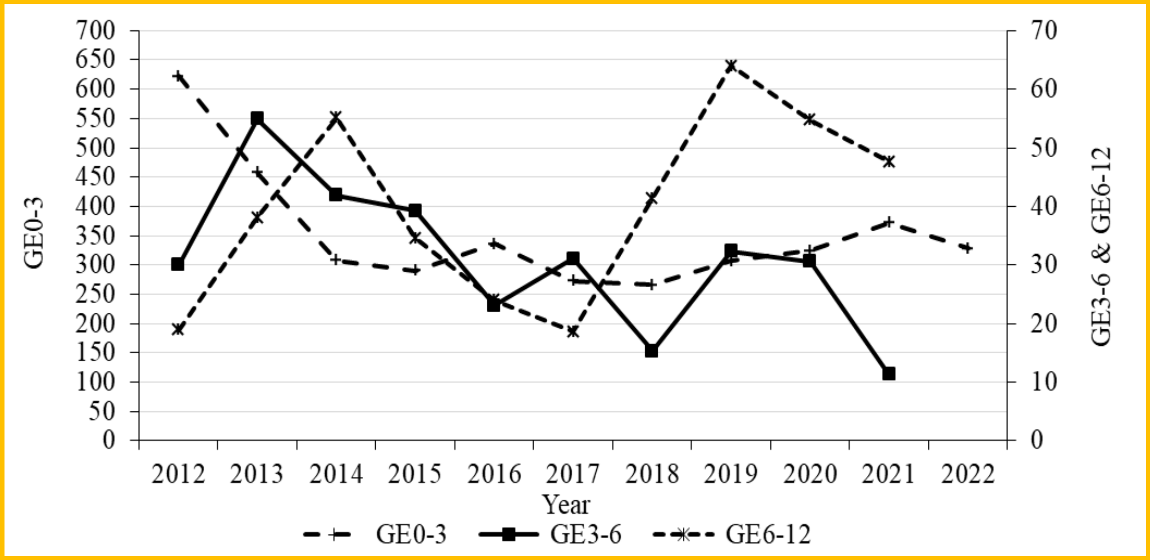
Amhara Agricultural Research Institute
Livestock Research Directorate

Proceedings of the 15th Annual Regional Conference on Completed Livestock Research Activities
October, 2022, Bahir Dar, Ethiopia



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Published June, 2023

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Correct citation: Assemu Tesfa, Alayu Yalew and Getnet Zeleke (Eds.). 2023. Proceedings of the 15th Annual Regional Conference on Completed Livestock Research Activities October, 2022, Amhara Agricultural Research Institute, Bahir Dar, Ethiopia.

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Preface

The livestock research directorate is one of the six research directorates in the Amhara Agricultural Research Institute. The directorate is conducting livestock research activities to solve the major livestock production constraints in the region. The research activities have both a basic and applied nature, with the latter having the lion's share of all activities. The directorate had a ten-year strategic plan on which the research activities are geared towards achieving the goals in the plan. However, preparing a research proposal, conducting research, and finalizing an experiment are not an end to any research process. The collected data and the analysis results have to be written in the form of a scientific paper and have to be published. It is through publishing that the findings of any research activity can be communicated to the end-user. Unless the results are published, the efforts made and money invested in conducting the experiments will be a loss. The contents of this proceeding are papers presented in our annual regional completed research activities review forum. In this proceeding, several research results that are very relevant to end-users are compiled in the area of animal production, animal breeding, feeds and nutrition, animal health, apiculture, poultry, and fishery. I hope the research results published in this proceeding will contribute to the development of the livestock sector in the region in particular and in the country at large. The papers in this proceeding will also have an impact on modernizing the traditional livestock production system in our region. In addition, the contents of this proceeding will also be important reference material for researchers, university students and instructors, investors, and development workers. Finally, I would like to thank those researchers and their assistants who contributed and shared their research results to be published in this proceeding. My special thanks also go to the reviewers for their unreserved contribution in reviewing the articles and the editors who edited the proceeding. In addition, I would like to thank ARARI for covering the cost associated with the reviewing of the papers, editing of the proceedings, and printing. On this occasion, I would like to remind our researchers to publish their research findings in time with the required quality in peer reviewed journals.

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Effect of improved feeding practice on weaning weight and age of Fogera calves at Andassa Livestock Research Center, Amhara Region, Ethiopia

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ABSTRACT

The study was conducted with the objective of evaluating the effect of improved feeding practice on weaning weight and age of Fogera calves kept at Andassa Livestock Research Center. A total of 52 Fogera calves born from September 2020 to March 2021 were randomly assigned to three feed treatments; 1, Grazing plus Grass hay; 2, Grazing and improved forage plus noug seed cake and 3, Grazing and concentrate feed. New born calves stayed with their dams at maternity pen and have free access to suckle their dams for the first four days so that they consume colostrum. They were then separated from their dams and allowed to suckle at milking times until weaning. Calves returned from grazing at mid-day were separated into their respective feeding groups. Calves had access to get tap water from the watering trough at the barn and occasionally from Andassa river. Disease control and prevention scheme was being carried out and sick calves were kept in isolation room and treated accordingly. Results of the study showed, calves fed concentrate had attained the planned 100 kgs weaning weight at significantly ($p<0.01$) shorter age than other treatment groups. Weaning age of concentrate fed calves has reduced by thirty and forty-eight days compared to improved forages and grass hay fed calves, respectively. Concentrate fed calves had significantly higher ($p<0.01$) feed intake compared to other feed treatments from three months of age until weaning. Based on the results of the study it is recommended that calves should be fed good quality concentrate feed to promote early solid feed intake, increase preweaning growth and reduce weaning age.

Key words: *Fogera calves, growth rate, improved feeding, weaning age, weight gain*

INTRODUCTION

Livestock are an integral part of farming system in most parts of the world. Ethiopia is an agriculture based and densely populated developing country where most of the people are dependent for their livelihood mainly on crop and livestock farming (Amare B. *et.al*., 2019). Cattle production plays an important role in the economies of farmers and pastoralists and the country at large (Kebamo *et.al*, 2019).

Calf rearing is one of the most important and sensitive management plans in dairy cattle production systems. Dairy calves are born as pseudo-monogastric with a non-functional rumen and they initially rely on milk to receive their required energy for maintenance and growth (Baldwin *et al*. 2004). Dairy calves are usually fed restricted daily amounts of milk (about 10% of their body weight) along with ad *libitum* starter feed to promote early solid intake and accelerate rumen development. Encouraging consumption of starter feed at a young age also helps prepare the calf's digestive system for the transition from a liquid diet to a dry diet during the weaning period. Consuming dry feed prior to weaning also helps minimizes nutritional stress during that time. A sustainable and effective dry feed is one with an adequate crude protein. According to NRC (2001), the crude protein content for calf starter diet is 18% on a dry matter basis and metabolizable energy value of three Mcal/kg of DM. Traditionally, weaning period take a long about 10 months when calves are reared with their dams. Time of weaning is a significant point in dairy calf rearing and weaning age can influence calf performance and health parameters directly. Average weaning period for Fogera calves at Andassa livestock research center (ALRC) is about eight months, and at this age recorded weaning weight were 99.9 kg (Asheber, 1992), 100.9 kg (Gidey, 2001) and 102.2 kg (Asemu, 2017). Good calf rearing strategy through supplementation with other feeds so as to wean the calves at an early age will have effect on on-set and intensity of post parturient oestrus resulting in an increase of the calf crop yield through reduction of calving interval (Addisu and Hegde, 2003). Improving the feeding practice of Fogera calves is crucial to increase their preweaning growth rate which creates the opportunity for early weaning. Therefore, the objectives of this study were to improve growth rate, weaning weight, and weaning age of

Fogera calves through improved feeding practice and to evaluate the economic feasibility of feed supplementation on growth and weaning age of calves.

MATERIALS AND METHODS

Study area

The study was conducted at the Andassa Livestock Research Center of the Amhara Region Agricultural Research Institute, which is 1730 m above sea level in the Bahir Dar Zuria (11°42'–11°92' N, 37°07'–37°65' E) district of the Amhara region. It receives an average annual rainfall of 1150 mm, and temperatures range from 6.5 to 30 °C (Shigdaf *et al.*, 2020). The soil is dominantly characterized by dark clay soil, which is seasonally water logged in the rainy season and cracked when dry. The dominant grass vegetation of the area includes Cynodon, Hyperhenia, Andropogon, Paspalum, Cetaria, Elusin, Eragrostis, Sporobulus and Trifolium species (Yihalem, 2005).

Calf management

New born calves stayed with their dams at maternity pen and have free access to suckle their dams for the first four days so that they consume colostrum. They were then separated from their dams and allowed to suckle at milking times until weaning. Calves from all treatment groups stayed around their calf pen until three months of age and allowed for grazing thereafter in the morning. Calves grazed four hours/day starting 8:00 am to 12:00 am and separated into their respective feeding groups. Calves had access to tap water on the watering trough and occasionally from Andassa river when tap water was not available. Similar to the whole herd, disease control and prevention scheme was being carried out. Sick calves were kept in isolation room and treated accordingly. Improved forage (Napier grass and desmodium) was developed at ALRC forage development site and concentrate feed was prepared at ALRC feed mill. The concentrate feed composed feed ingredients; ground maize (48%), wheat bran (23%), noug seed cake (28%), limestone (0.75%) and salt (0.25%).

Table 1. Nutrient composition of feed ingredients (dry matter basis)

Ingredients	Nutrients (% DM)					
	DM	CP	ME Mcal/kg	NDF	ADF	ADL
Noug seed cake	91.5	33.1	2.34	35.3	27.8	10.6
Wheat bran	89.4	17.6	2.50	35.8	11	2.5
Maize	90.4	10.2	3.14	11.7	3.6	0.5
Grass hay	87.8	4.20	1.92	74.2	51.2	7.6
Napier grass	17.9	9.20	1.74	62.6	45.1	8.3
Desmodium	24.2	15.5	2.01	51.4	37.1	9.1

DM = dry matter; CP = Crude protein; ME = Metabolizable Energy; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent Lignin

Note:- the DM content of Napier grass and Desmodium is as fed basis

The concentrate feed composed 18.2% CP and 2.73 Mcal/kg metabolizable energy. Mixture of Napier grass (70%) and desmodium (30%) plus noug seed cake composed 18.7% CP and 2.21 Mcal/kg metabolizable energy. The nutrient composition of the concentrate feed ingredients was referred from the report of Kegne *et al* (2021), grass hay and Napier grass from Shigdaf *et al* (2020) and desmodium from feedipedia (2020) (Table 1).

Experimental design and treatments

Experimental calves were randomly assigned to three treatment group; T1, control (Grazing + Grass hay); T2, Grazing + improved forage plus noug cake and T3, Grazing + concentrate.

The model used was: -.

$$Y_{ijk} = \mu + d_i + a_j + da_{ij} + error_{ijk}$$

Where: - Y_{ij} is feed intake, weight gains and weaning age; μ is the common mean; d_i is the effect of the i^{th} diet; a_j is the effect of the j^{th} age category (for feed intake only); da_{ij} is the interaction effect of the i^{th} diet and j^{th} age category; error is the residual error

Data collection and statistical analysis: -

Data on birth weight, weight at different ages, ages at weaning and feed intake (feed offered minus refusal) were collected for calves born from September 2020 to March 2021. The daily average feed intake for each feeding group was calculated by dividing the group feed intake by the number of calves in the group. The collected data entered and managed with Excel and subjected to analysis of variance using the General Linear Model (GLM) procedure of SPSS, version 25. Pearson correlation was calculated between weight at different ages of calves and dams milk yield. Tukey multiple comparisons was used to test differences between observed means. Partial budget analysis was conducted to select cost-effective feeding technology among the three feed treatments.

Grass hay fed calves had the longest weaning age in this study and hence calves weaning weights of improved forage and concentrate fed calves were adjusted to the weaning age of grass hay fed calves using their respective weight gains to compare them at similar weaning age. The amount of feed each calf consumed during the experimental period multiplied by the estimated market price of the feed was used to calculate costs of feed. The estimated market price for hay was 4.50 ETB/kg, improved forage 5.00 ETB/kg, noug cake 20.00 ETB/kg and 15.00 ETB/kg of concentrate feed. Costs of labor for each calf was calculated from the actual cost of daily laborers employed for managing the calves during the entire experimental period. Estimated selling price of 300.00 Birr/kg of live body weight was used to compute the partial budget analysis.

RESULT AND DISCUSSION

Growth of Fogera calves from birth to weaning and weaning age

Growth of Fogera calves from birth to weaning and their corresponding weaning age is shown in table 2. Growth of calves had significant variation at three ($p < 0.05$) and six ($p < 0.01$) months of age. At six months, concentrate fed calves were significantly ($p < 0.01$) heavier than other treatment groups. Concentrate fed calves on average were 12.2kg and 13.2kg heavier than improved forage and grass hay fed calves respectively at six months of age, which showed preweaning growth of calves could be improved by concentrate feed supplementation. Concentrate fed calves had attained the planned 100 kgs weaning weight at significantly ($p < 0.01$) shorter age (7.24 months) than improved forage (8.23 months) and grass hay (8.83 months) fed calves. Weaning age of concentrate fed calves has reduced by thirty and forty-eight days compared to improved forage and grass hay fed calves, respectively. Kassahun *et al* (2021) had reported birth weight of 21.3 kgs and weaning weight of 98 kgs at eight months of age for Fogera calves at Andassa Livestock Research Center. The grand mean body weight gain (Table 3) per day of calves showed a decreasing pattern from birth (0.37kg) to weaning age (0.27kg).

Table 2. Weight (kg) of calves from birth to weaning and weaning age of calves(months)

Variables	No.	Birth	One month	Three months	Six months	At weaning	Age at weaning
Overall mean	52	21.0±0.41	33.8±0.67	54.1 ± 1.05	83.2±1.65	100.1 ± 0.7	8.10± 0.17
Grass hay	19	20.8±0.67	33.0±1.11	50.5^{b}± 1.73	78.5^{b}±2.73	99.4 ± 1.18	8.83^{a}±0.28
Improved forage	17	21.1±0.71	33.4±1.18	55.3^{ab}±1.83	79.5^{b}±2.89	99.5 ± 1.24	8.23^{a}±0.29
Concentrate	16	21.2±0.73	34.9±1.21	56.7^{a}± 1.88	91.7^{a}±2.97	101.4±1.28	7.24^{b}±0.30
Sig.		0.896	0.469	0.044	0.003	0.444	0.001

Means within column with different superscripts are significantly different; * = significant at P < 0.05, ** =p < 0.01

Table 3. Weight Gain per day (kg) of calves at different ages

Variables	No.	Birth to three months	Three to six months	Six to weaning age
Grand mean	52	0.37	0.32	0.27
Grass hay	19	0.33	0.31	0.25
Improved forage + Noug cake	17	0.38	0.27	0.29
Concentrate	16	0.39	0.39	0.26

Correlation between growth of calves and their dam's milk yield is presented in Table 4. Growth of calves had significant (p<0.01) correlation (0.46) with milk yield of dams until six months of age which implied weaning of calves could be practiced at six months age. The decreased milk yield (1.58 liters/day) of dams at late lactation stage had no significant contribution to the growth of calves implying that the requirements of nutrients for maintenance and growth were met from grazing and supplementary feeding.

Table 4. Correlation between growth of calves and dam's milk yield

Variables	100 Days Milk yield	200 Days Milk yield	300 Days Milk yield
One month weight	0.46**	0.30^{NS}	0.62**
Three months weight	0.55**	0.56**	0.82**
Six months weight	0.48**	0.46**	0.70**
Weaning weight	0.09^{NS}	0.14^{NS}	0.20^{NS}

Correlation significant at ** $p < 0.01$, NS= Not significant

Feed intake and nutrient requirements of calves

Daily dry matter feed intake of calves varied based on feed types, age categories and interaction of feed types by age categories (Table 5).

Table 5. Average daily dry matter feed intake of calves (kg)

Variables (N= 52)	Mean ± SE
Feed types	0.003
Grass hay	$0.48^{b} \pm 0.01$
Improved forage + NC	$0.51^{b} \pm 0.01$
Concentrate	$0.60^{a} \pm 0.01$
Age categories	0.001
Up to one month	$0.14^{d} \pm 0.02$
One to three months	$0.27^{c} \pm 0.01$
Three to six months	$0.57^{b} \pm 0.01$
Six to weaning age	$1.24^{a} \pm 0.02$
feed types by age categories	0.001
One to three months (Improved forage + Noug cake)	0.26 ± 0.03
One to three months (Concentrate)	0.29 ± 0.02
Three to six months (Grass hay)	$0.41^{c} \pm 0.03$
Three to six months (Improved forage + Noug cake)	$0.51^{b} \pm 0.02$
Three to six months (Concentrate)	$0.62^{a} \pm 0.02$
Six to weaning age (Grass hay)	$0.55^{c} \pm 0.03$
Six to weaning age (Improved forage + Noug cake)	$1.13^{b} \pm 0.02$
Six to weaning age (Concentrate)	$1.36^{a} \pm 0.03$

Means in the same column with different superscripts are significantly different; ** = significant at $P < 0.01$

Results of this study showed at the age of three months average weight for improved forage fed calves was 55.3kg (Table 2) with daily weight gain of 380 g/day and concentrate fed calves weighed 56.7kg with daily weight gain of 390 g/day (Table 3). Calves at three months of age consumed on average 2.14 liters of milk per day based on farm milk records which contained 0.26kg dry matter. The dry matter content of the milk was referred from (Addisu *et al,* 2020) in a study of milk yield and composition of Fogera cows fed with Napier grass and concentrate feed at Andassa livestock research center. In this study the total solids of milk were 12% and was analyzed using lacto scan milk analyzer. Thus, improved forage plus noug seed cake fed calves consumed 0.26kg from milk plus 0.26kg from treatment feed with a total of 0.52 kg dry matter. Concentrate fed calves consumed 0.26kg from milk plus 0.29kg from treatment feed with a total of 0.55 kg dry matter which is below compared to 0.76kg (NRC, 2001) daily dry matter requirement of 50kg calf gaining 400 g/day.

Based on NRC (2001), whole milk contains 25.4 CP (% of DM). Thus, the daily 66g CP intake from 0.26kg dry matter milk plus 49g from treatment feed totals 115g CP for maintenance of 55.3kg with weight gain of 380 g/day for calves fed improved forage plus noug seed cake at three months of age which is below compared to the NRC (2001) daily 154g CP maintenance requirement of 50kg calf with weight gain of 400 g/day. Based on NRC (2001), whole milk contains 5.37 Mcal/kg of DM metabolizable energy (ME). Thus, the daily 1.40 Mcal ME from 0.26kg dry matter milk plus 0.58 Mcal from treatment feed totals 1.98 Mcal ME for maintenance of 55.3kg with weight gain of 380 g/day for calves fed improved forage plus noug seed cake is below to the 3.15 Mcal maintenance requirement of 50kg calf with weight gain of 400 g/day (NRC, 2001).

The daily 66g CP intake from milk plus 53g from treatment feed totals 119g CP intake for maintenance of 55.3kg with weight gain of 380 g/day for calves fed concentrate at three months of age is below compared to the NRC (2001) daily 154g CP maintenance requirement of 50kg calf with weight gain of 400 g/day. The daily 1.40 Mcal from milk plus 0.79 Mcal from treatment feed totals 2.19 Mcal ME for maintenance of 55.3kg with weight gain of 380 g/day for calves fed concentrate is below to the 3.15 Mcal ME maintenance requirement of 50kg calf with weight gain of 400 g/day (NRC, 2001).

The amount of crude protein and metabolizable energy each age categories of calves gained from daily feed intake in this study and the NRC (2001) nutrient requirement shown in parenthesis is presented in Table 6. The comparison has shown feed intake of calves in this study did not meet the NRC nutrient requirement. The limitation of this study is that feed intake from grazing pasture was not estimated which could have contribution to meet part of the nutrient requirements of calves.

Table 6. Daily mean CP (g) and ME (Mcal) intake versus NRC requirement of calves at different ages

Feed type	**Nutrients**	**One to three months**	**Three to six months**	**Six to weaning age**
Grass hay	CP	66	73 (224)	71 (316)
	ME	1.40	1.97 (4.67)	2.07 (6.45)
Improved forage + Noug Cake	CP	115 (154)	151 (224)	259 (316)
	ME	1.98 (3.15)	2.31 (4.67)	3.52 (6.45)
Concentrate	CP	119 (154)	169 (224)	296 (316)
	ME	2.19 (3.15)	2.87 (4.67)	4.73 (6.45)

CP= crude protein, ME= metabolizable energy; Values in parenthesis are NRC nutrient requirement

Partial Budget Analysis

The partial budget analysis result showed that concentrate, grass hay, and improved forage feed treatments gave an average net benefit from weaned calves 25059.54, 22578.65 and 20221.58 ETB, respectively. Concentrate feeding gave the highest net benefit compared to other treatments (Table 7).

Table 7. Partial budget analysis of weaning age of calves for different feeding groups

Costs and Benefits	**Unit**	**Amount used and costs**					
		Grass hay		**Improved forage**		**Concentrate**	
		Amount	Cost ETB	Amount	Cost ETB	Amount	Cost ETB
Price of calf	ETB		6240.00		6330.00		6360.00
Concentrate	Kg	0	0	0	0	151	2265.00
Improved forage	Kg	0	0	535	2675.00	0	0
Noug cake	Kg	0	0	84	1680.00	0	0
Imp Forage + NC	Kg	0	0		4355.00	0	0
Hay	Kg	96	432.00	0	0	0	0
Labor cost	ETB		569.35		509.42		479.46
Total cost (A)	ETB		7241.35		11194.42		9104.46
Gross benefit (B)	ETB		29820.00		31416.00		34164.00
Net benefit (B-A)	ETB		22578.65		20221.58		25059.54
Cost benefit ratio(B/A)	ETB		4.12		2.81		3.75

CONCLUSION AND RECOMMENDATION

The study showed concentrate fed calves had better dry matter feed intake and attained the planned 100 kgs weaning weight at significantly shorter age than other treatment groups. Weaning age of concentrate fed calves has reduced by thirty and forty-eight days compared to improved forages and grass hay fed calves, respectively. Concentrate fed calves had significantly higher ($p<0.01$) feed intake compared to other feed treatments from three months of age until weaning. Based on the results of the study it is recommended that calves should be fed good quality concentrate feed to promote early solid feed intake, increase preweaning growth and reduce weaning age.

ACKNOWLEDGEMENTS

The authors would like to thank Bureau of Finance and Economic Development of Amhara region for the release of the Fogera capital budget from which feed and labor costs were covered. Those who participated in improved forage development, preparation of calf concentrate feed, calves' management and data collection are highly acknowledged.

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Risk Factors and Genetic Parameter Estimates for Pre-weaning Survival of Fogera Calves

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ABSTRACT

This study was undertaken to investigate the most important factors that influence survival and to estimate genetic parameters for pre-weaning survival of Fogera calves. About 1043 Fogera calves death records maintained at Andassa Livestock Research Center collected from 1984 to 2021 was used. The data were collected from the data sheets, including birth weight, pedigree details, sex, season, and year of birth. Survival rate and risk ratio were analyzed using Weibull proportional hazard model with Survival Kit version 6.1 software. The heritability and genetic variances was estimated using sire model. The survival rate was scored as 1 (alive) or 0 (died) in accordance with the records. The proportion of right-censored calves up to 1, 4, and 8 months of age was 90.8, 87.8, and 83.5 %, respectively. Around 55.8% of all deaths (16.5%) of death occurred up to one month of age. Birth year, sex, season, and weight at birth were the risk factors for calf mortality. The heritability (h^2) estimates for the survival of calves at 1, 4 and 8 months of age from the Weibull proportional hazard model were 0.26±0.14, 0.22±0.13, and 0.38±0.18, respectively. A relatively higher estimate of heritability (0.38±0.18) at age of eight in the current study implies inclusion of survival traits as selection criteria in the breeding program will enhance the survival rate. Similarly, higher differences in estimated breeding values (ranged from -0.857 to 0.780) of sires for survival suggests that selection of sires with higher estimated breeding values could improve the survival potential of calves.

Keywords: *Birth weight, estimated breeding value, heritability, risk ratio, survival rate*

INTRODUCTION

Cattle production is a major component of the livelihoods in Ethiopia with an estimated population of 70.3 million (CSA, 2021). The indigenous cattle breeds are raised for multiple purposes and they are source of milk, meat, and draft as well as manure production (Tucho et al., 2021). However, there is a big gap between the population and productivity in terms of milk yield which caused unbalance between the demand and supply. Thus, to overcome the increasing milk demand due to the fast human population, intensification of animal products in terms of quality and quantity is essential.

Fogera breed is one of the indigenous cattle breeds in Ethiopia which is originated from the area around Lake Tana in Gondar and west Gojjam administrative zones. The breed is a source of draught power, meat and, milk (Bitew et al., 2010). The breed is characterized as large size and tall animals with long legs. Besides, the breed performs well in the heavy fly burden and swampy areas (Anteneh, 2010). Nevertheless, the population of Fogera cattle is showed a declining trend over years (Mekuriaw and Kebede, 2015). As a result, Fogera cattle breeding and multiplication ranch were established with the aim of conserving and improving the breed for its milk production.

Calf survival is the most important factor to be consider in the dairy sector for better profitability (Prasad et al., 2004). In recent times, cattle breeding programs in Ethiopia have focused primarily on reproduction traits to maximize genetic gain. However, there is no documented report that survival traits included in any breeding program. Inclusion of survival analysis in the breeding program could enhance milk productivity due to the positive genetic correlation between each other (Hudson and Van Vleck, 1981; Peñagaricano and Khatib, 2012; Rocha et al., 2017). Mortality at an early stage causes great economic loss in the dairy industry, due to death loss, treatment cost, decreased lifetime productivity, and limited dairy herd expansion and genetic selection (Miguel et al., 2016). In addition, the mortality of calves from birth to weaning highly affects the breeding program through the loss in value of the calf, and the genetic value that will be used for replacement heifers and bulls for the next generation. As a result, of the birth of calves is a long-term investment, strong attention is essential for their survival. Thus, knowledge of the influence of non-genetic factors on calf survival and the contribution of genetic variation to calf survival are very important to enhance the calf survival rate. However, there is little evidence on risk factors of mortality (Wudu et al., 2008; Kebamo, 2019; Gessesse et al., 2021) but the genetic parameter estimates for the survival of Fogera calf is not documented in Ethiopia. Therefore, the objectives of this study were to evaluate the survival potential of calves, identify risk factors, and estimate genetic parameter estimates for survival traits of Fogera cattle at different ages.

MATERIALS AND METHODS

Study area

The study was conducted at Andassa Livestock Research Center located at an altitude of 1730 m.a.s.l and at 11°29′ North and 37°29′ East on the street way 22 km from Bahir Dar to Tis Abay. The Center receives an average annual rainfall of 1150 mm, and temperature ranges from 6.5 to 30 °C. The center currently own 500 pure Fogera with about 300 breeding cows.

Herd management

Cattle were managed with a semi-intensive management system. The mating system was adjusted according to the recommendation by Timlin et al. (2021) with the bull to cow ratio of 1:50. The herd groups were arranged to graze in three separately located grazing areas namely Nechita, Doro bet and Ameradifa grazing areas to control closely related animals. The assigned bulls were kept with cows both during the day and night times. Each herd groups had two herdsmen to collect mating, health and feeding related data. All data related recorded by the herdsmen will be recorded on cow card history. Even though Hernandez-Castellano et al. (2015) recommended that the first day after birth is important for colostrum feeding, newborn calves were kept with their dams for enough colostrum suckling for 4 days.

Birth weight was measured using live weight within 24 hours and weaning weight was measured at 8 months of age. The mating plan was arranged based on the pedigree information using pedigree viewer software. Calves suckled two times per day at 6:00AM and 4:00PM until weaning. All breeding cattle were allowed to graze on green pasture for 10 hour/day. Considering their physiology, dry period concentrate supplementation for pregnant cows and calves was practiced to sustain their maintenance in the center. All animals were housed in semi-opened concrete barns at night and had free access to water freely. Regular vaccination against common cattle diseases in the area such as Foot and Mouth Disease, Lumpy Skin Disease, Anthrax, and seasonal deworming for internal and external parasites were given. Sick animals were isolated immediately and treated in isolation until recovery.

Data collection and traits studied

The total numbers of records considered for the analysis were 1043. The data for Fogera calve were collected from 1984 to 2021. The survival from birth to 1, 4, and 8 months of age was evaluated. Survival at different ages was recorded as a binary trait where calves that were still alive at the end of the specified period (right-censored) were coded as 1, and 0 if died. The survival analysis excluded calves that were removed from the herd because of culling and death due to physical injury.

Statistical analysis

The survival data were analyzed with a Weibull proportional hazard model using Survival Kit version 6.1 (Ducrocq et al., 2010). The plot of the Kaplan-Meier as a non-parametric estimation of the survival curve, with shape parameter ρ and scale parameter λ of the Weibull distribution was used to assess the validity of applying a Weibull proportional hazard model. The result of this plot combination showed a straight line which confirms that the data followed the Weibull distribution (Figure 1). In addition, Weibull distribution does not assume a constant hazard rate and therefore has broader applications; hence, Weibull survival distribution was estimated for the probability of survival (Abdelqader et al., 2017). The Weibull survival mixed model or the proportional hazards model for the death of a particular calf at a time (t) was modeled as:

$$\lambda(t) = \lambda_0(t) \exp [A_i + C_j + S_k + W_l + Sire_m]$$

Where, $\lambda(t)$ is the hazard function for probability of calf being died at time t, $\lambda_0(t)$ is the Weibull baseline hazard function with shape parameter ρ and scale parameter λ according to (Casellas et al., 2007). A is the fixed effect of year (1984-2021, year was grouped to seven categories), C is the fixed effect of season (wet and dry), S is the fixed effect of sex (male and female), W is the fixed effect of birth weight of calf (<20, 20-24, and ≥25) and $Sire_m$ is random effect of m^{th} sire with the multivariate normal distribution (Ducrocq, 1997) with mean zero and variance A σ^2_s, in which σ^2_s is the sire variance and A is the relationship matrix among sires.

Heritability was estimated according to (Yazdi et al., 2002) by assuming a proportion of uncensored records:

$$h^2 = [4\sigma^2_s] / [\sigma^2_s + 1/p]$$

Where, h^2 is the coefficient of heritability for kid survival, σ^2_s is the genetic variance of sire and p is the proportion of uncensored records.

The estimated breeding values were standardized, dividing them by the estimated sire genetic standard deviation. Thus, higher genetic values are associated with a higher risk of mortality. In addition, they were multiplied by -1 to be easier to interpret: a positive EBV is related to sires transmitting a better survival or lower risk of mortality according to Ducrocq (2005). The genetic trend was estimated by computing average EBV by year of birth.

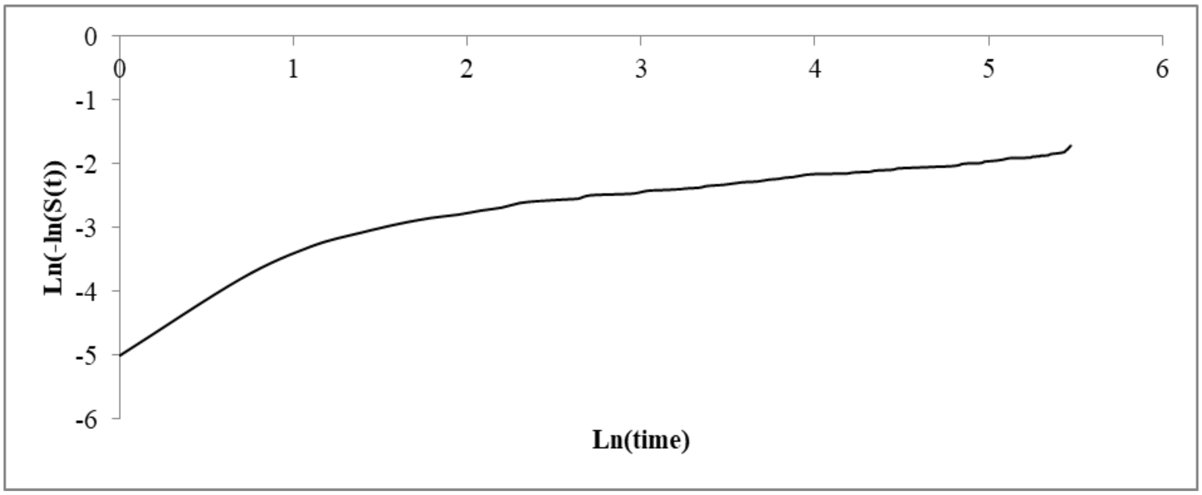

Figure 1. Graphical test for the Weibull distribution assumptions for survival of Fogera calves from birth to weaning

RESULT AND DISCUSSION

Proportion and time of failure

The observed failures and average time of failure for each level of risk factors of calf mortality are shown in Table 1. The pre-weaning mortality rate of male calves (21.3%) was higher than the mortality of female calves (13.4). The average failure time for males was earlier than the corresponding female calf which might be attributed to management discrimination against male calves since female calves were in high demand for future replacement herds. In agreement with the current result, males had higher mortality rates and lower average time of failure (Sallam, 2019). Calves born in the dry season had a relatively higher number of failures (5.71%) compared to calves born in the wet season (11.9 %). This could be explained by seasonal variation in green forage and pasture availability across seasons. Calves born in the wet season can get enough nourishment from their dams resulted low number of failure, which is missed in dry season. Calves with light (21.4%) and heavy (20.9%) birth weight had high mortality rate compared to calve with moderate (13.5%) birth weight. The failure time of calve with light birth weight was earlier compared to calve with moderate and heavy birth weight category. In agreement with the current finding, Mccorquodale et al. (2008) reported that light calves had low total protein scores and are at increased risk of mortality when compared to heavy calves. Similar to the reports of Vinet et al. (2018), relatively higher risk of calf mortality in the current study with higher birth weight of calves (>25kg) may be due to stresses at birth.

