit, Boer goats are considered less susceptible to infestation by internal parasites (Casey and Van Niekerk, 1988). Boer goats are thought to have exceptional ability to withstand and resist diseases such as blue tongue, prussic acid poisoning, and enterotoxaemia (http://studbook.co.za/boergoat/value.html).

2.4 Growth performances of kids and body weight changes of the Does

The difference in birth, weaning, six-month and yearling weights of different breeds are presented in Table 1. From the presented values it is observed that the traits are influenced by both genotype of the animals and the environment where they are reared. Studies by Abd-Allah *et al.* (2015) concluded that the lower body weight of Baladi kid was correlated with the weight of the does at mating. Weight of the dam also correlates with the birth weight of kids. The differences in birth weight between kids born could be the results of maternal nutrition (high and low nutrients available for the foetus (Abd-Allah *et al.* 2015).

Table 1: Average live body weights at different ages of different breeds in different locations

Different weights in kg.				Breed	Location	Source
BW	WW	6mW	YW			
3.48±0.04				Boer	Croatia	Đuričić *et al.* (2012)
3.08	12.84	16.43	35.27	Boer	Egypt	Abd-Allah *et al*. (2015)
3.78±0.03	10.57±0.11	17.02±0.25	32.01±0.95	Ettawa		Hasan *et al*. (2014)
1.49±0.13				Black Bengal	Bangladesh	Faruque, (2010)
2.0	10.7	16.0	24.2	Zaraibi		Shaat *et al*. (2007)
1.94	8.54	11.41	22.28	Baladi	Egypt	Abd-Allah *et al*. (2015)
3.06	12.91			Saanen	Turkey	Ince, (2010)
2.84±0.08	21.10±0.72			Boer xArsi Bale	Ethiopia	Debele *et al.* (2015)
2.68±0.02	9.82±0.17	13.54±0.20	19.53±0.38	Boer x CHG		Deribe *et al.* (2015)
2.01±0.03	9.02±0.18		20.61±0.74	CHG		Derib and Taye (2013)
2.89±0.38	10.39±1.86	13.90±2.19	19.05±3.51	Boer x WG25%		Girma *et al.* (2016)
2.60±0.02	9.63			Boer x CHG		Zeleke *et al.* (2017)
1.91±0.06				Boer x Mubende	Uganda	Ssewannyana, *et al.* (2004)
2.06±0.08				Boer x Mubende(75%)		
1.98±0.05				Mubende		
2.01±0.05				Boer x Teso		
1.74±0.11				Boer x Teso (75%)		
1.54±0.07				Teso		
2.33	10.64			Raini Cashmere	Iran	Arsalan *et al* (2012)
3.87±0.85				Boer	China	Zhang *et al.* (2008)

BW = birth weight, WW = weaning weight, 6mW = six month weight, YW = yearling weight, CHG = Central Highland Goat, WG =Woitu Giji

Average pre-weaning daily weight gain of Boer x Arsi-Bale kids (Table 2) (Debele *et al.*, 2015) were higher than the values from the other kid breeds including those from Boer and Baladi kids (Abd-Allah *et al*., 2015). The findings indicate that the weight gain of the Boer goats at an early stage of life was slower which may also be attributed to genotype by environment interaction. The differences in pre-weaning daily weight gain can be closely associated with level of milk intake (of the kids) during the weaning period (Abd-Allah *et al*., 2015). Provision of improved feeding system during late pregnancy and lactation period might increase the growth performance of kids at foetal and pre weaning stage.

Table 2: Average live body weight gains at different ages of different breeds in different locations

Different weights gains in g.			Breed	Location	Source
PrWADWG	W-6mADWG	6m-YADWG			
80.45	69.54	104.66	Boer	Egypt	Abd-Allah *et al*. (2015)
96.8	60.0		Zaraibi		Shaat *et al*. (2007)
56.45	43.63	60.00	Baladi	Egypt	Abd-Allah *et al*. (2015)
175.83 ± 6.0			Boer x Arsi Bale	Dilla	Debele *et al.* (2015)
78.67±1.53	37.27±1.85		Boer x CHG	Sirinka	Derib *et al.* (2015)
76.6±2.3			CHG	Sekota	Deribe and Taye (2013)
88.00			Raini Cashmere	Iran	Arsalan *et al.* (2012)
77.4±1.6			Boer x CHG	Sirinka, Ethiopia	Zeleke *et al.* (2017)

PrWADWG = pre-weaning average daily weight gain, W-6mADWG = weaning to six month average daily weight gain, 6m-YADWG = six month to yearling average daily weight gain CHG= Central Highland Goats

Factors such as weaning age, weaning stress and compensatory growth can influence the growth rate at the subsequent stages. At Post-weaning, kids of different groups lose weight as a result of weaning stress. This trait too is influenced by both genotype and environment especially during the period just after weaning (Lu and Potchoiba, 1988).

Findings of a study by Abd-Allah *et al*. (2015) indicated that there is a surge in daily weight gain after overcoming the weaning stress. The weight gain varies across the breeds and the interaction of the genotype with those of the environment where the animals were reared.

Body weight of the does at different physiological stages is presented in Table 3. The enhancement of body weight of the does are correlated with the advancement of the gestation period. This trait too varies across the breeds/ genotypes. The differences in weight may also be attributed to the development of the foetus and embryonic fluids (Abd-Allah *et al.*, 2015).

Table 3: Body weight of does at different physiological stages

Body weights of does in kg.		Breed	Location	Source
At breeding	At kidding			
31.5	36.16	Boer	Egypt	Abd-Allah *et al.* 2015
24.10	28.55	Baladi	Egypt	Abd-Allah *et al.* 2015
	45.6	Boer	Tennessee, USA	Richard & Maria, 2009
	46.6	Kiko		
	42.1	Spanish		

2.4 Reproductive performances

Fertility (percent of does kidding/ does joined) among different breeds of does reared at different locations are presented in Table 4. The results as indicated show that the highest fertility was reported by Đuričić *et al*. (2012) among the Boer does reared at Croatia. While the study by Ince (2010) indicated that the infertility rate was 11.5% among the Saanen does of two-year old group while it was 0.09% among the does aged five-year or older. This differences in fertility might be attributed to differences in hormone concentration besides other physiological factors which also vary across the races and on other non-genetic factors.

Table 4: Fertility, Litter size at birth, litter weight at birth and litter size at weaning.

Reproductive traits				Breed	Location	Source
% F	LSB	LWB	LSW			
93.4				Boer	Croatia	Đuričić *et al*. 2012
60	1.66		1.33	Boer	Egypt	Abd-Allah *et al*. 2015
	1.94± 0.1			Black Bengal	Bangladesh	Faruque, 2010
80	1.75		1.25	Baladi	Egypt	Abd-Allah *et al*. 2015
	1.83±0.04	5.78±0.12		Boer	Tennessee,	Richard & Maria,
	1.84±0.04	5.63±0.12		Kiko	USA	2009
	1.95±0.04	6.01±0.13		Spanish		
	1.16±0.04			CHG	Sekota	Taye *et al.* 2013
	2.09			Boer	South Africa	Erasmus, 2000
	1.76±0.67	6.54±2.51	1.62±0.62	Boer	China	Zhang *et al*. 2009
	1.75±0.02			CHG	Sirinka,	Zeleke *et al.* 2017
	1.62±0.03			Boer x CHG	Ethiopia	

F= Fertility ,LSB = litter size at birth, LWB = litter weight at birth, LSW = litter size at weaning, TWR = twinning rate

The largest average litter size at birth were reported 2.09 by Erasmus, (2000) among the Boer does raised in South Africa while it was lower,1.62±0.03 among the Boer x CHG does reared in Ethiopia(Zeleke *et al.*, 2017). The fertility of the does are fallout of both genetic and non-genetic factors. Among the non-genetic factors the amount of nutrition received by the dam correlates with the litter size at birth and also at weaning (Abd-Allah *et al.*, 2015).

2.5 Survivability

Mortality among the kids is highly correlated with the weight of the dam at kidding. Finding of a study by Chowdhury *et al.*(2002) on Black Bengal does have indicated that the kid mortality was highest (87%) among the dams weighing less than 10 kg which decreased exponentially with the increase in dam`s weight. Mortality rate of kids from birth to weaning and weaning to yearling were 20% and 12.5% in Boer goats while for the Baladi goats reared in Egypt the corresponding figure were 28.57% & 20% respectively (Abd-Allah *et al*., 2015). In the study by Ince (2010) in Saanen goats in Turkey; the survival rate of the kids were assessed to be 79%.

Losses in the pre-weaning period can be minimized by improving the management of the kids and selecting the does for maternal traits and as survivability is a lowly heritable trait then improvement through selection is not quite possible in the real sense (Abd-Allah *et al*., 2015).

2.6 Genetic parameter estimates

2.6.1 Heritability

Heritability estimates correlate the genetic similarity between the parents and the offspring's. The heritability values can be grouped into (low, moderate or high) which vary across the traits and also are grossly influenced by environmental factors which in turn influence the phenotypic variance of the trait in question. Studies by Pirchner, (1983) indicate that growth traits are moderately heritable while the reproduction and survival traits are grossly influenced by the environmental factors and hence lowly heritable.

The highest heritability estimates for birth weight (among the kids) were reported by Hasan *et al*. (2014) in Ettawa Grade Goats (Table 5) while the lowest values were reported by Thiruvenkadan (2009) in Tellicherry goats. Studies by Otuma and Onu, (2013) concluded that the traits is moderately heritable.

The heritability estimates for weaning weight of Boer goats ranged between 0.04 ± 0.01and 0.35 ± 0.07 (Table 5). The studies indicate that the trait is influenced by non-genetic factors too and therefore can be improved through management and selection alike.

Table 5: Heritability estimate of different growth traits, litter size, pre and post-weaning weight gains

Heritability estimate				Breed	Location	Source
BW	WW	6MW	YW			
0.36	0.60		0.36	Boer	Namibia	ELS, (1998/1999)
		0.19± 0.42	0.12± 0.01	Teddy	Pakistan	Kuthu *et al.* (2015)
0.18 ± 0.04	0.19 ± 0.05			Boer	South Africa	Van Niekerk *et al.* (1996)
0.47 ± 0.12	0.04 ± 0.01			WADG	Maidug uri	Alade *et al*. (2010)
0.41 ± 0.03			0.41 ± 0.03	NCBG	Nigeria	Otuma and Onu. (2013)
0.24		0.31		Boer	South Africa	King, (2009)
0.54 ± 0.12	0.35 ± 0.07	0.37 ± 0.09	0.68 ± 0.16	Ettawa		Hasan *et al*. (2014)
0.21	0.16			Zaraibi		Shaat *et al*. (2007)
0.06 ± 0.07	0.34 ± 0.16			Tellicherry	India	Thiruvenkadan, (2009)
0.12±0.05	0.08±0.06			Raini Cashmere	Iran	Arsalan *et al.* (2012)

BW = birth weight, WW = weaning weight, 6MW = six month weight, YW = yearling weight, NCBG = Nigerian crossbred goats, WADG = West African dwarf goats, Findings of a study by Meyer, (1992) indicated that the models not accounting for maternal genetic effects could result in substantially higher estimates of additive direct genetic variance and, therefore, overestimating the estimates of h^2. The highest heritability estimate for six month weight were reported by Hasan *et al.* (2014) in Ettawa grade goats.The heritability estimates of yearling weight (Table 5) varied between 0.12 ± 0.01 (Kuthu *et al.,* 2015) and 0.68 ± 0.16 (Hasan *et al.,* 2014), indicating that the traits is also influenced by non-genetic factors and therefore selection for the trait may be helpful at least to a certain extent.

2.6.2 Genetic correlation

Estimating genetic correlation is important in such a way that to know which traits are highly correlated with the important traits of interest; to select animals for the traits of interest based on other traits (Falconer, 1989). Traits can be genetically correlated by the means of two ways which are pleiotropism and linkage. Pleiotropism brings genetic correlations when one gene affects or is responsible for many traits, while linkage shows genetic correlations due to the close association of two genes which are responsible for two or many traits (Falconer, 1989).

The correlation values indicated that the live body weights at different ages (Table 6) was moderate to high genetic correlation. The results therefore indicate that selection carried out at an early stage of life can often result in animals with high body weight at yearling age (King, 2009; Otuma and Onu 2013; Shaat *et al.,* 2007; Thiruvenkadan, 2009).

Table 6: Genetic correlation estimates between body weights traits at different ages.

Genetic correlation estimates between						Breed	Location	Source
BW & WW	BW & 6mW	BW & YW	WW & 6mW	WW & YW	6mW &YW			
		0.81				NCBG	Nigeria	Otuma and Onu. (2013)
0.42	0.47	0.62	0.77	0.82	0.77	Zaraibi		Shaat *et al*. (2007)
0.36 ± 0.18						Boer	South Africa	Van Niekerk *et al.* (1996)
0.37						WADG	Maiduguri	Alade *et al*. (2010)
0.69 ± 0.53	0.38 ± 0.42	0.08 ± 0.36	0.82 ± 0.11	0.88 ± 0.24	0.89 ± 0.14	Tellicherry	India	Thiruvenkadan, (2009)
0.35	0.04	0.03	0.64	0.71	0.76	Ettawa		Hasan *et al*. (2014)
			0.89			Boer	South Africa	King, (2009)
					0.64	Teddy	Pakistan	Kuthu *et al.* (2015)
0.55±0.05						Raini Cashmere	Iran	Arsalan *et al.* (2012)

BW = birth weight, WW = weaning weight, 6mW = six month weight, YW = yearling weight, NCBG = Nigerian crossbred goats, WADG = West African dwarf goats.

The results therefore indicate that the kids with higher early age body weights may not be those with higher later age body weights as the non-genetic factor have important role to play in this regard and can be improved through management alongside selection (Al-Najjar *et al.*, 2010).

2.7 Non genetic Factors influencing the growth traits

2.7.1 Year and season of birth

Year and season of birth had a significant effect on birth weight, weaning weight, six month weight, yearling weight, pre-weaning average daily weight gain, post-weaning average daily weight gain and kid mortality rate at birth (Al-Najjar *et al.*, 2010; Hasan *et al.*, 2014; King, 2009; Thiruvenkadan, 2009), while it had no significant effect on mortality from birth to weaning and litter size (Al-Najjar *et al.*, 2010; Faruque, 2010; Andries, 2013)

The variation in the weight across different years and seasons may be due to differences in management at the farm, availability of feed, prevalence of diseases and parasites (Gunawan and Noor 2006; King, 2009, Al-Najjar *et al.*, 2010, Hasan *et al.*, 2014).The variations in weights (due to season of birth) can be associated with variations for rainfall that in turn affects pasture production and feed availability (Al-Shorepy *et al.*, 2002; Otuma and Onu 2013). However, finding of a study by Hasan *et al.* (2014) indicate that among the Ettawa Grade goats, kids born during the dry season were always heavier and perform better when compared to those born during the rainy season. This variations in body weight as observed may be ascribed to the availability of pastures to the pregnant dams (Hasan *et al.* 2014).

2.7.2 Parity and age of dam

Parity had a significant effect on the birth weight, weaning weight, six month weight, yearling weight, pre-weaning average daily weight gain, doe weight after kidding, litter size, litter weight, mortality rates at birth and from birth to weaning (Hoque *et al.*, 2002;Otumaand Onu2013;Hasan *et al.*, 2014;Thiruvenkadan, 2009;Al-Najjar *et al.*, 2010).The studies also show that parity had no significant effect on birth weight and growth and daily weight gain of goats of all age categories (Alemu, 2015;Faruque, 2010).

The average weaning weight and post-weaning weight increased with the increase in age (1-3 years) of the dam. This may be due to differences in maternal effects, nursing and maternal behaviour of dam in different ages (King, 2009). The differences in mortality of the kids might be due to the maternal instincts and lactal secretions of the does (Al-Najjar *et al.,* 2010). The parity of dam may influence her uterine development but as the numbers of parity increase (>4) the survivability of the kids may be compromised as the lactation yield decreases (Zhang *et al.,* 2009).

2.7.3 Kid sex and type of birth

Some authors reported that sex of the kids and type of birth had a significant effect on birth weight,weaning weight,six month weight, yearling weight,pre-weaning average daily weight gain and survivability (Alemu, 2015; Andries, 2013; Đuricić *et al.,* 2012; Hasan *et al.,* 2014;Ince, 2010;Thiruvenkadan, 2009). Contrary to the same it was also reported that sex of the kids and type of birth had no significant effect on birth weight, mortality rates from birth to weaning (Al-Najjar *et al.,* 2010; Faruque, 2010).

The effect of sex of the kid might be attributed to differences in physiological processes in the two sexes. The sexual dimorphism of the kids may be ascribed to the differences in the endocrine system of the two sexes where estrogen hormone has a limited effect for growth in females. That was one reason why females have smaller body when compared to the males (Baneh and Hafezian, 2009).

Effect of type of birth might be attributed due to the competition for uterine space and foetal nutrition, especially at the last trimester of pregnancy. This is followed by the competition of the kids for suckling till the weaning age (Al-Shorepy *et al.*, 2002).

The enhancement in mortality rates at birth among the kids born as single may be due to dystocia, as heavier kids usually succumb to such problems. The mortality rate of the kids born as multiple births may be attributed to low birth weight and/or due to poor nursing of the dam. It may also be due to improper management practices (Al-Najjar *et al.*, 2010). Animals with low birth weights usually have lower energy reserves and were therefore less able to withstand harsh environments. Growth advantage of single in early period might result from its lower competition for nutrition supply of dam in gestation period than the multiple birth ones (Zhang *et al.*, 2009).

3. Materials and Methods

3.1. Location of the study area

The study was conducted on-station at Ataye site of Debre-Birhan Agricultural Research Center, North Shoa zone, Ethiopia which is located at 285 km North of Addis Ababa along the way to Dessie. The geographical location of the area is 1491 m above sea level, 10^o 35$^'$ N latitude and 39^o 93'E longitude. The climate of the area is warm with annual minimum and maximum temperatures of 12.6 °C and 30.1°C respectively. The area receives an average annual rain fall of 969.3 mm. The dominant soil type of the area is deep, clay with shallow water table in low lying areas (Girma & Desta, 2007).