The mortality rate and average time of failure of calve across years was varied and a higher mortality rate were observed for calves born in 2000-2004. The higher mortality rates recorded in the above study periods might be poor feeding and health management practices employed in the center. Better feeding and health management practices and small number of records considered in the analysis contributed to the no-failure records in the two-year categories (1977-1984 and 1985-1989). Similar to the reports of Mellado et al. (2014) the variability of mortality rate and average time of failure of calve across years in this study could be due to high environmental sources of variations such as rainfall, humidity and temperature, which could influence feed availability and poor pasture development due to variability of rainfall patterns over the years. Moreover, inconsistent data set used for survival analysis compared to the long duration of study periods could be taken as a limitation of the study that may affect the levels of significance for each risk factor.

Risk ratio and risk factors of calf mortality

The proportion of right- censored and associated risk factors for mortality of Fogera calf are shown in Table 2. The proportions of the right-censored calves at 1, 4, and 8 months of age were 90.8, 87.8, and 83.5%, respectively. Fogera calf mortality in the current study up to weaning age was relatively lower (16.5%) than the previous reports (Kebamo, 2019). The higher risk of mortality from the total risk occurred before the age of one month (Table 2) and it was due to the higher sensitivity of calves at an early age to diseases and changes in environmental conditions. Similar result to the current finding, Riley et al. (2004) reported that survival up to one month of age is directly or indirectly associated with the condition of dams. The result showed that the calves survival rate was significantly (P<0.05) associated with different fixed factors such as season and calf weight at birth.

Table 1. Observed failures and average time

Source of variation	N	1 month NF (%)	1 month AT(days)	4 months NF (%)	4 months AT(days)	8 months NF (%)	8 months AT(days)
Sex							
Male	409	46(11.2)	27.6	62(15.2)	105.3	87(21.2)	204.9
Female	634	50(7.89)	28.2	66(10.4)	109.5	85(13.4)	215.2
Season							
dry	588	70(11.9)	27.3	89(15.1)	104.7	109(18.5)	204.8
wet	455	26(5.71)	28.8	39(8.57)	112.0	63 (13.8)	219.5
Birth weight (kg)							
<20	252	37(14.7)	26.7	46(18.2)	101.6	54 (21.4)	197.5
≥20-24	638	43(6.74)	28.5	65(10.2)	110.4	86(13.5)	216.8
≥25	153	16(10.5)	27.5	17(11.1)	107.8	32(20.9)	209.8
Year							
1984-1991	16	0(0.0)	30.0	0(0.0)	120.0	0(0.0)	240.0
1992-1996	65	0(0.0)	30.0	0(0.0)	120.0	0(0.0)	240.0
1997-2001	394	30(7.61)	28.5	44(11.1)	109.3	48(12.2)	215.5
2002-2006	225	27(12.0)	27.3	32(14.2)	105.3	47(20.9)	205.4
2007-2012	62	31(50.0)	18.4	37(59.7)	59.2	39(62.9)	105.8
2013-2016	87	6(6.90)	28.3	8(9.20)	110.1	9(10.4)	218.2
2017-2021	194	2(1.03)	29.7	7(3.61)	117.5	29(14.9)	227.8

N number of observations; NF number of failures; AT Average Time

All the listed fixed factors considered in the current study significantly affected (P< 0.01) the survival of Fogera calve. The sex of calves exerted a significant influence on the survival of calves. The risk of mortality with male calves was 1.88 times and 1.87 times that with female calves up to one and four months of age, respectively. However, up to eight months of age, the risk of mortality with female calves was reduced by 52% compared with male calves. The higher mortality of male calves up to one and four month observed in the current study was in agreement with previous studies (Riley et al., 2004; Schmidek et al., 2013; Condon et al., 2021). Similar to the current study, the superior survival of female calves compared to males was reported earlier (Cecchinato et al., 2008). The superior survival of female calves up to eight months of age may be due to better management given to females as replacements for the future herd; which is in agreement with the reports of Mukasa-Mugerwa et al. (2000). Reports supported the current study also implied that relatively higher metabolic rates of males (Getachew et al., 2015) and increasing activity of hormones such as estrogen (Kocak et al., 2007) may have influenced the differences between sexes.

The birth weight of calves had a significant influence on the survival of calves up to one and four months of age. However, its effect was non-significant (P>0.05) for survival up to eight months of age. Risk of mortality showed inversely associated with weight at birth of calves. Calves born with very light birth weight (<20 kg) showed the highest risk of mortality than calves with moderate (≥20-24 kg) birth weight. The risk of mortality with calves with light birth weight was 1.83 times and 1.51 times that of moderate weight up to one and four months of age, respectively. The higher mortality rates of calves with lower birth weight could be due to low serum total protein amount which contributes to lower immunity of light calves and lower adipose tissue accumulation that reduced the immunity of calves (Mccorquodale et al., 2013). Nevertheless, the risk of mortality for calves with heavy birth weight was statistically similar to moderate birth weight and supported by earlier results elsewhere in the world (Hudson and Van Vleck, 1981; Tarres et al., 2005).

In a similar fashion, the season of calving significantly affected the survival of calves at different ages. Calves born in the wet season had a lower risk of mortality than those born in dry season. Better feed availability in the wet season could help cows to nourish their calves and better survive than those born in the dry season. The risk of mortality with calves born in the wet season was significantly reduced by 55% up to one month and by 47% to four months of age compared with calves born in the dry season. However, the reduction of mortality in calves born in wet season was non-significant up to eight months of age. A conflicting result was reported on the effect of season of birth on survival of calves for Ontario Holstein heifer calves (Mccorquodale et al., 2013). Similar results were reported for different sheep breeds elsewhere in the world (Getachew et al., 2015; Sallam, 2019; Tesema et al., 2020). Higher mortality in the dry season may be associated with a lower amount of colostrum produced in the dry season according to the reports of Gulliksen et al. (2009) for Norwegian calves.

The result of this study demonstrated that there was a significant difference of mortality rates over the years of calving. This could be explained by several factors, such as natural forage availability, dynamics of herd management practices, and influences of other environmental factors such as, late or no vaccination and deworming which is in line with previous studies (Tarres et al., 2005). The estimates of the corresponding risk ratios did not follow a consistent trend. The risk of mortality for calves born between the years 2007-2012 was higher than the rest of the study period (Table 2); which implies variability of calf management- associated factors across the study years. The risk of mortality with calves born in 2007-2012 was 7.45 times and 7.56 times that with calves born in 1997-2001 up to four and eight months of age, respectively.

Table 2. Risk ratio for each factor level relative to the reference (1.00)

Source of variation	**RR1M**	**RR4M**	**RR8M**
Right censored	90.8%	87.8%	83.5%
Sex	P=0.0034	P=0.0001	P=0.0001
Male	1.88**	1.87***	1.00
Female	1.00	1.00	0.48*
Season	0.0001	0.0003	0.0081
Dry	1.00	1.00	1.00
Wet	0.45***	0.53**	0.77ns
Birth weight (kg)	P=0.0093	P=0.0271	P=0.2070
<20	1.83**	1.51*	1.24ns
≥20-24	1.00	1.00	1.00
≥25	1.01ns	0.81ns	1.18ns
Year	P=0.0001	P=0.0001	P=0.0001
1984-1991	0.00	0.00	0.00
1992-1996	0.00	0.00	0.00
1997-2001	0.14***	1.00	1.00
2002-2006	0.15***	1.08ns	1.08ns
2007-2012	1.00	7.45***	7.56***
2013-2016	0.15**	0.65ns	0.47ns
2017-2021	0.009***	0.17***	0.53ns

RR = risk ratio; *** = P < 0.001; ** = P < 0.01; *= P < 0.05; ns = non-significant

Kaplan-Meier survival function and cumulative hazard curve of calves from birth to 8 months of age are shown in Figure 2. The hazard of mortality of calves was higher up to 30 days and tends to increase at a decreasing rate after one month of age. On the contrary, the probability of calf survival was decreasing at an increasing rate up to 30 days and then decreasing at a decreasing rate. From the total death of calves (16.5%) to weaning age, about 55.8% (9.20%) of death occurred up to 30 days of age. The survival curve had a highly downward pattern from the time of birth and continued to age of 30 days but their survival improved immediately after one month of age. A similar pattern of calf survival was reported by Schmidek et al. (2013) and Tarres et al. (2005) for different beef breeds. The higher mortality of calves justifies the need for critical attention on management interventions during one month on postnatal periods.

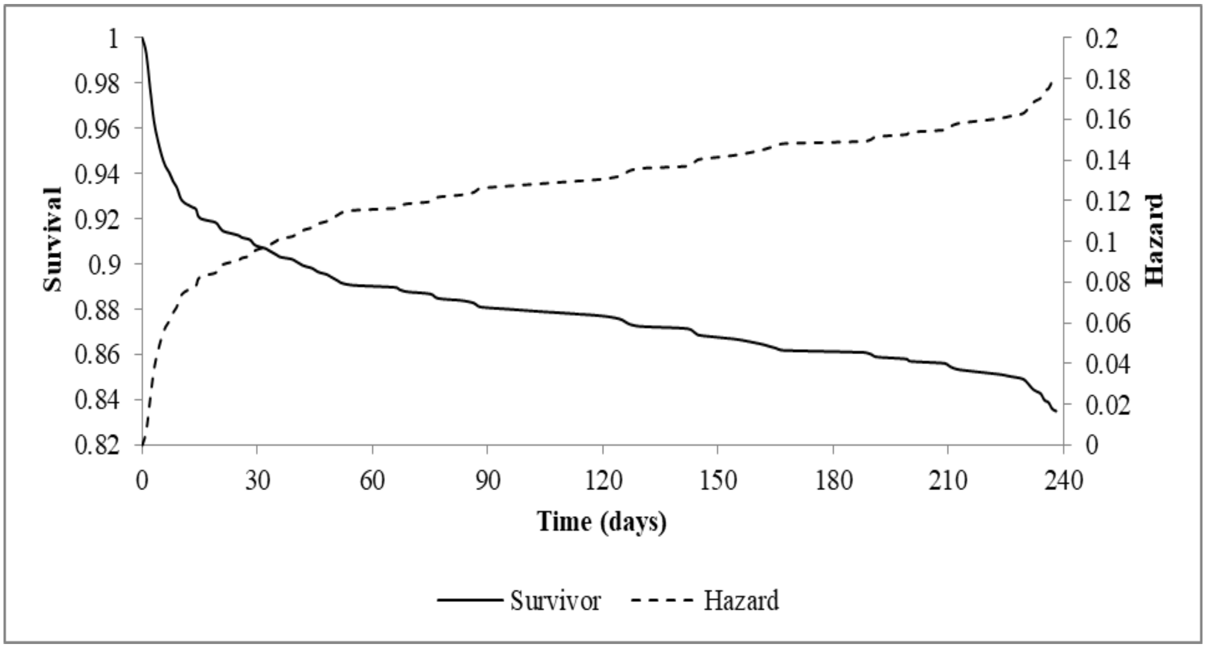

Figure 2. Kaplan-Meier survival function and cumulative hazard curve of calves from birth to weaning age

Heritability estimates of calf survival using Weibull sire model

The estimates of variance and heritability for the survival of Fogera calves at 1, 4, and 8 months of age from the Weibull sire model are presented in Table 3. From the Weibull proportional hazard model, the heritability estimates were not the same at different ages. The heritability estimates for calf survival at 1, 4, and 8 months of age were 0.26, 0.22, and 0.38, respectively. A relatively, lower heritability estimate for the survival of calves until the age of one and four months compared to eight months of age was more likely due to having a higher influence on feeding and health management, factors and lower contribution of the genetic variation and selection for genetic improvement targeting at age of one and four would bring slow progress than the age of eight. The current estimates of heritability for survival traits at pre-weaning ages were much higher than most of the previous studies for different beef-type breeds in the world (Goyache et al., 2003; Riley et al., 2004; Fuerst-Waltl and Sørensen, 2010; Pritchard et al., 2013; Schmidek et al., 2013; Henderson et al., 2014; Vinet et al., 2018). Although selection based on improved calf survival could enhance the profitability of dairy farms, it was ignored in many cattle breeding stations in Ethiopia. Lower heritability estimates for calf survival traits at one and four months of age in the current study implies that selection for genetic improvement targeting survival of those traits at this age reduces the genetic variability and slows genetic progress over eight months of age. In general, the medium to high heritability estimates for pre-weaning survival potential of Fogera calves at the ages of eight in the current study implied improvement of the survival rate of calves was effective and enough genetic variation existed in the study population. Therefore, considering survival traits at weaning age needs to be included in selective breeding programs along with better management intervention.

Table 3. Variance and heritability estimates for pre-weaning survival of Fogera calf

Traits	σ^2_s± SE	h^2± SE
Survival to 1 month	0.74±0.44	0.26±0.14
Survival to 4 months	0.48±0.29	0.22±0.13
Survival to 8 months	0.65±0.34	0.38±0.18

σ^2_s sire genetic variance; h^2 heritability estimate; SE standard error

Estimated breeding value (EBV) for survival traits

The estimated breeding value (EBV) of the top 20 sires for pre-weaning survival is presented in Figure 3. Even though the survival of calves is directly affected by the genetic merit of both the sirs and the dams, survival traits were analyzed from censored records of calves born per selected sires according to Vollema and Groen (1998). In this regard, the mean number of censored records per sire was 17. The Estimated breeding values of sires in the current study, for pre-weaning survival, was varied -0.857 to 0.780 with an overall mean of 0.022. However, most (53%) of the sire had a positive EBV (0.011 to 0780). The variation in the breeding values for survival traits indicated appreciable differences existed between sires. The estimated breeding values of the top 20 sires ranged between 0.204 and 0.780 with an overall mean of 0.338 which indicated sires with superior survival potential were used in the breeding program. The highest estimated breeding value (0.780) obtained in the current study implies best sires were existed that transmitted a better survival or lower risk of mortality to their off-springs. The estimates of breeding values for survival traits in the current study is higher than the previous result (Davis et al., 2020) for different beef and dairy crossbred calves. In the current study, a genetic standard deviation of 3% for survival potential was observed between sires which could be used to select the best and worst bulls with regard to calf survival potential. Therefore, higher estimated breeding values had better survival and subsequently, calves born from bulls of higher estimated breeding values of survival had a chance of better survival. In this study, a higher pre-weaning survival difference was observed among total sires and also among sires having positive breeding values. The estimated breeding value of the top 20 sires was 54.5% higher than the average EBV of sires having a positive breeding value. Reports indicated presence of 8% differences in breeding values in the first 180 days from birth (Norberg et al., 2013). Therefore, selection of sires based on better estimated breeding values for survival traits in combination with milk traits would improve the survival rate of calves and it should be included in the breeding program.

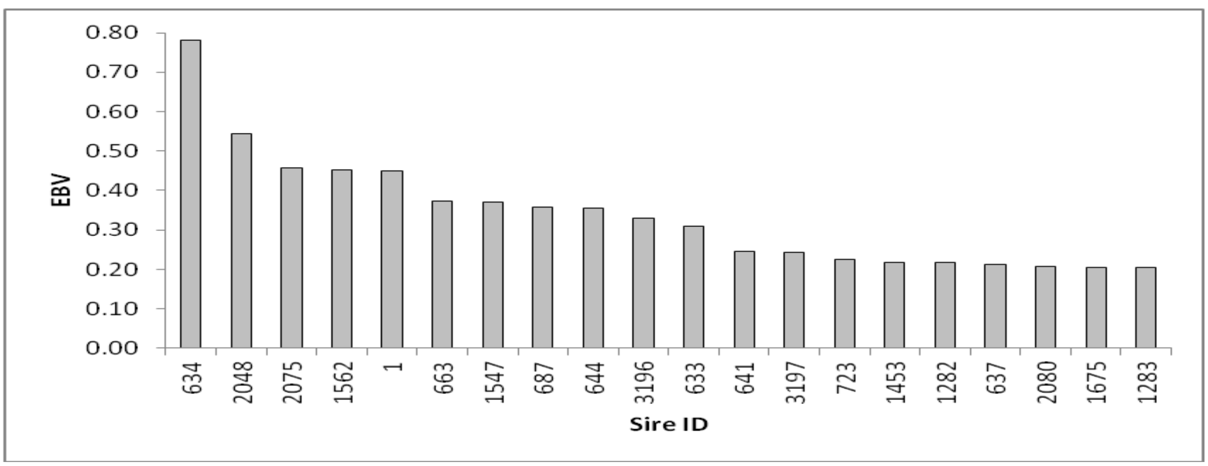

Figure 3. Estimated breeding value for pre-weaning survival of top 20 sires

The genetic trend of sires for mortality traits from birth to 8 months of age during the period from 1984 to 2021 is presented in Figure 4. The genetic trend from 1984 to 1991 clearly showed significant improvement on breeding values while critical deterioration was observed till then for calf survival. Generally, the survival potential of Fogera calves in the study periods genetically decreases 0.0334 days every year. The observed genetic reduction for survival traits from the year

2001 to 2021 might be the frequent use of worst sires with lowest estimated breeding values for survival traits as survival was not considered during bull selection. Therefore, selection of sires with higher estimated breeding values for survival traits could be used for reduced calf mortality in the breeding programme.

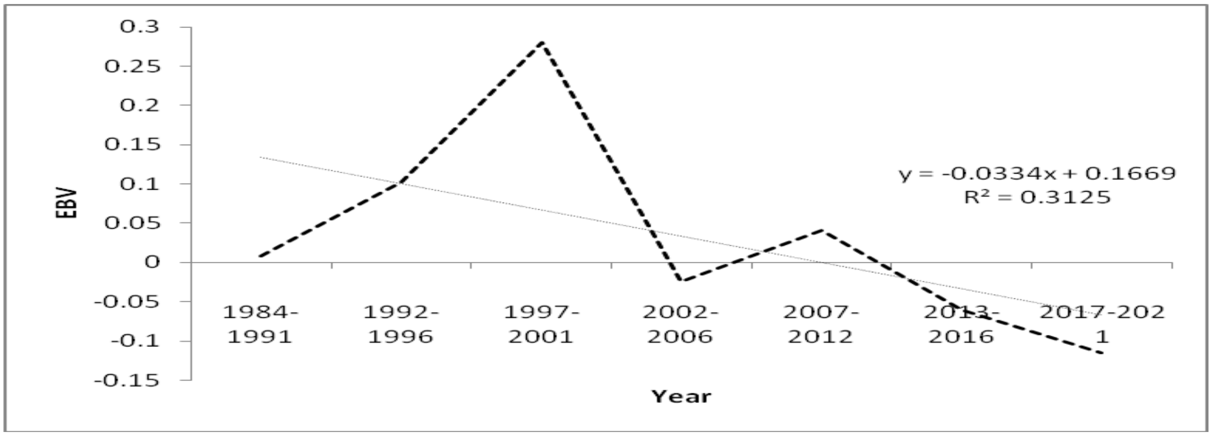

Figure 4. Estimate of the genetic trend for survival of Fogera calve

CONCLUSION AND RECOMMENDATIONS

The pre-weaning survival rate of Fogera calves was high and of the total mortality, higher mortality was occurred during the first 30 days of age. High mortality rates were observed for calves having lighter weight at birth and born during dry periods. The presence of enough variability within the population, as indicated by moderate heritability estimates for the pre-weaning survival of Fogera calves, suggested that selection could improve calves' survival potential by incorporating survival traits in the breeding program. Furthermore, the variations in estimated breeding values of sires for survival traits imply that sires with higher estimated breeding values for survival traits should be used for lower calf mortality

ACKNOWLEDGMENT

The authors appreciate Andassa Livestock Research Center for allowing the data in writing this research article.

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Productive and Reproductive Performances of Simien Sheep under Smallholder Management System in North Gondar Zone, Ethiopia

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ABSTRACT

The study aimed to evaluate the growth and reproductive performance of Simien sheep managed under the smallholder management system in Debark and Dabat districts. The data were collected from June 2017 to September 2021. A total of 2410 sheep of 152 sheep owner households from the two sites was used for the study. Growth and reproductive performance data were analyzed and estimated by the GLM procedure of SAS (version 9.4). The overall least square mean weight (±SE in kg) at birth, three months, six months, nine months and twelve months were 2.40±0.01, 12.25±0.07, 15.51±0.18, 19.01±0.21, and 21.58±0.36, respectively. The overall litter size, lambing interval (days) and age at first lambing (days) (±SE) of Simien sheep was 1.18±0.01, 260.63±24.19, and 388.59±18.33, respectively. The sex of lamb had a significant effect on weight at birth ($P<0.0001$), three months ($P<0.01$), and six months ($P<0.05$) of age; and male lambs were heavier ($P<0.05$) than female lambs. Lambs born in 2021 were significantly ($P<0.001$) heavier than in other years. Lambs born at the 3rd to 6th parity were significantly heavier ($P<0.001$) than lambs born below and above the 3rd and 6th parity at birth. Single-born lambs were significantly heavier ($P<0.001$) than twin lambs at birth, three months and six months of age. Lambs born in heavy post-partum weights of dams were significantly heavier and had high litter size ($P<0.05$) than lambs born in light and medium post-partum weights of dams. Lambs born at ≥4th parity had significantly high litter size ($P<0.001$) than lambs born at lowering parities. Lambs born in the birth year 2021 had significantly high litter sizes ($P<0.05$) than other birth years. The factor of birth year and post-partum weight significantly affected all parameters considered in this study, which needs an improvement in management through full-package husbandry practice intervention.

Keywords: *community-based breeding, non-genetic factors, growth trait, litter size, Simien sheep.*

INTRODUCTION

Sheep are the most important livestock species next to cattle with diverse genotypes and a huge population in Ethiopia. They contribute substantially to the livelihoods of smallholder households as a source of income, food (meat and milk), and non-food products such as manure, skins and wool. They also serve as a means of risk mitigation during crop failures, property security, monetary saving and investment, and many other socioeconomic and cultural functions (Adane, 2008; Legesse et al., 2008; Duguma et al., 2010). Demand and prices for sheep and goat meat show an increasing trend due to urbanization, increased income in the cities, and increased demand from the Gulf countries. However, the annual meat production from small ruminants is relatively small compared with the number of heads. The average annual off-take rate and carcass weight per slaughtered animal in Ethiopia for 2000-2007 were estimated at 32.5% and 10.1 kg, respectively (FAO 2009), which if the lowest among sub-Saharan African countries.

Previous studies have shown that indigenous Ethiopian sheep and goat breeds have the potential to produce more and better meat and skins, so long as they are fed, managed and bred better. To do this, farmers need to be organized to continuously retain and access better breeding rams, forestall inbreeding, and have better access to markets. Selective pure breeding of the adapted indigenous breeds is the best possible option for genetic improvement in tropical countries. Indigenous breeds in harsh tropical environmental conditions have special adaptive features such as tolerance of a wide range of diseases, water scarcity and the ability to better utilize limited and poor-quality feed (Baker and Gray, 2004; Kosgey and Okeyo, 2007). The recent approach of establishing community-based breeding programs is advocated for low-input traditional smallholder farming systems (Sölkner et al., 1998; Kahi et al., 2005; Haile et al., 2009, Wurzinger et al., 2011). This is because community-based breeding programs take into account the needs, views, decisions, and active participation from inception through to implementation and their success is based upon proper consideration of farmers' breeding objectives, infrastructure, participation, and ownership (Mueller 1991; Sölkner et al. 1998; Wurzinger et al., 2011). According to Solomon (2008), Ethiopia has 8 sheep breed groups and 14 populations; of which Simien sheep is among them. This paper was initiated to assess productive and reproductive performances of Simien sheep under farmer's management conditions and to identify factors influencing the performances of Simien sheep under the community based breeding program.

MATERIALS AND METHODS

Description of the Study Area

Two villages of Debark and Dabat, one in each district were studied. These districts are the major Simien sheep farming areas in the North Gondar highlands of North Western part of Ethiopia. The villages were Daber from Debark and Chanbelege from Dabat. Although the geographic coordinates and the topography characteristics of these villages vary (Table 1), the livestock farming systems and also having good potential and large area coverage in Simien sheep rearing are marks of similarity between the two villages. Farmers are organized into cooperatives to improve and conserve the Simien sheep breed through a participatory selection scheme. The known farming system of the area is mixed crop-livestock production.

Table 1. Description of Debark and Dabat Districts

Features	**Debark**	**Dabat**
Altitude/ elevation (m.a.s.l.)	2712 to 3122	1500-3200
Temperature (^oC)	6.2 to 20.7	18-35
Rainfall (mm)	900-1400	600-1400
Human population	169,835	145,509
Distance from Addis Ababa (Km)	830	800
Geographic coordinates		
Longitude	37^o90'00"E	37^o45'54"E
Latitude	13^o13'30"N	12^o59'00"N
Animal population		
Cattle	380,403	209,117
Sheep	123,948	214,150
Goat	61,974	113,100

Source: Respective district agricultural planning office (2015) and CSA, (2009)

Description of Simien Sheep Breed

Simien sheep is one of the sheep breeds of Ethiopia characterized by short fat-tailed curved upward, plain and patchy coat color patterns dominated by brown color, fur long coarse hair type of females and fur short smooth hair of males, the majority of which lack wattle and ruff, with ewes usually polled and rams are mostly horned with curved and spiral shape (Surfed et al., 2019) and fleece fibre type (Solomon, 2008). It lives in the sub-alpine ecology of the country having a population of about 347,600 with high economic merit, high cultural values and ecological values. It is found in the first non-safe threat status and requires conservation priority out of the five breeds under threat. The high within-breed diversity, lowest kinship, high heterozygosity and high allelic richness make the breed unique and important (Solomon, 2008; Surafel, 2012).

Description of the breeding program

Two breeding programs were established for the Simien sheep breed in the two districts. The breeding program has been implemented since 2017 following the guideline for the establishment of sheep and goat community-based breeding programs (Haile et al., 2009).

Community selection and designing a breeding scheme

Participating communities and research villages were selected by a team of researchers, development agents, and district and kebele livestock production experts. During village selection important criteria; communities have common grazing land and watering point, a minimum of 300 breeding ewes, the villages have clear demarcation with other villages like rivers and mountains, and the willingness of the community members to get involved in the improvement program were considered. After the selection of the participant farmers, four alternative breeding schemes i.e. within the village at 10% and 5% and across the village at 10% and 5% proportion) were simulated and evaluated based on their genetic gain and economic benefit. Alternatives were set considering genetic improvement while conserving genetic resources.

Then after, the simulation results of the four alternatives were presented to the participant farmers. Participant farmers could have a chance to identify a better alternative for best breeding gain because of the large selection differential and this can play a great role to reduce the inbreeding effect that can happen associated with the population of breeding ewe and level of selection intensity (Abegaz et al., 2020). This advantage and disadvantages of each scenario were further evaluated through discussion. The scheme preferred by the participant was considered the best scheme and was implemented as a scheme for the community-based improvement tool.

Animal identification and data collection

The identification number with plastic ear tags was given to all sheep belonging to the participant farmers. The weight, age and color of the animal were taken during identification. A simple record sheet was developed for continuous data collection. Enumerators were recruited and trained for data collection, animal identification and day-to-day follow-ups.

Rams screening, selection, and management

The young rams at the age of around 6 months were screened based on their breeding value estimated for six months' weight. Candidate rams with visible defects were not taken into consideration during the selection process. Selection has taken into account the subjective evaluation of the dam's performance in addition to the candidate's performance. The candidate rams were then brought to the central place. Lastly, the farmer's committee picked the best sires after taking physical and morphological traits into account.

The ram user groups were established based on the number of breeding ewes they have, settlement and communal grazing area for easy management of the selected rams. The selected rams were distributed for each ram user group. The unselected rams were castrated and sold before they reach sexual maturity. Rams were rotated among ram user groups yearly to avoid inbreeding problems.

Data Collection and Management

Data were generated by monitoring 2410 lambs born between June 2017 and September 2021. All sheep populations in the selected districts were identified by labelled permanent plastic ear tags. Different productive and reproductive data: birth date, and then after weight at the interval of three months (3, 6, 9, and 12 months age), birth type, sex of lamb, dam post-partum weight and dam parity were recorded. Growth data were taken using a hanging scale having a 50 kg capacity with 200-gram precision.

Statistical Analysis

Data collected on growth performance and litter size/prolificacy of lambs was analyzed using the General Linear Model (GLM) procedures of SAS (version 9.4). Fixed effects considered in the model were district (Debark, Dabat); sex (male, female); parity (1 to $\geq$7), type of birth (single, twin); the season of birth (dry (October-May), wet (June-September)); year of birth (2017, 2018, 2019, 2020); and weight of dam at birth (heavy weight, medium weight and light weight). Interaction effects were not retained in the final model as their effects were not significant in the preliminary analysis. Tukey Kramer test was used to identify the presence of significant effects between factors at P<0.05.

The following GLM models were used.

$Y_{ijklmno} = \mu + D_i + S_j + Y_k + P_l + L_m + X_n + Wo + e_{ijklmno}$;

Where: $Y_{ijklmno}$ is the weight and litter size; μ is the overall mean; D_i is the fixed effect of the i^{th} district; S_j is the fixed effect of the j^{th} season; Y_k is the fixed effect of k^{th} year of birth; P_l is the fixed effect of l^{th} parity; L_m is the fixed effect of m^{th} type of birth; X_n is the fixed effect n^{th} of sex; W_O is the fixed effect both of the weight of dam at birth; $e_{ijklmno}$ is the random error

RESULT AND DISCUSSION

Growth Performance

The growth performance (least-squares means) of Simien sheep is presented in Table 2. The overall least squares mean of body weight at birth was 2.40±0.01kg. The birth weight result of this study showed corresponding results to some Ethiopian indigenous breeds managed under the same condition (Gumer sheep 2.09±0.02 (Ebadu and Habtamu, 2022), Menz sheep 2.58±0.004 (Abebe et al, 2021), Dawuro sheep 2.55±0.04 (Habtegiorgis et al, 2022), Abera sheep 2.8±0.015 (Marufa et al., 2017), and Horro 2.55 (Haile et al., 2020)). However, the birth weight finding of this breed was lower than the Bonga breed 3.13±0.01 (Areb, 2019), and the Doyogena sheep 3.05±0.02 (Habtegiorgis et al., 2022). It was also heavier than sheep breeds which were kept under an extensive production system without community-based breeding programs. Among them, Gumuz sheep and Washera sheep breeds (Asemare et al., 2021), Afar sheep (Mekuriya et al., 2014), (Mesfin et al., 2020), Arsi-Bale sheep (Derib, 2009), and Menz sheep (Kassahun et al., 2000;

Solomon et al., 2007; Mukasa-Mugerwa, et al., 2000; Selamawit et al., 2004). The current birth weight result was a clear indicator of the improvement because of the community-based breeding program (CBBP) that akin results in CBBP villages and higher than villages without CBBP.

The weight at three, six, and twelve-month weight was comparable with Abera sheep (Marufa et al., 2017), and Menz sheep (Abebe et al, 2021), but heavier than Gumer sheep at all counterparts (Ebadu and Habtamu, 2022). The breeding ram selection preference of the community in both study sites was completely red color because of the better marketing opportunity. However, the study showed that the black color could have a growth alteration effect on birth and growth traits (Getachew et al., 2020), therefore we expected that our improvement measure was altered.

Effect of Sex of Lamb: Weight at different growth levels was significantly affected by sex ($P<0.05$) (Table 2). Male lambs weighed heavier than their female counterparts at birth ($P<0.0001$), three months ($P<0.01$), and six-month ($P<0.05$). The larger weight of males in comparison to female lambs might be due to the hormonal differences in their endocrinological and physiological functions (Ebangi et al., 1996; Gardner et al., 2007). Differences in sexual chromosomes, probably in the position of genes related to growth, physiological characteristics, and difference the in endocrinal system (type and measure of hormone secretion especially sexual hormones) lead to differences in animal growth. About the endocrinal system, the estrogen hormone has a limited effect on the growth of long bones in females. It could be one of the reasons why females have a smaller body and lighter weight than males (Rashidi et al., 2008; Roshanfekr et al., 2011). This is also consistent with other literature (Kassahun, 2000; Markos, 2006; Mengistie et al., 2009). The difference in weight between sexes was prolonged as age advanced. Male lambs had higher weights than females after and before weaning and such differences are supported by literature (Adu et al., 1985; Mavorogenis and Constanntinous 1986; Nawaz and Khalil, 1998; Rastogi, 2001; Belay and Haile 2009).

Effect of Birth Year: The birth year was observed to be a significant ($P<0.0001$) source of variation on all growth parameters (Table 2). The observed weight across the growth stages of lambs born in 2021 was heavier than all other previous years. A similar observation on the effect of year of birth was made by Hassen et al. (2004), and Habtegiorgis et al. (2022). Since the study was conducted in a field where extensive management systems were practiced, the influence of year on growth for the weight of lambs might be associated with year-after-year variation of feed availability, husbandry practice, feeding condition, management, the incidence of disease, herdsman's skills and environmental factors (Belay and Haile, 2009). Despite this, the growth performance was recorded in increasing trend over the years that could be clear proof of improvements because of selection. The current three and six-month weight results were even higher than the result reported by Surafel et al. (2012) for the same breed, which was studied before the intervention of a community-based breeding program.

Effect of Birth Type: Type of birth showed a significant ($P<0.0001$) effect on birth, three, and six-month weight and single-born lambs were heavier than their twin-born contemporaries (Table 2). This result showed weight variation associated with birth type is in harmony with other authors' reports for Gumuz sheep (Solomon, 2007) and Washera sheep (Mengistie et al., 2009; Lakew, 2011). This difference at birth could be due to competition of the fetus in the uterus for space, as in all placental mammals, the maternal uterine space has a restricted capacity to gestate offspring, and as litter size increases, individual birth weights decline (Gardner et al., 2007). However, the effect of birth type was non-significant ($P>0.05$) at nine and twelve-month weight. This could be the effect of mothering ability and suckling competition becoming terminated and the physiological perspectives of the dam could be advanced.

Effect of Birth Season: Birth season had not shown a significant effect ($P>0.05$) on three and twelve-month weight (Table 2). The effect of season on growth performance was significant ($P<0.01$ at birth, $P<0.001$ at six-month, and $P<0.05$ at nine-month weights) and was not clear-cut and consistent and lambs born in the wet season were heavier than lambs born in the dry season. This result might be due to the difference in feed availability and weaning shock; when the lambs are transferred from highly nutritious feed (milk) to poor nutrition (roughage) reflecting environmental effects that correlate to feed availability positively. Lambs born in the dry season could highly shocked than lambs born in the wet season associated with feeding stress (Agyemangy et al., 1991; Nawaz and Khalil, 1998). It is expected that better feeding of ewes in the wet season might have resulted in greater weight of lambs than in the dry season. The pasture grass, forage and pleasant surroundings have a positive effect on animal growth. Dixit et al. (2001) stated that the effect of year and season is statistically significant on the weight of the lambs.

Effect of Parity: Parity showed a significant effect (P<0.0001) on the birth weight of lambs (Table 2); which is in agreement with (Mengistie et al., 2010; Solomon et al., 2011; Aemero et al., 2012). Lambs born from ewes at first to three parity were significantly (P<0.0001) lighter than lambs born from four, five and six parities and the result was supported by Berhanu and Aynalem (2009). This might be because the reproductive organs of the first parity ewes were less developed to bear large fetuses (Markos, 2006). Different researchers had reported that a lamb's birth weight increases as the dam's age advanced (Awogichew, 2000; Duguma et al., 2002; Gardner et al., 2007).

Effect of Dam Weight: In the observed result, dam weight had a highly significant effect on lamb weight at birth (P<0.0001), three (P<0.0001), six (P<0.0001), and nine (P<0.001) months. Lambs born in heavy weight dams were heavier than lambs born in medium and light body weight dams. This result might be associated with the better mothering ability of dams as the age and body condition of dams advanced (Petrović et al., 2015). The presence of a significant effect of ewe weight on growth of lambs was supported by (Momani et al., 2002; Krizek et al., 1983); young and old ewes had lighter lambs, also mature sheep had the heaviest lambs (Petrović et al., 2015; Shahroudi et al., 2003; Kalantar 2003; Dixit et al., 2001; Matika et al., 2003; Rashidi et al., 2008).

Effect of Location: Location (working district) had shown a significant (P<0.05) effect on the weight of lambs at three, six and nine-month growth stages. It was consistently observed that the lambs born in the Dabat district were heavier at three and six months of weight than lambs born in Debark district (Table 2). The variation in growth traits among locations is also supported by previous results that compared the performance of sheep in different locations (Gatenby et al., 1997; Gautsch, 1992; Mukasa-Mugerawa et al., 2000). In the present study, the lambs born in the better rangeland available area (Dabat) showed a higher growth indicating better feed access for lambs and lactating ewes. The altitude of Debark is reported to be higher than that of Dabat and characterized as a marginal area where feed available to the sheep population was minimal

Table 2: Simien sheep weight at different ages

Source of Variation	Birth Weight (Kg)		3 Month Weight (Kg)		6 Month Weight (Kg)		9 Month Weight (Kg)		12 Month Weight (Kg)	
	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE
Overall	2410	2.40±0.01	2227	12.25±0.07	1530	13.61±0.08	767	19.01±0.12	494	21.58±0.36
CV (%)	11.56		14.68		13.61		10.5		19.56	
Sex		****		**		*		NS		NS
Male	1333	2.43±0.01^{a}	1225	12.35±0.08^{a}	791	15.64±0.11^{a}	366	18.99±0.14	222	21.46±0.43
Female	1077	2. 37±0.01^{b}	1002	12.14±0.08^{b}	739	15.37±0.10^{b}	401	19.02±0.14	272	21.69±0.39
Birth year		****		****		****		****		****
2017	189	2.02±0.02^{c}	172	11.83±0.15^{d}	154	14.34±0.19^{d}	106	17.60±0.21^{c}	73	19.79±0.56^{d}
2018	738	2.32±0.01^{c}	691	11.85±0.09^{cd}	518	15.74±0.13^{b}	309	18.87±0.17^{bc}	180	20.92±0.51^{c}
2019	434	2.41±0.02^{b}	385	12.31±0.11^{c}	255	15.82±0.15^{ab}	79	18.90±0.24^{b}	26	21.13±0.86^{b}
2020	549	2.60±0.02^{ab}	526	12.34±0.10^{b}	354	15.58±0.14^{c}	192	19.36±0.17^{ab}	102	22.53±0.51^{ab}
2021	500	2.65±0.02^{a}	453	12.91±0.10^{a}	249	16.05±0.16^{a}	81	20.32±0.24^{a}	113	23.51±0.48^{a}
Birth season		**		NS		***		*		NS
Dry	1698	2.42±0.01^{a}	1614	12.18±0.07	1083	15.30±0.01^{b}	445	19.88±0.13^{a}	349	21.53±0.38
Wet	712	2.38±0.02^{b}	613	12.32±0.09	447	15.71±0.11^{a}	222	19.14±0.17^{b}	145	21.62±0.48
Birth type		****		****		****		NS		NS
Single	1950	2.62±0.01^{a}	1837	12.58±0.06^{a}	1254	15.88±0.08^{a}	659	19.07±0.11	437	21.15±0.30
Twin	460	2.18±0.02^{b}	390	11.92±0.11^{b}	276	15.13±0.15^{b}	108	18.95±0.20	57	21.99±0.61
Parity		****		NS		NS		NS		NS
1	453	2.35±0.02^{c}	439	12.11±0.10	286	15.53±0.15	151	18.87±0.18	92	21.65±0.53
2	334	2.39±0.02^{bc}	318	12.26±0.12	201	15.61±0.17	91	19.08±0.22	58	21.59±0.63
3	380	2.40±0.02^{b}	345	12.27±0.12	227	15.77±0.16	120	19.16±0.20	84	21.07±0.54
4	393	2.41±0.01^{a}	347	12.89±0.12	257	15.34±0.15	123	19.90±0.20	86	21.20±0.56
5	345	2.42±0.02^{a}	318	12.24±0.14	228	15.31±0.16	118	19.18±0.21	70	21.19±0.58
6	238	2.42±0.02^{a}	216	12.35±0.14	157	15.78±0.19	82	18.98±0.24	56	21.48±0.64

≥7	267	2.40±0.02[b]	244	12.21±0.13	174	15.21±0.18	82	18.89±0.23	48	22.84±0.66
PPW		****		****		****		***		NS
Light	337	2.32±0.02[c]	287	11.78±0.12[b]	211	15.48±0.17[ab]	124	19.69±0.14[a]	97	21.96±0.57
Medium	1645	2.43±0.01[b]	1440	12.53±0.02[a]	989	15.74±0.09[a]	512	19.54±0.08[b]	322	21.59±0.36
Heavy	428	2.44±0.02[a]	500	12.43±0.10[a]	330	15.31±0.13[b]	131	19.48±0.16[ab]	75	21.18±0.53
Village		NS		****		****		***		NS
Debark	988	2.40±0.02	948	11.68±0.09[b]	763	15.00±0.12[b]	510	19.77±0.15[a]	366	20.72±0.43
Dabat	1442	2.39±0.01	1279	12.81±0.07[a]	767	16.01±0.10[a]	257	19.25±0.15[b]	128	22.43±0.45

Means with different superscripts within the same column & class are statistically different; NS = non-significant; *p<0.05; ** p<0.01; *** p<0.001; **** p<0.0001; N= the number of observations, PPW= post-partum weight, PPW = post-partum weight.

Reproductive performance

Litter Size: The overall least-square means (LSM ±SE) of the litter size investigated was 1.18±0.01 litter per head per ewe (Table 3). Litter size was significantly (P<0.0001) affected by the year of lambing, parity, and district. The litter size of Simien sheep was higher than some of Ethiopian indigenous sheep breeds managed under an extensive production system (Gumuze sheep (Solomon, 2007), Menze (Gautsch, 1987; Agyemang et al., 1985; Mukasa-Mugerwa et al., 2002; Niftalem. 1990), Afar (Wilson, 1982), Washera (Mengiste, 2008), and Blackhead Somali (Galal, 1983)). It had also corresponding results with the Bonga (Ebadu Areb, 2019), and Doyogena (Habtegiorgis, 2022) sheep breed which was managed under a community-based breeding program. Unlikely, the litter size of this breed was lower than Gumer sheep 1.56±0.02, 1.75±0.02 (Habtegiorgis et al, 2020a, 2022b, respectively).

Ewes lambed during the years 2021, 2020 and 2017 were more prolific than ewes lambed in 2018 and 2019. It was also clear that the improvement was because of the selection (twining birth was used as a goal trait for selection) that we had applied to meet the improvement and conservation objective. In the current study, the birth season had no significant (P>0.05) effect on litter size, which agrees with the report of Godfrey (2005). In contrast to the findings of this study, various authors pointed out a significant effect of season and parity on litter size (Habtegiorgis et al, 2022; Berhanu and Aynalem, 2009; Deribe, 2009; Ali et al., 2009; Legesse, 2008; Berhan and van Arendonk, 2006; Suleiman et al., 2005; Mourad et al, 2001; Maria and Ascaso, 1999; Awemu et al., 1999). Parity of the ewe showed a significant effect on litter size (P<0.0001), and higher litter size was recorded as the parity of the dam advanced. This finding was in harmony with a result reported by Habtegiorgis et al, (2022) which studied on Doyogena sheep breed under a community-based breeding program. Litter size tends to be improved with advancement of age and parity which could be because the ewe had a chance to produce a multiple ovulation rate, improved uterine capacity and related physiological maturity (Drouilhet et al., 2013; Mengiste et al 2010). Location showed a significant effect (P<0.0001) on the litter size that lambs born in the Dabat district had higher litter size than Debark district. This difference could be attributed to the difference in the management of ewe, feed availability due to altitude difference, and access to health services.

Table 3. Reproductive performance of Simien sheep

Source of Variation	Litter Size (number)		Lambing interval (days)		Age at First Lambing (days)	
	N	LSM±SE	N	LSM±SE	N	LSM±SE
Overall	2531	1.18±0.01	857	260.63±24.19	333	388.59±18.33
CV (%)		31.16		18.44		10.89
Birth year		****		****		****
2017	191	1.19±0.03[b]	109	333.21±14.23[a]	-	-
2018	738	1.17±0.02[bc]	235	238.81±11.63[b]	5	392.01±33.52[c]
2019	470	1.13±0.02[c]	275	262.26±10.89[b]	59	443.86±18.97[b]
2020	602	1.19±0.01[b]	196	224.73±12.15[bc]	110	364.23±19.86[a]
2021	559	1.21±0.02[a]	109	213.21±14.23[c]	117	354.27±22.04[bc]
Birth season		NS		NS		NS
Dry	1813	1.19±0.01	626	256.84±24.51	234	402.62±22.98
Wet	747	1.17±0.02	231	264.42±25.10	99	374.56±18.00
Parity		****		NS		****
1	502	1.12±0.02[d]	33	236.88±33.60	142	524.78±43.27[a]
2	361	1.12±0.02[d]	146	266.04±26.43	73	472.65±48.99[a]
3	400	1.13±0.02[d]	125	268.85±26.90	31	295.09±63.40[c]
4	409	1.16±0.02[c]	150	274.75±26.40	31	433.31±64.42[b]
5	359	1.22±0.02[b]	149	246.17±26.29	24	415.73±68.50[b]
6	243	1.23±0.02[b]	104	259.46±26.07	13	454.23±90.98[bc]
≥7	289	1.26±0.02[a]	150	272.25±26.12	19	399.42±75.06[bc]
Village		****		***		***
Debark	1061	1.07±0.01[b]	330	259.37±25.07[b]	131	397.00±20.90[a]
Dabat	1499	1.29±0.01[a]	527	261.89±24.33[a]	202	380.18±18.30[b]

Means with different superscripts within the same column & class are statistically different; NS = non-significant; *p<0.05; ** p<0.01; *** p<0.001; **** p<0.0001; N= the number of observations, PPW= post-partum weight, PPW = post-partum weight.

Lambing interval: The overall least-square means (LSM±SE) of the lambing interval (days) investigated was 260.63±24.19 (Table 3). The lambing interval was significantly (P<0.0001) affected by the year of lambing, and district (P<0.001). The current result showed that the steady lambing interval improvement across working years. This showed the positive response of selection implemented in the improvement of reproductive performances of this breed. This result was higher than the Bonga breed 283.5±9.9 (Ebadu, 2019) and the Doyogena sheep breed

281.22±8.8 (Habtegiorgis et al., 2022). The lambing interval was not significantly (P>0.05) affected by the birth season and parity. However, this was not in agreement with Gautsch (1987) and Mengiste (2008) those reported as parity increases the lambing interval decreases. The effect of location on the lambing interval was significant (P<0.0001); which might be attributed to the difference in the management of ewes, feed availabilit.

Age at first lambing: The overall least-square means (LSM±SE) of the age at first lambing (days) investigated was 388.59±18.33 (Table 3). The result showed comparable with the earlier report of Ebadu (2019), where 375±12.5 days of age at first lambing under community-based breeding program management conditions in Kaffa Zone, Ethiopia. The current study result showed that the Simien sheep breed had shorter age at first lambing than Adilo (Getahun et al., 2008), Afar (Fsahatsion, et al., 2013), Blackhead Somali (Fekerte, 2008), Bonga (Edea, 2008; Zewdu et al., 2009), Gumz (Abegaz et al., 2011), Menz (Tesfaye et al., 2013), Washera (Tesfaye et al., 2013; Taye et al., 2011), and Doyogena sheep breed (Habtegiorgis et al., 2022). The effect of lambing year on age at first lambing was significant (P<0.0001). The current finding showed that the age at first lambing had decreased day after day and better age at first lambing was recorded in 2021 and 2020 than in the previous years. This was the clear confirmation of reproductive performance improvement because of selection.

Parity had a significant effect (P<0.0001) on age at first lambing. The ewe which had advanced parity showed better age at first lambing. This could be because the lambs born from multi-parous ewes had higher growth rates and reached sexual maturity at an early age which is associated with better mothering ability of the ewes (Belay and Haile, 2009). The effect of the district on age at first lambing was significant (P<0.001). Ewe born at Dabat CBBP site had better age at first lambing than Debark site. This difference could be attributed to the difference in environment and feed availability and altitude difference.

CONCLUSION AND RECOMMENDATION

The results obtained in this study indicated that the growth and reproductive performance of Simien sheep had been improved through the implementation of community-based breeding program. Birth year, the post-partum weight of the ewe and the parity of the ewe were the major sources of variations in growth and reproductive performance. From the result, clear phenotype improvement was observed in both growth and reproductive performance across working years which could be the contribution of interventions, including selection, implemented under the CBBP. In both study sites, the community's selection for color was preferably red cot color and this could affect the linkage between color and genetic progress of growth traits, which indicated the breeding program could consider the inclusion of coat color in the selection index. This result confirmed that appropriate and scientific selection in community-based breeding programs could be effective in improving the productive and reproductive performance and better conservation measures of Simian sheep. Based on these conclusive remarks, the following recommendations were made.

- To confirm the real genetic gain and improvement of this breed it is recommended to do further genetic evaluation in both productive and reproductive performance.
- Reproductive traits (especially litter size) are usually characterized by low heritability, and thus, phenotypic selection is often ineffective and slow. Thus to improve fertility characteristics such as ovulation rate and litter size, it is recommended to select breeding animals based on their genotype and further genome-wide association study for better prolificacy is needed.
- Since growth and reproductive performance showed an increased trend, thus establishing a well-organized cooperative and implementing an advanced way of selection (marker-assisted) is recommended for bringing further improvement and conservation.
- Improvement of the production environment through feed and feeding technology interventions, health and other management should better be integrated with the breeding program.

ACKNOWLEDGEMENT

The authors acknowledge participant farmers, agricultural extension agents and district livestock experts of the Debark and Dabat districts for their cooperation to conduct the study. The authors would also like to acknowledge Gondar Agricultural Research Center (GARC) and International Center for Agricultural Research in the Dry Areas (ICARDA), Livestock and Fishery Sector Development Program (LFSDP) for their technical and financial support.

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Breeding Soundness Evaluation of Rams in Selected Community Based Breeding Program Sites of the Amhara Region

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ABSTRACT

The objective of this study was to evaluate the breeding soundness of rams used in the existing community-based breeding programs (CBBPs) of Washera and Simien sheep. Semen was evaluated in April 2022. Physical soundness, scrotal and other linear body measurements, and semen analysis were all performed during the breeding soundness evaluation. The overall performance for physical soundness of Washera and Simien sheep was 90.71 and 86.86%, respectively. The mean (standard deviation) of semen volume per ejaculation was 0.71(0.19) ml, with a minimum of 0.4 ml from Simien sheep and 1.2 ml from Washera sheep. The average gross semen motility score and semen concentration (10^9) were 3.50(0.52) and 4.06(1.67), respectively. Semen concentration was significantly affected by breed, with the lower concentration being 7.7 (10^6) in Simien sheep and the higher 6.98 (10^9) in Washera sheep rams. The current study's average vitality and abnormality percentages were 90.53 (2.16%) and 8.81 (1.30%), respectively. Based on the overall breeding soundness examination, 87.63% of Wahera rams and 81.95% of Simien sheep rams, for a total of 85.15%, were satisfactory for successful mating, whereas 13.62% of the rams failed the examination. According to the findings *i*n the CBBP sites of Washera and Simien sheep, rams above 22.5cm of SC and above 80% for physical soundness, with acceptable range of semen characteristics can be used for mating and distribution. Besides, to understand the level of SC for mating rams, further study considering wider range of age and SC values is important to suggest lower and upper limit as appropriate.

Keywords: *Breeding soundness, community based, ram, semen characteristics*

INTRODUCTION

Reproductive performance is the most significant factor impacting flock profitability, in which the reproductive capacity of the rams plays a key role. In fact, the ram contributes half of a flock's reproductive potential and genetic change (Mozo et al., 2015; Rekik, 2016), which requires care during selection. Rams' reproductive capacities are directly or indirectly involved in the reproductive process, either during natural reproduction or through the production of semen for artificial insemination (Allaoui et al., 2014). Producers can perform breeding soundness examinations (BSE) to help determine if a male is capable of mating a female or not. A breeding soundness examination is an overall evaluation of a male's potential capacity to serve and impregnate a given number of females over a specified period (Mozo et al., 2015). The assessment includes a physical examination, body condition score (BCS), scrotal circumference (SC), an inspection of the reproductive organs, semen collection and evaluation (Kroeze, 2013; Pezzanite et al., 2019), libido assessment (Mozo et al., 2015), and screening for sexually transmitted diseases (STDs) (Rekik, 2016). The scrotal circumference (SC) reflects the weight of the gonad and thus the ability of sperm production (Salhab et al., 2003), and is also a highly valuable indicator of the onset of puberty, total sperm production, sperm quality, pathological conditions of the testes, and the potential for sub-fertility or infertility (Ott, 1991).

In seasonal breeders, breeding soundness examinations should be done at least two months before the breeding season to allow sheep owners to recover rams from pathologies or poor physical conditions (Fthenakis et al., 2001; Mozo et al., 2015) and in non-seasonal sheep populations, like Ethiopian sheep breeds, a continuous evaluation is required and the examination should also be a routine activity in breeding programs (Rekik, 2016). Periodical BSE identifies the primary causes of ram failures, making it a crucial tool for increasing the herd's reproductive efficiency (Oliveira, 2014). Based on the BSE, rams can be classified as unsatisfactory, questionable, satisfactory, or excellent. Satisfactory rams will achieve good reproductive performance if coupled to ewes at a 1:50 ratio for 60 days (Tibary et al., 2018; Kroeze, 2013).

The selection and distribution of rams for mating in Ethiopia's existing CBBP sites is already in operation based on simple physical evaluation, pedigree information, and breeding values for selected target traits. Both of these methods do not guarantee ram fertility. Nowadays, the number of CBBP sites has increased across the country under the budget support of various government and non-governmental initiations as it was reported to have tangible genetic progress and economic benefit (Muller et al., 2019). Furthermore, scaling up the CBBP achievements hasalso been started. The scaling-up activities were designed to be managed by livestock extension with the support of research centers (EIAR, 2017). The rams to be distributed were sourced from existing CBBPs, and as these animals are genetic materials, their failure to mate after distribution costs the program. Therefore, BSE should be done as a routine activity prior to ram distribution. This study, therefore, was initiated to determine the effect of breed, body condition, and scrotal circumference on different semen parameters and to evaluate the breeding soundness of rams used in the existing CBBPs of Washera and Simien sheep to set standards for use and distribution of satisfactory rams.

MATERIAL AND METHODS

Study sites and breeds

The study was conducted at the Washera and Simien sheep community-based breeding program sites fin Sekela and Dabat district of the Amhara region, respectively.

Sekela district is 160 kilometers south of Bahir Dar, the capital of the Amhara National Regional State, and 74 kilometers north of Finote Selam, the capital of the West Gojjam Zone. The district has 27 kebeles, of which 26 are rural-based. The district's total area coverage is estimated to be 6534.5 hectares, with highland (Dega), midland (Woynadega), and lowland (Qola) agro-ecologies accounting for 70%, 18%, and 12%, respectively. It is situated at 10°55'0"N latitude and 37°31' 60"E longitude, at an elevation of 3062 meters above sea level. The average annual rainfall in the area ranges from 1600 mm to 1800 mm, with an average temperature of 18°C (Yaregal, 2021).

Dabat district is located at 12°59'3" N and 37°45'54" E in Amhara National Regional State, North Gondar Zone. It receives an average annual rainfall of about 1100mm, with the rainy season lasting from June to October. The annual mean maximum and minimum temperatures are 19.9°C and 8.58°C, respectively (Tafere, 2012).

Description of the breeding program

The breeding program in Washera sheep genetic improvement and conservation was started in 2000 at Quarit and Yilmananadensa districts as village based breeding program. With a long journey of ups and downs in the breeding program of the breed, currently two villages at Sekela district were established for the genetic improvement of Washera sheep under the management of Andasa Livestock Research Center. The approached followed is community based breeding program (CBBP). In the program, growth rate (mainly six month weight), and twining rate were breeding objectives selected by the farmers. The breeding was controlled, only the selected rams could get the chance to mate with the females. The weaned lambs are ranked and the highest-ranking 20-25% of the animals is retained for breeding based on consecutive weight changes starting from three month according to their breeding value. Selected rams mate in the ratio of 1:30 under ram user group arrangement. Ram exchange between unrelated pedigree rams was done between groups. Ram selection continues in the same fashion as described above.

The breeding program for Simien sheep was started around 2017 as a community based breeding program approach at selected villages of Dabat and Debark districts and run by Gondar Agricultural Research Center. The selection criteria used to select mating rams was yearling weight, twining rate and survival of kids. The young rams (≥6 month) were screened based on their breeding value (own and maternal performance record information, farmers preference selection index) and independent culling of animals for observed defects was done. The selection of best rams' was made by representative farmers from the community in relation with researchers. With a similar approach with Washera sheep the rams were used with ram user groups and rotation of them kept similar.

Source and type of data

Active matting rams from the community based programs of the two breeds were selected purposively. For physical soundness evaluation, a total of 63 rams (28 from Washera sheep and 35 from Simien sheep) were used and physical body measurements were taken from these rams. The semen samples were collected from 16 rams, 10 from Washera sheep and 6 from Simien sheep and the semen analysis was conducted in April 2022. The rams had an age category of one to five years of age. From the total, five rams at both breeds were replacement rams with no mating history and the remaining had a minimum of six month to one year age of mating service.

Data collection procedures

Physical soundness examination

The physical soundness examination includes testicular symmetry (1 = symmetric and 2 = non-symmetric), testicular shape (1 = normal and 2 = abnormal), scrotal firmness (1 = firm rubber ball and 2 = extremely hard and very soft), body condition score (thin = 1-2 score, moderate = 2-3, and fattened: above 3), rear leg conformation (1 = desirable and 2 = camped behind, bowleggedness (base narrow) and toed-out stance (base wide)), and alertness (1 = healthy and alert and 2 = non-healthy and inactive), and general health condition of eyes, feet, head, neck, and nasal cavity. These parameters were collected with a degree of acceptance. Each level of the evaluation was done using the breeding soundness examination (BSE) reference standards established by Yelich (2008) and Mozo et al. (2015), and the interpretation was performed using Tibary et al. (2018).

Scrotal and other linear body measurements

The scrotal circumference was measured at the widest part of the scrotum and recorded in centimeters. Body measurements like heart girth (cm), weight (kg), height at prepuce (cm), rump height (cm), body length (cm), height at weather (cm) and face length (cm) were collected from rams at the CBBP sites. The estimated body weight was determined using the following formula (https://practicalfarmers.org):

$$\mathbf{BW} = \frac{\mathbf{HG}\ (inch)^2 * \mathbf{BL}\ (\mathbf{inch})}{300}$$

Where: BW is the estimated body weight in pounds, HG is the heart girth in inches, and BL is the body length in inches.

Semen Analysis

Semen was collected using an artificial vagina (AV) at a temperature of 42–43°C. The ram's prepuce was cleaned before collection to prevent contamination of the semen. The semen collection was done in the morning and in shaded areas to avoid ram tiredness and sperm death from direct sunlight. The libido of the ram was measured and scored from 5 to 1 (Tibary et al., 2018; Goshme et al., 2020), as described below:

- Excellent (5): When the ram is eager to mount the teaser ewe after being introduced to the test pen and the staff is still unable to hold it.
- Very good (4): The ram mounts immediately after the teaser, but the staff manages to keep it under control.
- Good (3): The ram sniffs around the teaser when brought to it and begins to mount after 1-2 minutes.
- Poor (2): The ram sniffs around the teaser for a while, mounts it in three to four minutes, collapses the artificial vagina, and mounts it repeatedly while ejaculating.
- Very poor (1): The ram shows no interest in sniffing or mounting.

Semen evaluation

Semen color was evaluated subjectively and classified as milky, watery, thin creamy, creamy, and thick creamy (Goshme et al., 2020). Semen volume was measured using a graduated collecting glass (0.1 mL graduation). Ejaculates were placed in a thermos flask containing water at 35-37°C while being processed. Sperm mass motility was estimated subjectively by using a phase contrast microscope. For that purpose, semen was collected using a pipette, dropped on a slide, covered with a cover slip, and examined using the objective lens at 10 times magnification. The mass motility was assigned a score between 0 and 5 based on the intensity of the wave motion. The value of sperm mass motility was calculated based on Goshme et al. (2020), as described below:

- 0 = zero (all spermatozoa are immotile).
- 1 = Very poor (weak movement of semen with 10% active spermatozoa).
- 2 = Poor (poor movement of semen with20–40% active spermatozoa).
- 3 = Fair (small, slow-moving wave with 40–75% active sperm cells).
- 4 = Good (dense, vigorous wave movement with 75-90% active sperm cells).
- 5 = Very good (cloudy, dense, and rapidly moving waves with more than 90% active spermatozoa).

The concentration of sperm was measured using a portable spectrophotometer pre-calibrated for ram semen (Ovine-caprineAccuread photometer; IMV®, France). Sperm cell concentration was estimated using a micropipette to take normal saline (0.9%) and put 4 ml of normal saline and 10 microliters of fresh semen on the UV Macrocell (UV Macro Cell 2.5-4.5 ml, Great Britain) and mix gently and measure the concentration using an Accu Read IMV Technologies SA, 232 Spectrophotometer.

For spermatozoa live/dead ratio (semen morphology), semen was stained with eosin-nigrosin stain followed by microscopic examination (40 times). Spermatozoa with red heads were counted as dead cells, while those with colorless heads were considered live spermatozoa (Tibary et al., 2018). The proportion of morphologically abnormal spermatozoa was determined by examining 200 spermatozoa in an eosin-nigrosin smear under the same magnification. The spermatozoa were evaluated for vitality (percentage of live spermatozoa) and abnormal percentages (head, midpiece, and tail abnormal).

Statistical Analysis

Breed, body condition score, scrotal circumference, libido, and age were used as factors to evaluate the semen characteristics. The data were analyzed using the General Linear Model (GLM) procedures of the SPSS (version 22). Post-hoc Least Significant Difference (LSD) tests were used to compare the means. The results are presented as means (SD), with $p<0.05$ set as the level of statistical significance.