The research site is located 3 km from Ataye town towards Dessie. The barn for the goats is constructed in a mountainous area using corrugated iron sheet in the four sides and the roof. Based on the rainfall pattern and green feed availability, the season of the study area is divided in to two; wet and dry season. Months within the wet season are March, April, July, August, September and October while January, February, May, June, November and December are in the dry season (Girma & Desta, 2007).

3.2. Study population

Presently the Ataye site houses several genotypes of the goats viz Boer and Central Highland Goats and their crosses. The kids available at the location include Boer kids, F_1 kids (Boer x CHG), F_2 kids (F1 x F1) and 75: 25 % Boer: CHG kids (Boer x F_1). The Boer goats were imported from South Africa and quarantined at Sebeta before transported to the research station. The Central Highland goats were bought from the local market available around the site and quarantined at Debre-Birhan and Ataye respectively.

3.2.1. Feeding, watering and health care management

The Boer goats

Most of the time the Boer goats and their crossbred kids were kept in-door being offered *ad libitum* grass hay prepared, stored and transported from Debre-Birhan Agricultural Research Center situated 140 km away. Chopped pasture (Napier grass, *Desmodium spp*. and vetch) was also provided fresh to them along with the hay. Commercially prepared concentrate was provided within the range of 300 - 500 g/h/d to the adults and 100 – 200 g/h/d to the kids (based on their body weight and the feed availability across the year), the feed was offered twice a day in the morning and in the afternoon. Fetched water (from a nearby river) was provided twice a day to the Boer goats.

The Central Highland Goats

The Central Highland Goats were allowed to browse twice during the day time in the morning and afternoon. Commercial concentrate was also provided @ 200-300 g/h/d once in the afternoon (the amount was calculated based on their body weight), in the evening the goats were provided (with grass hay) at dusk prior to being housed in the barns. These goats walked to the nearby river (twice a day) to quench their thirst. The health care of the goats were ensured by a qualified veterinarian who provided strategic deworming and regular follow-up of treatments on case to case basis. The goats and the barns were regularly sprayed with acaricides so as to make them free from external parasites.

3.2.2 Mating plan

The mating plan was carried out as recommended by the strategic plan of DBARC. The bucks were selected for joining the does for breeding purpose and the does which were considered pregnant were regularly taken away to a separate pen, while those which were still barren were still allowed to be joined with the buck. The mating was so ensured to minimise inbreeding among the flocks. The average buck to doe ratio was 1:20/25, the breeding (pure and crossbreeding) were arranged in separate pens In the crossbreeding scheme one buck was allowed to join 20-25 does for a period of one to three months, during which it was considered that all the does were covered. In order to ensure optimum conception sometimes the bucks joined the does even till five months, this however depended on the libido of the bucks. Based on the period of joining and covering of the does the period were categorised into short mating (less than one month), medium (one to three months) and long (prolonged over three months).

Pre-mating weights (weight of the does prior to joining the buck) were also categorized as suggested by Delgadillo *et al.* (1999). During the period of the study the average pre-mating weight of the does (Mean± SD) was recorded to be 26 ± 6 Kg. Thus, based on the body weight the does were blocked in three categories viz. light (below 20 kg), average (20.1 – 30 kg) and heavy (above ≥30 kg).

3.3 Data collection

The study was carried out on the secondary data collected encompassing 2012 till 2017. Data on body weights were recorded in the morning prior to grazing and watering. The recorded data pertained to the growth performance (birth weight, weaning weight, six month weight and yearling weight), reproductive performance (litter size at birth, litter weight at birth, post-partum weight, litter size at weaning, litter weight at weaning, conception rate, kidding rate, fertility rate, abortion rate and stillbirth rate) and survivability (number of days survived, date of mortality and status of the kids) traits.

Kids were also categorised into those born as single, twins or triplets. However, as the sample size was limited the type of birth were broadly classified as those born single and multiple. Similarly the parity of the does too were categorized as 1^{st}, 2^{nd}, 3^{rd} and $\geq 4^{th}$. Parities above 4^{th} were merged together.

Growth performances of Boer, F_1, F_2 and 75 %.

- Birth weight: weight of the kid taken within 24 hours of kidding
- Weaning weight: weight of the kid @ 90 days of age
- Six month weight: weight of the kid @ 180 days of age
- Yearling weight: weight of the kid @ 365 days of age

Reproductive performances of Boer, CHG and crossbreds 50%_F1

- Litter size at birth: Numbers of kids born /doe
- Litter weight at birth: weight of kids born /doe
- Pre-mating weight: weight of the doe just before joining the buck
- Post-partum weight: weight of the doe after kidding (taken within 24 hours of kidding)
- Litter size at weaning: number of kids reached weaning age per doe
- Litter weight at weaning: weight of all the litter mates at weaning
- Conception rate: number of does conceived / number of does joined
- Kidding rate: number of live kids born / number of does conceived

- Abortion rate: numbers of abortions / number of does conceived

Survivability traits (of Boer, crossbreds 50 %_F1, F2 and 75%)

- Number of days survived: Numbers of days alive after kidding
- Survival status of the goats: live/died kid/s at a particular period of time

3.4 Statistical analysis

The data on growth and reproductive performances were analyzed using the GLM procedure of SAS 9.0 software. Means were compared using Tukey-Kramer (SAS, 2002). Some of the reproductive traits (conception, kidding and abortion rate) were analyzed using the non-parametric test procedure of SAS 9.0 (SAS, 2002). Means were compared using the chi square procedure of SAS 9.0 (SAS, 2002).

The genetic parameter estimates (heritability, genetic and phenotypic correlation and breeding value estimates (BVE)) of the growth traits were analyzed using WOMBAT: a program for mixed model analyses by restricted maximum likelihood (REML) procedure by fitting an Individual Animal Model (Meyer, 2006; Meyer, 2012 and Wilson et al., 2010).

- The genetic parameters were estimated using the paternal half sib model with the following formulas.

$$h^2 = \frac{V_A}{V_P}$$

Where

- h^2 = heritability
- V_A = additive genetic variance
- V_P = total phenotypic variance

$$r_{G(1,2)} = \frac{COV_{(1,2)}}{\sqrt{\sigma_1^2 * \sigma_2^2}}$$

Where

- $\mathrm{r}_{\mathrm{G}(1,2)}$ is genetic correlations between trait 1 and 2.
- $COV_{(1,2)}$is the covariance between the two traits.
- $\sigma_1^2$is the variance of trait 1.
- $\sigma_2^2$is the variance of trait 2.

$$r_{P(1,2)} = r_{G(1,2)} + r_{E(1,2)}$$

Where

- $r_{P(1,2)}$is the phenotypic correlation between traits 1 and 2.
- $r_{G(1,2)}$is the genetic correlation between traits 1 and 2.
- $r_{E(1,2)}$ is the environmental correlations between traits 1 and 2.

$$EBV_i = h_i^2 * (P_i - \rho_i)$$

Where

- EBV_iisthe estimated breeding value for a given trait
- $h_i^2$is the heritability value for a given trait
- $P_i$is average performance of the kids of a said buck for a given trait
- $\rho_i$is average performance of all the kids born from all the bucks included in the population for a given trait

❖ NB: some of the kids were full-sibs while some were half-sibs, V_A was estimated accordingly by the software.

The data on the survivability at different ages (survival at the fourth day, at weaning, at six month and at yearling) were analyzed using the WEIBULL® proportional hazard model using survival kit version 6.0 (Ducrocq *et al.*, 2010). Similar to the reproductive analysis means were compared using the chi square procedure of SAS 9.0 (SAS, 2002).

The collected data on the growth performances (body weight traits) were adjusted using the following formula.

$$ADJWWT = \frac{90(W2 - BW)}{D} + BW$$

$$ADJ6MWT = \frac{180(W3 - BW)}{E} + BW$$

$$ADJYWT = \frac{90(W4 - BW)}{F} + BW$$

$$PrWADWG = \frac{ADJWWT - BW}{90}$$

$$W - 6MADWG \ = \frac{ADJ6MWT - ADJWWT}{90}$$

$$6M - YADWG \ = \frac{ADJYWT - ADJ6MWT}{180}$$

Where;

BW= Birth weight

ADJWWT = Adjusted weaning weight

ADJ6MWT= Adjusted six month weight

ADJYWT=adjusted yearling weight

PrWADWG= Pre-weaning average daily weight gain

W-6MADWG= Weaning to six month average daily weight gain

6M-YADWG = Six month to yearling average daily weight gain

W2= Weight at given age D (D = weaning age)

W3= Weight at given age E (E = six months weight)

W4= Weight at given age F (F = yearling age)

3.4.1 Statistical model

Several statistical models were used for analyzing the data on the growth, reproductive and survivability performances of the studied genotypes. Details on each models used are as follows.

The data on growth performances of the kids (birth weight, weaning weight, six month weight, yearling weight and average daily weight gains at different ages) were analyzed using the following model

Model: $Y_{ijklmn} = \mu + A_i + B_j + C_k + D_l + E_m + F_n + e_{ijklmn}$

Where;

- Y_{ijklm} is an observation
- μ is the overall mean
- A_i is the fixed effect of the i^{th} **sex** (i = male or female)
- B_j is the fixed effect of the j^{th} genotype of the **kid** (j = **B**oer, Boer 50%_F_1, Boer 50%_F_2 or Boer 75%)
- C_k is the fixed effect of the k^{th} parity of the **doe** (k= 1^{st}, 2^{nd}, 3^{rd} or 4^{th} and above parities).

- D_l is the fixed effect of the l^{th} **type of birth** (l= single or multiple)
- E_m is the fixed effect of the m^{th} **year of birth** (m = 2012, 2013, 2014, 2015, 2016 or 2017)
- Fn is the fixed effect of the n^{th} **season of birth** (n = Wet season (Mar, Apr, Jul, Aug, Sep & Oct), Dry season (Jan, Feb, May, Jun, Nov & Dec)
- e_{ijklmn} is the random error attributed to the n^{th} kid.

The data on reproductive performances of the does (conception rate, kidding rate and abortion rate) were analyzed using the following model

Model: $Y_{ijklm} = \mu + A_i + B_j + C_k + D_l + E_m + e_{ijklm}$

Where;

- Y_{ijklm} is an observation
- μ is the overall mean
- A_i is the fixed effect of the i^{th} genotype of the **doe** (i = Boer, CHG or Boer 50%_F1)
- B_j is the fixed effect of the j^{th} year of **mating** (j =2012,2013,2014,2015 or 2016)
- C_k is the fixed effect of the k^{th} season of **mating** (k= Wet season (Mar, Apr, Jul, Aug, Sep & Oct), Dry season (Jan, Feb, May, Jun, Nov & Dec).
- D_l is the fixed effect of the l^{th} **length of joining of the does to the bucks**(l= short (<1 month), medium (1 – 3 months) or long (>3 months)
- E_m is the fixed effect body weight of the doe at joining the bucks (m=1= (≤20 kg), 2= (20.1 – 30 kg) or 3= (>30 kg))
- e_{ijklm} is the random error attributed to the n^{th} kid.

The data on reproductive performances of the does (litter size at birth, litter size at weaning, litter weight at birth and litter weight at weaning) were analyzed using the following model

Model: $Y_{ijklm} = \mu + A_i + B_j + C_k + D_l + E_m + e_{ijklm}$

Where

- Y_{ijklm} is an observation
- μ is the overall mean
- A_i is the fixed effect of the i^{th} genotype of the **doe** (i = Boer, CHG or Boer 50%_F1)
- B_j is the fixed effect of the j^{th} **type of birth** (j = single or multiple)
- C_k is the fixed effect of the k^{th} parity of the **doe** (k=1st, 2nd, 3rd or 4th & above parities).
- D_l is the fixed effect of the l^{th} **year of kidding** (l= 2012, 2013, 2014, 2015, 2016 or 2017)
- E_m is the fixed effect of the m^{th} **season of kidding** (m = Wet season (Mar, Apr, Jul, Aug, Sep & Oct), Dry season (Jan, Feb, May, Jun, Nov & Dec))
- e_{ijklm} is the random error attributed to the n^{th} kid.

The data on reproductive performances of the does (body weight of does at mating, at kidding and change) were analyzed using the following model

Model: $Y_{ijklm} = \mu + A_i + B_j + C_k + e_{ijklm}$

Where;

- Y_{ijklm} is an observation
- μ is the overall mean

- A_i is the fixed effect of the i^{th} genotype of the **doe** (i = Boer, CHG or Boer 50%_F1)
- B_j is the fixed effect of the j^{th} year of **mating** (j =2012,2013,2014,2015 or 2016)
- C_k is the fixed effect of the k^{th} season of **mating** (k= Wet season (Mar, Apr, Jul, Aug, Sep & Oct), Dry season (Jan, Feb, May, Jun, Nov & Dec)).
- e_{ijklm} is the random error attributed to the n^{th} kid.

The genetic parameters and breeding values were estimated using the following model

Model: $Y_{ijklmnopq} = \mu + B_j + C_k + D_l + E_m + F_n + W_{q\,(op)} + X_r + e_{ijklmn}$

Where;

- $Y_{ijklmnopq}$ is an observation
- μ is the overall mean
- B_j is the fixed effect of the j^{th} **sex** (j= male or female)
- C_k is the fixed effect of the k^{th} **type of birth** (k= single or multiple).
- D_l is the fixed effect of the **l^{th} parity of the doe** (l=1^{st}, 2^{nd}, 3^{rd} or 4^{th} & above parities)
- E_m is the fixed effect of the m^{th}**year of birth** (m = 2012, 2013, 2014, 2015, 2016 or 2017)
- Fn is the fixed effect of the n^{th}**season of birth** (n = Wet season (Mar, Apr, Jul, Aug, Sep & Oct), Dry season (Jan, Feb, May, Jun, Nov & Dec))
- $W_{q\,(op)}$ is the random effect of the k^{th} kid within the op^{th} family
- X_r is the covariate effect of the r^{th} doe PPWT
- $e_{ijklmnopq}$ is the random error attributed to the n^{th} kid.

Note: -1. Genetic parameters were estimated separately for the pure and cross-breeding.

2. Effects of sires and dams were ignored/ not considered for the genetic parameter estimates.

The data on survivability performances of the kids (survival at the fourth day, at weaning, at six month and at yearling) were analyzed using the following model

Model: $\lambda(t) = \lambda_0(t) \exp(A_i + B_j + C_k + D_l + E_m + F_n)$ Where;

- $\lambda(t)$ is the hazard function (probability of a kid being died) at time t
- $\lambda_0(t)$ is the baseline hazard function which is assumed to follow the WEIBULL distribution
- A_i is the fixed effect of i^{th} **genotype of the kid** (i = Boer, F1(Boer x CHG), Boer 50%_F2 or Boer 75%)
- B_j is the fixed effect of j^{th} **sex** (j = male or female)
- C_k is the fixed effect of k^{th} **type of birth** (k= single or multiple).
- D_l is the fixed effect of l^{th} **parity of the doe** (l=1st, 2nd, 3rd or 4th & above parities)
- E_m is the fixed effect of m^{th}**year of birth** (m = 2012, 2013, 2014, 2015, 2016 or 2017)
- Fn is the fixed effect of n^{th}**season of birth** (n = Wet season (Mar, Apr, Jul, Aug, Sep & Oct), Dry season (Jan, Feb, May, Jun, Nov & Dec))

4. Results

4.1 Growth performances

The results pertaining to the effects of genotypes, sex, parity of the doe, type of birth, year and season of birth on growth performances of Boer goats and their crosses with CHG (F_{1}, $F_{2(a)}$ and backcross $F_{2(b)}$ are presented in Table 7 and 8.

The results indicate that buckling had higher ($P<0.01$) weight at birth, six months and yearling when compared to the doeling. The results also indicated that the Boer kids had higher ($P<0.0001$) weight at birth, at weaning and at 6 months of age ($P<0.05$). During the same period the kids of $F_{2(b)}$ crosses followed the Boer observation at the birth and weaning weight, while the F1 crosses performed better at six months of age. There were no differences across the parities for the traits included in the study. The results further indicated that kids born single weighed more than those from multiple births. The effect of year too was ($P<0.0001$) on the studied traits, with higher birth and weaning weights recorded among the kids born in 2017 while those born in 2016 had highest six months body weight and yearling weight (this is because of non-availability of the data for 2017). Furthermore the season of birth too influenced ($P<0.0001$) most of the studied traits with kids born in the wet season weighing the heaviest and so were they at the weaning weight.