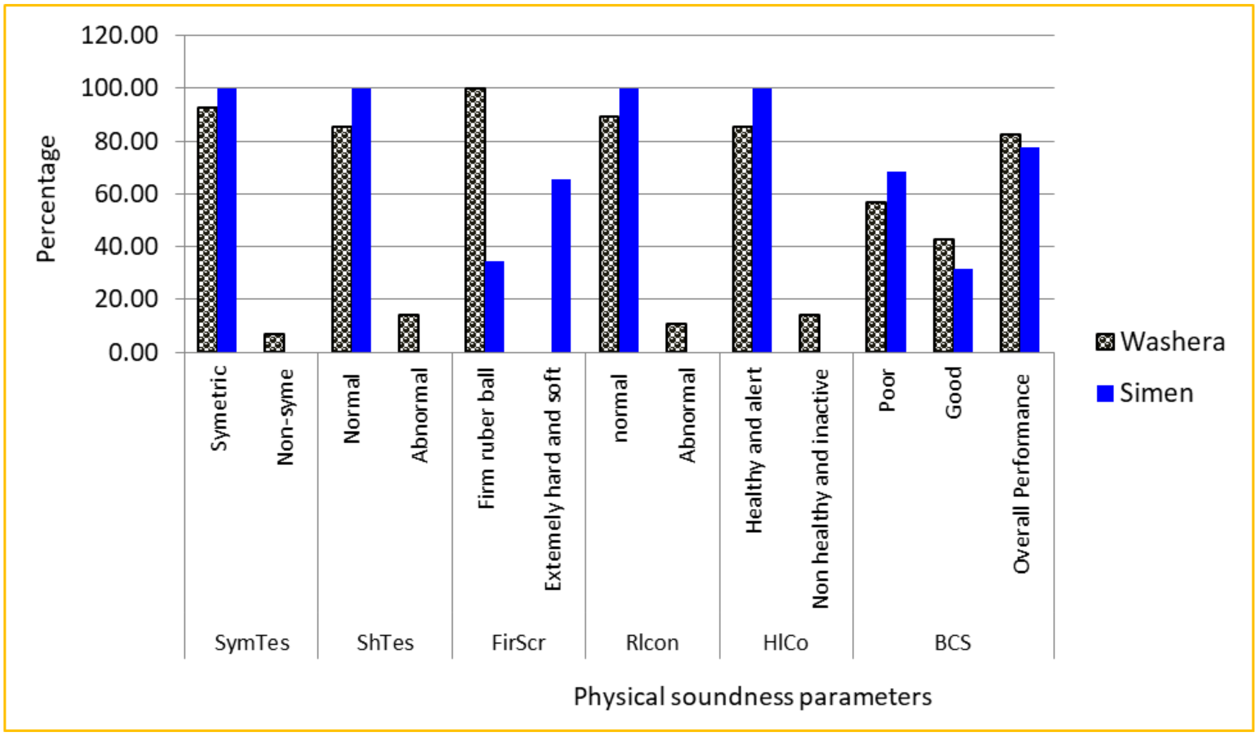
$$\mathbf{Y_{ijklmi} = \mu + B_i + L_j + C_k + S_l + A_m + e_{ijklm}}$$

Where: Y_{ijklm} is the characteristics of the semen (volume, motility, color, concentration, vitality, and abnormal), μ is the overall mean, B_i is the effect of i^{th} breed (Washera and Simien), L_j is the effect of j^{th} libido score (3, 4 and 5), S_k is the effect of k^{th} body condition score (Medium (2-3 BCS) and Good (>3BCS)), C_l is the effect of the l^{th} scrotal circumference (≤20cm, 21-23cm, and >23cm), A_m is the effect of m^{th} age (<12 months, 12-24 months, and >24 months), and e_{ijklm} is the residual effect.

RESULT AND DISCUSSIONS

Rams' Physical Soundness

The overall performance of Washera and Simien sheep for physical soundness was 82.74 and 77.62%, respectively (Figure 1), which was a good indicator for the selection of rams at CBBP sites. The parameters sued in physical soundness had evaluated based on the degree of acceptance and average was calculated for each parameter and the overall was averaged from all parameters. Physical soundness also indicates the ram's ability to deliver semen to ewes and the producers' management level. Physical problems like lameness, blindness, and penile or preputial issues may not affect semen production or quality. However, rams will be unable to find and mate with estrous ewes, resulting in poor reproductive performance (Tibary et al., 2018).



SymTes = symmetricity of testicles; ShTes = shape of testicles; FirScr = firmness of the scrotum; Rlcon = rear leg conformation; HlCo = health condition of the ram

Figure 1. Physical examination results for Washera and Simien sheep rams.

Effect of Fixed Factors on Semen Quality Parameters

Semen volume: The mean (SD) semen volume per ejaculation was 0.71(0.19) ml, with a minimum of 0.4 ml from Simien sheep and maximum of 1.2 ml from Washera sheep. Semen volume could have been higher if there had been training with the artificial vaginal a day or two before. The volume varied significantly ($P<0.01$) between breeds, libido score, and ram age (Table 1). Rams with five libido scores and rams older than two years gave a higher volume of semen per ejaculation. A significant difference between semen volume and breed and age was also reported (Arrebola-Molina et al., 2020; Rege et al., 2000) for different sheep breeds in Spain. The average volume of semen per ejaculate (ml) was comparable to that of the Menz sheep ram (0.7 ml) but lower than that of the Dorper sheep ram (1.14 ml) and the AwassixMenz (AXM) crossbred (0.92 ml) (Goshme et al., 2020).

Gross semen motility score: The average gross semen motility score was 3.50 (0.52), indicating that more than 70% of sperm cells are active (Table 1). In the current study, no factor had a significant ($P>0.05$) difference in semen motility. Similarly, Arrebola-Molina et al. (2020) found no significant differences in semen mass motility between breeds or BCS. Furthermore, the current study's average motility score was comparable to the average mass motility scores of Awassi X Menz (3.4), Dorper (3.18), and Menz (3.17) sheep (Goshme et al., 2020).

Semen concentration: Sperm concentration is the number of sperm per milliliter of semen, and total sperm count is the total number of sperm in the entire ejaculate (sperm concentration times semen volume) (Centola, 2018). Semen concentration was significantly affected by breed; the lower concentration was 7.7 (10^6) in Simien sheep and 6.98 (10^9) in Washera sheep rams. Furthermore, libido score significantly affects sperm concentration (Table 1). The current concentration observed in both breeds provides a good insight for conducting artificial insemination to speed up genetic dissemination. According to Larsen (2021), 300 million spermatozoa were used for single insemination. Based on this data, 10 ewes can be inseminated with an average number of 4.06 (1.67) (10^9) spermatozoa and 0.71(0.19) ml of semen volume. The current study's average semen concentration (10^9) was higher than the Menz (2.44) and Awassi X Menz (3.34) sheep breeds and comparable to the Dorper (4.1) sheep breeds (Goshme et al., 2020). The current study's concentration was considered normal based on Faigl et al.

(2012), who reported a normal concentration range of 3.5 to 6.0 billion. A similar study discovered no statistically significant difference in sperm concentration between breeds and BCS (Arrebola-Molina et al., 2020).

Semen morphology: The vitality and abnormality percentages were estimated using morphology analysis (Table 1). The current study's average vitality and abnormality percentages were 90.53% (2.16) and 8.81% (1.30), respectively (Figures 2 and 3). The percentages of abnormalities in the head, midpiece, and tail were 0.16, 0.32, and 8.52%, respectively. The current result exceeded the findings of Faigl et al. (2012) and Goshme et al. (2020), who reported an average vitality range of 70-80 and 84.04% for different breeds, respectively. Only the libido score and age showed a statistically significant ($P<0.05$) difference in semen vitality.

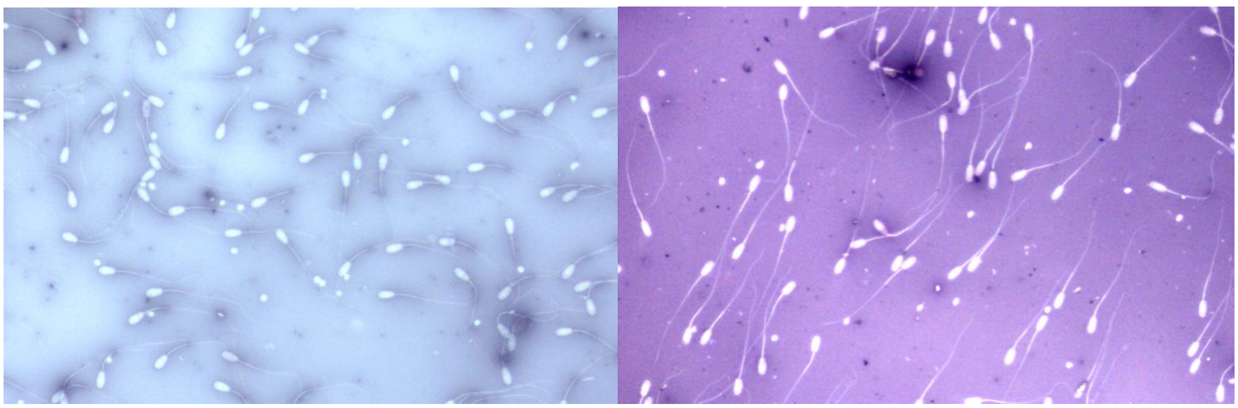


Figure 2. Morphologically normal sperm cells (eosin-nigrosin stain)

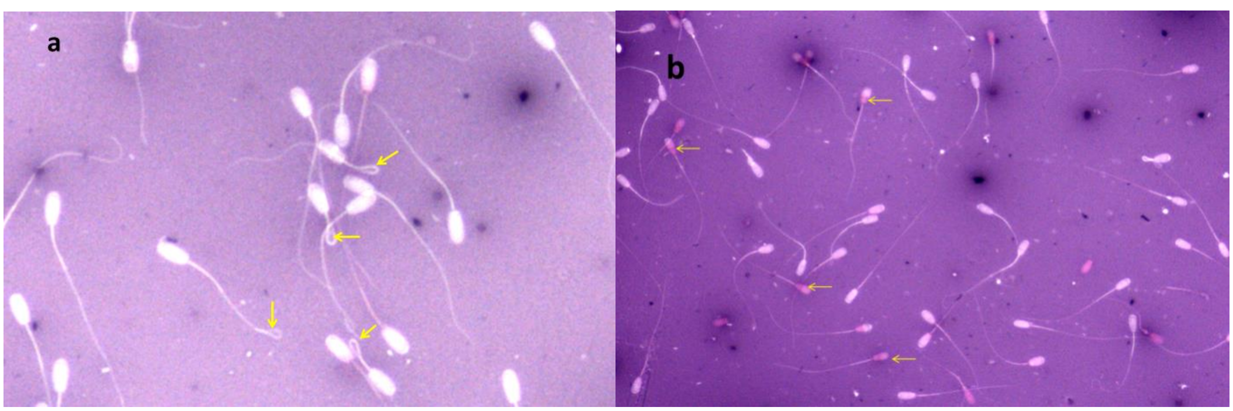


Figure 3. Morphologically abnormal of sperm cells: (a) bended and terminally coiled tails, (b) abnormal head (eosin-nigrosin stain)

Semen color: The average value for semen color was 2.94 (1.48), characterized as thin creamy from the five color ranges. The color observed in this study coincided with the findings of Pankaj et al. (2018), who reported a color range of 1.9 (1.0) to 4 (0.0). Color can indicate injury or infection in the reproductive tract (Pankaj et al., 2018) and sperm concentration.

Correlation between semen quality parameters

In the current study, the mean (SE) values for SC, libido score, and BCS were 23.06 (0.52), 4.31 (0.19), and 2.50 (0.10), respectively. Higher libido scores were observed in both breeds, increasing the ram's ability to deliver semen to females (Tibary et al., 2018). A positive significant ($P<0.05$) correlation was found in the age of the ram with semen volume and concentration, body condition with libido score and semen color, libido score with semen concentration, and semen volume with mass motility and concentration (Table 2). Furthermore, the scrotal circumference was strongly correlated to body weight and condition score. There was a significant correlation between body condition and scrotal circumference, as well as scrotal circumference and sperm abnormality (Goshme et al., 2020). A similar study found a significant correlation between age and sperm volume, scrotal circumference with age, and BCS (Arrebola-Molina et al., 2020).

Effect of Breed and Age on Scrotal Circumference and Physical Body Measurements

There is a significant ($P<0.05$) difference between the breeds in all physical body measurements. This indicates that the ram sources were from different breeds, each with distinct characteristics and adaptations (Table 3). Washera and Simien sheep breed rams had average scrotal circumferences of 24.21 (0.65) and 22.05 (0.53) cm, respectively, with a mean of 23.13 (0.42) cm. A higher average scrotal circumference was reported for Washera sheep at 27.5 (1.29) cm (Tesfaye et al., 2009) and Simien sheep at 24.2 (1.8) cm (Melaku et al., 2019). The average scrotal circumference of Ethiopian sheep breeds viz. Horro, Bonga, and Menz increases from 25 cm at one year to 30 cm at four years of age. The target scrotal circumference for larger breeds, such as Awassi, is reported to be 36-38 cm (Rekik, 2016). Compared with these findings and the guideline (Pezzanite et al., 2019), the average scrotal circumference recorded in the current study is satisfactory for breeding purposes.

According to reports, SC contributed significantly to BSE in males (Tibary et al., 2018). Age had a significant ($P<0.01$) effect on SC, with scrotal circumference increasing as age advances.

According to this finding, rams older than two years have an excellent scrotal circumference, so it is preferable to use rams older than two years at breeding sites. Other studies have also found a significant relationship between age and scrotal circumference (Rekik, 2016; Pezzanite et al., 2019).

Table 1. Mean (SD) values of semen quality parameters across different fixed factors

Parameters	Volume/ejaculation (ml)	Motility (1-5)	Color	Concentration (10^9)	Vitality (%)	Abnormal (%)
Overall	0.71(0.19)	3.50(0.52)	2.94(1.48)	4.06(1.67)	90.53(2.16)	8.81(1.30)
Breed	*	ns	ns	*	ns	ns
Washera	0.76(0.21)	3.60(0.52)	3.10(1.52)	4.49(1.54)	90.20(1.70)	8.60(1.51)
Simien	0.62(0.15)	3.33(0.52)	2.67(1.51)	3.34(1.77)	91.08(2.87)	9.17(0.88)
BCS	ns	ns	ns	ns	ns	ns
Medium	0.68(0.16)	3.46(0.52)	2.73(1.56)	3.91(1.91)	90.68(2.42)	8.82(1.52)
Good	0.76(0.27)	3.60(0.55)	3.40(1.34)	4.39(1.08)	90.20(1.64)	8.80(0.76)
SC	ns	ns	ns	ns	ns	**
≤20cm	0.75(0.07)	4.00(0.00)	4.50(0.71)	5.69(1.82)	90.25(2.47)	9.50(0.00)[a]
21-23cm	0.72(0.19)	3.33(0.52)	1.67(1.21)	3.24(1.86)	90.50(2.53)	9.50(1.09)[a]
>23cm	0.69(0.23)	3.50(0.53)	3.50(1.07)	4.26(1.29)	90.63(2.13)	8.13(1.30)[b]
Libido score	*	ns	ns	**	**	ns
3	0.67(0.06)[b]	3.33(0.58)	2.00(1.73)	3.48(1.22)[ab]	88.67(1.76)[b]	9.33(1.26)
4	0.62(0.15)[b]	3.60(0.55)	3.00(1.41)	2.90(1.98)[b]	92.20(2.08)[a]	9.20(1.15)
5	0.78(0.24)[a]	3.50(0.53)	3.25(1.49)	5.00(1.11)[a]	90.19(1.75)[ab]	8.38(1.41)
Age	*	ns	ns	ns	*	*
<12 month	0.68(0.16)[b]	3.60(0.55)	2.60(1.82)	3.61(2.65)	90.60(2.33)[a]	9.70(0.76)[a]
12-24 month	0.67(0.16)[b]	3.43(0.53)	3.00(1.41)	4.05(1.15)	91.50(1.85)[a]	7.71(1.07)[b]
>24 month	0.80(0.29)[a]	3.50(0.58)	3.25(1.50)	4.63(1.11)	88.75(1.71)[b]	9.63(0.63)[a]

BCS = body condition score; SC = scrotal circumference; ns = non-significant; *P<0.05; **P<0.01

Table 2. Partial correlation between semen quality parameters

Variable	Age	SC	BW	BCS	LS	SV	Color	MS	Concn	Viability	AP
Age		0.222	0.608**	0.284	0.027	0.649***	0.213	0.284	0.410*	-0.395*	0.089
SC			0.445**	0.384*	0.203	-0.137	0.218	0.116	0.086	0.306	-0.609***
BW				0.627***	0.232	0.283	0.299	0.036	0.134	-0.262	-0.355*
BCS					0.658***	0.065	0.476**	0.044	0.309	0.239	-0.525**
LS						0.255	0.286	0.045	0.446**	0.145	-0.305
SV							0.194	0.521**	0.564**	-0.283	0.325
Color								0.553**	0.558**	0.257	-0.188
MS									0.463**	0.261	0.270
Concn										-0.207	-0.091
Viability											-0.273
AP											

SC = scrotal circumference; BW = body weight; BCS = body condition score; LS libido score; SV = semen volume; MS = mass motility; Concn = concentration; AP = abnormality percentage.

Table 3. Effect of breed and age on somebody measurement parameters

Parameters	N	BW	SC	BCS	HW	BL	HR	FL	HP
Overall	63	25.26(0.67)	23.13(0.42)	2.26(0.07)	66.93(0.48)	50.61(0.80)	68.85(0.62)	18.26(0.20)	33.60(0.46)
Breed		***	**	**	**	*	***	*	*
Washera	28	27.64(1.04)	24.21(0.65)	2.33(0.11)	69.65(0.74)	52.24(1.24)	71.01(0.96)	18.61(0.31)	34.64(0.71)
Simien	35	22.88(0.85)	22.05(0.53)	2.19(0.09)	64.21(0.61)	48.99(1.02)	66.68(0.79)	17.91(0.26)	32.56(0.58)
Age		***	**	**	**	*	**	*	**
0PPI	19	22.92(1.20)	20.79(0.75)	2.06(0.12)	63.29(0.86)	52.92(1.44)	66.87(1.12)	17.24(0.37)	32.27(0.82)
1PPI	19	19.12(1.16)	21.77(0.72)	2.02(0.12)	63.56(0.83)	44.55(1.39)	66.36(1.08)	17.61(0.35)	32.00(0.79)
2PPI	12	26.94(1.49)	23.19(0.93)	2.28(0.15)	68.94(1.07)	52.94(1.79)	70.50(1.39)	18.44(0.45)	33.69(1.02)
3PPI	13	32.07(1.47)	26.76(0.91)	2.67(0.15)	71.93(1.05)	52.04(1.75)	71.65(1.36)	19.76(0.45)	36.43(1.00)

SC = scrotal circumference; BW = body weight; HP = height at prepuce; BCS = body condition score; HW = height at weather; BL = body length; HR = height at ramp; and FL = face length; *P<0.05; **P<0.01; ***P<0.001

Correlation among Scrotal Circumference and Other Body Measurements

According to the partial correlation, all body measurements correlated positively with scrotal circumference (Table 4). Scrotal circumference of rams was significantly (P<0.01) correlated with body weight, body condition score, body length, and face length. There was a significant relationship between scrotal circumference and age and body weight for Menz rams (Mukasa-Mugerwa and Ezaz, 1992; Allaoui et al., 2014). Nutrition can improve measurements like body weight and condition, and the positive correlation between these traits and SC indicates that nutrition can improve ram fertility and SC.

During feeding trials, Mehari et al. (2009) found a 0.45 cm scrotal circumference gain in Arsi breed ram lambs, and Mukasa-Mugerwa and Ezaz (1992) reported a gain in scrotal circumference and other body measurements in Menz rams with different nutrition levels. Dana et al. (2000) found that non-supplemented rams had a 10% decrease in scrotal circumference. Azizunnesa et al. (2013) declared that rams supplemented with concentrate had higher levels of SC and semen-related parameters. Excessive concentrate feeding, on the other hand, increases scrotal fat, which lowers sperm concentration and other semen characteristics (Vipond and Morgan, 2008). As a result, feeding should be at its optimal level to control the ram's over and under body conditions.

Table 4. Partial correlation between scrotal circumference and other body measurements

	Age	BW	SC	HP	BCS	HW	BL	HR	FL
Age		0.531***	0.590***	0.399**	0.394**	0.635***	0.081	0.406**	0.491***
BW			0.576***	0.356**	0.706***	0.686***	0.813***	0.625***	0.640***
SC				0.372**	0.461***	0.469***	0.314*	0.332**	0.437***
HP					0.352**	0.471***	0.158ns	0.302*	0.335**
BCS						0.418**	0.611***	0.497***	0.358**
HW							0.323*	0.698***	0.510***
BL								0.427**	0.388**
HR									0.465***
FL									

SC = scrotal circumference; BW = body weight; HP = height at prepuce; BCS = body condition score; HW = height at weather; BL = body length; HR = height at ramp; and FL = face length***;*** *P<0.05; **P<0.01; ***P<0.001

Breeding Soundness Examination (BSE) and Interpretation

Rams are classified into three categories: satisfactory, questionable, and unsatisfactory, based on BSE. The category was based on physical examination score, scrotal circumference, and semen characteristics (Tibary et al., 2018). Values above the average were used as the cut values to assess the satisfactory rams. Based on the breeding soundness examination (Table 5), 87.63% of Wahera rams and 81.95% of Simien sheep rams, with an overall rating of 85.15%, were satisfactory for successful mating. Physical examination, body condition, scrotal circumference, and semen color were the main reasons for failure. Oliveira et al. (2014) reported a significantly higher rate of ram BSE failure (22.15%). Ram conformation (Arrebola-Molina et al., 2020), as well as body condition and semen character (Oliveira et al., 2014), have also been reported as causes for ram BSE failure. There was no significant difference between satisfactory and questioned rams in semen quality parameters (Table 5). The rams can successfully serve up to 30 ewes in an unsynchronized free grazing flock.

Those rams (14.85%), which were not satisfactory in this study, were mainly failed in BCS score, SC, and sperm color; and there is no any difference in semen quality parameters (Table 5). These characteristics have all been highly correlated with the season and nutrition (Bagley, 1997; Vipond and Morgan, 2008; Goshme et al., 2020), indicating that these rams can be satisfactory if well managed and classified as questionable rams for this study. Satisfactory rams should also be in good general health, have good body conformation, a normal genital tract, and have no history of infertility (Tibary et al., 2018). Values above the average for BCS and SC were used as the cut values to assess the satisfactory rams; while for semen characteristics references were taken from reports (Tibary et al., 2018; Rekik, 2016; Pezzanite et al., 2019; Arrebola-Molina et al., 2020).

Table 5. Breeding soundness examination parameters for satisfactory rams

Average values for satisfactory ram	Breed		Overall
	Washera	Simien	
Physical examination (above 80% sound)	82.74	77.62	80.18
Body condition score (above 2)	92.8	88.90	91.5
SC (above 22.5cm)	67.86	57.14	61.9
Semen color (thin to thick creamy)	70	50	62.5
Sperm morphology (≥70%)	100	100	100
Sperm motility (≥30 % progressive motility	100	100	100
Abnormal sperm cells (< 15-20%)	100	100	100
Overall average (%)	87.63	81.95	85.15

CONCLUSION AND RECOMMENDATIONS

Implementing BSE as a routine activity under CBBP sites can improve the productivity of participant farmers under the program through the introduction of fertile ram. Both breeds' better libido and semen characteristics allowed the use of artificial insemination to speed up the program's genetic and financial gains. Rams on the CBBP sites are handled by hand at farms, with varying management and mating schedules throughout the year. This condition requires careful management of rams throughout the year to improve the lambing rate and shorten the ewe's mating age, resulting in an increasing kid crop. With the overall soundness, disseminating/use of these few abnormal animals will have significant effect on breeding and economic benefit so that routine evaluation is crucial. In the CBBP sites of Washera and Simien sheep, rams above 22.5 cm of SC and above 80% for physical soundness, and acceptable range of semen characteristics can be used for mating and distributed for other CBBP sites. Besides, to understand the level of SC for mating rams, further study considering wider range of age and SC values is important to suggest lower and upper limit as appropriate. On top of this, considering the physical soundness, rams those are alert and active, without feet, eyes, or conformation anomalies, can be selected for mating in areas lacking laboratory facilities for semen evaluation. Besides these BSE parameters, selection should also consider rams with higher breeding values based on traits of interest. As the activity had done at one season, it will be better to conduct in different seasons by training the rams and repeatedly. Overall, the results indicate the importance of furnishing semen evaluation equipment in order to better evaluate rams on semen-related parameters, which would be done with research centers and supporting projects working in small ruminant CBBPs. For the CBBP to be more effective and to accelerate gains, the technical capacity for artificial insemination still has to be developed.

ACKNOWLEDGEMENTS

We express sincere thanks to the Ethiopian Institute of Agricultural Research (EIAR) for their collaboration and financial support and to the Gondar Agricultural Research Center (GARC) and the Debre Birhan Agricultural Research Center (DBARC) for their contributions of human expertise and material support during data collection. The efforts of Eyasu Zeleke and Melese Gelagay in the fieldwork are thankfully acknowledged.

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Genetic Evaluation of Growth Rate and Efficiency-related Traits in Dorper x Local Crossbred Sheep Population

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ABSTRACT

The present study was carried out to estimate genetic and phenotypic parameters for growth rate and efficiency-related traits in Dorper crossbred sheep population. Data on body weight collected from 2012 to 2021 at Debre Birhan Agricultural Research Center, Amhara Regional State, Ethiopia, were used to estimate phenotypic and genetic parameters for daily gain from birth to weaning (DG0-3), daily gain from weaning to six months (DG3-6), and daily gain from six months to yearling (DG6-12) and corresponding kleiber ratios (KR0-3, KR3-6, KR6-12), efficiency of growth (GE0-3, GE3-6, GE6-12) and relative growth rate (RG0-3, RG3-6, RG6-12). Genetic parameters were estimated by restricted maximum likelihood (REML) procedure fitting six different univariate animal models and the most appropriate model for each trait was determined by log-likelihood ratio test. Multivariate analysis was carried out to estimate correlations between traits. Year and season of birth had a significant effect ($P<0.001$) in all studied traits. Direct heritability estimates for DG0-3, DG3-6, DG6-12, KR0-3, KR3-6, KR6-12, GE0-3, GE3-6, GE6-12, GR0-3, GR3-6, and GR6-12 were 0.45±0.15, 0.04±0.06, 0.15±0.11, 0.30±0.08, 0.13±0.11, 0.14±0.12, 0.34±0.15, 0.39±0.17, 0.31±0.14, 0.25±0.08, 0.23±0.13, and 0.23±0.13, respectively. Additive genetic coefficient of variation (CV_A) were used as a measure of genetic variability and ranged from 7.26% (KR0-3) to 48.45% (GE3-6). The genetic and phenotypic correlation between studied traits ranged from -0.47 to 0.98. Genetic correlation estimates between DG3-6 and other traits were positive and high in magnitude to their respective growth phase (0.95, 0.86, and 0.91 for KR3-6, GE3-6, and GR3-6, respectively. The Dorper crossbred sheep is a meat type and reaches market weight at about six months of age, focusing on improving traits measured during weaning to six months of age is more economical and feasible. Selection based on DG3-6 is recommended to improve efficiency related traits.

Keywords: *Efficiency-related traits, genetic correlation, genetic parameter, heritability*

INTRODUCTION

Ethiopia holds the largest sheep population with a constantly growing heads of 42.91 million (CSA, 2021). Despite the huge number and large importance, productivity of the flock is very low. The carcass yield per animal slaughter is estimated to be 10 kg which is lower than the sub Saharan African sheep breeds (13 kg) (Abdi *et al*., 2019; Legese and Fadiga, 2014). Although the indigenous sheep breeds are adapted to the existing environmental situation, they have limited genetic capacity to sustaining the fast growing demand for animal product (Getachew *et al*., 2016). To this end, to meet the ever-increasing demand for animal product, crossbreeding program based on exotic sires (mainly Awassi and Dorper) has been implemented since the early 1980s.

The pure Dorper nucleus flock was established at Debre Birhan Agricultural Research Center (DBARC) to be used as an improver breed in a crossbreeding program in 2011. While Dorper-based crossbreeding program has been implemented to improve the growth rate and carcass quality of indigenous sheep population in 2012. The research on Dorper-based crossbreeding program was focused on the development of synthetic breed from Dorper-local sheep crossing, production of 50% crossbred rams, and utilization of the crossbred ram in village-based crossbreeding program. The synthetic breed development and 50% crossbred ram production has been implemented at DBARC sheep research station and a new breed-to-be is in the making. While the village-based crossbreeding program has been implemented in pre-defined demarcated area of Amhara region in order to prevent the indigenous breeds from unnecessary genetic dilution. The rapid weight gain, high carcass quality, and non-selective grazing ability of the crossbred lambs under farmer management condition make them one of the preferred breed for the genetic improvement of the local populations in the central highland of Ethiopia (Abebe *et al*., 2016; Mekonnen *et al*., 2018).

Besides, focusing on improving productivity through genetic improvement, improving the feed utilization efficiency of the breed is vital for efficient and sustaining the breeding program. Currently, due to rapid population growth and urbanization in the country, grazing pastures are shrinking and shifting into arable land. As a result, sheep production in the central highland of Ethiopia are being shifting from extensive system to semi-intensive system in which feed cost comprises most of the production costs. Therefore, improving efficiency of meat production by reducing the cost of mutton production is crucial to improve the efficiency of genetic improvement program (Ghafouri-Kesbi and Gholizadeh, 2017). To include such traits in the selection index, knowledge on genetic parameters regarding both growth rate and efficiency-related traits is vital. While information on genetic parameters for growth traits and kleiber ratio is available (Shanbel *et al.*, 2022; Zeleke *et al.*, 2020), there is no information regarding genetic parameter for efficiency of growth and relative growth rate in Dorper x Local sheep in Ethiopia. Therefore, this study was conducted to evaluate the on-ongoing Dorper x Local sheep crossbreeding program and generate information to optimize the breeding program by evaluating the genetic parameters for growth rate and efficiency-related traits of Dorper crossbred sheep population.

MATERIALS AND METHODS

The breeding flock and management

Data used in this study were obtained from the sheep research station of Debre Birhan Agricultural Research Center (DBARC), Amhara Regional State, Ethiopia which is located 120 km North-east of Addis Ababa at a latitude of 09°36′23″N and longitude of 39°39′10″E. The altitude is approximately 2,765 m.a.s.l. The area is characterized by a bi-modal rainfall pattern, where the main rainy season is from June to September and unreliable short rainy season is expected from February/March to April. Since 2012, local ewes were mated with pure Dorper rams to produce 50% crossbred lambs at the research station. Then the crossbred ewe lambs produced in the first cross were mated with the best 50% crossbred rams (Inter se mating) to develop synthetic breed through successive crossing. However, the third generation (F3) mating has been started since 2019. In this regard, about 1350 crossbred animals descended from 46 sires (25 pure Dorper to produce F1 crossbred lambs and 21 crossbred Dorper rams (50%) for successive crossing) and 586 dams (265 local and 321 Dorper 50%) were produced from 2012 to 2021. Breeding rams were selected based on estimated breeding value (EBV) on six months weight and other morphological traits such as color, absence of horn, and body conformations. Ewes were first exposed to ram at about 14 months of age. Controlled mating was practiced, and one selected breeding ram was allowed to mate with 25 to 30 ewes and mating were lasted on average of 60 days. Since 2019, MateSel software has been applied to make mating group in order to control inbreeding and to maximize genetic gain across generation. New born lambs were weighed and ear-tagged at the time of birth or 24 h afterwards and animal's parent, date of birth, sex of lamb, birth litter size, and color were recorded. Lambs were usually separated from their dam at 3 months of age.

The animal were allowed to graze on natural pasture during the day time for 6 to 7 h and penned at night during dry and short rainy seasons (from September to June). On the other hand, because of high occurrence of mortality due to fasciolosis outbreak in 2014, all animals were forced to stay indoors at day and night times during the main rainy season (from July to September) and fed dry hay as a basal diet without any supplementation of vitamins and minerals premix. However, since 2019, the animals were allowed to feed on green forage and grass with a cut and cray feeding system. The experimental animal were supplemented with 200 to 400 g/head/day mixed concentrate depending up on status, age category, and availability of grazing feed. The mixed concentrate had 19.9% crude protein and 79% total digestive nutrient. The animal has free access to fresh water twice a day. As a routine flock health management practice of the research center, the experimental animals were drenched against internal parasites and were vaccinated against common viral diseases occurring in the area.

Data collection, management and analyses

Traits considered in this study were birth weight (WT0), weaning weight (WT3), six months weight (WT6), yearling weight (WT12), daily gain from birth to weaning (DG0-3), daily gain from weaning to six months (DG3-6), daily gain from six months to yearling (DG6-12), kleiber ratio from birth to weaning (KR0-3), kleiber ratio from weaning to six months (KR3-6), kleiber ratio from six months to yearling (KR6-12), growth efficiency from birth to weaning (GE0-3), growth efficiency from weaning to six months (GE3-6), growth efficiency from six months to yearling (GE6-12), relative growth rate from birth to weaning (GR0-3), relative growth rate from weaning to six months (GR3-6) and relative growth rate from six months to yearling (GR6-12). Birth weight was taken within 24 h after the birth of a lamb. Weaning, six month and yearling weights were taken by synchronized lambing occurred within 5 days interval from the actual weighted dates and adjusted to the exact days of 90, 180 and 365 respectively. In meat type breed, daily gain is an important component of market lamb production and affects the economic success of producing slaughter lambs (Eskandarinasab *et al.*, 2010). Daily gain was calculated as

DG0-3 = ((WT3-WT0)/90) X 1000, DG3-6 = ((WT6-WT3)/90) X 1000 and DG6-12 = ((WT12-WT6)/180) X 1000. The Kleiber ratio has been proposed as an efficient criterion for feed efficiency under low-input range conditions which provides a good indication of how economically an animal grows (Mohammadi et al., 2011). Kleiber ratio was computed as KR0-3 = ADG0-3/WT3$^{0.75}$, KR3-6 = ADG3-6/WT6$^{0.75}$ and KR6-12 = ADG6-12/WT12$^{0.75}$, accordingly to Kleiber (1947). Efficiency of growth was calculated as GE0-3 = ((WT3-WT0)/WT0) X 100, GE3-6 = ((WT6-WT3)/WT3) X 100 and GE6-12 = ((WT12-WT6)/WT6) X 100. Relative growth rate was computed as GE0-3 = (Log_e (WT3) - Log_e (WT0))/90) X 100, GE3-6 = (Log_e (WT6) - Log_e (WT3))/90) X 100 and GE6-12 = (Log_e (WT12) - Log_e (WT6))/180) X 100. Additive coefficient of variation (CV_A) allow us to have an insight into the genetic variability of traits as well as to compare precisely traits measured at different times or in different population (Ghafouri-Kesbi & Gholizadeh, 2017). Additive coefficient of variance estimated as (CV_A) = $\frac{\sqrt{\sigma_a^2}}{\bar{x}} x100$ where σ^2_a is additive genetic variance and $\bar{x}$ is the sample mean.

Fixed effects for growth rate and efficiency-related traits were estimated using the GLM procedure of SAS 9.1 software. The fixed effects considered were: generation of lambs in three class (1st, 2nd and 3rd), second and third generation lamb was produced by self-mating of first and second generation lambs respectively, sex of lambs in two classes (male and female), birth litter size in two classes (single and twin), parity of dam in six classes, year of lambing in 10 classes (2012–2021) and season of lambing in three classes (rainy, dray and short rainy season). Means were compared using Tukey-kramers test.

The model used for the analysis of growth rate and efficiency-related traits was

$Y_{ijklm} = \mu + Gr_i + Yr_j + Bt_k + Bs_l + P_m + S_n + e_{ijklmn}$

Where Y_{ijklm} is an observation; μ is overall mean; Gr_i is fixed effect of lamb generation; Yr_j is fixed effect of year of birth; Bt_k is fixed effect of birth type; Bs_l is fixed effect of birth season; P_m is fixed effect of parity; S_n is fixed effect of sex of lamb and e_{ijklmn} is residual error.

(Co) variance components and genetic parameters were estimated using restricted maximum likelihood (REML) method fitting univariate animal model using WOMBAT software (Meyer, 2012). Multivariate analysis was applied for genetic and phenotypic correlation estimates. By excluding or including permanent environmental or maternal genetics effects, the following six Univariate animal models were fitted for each trait.

Table 1. Characteristics of data structure.

Parameters	Traits											
	DG0-3	DG3-6	DG6-12	KR0-3	KR3-6	KR6-12	GE0-3	GE3-6	GE6-12	GR0-3	GR3-6	GR6-12
No. of records	905	688	434	905	688	434	905	688	434	905	688	434
No. of animals	1110	859	542	1110	859	542	1110	859	542	1110	859	542
Sire[a]	43	39	32	43	39	32	43	39	32	43	39	32
Sire[b]	7	7	2	7	7	2	7	7	2	7	7	2
NPR/Sire	21.05	17.64	13.56	21.05	17.64	13.56	21.05	17.64	13.56	21.05	17.64	13.56
Dam[a]	267	218	132	267	218	132	267	218	132	267	218	132
Dam[b]	98	79	54	98	79	54	98	79	54	98	79	54
NPR/Dam	3.39	3.16	3.29	3.39	3.16	3.29	3.39	3.16	3.29	3.39	3.16	3.29
Mean	108.84	42.61	50.88	15.65	4.73	4.11	327.13	32.56	53.24	1.57	0.28	0.23
S.D.	37.35	38.69	26.73	2.42	4.03	1.86	128.18	31.91	29.72	0.32	0.25	0.11
CV (%)	30.52	72.79	39.06	13.83	69.24	36.56	33.95	80.36	46.55	18.14	72.11	39.81

[a] Number of sires and dams with progeny, [b] Number of sires and dams with progeny and record, NPR: Average number of progeny with records, S.D.: standard deviations, CV.: Coefficient of variation, DG0-3: daily gain from birth to weaning, DG3-6: daily gain from weaning to six months, DG6-12: daily gain from six months to yearling, KR0-3: kleiber ratio from birth to weaning, KR3-6: kleiber ratio from weaning to six months, KR6-12: kleiber ratio from six months to yearling, GE0-3: growth efficiency from birth to weaning, GE3-6: growth efficiency from weaning to six months, GE6-12: growth efficiency from six months to yearling, GR0-3: relative growth rate from birth to weaning, GR3-6: relative growth rate from weaning to six months, GR6-12: relative growth rate from six months to yearling

Model (1) $y = \mathbf{X}\beta + \mathbf{Z}_a\alpha + e$

Model (2) $y = \mathbf{X}\beta + \mathbf{Z}_a\alpha + \mathbf{Z}_{pe}pe + e$

Model (3) $y = \mathbf{X}\beta + \mathbf{Z}_a\alpha + \mathbf{Z}_m m + e \quad Cov(\alpha, m) = 0$

Model (4) $y = \mathbf{X}\beta + \mathbf{Z}_a\alpha + \mathbf{Z}_m m + e \quad Cov(\alpha, m) \neq 0$

Model (5) $y = \mathbf{X}\beta + \mathbf{Z}_a\alpha + \mathbf{Z}_m m + \mathbf{Z}_{pe}pe + e \quad Cov(\alpha, m) = 0$

Model (6) $y = \mathbf{X}\beta + \mathbf{Z}_a\alpha + \mathbf{Z}_m m + \mathbf{Z}_{pe}pe + e \quad Cov(\alpha, m) \neq 0$

Where y is a vector of observations on the considered traits; β, α, m, pe and e are vectors of significant fixed effects, direct additive genetic effects, maternal genetic effects, permanent environment effects and the residual effects, respectively. Whereas $\mathbf{X}$, $\mathbf{Z}_a$, $\mathbf{Z}_m$ and $\mathbf{Z}_{pe}$ are corresponding incidence matrices relating the fixed effect, direct additive genetic effects, maternal additive genetic effects and permanent environmental effects of the dam. Total heritability (h^2_t) was estimated using the formula $\sigma^2_a + 0.5\sigma^2_m + 1.5\sigma_{am}/\sigma^2_p$ (Willham, 1972). Where σ^2_a is additive variance, σ^2_m is maternal variance, σ_{am} is covariance between direct and maternal additive genetic effect and σ^2_p is total phenotypic variance. Direct heritability (h^2_a), maternal heritability (h^2_m) and relative permanent maternal environmental effects (c^2) were calculated as ratios of estimates of σ^2_a, σ^2_m and σ^2_c respectively, to the phenotypic variance σ^2_p. Likelihood ratio tests were conducted, to choose the best model and to test the significance of random effects for each trait (Meyer, 2006).

RESULT AND DISCUSSION

Phenotypic performance

Mean, standard deviation (SD), coefficient of variation (CV), and pedigree structure of studied traits are presented in Table 1. Crossbred lambs had remarkably higher daily gain, kleiber ratio, efficiency of growth and relative growth rate during the pre-weaning phase compared to the post-weaning growth phases. The result is in close agreement with the findings of Eskandarinasab *et al.,* (2010); Ghafouri-Kesbi *et al.,* (2011); Ghafouri-Kesbi and Gholizadeh, (2017); Mohammadi *et al.,* (2012) in different sheep breeds. In addition, traits measured during the pre-weaning period had smallest phenotypic coefficient of variation (CV). This shows that during the pre-weaning period, lambs are less affected by environmental factors owing to maternal support. However, after weaning lambs exposed to environmental stress, which affects growth of lambs. Moreover, traits measured from weaning to six months of age had higher phenotypic coefficient of variation (CV) compared to other growth phases. On the other hand, lambs had higher daily gain and efficiency of growth during six months to yearling growth phase than weaning to six months. This result revealed that lambs were highly influenced by environmental factors just at weaning period than other growth phases. This implies that special attentions is required during pre-weaning growth phase to produce productive replacement flock and sustaining the breeding program.

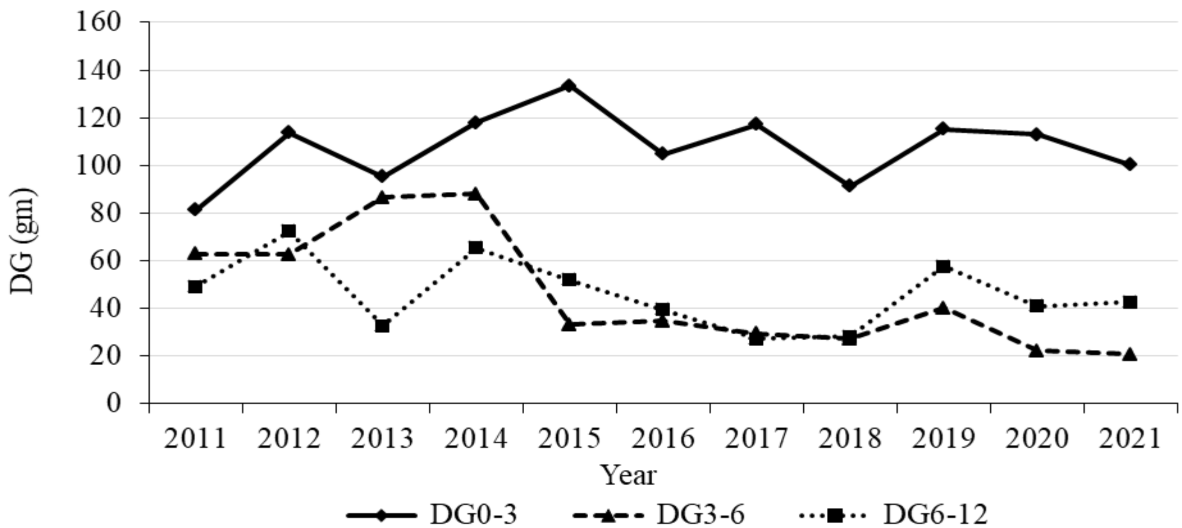

Figure 1. Phenotypic daily gain trend by year of birth.

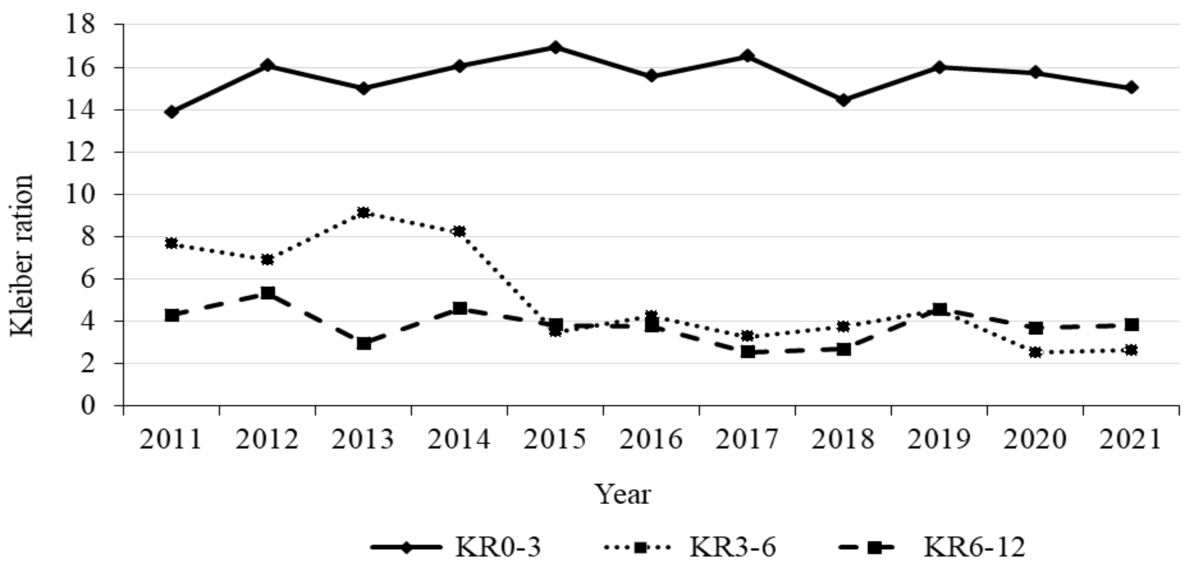

Figure 2. Phenotypic Kleiber ratio trend by year of birth.

Least squares means (+SE) for the traits studied are presented in Tables 2 and 3, respectively. Year of birth had significant effect ($p<0.001$) in all studied traits. The significant effect of birth year on growth performances has been reported (Baneh and Hafezian, 2009; Ghafouri-Kesbi *et al.*, 2011; Ghafouri-Kesbi and Gholizadeh, 2017) for different sheep breeds. The effect of birth year arises from differences in climatic and environmental condition, and animal management in different years (Bakhshalizadeh *et al.*, 2016; Mohammadi *et al.*, 2010). Climate and environmental changes have an effect on the quality and quantity of grazing pasture, which affect the availability of feed and other requirements for animals. Phenotypic performance for all studied traits showed a declining trend over years (Figures 1 to 4). This has happened due to deliberate shift of animals management associated with fasciolosis outbreak as of the year 2014. Because of high occurrence of mass mortality in the research center due to fasciolosis outbreak over the subsequent years, all animals were not allowed to graze on natural pasture during winter season (July to September), kept indoor and fed only dry hay as a basal diet and supplemented with 200g head/day mixed concentrate without any supplementation of vitamins and mineral premix. This management strategy could expose the animals to vitamin E deficiency. Vitamin E deficiency is often associated with feeding growing lambs for long period (two-three months) with little or no access to green feed. Moreover, selenium and vitamin E are stored for a short period in the body, and a continual dietary supply is essential. According to Ramírez-Bribiesca *et al.* (2005) and Ziaei (2015) deficiency of either or both selenium and vitamin E can reduce growth, reproductive performance and immune response of the animals.

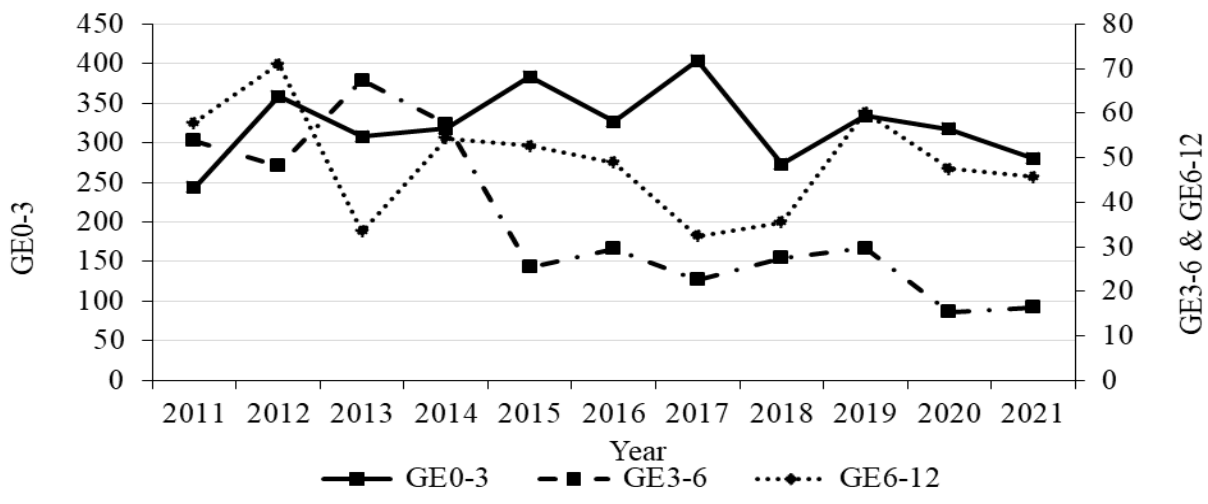

Figure 3. Phenotypic growth efficiency trend by year of birth

Table 2. Least-squares means±S.E for daily weight gain and Kleiber ratio.

Parameters	DG0-3	DG3-6	DG6-12	KR0-3	KR3-6	KR6-12
Birth year	***	***	***	***	***	***
Generation	ns	**	***	ns	**	***
F1	110.19±14.24	26.36±13.71[ab]	44.26±9.88[ab]	16.02±0.93	3.46+1.45[ab]	4.03±0.75[ab]
F2	89.39±20.46	40.23±19.31[a]	42.56±13.08[b]	14.51±1.33	4.54+2.04[a]	3.69±0.99[b]
F3	86.18±21.25	17.30±20.17[b]	66.89±13.80[a]	14.42±1.38	2.19+2.13[b]	5.83±1.04[a]
Sex	ns	ns	**	ns	ns	ns
Male	96.43±10.16	28.52±10.01	53.76±7.79	14.99±0.66	3.35±1.06	4.57±0.59
Female	94.08±10.06	27.41±9.84	48.72±7.62	14.97±0.66	3.44±1.04	4.47±0.58
BLS	***	ns	ns	***	ns	ns
Single	108.07±9.92	31.28±9.64	53.89±7.45	15.46±0.65	3.25±1.02	4.02±0.56
Twin	82.43±10.58	24.65±10.60	48.58±8.29	14.50±0.69	3.54±1.12	4.64±0.63
Parity	***	ns	*	ns	ns	**
1	87.58±10.05[b]	31.25±9.83	48.55±7.57[ab]	14.80±0.66	3.82±1.04	4.51±0.57[ab]
2	95.10±10.23[ab]	31.47±10.06	49.09±7.84[ab]	15.05±0.67	3.84±1.06	4.38±0.59[ab]
3	102.76±10.39[a]	25.17±10.24	44.06±7.91[b]	15.40±0.68	2.97±1.08	3.93±0.60[b]
4	94.62±10.52[ab]	24.84±10.44	55.46+8.03[a]	14.88±0.69	3.14±1.10	4.81±0.61[a]
5	95.85±11.08[ab]	29.69±11.02	45.23±8.88[ab]	15.00±0.72	3.54±1.16	3.88±0.67[b]
≥6	95.62±11.46[ab]	25.37±11.56	65.03±9.70[a]	14.75±0.75	3.05±1.22	5.61±0.73[a]
Birth season	***	***	***	***	***	*
Main rainy	92.37±10.40[b]	33.10±10.17[a]	55.67±7.86[a]	14.70±0.68[b]	3.92±1.07[a]	4.72+0.59[ab]
Dry	74.90±10.02[c]	35.85±9.81[a]	53.42±7.62[ab]	13.58±0.65[c]	4.61±1.04[a]	4.82+0.58[a]
Short rainy	118.49±10.54[a]	14.95±10.60[b]	44.63±8.37[b]	16.67±0.69[a]	1.65±1.12[b]	4.02±0.63[b]

[abc]On the same column, numbers bearing the same superscript are not statistically different at p >0.05. ns: not significant. ***P<0.001; ** P<0.01 and * P<0.05; BLS: birth litter size; F1: generation one, F2: generation two; F3: generation three. For trait abbreviations see footnote of Table 1.

Generation of lambs significantly influenced all studied traits in post-weaning growth phases except GE3-6 ($P<0.05$) but not significant effects in all traits measured during pre-weaning growth period. Second-generation lambs had significantly higher ($p<0.001$) DG3-6, KR3-6 and GR3-6 compared to third-generation lambs. This difference can be explained by higher heterosis effects in second-generation than third-generation lambs (due to loss of heterosis effects across generation). The result is in close agreement with results reported by Boujenane *et al.* (2015) in inter se mating between D'man-Sardi sheep crosses. Contrary to the present finding Gizaw *et al*. (2012) reported that performance of third-generation lambs were higher than first and second generation lambs in Awassi-Menz sheep crosses. However, from six months to yearling growth period, third-generation lambs had significantly higher ($p<0.001$) in all studied traits compared to second-generation lambs. This can be due to the small data size in third generation lambs.

Sex of lambs had significant effect ($p<0.01$) in DG6-12, but not in other studied traits. Male lambs had significantly higher DG6-12 compared to females ($p<0.01$). The effect of sex on DG6-12 may be attributed to differences in endocrine system where estrogen hormone has a limiting effect on growth of long bones in female lambs (Baneh and Hafezian, 2009). The result is contrary to the report of Eskandarinasab *et al.,* (2010); Ghafouri-Kesbi and Gholizadeh, (2017); Mohammadi *et al.* (2012) who find significant effect of sex in all studied traits. Single lambs had significantly higher daily gain and kleiber ratio than twin lambs in pre-weaning growth phase ($p<0.001$). It is expected that milk from a dam may not be sufficient enough to feed twins than single counterparts. Marked effect of birth type on daily weight gain and kleiber ratio is in agreement with other reports (Eskandarinasab *et al.,* 2010; Ghafouri-Kesbi and Gholizadeh, 2017; Mohammadi *et al.,* 2012).

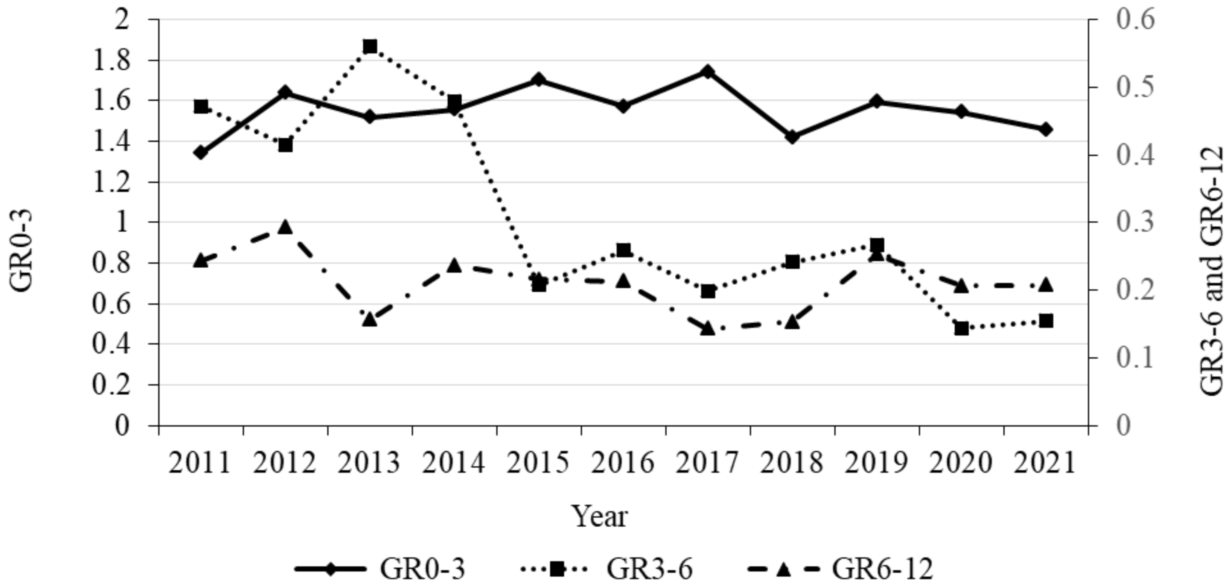

Figure 4. Phenotypic relative growth rate trend by year of birth

The effect of parity was significant on DG0-3, DG6-12, KR6-12, GE6-12 and GR6-12 ($p<0.05$). In the current study, the effect of parity on studied traits is not much important. This result is contrary to the reports of (Eskandarinasab *et al.*, 2010; Ghafouri-Kesbi and Gholizadeh, 2017; Kholghi *et al.*, 2014) for different sheep breeds. Birth season had significant source of variation in all studied traits ($p<0.001$). Lambs born during short rainy season had higher ($p<0.001$) daily gain, kleiber ratio, efficiency of growth and relative growth rate during the pre-weaning growth phase. During the short rainy season, lambs were allowed to graze on natural pasture (they feed green forages) but during main rainy season lambs were restricted from grazing of green pasture and fed dry hay as a basal diet without any supplementation of vitamins and minerals premix. This practice is not enough to cover the nutritional requirements of the growing lamb. On the other hand, lambs born during main rainy and dry seasons had higher phenotypic performance during post-weaning growth period in all studied traits. The higher post-weaning phenotypic performance of lambs born during main rainy and dry seasons is attributed to the higher abundance of grazing pasture following the main rain and during short rainy seasons. This can be also due to the effect of compensatory growth which is a period of accelerated growth following a period of restricted development (Kesbi and Tari, 2015).

Table 3. Least-squares means±S.E for efficiency of growth and relative growth rate.

Parameters	GE0-3	GE3-6	GE6-12	GR0-3	GR3-6	GR6-12
Birth year	***	***	***	***	***	***
Generation	ns	ns	***	ns	*	***
F1	359.07±47.60	24.00±11.56	51.58±12.32^{ab}	1.65±0.12	0.21±0.09^{ab}	0.23±0.04^{ab}
F2	319.79±68.40	34.81±16.29	50.89±16.31^{b}	1.50±0.17	0.29±0.13^{a}	0.21±0.06^{b}
F3	307.72±71.04	21.54±17.02	87.50±17.21^{a}	1.48±0.18	0.16±0.13^{b}	0.35±0.06^{a}
Sex	ns	ns	ns	ns	ns	ns
Male	326.46±33.96	26.86±8.44	64.39±9.72	1.54±0.09	0.22±0.07	0.27±0.04
Female	331.25±33.63	26.71±8.30	62.26±9.50	1.56±0.09	0.23±0.06	0.26±0.03
BLS	ns	ns	ns	ns	ns	ns
Single	317.01±33.16	24.49±8.13	60.04±9.29	1.53±0.08	0.20±0.06	0.25±0.03
Twin	340.71±35.39	29.08±8.94	66.61±10.34	1.56±0.09	0.24±0.07	0.28±0.04
Parity	ns	ns	*	ns	ns	**
1	344.66±33.62	31.05±8.29	63.99±9.44^{a}	1.58±0.09	0.26±0.06	0.27±0.03^{a}
2	335.00±34.20	30.71±8.49	59.44±9.77^{ab}	1.57±0.09	0.25±0.07	0.25±0.04^{ab}
3	350.58±34.74	24.01±8.64	53.26±9.86^{b}	1.60±0.09	0.20±0.07	0.23±0.04^{b}
4	315.44±35.16	23.22+8.81	69.24±10.01^{a}	1.52±0.09	0.20±0.07	0.28±0.04^{a}
5	325.03±37.07	25.91±9.29	55.57±11.08^{ab}	1.54±0.09	0.22±0.07	0.23±0.04^{ab}
≥6	302.44±38.31	25.81±9.75	78.45±12.09^{a}	1.48±0.10	0.21±0.08	0.33±0.04^{ab}
Birth season	***	***	**	***	***	**
Main rainy	298.40±34.77^{b}	28.58±8.58^{b}	66.66±9.81^{ab}	1.48±0.09^{b}	0.25±0.07^{b}	0.27+0.04^{ab}
Dry	253.52±33.50^{c}	38.35±8.27^{a}	69.52±9.50^{a}	1.36±0.09^{c}	0.31±0.06^{a}	0.29+0.03^{a}
Short rainy	434.65±35.25^{a}	13.43±8.94^{c}	53.79±10.43^{b}	1.80±0.09^{a}	0.11±0.07^{c}	0.23±0.04^{b}

^{abc} On the same column, numbers bearing the same superscript are not statistically different at p =0.05. ns: not significant. ***P<0.001; ** P<0.01 and * P<0.05; BLS: birth litter size; F1: generation one; F2: generation two; F3: generation three. For trait abbreviations see footnote of Table 1.

Genetic parameters estimates

The estimates of (co)variance components and corresponding genetic parameters are presented in Table 4. The most appropriate models for pre-weaning daily gain and efficiency of growth were Model 6 and 4, respectively. Fitting a permanent environmental and maternal genetic effect substantially increased the log-likelihood values, indicating a significant effect of permanent environmental and maternal genetic effect on pre-weaning daily gain. Moreover, including maternal genetic effect (Model 4) significantly increased the log-likelihood values over other models, indicating that the covariance between direct and maternal effect was significant for pre-weaning efficiency of growth. On the other hand, a model that include only direct additive genetic effects (Model 1) was the most appropriate to evaluate pre-weaning kleiber ratio and relative growth rate. Based on the most appropriate models (Model 6, Model 1, Model 4 and Model 1) direct heritability estimates for pre-weaning daily gain, kleiber ratio, efficiency of growth, and relative growth rate were 0.45±0.15, 0.30±0.08, 0.34±0.15, and 0.25±0.08, respectively. Estimated value of CV_A for pre-weaning daily gain, kleiber ratio, efficiency of growth and relative growth rate were 18.85%, 7.26%, 20.07%, and 9.0%, respectively. Direct heritability estimates and CV_A recorded in the pre-weaning growth period were higher than other findings in different sheep breeds (Eskandarinasab *et al.*, 2010; Ghafouri-Kesbi and Gholizadeh, 2017). Based on the appropriate model, the estimates of maternal heritability for daily gain and efficiency of growth were 0.14+0.14 and 0.19+0.10, respectively.

Table 4. Estimate of variance components and heritability for efficiency related traits.

Traits	**M**	σ^2_a	σ^2_m	σ_{am}	σ^2_c	σ^2_e	σ^2_P	h^2_a	h^2_m	r_{am}	c^2	h^2_t	CV_A	**Log (L)**
DG0-3	**6**	420.77	134.20	-189.43	84.84	493.12	943.49	0.45±0.15	0.14±0.14	-0.80±0.23	0.09+0.08	0.22	18.85	-3432.46
DG3-6	**1**	31.03				855.22	886.25	0.04±0.06				0.04±0.06	13.07	-2606.68
DG6-12	**1**	59.43				325.81	385.24	0.15±0.11				0.15±0.11	15.15	-1440.83
KR0-3	**1**	1.29				3.06	4.35	0.30+0.08				0.30±0.08	7.26	-1110.79
KR3-6	**6**	1.26	1.59	-1.35	0.12	8.13	9.75	0.13±0.11	0.16±0.14	-0.96±0.28	0.01±0.09	0.00	23.73	-1123.96
KR6-12	**1**	0.31				1.84	2.15	0.14±0.12				0.14±0.12	13.55	-398.64
GE0-3	**4**	4309.88	2412.74	-2051.41		7966.08	12637.29	0.34±0.15	0.19±0.10	-0.64±0.23		0.19	20.07	-4574.36
GE3-6	**4**	248.88	192.80	-202.12		404.55	644.11	0.39±0.17	0.30±0.12	-0.92±0.12		0.07	48.45	-2480.03
GE6-12	**1**	183.72				418.91	602.63	0.31±0.14				0.31±0.14	25.46	-1524.33
GR0-3	**1**	0.02				0.06	0.08	0.25±0.08				0.25+0.08	9.0	617.00
GR3-6	**4**	0.008	0.009	-0.008		0.029	0.038	0.23±0.13	0.24±0.11	-0.93±0.18		0.01	31.94	697.54
GR6-12	**1**	0.002				0.006	0.008	0.23+0.13				0.23±0.13	19.44	734.11

σ^2_P phenotypic variance; σ^2_a additive variance; σ^2_m maternal variance; σ^2_c common environment variance; σ^2_e error variance; h^2a direct heritability; h^2m maternal heritability; h^2c ration of common environment variance to the total phenotypic variance; h^2t total heritability; r_{am} genetic correlation between direct and maternal additive heritability; σ_{am} .covariance between direct and maternal additive genetic effect; CV_A additive coefficient of variance; Log (L) log Likelihood. For trait abbreviations see footnote of Table 1.