Table 7: Least squares means and standard errors of body weight from birth to yearling of Boer goat and its crosses with CHG

Source of Variation	Birth weight (kg)		Weaning weight (kg)		Six month weight (kg)		Yearling weight (kg)	
	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE
Overall mean	512	2.68±0.04	254	9.11±0.19	197	11.69±0.26	162	16.41±0.38
CV (%)	512	23.65	254	25.99		25.41		25.08
Kid Sex		**		**NS**		**		**
Male	252	2.86±0.07[a]	125	9.45±0.35	95	11.34±0.63[a]	74	17.80±1.03[a]
Female	260	2.69±0.07[b]	129	9.48±0.36	102	9.86±0.62[b]	88	15.41±1.00[b]
Kid Breed		***		***		*		**NS**
Boer	128	3.05±0.06[a]	57	10.87±0.36[a]	42	12.47±0.51[a]	28	18.30±0.88
F1	315	2.62±0.04[bc]	166	8.80±0.22[b]	141	11.15±0.31[ab]	125	16.73±0.48
F2(a)	44	2.50±0.13[c]	18	8.37±0.74[b]	10	9.14±1.18[b]	6	15.08±2.12
F2(b)	25	2.94±0.15[ab]	13	9.80±0.75[ab]	4	9.64±1.59[ab]	3	16.30±2.51
Doe Parity		**NS**		**NS**		**NS**		**NS**
1st	193	2.66±0.06	98	9.15±0.31	75	10.38±0.53	61	15.46±0.86
2nd	138	2.76±0.07	77	9.27±0.40	62	10.49±0.69	54	17.00±1.08
3rd	98	2.79±0.10	43	9.95±0.52	35	11.20±0.83	26	16.83±1.34
4th&above	83	2.90±0.11	36	9.47±0.58	25	10.33±0.92	21	17.12±1.47
Type of birth		***		***		***		**
Single	227	3.15±0.07[a]	136	10.62±0.34[a]	106	11.95±0.59[a]	89	17.84±0.96[a]
Multiple	285	2.40±0.07[b]	118	8.30±0.38[b]	91	9.25±0.67[b]	73	15.37±1.07[b]
Year of birth		***		***		***		**
2012	90	2.57±0.12[cd]	45	8.09±0.66[c]	39	9.72±0.97[bc]	31	14.21±1.50[b]
2013	28	2.43±0.15[cd]	18	7.43±0.70[c]	16	8.47±1.00[c]	13	15.08±1.56[ab]
2014	68	2.44±0.10[d]	33	6.80±0.56[c]	28	9.07±0.83[c]	20	18.39±1.41[a]
2015	133	3.07±0.08[b]	87	10.18±0.43[b]	74	11.50±0.67[b]	68	16.04±1.08[ab]
2016	105	2.78±0.07[c]	48	11.07±0.41[b]	40	14.25±0.63[a]	30	19.28±1.00[a]
2017	88	3.37±0.08[a]	23	13.18±0.56[a]	-	-	-	-
Season of birth		***		***		**NS**		**NS**
Wet	178	2.97±0.07[a]	84	10.42±0.42[a]	72	11.17±0.67	56	17.43±1.08
Dry	334	2.59±0.07[b]	170	8.50±0.36[b]	125	10.03±0.64	106	15.78±1.05

Values within each sub-class are significantly different at *P<0.05, **P<0.01, ***P<0.0001. F1= (Boer buck x CHG doe), F2 (a) = (50% F1 buck x 50% F1 doe) and F2 (b) = (Boer buck x 50% F1 doe). Wet season= (Mar, Apr, Jul, Aug, Sep and Oct) and Dry season= (Jan, Feb, May, Jun, Nov and Dec).

The results from Table 8 pertain to gain in weight of the buck and doe kids at different stages of their growth. The findings indicate that weight gain to weaning was similar across both the sexes while the buck kids weighed more ($P<0.001$) across the weight gain from weaning to six months of age and also weighed ($P<0.05$) higher six months to yearling. Differences across the genotypes too were observed among the traits where the Boer kids weighed more ($P<0.01$) when compared to their counterparts from other genotypes. The weight of the Boer kids was closely followed by those of $F_{2(b)}$ genotypes. The findings also indicated that the weights from weaning to six months and also from six months to yearling did not vary across the genotypes.

The effect of parity did not influence ($P>0.05$) the weight gains across all the age groups studied. However, the single born kids gained more weight till weaning with no differences recorded thereafter in the trait. The results pertaining to the effect of non-genetic factor's viz. effect of year and season too influenced the traits with higher ($P<0.001$) weight gain (till weaning) was recorded among the kids born in 2017 followed by those born in 2016. The results pertaining to the weight gain, (weaning till six months old) also indicate that the same was highest ($P<0.001$) in the year 2016, while the weight gain from six months to yearling indicate that highest weight gain ($P<0.001$) was recorded among the kids born in 2014, with no differences in weight gain across all the other years.

The results pertaining to the season of birth also indicates that the kids born in wet season gain higher ($P<0.001$) weight till weaning while no differences were observed for the other age groups.

Table 8: Least squares means and standard errors of gain to 90, 90-180 and 180-365 days of Boer and their crosses with CHG (g/d)

Source of Variation	Gain to weaning (g/d)		Gain weaning to six month (g/d)		Gain six month to yearling (g/d)	
	N	LSM±SE	N	LSM±SE	N	LSM±SE
Overall mean	253	69.73±1.89	197	30.48±1.54	162	24.33±1.21
Kid Sex				***		*
Male	124	73.24±3.66	95	30.81±4.02^{a}	74	32.22±3.14^{a}
Female	129	75.42±3.77	102	17.99±4.01^{b}	88	27.58±3.07^{b}
Kid Breed		**				
Boer	57	83.94±3.76^{a}	42	25.57±3.29	28	27.62±2.69
F1	165	67.05±2.26^{b}	141	31.46±2.00	125	28.40±1.46
F2 (a)	18	67.65±7.66^{ab}	10	15.62±7.58	6	33.03±6.49
F3 (b)	13	78.70±7.74^{ab}	4	24.94±10.22	3	30.55±7.69
Doe Parity						*
1st parity	97	71.30±3.23	75	25.84±3.41	61	25.44±2.63^{b}
2nd parity	77	72.03±4.16	62	26.09±4.39	54	32.16±3.31^{a}
3rd Parity	43	80.49±5.32	35	24.70±5.30	26	27.31±4.11^{ab}
4th& above	36	73.51±5.98	25	20.95±5.92	21	34.68±4.51^{a}
Birth type		***				
Single	136	82.80±3.48^{a}	106	25.56±3.76	89	29.72±2.95
Multiple	117	65.86±3.98^{b}	91	23.24±4.29	73	30.07±3.29
Year of Birth		***		***		***
2012	44	63.50±6.84^{cd}	39	21.74±6.21^{b}	31	20.09±4.59^{b}
2013	18	56.40±7.28^{d}	16	13.56±6.41^{b}	13	33.08±4.77^{b}
2014	33	49.48±5.77^{d}	28	25.50±5.31^{b}	20	46.53±4.33^{a}
2015	87	79.88±4.49^{bc}	74	17.50±4.27^{b}	68	24.68±3.30^{b}
2016	48	90.76±4.19^{ab}	40	43.68±4.02^{a}	30	25.12±3.07^{b}
2017	23	105.97±5.80^{a}	-	-	-	-
Season of Birth		**				
Wet	83	83.04±4.34^{a}	72	22.24±4.32	56	31.73
Dry	170	65.63±3.73^{b}	125	26.55±4.14	106	28.07

Values within each sub-class are significantly different at *P<0.05, **P<0.01, ***P<0.0001. F1= (Boer buck x CHG doe), $F_{2\,(a)}$ = (50% F1 buck x 50% F1 doe) and $F_{2\,(b)}$ = (Boer buck x 50% F1 doe). Wet season= (Mar, Apr, Jul, Aug, Sep and Oct) and Dry season= (Jan, Feb, May, Jun, Nov and Dec).

4.2 Reproduction performance

The effects of genotypes, year and season, length of exposure to bucks and weight at mating on conception, kidding and abortion percentages are presented in Table 9.

The findings show that the conception (%) was highest ($p<0.001$) among the F_1 does followed by those among the central highland does (CHG). The kidding (%) was the lowest ($P<0.001$) among the Boer does, while no differences were observed in the other two genotypes, while the reverse was true for the abortion (%).

The effect of year too showed differences ($P<0.001$) in all the traits studied, with the conception (%) being higher during 2016 and 2014, while the lowest conception was recorded in the beginning two years of the project. The results also indicated that the kidding (%) too varied($P<0.001$) across the years studied with more kidding in the year when the conception was the highest, while the trend too was the same for abortion(%) which was lowest in these years (2014,2016) with more numbers of abortions recorded in the year when the project was initiated *i.e.* 2012.

The results also indicated of mating season ($P<0.001$) influenced the conception (%) with higher conception recorded during the wet season. The results pertaining to the length of exposure of the does to the bucks also influenced the traits studied with highest ($P<0.001$) conception and kidding percentages when the does were exposed to the bucks for one to three months (medium duration) while for the abortion (%) the higher ($P<0.001$) rate was observed when does were exposed for a longer duration.

Weight at mating too influenced the kidding (%) with more numbers (P<0.001) kidding recorded among the does with optimum / medium (20> kg to ≤ 30 kg) body weight, while fewer kidding were recorded among the heavier does (>30 kg). The abortion (%) too was highest (P<0.001) among the light weight (≤ 20kg) does while it was least among the does with medium weight.

Table 9: Conception, kidding and abortion percentage of Boer, CHG and their cross F1

Source of Variation	Conception		Kidding		Abortion	
	N	Percentage	N	Percentage	N	Percentage
Overall	488	48.75	376	77.05	100	20.49
Doe Breed		***		***		***
Boer	162	37.41^{c}	95	58.64^{b}	65	40.12^{a}
CHG	261	54.38^{b}	228	87.36^{a}	27	10.34^{b}
F1	65	73.86^{a}	53	81.54^{a}	8	12.31^{b}
Mating Year		***		***		***
2012	129	39.94^{c}	79	61.24^{c}	46	35.66^{a}
2013	86	33.99^{c}	63	73.26^{bc}	23	26.74^{ab}
2014	105	68.18^{a}	93	88.57^{a}	9	8.57^{c}
2015	93	57.41^{b}	73	78.49^{ab}	16	17.20^{bc}
2016	75	68.81^{a}	68	90.67^{a}	6	8.00^{c}
Mating Season		***				
Wet	326	54.61^{a}	255	78.22	64	19.63
Dry	162	40.10^{b}	121	74.69	36	22.22
Length of exposure to breeding bucks		*		***		***
Short	52	43.33^{ab}	37	71.15^{b}	12	23.08^{b}
Medium	287	52.37^{a}	247	86.06^{a}	31	10.80^{c}
Long	149	44.74^{b}	92	61.74^{b}	57	38.26^{a}
Pre-mating weight				***		***
Light	73	41.71	55	75.34^{b}	16	21.92^{a}
Medium	273	49.37	233	85.35^{a}	33	12.09^{c}
Heavy	142	52.01	88	61.97^{c}	51	14.79^{b}

Values within each sub-class are significantly different at *=P<0.05, **P<0.01, ***=P<0.0001.N = number of does. CHG= Central Highland Goats and F1= (Boer buck x CHG doe).Wet season=

(Mar, Apr, Jul, Aug, Sep and Oct) and Dry season= (Jan, Feb, May, Jun, Nov and Dec).Short length of exposure is < 1 month, medium length of exposure is 1 – 3 months and long length of exposure is > 3 months. Light weight at mating is < 20 kg, medium is 20.1 – 30 kg and heavy is >30 kg.

The results pertaining to the effect of genotypes, type of birth, parity, year and season of kidding on litter size and weight are presented in Table 10. The results show that the litter weight at birth and weaning varied across genotypes. Litter weight (at both the stages) were higher (P<0.001 and P<0.01) among the Boer does, with no differences recorded among the other two genotypes. Litter weight at birth was highest (P<0.001) among the kids born as multiple birth, however no differences were recorded in their weaning weight.

Year of birth influenced (P<0.001) the litter size at weaning with higher size recorded in 2013 and 2015, while it was the least in the year 2017.Litter weight at birth too showed differences (P<0.001) across the years with heavier litters born in the year 2015 and 2017. Litter weight of the kids born in 2016 followed by 2015 were highest (P<0.001). The results also show that litter weight at birth and weaning were higher (P<0.01 and <0.05) during the wet season.

Table 10: Litter size and weight at birth and at weaning of Boer, CHG and their cross.

Source of Variation	Litter size				Litter weight			
	At birth		At weaning		At birth		At weaning	
	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE
Overall mean	381	1.40±0.03	381	0.67±0.03	377	3.63±0.07	219	10.68±0.28
CV (%)		3.69		91.97		25.43		34.88
Doe Breed						***		**
Boer	96	1.50±0.01	96	0.60±0.07	96	4.28±0.10[a]	50	12.46±0.61[a]
CHG	230	1.50±0.00	230	0.69±0.05	226	3.62±0.07[b]	141	10.36±0.37[b]
F1	55	1.50±0.01	55	0.72±0.13	55	3.68±0.19[b]	28	10.06±0.95[ab]
Type of birth		***		*		***		
Single	228	1.00±0.00[b]	228	0.59±0.06	226	3.19±0.09[b]	136	10.56±0.46
Multiple	153	2.00±0.00[a]	153	0.75±0.07	55	4.53±0.11[a]	83	11.36±0.56
Doe Parity								
1st	156	1.50±0.01	156	0.68±0.06	154	3.67±0.09	86	11.06±0.49
2nd	102	1.50±0.01	102	0.64±0.07	100	3.74±0.11	64	11.06±0.60
3rd	70	1.50±0.01	70	0.61±0.10	70	3.92±0.15	39	11.08±0.76
4th&above	53	1.50±0.01	53	0.75±0.11	53	4.12±0.17	30	10.63±0.87
Year of kidding				***		***		***
2012	73	1.50±0.01	73	0.61±0.12[ab]	71	3.57±0.18[b]	39	9.01±0.98[c]
2013	24	1.50±0.01	24	0.85±0.15[a]	23	3.39±0.22[b]	16	9.14±1.10[bc]
2014	55	1.50±0.01	55	0.68±0.10[ab]	55	3.53±0.15[b]	31	7.96±0.81[c]
2015	93	1.49±0.01	93	0.92±0.08[a]	92	4.33±0.12[a]	69	12.32±0.66[ab]
2016	72	1.50±0.01	72	0.66±0.08[a]	72	3.64±0.12[b]	42	12.65±0.62[a]
2017	64	1.50±0.01	64	0.30±0.09[b]	64	4.71±0.13[a]	22	14.68±0.93[a]
Season of kidding						**		*
Wet	136	1.50±0.01	136	0.60±0.07	135	4.05±0.11[a]	75	11.90±0.63[a]
Dry	245	1.50±0.01	245	0.74±0.06	242	3.67±0.10[b]	144	10.02±0.50[b]

Values within each sub-class are significantly different at *=P<0.05, **P<0.01, ***=P<0.0001.N = number of does. CHG= Central Highland Goats and F1= (Boer buck x CHG doe). Wet season= (Mar, Apr, Jul, Aug, Sep and Oct) and Dry season= (Jan, Feb, May, Jun, Nov and Dec).

The results pertaining to the effects of genotypes, year of mating and season on mating and kidding weight and the change thereof are presented in Table 11. The Boer does weighed higher (P<0.001) at both mating and kidding with no differences recorded across the other genotypes. The effects of year too was (P<0.001) on the studied traits with values being highest in 2016. However, the effect of season was not significant for the studied traits.

Table 11: Weight at mating andat kidding of Boer, CHG and their cross

		LSM±SE		
Source of variation	N	Body weight at Mating (Kg.)	Body weight at Kidding (Kg.)	Total Change (Kg.)
Over all mean	348	26.52±0.40	28.04±0.39	1.52±0.21
CV		17.13	15.22	
Doe breed		***	***	**NS**
Boer	79	$37.76±0.56^{a}$	$38.96±0.52^{a}$	1.20±0.46
CHG	217	$23.56±0.43^{b}$	$24.45±0.40^{b}$	0.90±0.36
F1	52	$23.04±0.79^{b}$	$25.32±0.74^{b}$	2.29±0.66
Mating year		***	***	**NS**
2012	73	$25.66±0.64^{c}$	$27.46±0.60^{c}$	1.80±0.53
2013	62	$27.59±0.83^{abc}$	$28.08±0.78^{bc}$	0.49±0.69
2014	85	$27.86±0.68^{bc}$	$30.19±0.64^{ab}$	2.33±0.57
2015	67	$28.85±0.68^{ab}$	$30.04±0.64^{ab}$	1.20±0.57
2016	61	$30.63±0.72^{a}$	$32.14±0.68^{a}$	1.50±0.60
Mating season		**NS**	**NS**	**NS**
Wet	234	27.99	29.36±0.45	1.37±0.40
Dry	114	28.24	29.80±0.52	1.56±0.46

Values within each sub-class are significantly different at *=P<0.05, **P<0.01, ***=P<0.0001.N = number of does. CHG= Central Highland Goats and F1= (Boer buck x CHG doe). Wet season= (Mar, Apr, Jul, Aug, Sep and Oct) and Dry season= (Jan, Feb, May, Jun, Nov and Dec).

4.3 Genetic parameter estimates

Heritability, of the body weight traits and their respective standard errors are presented in table 12. Similarly genetic and phenotypic correlations of the growth traits are also presented in Table 13 and 14.

4.3.1 Heritability

Heritability estimates for weight at different ages of Boer bucks indicate that the values for birth weight was higher among the crossbreds when compared to the Boer's. The heritability values for weaning weight was however higher for purebreds than the crossbreds. Similar trend was also observed in the heritability values for six months body weight. However, the reverse was true for the yearling weight.

Table 12: Heritability estimate of the body weight traits along with their respective additive genetic, environmental and phenotypic variances of Boer and crossbreds

Traits	Breed	VA	VE	VP	Heritability
Birth weight	Boer	0.227	0.302	0.529	0.429 ± 0.275
	F1	0.240	0.090	0.330	0.726 ± 0.169
Weaning weight	Boer	5.376	1.537	6.913	0.778 ± 0.502
	F1	2.862	1.403	4.265	0.671 ± 0.272
Six month weight	Boer	9.451	3.124	12.575	0.752 ± 0.518
	F1	5.160	2.821	7.981	0.647 ± 0.268
Yearling weight	Boer	5.005	16.995	22.000	0.227 ± 0.701
	F1	10.587	5.833	16.419	0.645 ± 0.273

F1 = (Boer x CHG), VA= additive genetic variances, VE= environmental variances and VP= phenotypic variances

4.3.2 Genetic and phenotypic correlation

The results pertaining to the genetic and phenotypic correlation between the weights of the Boer goats at different ages are presented in Table 13.

Among the Boer goats yearling weight was highly correlated (genetically) with weight at weaning and six-month. The findings also indicate that weaning weight is highly correlated with six months weight, while birth weight was correlated lower with both the weaning and yearling weights.

Among the Boer goats six-month weight was highly correlated (phenotypically) with weaning and yearling weights. The findings also indicate that weaning weight is highly correlated (phenotypically) with yearling weight, while birth weight was lowly correlated with weaning weight.