Fitting only direct genetic effect (Model 1) resulted in significantly ($p<0.05$) higher log-likelihood for DG3-6 in comparison to the rest models which included other effects. Fitting permanent environmental and maternal genetic effect (Model 6) improved the log-likelihood for KR3-6, indicating that covariance between direct and maternal genetic effect was significant for this traits. While Model 4 was the best model for GE3-6 and GR3-6. Based on the appropriate model direct genetic heritability estimates for DG3-6, KR3-6, GE3-6 and GR3-6 were 0.04+0.06, 0.13+0.11, 0.39+0.17, and 0.23+0.13, respectively. Estimates of CVA were 13.07%, 23.73%, 48.45% and 31.94% for DG3-6, KR3-6, GE3-6, and GR3-6, respectively. Maternal genetic heritability estimates for KR3-6, GE3-6 and GR3-6 were 0.16+0.14, 0.30+0.12, and 0.24+0.11 respectively. Model included only direct genetic effects (Model 1) was the most appropriate model for DG6-12, KR6-12, GE6-12, and GR6-12, respectively. Direct heritability estimates were 0.15±0.11, 0.14±0.12, 0.31±0.14, and 0.23±0.13 for DG6-12, KR6-12, GE6-12, and GR6-12 respectively and estimates of CVA for the corresponding trait were 15.15%, 13.55%, 25.46%, and 19.44% respectively. The estimates of CVA, direct and maternal genetic heritability in this study is remarkably higher than the estimate by Ghafouri-Kesbi & Gholizadeh, (2017) for Baluchi sheep in all growth periods. There are few previous reports on estimates of genetic parameters for efficiency-related traits in sheep. This study can help to include efficiency-related traits in the selection index to improve the efficiency of the ongoing genetic improvement program. Medium to higher estimates of direct heritability and CV_A in the current study indicates higher potential for genetic improvement of studied traits in the different growth periods.

Correlation estimates

The estimates of genetic and phenotypic correlations between studied traits are presented in Table 5. The genetic and phenotypic correlation between studied traits ranged from low to high in magnitude (-0.48 to 0.98). Traits measured during the pre-weaning growth phase had negative and weak genetic correlations with traits measured during the post-weaning growth phases (ranged from -0.34 to -0.08). It indicates that lambs with higher growth rate and efficiency-related traits in pre-weaning period have less efficient during the post-weaning period and vice versa. The negative and weak genetic correlations between those traits probably indicate that different genetic mechanisms are involved in expressing those traits at different stage of growth (Mohammadi *et al*., 2011; Mohammadi *et al.*, 2015). Similarly Mohammadi *et al*., (2010) find similar correlation estimates to the current study. In agreement to genetic correlations, phenotypic correlation between traits measured during pre-weaning growth phase had negative and weak correlation estimates with traits measured during post-weaning growth phases. Similar findings have been reported by Ghafouri-Kesbi & Gholizadeh, (2017) for Baluchi sheep. Compensatory growth phenomenon may play an important role, lambs with poor early growth possibly due to poor pre-weaning environment tended to have higher post-weaning growth than lambs in better pre-weaning conditions (Afolayan *et al.*, 2007).

Dorper crossbred sheep are a meat type and attains market weight at about six months of age in the central highland of Ethiopia. Furthermore, since genetic correlation between traits measured during pre-weaning growth period had negative and weak correlation estimates with traits measured during post-weaning growth period. As a result improving traits measured during weaning to six months of age is more feasible. The genetic correlation estimates between DG3-6 and other traits were positive and high in magnitude to their corresponding growth phase (0.95, 0.86, and 0.91 for KR3-6, GE3-6, and GR3-6, respectively). These positive and strong genetic correlations between DG3-6 and other traits imply no negative genetic change in efficiency-related traits due to selection for growth rate (Bakhshalizadeh *et al.*, 2016; Ghafouri-Kesbi and Gholizadeh, 2017; Gowane *et al.*, 2011). Moreover, strong and positive genetic correlations between DG3-6 and other traits measured during the same growth period indicated that selection for or against one trait would result in concomitant genetic - changes in other traits. Genetic correlation between efficiency-related traits during weaning to six months of growth period was positive and strong in magnitude (0.92 for KR3-6-GE3-6) which means that all the efficiency traits measured during this period can be improved simultaneously.

Table 5. Genetic (above diagonal) and Phenotypic (below diagonal) correlation

	Traits											
	DG0-3	DG3-6	DG6-12	KR0-3	KR3-6	KR6-12	GE0-3	GE3-6	GE6-12	GR0-3	GR3-6	GR6-12
DG0-3		-0.16	-0.08	0.94	-0.35	-0.24	0.72	-0.47	-0.35	0.77	-0.45	-0.33
DG3-6	-0.22		-0.12	-0.15	0.95	-0.27	0.14	0.86	-0.33	-0.13	0.91	-0.33
DG6-12	-0.06	-0.14		-0.07	-0.09	0.94	-0.07	-0.06	0.86	-0.06	-0.07	0.90
KR0-3	0.93	-0.18	-0.04		-0.33	-0.21	0.85	-0.46	-0.31	0.92	-0.43	-0.29
KR3-6	-0.40	0.95	-0.11	-0.36		-0.20	-0.26	0.92	-0.24	-0.26	0.98	-0.25
KR6-12	-0.22	-0.31	0.93	-0.19	-0.24		-0.15	-0.13	0.92	-0.16	-0.15	0.97
GE0-3	0.75	-0.15	-0.03	0.86	-0.27	-0.13		-0.33	-0.19	0.97	-0.32	-0.19
GE3-6	-0.49	0.87	-0.07	-0.47	0.92	-0.16	-0.32		-0.15	-0.36	0.98	-0.15
GE6-12	-0.34	-0.34	0.84	-0.30	-0.27	0.92	-0.20	-0.16		-0.21	-0.18	0.98
GR0-3	0.78	-0.14	-0.03	0.93	-0.28	-0.14	0.97	-0.36	-0.21		-0.34	-0.21
GR3-6	-0.48	0.91	-0.09	-0.45	0.98	-0.19	-0.32	0.98	-0.20	-0.35		-0.18
GR6-12	-0.31	-0.36	0.88	-0.27	-0.28	0.97	-0.18	-0.18	0.98	-0.20	-0.21	

For trait abbreviations see footnote of Table 1

CONCLUSION

Phenotypic performance for daily gain, kleiber ratio, efficiency of growth and relative growth rate showed a declined trend over the year. This was brought up by animal management decision to overcome mass mortality of breeding animals with fasciolosis outbreak occurred in the farm in 2014. The management strategies followed after fasciolosis outbreak exposed the breeding animals to deficiency of most important vitamins and minerals (vitamin E and selenium) for growth, reproduction and immune response. The genetic parameters estimated for efficiency-related traits in Dorper crossbred sheep population show that efficiency related traits have medium to high CV_A and heritabilities reflected some possibility to bring genetic improvement through selection. Sheep farming in central highland of Ethiopian is shifting from extensive to semi-intensive production system, including efficiency-related traits in the selection index, makes the breeding program more efficient and feasible. The Dorper crossbred sheep are a meat type and reaches market weight at about six months of age, focusing on improving traits measured during weaning to six months of age is expected to be more feasible. The genetic correlation estimates between DG3-6 and other traits were positive and high in magnitude to their respective growth phase, hence selection based on DG3-6 is recommended.

ACKNOWLEDGEMENT

The Dorper sheep experiment was financially supported by Amhara Agricultural Research Institute (ARARI) and Ethiopian Institute of Agricultural Research (EIAR). We would like to acknowledge all livestock breeding and management staff specially Mr. Deribew Bekele and Mr. Alemayehu H/Mikael, who over the years have assisted in managing the experimental flock and in data collection.

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Genetic Evaluation of Growth Rate and Efficiency-related Traits in Dorper Sheep

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ABSTRACT

Growth data from the breeding flock of Dorper sheep collected between 2012 and 2021 at Debre Birhan Agricultural Research Center, Amhara Region, Ethiopia were used in this study. (Co)variance components and corresponding genetic parameters for daily gain from birth to weaning (DG_{0-3}), daily gain from weaning to six months (DG_{3-6}), and daily gain from six months to yearling (DG_{6-12}) and corresponding kleiber ratios (KR_{0-3}, KR_{3-6}, KR_{6-12}), efficiency of growth (GE_{0-3}, GE_{3-6}, GE_{6-12}) and relative growth rate (RG_{0-3}, RG_{3-6}, RG_{6-12}) were estimated using restricted maximum likelihood (REML) procedure fitting six different univariate animal model. The most appropriate model for each trait was determined by log-likelihood ratio test. Multivariate analysis was carried out to estimate correlations between traits. Year of birth had a significant effect ($P<0.001$) in all studied traits. Furthermore, birth season had a significant effect ($p<0.01$) in traits measured during pre-weaning growth period. Phenotypic performance for all studied traits except traits measured from six months to 12 months of age showed a declined trend over years. Model including only direct genetic effects was chosen as the most appropriate for all studied traits, except for GE_{0-3} and GR_{0-3} whereas a model included maternal genetic effects was the most appropriate model. Direct heritability estimates were, respectively, 0.10 ± 0.06, 0.16 ± 0.07, 0.26 ± 0.13 and 0.26 ± 0.13 for DG_{0-3}, KR_{0-3}, GE_{0-3} and GR_{0-3}; 0.02 ± 0.05, 0.02 ± 0.04, 0.00 ± 0.04 and 0.03 ± 0.05 for DG_{3-6}, KR_{3-6}, GE_{3-6} and GR_{3-6}; and 0.22 ± 0.10, 0.14 ± 0.09, 0.11 ± 0.09 and 0.12 ± 0.09 for DG_{6-12}, KR_{6-12}, GE_{6-12} and GR_{6-12}. Estimates of the additive genetic coefficients of variation (CV_A) were used as a measurement of genetic variability and ranged between 0.78% (GE_{3-6}) and 27.13% (DG_{6-12}). Genetic correlations among the traits ranged from -0.56 (DG_{3-6} and GE_{6-12}) to 0.99 (KR_{3-6}-GR_{3-6}, GE_{3-6}-GR_{3-6}, GE_{6-12}-GR_{6-12}) and phenotypic correlation ranged from -0.61 (GE_{6-12}-DG_{3-6}) to 0.99 (GR_{3-6}-KR_{3-6}, GR_{3-6}-GE_{3-6}, GR_{6-12}-GE_{6-12}. Traits measured during the pre-weaning growth period had negative and weak genetic correlations with traits measured during the post-weaning growth period and ranged from -0.31 (DG_{0-3}-GE_{6-12}) to 0.20 (DG_{0-3}-DG_{3-6}). The importance of efficiency-related traits will increase significantly and will attract much more attention in sheep production in the central highland of Ethiopia. Including DG_{0-3} in the selection index is recommended to improve efficiency of the ongoing Dorper breeding program.

Keywords: *Efficiency of growth, Dorper, Genetic correlation, Heritability, Relative growth rate*

INTRODUCTION

The Dorper nucleus flock was established at Debre Birhan Agricultural Research Center (DBARC) in 2011 through the purchase of 16 rams and 100 ewes from the Republic of South Africa to be used as an improver breed for the crossbreeding program. The research on Dorper based breed improvement programmes was focused on the development of the purebred Dorper sheep through selective breeding, development of synthetic breed from Dorper-local sheep crossing, production of 50% crossbred rams, and utilization of the crossbred ram in village-based crossbreeding program. The flock showed good growth rate, mothering ability and adaptability under semi-intensive production system. In light of these, the breed is one of the most preferred breed for the genetic improvement of local breeds through crossbreeding programs (Besufkad *et al.*, 2021).

Rapid population growth and urbanization in the central highland of Ethiopia have caused a shift of grazing land into arable land. Thus, feed cost comprises most of the production costs in sheep production in the central highland of Ethiopia. Therefore, improving efficiency of meat production through reducing the cost of mutton production is crucial to increase the efficiency of genetic improvement program (Ghafouri-Kesbi & Gholizadeh, 2017). However, the ongoing purebred Dorper sheep breeding program is practiced through selective breeding based on the estimated breeding value (EBV) of six months weight. Therefore, besides improving growth traits, focusing on the feed utilization efficiency of the breed is also vital for efficient and sustaining the breeding program. Since much of the efforts and reports were focused on growth and reproductive traits, evaluating efficiency-related traits allows to design and implement efficient breeding program. Information is hardly available on the genetic parameter for efficiency-related traits in Dorper sheep under Ethiopian condition. Therefore, this study was conducted to evaluate the on-ongoing Dorper breeding program and generate information to optimize the breeding program by evaluating the genetic parameters for growth rate and efficiency-related traits of Dorper sheep breed.

MATERIALS AND METHODS

Data and breeding flock management

Data used in the present study were obtained from 2012 to 2021 from the breeding flock of pure Dorper sheep maintained at Debre Birhan Agricultural Research Center, Amhara region, Ethiopia. The research center is located 120 km North-east of Addis Ababa at an altitude of 2,765 m above sea level and at a latitude of 09°36′23″N and longitude of 39°39′10″E. The average rainfall is 923 mm per annum. The rainfall distribution is bimodal, where the main rainy season is from June to September and an unreliable short rainy season is expected from February to April. The average annual minimum and maximum temperature are 6.59^{o}C and 19.87^{o}C, respectively and frost is common from October to January. During dry and short rainy seasons, animal were grazed on natural pasture daily for 6 to 7 h and penned at night. But, during main rainy season (from July to September) all breeding flocks were kept indoor day and night to prevent from fasciolosis infestation and fed dry hay as a basal diet without supplementation of vitamins and mineral premix since 2014. However, since 2019, the animals were allowed to fed green forage during main rainy season with a cut and cray feeding system. The experimental animal were supplemented with 300 to 400 g/head/day mixed concentrate depending up on status, age category, and availability of grazing feed. As a routine flock health management practice of the research center, the experimental animals were drenched against internal parasites and were vaccinated against common viral disease of the area.

Controlled mating was practiced and one selected sire was allowed to mate with 20 to 25 ewes in a single-sire mating system and mating was lasted on average for 60 days. Breeding rams were selected based on estimated breeding values (EBV) at six months weight and their physical conformation of the animals with the aim of improving growth and carcass yield. Intensive selection was focused on the male side. Ewes were first joined to ram depending on their weight and age at first mating i.e. 12 months of age. Since 2020, MateSel software developed by

Kinghorn, (2010) has been used to make the mating group in order to control inbreeding across generations. The dataset contained the animal ID, animal's parents, date of birth, sex of lamb, type of birth, color of lamb, and records of body weight at birth, 3, 6 and 12 months of age. Lambs were weaned at 90 days of age.

Data analyses

Traits considered in the current study were birth weight (WT0), weaning weight (WT3), six months weight (WT6), yearling weight (WT12), daily gain from birth to weaning (DG_{0-3}), daily gain from weaning to six months (DG_{3-6}), daily gain from six months to yearling (DG_{6-12}) and corresponding kleiber ratios (KR_{0-3}, KR_{3-6}, KR_{6-12}), efficiency of growth (GE_{0-3}, GE_{3-6}, GE_{6-12}) and relative growth rate (RG_{0-3}, RG_{3-6}, RG_{6-12}). Birth weight was taken within 24 h of the birth of lamb. Weaning, six month and yearling weights were taken by synchronized lambing occurred within 5 days interval from the actual weighted dates and adjusted to the exact days of 90, 180 and 365 respectively. In meat sheep, daily gain is an important component of market lamb production and affects the economic success of producing slaughter lambs (Eskandarinasab *et al.*, 2010).

Daily gain was calculated as DG_{0-3} = ((WT3-WT0)/90) X 1000, DG_{3-6} = ((WT6-WT3)/90) X 1000 and DG_{6-12} = ((WT12-WT6)/180) X 1000. The Kleiber ratio has been proposed as an efficient criterion for feed efficiency under low-input range conditions which provides a good indication of how economically an animal grows (K. Mohammadi *et al.*, 2011). Kleiber ratio is useful to identify animals with high efficiency of growth relative to body weight. Animals with higher kleiber ratio require lower maintenance energy. Kleiber ratio was computed as $KR_{0-3} = ADG_{0-3}/WT3^{0.75}$, $KR_{3-6} = ADG_{3-6}/WT6^{0.75}$ and $KR_{6-12} = ADG_{6-12}/WT12^{0.75}$, accordingly to Kleiber (1947). Efficiency of growth was calculated as GE_{0-3} = ((WT3-WT0)/WT0) X 100, GE_{3-6} = ((WT6-WT3)/WT3) X 100 and GE_{6-12} = ((WT12-WT6)/WT6) X 100. Relative growth rate was computed as GE_{0-3} = (Log_e (WT3) - Log_e (WT0))/90) X 100, GE_{3-6} = (Log_e (WT6) - Log_e (WT3))/90) X 100 and GE_{6-12} = (Log_e (WT12) - Log_e (WT6))/180) X 100. Additive coefficient of variation (CVA) allow to have an insight into the genetic variability of traits as well as to compare precisely traits measured at different times or in different population (Ghafouri-Kesbi & Gholizadeh, 2017).

Additive coefficient of variance estimated as (CV_A) = $\frac{\sqrt{\sigma_a^2}}{\bar{x}} x100$ where σ^2_a is additive genetic variance and $\bar{x}$ is the sample mean.

Fixed effects for growth rate and efficiency-related traits were estimated using the GLM procedure of SAS 9.0 software. The fixed effects considered were sex of lambs in two classes (male and female), birth litter size in two classes (single and twin), parity of dam in six classes, year of lambing in 10 classes (2012–2021) and season of lambing in three classes (rainy, dry and short rainy season). Means were compared using Tukey-kramers test.

The model used for the analysis of growth rate and efficiency-related traits was

$$Y_{ijklm} = \mu + Yr_i + Bt_j + Bs_k + P_l + S_m + e_{ijklm}$$

Where Y_{ijklm} is an observation; μ is overall mean; Yr_i is fixed effect of year of birth; Bt_j is fixed effect of birth type; Bs_k is fixed effect of birth season; P_l is fixed effect of parity; S_m is fixed effect of sex of lamb and e_{ijklm} is residual error.

(Co)variance components and genetic parameters were estimated using restricted maximum likelihood (REML) method fitting univariate animal model using WOMBAT software (Meyer, 2012). Multivariate analysis was applied to estimate genetic and phenotypic correlations. By excluding or including permanent environmental or maternal genetics effects, the following six Univariate animal models were fitted for each trait.

Model (1) $y = X\beta + Za\alpha + e$

Model (2) $y = X\beta + Za\alpha + Zpepe + e$

Model (3) $y = X\beta + Za\alpha + Zmm + e$ Cov (α, m) = 0

Model (4) $y = X\beta + Za\alpha + Zmm + e$ Cov (α, m) ≠ 0

Model (5) $y = X\beta + Za\alpha + Zmm + Zpepe + e$ Cov (α, m) = 0

Model (6) $y = X\beta + Za\alpha + Zmm + Zpepe + e$ Cov (α, m) ≠ 0

Where y is a vector of observations on the considered traits; β, α, m, pe and e are vectors of significant fixed effects, direct additive genetic effects, maternal genetic effects, permanent environment effects and the residual effects, respectively. Whereas **X**, $\mathbf{Z}_a$, $\mathbf{Z}_m$ and $\mathbf{Z}_{pe}$ are corresponding incidence matrices relating the fixed effect, direct additive genetic effects, maternal additive genetic effects and permanent environmental effects of the dam. Total heritability (h^2_t) was estimated using the formula $\sigma^2_a + 0.5\sigma^2_m + 1.5\sigma_{am}/\sigma^2_p$ (Willham, 1972). Where σ^2_a is additive variance, σ^2_m is maternal variance, σ_{am} is covariance between direct and maternal additive genetic effect and σ^2_p is total phenotypic variance. Direct heritability (h^2_a), maternal heritability (h^2_m) and relative permanent maternal environmental effects (c^2) were calculated as ratios of estimates of σ^2_a, σ^2_m and σ^2_c respectively, to the phenotypic variance σ^2_p. Likelihood ratio tests were conducted, to choose the best model and to test the significance of random effects for each trait (Meyer, 2006).

Table 1. Characteristics of data structure

Parameters	Traits											
	DG_{0-3}	DG_{3-6}	DG_{6-12}	KR_{0-3}	KR_{3-6}	KR_{6-12}	GE_{0-3}	GE_{3-6}	GE_{6-12}	GR_{0-3}	GR_{3-6}	GR_{6-12}
No. of records	732	560	452	732	560	452	732	560	452	732	560	452
No. of animals	855	681	568	855	681	568	855	681	568	855	681	568
Sire[a]	34	28	27	34	28	27	34	28	27	34	28	27
Sire[b]	22	17	16	22	17	16	22	17	16	22	17	16
NPR/Sire	21.53	20	16.74	21.53	20	16.74	21.53	20	16.74	21.53	20	16.74
Dam[a]	239	200	177	239	200	177	239	200	177	239	200	177
Dam[b]	149	115	104	149	115	104	149	115	104	149	115	104
NPR/Dam	4.91	4.87	4.35	4.91	4.87	4.35	4.91	4.87	4.35	4.91	4.87	4.35
Mean[b]	133.48	60.88	49.49	16.55	5.49	3.60	334.80	33.73	43.82	1.58	0.30	0.19
S.D.	42.46	47.41	31.76	2.43	3.81	2.14	140.48	25.92	30.96	0.33	0.21	0.12
CV (%)	28.52	69.38	56.70	13.13	62.20	53.40	33.82	69.32	62.27	17.62	63.74	56.40

[a] Number of sires and dams with progeny, [b] Number of sires and dams with progeny and record, NPR: Average number of progeny with records, S.D.: standard deviations, CV.: Coefficient of variation, DG_{0-3}: daily gain from birth to weaning, DG_{3-6}: daily gain from weaning to six months, DG_{6-12}: daily gain from six months to yearling, KR_{0-3}: kleiber ratio from birth to weaning, KR_{3-6}: kleiber ratio from weaning to six months, KR_{6-12}: kleiber ratio from six months to yearling, GE_{0-3}: growth efficiency from birth to weaning, GE_{3-6}: growth efficiency from weaning to six months, GE_{6-12}: growth efficiency from six months to yearling, GR_{0-3}: relative growth rate from birth to weaning, GR_{3-6}: relative growth rate from weaning to six months, GR_{6-12}: relative growth rate from six months to yearling

RESULT AND DISCUSSION

Environmental effects

Phenotypic means, standard deviation (SD), coefficient of variation (CV), and pedigree structure of studied traits are presented in Table 1. Number of observations decreased with increasing age from birth (n=997) to yearling (n=452) because of culling related to death and sale of animals. The coefficient of variation for the studied traits was ranged from 13.13% for KR_{0-3} to 69.38% for DG_{3-6}. (Ehsaninia, 2021; Eskandarinasab *et al.,* 2010; Ghafouri-Kesbi and Gholizadeh, 2017); Gowane *et al.*, (2011) reported smaller values of CV for studied traits in different breed of sheep than the values in the current study. Traits measured during the pre-weaning period had smallest phenotypic coefficient of variation (CV) and higher phenotypic performance compared to traits measured during the post-weaning growth periods in all studied traits. During the pre-weaning period lambs are less affected by environmental stress owing to maternal support and physiologically in higher growth period. Our present result is in agreement with the report of (Eskandarinasab *et al.,* 2010; Ghafouri-Kesbi *et al.,* 2011; Ghafouri-Kesbi & Gholizadeh, 2017; Mohammadi *et al.,* 2012). After weaning as the lambs are exposed to environmental factors, which brings a delayed growth of lambs. Moreover, traits measured from weaning to six months of age had higher phenotypic coefficient of variation (CV) compared to other growth phases.

The least squares means and standard errors for the traits studied are presented in Tables 2 and 3. All the traits under study were significantly ($p<0.001$) influenced by lamb’s birth year. Difference in animal management, climatic and environmental conditions and disease incidence in different years are the probable reasons for variations in growth performance of lambs across birth years (Bakhshalizadeh *et al.,* 2016). The effect of birth year in the current study in all studied traits is in line with previous reports in different sheep breeds (Baneh & Haferzian, 2009; Ghafouri-Kesbi *et al.,* 2011; Ghafouri-Kesbi & Gholizadeh, 2017). The current results revealed that phenotypic performance for all studied traits except traits measured from six months to yearling showed a declined trend over years (Figures 1 to 4). This was happened due to the change of animal management with high occurrence of animal mortality due to fasciolosis outbreak in the year 2014, all animals were kept indoor during day and night in the main rainy season (July to September) and fed only dry hay as a basal diet and supplemented with 200g head/day mixed concentrate without supplementing vitamins & mineral premix.

Table 2. Least-squares means and standard errors of daily gain and kleiber ratio in Dorper sheep.

Parameters	DG_{0-3}	DG_{3-6}	DG_{6-12}	KR_{0-3}	KR_{3-6}	KR_{6-12}
Birth year	***	***	***	***	***	***
Sex	ns	ns	***	ns	ns	ns
Male	148.32±8.86	51.95±10.29	55.67±7.05	17.58±0.51	4.81±0.83	4.03±0.48
Female	147.18±8.70	46.49±10.04	48.54±6.79	17.71±0.50	4.48±0.81	3.68±0.47
BLS	***	ns	ns	ns	ns	ns
Single	144.60±4.12	58.23±5.16	52.19±3.58	17.13±0.23	5.09±0.42	3.60±0.24
Twin	127.12±5.96	53.89±7.51	55.63±5.39	16.79±0.34	5.43±0.61	4.12±0.35
Parity	***	ns	**	**	ns	**
1	131.38±9.00^{b}	42.53±10.39	54.51±7.10^{ab}	17.05±0.51^{b}	4.59±0.84	4.29±0.49^{a}
2	149.44±9.37^{a}	43.52±11.04	61.18±7.53^{a}	17.84±0.53^{a}	4.22±0.89	4.45±0.52^{a}
3	155.59±9.37^{a}	53.42±10.96	51.28±7.50^{ab}	17.92±0.54^{a}	4.64±0.89	3.79±0.51^{ab}
4	149.40±8.83^{a}	47.65±10.23	45.23+7.00^{b}	17.79±0.50^{ab}	4.31±0.83	3.36±0.48^{b}
_5	149.81±9.75^{a}	45.71±11.57	48.69±8.22^{ab}	17.76±0.56^{ab}	4.32±0.93	3.51±0.56^{ab}
≥6	150.87±10.60^{ab}	62.49±12.83	51.73±9.35^{ab}	17.49±0.61^{ab}	5.81±1.04	3.74±0.64^{ab}
Birth season	**	ns	ns	***	ns	ns
Main rainy	149.15±9.59^{a}	43.32±11.14	56.53±7.77	17.70±0.55^{a}	4.14±0.90	4.16+0.53^{a}
Dry	135.35±9.09^{b}	44.87±10.40	51.95±7.15	16.81±0.52^{b}	4.52±0.84	3.93+0.49^{a}
Short rainy	158.75±9.98^{a}	59.47±12.32	47.82±8.59	18.42±0.77^{a}	5.28±1.00	3.46±0.59^{b}

^{ab}On the same column, numbers bearing the same superscript are not statistically different at p =0.05. ns: not significant. ***P<0.001; ** P<0.01 and * P<0.05; BLS: birth litter size. For trait abbreviations see footnote of Table 1.

In this strategy the available feed may not be enough to cover the nutritional requirements of growing lambs and may expose the animals to vitamin E deficiency. According to Ramírez-Bribiesca *et al.*, (2005); Ziaei, (2015) deficiency of either or both selenium and vitamin E can reduce growth, reproductive performance and immune response of the animals. Besufkad *et al.*, (2021) reported that survival rate of Dorper, Menz and Dorper x Menz 50% showed a declined trend over years at Debre Birhan Agricultural Research Center (DBARC) since 2014.

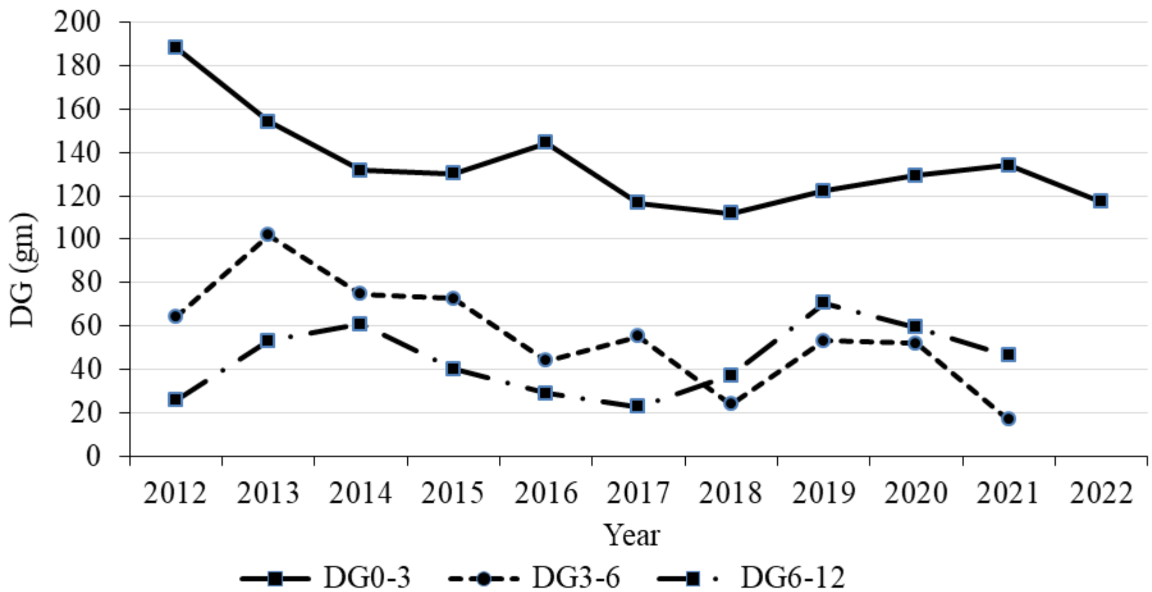

Figure 1. Phenotypic daily gain trend by year of birth.

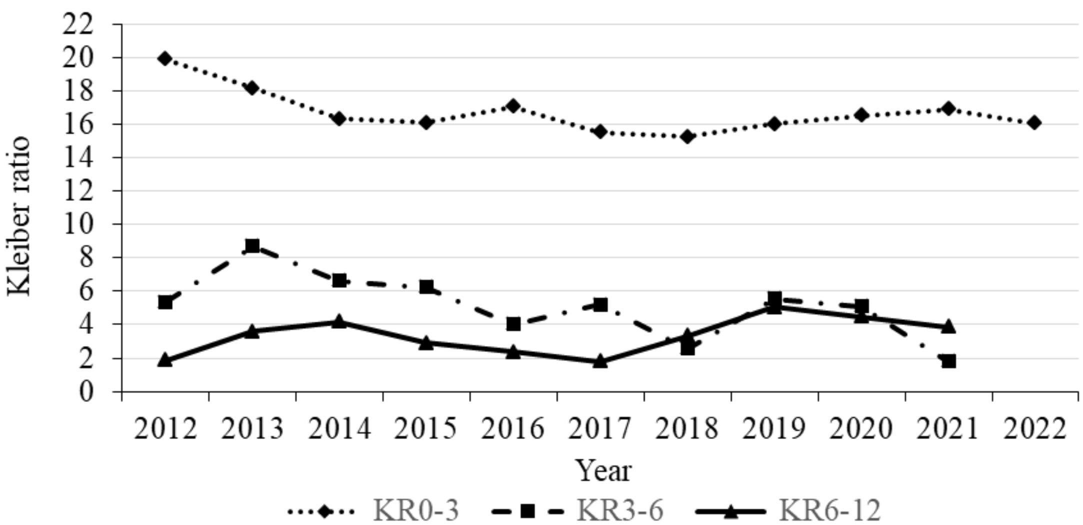

Figure 2. Phenotypic kleiber ratio trend by year of birth

The present finding showed that sex of lambs had no significant effects in all studied traits except in DG_{6-12}. However, the current results revealed that litter size at birth had significant effect on DG_{0-3}, GE_{6-12} and GR_{6-12}. Contrary to the present findings, the significant effect of sex of lambs and litter size at birth in studied traits were reported by Eskandarinasab *et al.,* (2010) for Iranian fat-tailed Afshari sheep and Ghafouri-Kesbi & Gholizadeh, (2017) for Baluchi sheep. Parity has a significant effects ($P<0.01$) in DG_{0-3}, DG_{6-12}, KR_{0-3}, KR_{6-12}, GE_{6-12} and GR_{6-12} but not in other studied traits. Significant effect of parity on those traits can be explained by difference in uterine capacity, milk production, and mothering ability of ewes at different parities (Dass *et al.,* 2004; Ghafouri-Kesbi & Gholizadeh, 2017). Contrary to the present findings Eskandarinasab *et al.,* (2010); Ghafouri-Kesbi & Gholizadeh, (2017); Kamjoo *et al.,* (2014); Kholghi *et al.,* (2014) reported marked effect of parity on the studied traits. Generally, our results showed that the effect of parity on the studied trait was not much important. Lamb's birth season had significant effect in traits measured during pre-weaning growth periods. Lambs born during dry season had lower ($p<0.001$) DG_{0-3}, KR_{0-3}, GE_{0-3} and GR_{0-3} than lambs born during main and short rainy seasons. Lambs born in dry seasons had inferior growth performance. The amount and quality of feed is not enough to cover the nutritional requirement of growing lambs born during dry season. Developing appropriate feeding management option may help to reduce impact of season on productive and reproductive performance of the sheep evaluated in the current study.