Table 13: Genetic correlations below diagonal and phenotypic correlations above diagonal among the body weight traits of Boer goats

Traits	Birth weight	Weaning weight	Six month weight	Yearling weight
Birth weight		0.307 ± 0.157	0.487 ± 0.140	0.471 ± 0.205
Weaning weight	0.225 ± 0.523		0.850 ± 0.066	0.650 ± 0.173
Six month weight	0.525 ± 0.474	0.947 ± 0.178		0.828 ± 0.108
Yearling weight	0.237	1.000	0.951 ± 0.846	

The results pertaining to genetic and phenotypic correlation for F1 crossbreds are presented in Table 14. Among the 50% F_1goatssix-month weight was highly genetically correlated with weaning and yearling weights. The findings also indicate that birth weight is highly correlated with yearling weight, while birth weight was correlated lower with weaning weight.

Similar to the Boer goats, six-month weight was highly phenotypically correlated with weaning and yearling weights among the 50% F_1 goats. The findings also indicate that weaning weight is highly correlated (phenotypically) with yearling weight, while birth weight were lowly correlated with weaning weight.

Table 14: Genetic correlations below diagonal and phenotypic correlations above diagonal among the body weight traits of the cross 50% F1 goats

Traits	Birth weight	Weaning weight	Six month weight	Yearling weight
Birth weight		0.195 ± 0.098	0.271 ± 0.095	0.296 ± 0.095
Weaning weight	0.316 ± 0.272		0.825 ± 0.035	0.692 ± 0.060
Six month weight	0.573 ± 0.245	0.930 ± 0.094		0.842 ± 0.034
Yearling weight	0.693 ± 0.232	0.636 ± 0.218	0.870 ± 0.106	

4.3.3 Sire ranking

The findings of this study as presented in Table 15 shows the sire ranking among the Boer goats (based on the performance of their offspring's) for pure breeding indicated differences across sires for all the traits included in the study. While the EBV of buck number 0269 had the highest for birth weight, the values were higher for buck number PJN 2 for weight at all the other ages. The findings also show that the transmitting ability of the buck KL 13 was the least among all the studied bucks.

Table 15: Sire ranking based on their estimated breeding value (EBV) for the body weight traits at different age stages among the Boer goats

Birth weight		Weaning weight		Six month weight		Yearling weight	
Buck ID	**EBV**	Buck ID	**EBV**	Buck ID	**EBV**	Buck ID	**EBV**
0269	**+0.33**	PJN 2	**+1.36**	PJN 2	**+1.03**	PJN 2	**+1.29**
9082	**+0.08**	JM 4	**+0.65**	0269	**+0.64**	JM 4	**+0.62**
BK 76	**0.00**	BK 76	**0.00**	JM 4	**+0.63**	BK 76	**0.00**
JM 4	**-0.06**	0269	**-0.05**	BK 76	**0.00**	0269	**-0.03**
PJN 2	**-0.25**	9082	**-0.67**	9082	**-0.60**	9082	**-0.64**
KL 13	**-0.38**	KL 13	**-1.89**	KL13	**-3.00**	KL 13	**-1.84**

The results pertaining to the transmissing ability of the bucks used for developing the crossbred kids indicating effects of nicking with the breed of Central Highland Goat does too indicate differences across the sires. The results show the nicking effects of buck 0269 is the highest for the birth weight, while buck 1020 had the highest EBV for weaning and six months body weight. The results also show that the kids with lowest yearling weight were those sired by KL 13.

Table 16: Sire ranking based on their estimated breeding value (EBV) for the body weight traits at different age stages of the cross F1 goats

Birth weight		Weaning weight		Six month weight		Yearling weight	
Buck ID	**EBV**	Buck ID	**EBV**	Buck ID	**EBV**	Buck ID	**EBV**
0269	**+0.47**	1020	**+1.61**	1020	**+1.73**	KL 13	**+2.82**
1095	**+0.32**	BK 52	**+1.08**	BK 52	**+0.95**	1095	**+1.31**
KL 13	**+0.31**	1095	**+0.48**	1095	**+0.92**	1020	**+1.05**
10019	**+0.16**	1047	**+0.45**	KL 13	**+0.74**	0269	**+0.34**
1061	**+0.11**	KL 13	**-0.19**	1047	**+0.16**	BK 52	**+0.30**
1020	**+0.08**	JM 4	**-0.25**	0269	**+0.01**	10019	**-0.08**
ATY 01	**-0.17**	0269	**-0.33**	10019	**-0.61**	ATY 01	**-0.09**
BK 52	**-0.18**	ATY 02	**-0.46**	JM 4	**-0.95**	1047	**-0.44**
1047	**-0.25**	10019	**-0.75**	ATY 02	**-1.08**	1061	**-1.58**
JM 4	**-0.31**	1061	**-0.95**	1061	**-1.21**	ATY 02	**-1.88**
ATY 02	**-0.41**	ATY 01	**-1.35**	ATY 01	**-1.28**	JM 4	**-2.15**

4.4 Kid Survivability

Number of kids and proportion in percentage, mean, minimum and maximum number of days of the censored (survived) and uncensored (failure) records are presented in Table 17. Survival percentages of the kids (due to various genetic and non-genetic factors) across different ages are presented in Table 18. The effect/ risk ratio of genotypes and effects of non-genetic factors (kid sex, type of birth, doe parity, year and season of birth) on the survivability performances of kids at different age stages are also presented in Table 19.

The results as presented in Table 17 the proportion of censored (survived) kids until the fourth day, weaning, six month and yearling the genetic effects decreased as the age progressed whereby the non-genetic factors predominated over the genetic factors.

Table 17: Number of censored and uncensored (failure) records of kids from birth to yearling age

Category	No of kids	Mean	Minimum	Maximum
At 4th day				
Censored	384 (73.99%)	4	4	4
Uncensored	135	1.5	1	3
At weaning				
Censored	278 (53.57%)	90	34	90
Uncensored	241	10.7	1	82
At six month				
Censored	249 (47.98)	180	34	180
Uncensored	270	23.6	1	172
At yearling				
Censored	209 (40.27%)	365	34	365
Uncensored	310	51.5	1	361

The results pertaining to the probability of survivability of the kids at different stages of their growth across genotypes, kid sex, parity, type, year and season of birth are presented in Table 18.

The results indicate that there were differences (P<0.001) across the genotypes with at the 4th day and yearling stages, while at the former the Boer kids had higher survivability followed by those of $F_{2(a)}$ and $F_{2(b)}$. At the yearling stage the F1 yearlings had higher survivability. Differences were however not recorded across sexes of the kids and the parity of the dam for survivability (%) across all the age categories.

The single born kids had a higher (P<0.001) survivability when compared to the multiple born counterparts. The year of birth too influenced (P<0.001) the survivability of the kids, although the results were not consistent. The kids survived better till 4th day in 2012 and 2015, while survivability across all the age groups was higher in 2015. The season of birth only influenced the survivability of the kids at 4th day with the same being higher (P<0.01) among the kids born during the wet season.

Table 18: Chi square probabilities for survival of the kids at different ages

Source of Variation	Survival percentage			
	At 4th day	At weaning	At six month	At yearling
Kid Breed	***			***
Boer	82.17a	55.81	46.51	32.56b
F1	71.03b	53.89	49.22	43.93a
F2(a)	68.18ab	47.73	45.45	38.64ab
F2(b)	80.00ab	48.00	44.00	36.00ab
Kid Sex				
Male	73.05	53.91	48.05	38.28
Female	74.90	53.23	47.91	42.21
Type of Birth	***	***	***	***
Single	82.97a	66.81a	60.26a	51.09a
Multiple	66.90b	43.10b	38.28b	31.72b
Doe Parity				
1st parity	78.68	54.82	47.21	38.58
2nd parity	74.47	55.32	49.65	42.55
3rd Parity	66.33	48.98	45.92	36.73
4th& above	71.08	53.01	49.40	44.58
Year of Birth	***	***	**	**
2012	80.00a	55.79ab	47.37ab	33.68b
2013	75.86ab	62.07ab	55.17ab	44.83ab
2014	75.36ab	47.83b	40.58b	28.99b
2015	84.21a	65.41a	55.64a	51.13a
2016	61.90b	45.71b	44.76ab	35.24b
2017	64.77b	44.32b		
Season of Birth	**			
Wet	80.00a	55.00	49.44	38.89
Dry	70.80b	52.80	47.20	41.00

Values within each sub-class are significantly different at *=P<0.05, **P<0.01, ***=P<0.0001. F1= (Boer buck x CHG doe), F2 (a) = (50% F1 buck x 50% F1 doe) and F2 (b) = (Boer buck x 50% F1 doe). Wet season= (Mar, Apr, Jul, Aug, Sep and Oct) and Dry season= (Jan, Feb, May, Jun, Nov and Dec).

Table 19 presents the Chi square probabilities for survival and risk ratio of the kids at different ages. The results showed that at the 4th day the risk was higher among the F2 (a) kids followed by F1 kids with the lowest risk was recorded among the $F_{2(b)}$ kids. Furthermore, the survivability risk was higher among the F2 (a) kids at all the other age categories (weaning, six months and yearling).

The results also showed that the survivability of the kids (irrespective of sexes) were more or less similar. The results also indicated that the kids born as multiple births had higher risk at all the age categories. The risk was lowest among the kids born from the higher parities and across all the age groups, while the risk at the third parity was slightly higher. Year of birth also influenced the survivability of the kids with those born in 2017 being at a higher risk (at 4th day and weaning), while those born in 2014 had high risk at age six months and yearling. The kids born during the dry season had higher risk at all ages.

Table 19: Chi square probabilities for survival and risk ratio of the kids at different age levels

Source of Variation	At 4th day		At weaning		At six month		At yearling	
	N	Risk ratio	N	Risk ratio	N	Risk ratio	N	Risk ratio
Kid Breed		***						***
Boer	23	1.000	57	1.000	69	1.000	87	1.000
F1	93	1.852	148	1.063	163	0.936	180	0.824
F2(a)	14	1.878	23	1.365	24	1.213	27	1.275
F2(b)	5	0.875	13	1.015	14	0.973	16	1.044
Kid Sex								
Male	69	1.008	118	0.963	133	0.984	158	1.064
Female	66	1.000	123	1.000	137	1.000	152	1.000
Type of Birth		***		***		***		***
Single	39	1.000	76	1.000	91	1.000	112	1.000
Multiple	96	2.651	165	2.499	179	2.289	198	2.101
Doe Parity								
1st parity	42	1.000	89	1.000	104	1.000	121	1.000
2nd parity	36	1.137	63	1.033	71	0.976	81	1.069
3rd Parity	33	1.176	50	1.103	53	1.064	62	1.208
4th& above	24	0.662	39	0.767	42	0.780	46	0.882
Year of Birth		***		***		**		**
2012	19	1.000	42	1.000	50	1.000	63	1.000
2013	7	1.857	11	1.057	13	1.093	16	0.967
2014	17	2.299	36	1.643	41	1.596	49	1.397
2015	21	0.496	46	0.595	59	0.688	65	0.582
2016	40	2.466	57	1.474	58	1.320	68	1.125
2017	31	2.529	49	2.040				
Season of Birth		**						
Wet	36	1.000	81	1.000	91	1.000	110	1.000
Dry	99	2.370	160	1.324	179	1.295	200	1.209

Values within each sub-class are significantly different at *=P<0.05, **P<0.01, ***=P<0.0001. F1= (Boer buck x CHG doe), F2 (a) = (50% F1 buck x 50% F1 doe) and F2 (b) = (Boer buck x 50% F1 doe). Wet season= (Mar, Apr, Jul, Aug, Sep and Oct) and Dry season= (Jan, Feb, May, Jun, Nov and Dec), Kaplan – Maier survivor curve of kids from birth to yearling age is presented as Figure 1. The survivability declined/ decreased rapidly from birth until 20 days age.Thereafter, the survivability showed a stabilising effect (0.40).However the effects of the non-genetic factors influenced the survival of the kids till the studied age.

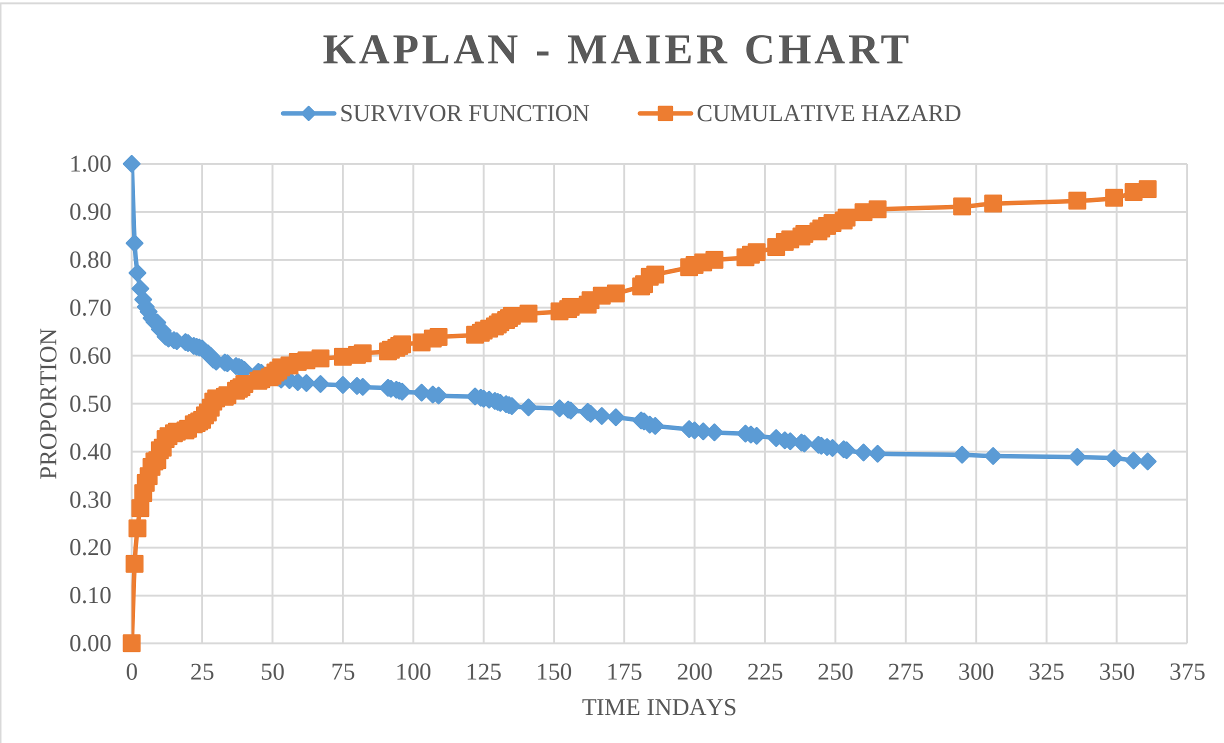
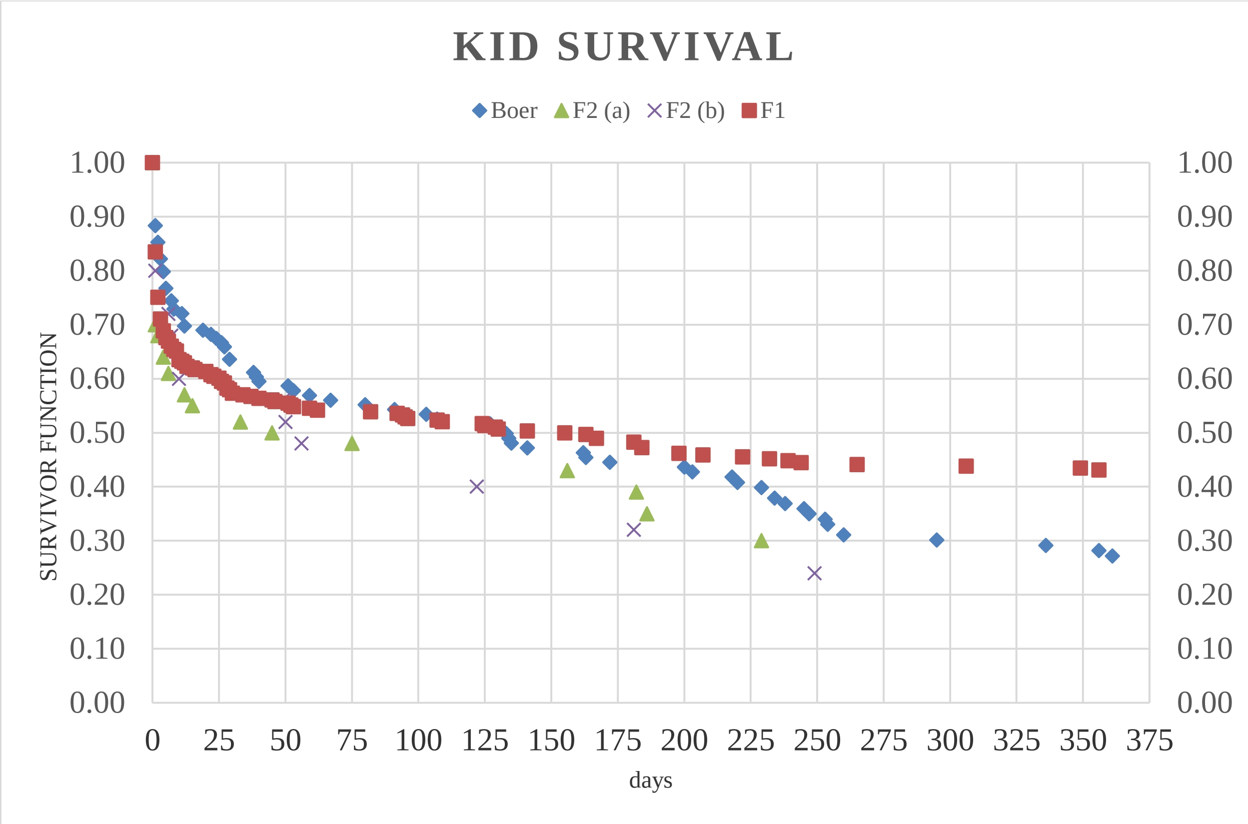


Fig. 1: Kaplan – Maier survival function and cumulative hazard curve of kids from birth to yearling age

Kaplan – Maier survivor curve of kids by breed from birth to yearling age is presented as Figure 2. The survivability among the Boer kids declined/ decreased rapidly as the age progressed, however there was a stabilizing effect among the, F1 kids .



F1= (Boer buck x CHG doe), F2 (a) = (50% F1 buck x 50% F1 doe) and F2 (b) = (Boer buck x 50% F1 doe).

Fig. 2: Kaplan – Maier survival curve by kid breed from birth to yearling age

5. Discussion

5.1 Growth performance of kids of Boer and their crosses with Central Highland Goats.

The findings of the current study show that the buck kids were heavier than the doe kids. The observations follow the Rensch's rule (Rensch, 1950) where the males of a particular species are usually larger than the females. The differences between the buck and doe kids may be further ascribed to testosterone hormones secreted by the buck kids results in enhancement of muscle mass and skeletal development (Baneh and Hafezian, 2009). The sexual dimorphism of the kids may be ascribed to the differences in the endocrine system of the two sexes; estrogen hormone has a limited effect for growth in females (Chriha & Ghadri, 2001; Baneh and Hafezian, 2009).

Similar observations among the goats of Arsi-Bale,Boer x Woyito-Guji 25 %and Tunisian local goat breed were also reported by Dadi *et al.* (2008); Girma, *et al.*(2016) and Mabrouk *et al.* (2010) respectively. Contrary to the present findings Derib *et al.*, (2015) reported that no significant differences were observed in the weight of yearling bucks and does of Boer x CHG crossbreds.

The study further indicated differences ($P<0.001$) in the weight of the kids across the genotypes studied, with higher weights at almost all ages among the Boer kids when compared to their crossbred counterparts. The weight of the kids of F2 (b) genotype followed that of the Boer's, which can be ascribed to the higher proportion of paternal genes (from the Boers).The findings are in agreement with the findings of Sanchez *et al.*(1994)who also reported that the higher crosses with exotic breeds have more than intermediate body weight at all ages. Care has to be taken to rear the higher crosses especially under the farmers' condition as they may exhibit tropical degeneration, thereby the overall performance can be lower than the F1 crosses (Lipson *et al.*, 2011). While Ajoy-Mandal *et al.* (2006) reported that the weight and size of kids at birth are determined not only by their own genetic potential (additive effect) but also by extra-chromosomal inheritance and intra-uterine environment (maternal effects).

The findings also show that the body weight at different ages among the kids born as single births were higher than those multiple births. These observations are in close accordance with the reports of Mabrouk *et al.* (2010); King, (2009); Đuričić *et al.* (2012); Ince, (2010); Andries, (2013); Hasan *et al.* (2014); Thiruvenkadan, (2009) and Alemu, (2015) among the different goats breeds. This difference can be due to limited uterine space during pregnancy for multiple birth and competition for milk suckling between the multiple born kids during birth to weaning (Al-Shorepy *et al.*, 2002). Similarly as the number of fetuses increases, the number of caruncles attached to each foetus decrease thus resulting in the reduction of feed supply to the foetus and hence the birth weight of those kids decreases in multiple births (Robinson *et al.*, 1977).

The results also indicate that the effect of year and season influenced the growth of the kids/yearlings, which is in close accordance with the reports of Mabrouk *et al.* (2010), Al-Najjar *et al.* (2010); Otuma and Onu (2013); Zhang *et al.* (2008); King, (2009); Schoeman *et al.*(1997) and Zhang *et al.*(2002) who reported body weight of different breed of goats and their crosses differed across the studied years and seasons.

The effect of year and season on the traits studied can be due to temporary environmental effects like variations in incidences of diseases, availability of fodder, management, sample size and climate (differences of rainfall which in turn influenced grass production and feed availability) (Gunawan and Noor 2006; Zhang *et al.*, 2008; Gebrelul *et al*., 1994; Al-Shorepy *et al*., 2002).The effect of year may also be ascribed to the global climate change viz. El Nino and/or

La Nina effect (Rust & Rust, 2013).The above studies indicated that the non-genetic factors can be minimized by management of the animals.

The effect of season is generally low among animals reared under intensive/semi intensive management when compared to those reared under extensive management (Lipson *et al.,* 2011). It has also been suggested that the effect of season on growth is higher among the animals reared in the temperate climate whereas effect of season is generally low among the animals reared in the equatorial zone (Lipson *et al.,* 2011).

The birth weight of the Boer kids as recorded in this study in Table 7 arecomparablewith reports by Abd-Allah *et al.*(2015) and Ince, (2010) among Boer and Saanen kids respectively. Higher weights have also been reported by Đuričić *et al.*(2012) and Hasan *et al.*(2014) among Boer and Ettawa kids respectively. The birth weight of the Boer kids as observed in this study were recorded to be higher than those reported by Faruque, (2010); Shaat *et al.*(2007); Thiruvenkadan, (2009) and Alemu, (2015) among Black Bengal, Zaraibi, Tellicherry and CHG kids respectively.

The birth weight of the crossbreds as recorded in the study are in close accordance's with Boer x CHG crossbreds as reported by Derib *et al.*(2015). Lower weights have also been reported by Ssewannyana *et al.* (2004) among Boer x Mubende 50% and Boer x Teso 50% crosses. The birth weight as observed in this study were recorded to be lower than those reported by Debele *et al.*(2015) and Girma *et al.*(2016) among Boer x Arsi Bale kids and Boer x Woyito-Guji 25 % crosses.

The results pertaining to the weaning weight of the Boer kids also indicated similarity with the reports ofHasan *et al.*(2014);Shaat *et al.* (2007) and Alemu, (2015) among Ettawa, Zaraibi and

CHG kids respectively. Higher weaning weight was also reported by Abd-Allah *et al.* (2015) and Ince, (2010) among the Boer and Saanen kids respectively. The weaning weight of the Boer kids in this study werealso higher than those reported by Abd-Allah *et al.* (2015) and Thiruvenkadan, (2009) among Baladi and Tellicherry kids respectively.

The results pertaining to the weaning weight of the crossbreds also indicated similarity with the reports of Deribe and Taye, (2013) among the CHG goats. Higher weaning weight was also reported among the Boer x Arsi bale, Boer x CHG and Boer x Woyito-Guji 25 % crossbreds as reported by Debele *et al.* (2015); Derib *et al.* (2015) and Girma *et al.* (2016).

The results pertaining to the six month and yearling weight of the Boer kids/ yearlingsare in close accordance with the observations of Thiruvenkadan(2009) among Tellicherry kids. Whereas the values were lower than those reported by Shaat *et al.*(2007); Abd-Allah *et al.*(2015); Hasan *et al.*(2014) and Alemu, (2015) among the Zaraibi, Boer, Ettawa and CHG kids/ yearlings respectively. Similarly the findings regarding the six months and yearling weight of the crossbreds in this study are also lower than the reports of Derib *et al.*(2015) and Girma *et al.*(2016) among the Boer x CHG and Boer x Woyito-Guji (25 %)crossbreds.

5.2 Body weight gain at different stages of growth among the Boer and crossbreds

The findings as presented in Table 8 indicate that the gain among the buck kids at post weaning stage was higher than the doe kids, indicating less post weaning stress among the bucks, which can also be ascribed to the androgenic effect as suggested by Baneh and Hafezian (2009).The findings also show that body weight gain till weaning age was different across genotypes where Boer kids were found to be the highest till weaning. The findings are in close accordance with reports by Abd-Allah *et al*. (2015) who concluded that lacteal yield of the dams' favours growth of the kids.

The effect of parity was not significant on the growth of the kids from birth to weaning and thereafter from weaning to six months. The results are partially in line with the reports of Dadi *et al.*(2008) who worked on Arsi-Bale goats while they are contrary to the observations of Hoque *et al.,* (2002) Otuma and Onu, (2013) and Thiruvenkadan(2009) on different Goat breeds. It is expected that the lactation yield is lower in the first parity which shows an increase in the subsequent lactations thereafter decreasing as the doe ages (Zhang *et al.,* 2009).Similarly, effect of parities was expected due to differences in maternal effects, nursing and maternal behaviour of dam in different ages (King, 2009).

The non-significant effect of parity may be ascribed to above average lacteal yield of the dams which satisfies the need of the kids. The differences due to parity in the body weight changes (six months to one year) may be ascribed to the effect of long term weaning shock among the kids (Abebe, 2008). This may also be because all the kidding may have not taken place in the same season thereby influencing the weaning shock (Abebe, 2008).

The findings also show that the weight gain among the kids born as single births were higher till weaning. Thereafter compensatory growth among the kids born as multiple birth narrowed the gap thereby leading to no significant differences. These observations are in close accordance with the reports of Thiruvenkadan (2009) on Tellichery Goat breeds. These differences may be ascribed to low birth weight of the kids born as multiple births where kids having larger birth weight gained more body weight during pre-weaning period (Kuthu *et al.,* 2013; Thiruvenkadan, 2009).

The findings also indicate differences across years in the weight gain of the kids, which is in close accordance with the findings of Hasan *et al.* (2014) and Thiruvenkadan, (2009) on different Goat breeds. The differences as observed might be ascribed due to the above reasons for the body weight traits. Similarly season influenced the gain from birth to weaning which can be due to the maternal effect (milk yield variation), as it can be associated with variations for rainfall that in turn affected pasture production and feed availability (Al-Shorepy *et al.*, 2002; Otuma and Onu 2013).The findings are in close accordance with the findings of Andries(2013) at Frankfort Kentucky.

Totally the results pertaining to the weight gains at different ages of the kids in this study were lower than reports by Debele *et al.*(2015);Derib *et al.*(2015); Deribe and Taye(2013) and Shaat *et al.*(2007) among Boer x Arsi bale, Boer x CHG, CHG and Zaraibi kids.

5.3 Effects genetic and non-genetics factors on conception, kidding and abortion

The findings as presented in Table 9 show that effect of genetic and non-genetic factor on conception, kidding and abortion. The findings show that genotype influenced all the traits studied, which may be ascribed to the adaptation of the genotypes to a particular agro climate (Mellado *et al.,* 2006; Abd-Allah *et al*., 2015). The findings also indicate that the conception and kidding percentages were highest among the crossbreds which can be attributable to the heterosis effect (Gosey, 1991). The above traits were also lower among the Boer does which is in line with the findings of Khanal (2016) who reported that Kiko, Spanish and their crossbreddoes have higher kidding rate when compared to the purebreds.

Higher abortion among the Boer does can be ascribed to their adaptation (biotic and abiotic stress related factors). The findings are in close accordance with the reports of Unanian and Silva

(1989) who reported that incidences of abortions rates were higher in stressed/ exotic breeds than in native.

The results of adaptation of the does to the agro climate can also be evident from the higher conception, kidding and lower abortion percentages across the years. The observations are in close accordance with the findings of Mellado *et al.* (2006) who recorded that conception was highest among does which had least stress. Mating season affects conception percentage which is in line with the report of Bushara *et al.* (2016) and Mellado *et al.* (2006). Conception was recorded to be highest in the wet season where the does had ample amount of green fodder, which is contrary with the findings of Mellado *et al.* (2006) who report that conception was higher in the summer than in the fall. The effect of season was non-significant on kidding and abortion percentages.

The results related to the length of exposure of the doe to the buck indicated that longer and shorter duration of exposure resulted in lower conception, kidding and higher incidences of abortion percentages. This might be ascribed to unnecessary butting by the bucks which can lead to higher incidences of abortion at early stages of conception (Browning, 2014).

The findings also indicate that low kidding and high abortion and similar conception percentages among the light and heavy animals were observed when compared to those does with optimum body weight. These reports are in close accordance with those of Mellado *et al.*, (2004). The differences as observed may be ascribed due to body reserves of the does. Does with lower weight cannot provide adequate nutrition to the growing embryo leading to higher incidences of abortion (Mellado *et al.*, 2004).

The lack of significant effect of body weight of does at mating on conception suggests that the majority of does responded to the buck stimulus regardless of their body energy reserves (Mellado *et al.,* 2004).Similarly Goonewardene *et al.* (1997) also indicate that loss of mating weight does not affect estrus response and conception rates in goats. Thus, apparently the reproductive strategy of does is to respond to the presence of the buck even with low body energy storages, and once pregnant, does maintain or expel their foetuses depending upon feed availability and reserves (Mellado *et al.,* 2004). This show, to avoid abortion the body weight at mating should not be much less or much high. The findings on conception and kidding percentage among all the doe breeds from this study were lower than those reported by Đuričić *et al.* (2012) among Boer does.

5.4 Effect of genetic and non-genetic factors on litter size and weight of the does

The results as presented in Table 10 indicate that litter weight at birth and weaning differed across the genotypes. The differences can be ascribed to the birth weight of the kids and the effect of their genetic makeup. The results pertaining to the litter size at birth and weaning also litter weight indicate that it was higher among the kids born as multiple births, as multiple births was in accordance with these traits; litter size and weight are correlated (Mellado *et al.,* 2011; Marzouk *et al.,* 2000). Increase the former would invariably lead to increase in the later. These observations are in accordance with that of Dadi *et al.,* (2008) among the Arsi-Bale goats.

The findings on litter size and weight at birth among all the doe breeds from this study (Table 10) were lower than those reported by Richard and Maria, (2009); Abd-Allah et al., (2015); Faruque, (2010) and Taye *et al.* (2013) among Boer, Kiko, Spanish, Baladi, Black Bengal and CHG does.

5.5 Effects of genetic and non-genetic factors on body weight of does at mating and kidding

The results as presented in Table 11 indicated that body weights at mating and kidding varied across the genotypes studied. Boer does weighed heaviest across the traits studied which is contrary to the findings of Khanal, (2016) who reported that Boer does were the lowest in body weight at mating than the Kiko and their crossbred does.

The effect of year too influenced the body weight at mating and kidding indicating the effects of management, incidences of diseases and parasites and adaptability of the does to the studied location, the observations are in close accordance with those of Mellado *et al.* (2006).The findings also indicate that there wasn't effect of season on the traits studied which is contrary to the observations of Bushara *et al.*(2016) who reported significant effect of seasonon the abovetraits among the Taggar Goats.

5.6 Heritability among the body weight traits

Heritability estimates for the weight at different ages (birth, weaning, six months and yearling) for the Boer and the crossbred bucks as presented in Table 12 decreased as the age progressed. The findings also indicate that the values are moderate to high; but slightly overestimated which can be ascribed to the small sample size and fallout of incomplete pedigree records (Falconer, 1989). Thus it leads to estimation of "phantom heritability" as observed in the present study. This might be also ascribed to genetic interaction leading to higher estimates of the genetic correlation values between the traits (Tables 13 and 14).

The h^2 values as estimated for the birth weight for the Boers are within the range of values reported by Otuma and Onu (2013); Alade *et al.* (2010) and Hasan *et al.*(2014) among the NCBG,WADG and Ettawa goats respectively. However the values are higher than those reported by Van Niekerk *et al*. (1996); King (2009); Shaat *et al.* (2007) and Thiruvenkadan (2009) among the Boer, Zaraibi and Tellicherry goats. But the corresponding values for the crossbredswere higher than the above reports.

The h^2 values as estimated for the weaning and six months weight for the Boers and the crossbreds are higher than values reported by ELS (1998/1999); Van Niekerk *et al.* (1996); King (2009); Kuthu *et al.* (2015) and Hasan *et al.* (2014) among the Boer, Teddyand Ettawa goats.

The h^2 values estimated for theyearling weight for the crossbreds are within the range of values reported by Hasan *et al.* (2014) among the Ettawa goats.Lower values for the trait too have been estimated for the Boers in this study which is also lower than the values reported by ELS (1998/1999) and Otuma and Onu (2013) among Boer and NCBG goats.

5.7 Genetic correlation among the body weight traits

The genetic correlation between weights at different ages as presented in Table 13 and 14. The genetic and phenotypic correlations are a fallout of pleiotropy (mediated and biological), linkage disequilibrium (Falconer 1989; Paaby and Rockman, 2012). The high values of genetic correlation may be ascribed to biases viz. population stratification such as assortative mating ("gametic phase disequilibrium"), spurious stratification such as ascertainment bias/self-selection (Pirchner, 1983).

The genetic correlation estimated between birth and weaning weight, irrespective of genotypes are lower than the values suggested by Van Niekerk *et al.* (1996); Shaat *et al.* (2007) and Thiruvenkadan (2009) among Boer, Zaraibi and Tellicherry goats. However the values between birth and six months weightwere higher than those reports by Hasan *et al.*(2014); Shaat *et al.*(2007) and Thiruvenkadan, (2009) among the Ettawa, Zaraibi and Tellicherry goats.

The genetic correlation estimated between birth and yearling weight among the Boers were higher than the values reported by Thiruvenkadan(2009) and Hasan *et al.*(2014) among the Tellicherry and Ettawa goats. Similarly the value for the crossbreds were higher than the above values and also the value reported by Shaat *et al.*(2007) among the Zaraibi goats.While higher values are reported by Otuma and Onu (2013) among the NCBG goats.

The genetic correlation estimated between weaning and six month weight (irrespective of genotypes) and the values between weaning and yearling weight among the Boers are higher than the values suggested byKing(2009); Hasan *et al.*(2014) and Shaat *et al.*(2007) among the Boer, Ettawa and Zaraibi goats. While higher values were estimated for the crossbreds.

The findings pertaining to the genetic correlation between six month weight and yearling weight (irrespective of genotypes) are well within the range of values suggested by Thiruvenkadan(2009) among the Tellichery goats, while lower values were reported by Kuthu *et al.*(2015); Hasan *et al.*(2014) and Shaat *et al.*(2007) among the Teddy, Ettawa and Zaraibi goats.