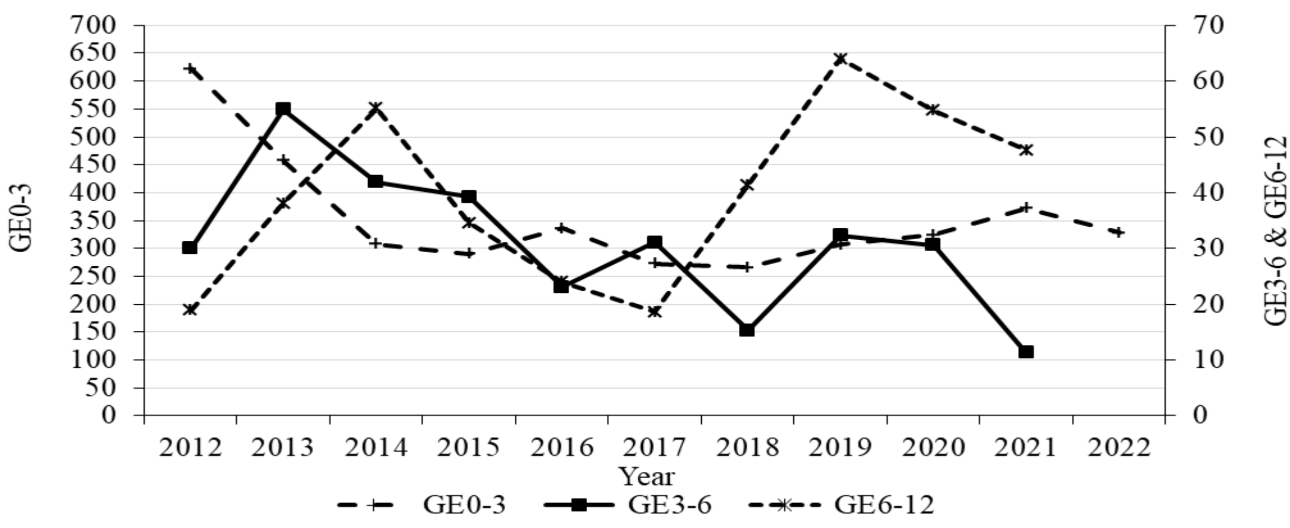

Figure 3. Phenotypic growth efficiency trend by year of birth

Table 3. Least-squares means and SE of growth efficiency and relative growth rate in dorpers.

Parameters	GE_{0-3}	GE_{3-6}	GE_{6-12}	GR_{0-3}	GR_{3-6}	GR_{6-12}
Birth year	***	***	***	***	***	***
Sex	ns	ns	ns	ns	ns	ns
Male	403.30±26.34	27.63±5.70	48.38±6.86	1.74±0.06	0.26±0.05	0.21±0.03
Female	411.60±25.89	25.15±5.56	44.43±6.61	1.78±0.06	0.24±0.05	0.19±0.03
BLS	ns	ns	*	ns	ns	*
Single	356.34±12.25	29.24±2.86	43.41±3.48	1.64±0.03	0.27±0.02	0.19±0.01
Twin	386.82±17.72	34.49±4.16	54.41±5.24	1.71±0.04	0.31±0.03	0.24±0.02
Parity	ns	ns	**	ns	ns	**
1	400.09±26.78	28.63±5.75	54.55±6.91^{a}	1.74±0.07	0.26±0.05	0.23±0.03^{a}
2	424.21±27.87	23.84±6.11	53.90±7.32^{a}	1.80±0.07	0.23±0.05	0.23±0.03^{a}
3	415.55±27.88	26.18±6.07	44.98±7.29^{ab}	1.78±0.07	0.24±0.05	0.19±0.03^{ab}
4	412.11±26.28	24.05±5.66	39.80±6.80^{b}	1.78±0.07	0.23±0.05	0.17±0.03^{b}
5	408.15±29.30	23.83±6.40	38.76±7.99^{ab}	1.77±0.07	0.23±0.05	0.18±0.03^{ab}
≥6	384.58±31.53	31.83±7.10	45.42±9.09^{ab}	1.70±0.08	0.30±0.06	0.20±0.04^{ab}
Birth season	***	ns	ns	***	ns	ns
Main rainy	400.35±28.53^{b}	23.25±6.17	50.05±7.55	1.76±0.07^{a}	0.22±0.05	0.22+0.03
Dry	356.98±27.02^{c}	26.18±5.74	49.16±6.95	1.64±0.07^{b}	0.25±0.05	0.21+0.03
Short rainy	465.02±29.69^{a}	29.75±6.82	40.00±8.35	1.89±0.07^{a}	0.28±0.06	0.18±0.04

a,b On the same column, numbers bearing the same superscript are not statistically different at p =0.05. ns: not significant. ***P<0.001; ** P<0.01 and * P<0.05; BLS: birth litter size. For trait abbreviations see footnote of Table 1

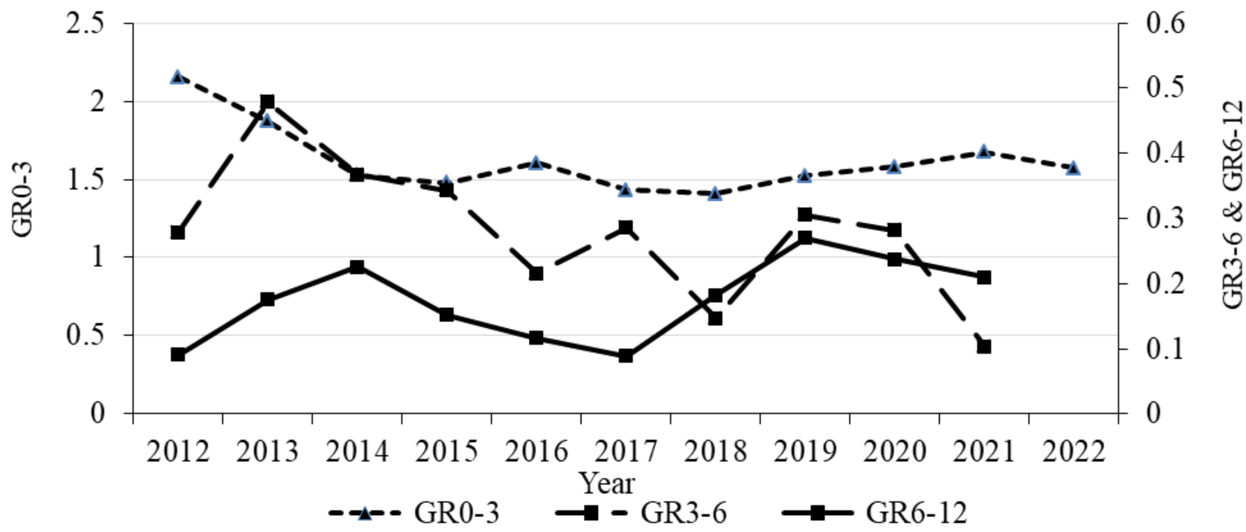

Figure 4. Phenotypic relative growth rate trend by year of birth

Genetic parameters estimates

The estimates of (co)variance components and corresponding genetic parameters obtained from univariate analyses based on most appropriate models are presented in Table 4. The most appropriate model for the studied traits was model included only direct additive genetic effects (Model 1) except for pre-weaning efficiency of growth and relative growth rate. Fitting permanent and maternal genetic effects in the model had no significant effects in log-likelihood values compared to Model 1, which indicates trivial effect of permanent and maternal genetic effect on those traits. The most suitable model for pre-weaning efficiency of growth and relative growth rates was a model included maternal genetic effects (Model 4). Estimates of direct heritability and additive coefficient of variance for DG_{0-3}, KR_{0-3}, GE_{0-3}, GR_{0-3} were 0.10$\pm$0.06, 0.16$\pm$0.07, 0.26$\pm$0.13, 0.26$\pm$0.13 and 8.9%, 5.25%, 17.51%, 8.95%, respectively. The estimates of maternal heritability (h^2_m) for GE_{0-3} and GR_{0-3} were 0.21$\pm$0.10 and 0.17$\pm$0.09, respectively. Direct heritability estimates for traits measured during pre-weaning growth period were higher than traits measured during post-weaning growth period except for daily gain. This might reflect the effect of management practice during post-weaning growth period on the animal performance. Direct heritability estimates, maternal heritability and CV_A for the pre-weaning growth period recorded in the current study were higher than values reported by Ghafouri-Kesbi & Gholizadeh, (2017) in Baluchi sheep and K. Mohammadi *et al.*, (2015) in Lori sheep.

Based on the most suitable model (Model 1) for DG_{3-6}, KR_{3-6}, GE_{3-6} and GR_{3-6}, the estimates of direct heritability and CV_A were 0.02±0.05, 0.02±0.04, 0.00±0.04, 0.03±0.05 and 9.70%, 8.06%, 0.78%, 10.54%, respectively. Lower direct heritability estimates were recorded from weaning to six months growth period compared to the other growth periods in all studied traits. Lower direct heritability estimates of traits measured from weaning to six months of age might signify the effects of management practice or variation in environmental and nutritional conditions of the grazing pastures on the animal performance (Eskandarinasab *et al.*, 2010; H. Mohammadi *et al.*, 2013). As the center's routine practice, lambs were weaned in the beginning of December when grazing pasture is not enough to support the nutritional requirement of the growing lambs. Under this condition the lambs may not express their genetic potential for post-weaning performance. In line with the present finding low estimates of direct heritability for the studied traits were reported by Ghafouri-Kesbi & Gholizadeh, (2017) in Baluchi sheep and Eskandarinasab *et al.*, (2010) in Iranian fat-tailed Afshari sheep. The low direct heritability estimates in the studied traits indicate that genetic improvement on the traits is difficult. Direct heritability estimates and CV_A for DG_{6-12}, KR_{6-12}, GE_{6-12}, GR_{6-12} were 0.22±0.10, 0.14±0.09, 0.11±0.09, 0.12±0.09 and 27.13%, 19.95%, 21.02%, 16.64%, respectively. Ghafouri-Kesbi & Gholizadeh, (2017) reported lower direct heritability estimates compared to our findings.

Table 4. Estimate of variance components and heritability for efficiency related traits.

Traits	M	σ^2_a	σ^2_m	σ_{am}	σ^2_e	σ^2_P	h^2_a	h^2_m	r_{am}	h^2_t	CV_A	Log (L)
DG_{0-3}	1	140.99			1225.44	1366.43	0.10±0.06			0.10±0.06	8.90	-2943.832
DG_{3-6}	1	34.90			1743.58	1778.48	0.02±0.05			0.02±0.05	9.70	-2313.194
DG_{6-12}	1	180.22			631.03	811.25	0.22±0.10			0.22±0.10	27.13	-1675.037
KR_{0-3}	1	0.756			3.941	4.697	0.16+0.07			0.16±0.07	5.25	-936.220
KR_{3-6}	1	0.196			11.546	11.742	0.02±0.04			0.02±0.04	8.06	-971.078
KR_{6-12}	1	0.516			3.227	3.743	0.14±0.09			0.14±0.09	19.95	-531.132
GE_{0-3}	4	3436.02	2740.55	-2734.62	9793.19	13235.10	0.26±0.13	0.21±0.10	-0.89±0.14	0.05	17.51	-3733.30
GE_{3-6}	1	0.07			568.91	568.98	0.00±0.04			0.00	0.78	-1996.546
GE_{6-12}	1	84.82			666.43	751.25	0.11±0.09			0.11±0.09	21.02	-1664.183
GR_{0-3}	4	0.02	0.014	-0.013	0.059	0.08	0.26±0.13	0.17±0.09	-0.80±0.19	0.09	8.95	507.25
GR_{3-6}	1	0.001			0.037	0.038	0.03+0.05			0.03+0.05	10.54	568.421
GR_{6-12}	1	0.001			0.010	0.011	0.12+0.09			0.12+0.09	16.64	703.057

σ^2_P phenotypic variance; σ^2_a additive variance; σ^2_m maternal variance; σ^2_e error variance; h^2a direct heritability; h^2m maternal heritability; h^2t total heritability; r_{am} genetic correlation between direct and maternal additive heritability; σ_{am} .covariance between direct and maternal additive genetic effect; Log (L) log Likelihood. For trait abbreviations see footnote of Table 1

Correlation estimates

Genetic and phenotypic correlations among the studied traits are presented in Table 5. The genetic correlations from multivariate analyses between traits considered in this study ranged from low to high in magnitude (-0.54 to 0.99). Traits measured during the pre-weaning growth period had negative and weak genetic correlations with traits measured during the post-weaning growth period and ranged from 0.20 (DG_{0-3}-DG_{3-6}) to -0.31 (DG_{0-3}-GE_{6-12}). This implies that lambs with higher growth rate and efficiency-related traits in pre-weaning period have less efficient during the post-weaning period and vice versa. Moreover genetic and phenotypic correlations between pre-weaning and other post-weaning growth periods is deceased as the age advances overtime, which is in agreement with the finding of Eskandarinasab *et al.,* (2010) for Iranian fat-tailed Afshari sheep. The negative and weak genetic correlations between those traits may indicate that different genetic mechanisms are involved in expressing those traits at different growth periods (K. Mohammadi *et al.,* 2011, 2015). Furthermore, this negative genetic correlation could be a consequence of estimated negative values of post-weaning daily gain for some animals (approximately 6.5% of the animals had negative daily gain from weaning to six months of age). Eskandarinasab *et al.,* (2010) stated that daily gain during a period of restricted nutrient intake often negatively correlated both phenotypically and genetically with body weight and daily gain during a period of sufficient nutrient intake. Similar to the genetic correlation, phenotypic correlation between traits measured during pre-weaning growth period had negative and weak correlation with traits measured during post-weaning growth period and ranged from -0.43 (KR_{0-3}-GE_{6-12}) to 0.16 (DG_{0-3}-DG_{3-6}). In line with the present finding negative genetic correlation between traits measured during pre and post-weaning growth period were reported by Ghafouri-Kesbi & Gholizadeh, (2017) for Baluchi sheep. Lambs with poor early growth rate in pre-weaning period tended to have higher post-weaning growth than lambs in better pre-weaning conditions (Afolayan *et al.,* 2007). Genetic correlation between efficiency-related traits ranged from -0.51 (KR_{3-6}-GE_{6-12}) to 0.96 (KR_{3-6}-GE_{3-6}) which implies that not all efficiency traits can be improved simultaneously following selection and that at each time, selection should focus on the trait of higher importance.

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Table 5. Genetic (above diagonal) and Phenotypic (below diagonal) correlation

	Traits											
	DG0-3	DG3-6	DG6-12	KR0-3	KR3-6	KR6-12	GE0-3	GE3-6	GE6-12	GR0-3	GR3-6	GR6-12
DG0-3		0.20	0.03	0.94	0.01	-0.17	0.74	-0.10	-0.31	0.79	-0.09	-0.28
DG3-6	0.16		-0.34	0.14	0.95	-0.48	0.06	0.91	-0.56	0.07	0.92	-0.55
DG6-12	-0.12	-0.40		0.05	-0.31	0.95	0.02	-0.34	0.87	0.05	-0.32	0.90
KR0-3	0.94	0.16	-0.12		-0.01	-0.15	0.85	-0.12	-0.29	0.93	-0.11	-0.26
KR3-6	-0.04	0.95	-0.32	-0.02		-0.42	-0.01	0.96	-0.51	-0.03	0.99	-0.49
KR6-12	-0.30	-0.54	0.95	-0.30	-0.44		-0.11	-0.43	0.95	-0.11	-0.41	0.98
GE0-3	0.74	0.09	-0.09	0.84	-0.03	-0.21		-0.08	-0.22	0.97	-0.06	-0.19
GE3-6	-0.14	0.92	-0.35	-0.11	0.96	-0.45	-0.10		-0.49	-0.11	0.99	-0.48
GE6-12	-0.42	-0.61	0.85	-0.43	-0.52	0.94	-0.30	-0.49		-0.23	-0.48	0.99
GR0-3	0.80	0.12	-0.10	0.93	-0.02	-0.24	0.96	-0.09	-0.35		-0.09	-0.20
GR3-6	-0.14	0.92	-0.32	-0.11	0.99	-0.43	-0.09	0.99	-0.48	-0.09		-0.47
GR6-12	-0.40	-0.60	0.89	-0.40	-0.50	0.98	-0.28	-0.49	0.99	-0.32	-0.47	

CONCLUSION

Phenotypic performance for all studied traits except traits measured from six months to yearling showed a declined trend over years due to change of management practice following the incidence of disease outbreak in the farm. The genetic parameters estimated for Dorper sheep show that efficiency related traits have low to medium heritability estimates and possibility improving management helps a lot. The importance of efficiency-related traits will increase significantly and will attract much more attention in sheep production in the central highland of Ethiopia. Including efficiency-related traits in the selection index, make the breeding program more efficient and feasible. Including $DG_{0\text{-}3}$ in the selection index is recommended to improve efficiency of the ongoing Dorper breeding program.

ACKNOWLEDGEMENT

The Dorper sheep experiment was financially supported by Amhara Agricultural Research Institute (ARARI) and Ethiopian Institute of Agricultural Research (EIAR). We would like to acknowledge all livestock breeding and management staff specially Mr. Deribew Bekele and Mr. Alemayehu H/Mikael, who over the years have assisted in managing the experimental flock and in data collection.

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Selection response on growth and milk production performance of Abergelle goat managed under station condition in Wag-himra, Ethiopia

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ABSTRACT

A study was conducted at Aybera main animal breeding and feeding experimental site in Wag-himra administrative zone, Amhara regional state, Ethiopia. The objective of the study was to improve the performance of the most preferred (growth and milk production) traits of Abergelle goat breed through selective breeding while conserving the breed at station conditions. A total of 469 for body weight and 345 for milk yield records were used for performance evaluation. Experimental animals were managed semi-intensively where they were arranged into grazing lands during day time with daily concentrate feed supplementation. The selection of breeding bucks was conducted once in a year based on the indexed estimated breeding value of yearling weight and their respective dam milk yield performance. Top-ranked bucks selected from the flock were used as replacements at the nucleus while surplus bucks were disseminated to nearby community-based breeding program (CBBP) villages. The general linear model procedure of SAS software (version 9.0) was employed to evaluate the selective breeding progress of the station breeding program based on body weight and milk yield during 2016-2020. The overall least square means of (±SE) birth, three-month, six-month, 9 month and yearling weights were 1.99±0.02, 6.54±0.08, 8.55±0.09, 11.14±0.12, and 13.74±0.14 kg, respectively. The overall least square means (±SE) of lactation milk yield, average daily milk yield and lactation length were 31.28±1.04 kg, 0.39±0.09 kg and 8.45±0.25 weeks, respectively. With four consecutive election years, birth weight has increased from 1.23±0.05 to 2.16±0.03 kg, three-month weight from 5.53±0.21 to 7.70±0.15kg, and six-month weight from 7.67±0.22 to 8.66±0.10kg, while nine-month and yearling weights did not improve significantly. Wet season birth was important for increasing milk production and lactation length. The growth and milk production performances of progenies produced at the station were low in comparison to on-farm-produced progenies under CBBP conditions at all growth stages. Therefore, it is recommended that critical economic

evaluation of station breeding programs should be undertaken in terms of the cost incurred to maintain nucleus flocks and the return it provides for genetic improvement of the breed as it was low performed compared to CBBP conditions.

Keywords: *Abergelle goat; CBBP; Selection response; Wag-himra*

INTRODUCTION

Goats are amongst the commonest farm animal species, which sustain the livelihoods of billions of smallholder farmers, pastoralists, and agro-pastoralists in the world. They fulfill various functions such as generating cash income, serving as household security, accumulating capital, and fulfilling cultural obligations (Dhaba *et al*., 2012; Girum *et al.*, 2012; Solomon *et al*., 2014). In developing countries, goats make a very valuable contribution, especially to the poor in rural areas.

According to FAO (FAOSTAT, 2020), the Ethiopian goat population increased by 56.6% in the last decade with a total number of 52.46 million heads of goat in 2020 making the country the second most goat-populous location in Africa next to Nigeria. In 2020, Ethiopia's goat population accounts for 4.7% and 10.7% of the World and African goat populations, respectively. Though the population density of goats in mid- and low-altitude areas is high, they are produced across the country from the arid lowlands to the coolest highland areas. The higher number of live animals confirms the importance of goats as a potential source of meat, milk, skin, fiber, and other socio-cultural aspects of the rural people. In addition, goats have a higher multiplication rate, lower capital investment, greater job creation opportunities for jobless youths and unique adaptation to harsh environments (Banerjee, *et al,* 1995, Alade *et al*., 2010; Solomon *et al*., 2014). They are also important protein sources in the diets of the poor and help to provide extra income and support. Goats provide 30% of all domestic meat consumption and generate cash income from exports of meat, mainly as live animals and skins (Tadess Bekele, 2004). More specifically, in the lowland areas of Wag-himra, around 70% of the household liquid cash income is generated from the livestock sector especially from goats.

However, in the country goat production and productivity is characterized by minimum profit resulting from under-exploitation of indigenous genetic resource, poor or seasonal fluctuations of feed resources, periodic droughts, extensive dry seasons and severe feed shortages resulting in under nourishment and low productivity among the animals with an average carcass weight produced from yearling goat in Ethiopia is only 8.5 kg (Mlynek, 2000). Different authors (Abegaz *et al*., 2010; Gizaw *et al*., 2010; Abegaz *et al*., 2014; Ahmed, 2017) reviewed and documented that the present production levels of indigenous goats with existing breeding strategies and practices are far below their potential. This resulted in the productivity per unit of animal and the contribution of this sector to the livelihoods of farmers in rural areas and the national economy being relatively low due to various technical and non-technical constraints.

Aberegelle goat breed is among the rift valley families of goats in the country, widely distributed in the low land areas of Wag-himra, Raya areas in North Wollo and around East Bellessa in Gondar. In these areas goats are kept for multifunctional roles but mainly to generate cash income, meat and milk consumption (Abegaz *et al*., 2013). The breed has smaller birth, weaning and post weaning weight in comparison to other breeds in the country. But the breed is reported for better milk production performance when compared to like Woyto-guji breed and others in the same family. The breed also characterized by its, long kidding intervals, delicious meat taste and high resistance to drought and harsh environment. Farmers in low land of wag- himra engaged the breed for the purpose of meat and milk production. The breed population size in 2017 was reported 432,840 only in wag-himra zone without considering the whole breeding tracts of the breed (CSA), 2017).

The livestock breed of all species in the country is produced without clear demarcations of breeding and reproduction resulted in population admixture. This admixture adversely affected the performance of the breeds not expressing their optimum potential in a given environment. To overcome this problem, maintenance and conservation of pure breeding stock at station condition is the first and most important component. It will help to maintain elite nucleus flocks of the desired breed and improving its productivity through selection. In addition, the nucleus will serve as an improved sire source for the nearby community breeding villages and individual smallholders. So, the study was required to establish nucleus flock for pure Abergelle goat. The work was therefore done with objectives of to evaluate the performance of growth and milk production traits of Abergelle goat breed at station condition and to disseminate improved bucks to nearby CBBP villages which serve as source of improved breeding population.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Sekota Zuria district at Aybra main breeding and feeding trial site, which is located at 12$^{0.}$ 41´ 11.92´´N and 39^{0}.00´58´´E in Wag- himra administration zone of the Amhara region. The study area was 17 Km far from Sekota town, 447km from the Bahir Dar and 737km from Addis Ababa, capital city of Ethiopia. The district has rugged topography characterized by mountains, steep escarpments and deeply incised valleys. The farming practice of the area is mixed crop-livestock production. The annual rain fall of the area was 650 mm with very short and an erratic distribution. The maximum and minimum temperature of the area is 26.6^{o}C and 31.6^{o}C respectively with an altitude of 1933 m.a.s.l. The main rainy season in the area starts from late June and to mid-July and ends during late August.

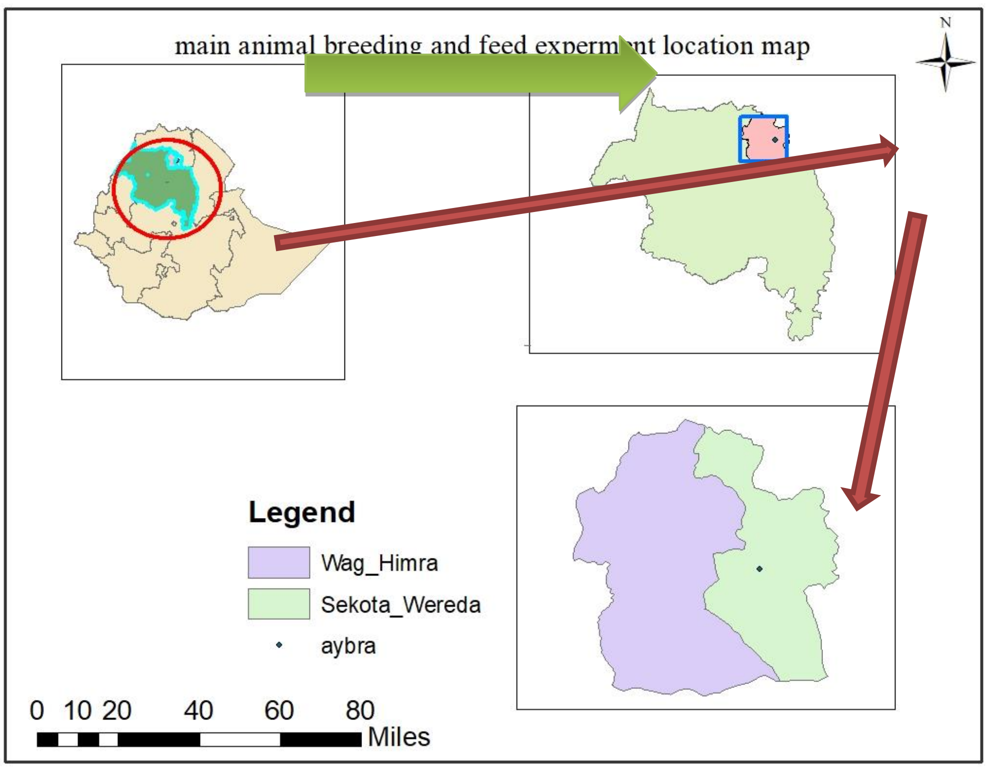

Figure 2. Map of the study area

Animal management and data recording

Founder doe’s and sires of the station were bought from the local markets of the breeding tracts of pure Abergelle goat breed with the assumption of zero breed dilution in late 2015. These animals were purposively selected for earlier parities (1-3) by farmers recall method in addition to information of being not pregnant at the time of buying. During the beginning of the nucleus breeding program, a total of 100 does and 5 bucks (1:20 mating ratio) were arranged in to five breeding groups. The bucks served in one breeding group were purposively rotated to other breeding groups in the next mating to control inbreeding. After rotated to all the breeding groups, bucks were either distributed to the established nearby CBBP village or culled out from the flock based on its performance. The nucleus was totally linked with one CBBP village where continuous distribution of improved bucks was made every year.

Adult animals were managed semi-intensively where they arranged in to a grazing land during the day time and supplemented with 200g commercial concentrate and cow pea hay in the morning and evening during feed shortage season while in feed available season animals are totally managed at grazing lands. Kids were suckled their dams up to three months of age and then separated from their mother to join the younger stock group. All groups of animals received programed vaccinations and treatment against major diseases in the area. Data was recorded by an enumerator who trained for data collection and flock follow-up. Herding system was strict to control inbreeding and season of mating.

Description of the nucleus breeding program and its structure

The breeding program was implemented based on the identified breeding objective traits of the breed in the area. Growth and milk production performance improvement were the target breeding objective traits of Abergelle goat breed identified by (Solomon Abegaz, 2014). Growth performance was evaluated based on weight at different age group selection criteria's (birth weight up to yearling weight) while milk yield was evaluated based on total milk yield, average daily milk yield and lactation length criteria's. Kids born without known sire and dam especially during the beginning year (2015) were removed from the performance evaluation during data analysis.

Selection of bucks was conducted at yearling age by combining individual's yearling weight and their respective dam milk production performance. The selection index was constructed based on adjusted deviation of selected means from population mean with 60% share for growth performance and 40% percent for milk production performance based on a quick survey data from CBBP villages. The adjusted growth and milk production performances deviation then multiplied by heritability values of 0.3 and 0.25 from meta-analysis study by Jembere *et al*. (2015), respectively. Bucks were then selected by their indexed estimated breeding values from growth and milk production performances by partitioning for various fixed effects. EBV trend was unable to present here due to shorter generation of the program, very few and non-consistent selection candidates over years and very small produced progenies that were not sufficient for comparisons. Birth type, season, year and parity were identified sources of variation for both growth and milk production performance traits during the course of selection. The selected sires in the nucleus are either used for replacements or directly distributed to CBBP village.

Data analysis

Productive performances (continuous type) data for growth and milk production were analyzed using the GLM procedures of SAS software version 9.0. The least-squares means of traits was done using the Tukey HSD test for statistically significant effects at 0.05 alpha level based on the GLM analysis result. Indexed estimated breeding value was performed using Microsoft excel program. Birth type, sex, season of birth, parity and year were fitted as fixed factors for body weight variables whereas season of birth, parity and year were fitted as fixed factors for milk production traits. The association of body weight of kids at different age was evaluated using Pearson correlation analysis. Two separate models were utilized for growth and milk production performance evaluation.

For growth performance;

$Y_{ijklm} = \mu + B_i + S_j + Z_k + P_l + Y_m + e_{ijklm}$

Where: Y_{ijklm} = the observed growth performance of goat by weight mainly at birth weight, weaning weight to yearling weight; μ = overall mean; B_i = is the effect of i^{th} birth type (single and twin); S_j = is the effect of j^{th} sex (male and female); Z_k = is the effect of k^{th} birth season (wet from late June to end of December and dry from January to first June); P_l = is the effect of l^{th} parity (1 to 6); Y_m = is the effect of the m^{th} year (2015-2020); e_{ijklm} = is random residual error

For milk production performance traits;

$Y_{ijk} = \mu + S_i + P_j + Y_k + e_{ijkl}$

Where: Y_{ijkl} is the observed milk yield; μ = overall mean; S_i = is the effect of i^{th} birth season (wet and dry); P_j= is the effect of j^{th} parity (1-6); Y_k= is the effect of k^{th} year (2016-2020); e_{ijkl} = is random residual error

RESULT AND DISCUSSION

Selection progress on growth performance of goats

The overall least- square mean of birth, three-month, six-month, nine-month, and yearling weights of kid's were 1.99±0.02, 6.54±0.08, 8.55±0.09, 11.14±0.12, and 13.74±0.14 kg, respectively kg as presented in Table 1. The birth weight result found in this study was inline with the values reported for the same breed by Deribe and Taye, (2013) in farmer management practice, 1.91kg and Amare, et al., (2020) in CBBP conditions of Saziba village, 2.0 kg. Birth weight had lower association with other weight groupsThe fixed effects birth type, sex, season and year of birth had a significant effect on birth weight. The heavier the birth weight at later parities but not statistically significant could be result from the physiological imprint in the uterus during the first pregnancy will facilitate relatively greater fetus growth in subsequent pregnancies (Gardner *et al*., 2007). Kids born single had higher birth weight than those born as twins. This difference could be directly linked with the absence of competition from mother side for food in singletons. Male kids and those born during wet season had significantly higher birth weight than females and dry season born ones, respectively. This might be due to the physiological performance of males during embryonic development in uterus of dams is high and during wet season follicular growth of does could be supported by available forage, respectively.