5.8 Phenotypic correlations among the body weight traits

The correlations (phenotypic) can be due to a fallout of genetic and similarity/dissimilarity due to common environments (Falconer, 1989). Thus the values of phenotypic correlations are usually higher than the genetic correlations. However the values can be otherwise if the environmental correlation values are negative which the genetic correlation values are positive or vice versa (Falconer 1989).

The phenotypic correlation between the body weight traits at different ages (irrespective of the genotypes) indicate that the values are quite high when compared to the findings of Shaat *et al.* (2007) among the Zaraibi goats. While the results were in close accordance with the findingsof Dadi *et al.*, (2008) among the Arsi-Bale goats.

5.9 Estimated breeding values of the sires included in the study

The results as presented in Tables 15 and 16 indicate the estimated breeding values (EBV) of the sires included in the study. The findings showed differences in transmissing abilities of the sires for the traits studied. Identification of the sires based on their EBV can be correlated with the breeding objectives. EBV values are influenced by the heritability of the trait besides the coefficient of variation between the values of the offspring's of the sire and those of a random mating population maintained at the same location and under similar management (Pirchner, 1983). The results for the EBV can be misleading if not estimated from a large sample size and if the offspring's are selected (Pirchner, 1983).

The G X E, Dominance and common environmental variance may be important components of variance in yearling weight thus not including them may produce an overestimation of the predicted response; thus inclusion of the same can influence the sire ranking (Pirchner, 1983). This can also partially affect the genetic evaluation (response), through change in ranking of the selected animals (Pirchner, 1983). Prediction of breeding values is influenced by the numbers of offspring's of a particular individual besides the population structure themselves and by the G X E if the genetic traits estimated are not connected themselves (Falconer, 1989)

5.10 Survival studies of the kids

The results pertaining to the censored and uncensored data on the survivability of the kids (Table 17) shows that high kid mortality rate was observed at the pre-weaning period, whichare much lower than the findings of Debele *et al.*(2015); Zeleke *et al.*(2017) and Abd-Allah *et al.* (2015) among the Boer x Arsi bale, Boer x CHG, Boer and Baladi goats. It has also been reported that over the age the effects of the non-genetic factors increase which is in lieu of the genetic influence resulting in low heritability of survivability (Getachew *et al.* 2015; Vatankhah and Talebi, 2009).

The results pertaining to the chi square probability of survivability indicates that there are differences in survivability at birth and yearling across the genotypes studied. Survival at early stages of life and time immediately after weaning are critical for kid survival due to the changes in kid environment (Southey and Leymaster, 2008; Vatankhah and Talebi, 2009). Similarly Hatcher *et al.* (2010) and Curtis (1969) reported that underweight kids have lower energy reserves and less able to withstand harsh environment which lead to lower chances of survivability. It was also reported that the dam weight and lactal yield of the dam too influence the survivability of the kids (Southey and Leymaster, 2008).Improving the condition of does at kidding, improving kid birth weight, better management at birth and after weaning jointly lead to reduced mortality of kids (Hatcher et al., 2010; Southey and Leymaster, 2008; Tibbo, 2006).

The results also show that the survivability of the F1 (crossbreds) were higher at the yearling stages which is in line with the findings of Jönsson (2015)and Khanal (2016) who reported that the crossbreds were better in survival than the purebreds among dairy cows and Boer goat crosses respectively. This may be ascribed to the hetrosis effect (Gosey, 1991). The results also show that the Boer kids had a lower probability of survivability which is in line with the findings of Davendra and Burns (1983), who reported that the Boer goats have a lower adaptability under the East African conditions.

The findings indicate that the probability of survival of the kids born single were higher which is in close accordance with the findings of Getachew *et al.*(2015) and Devendra and Burns(1983). This may further be ascribed to the low body weight of the kids born as multiple births when compared to those born single (Naude and Hofmeyr, 1981). It may also be due to poor nursing of the dam and improper management practices to the multiple (Al-Najjar *et al.*, 2010).

The probability of survival of the kids in this study vary across the years, which is in line with the findings of Getachew *et al.* (2015); Perez-Razo *et al.* (1998); Al-Najjar *et al.* (2010) and Vatankhah and Talebi (2009). This is because of variation in incidences of diseases, parasites, climatic conditions, rearing methods and managerial systems (Vatankhah and Talebi, 2009; Al-Najjar *et al.*, 2010).

The findings from this study indicate that the probability of survival of the kids born from different parities were not different which is in line with the study of Perez-Razo *et al.* (1998) while it was contrary to the study by Al-Najjar *et al.* (2010) who reported that parity affects survivability due to an age effect; as dams increased in maturity the survival rate of kids improved, due to the maternal instincts and lactal secretions of the does. The parity of dam may influence her uterine development but as the numbers of parity increase (>4) the survivability of the kids may be compromised as the lactation yield decreases (Zhang *et al.*, 2009).

The study also show that kid sex had no influence on the probability of survivability at all ages and season of birth had no influence on the probability of survivability at all ages except at the fourth day, which is in close accordance with the values reported by Al-Najjar *et al.* (2010) while it was in contrary to the findings of Getachew *et al.,* (2015) who reported that kid sex and season of birth affects survival at weaning. Effect of season can be attributable to the nutrient availability to the dam thereby influencing the lactal yield (Mukasa-Mugerwa *et al.,* 2000; Vatankhah and Talebi, 2009). The effect of the season weans off as the animals mature and adapt to the surrounding agro climate (Al-Najjar *et al.* (2010).

The findings pertaining to the risk ratio as presented in Table 19, show that the genotypes too influence the trait. The kids from F2(a) had higher risks at the fourth day and at yearling which can be due to lowering of heterosis (which is halved) in each round of mating (Gosey, 1991). The findings from this study also show that parity had no effect on the risk ratio and survival at all ages, which is in close accordance with the findings of Getachew *et al.* (2015).

The findings of Figures 1 and 2 indicate that the survivability and cumulative hazard are negatively correlated. These observations are in close accordance with the findings of Getachew *et al.* (2015) among the Menz, Wollo and their crossbreds with Awassi sheepwho indicated that the heritability of survivability is low and survivability in an animal is influenced largely by non-genetic parameters.

6. Summary and conclusion

6.1 Summary

This study was conducted on-station in Ataye site of Debre-Birhan Agricultural Research Center, North Shoa zone, Ethiopia which is located at 285 km North of Addis Ababa along the way to Dessie. Data of 512 kids/ yearlings of Boer and their crosses with Central Highland Goats from 381 kiddings, recorded between 2012 and 2017 were used in the study. General Linear Models were used to investigate genetic and non-genetic factors affecting body weight and daily weight gain from birth to 1 year of age, litter size and weight at birth and at weaning. Chi square and sub-dividing analysis were also used to investigate genetic and non-genetic factors affecting conception, kidding and abortion rates.

Survival analysis applying proportional hazards models and chi square sub-dividing analysis was used to investigate genetic and non-genetic factors affecting kid survival from birth to 1 year of age. Similarly REML procedure by fitting an Individual Animal Model were used for the estimation of genetic parameters and sire ranking based on their breeding value estimates were also studied.

The overall least-squares means for body weight at birth, at weaning, at six months and at yearling in kg and body weight gain to weaning, weaning to six-months and six months to yearling in grams were 2.68 ± 0.04, 9.11 ± 0.19, 11.69 ± 0.26, 16.41 ± 0.38, 69.73 ± 1.89, 30.48 ± 1.54 and 24.33 ± 1.21 respectively.

Genotype and all the non-genetic factors affects the body weight and weight gain from birth to 1 year of age, except some; doe parity didn’t significantly affect body weight from birth to 1 year age and body weight gain till six-months age. Additional to this weaning weights were not affected by kid sex. Yearling weights were not affected significantly by kid breed and season of birth. Similarly season of birth did not affect six-month weight.

Least-squares means for body weight at birth in kg of Boer, F1, F2 (a) and F2 (b) kids were 3.05 ± 0.06, 2.62 ± 0.04, 2.50 ± 0.13 and 2.94 ± 0.15 respectively. Least-squares means for body weight at weaning in kg of Boer, F1, F2 (a) and F2 (b) were 10.87 ± 0.36, 8.80 ± 0.22, 8.37 ± 0.74 and 9.80 ± 0.75. Least-squares means for body weight at six month in kg of Boer, F1, F2 (a) and F2 (b) were 12.47±0.51, 11.15 ± 0.31, 9.14 ± 1.18 and 9.64 ± 1.59. Least-squares means for body weight at yearling in kg of Boer, F1, F2 (a) and F2 (b) were 18.30 ± 0.88, 16.73 ± 0.48, 15.08 ± 2.12 and 16.30 ± 2.51.

Least-squares means for body weight gain to weaning in grams of Boer, F1, F2 (a) and F2 (b) kids were 83.94 ± 3.76, 67.05 ± 2.26, 67.65 ± 7.66 and 78.70 ± 7.74. Least-squares means for body weight gain weaning to six-months in grams of Boer, F1, F2 (a) and F2 (b) were 25.57 ± 3.29, 31.46 ± 2.00, 15.62 ± 7.58 and 24.94 ± 10.22. Least-squares means for body weight gain six-months to yearling in grams of Boer, F1, F2 (a) and F2 (b) were 27.62 ± 2.69, 28.40 ± 1.46, 33.03 ± 6.49 and 30.55 ± 7.69.

The overall conception, kidding and abortion percentages of the does were 48.75, 77.05 and 20.49. Genotype and all the non-genetic factors affects the studied traits but kidding and abortion percentages were not affected significantly by mating season similarly conception percentages were not affected by mating weight. The percentages (conception, kidding and abortion) of Boer, Central Highland Goats and F1 cross does were (37.41, 58.64 and 40.12), (54.38, 87.36 and 10.34) and (73.86, 81.54 and 12.31).

The overall least-squares means for litter size at birth and at weaning and litter weight at birth and at weaning were 1.40 ± 0.03, 0.67 ± 0.03, 3.63 ± 0.07 and 10.68 ± 0.28. The studied traits were not affected significantly by doe parity. Similarly litter size at birth and at weaning was not affected significantly by doe breed and season of kidding. Litter size at birth was not affected by year of kidding while litter weight at weaning was not affected by type of birth.

Least-squares means for (litter size at birth and at weaning and litter weight at birth and at weaning) among the Boer, Central Highland Goats and F1 cross does were (1.50 ± 0.01, 0.60 ± 0.07, 4.28 ± 0.10 and 12.46 ± 0.61), (1.50 ± 0.00, 0.69 ± 0.05, 3.62 ± 0.07 and 10.36 ± 0.37) and (1.50 ± 0.01, 0.72 ± 0.13, 3.68 ± 0.19 and 10.06 ± 0.95).

The overall least-squares means for body weight at mating and at kidding in kg of the studied does were 26.52 ± 0.40 and 28.04 ± 0.39. These traits were affected significantly by doe breed and mating year but not by mating season. Least-squares means for body weight (at mating and at kidding) in kg of the Boer, Central Highland Goats and F1 cross does were (37.76 ± 0.56 and 38.96 ± 0.52), (23.56 ± 0.43 and 24.45 ± 0.40) and (23.04 ± 0.79 and 25.32 ± 0.74).

The heritability values from this study are generally medium to high which may be slightly over estimated due to small sample size. The values among the (Boer and 50% F1) for body weight at birth, at weaning, at six-months and at yearling ages were (0.429 ± 0.275 and 0.726 ± 0.169), (0.778 ± 0.502 and 0.671 ± 0.272), (0.752 ± 0.518 and 0.647 ± 0.268) and (0.227 ± 0.701 and 0.645 ± 0.273). Similarly medium to high genetic and phenotypic correlations were also estimated in this study. Sires were also ranked based on their estimated breeding values for body weight from birth to 1 year age among the pure and crossbreeding.

The overall censored or kid survival percentages at fourth day, at weaning, at six-months and at yearling were 73.99, 53.57, 47.98 and 40.27. The above survivability traits were not affected by kid sex and doe parity at all. Similarly survival at weaning and at six-month age was not influenced by breed of the kid. Season of birth also affects only the early age survival; at fourth day. The survivability percentages of (Boer, F_1, $F_{2\ (a)}$ and $F_{2\ (b)}$) at fourth day, at weaning, at six-months and at yearling were (82.17, 71.03, 68.18 and 80.00), (55.81, 53.89, 47.73 and 48), (46.51, 49.22, 45.45 and 44.00) and (32.56, 43.93, 38.64 and 36.00).

6.2 Conclusion

The results indicate that Boer kids had a better growth when compared to their counterparts till six months of age. The Boer kids had better survivability till 4^{th} day after birth thereafter the survivability at yearling stage was higher among the F1 kids. The study further indicates that the overall survivability of the kids across all the genotypes were quite low.

The results further indicated that the overall reproductive performance across all the genotypes were suboptimal .The study also shows that the does were moderately prolific with above average litter size.

Though the heritability of the traits studied were more or less high indicating incidences of phantom heritability which can be ascribed to small size of the population, they are also showing the viability of within breed selection. The estimated values of heritability can be ascribed to common environmental factors which again let to overestimation of the values.

Genetic and phenotypic correlations irrespective of the genotypes indicated that body weight at weaning and six month and thereafter at yearling were accessed to be significantly higher, indicating that weaning weight can be considered as trait for selecting animals at six months of age and thereafter body weight at yearling.

The EBV for sire ranking of (pure-breeding) indicated differences among the bucks for the body weight traits. Based on this buck number 0269 had the highest transmitting ability for body weight at birth however, buck number PJN 2 had the highest transmissing ability for body weights at weaning, six-month and yearling stages.

The EBV for sire ranking of cross-breeding indicated differences across the bucks for the traits related to body weight at different ages. Based on this buck number 0269 had the highest transmitting ability for body weight at birth however, buck number 1020 had the highest transmitting ability for body weights at weaning and six-month. Buck number KL 13 had also the highest transmitting ability for body weight at yearling.

Generally the Boer goats outperformed the crossbreds at early age. While the reverse became true as the age progressed. So in order to continue using this cross-breeding program, it is mandatory to maintain the pure lines of both the parental breeds and the crossbreds (for further synthetic breed formation).

Based on this study the overall performances (growth, reproduction and survival), of the Boer goats were below expectation, which indicates their sub-optimal adaptability to the study area. So in order to make a general conclusions/ recommendations, evaluating them based on large sample size and their performance evaluation need to be carried out across different locations with different management regime.

7. References

Abd-Allah S., Salama R., Mohamed M. I., Mabrouk M. M., EL-Kady R. I., Kadry A. I. & Ahmed S. M. 2015. A comparative study on reproductive and productive performance of Boer and Baladi goats raised under similar environmental conditions in Egypt. *International Journal of ChemTech Research*. 8(9): 225-236.

Abebe G. 2008. Successful rearing of lambs and kids. Technical bulletin No.15. In Yami A, Merkel R.C. and Goetsch A.L. 2008. Sheep and goat production handbook for Ethiopia. Ethiopian Sheep and Goat Productivity Improvement Program.

Ademosun A. A. 1990. Achievements, difficulties and future prospects in small ruminant livestock development in the Tropics. In: Livestock Production and Diseases in the Tropics. Faculty of Veterinary Medicine. University of Utrecht, Utrecht, The Netherlands, pp 39 - 46.

Ajoy-Mandal, Neser F. W. C., Rout P. K., Roy R. and Notter D. R., 2006. Estimation of direct and maternal (co)variance components for pre-weaning growth traits in Muzaffarnagari sheep. *Livestock Science* 99: 79–89.

Alade N.K., Dilala M.A. & Abdulyekeen A. O. 2010. Phenotypic and genetic parameter estimates of litter size and body weights in goats. *International Journal of Science and Nature*. 1(2): 262- 266.

AL-Najjar K., Salhab., AL-Merestani R., Kasem R., AL-Azzawi W., Dawa M., Omed H. & Saatci M. 2010. Environmental Factors Affecting Kid Mortality in Shami Goats Kafkas University Veterinary Faculty Derg 16(3): 431-435.

Al-Shorepy S. A., Alhadrami G.A. & Abdulwahab K. 2002. Genetic and phenotypic parameters for early growth traits in Emirat goat. *Small Ruminant Research*. 45:217-223.

Alubel Alemu 2015. On-farm phenotypic characterization and performance evaluation of Abergelle and Central Highland goat breeds as an input for designing community-based breeding program. MSc. Thesis, Haramaya University, Haramaya, Ethiopia. 128 pp.

Andries K. M. 2013. Growth and Performance of Meat Goat Kids from Two Seasons of Birth in Kentucky. *Sheep and Goat Research Journal* 28:16-20

Anous M.R. & Mourad M.M. 1993. Crossbreeding effects on reproductive traits of does and growth and carcass traits of kids. *Small Ruminant Research*.12:141–149.

Ayalew W., Rischkowsky, B., King, J.M., Bruns, E., 2003. Crossbreds did not generate more net benefits than indigenous goats in Ethiopian smallholdings. *Agricultural Systems* 76: 1137–1156.

Baneh H. & Hafezian S. H. 2009. Effect of environmental factor on growth traits in Ghezel sheep. *African Journal of Bio-technology*.8:2903-2907.

Barazandeh A., MoghbeliS. M., Vatankhah M. and MohammadabaM. 2012. Estimating non-genetic and genetic parameters of pre-weaning growth traits in Raini Cashmere goat. *Tropical Animal Health Production* 44: 811–817

Belete S. 2009. Production and marketing systems of small ruminant in Gomma district of Jimma zone, Western Ethiopia. MSc thesis, Hawassa University, Ethiopia.

Berhane H and Eik L. O. 2006 Effect of Veth (Vicia sativa) hay supplementation to Begait and Abergelle goats in Northern Ethiopia II. Reproduction and growth rate. *Small Ruminant Research,* 64, 233 – 240

Boer Goat News, 1998. Boer Goat Breeders Association of South Africa 45 – 52

Bonsma J. 1980. Livestock Production: A Global Approach. Tafelberg, Cornell University. 201 pp.

Browning M. L. L. 2014. Small Ruminant Management: Winter Kidding & Lambing Seasons. Alabama Cooperative Extension System (Alabama A&M and Auburn Universities). Accessed on 12th October 2017 www.aces.edu/urban

Browning R. Jr., & Leite-Browning M. L. 2009. Breed evaluation for health, reproductive, and carcass traits in meat goats: observations from the southeastern US. 40 SINCORTE 4º Simpósio Internacional Sobre Caprinos e Ovinos de Corte Feira Nacional do Agronégocio da Caprino-Ovinocultura de Corte 16 a 20 de Novembro de 2009 João Pessoa Paraíba – Brasil.

Bushara I., El-Gazafey Besheer., Mudalal. M.O., Mekki D M., Umsalama A. hmed M.A and Abu Nikhaila A. M. A. 2016. Effect of Different Seasons on Taggar Goat Performance. *International Journal of Research Studies in Agricultural Sciences* 2 (7): 22-26

Cameron M. R., Luo J., Sahlu T., Hart S. P., Coleman S. W., & Goetsch A. L. 2001. Growth and slaughter traits of Boer x Spanish, Boer x Angora, and Spanish goats consuming a concentrate-based diet. *Journal of Animal Science*79:1423-1430.

Casey N.H. & Van Niekerk W.A. 1988. The Boer goat. I. Origin, adaptability, performance testing, reproduction and milk production. *Small Ruminant Research*.1:291-302.

Chowdhury S.A., Bhuiyan M.S.A. and Faruk S. 2002. Rearing Black Bengal goat under Semi-intensive management. 1. Physiological and reproductive performances. *Asian-Australian Journal of Animal Science*. 15(4): 477-484.

Chriha A. and Ghadri G. Caprine in the Arab world. 2. ed. Department of Livestock Production. Fateh University: Libby Conservation of Biodiversity and Environments in the Arab Countries, 2001. 478p.

Cunningham E P and O Syrstad. 1987. Crossbreeding Bos indicus and Bos taurus for milk production in the tropics. FAO Animal Production and Health Paper No. 68. FAO, Rome.

Curtis HJ (1969). Animal growth and nutrition. (Lea and Fibger, Philadelphia, USA), pp. 165-174.

Dadi H., Duguma G, Shelima B, Fayera T, Tadesse M, Woldu T and Tucho T. A. 2008. Non-genetic factors influencing post-weaning growth and reproductive performances of Arsi-Bale goats. Livestock Research For Rural Development volume 20, Article no 114. Accessed on 4th October 2017 http://www.lrrd.org/lrrd20/7/dadi20114.html

Debele S., Habta M., Yinessu A. &. Admassue B. 2015. Pre-weaning growth performance of Boer cross with local goat in Gedio zone, Ethiopia. International *Journal of Agricultural Sciences and Veterinary Medicine* 3(3): 14 – 20

Degen A., 2007. Sheep and goat milk in pastoral societies. *Small Ruminant Research*. 68: 7–19.

Delgadillo J.A., Canedo G. A., Chemineau P., Guillaume D., Malpaux B. 1999. Evidence for an annual reproductive rhythm independent of food availability in male Creole goats in subtropical northern Mexico. *Theriogenology*. 52: 727–737.

Dereje T., Mengistu U., Getachew A. and Yoseph M. 2015. A review of productive and reproductive characteristics of indigenous goats in Ethiopia. *Livestock Research for Rural Development*. 27: 34. http://www.lrrd.org/lrrd27/2/dere27034 accessed on November 14, 2017.

Deribe B. & Taye M. 2013. Growth performance and carcass characteristics of central highland goats in Sekota District, Ethiopia. *Scientific Journals* 2(8): 250-258

Deribe B., Tilahun M., Lakew M., Belayneh N. and Zegeye A. 2015. On-Station Growth Performance of Crossbred Goats (Boer X Central Highland) at Sirinka, Ethiopia. *Asian Journal of Animal Sciences* 9 (6): 454-459

Deribe G. 2009. On-farm performance evaluation of indigenous sheep and goats in Alaba, Southern Ethiopia. MSc Thesis, Hawassa University, Ethiopia

Devendra C. & Burns M. 1983.Goat Production in the Tropics, 2nd Edition, Commonwealth Agricultural Bureau, Farnham Royal, UK.Tech.Comm.19 183p.

Ducrocq V., Sölkner J. and Mészáros G., 2010. The Survival Kit v6.0 User's Manual 83pp.

Đuričić D., Grizelj J., Dobranić T., Harapin I., Vince S., Kočila P., Folnožić I., Lipar M., Gračner G. G., & Samardžija M. 2012. Reproductive performance of Boer goats in a moderate climate zone, *Veterinarski Arhiv*. 82(4): 351-358

ELS J.F. 1998/1999. Heritability estimates for growth traits in the improved Boer goat. Ministry of Agriculture Water and Rural Development, Livestock Research. Republic of Namibia AGRICOLA 51-52.

Erasmus J.A. 2000. Adaptation to various environments and resistance to disease of the Improved Boer goat. *Small Ruminant Research* 36: 179 – 187

Falconer D S. 1989. Introduction to Quantitative Genetics. 3rd ed. Longman Scientific &Technical.

Farm-Africa, 1996. Goat types of Ethiopia and Eritrea. Physical discription and management systems. Published jointly by FARM-Africa, London, UK, and ILRI (International Livestock Research Institute), Nairobi, Kenya. 76pp.

Faruque S., Chowdhury S. A., Siddiquee N. U. & Afroz M. A. 2010. Performance and genetic parameters of economically important traits of Black Bengal goat. *Journal of Bangladesh Agriculture University*. 8(1): 67–78

Gebrelul S., Sartin III, L.S., Iheanacho M., 1994. Genetic and non-genetic effects on the growth and mortality of Alpine, Nubian and crossbred kids. *Small Ruminant Research* 13: 169–176.

Getachew T., Gizaw S., Wurzinger M., Haile A., Rischkowsky B., Okeyo A. M., Sölkner J. and Mészáros G.. 2015. Survival analysis of genetic and non-genetic factors influencing ewe longevity and lamb survival of Ethiopian sheep breeds. *Livestock Science* 176: 22–32

Getahun L. 2008. Productive and economic performance of small ruminant production in production system of the highlands of Ethiopia. PhD dissertation. University of Hohenheim, Stuttgart, Hohenheim, Germany

Girma M., Getachew S., Tera A., Getaneh D. & Birhanu T. 2016. Participatory on Farm Evaluation and Demonstration of 25% Crossbred (Boer x Woyito-Guji) Goats in Benatsemay District of South Omo Zone, SNNPR, Ethiopia. *Journal of Biology, Agriculture and Healthcare* 6(21): 41 – 45

Girma Y. & Desta G. 2007. Investigation of salinity problems of Effratana Gidim and Kewot Woredas. Proceeding of the 2nd annual regional conferences on completed Natural Resources Management Research Activities. September 18-19, 2008. (pp.81-90). Bahir Dar, Ethiopia.

Gizaw S., 2009. Goat breeds of Ethiopia: A guide for identification and utilization technical bulletin no.27. 9 pp. In sheep and goat production handbook for Ethiopia. Ethiopian Sheep and Goat Productivity Improvement Program.

Goonewardene L.A., Whitmore W., Jaeger S., Borchert T., Okine E., Ashmawy O., Emond S., 1997. Effect of pre-breeding maintenance diet on subsequent reproduction by artificial insemination in Alpine and Saanen goats. *Theriogenology* 48: 151–159.

Gosey James A. 1991. Crossbreeding Systems and the Theory behind Composite Breeds. Range Beef Cow Symposium. 236. Accessed on 10th October 2017 http://digitalcommons.unl.edu/rangebeefcowsymp/236.

Greyling J.P.C. 2000. Reproduction traits in the Boer goat doe. *Small Ruminant Research* 36: 171 – 177

Gunawan A. & Noor R. R. 2006. Estimation of heritability of birth and weaning weight of the fighting type of Garut sheep *Media Peternakan* 29: 7-15.

Hasana F., Jakariab, & Gunawan A. 2014. Genetic and Phenotypic Parameters of Body Weight in Ettawa Grade Goats.*Media Peternakan*. 37(1): 8-16.

Hassen H., Lababidi, S., Rischkowsky, B., Baum, M. & Tibbo, M., 2012. Molecular characterization of Ethiopian indigenous goat populations. *Tropical Animal Health and Production*. 44: 1239–1246.

Hatcher S., Atkins, K.D., Safari, E., 2010. Lamb survival in Australian Merino sheep: a genetic analysis. *Journal of Animal Science* 88: 3198–3205.

Hoque M. A., Amin M. R. & Baik D. H. 2002. Genetic and Non-genetic Causes of Variation in Gestation Length, Litter Size and Litter Weight in Goats.Asian-Australian. *Journal of Animal Science*. 15(6): 772-776.

Horst P. 1983. The concept of production adaptability of domestic animals in tropical and subtropical regions. *Journal of South African Veterinary Association* 54(3): 159

IBC (Institute of Biodiversity Conservation). 2004. The State of Ethiopia's Farm Animal Genetic Resources: Country Report. A Contribution to the First Report on the State of the World's Animal Genetic Resources. IBC, Addis Ababa, Ethiopia.

Ince D. 2010. Reproduction performance of Saanen goats raised under extensive conditions. *African Journal of Biotechnology*. 9(48): 8253-8256

Jemal G. 2008. Phenotypic characterization and performance evaluation of abergelle goat under traditional management system in Tanqua-Abergelle District of Tigray, Ethiopia. MSc Thesis, Mekelle University, Mekelle, Ethiopia.

Jönsson Rebecka. 2015. Estimation of heterosis and performance of crossbred Swedish dairy cows. Swedish University of Agricultural Sciences Department of Animal Breeding and Genetics 459 Uppsala MSc Thesis pp 38.

Judith Moses. 2006. Goat and Sheep Production and Marketing in the Amhara Region of Ethiopia. AMAREW project. 28 pp.

Khanal Piush. 2016. Influence of crossbreeding and non-genetic factors on doe fitness traits of Boer F1 and foundation breeds in South Eastern United States. Tennessee State University United States. MSc Thesis 83 pp.

King F. J. M. 2009. Production parameters for Boer goats in South Africa. MSc. Thesis, University of the Free State, Free State, South Africa.

Kuthu Z. H., Javed K., Ahmad N., Hussain A. & Khan S. A. 2015. Genetic evaluation of post-weaning growth traits in Teddy goats. *Journal of Dairy, Veterinary & Animal Research* 2(2): 1-7.

Lipson J., Reynolds T. & Professor Anderson L. 2011. Environmental Implications of Livestock Series: Goats. Evans School Policy Analysis and Research (EPAR) Brief No. 156. 14 pp.

Lu C. D. 1989. Effect of heat stress on goat production. *Small Ruminant Research* 2:151-162.

Lu C.D. and Potchoiba M. J. 1988. Milk feeding and weaning of goat kids. *Small Ruminant Research*. 1:105-112.

Mabrouk O., Sghaier N., Costa R. G., Amor G., Ame B. A. E. and Delgado J. V. 2010. The effect of non-genetic factors on the early body weights of Tunisian local goats. *Revista Brasileira de Zootecnia*. 39 (5): 1112-1117

Mahlet S. 2008. Reproduction in Arsi-Bale female goats and growth performance of Toggenburg x Arsi-Bale crosses. MSc Thesis, Hawassa University, Ethiopia.

Marzouk K. M., Feel El F. M. R., Hassan H. A. and Sallam M. T. 2000 Evaluation of French Alpine goats under Egyptian condition. In proceedings of the 7th International conference on goats, France, 15 – 21 May 2000. France. 236 – 238

McDowell R. E. 1972. Improvement of Livestock in Warm Climates. W H Freeman & Co. San Francisco.

McDowell R. E. 1988. Strategies for genetic improvement of cattle in warm climates. In: Proc. Second National Livestock Improvement Conference. 24 - 26 Feb. 1988, Addis Ababa. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Mellado M., Meza-Herrera C. A., Arévalo J. R., De Santiago-Miramontes M. A., Rodríguez A., Luna-Orozco J. R. and Veliz-Deras F. G.. 2011. Relationship between litter birthweight and litter size in five goat genotypes. *Animal Production Science*. 51: 144–149

Mellado M., Valdéz R., García J. E., López R. and Rodríguez A. 2006. Factors affecting the reproductive performance of goats under intensive conditions in a hot arid environment. *Small Ruminant Research* 63: 110-118

Mellado M., Valdez R., Lara L.M and Garcia J.E. 2004. Risk factors involved in conception, abortion, and kidding rates of goats under extensive conditions. *Small Ruminant Research* 55: 191–198

Mesfin T. 2007. The influence of age and feeing regimen on the carcass traits of Arsi-Bale goats. Livestock Research for Rural Development, 19, #47. Accessed on November 2, 2017 from http://www.lrrd.org/lrrd19/4/tade19047.html

Mestawet T. A., Girma A. Ådnøy T., Devold T., Narvhus T. G., & Vegarud G. E. J. A. 2012. Milk production, composition and variation at different lactation stages of four goat breeds in Ethiopia. *Small Ruminant Research*. 105:176–181.

Mestawet T. A., Girma A., Ådnøy T., Devold T. G. & Vegarud G. E. 2014. Effects of crossbreeding and mutation at the αs1-CN gene in the Ethiopian and crossbred goats on casein content, and coagulation properties of their milks. A short review. *Small Ruminant Research* 122: 170-75.

Meyer K. 1992. Variance components due to direct and maternal effects for growth traits of Australian beef cattle. *Livestock Production Science*. 31:179-204.

Meyer K. 2006. WOMBAT: Digging deep for quantitative genetic analyses by restricted maximum likelihood. Proc. 8th World Congress on Genetics Applied to Livestock Production, August 13-18, 2006, Belo Horizonte, Brazil Communication. 27: 4.

Meyer K. 2012. WOMBAT Version 1.0 a program for Mixed Model Analyses by Restricted Maximum Likelihood: User notes. Animal Genetics and Breeding Unit, Armidale, 103p.

Misra A.K. & Singh, K. 2002. Effect of water deprivation on dry matter intake, nutrient utilization and metabolic water production in goats under semi-arid zones of India. *Small Ruminant Research*. 46: 159–165.

Morand-Fehr P., Fedele V., Decandia M. & Le-Frileux Y. 2007. Influence of farming and feeding systems on composition and quality of goat and sheep milk. *Small Ruminant Research*. 68: 20–34.

Mukasa-Mugerwa E., Lahlou-Kassi A., Anindo D., Rege J., Tembely S., Tibbo M., Baker R., 2000. Between and within breed variation in lamb survival and the risk factors associated with major causes of mortality in indigenous Horro and Menz sheep in Ethiopia. *Small Ruminant Research* 37: 1–12.

Naude R.T. and Hofmeyr H.S., 1981. Meat Production. In: Gall C. (Ed.) Goat Production. Academic Press, London, New York, 285-307.

Otuma M. O. & Onu P. N. 2013. Genetic effects, relationships and heritability of some growth traits in Nigeria crossbreed goats. *Agriculture and Biology Journal of North America.* 4(4): 388-392

Paaby-Annalise B. and. Matthew R. V. 2013. The many faces of pleiotropy. National Institute of Health Trends Genetics 29(2): 66–73.

Perez-Razo M. A., Sánchez G. F. and Meza H C. 1998. Factors affecting kid survival in five goat breeds. *Canadian Journal of Animal Science*s. 78: 407–411

Pirchner F. 1983. Population Genetics in Animal Breeding. The University of California. The Springer. 414 pp

Rensch B. 1950. Die Abhangigkeit der relative sexual differenz von der korpergrosse. *Bonner Zoologische Beitrage* 1: 58 – 69.

Robinson J. J., Mcdonald I. and Crafts R. M. J. (1977). Studies on reproduction in prolific ewes 1 Growth of products of conception *J of Agricultural Science Cambridge* 88: 539 – 552

Rust J. M. and Rust T. 2013. Climate change and livestock production: A review with emphasis on Africa. *South African Journal of Animal Science* 43 (3): 255 – 267

Sanchez G. F. F., Montaldo V. H. and Juarez L. A. 1994. Environmental and genetic effects on birth weight in gradedup goat kids. *Canadian Journal of Animal Science*. 74: 397 – 400

SAS Software (Statistical Analysis System, SAS Institute Inc., Cary, NC, USA).

Schoeman S.J., Els, J.F., van Niekerk, M.M., 1997. Variance components of early growth traits in the Boer goat. *Small Ruminant Research* 26: 15–20.

Shaat I., Mabrouk M., Raheem A. A. & Hamed A. 2007. Estimates of heritability and correlation for milk and growth traits in zaraibi goat. *Egyptian Journal of Animal Production* 44(2): 161-171.

Silanikove N. 2000. The physiological basis of adaptation in goats to harsh environments. *Small Ruminant Research*. 35: 181–193.

South African Boer Goat Breeders' Association Accessed on 14th October 2016 http://studbook.co.za/boergoat/stand.html.

Southey B.R., and Leymaster K.A., 2008. Survival analysis of lamb mortality in a terminal sire composite population. *Journal of Animal Science* 79: 2298–2306.

Ssewannyana E., Oluka J. & Masaba J.K. 2004. Growth and performance of indigenous and crossbred goats, Uganda. *Journal of Agricultural Sciences* 9: 537 – 542

Tatek W., Hailu D., Mieso G. and Dadi G. 2004. Productivity of Arsi Bale goat types under farmers' management condition: a case of Arsi Negelle. Proceeding of the 13th Annual Conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, 25-27 August 2004, 67-71

Taye M., Deribe B. & Hayle-Melekot M. 2013. Reproductive performance of central highland goats under traditional management in Sekota district, Ethiopia. *Asian Journal of Biological Sciences* 6(5): 271 – 276.

Tesfaye A. 2004. Genetic characterization of indigenous Goat populations of Ethiopia using microsatellite DNA markers. PhD thesis, NDRI, India.

Tesfaye G., Sisay L., Dereje T., Abebe M. and Solomon G. 2006. Growth and reproductive performance of Central Highland goats in North Shoa and South Wollo. Proceeding of the first annual conference on completed livestock research activity organized in Bahir Dar, Ethiopia, 14-17 August 2006, 7-13

Thiruvenkadan A.K., Murugan M., Karunanithi K., Muralidharan J. & Chinnamani K. 2009. Genetic and non-genetic factors affecting body weight in Tellicherry goats. *South African Journal of Animal Science*. 39:107 – 111.

Tibbo M., 2006. Productivity and Health of Indigenous Sheep Breeds and Crossbreds in the Central Ethiopian Highlands Doctoral Thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden.

Unanian M. M. and Silva, A. E. D. F., 1989. Studies associating rnalnutririon with nbortion in goats in the northeastern region of Brazil. *Pesquisa Agrop, Bras*. 24 1221-1228.

Van Niekerk M. M., Schoeman S. J., Botha M. E. & Casey N. 1996. Heritability estimates for pre-weaning growth traits in the Adelaide Boer goat flock. *South African Journal of Animal Science*. 26(1): 6-10

Vatankhah M., Talebi, M.A., 2009. Genetic and non-genetic factors affecting mortality in Lori-Bakhtiari lambs, *Asian-Australian Journal of Animal Science* 22: 459–464.

Von-Kaufmann R. R. and Peters K. J. 1990. Achievements and difficulties in ruminant livestock development in the humid and subhumid zones of west and central Africa. In: Kuil, H, R W Paling and J E Huhn (Eds). 1990. Proc. 6th International Conference of Institutes for

Tropical Veterinary Medicine. 28 August – 1 September, 1989, Wageningen, The Netherlands, Faculty of Veterinary Medicine, Utrecht University, Utrecht, The Netherlands, 21 - 28.

Walle M., Ayichew D., Ali S. T. & Abriham S. 2015. On Station Growth Performance of Crossbred Goats (Boer X Central Highland) at Sirinka, Ethiopia. *Asian Journal of Animal Sciences* 9(6): 454-459

Wilson A. J., Reale D., Clements M. N., Morrissey M. M., Postma E., Walling C. A.,. Kruuk L. E. and Nussey D. H. 2010. An ecologist's guide to the animal model. *Journal of Animal Ecology*. 79: 13–26

Wondwosen A., Solomon M. and Adugna T. 2010. Supplementation of cottonseed, linseed, and noug seed cakes on feed intake, digestibility, body weight and carcass parameters of sidama goats. *Tropical Animal Health and Production,* 42: 623-631

Yami A. & Merkel R.C. 2008. Sheep and goat production handbook for Ethiopia. Ethiopian Sheep and Goat productivity Improvement Program. Addis Ababa, Ethiopia, 348 pp.

Zeleke M. 2007. Environmental influences on pre-weaning growth performance and mortality rates of extensively managed Somali goats in Eastern Ethiopia. Livestock Research for Rural Development. Volume 19, Article #186. Accessed on November 2, 2017, from http://www.lrrd.org/lrrd19/12/Zele19186.htm

Zeleke T., Tilahun M., Deribe B., Lakew M., Belayneh N., Zegeye A. and Aychew D. 2017. Effects of non-genetic factors on pre-weaning growth, survivability and prolificacy of

Central Highland x Boer crossbred goats in North Eastern Ethiopia. Livestock Research for Rural Development. Volume 29, Article #136 accessed on 12th October 2017, from http://www.lrrd.org/lrrd29/7/Zele29136.html

Zhang C. Y., Chen S. L., Li X., Xu D. Q., Zhang Y. and Yang L. G. 2009. Genetic and phenotypic parameter estimates for reproduction traits in the Boer dam. *Livestock Science* 125: 60–65

Zhang C., Yang L. and Shen Z. 2008. Variance components and genetic parameters for weight and size at birth in the Boer goat. *Livestock Science* 115: 73–79

Zhang C.Y., Zhang Y., Xu D.Q., Li X., Su J. & Yang L.G. 2009. Genetic and phenotypic parameter estimates for growth traits in Boer goat. *Livestock Science*.124: 66-71.

Zhang H.P., Li L., Xu G.Y., Zhu X.D., Li G.Q., Hang H.Q., 2002. Estimation of genetic parameters of reproduction traits in Boer goat. *Animal Husbandry and Veterinary Medicine* 34: 1–12.

8. Appendices

Table 1: Least squares means and standard errors of genotype by environment interaction effects of growth traits of Boer and its crosses with CHG

Interaction effects	Birth weight		Weaning weight		Gain to weaning	
	N	LSM±SE	N	LSM±SE	N	LSM±SE
CV	512	22.86		24.90		33.72
Sex*breed		*		*		NS
Male						
Boer	68	3.14±0.10[a]	26	10.68±0.78	26	77.41±8.06
F1	150	2.68±0.05[b]	83	8.66±0.27	82	65.70±2.86
F2	22	2.69±0.33[ab]	10	9.68±1.58	10	76.74±16.38
F3	12	3.27±0.35[ab]				
Female						
Boer	60	2.87±0.10	31	10.69±0.70[a]	31	82.98±7.21
F1	165	2.58±0.05	83	8.39±0.30[b]	83	63.65±3.10
F2	22	2.49±0.30	8	10.10±1.55[ab]	8	80.64±16.02
F3	13	3.02±0.41				
Parity*breed		NS		NS		NS
1st						
Boer	50	2.77±0.16	26	10.50±0.87	26	78.80±9.06
F1	90	2.48±0.08	50	8.26±0.42	49	62.23±4.40
F2	40	2.46±0.16	16	9.75±0.77	16	78.42±8.03
F3	13	3.26±0.26				
2nd						
Boer	23	2.91±0.17	9	10.09±1.03	9	74.62±10.64
F1	101	2.57±0.07	61	8.24±0.37	61	61.51±3.88
F2	3	3.25±0.42				
F3	11	2.45±0.31				
3rd						
Boer	32	2.98±0.14	13	11.61±0.96	13	91.18±9.95
F1	64	2.70±0.09	28	8.75±0.50	28	67.68±5.18
4th						
Boer	23	3.36±0.17	9	10.55±1.25	9	76.18±13.00
F1	60	2.75±0.10	27	8.86±0.48	27	67.27±4.96
Season*breed		***		***		NS
Wet						
Boer	48	3.25±0.10	13	12.54±0.91[a]	13	98.40±9.47
F1	112	2.87±0.07	63	9.24±0.37[b]	62	70.04±3.93
F2	13	2.79±0.36	6	11.21±2.08[ab]	6	89.03±21.59
F3	5	3.51±0.60				
Dry						
Boer	80	2.77±0.11[a]	44	8.83±0.67	44	61.99±6.94
F1	203	2.38±0.06[b]	103	7.82±0.35	103	59.31±3.65
F2	31	2.38±0.35[ab]	12	8.57±1.39	12	68.35±14.42
F3	20	2.79±0.37[ab]	11			

Interaction effects	Birth weight		Weaning weight		Gain to weaning	
	N	LSM±SE	N	LSM±SE	N	LSM±SE
Year of birth *Breed		***		***		**NS**
2012						
Boer	38	3.02±0.19	19	10.14±1.08	19	80.42±11.15
F1	52	2.43±0.11	26	7.36±0.60	25	54.44±6.29
2013						
Boer	3	2.65±0.37	2	6.52±1.73	2	38.64±17.89
F1	25	2.27±0.14	16	7.35±0.66	16	56.07±6.82
2014						
Boer	21	3.09±0.16[a]	9	8.81±0.87	9	59.62±9.07
F1	41	2.09±0.10[b]	22	6.27±0.57	22	46.39±5.90
F2	2	2.05±0.58[ab]				
F3	4	2.68±0.52[ab]				
2015						
Boer	27	3.22±0.12	10	11.06±0.80	10	88.15±8.31
F1	93	3.07±0.08	69	9.56±0.40	69	71.52±4.22
F2	8	2.78±0.37	4	8.60±1.73	4	64.63±17.97
F3	5	3.14±0.48				
2016						
Boer	28	3.09±0.15	16	13.53±0.75[a]	16	111.26±7.80
F1	66	2.60±0.09	25	10.29±0.51[b]	25	81.90±5.33
F2	10	2.22±0.26	7	9.21±1.26[b]	7	79.02±13.02
2017						
Boer	11	2.97±0.20	8	10.34±0.88	8	103.08±25.92
F1	38	3.30±0.12	7	11.85±2.12	7	77.73±9.08
F2	24	3.30±0.41				
F3	15	3.99±0.43				
Type of birth *Breed		**NS**		***		**NS**
Single						
Boer	61	3.42±0.10 [a]	27	11.94±0.69[a]	27	88.17±7.20
F1	121	3.05±0.06 [b]	86	9.77±0.28[b]	86	74.19±2.91
F2	32	2.81±0.30 [ab]	14	11.94±1.75[ab]	14	96.02±18.17
F3	13	3.30±0.33 [ab]				
Multiple						
Boer	67	2.60±0.11 [a]	30	9.44±0.78	30	72.22±8.10
F1	194	2.21±0.05 [b]	80	7.29±0.30	79	55.16±3.12
F2	12	2.37±0.34 [ab]	4	7.83±1.71	4	61.37±17.71
F3	12	2.99±0.44 [ab]				

Values within each sub-class are significantly different at *=P<0.05, **P<0.01, ***=P<0.0001. F1= (Boer buck x CHG doe), F2= (F1 buck x F1 doe), F3= (Boer buck x F1 doe).

Table 2: Least squares means and standard errors of genotype by environment interaction effects of litter size and weight at birth and at weaning of Boer and its crosses with CHG

Source of Variation	Litter size			Litter weight			
	N	At birth	At weaning	At birth		At weaning	
		LSM±SE	LSM±SE	N	LSM±SE	N	LSM±SE
CV (%)		**3.78**	**89.82**		**24.71**		**34.49**
Type of birth *Doe breed							
		NS	**NS**		*******		*****
Single							
Boer	60	1.00±0.01	0.40±0.10	60	3.50±0.15	27	13.48±1.20[a]
CHG	124	1.00±0.01	0.69±0.06	122	3.11±0.09	87	9.64±0.45[b]
F1	44	1.00±0.02	0.76±0.18	44	2.86±0.27	22	10.11±1.39[ab]
Multiple							
Boer	36	2.00±0.01	0.77±0.13	36	5.02±0.19[a]	23	12.47±1.37
CHG	106	1.99±0.01	0.74±0.06	104	4.14±0.10[b]	54	10.53±0.56
F1	11	2.00±0.02	1.01±0.26	11	5.50±0.38[a]	6	13.11±2.01
Doe Parity *Doe breed							
		NS	**NS**		**NS**		**NS**
1st							
Boer	41	1.50±0.02	0.84±0.18	41	4.16±0.27	23	12.61±1.47
CHG	71	1.50±0.01	0.67±0.09	69	3.38±0.13	43	10.63±0.71
F1	44	1.50±0.01	0.64±0.13	44	4.14±0.20	20	11.45±1.19
2nd							
Boer	17	1.50±0.02	0.49±0.19	17	4.18±0.28	9	11.54±1.69
CHG	76	1.49±0.01	0.62±0.08	74	3.36±0.12	49	10.12±0.66
F1	9	1.50±0.02	0.87±0.22	9	3.94±0.33	6	10.30±1.79
3rd							
Boer	23	1.50±0.01	0.49±0.16	23	4.08±0.24	11	14.21±1.72
CHG	45	1.50±0.01	0.71±0.10	45	3.84±0.16	26	9.68±0.85
F1	2	1.50±0.04	1.15±0.46	2	4.46±0.68	2	13.08±3.00
4th&above							
Boer	15	1.50±0.02	0.52±0.21	15	4.62±0.31	7	13.55±2.23
CHG	38	1.50±0.01	0.87±0.11	38	3.90±0.17	23	9.90±0.83

Source of Variation	Litter size			Litter weight			
	N	At birth	At weaning		At birth		At weaning
		LSM±SE	LSM±SE	N	LSM±SE	N	LSM±SE
Year of kidding *Doe breed							
		NS	*******		*******		**NS**
2012							
Boer	32	1.50±0.02	0.35±0.21	32	4.00±0.32	17	12.33±1.93
CHG	41	1.50±0.01	0.79±0.13	39	3.39±0.19	22	8.01±1.04
2013							
Boer	3	1.50±0.03	0.73±0.36	3	3.72±0.56	2	7.78±2.83
CHG	21	1.50±0.01	0.72±0.15	20	3.15±0.23	14	9.59±1.17
2014							
Boer	18	1.50±0.02	0.68±0.17	18	4.32±0.26^{a}	9	10.10±1.44
CHG	33	1.50±0.01	0.66±0.12	33	3.02±0.17^{b}	20	7.66±0.97
F1	4	1.50±0.04	0.98±0.40	4	4.06±0.60^{ab}	2	7.24±3.27
2015							
Boer	18	1.50±0.01	0.55±0.15^{b}	18	4.64±0.22	8	14.71±1.46
CHG	64	1.49±0.01	1.25±0.10^{a}	63	4.30±0.15	53	11.61±0.72
F1	11	1.50±0.02	1.01±0.25^{ab}	11	4.22±0.38	8	11.13±1.85
2016							
Boer	17	1.50±0.02	0.86±0.18	17	4.23±0.26	13	15.69±1.28
CHG	46	1.50±0.01	0.47±0.10	46	3.30±0.15	23	12.01±0.90
F1	9	1.50±0.02	0.96±0.24	9	3.64±0.36	6	11.71±1.71
2017							
Boer	8	1.50±0.02	0.34±0.24	8	4.65±0.36	1	17.27±4.16
CHG	25	1.50±0.01	0.42±0.14	25	4.56±0.21	9	11.61±1.36
F1	31	1.50±0.02	0.60±0.25	31	4.79±0.38	12	16.37±1.89
Season of kidding *Doe breed							
		NS	*****		**NS**		******
Wet							
Boer	37	1.50±0.01	0.43±0.11^{b}	37	4.54±0.17^{a}	12	15.74±1.64^{a}
CHG	86	1.50±0.01	0.83±0.08^{a}	85	3.86±0.12^{b}	56	10.55±0.65^{b}
F1	13	1.50±0.01	0.80±0.26^{ab}	13	4.30±0.39^{ab}	7	12.55±2.03^{ab}
Dry							
Boer	59	1.50±0.01	0.74±0.12	59	3.98±0.17^{a}	38	10.22±1.11
CHG	144	1.50±0.01	0.61±0.07	141	3.39±0.10^{b}	85	9.61±0.62
F1	42	1.50±0.02	0.97±0.24	42	4.05±0.35^{ab}	21	10.67±1.77

Values within each sub-class across the columns are significantly different at *=P<0.05, **P<0.01, ***=P<0.0001 CHG= Central Highland Goats, F1= (Boer sire x CHG doe)

Table 3. Least squares means and standard errors of genotype by environment interaction effects of body weights of does at joining and at kidding of Boer and its crosses with CHG.

Source of variation		N	LSM±SE		
			Body weight at Mating (Kg.)	Body weight at Kidding (Kg.)	Change (Kg.)
CV			**16.51**	**14.76**	**230.87**
Mating year * Doe breed			*	***	**NS**
2012					
	Boer	31	34.21±1.23*	34.17±1.17*	-0.04±0.99
	CHG	42	22.07±0.71	23.79±0.67	1.72±0.57
2013					
	Boer	9	33.34±3.56	31.46±3.37	-1.89±2.86
	CHG	51	21.91±0.76	23.07±0.72	1.16±0.61
	F1	2	24.63±3.99	26.99±3.77	2.36±3.20
2014					
	Boer	19	35.46±1.42[a]	39.97±1.34[a]	4.51±1.14
	CHG	61	22.56±0.85[b]	23.20±0.81[b]	0.65±0.68
	F1	5	23.09±2.14[b]	23.69±2.02[b]	0.60±1.71
2015					
	Boer	10	44.57±2.88[a]	42.49±2.72[a]	-2.08±2.31
	CHG	42	22.64±0.87[b]	23.97±0.82[b]	1.33±0.70
	F1	15	23.52±2.47[b]	24.02±2.34[b]	0.51±1.98
2016					
	Boer	10	40.56±1.47[a]	43.33±1.39[a]	2.76±1.18
	CHG	21	25.19±1.15[b]	24.45±1.09[b]	-0.74±0.92
	F1	30	23.87±2.64[b]	25.43±2.50[b]	1.55±2.12
Mating season * Doe breed			**NS**	**NS**	**NS**
Wet					
	Boer	33	33.76±1.88[a]	35.03±1.77[a]	1.27±1.50
	CHG	156	23.85±0.58[b]	24.60±0.55[b]	0.75±0.46
	F1	45	23.36±1.36[b]	25.81±1.29[b]	2.45±1.09
Dry					
	Boer	46	41.50±1.07[a]	41.54±1.01[a]	0.04±0.85
	CHG	61	21.90±0.78[b]	22.80±0.74[b]	0.90±0.63
	F1	7	24.20±1.95[b]	24.26±1.84[b]	0.06±1.56

Values within each sub-class across the columns are significantly different at *=P<0.05, **P<0.01, ***=P<0.0001 CHG= Central Highland Goats, F1= (Boer sire x CHG doe)

Biographical sketch

The author of the thesis was born at Shire Indasilassie, North Western zone, Tigray, Ethiopia in 25, November 1988. He attended his Elementary School at Embadanso Elementary School from 1995 to 1997, at Hibret Elementary School 1998 and at Tsehaye Elementary School from 1999 to 2002. He have attended also his High School at Shire High School from 2003 to 2004 and Preparatory School at Shire preparatory School from 2005 to 2006. He thereafter graduated in BSc (Animal & Range Sciences) at Hawassa University from 2006 to 2009. After graduation he served with the Mojana Wereda Agricultural Office as an extension agent (Animal Science) from September 2010 to May 2012. He was then recruited by Debre Birhan Agricultural Research Center (Ataye site) as assistance researcher (Animal Breeding and Genetics) from May 2012 till October 2015. The author was enrolled in October 2015 to pursue his higher studies at Hawassa University, majoring in Animal Breeding. The author is married and has one daughter.