Year exerted a significant positive effect on the birth up to six-month weights of kids in the nucleus. The positive effect of year could be connected with selection of better performing parents for the next generation, control of inbreeding and the feeding management in the flock with substantial supplementation during feed shortage seasons. However, the growth performance values of this study at all growth stages were lower in comparison with reports of other studies for the same breed under CBBP and farmers management condition. For instance, Amare *et al*. (2020) reported 7.2, 10.1, 13.0 and 15.9kg for, weaning, six, nine-months and yearling weight of kids, and Deribe and Taye (2013) reported, 6.84, 9.13, 14.25 Kg weaning weight, six month and yearling weight respectively at farmers management condition. This could be due to the fact that founder animals of the nucleus were moved to agro-ecologically different area that has variation from the originated locality of the breed.

In addition, the flocks in the nucleus are managed in a confined system due to the shortage of grazing lands for them and even the available grazing land was degraded that barely host browsing shrubs that would treat them against their physiological and biological requirements. This phenomenon was confirmed by previous studies for the same breed that even under proper concentrate supplementation, yearling bucks didn't respond for body weight due to confinement that was against their feeding behavior (Amare *et al*., 2021). Goats by their nature are selective browsers in grazing lands and not respond for confined feeding especially on low available shrub lands.

The weaning, six month and the yearling weight were not significantly affected by parity of the doe but doe's with earlier and higher parity had a potential of giving higher birth weight kids. In first parity does, growth performances were lower compared with older doe's that have reached physiological maturity. It was in agreement with some other studies and the results of (Deribe and Taye, 2013). Birth weight improvement had a positive but smaller association with weaning weight than other weight groups but birth weight had no significant correlations with post weaning weights as a result birth weight improvement was not more important in any other growth traits except weaning weight. Birth weight had no positive correlation with three-month, six-month, nine-month and yearling weight, but the weaning weight with six-month weight, weaning weight with nine-month weight and weaning weight with yearling weight had positive correlation and also six-month weight with nine-month weight and nine-month weight with yearling weight had positive association. This implies that selection would be possible to be undertaken during earlier ages that improve the availability of selected bucks at both station and CBBP village throughout the year.

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Table 3. Least square means (±SE) of live weight at different age (kg) of Abergelle goat breeds managed at station condition

Variables		**BWT**	**N**	**TMWT**	**N**	**SMWT**	**N**	**NMWT**	**N**	**YWT**
	N	LSM±SE		LSM±SE		LSM±SE		LSM±SE		LSM±SE
Overall	**469**	**1.99±0.02**	**453**	**6.54±0.08**	**431**	**8.55±0.09**	**416**	**11.14±0.11**	**385**	**13.74±0.14**
CV%		18.55		22.89		19.38		20.28		18.81
Sex		*****		**ns**		**ns**		**ns**		**ns**
Male	228	1.79±0.03^{a}	221	6.61±0.11	206	8.94±0.12	198	11.63±0.16	180	14.45±0.21
Female	241	1.71 ±0.03^{b}	232	6.50±0.10	225	8.93±0.12	218	11.38±0.16	205	14.04±0.19
Birth type		***		*		**		ns		ns
Single	403	1.89±0.02^{a}	388	6.33±0.09	367	8.90±0.09^{b}	356	11.32±0.12	332	14.06±0.15
Twin	66	1.61±0.06 ^{b}	65	6.78±0.18	64	9.27±0.20^{a}	60	11.68±0.30	53	14.44±0.35
Season		*		ns		**		**		***
Wet	366	1.82±0.03^{a}	354	6.63±0.09	339	8.60±0.09^{b}	328	10.96±0.11^{b}	306	13.29±0.14
Dry	103	1.68±0.05^{b}	99	6.48±0.16	92	9.28±0.21^{a}	88	12.04±0.32^{a}	79	15.20±0.34
Year		***		***		***		ns		ns
2016	51	1.23±0.04^{e}	49	5.53±0.21^{d}	49	7.67±0.22^{c}	47	11.51±0.34	45	14.08±0.33
2017	69	1.58±0.06^{d}	67	6.38±0.17^{bc}	61	9.20±0.19^{ab}	58	11.06±0.19	53	13.75±0.25
2018	44	1.94±0.08^{b}	44	7.06±0.17^{ab}	42	9.37±0.22^{a}	40	11.62±0.21	38	14.24±0.32
2019	157	1.83±0.03^{c}	156	6.11±0.11^{cd}	144	9.43±0.18^{a}	136	11.42±0.22	113	14.25±0.27
2020	148	2.16±0.03^{a}	137	7.70±0.15^{a}	135	8.66±0.10^{b}	135	11.91±0.22	135	14.92±0.27
Parity		ns		ns		ns		ns		ns
1	108	1.77±0.05	105	6.64±0.18	101	9.01±0.21	93	11.84±0.25	84	14.80±0.32
2	86	1.78±0.05	84	6.55±0.16	79	8.91±0.19	79	11.71±0.28	73	14.67±0.33
3	78	1.81±0.06	73	6.36±0.19	68	8.67±0.21	66	11.17±0.26	60	14.01±0.31
4	73	1.78±0.06	72	6.54±0.19	70	8.90±0.19	68	11.39±0.28	64	14.28±0.36
5	68	1.69±0.06	65	6.42±0.19	61	8.92±0.23	59	11.15±0.28	56	13.76±0.32
≥6	56	1.66±0.06	54	6.82±0.26	52	9.21±0.24	511	11.76±0.32	48	13.96±0.38

Where: BWT=birth weight, TMWT=three month weight, SMWT=six month weight, NMWT=nine month weight, YWT= yearling weight, LSM= least square means and SE= standard error, *= p<0.005, **=p<0.001, ***=p<0.0001

Milk production performance

Milk is the most important product consumed by the community in the study area in Sekota Zuria district and in lowland of wag-himra. Milk data was used as a supportive trait for the selection of best performing breeding bucks that will be parents of the next generation. The overall least square means of the lactation milk yield (LMY), average daily milk yield (ADMY) and lactation length (LL) were 31.28±1.04kg, 0.39±0.09kg and 8.45±0.25 weeks, respectively as described in Table 3. The LMY, ADMY, and LL were significantly affected by the fixed factors season, year and parity. LMY, ADMY and LL was significantly affected by the season where does produce more milk in wet than dry season and this is due to the availability of forage and an increase in the lactation length in wet season.

The performance of produced progenies in the station for milk production traits was low in comparison to the reports of same breed under CBBP condition (Amare *et al*., 202). This could also connect with the confinement of experimental animals at station like the growth performance traits discussed above. Lactation milk yield, average daily milk yield and lactation length was significantly affected by year however the trend was not consistent. The reason for fluctuation of milk performance traits was due to variations in sampling methods during data collection where the latter two years milk data was collected based on small test day samples whereas the former three years were based on twelve-week samples. In addition, does are not controlled for birth to selective season that make them forced to give birth out of their original environment. This means, does in the lowland areas of Wag-himra are somehow seasonal breeders during September to December, but forced to give birth throughout the year at station and that might be the reason for lower milk production performance.

Table 3. Least square means± SE of lactation milk yield (kg) and lactation length (weeks) influenced by different factors

Variables	N	LMY (kg)	N	ADMY (kg)	N	LL (week)
		LSM±SE		LMS±SE		LSM±SE
Overall	345	31.28±1.04	345	0.39±0.09	345	8.45±0.25
CV%		36.70		30.44		27.86
Season		***		**		***
Wet	271	27.31±1.21[a]	271	0.35±0.01[a]	271	7.63±0.20[a]
Dry	74	18.68±1.88[b]	74	0.34±0.02[b]	74	5.66±0.26[b]
Year		***		*		**
2016	35	39.74±2.19[a]	35	0.43.4±0.01[a]	35	9.06±0.28[a]
2017	23	11.61±0.9[b]	23	0.20±0.02[c]	23	8.09±0.90[a]
2018	169	42.09±1.23[a]	169	0.48±0.01[a]	169	8.93±0.21[a]
2019	60	7.93±0.53[c]	60	0.33±0.01[b]	60	2.86±0.03[b]
2020	58	12.09±0.66[b]	58	0.30±0.01[b]	58	4.29±0.04[b]
Parity		**		**		ns
1	60	15.66±0.18[c]	60	0.30±0.02[bc]	60	6.05±0.36
2	91	24.62±0.21[ab]	91	0.35±0.02[bc]	91	7.29±0.37
3	63	21.75±0.22[bc]	63	0.33±0.03[b]	63	6.91±0.45
4	45	25.57±0.29[ab]	45	0.37±0.02[ab]	45	6.95±0.48
5	48	21.56±0.28[b]	48	0.37±0.03[ab]	48	5.92±0.44
≥ 6	38	27.00±0.32[a]	38	0.38±0.03[a]	38	6.75±0.49

Where LMY= Lactation milk yield; ADMY= Average daily milk yield; LL= lactation length; LSM= least square means; SE= standard error; * p=<0.005; ** p=<0.001; *** p=0.0001

CONCLUSION AND RECOMMENDATION

In this study, growth and milk production performance of Abergelle goat under the established station were evaluated. Body weight of kids showed increased trend in four round selections across years up to six-month weights but not improved for nine-month and yearling weights. The growth performances of progenies produced at station condition however, were smaller in comparison to CBBP and farmers management conditions at all growth stages. Milk yield performance of does showed non-consistent trend over the years in this study and it was also lower than the performances under CBBP condition. Strong consideration of the fixed factors like birth type, sex, parity, year and season of kidding remained an important source of variation during estimation of breeding value (EBV). Total milk production and lactation length increased in wet season which calls synchronization of birth at wet season. Thus, from this evaluation it is recommended that critical economic evaluation of station breeding programs should be undertaken in terms of the cost incurred to maintain nucleus flocks and the return it provides for genetic improvement of the breed as it was low performed compared to CBBP conditions.

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Selection Indices for Economically Important Traits in Boer x Central Highland Goats Using Principal Component Analysis

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ABSTRACT

This study aims to explore the relationships among pre-weaning growth traits, efficiency-related traits, and survival of kids by principal component analysis (PCA) to identify trait(s) that could be used as selection criteria and to construct selection indexes for crossbred goats based on principal components (PC). The data set contained records of birth weight (BW), weaning weight (WW), pre-weaning weight gain (ADG), pre-weaning Kleiber ratio (KR), pre-weaning relative growth rate (RGR), and pre-weaning survival (RR). Genetic parameter estimates were obtained using the restricted maximum likelihood method, using a single-trait animal model. The resulting estimated breeding values (EBV) for each trait were normalized and used in PCA and cluster analysis. The first two PCs were selected describing most of the variation of the seven traits studied. The first principal component (PC1) explained 57.71% and the second principal component (PC2) explained 14.57% of the breeding value variance, totaling 72.28% of the total genetic additive variance. PC1 explained most of the direct additive genetic variation and correlated with the EBVs of WW, ADG, KR, GE and RGR, whereas PC2 was correlated with EBVs of BW and RR. Besides, the cluster analysis categorized seven traits into two major groups. The first group includes BW and RR, whereas traits such as WW, ADG, KR, GE and RGR were included in the second group. Therefore, based on the PCA and cluster analysis which resulted in a similar grouping of the traits, animals with higher PC1 score could be used to improve WW, ADG, KR, GE and RGR, whereas animals with higher PC2 score could be used to improve BW and survival of kids. The selection of the most appropriate and specific selection index regarding the two groups of traits is to be determined by the breeding objectives defined for specific genetic improvement programs.

Keywords: *Breeding value, cluster analysis, selection index, survival*

INTRODUCTION

Goats are the source of a variety of products and services for smallholder farmers. To enhance their productivity, the crossing of indigenous goats with Boer goats was initiated in 2007 in Ethiopia. Beyond the crossing, its combination with selection could enhance genetic gain (Gizaw et al., 2012). Among production traits, pre-weaning growth traits have considerable genetic and phenotypic correlations with growth performance, meat production, reproductive, health and other production traits of small ruminants (Huisman and Brown, 2009; Gowane et al., 2011; Pickering et al., 2012; Mohammadi et al., 2014; Tesema et al., 2020a). Besides, goat producers sold most of the crossbred goats around six months of age (Tesema et al., 2021). In such a situation, improving the growth rate till the market age could enhance production efficiency. According to previous studies (Crowley et al., 2010; Ghafouri-Kesbi and Gholizadeh, 2017), improvements in growth and meat production efficiency could be made through selection for efficiency-related traits such as growth efficiency, relative growth rate and Kleiber ratio besides direct selection based on live weight. Thus, the selection of animals for these important traits has deterministic effects on the profitability of goat production enterprises.

Most genetic improvement programs define multi-trait breeding goals, which require the construction of selection indexes for simultaneous improvement of the traits of interest. The breeding values for each trait of interest are weighted by economic weights in the aggregate genotype (Hazel, 1943). Multiple trait selection using selection indices improves both the economic and breeding values and thus can be considered the fastest and most efficient manner to improve the aggregate breeding value (Hazel, 1943; Borzi et al., 2017). Hence, applying efficient selection indices by defining the economic value of the important traits is of great necessity. The economic weight of traits could be estimated using partial budget analysis, choice experiments by analyzing farmers' willingness to pay and bio-economic modeling (Gizaw et al., 2018). However, the economic weight associated with each genetic value in selection indices is empirically attributed due to illiteracy, lack of record-keeping and small flock sizes (Kosgey et al., 2003). Thus, making the selection more effective without empirical considerations is quite important to enhance the genetic gain.

Principal component analysis (PCA) based on the estimated breeding value of several traits is an approach used for exploring the genetic relationships among the traits and can be considered to be genetic selection indices (Buzanskas et al., 2013; Venturini et al., 2013), since standardized score coefficients are linear combinations of all predicted genetic values for traits (Buzanskas et al., 2013; Boligon et al., 2016). Because PCA accounts for trait correlations and may weight each trait using its eigenvector and contribution to the overall explained variance, it is used to construct more realistic selection indices (Tyriseva et al., 2011; Agudelo-Gómez et al., 2016). Therefore, PCA would facilitate the simultaneous selection of the traits of interest (Buzanskas et al., 2013; Vargas et al., 2018). The optimal strategy for genetic selection is a selection index based on economic weight; however, in developing countries where economic weight estimation is not always evident and easy for breeders due to a lack of economic data, the PCA is an objective method to weight traits (Amaya et al., 2021). Therefore, this study aimed to explore the relationships among pre-weaning growth, efficiency-related traits and survival of kids by PCA and cluster analysis to identify trait(s) that could be used as selection criteria and to construct selection indexes for crossbred goats.

MATERIAL AND METHODS

Data set description

Pedigree and phenotypic data used in this study were from Boer x Central Highland goats kept at Sirinka Agricultural Research Center, Ethiopia. Animals were managed semi-intensively. The kids were weaned after approximately 90 days of nurturing period by their dams. The investigated traits were birth weight (BW), weaning weight (WW), pre-weaning weight gain (ADG), pre-weaning Kleiber ratio (KR), pre-weaning growth efficiency (GE), pre-weaning relative growth rate (RGR) and pre-weaning survival (RR) of kids. Efficiency-related traits were computed as follow: GE = ((WW – BW)/BW) x 100, RGR = ((ln (WW) – ln (BW)) / 90 days) x 100 and KR = ADG/$WW^{0.75}$. The detailed descriptions of a data structure are summarized in Table 1.

Table 1. Description of the data structure for early growth and efficiency-related traits in Boer x Central Highland goats

Items	Traits						
	BW	WW	ADG	KR	GE	RGR	RR
Number of records	875	638	638	638	674	674	831
Number of sires	25	22	22	22	22	22	26
Number of dams	238	209	209	209	219	238	239
NPR/ sire	35	29	29	29	30.6	30.6	32
NPR/ dam	4	3	3	3	3.07	3.07	3
Mean	2.52	9.80	80.1	13.99	293.5	1.46	-
SD	0.57	3.39	35.0	2.12	131.4	0.36	-
CV %	19.2	28.7	37.4	14.2	39.0	37.1	-

BW, birth weight; WW, weaning weight; ADG, pre-weaning weight gain; KR, pre-weaning Kleiber ratio; RGR, pre-weaning relative growth rate; RR, pre-weaning survival; SD, standard deviation; CV, coefficient of variation; NPR, number of progeny with records

Data analysis

Genetic parameters estimation

The systematic effects included in the model were the kid's birth type (single and multiple births), sex of kid (male and female), the season of birth (dry, short and main rain), parity of doe (1, 2, 3, 4 and $\geq$5), year of birth (2009, 2010, …, 2018), dam genotype (local, F1 and F2), Boer blood level (25, 50, 62.5 and 75%) and kid genotype (F1, F2 and F3). The significance of systematic effects was evaluated using the GLM procedure of SAS (2002) software. After evaluating the significance of systematic effects, genetic parameter estimates for growth and efficiency-related traits were derived by AI-REML algorithm using WOMBAT software (Meyer, 2007). When the response data are binary (taking on only values 0 and 1), the distribution function is generally chosen to be the Bernoulli distribution. The appropriate link for this type of data is logistic regression or logit link. Thus, the estimates for survival were derived using the AI-REML method after logit transformation of the data with a linear mixed model using ASREML software (Gilmour et al., 2000) fitting animal model. By including and excluding the maternal genetic effect and maternal permanent environmental effect, six models were evaluated for each trait and the matrix representation of the selected models is presented in Table 2.

Table 2. Selected model for each trait

Traits	Selected model
BW	$\mathbf{y} = \mathbf{X\beta} + \mathbf{Z_1a} + \mathbf{Z_2m} + \boldsymbol{\varepsilon}$ with Cov ($\mathbf{a}, \mathbf{m}$) = 0
WW	$\mathbf{y} = \mathbf{X\beta} + \mathbf{Z_1a} + \mathbf{Z_2m} + \boldsymbol{\varepsilon}$ with Cov ($\mathbf{a}, \mathbf{m}$) = $A\sigma_{am}$
ADG	$\mathbf{y} = \mathbf{X\beta} + \mathbf{Z_1a} + \mathbf{Z_2m} + \mathbf{Z_3c} + \boldsymbol{\varepsilon}$ with Cov ($\mathbf{a}, \mathbf{m}$) = $A\sigma_{am}$
KR	$\mathbf{y} = \mathbf{X\beta} + \mathbf{Z_1a} + \mathbf{Z_2c} + \boldsymbol{\varepsilon}$
GE	$\mathbf{y} = \mathbf{X\beta} + \mathbf{Z_1a} + \mathbf{Z_2m} + \boldsymbol{\varepsilon}$ with Cov ($\mathbf{a}, \mathbf{m}$) = 0
RGR	$\mathbf{y} = \mathbf{X\beta} + \mathbf{Z_1a} + \mathbf{Z_2m} + \mathbf{Z_3c} + \boldsymbol{\varepsilon}$ with Cov ($\mathbf{a}, \mathbf{m}$) = $A\sigma_{am}$
RR	$\mathbf{y} = \mathbf{X\beta} + \mathbf{Z_1a} + \mathbf{Z_2c} + \boldsymbol{\varepsilon}$

Where **y** is the vector of the records of traits; **b, a, m, c** and **ε** are vectors of fixed effects, additive direct genetic, maternal additive genetic, permanent environmental effects of the dam and residual effects, respectively; $\mathbf{X}$, $\mathbf{Z_1}$, $\mathbf{Z_2}$ and $\mathbf{Z_3}$ are incidence matrices that relate these effects to the records. It was assumed that **a, m, c,** and **ε** are normally distributed with the mean zero and variance $\mathbf{A\sigma^2_a}$, $\mathbf{A\sigma^2_m}$, $\mathbf{I_p c^2}$ and $\mathbf{I_n \varepsilon^2}$, respectively. Where **A** is the numerator relationship matrix between animals; $\boldsymbol{\sigma_{am}}$ is the covariance between additive direct and maternal genetic effects; $\mathbf{I_p}$ and $\mathbf{I_n}$ are identity matrices with orders equal to the number of does and kids, respectively. $\boldsymbol{\sigma^2_a}$, $\boldsymbol{\sigma^2_m}$, $\mathbf{c^2}$ and $\boldsymbol{\varepsilon^2}$ are the direct additive genetic variance, maternal additive genetic variance, maternal permanent environmental variance and residual variance, respectively.

Principal component and cluster analysis

Principal component analysis is a multivariate statistical method that reduces a set of observable variables and accounts for the greatest amount of variance using the fewest possible composite variables. However, each variable had its own contribution to the total variance (Valsalan et al., 2020). In order to verify the accuracy of the factor analysis of the data sets, the Kaiser-Meyer-Olkin measures of sampling adequacy and Bartlett's test of sphericity were computed first. After these tests, the principal component analysis was performed using the PROC PRINCOMP procedure of SAS (2002). The number of principal components that explain the maximum genetic variation in the data was determined according to Kaiser (1958). The analyzed variables were the estimated breeding value of the birth weight, weaning weight, weight gain, Kleiber ratio, growth efficiency, relative growth rate and survival of kids. To avoid inconsistent solutions in the principal components due to the differences in scales and the magnitude of the variables, the EBV was standardized to zero mean and unit variance according to Boligon et al. (2016):

$$Zi = \frac{(Xi - \bar{X})}{\delta}$$

Where Z_i is the standardized value of X_i the variable, $\bar{X}$ is the mean of the i^{th} trait and δ_i is the corresponding standard deviation.
The standardized score coefficients of each EBV (trait) in each PC were obtained as follows (Buzanskas et al., 2013):

$$V_{ij} = \frac{eigenvector\ ij}{\sqrt{eigenvalue}\ j}$$

Where V_{ij} is the standardized score coefficient for EBVs of the i^{th} trait in the j^{th} principal component. The eigenvalue of the PC is connected with the variance of all EBVs of traits involved in the PC, which intern constitutes an eigenvector (Rencher, 2002). The absolute value of these eigenvectors explains the importance of traits in a PC.
Using the standardized estimated breeding value, each principal component can generate a new value, called a principal component score. The principal component scores (PCS) were calculated as follows:

$$PCSjk = \sum_{i=1}^{m} Vij \times SEBVik$$

Where PCS_{jk} is the principal component score for the k^{th} animal in the j^{th} principal component and V_{ij} is the standardized score coefficient for the estimated breeding value of the i^{th} trait in the j^{th} principal component and $SEBV_{ik}$ is the standardized estimated breeding value of i^{th} trait for the k^{th} animal.

Cluster analysis was used for the representation of the grouping of traits (Everitt et al., 2001) and the PROC CLUSTER procedure of the SAS program (SAS, 2002) using the hierarchical clustering method was used for cluster analysis. A complete linkage method which takes the farthest distance was used for cluster analysis.

RESULTS AND DISCUSSION

Correlation estimates based on standardized EBV

The correlations among investigated traits based on the standardized estimated breeding value are presented in Table 3. The correlation of birth weight with all traits except survival was found to be poor and negative. Likewise, survival was negatively correlated with all investigated traits except birth weight. Kleiber ratio, growth efficiency, relative growth rate, weaning weight and pre-weaning weight gain were highly associated with each other. These correlation estimates suggest that considering birth weight or survival and one or some of the traits related to feed efficiency (Kleiber ratio, growth efficiency and relative growth rate) would be important. Thus, traits such as Kleiber ratio, growth efficiency, relative growth rate, weaning weight and pre-weaning weight gain were the least important to explain the total variation. This indicates that including these traits in the breeding goal may not be important.

In fact, the magnitude of heritability estimates, genetic correlation and difficulty of trait measurement could affect the selection of traits to be considered as goal traits. The (co)variance and heritability estimates for these traits are described in detail in previous studies (Tesema et al., 2020a; Tesema et al., 2020b; Tesema et al., 2021). The direct heritability estimates for birth weight, weaning weight and pre-weaning weight gain were reasonable (Tesema et al., 2020a). The heritability estimate for efficiency-related traits (Tesema et al., 2021) and survival (Tesema et al., 2020b), on the other hand, was low and the expected genetic progress from selection could be slow. In addition, this result indicates the insufficiency of the original traits for effective selection due to low heritability and low correlation among traits (correlation of BW and RR with other traits) for multi-trait selection.

Table 3. Correlation matrix and heritability estimates (the diagonal) for investigated traits

	BW	WW	ADG	KR	GE	RGR	RR
BW	0.31[a];0.38[b]						
WW	-0.041	0.50[a];0.12[b]					
ADG	-0.047	0.806	0.57[a];0.09[b]				
KR	-0.061	0.612	0.923	0.18[a];0.18[b]			
GE	-0.064	0.550	0.739	0.809	0.001[a];0.054[b]		
RGR	-0.065	0.441	0.795	0.945	0.879	0.23[a];0.075[b]	
RR	0.258	-0.097	-0.084	-0.056	-0.027	-0.032	0.006[a];0.006[b]

BW, birth weight; WW, weaning weight; ADG, pre-weaning weight gain; KR, pre-weaning Kleiber ratio; RGR, pre-weaning relative growth rate; RR, survival; a=direct heritability estimate, b=total heritability estimates (Sources: Tesema et al., 2020a; Tesema et al., 2020b; Tesema et al., 2021)

Principal component analysis

In this study, the estimate of Kaiser-Meyer-Olkin, which is a measure of sampling adequacy was 0.673, which is higher than the acceptable level (0.5) recommended by Kaiser (1974), as well as higher than the value (0.6) recommended by Tabachnick and Fidell (2007). Bartlett's test of sphericity was used to determine whether the correlation matrix was significant for all traits investigated and the results were significant (chi-squared value: 5143.5, $P<0.0001$). This indicates that the correlation matrix is not an identity matrix and provides sufficient justification for the validity of the principal component analysis of data (Valsalan et al., 2020). According to Kaiser (1960), i.e. principal components with eigenvalues greater than one, two principal components were selected from seven PCs in this study. Eigenvalues of factors indicate the contribution of each component to total variation. The first principal component (PC1) explained 57.71% and the second principal component (PC2) explained

14.57% of the breeding value variance, totaling 72.28% of the total genetic additive variance (Table 4). Thus, two components are sufficient to explain most of the variation among genetic values estimated for the investigated traits.

Table 4. Eigenvalues and variance proportions for the principal components of the standardized estimated breeding values

Principal components (PC)	Eigenvalue	Variance	Cumulative variance
PC1	4.039	0.577	0.577
PC2	1.020	0.146	0.723
PC3	0.984	0.141	0.863
PC4	0.663	0.095	0.958
PC5	0.240	0.034	0.992
PC6	0.043	0.006	0.998
PC7	0.011	0.002	1.000

The degree to which variables and components correlate reflects the relative importance of the variables in the respective principal component. PC1 explained most of the direct additive genetic variation and correlated with the estimated breeding values of weaning weight, weight gain, Kleiber ratio, growth efficiency and relative growth rate, whereas PC2 was correlated with estimated breeding values of birth weight and survival of kids (Table 5, Figure 1). The selection of animals could be based on only two components rather than all attributes, according to the positive connection between principal components and estimated breeding values of traits. Birth weight and survival were negatively correlated with PC1 which accounted for 57.71% of the total variation while weaning weight and weight gain were negatively associated with PC2. These results indicate important biological relationships underlying the genetic relationships for traits that are important for crossbred goats breeding program.

The communality of investigated traits in this study is shown in Table 5. The variation in features that can be explained by a common component is called communality and its value is ranged between 0 and 1. The communality varied from 0.344 for BW to 0.933 for KR. This result is in line with the report of Valsalan et al. (2020). Values that are nearer 1 imply that the variation of a single variable is better explained by the extracted components. Thus, it shows that the variables have shared a lot of variances and the requirement to allow the PCA to classify them. However, According to Tesema et al. (2019), the low communality value of BW suggests that BW explained little of the total variation in the factors.

Table 5. Correlation coefficients between standardized breeding values of the studied traits with two principal components and communalities (h^2) of traits

Trait	PC1	PC2	Communalities
BW	-0.042	0.575	0.344
WW	0.371	-0.084	0.562
ADG	0.473	-0.006	0.904
KR	0.473	0.046	0.933
GE	0.443	0.072	0.799
RGR	0.456	0.084	0.849
RR	-0.043	0.805	0.669

BW, birth weight; WW, weaning weight; ADG, pre-weaning weight gain; KR, pre-weaning Kleiber ratio; RGR, pre-weaning relative growth rate; RR, survival

The loading plot for investigated traits is shown in Figure 1. According to Bodenmuller Filho et al. (2010), the correlation is very high and positive if the angle between the variables (vectors) is close to zero; the correlation is also high, but negative and will be more distant if the correlation is close to 180º; the variables are less correlated if the angle formed is about 90º. Thus, high correlation estimates were observed between weaning weight, pre-weaning weight gain, Kleiber ratio, relative growth rate and growth efficiency. In addition, these traits were less correlated with birth weight and survival of kids.

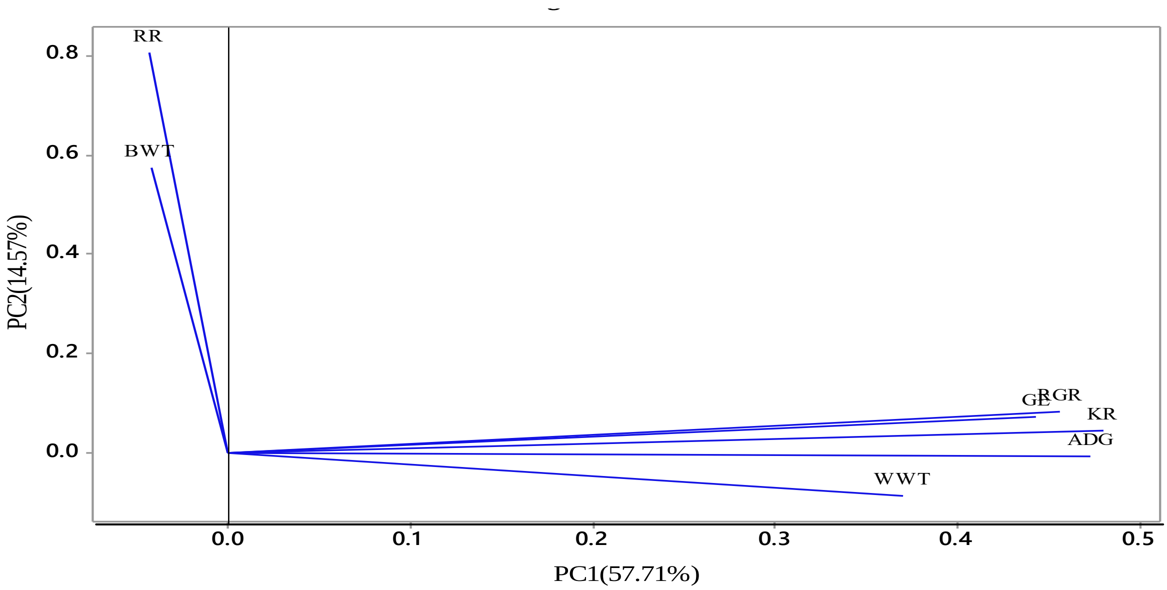

Figure 1. Loading plot for investigated traits

Selection indices

The best technique for genetic selection is the economic selection index. However, due to a lack of economic data in developing livestock systems, estimating economic weights for each feature is difficult. However, PCA allows for exploring the relationship between estimated breeding values and it is an objective method to weight traits (Buzanskas et al., 2012; Agudelo-Gómez et al., 2016; Amaya et al., 2021). The standardized score coefficients of each standardized estimated breeding value for all traits in two PCs are shown in Table 6. The weight of each trait in each PC was different. Traits such as WW, ADG, KR, RGR and GE had good weight in the first principal component, while BW and RR had good weight in the second principal component. Using these standardized score coefficients for each trait in both PCs, the principal component scores (PCS), which could be used as the selection index for each animal in the first two principal components were calculated as follows:

$PCS1 = -0.021*BV_{BW} + 0.184*BV_{WW} + 0.235*BV_{ADG} + 0.235*BV_{KR} + 0.221*BV_{GE} + 0.227*BV_{RGR} – 0.021*BV_{RR}$

$PCS2 = 0.569*BV_{BW} - 0.083*BV_{WW} - 0.006*BV_{ADG} + 0.045*BV_{KR} + 0.071*BV_{GE} + 0.083*BV_{RGR} + 0.797*BV_{RR}$

Where BV is the estimated breeding value, BW is the birth weight, WW is the weaning weight, ADG is pre-weaning weight gain, KR is the Kleiber ratio, GE is the growth efficiency, RGR is the relative growth rate and RR is the pre-weaning survival of kids.

The PCA analyses weighted characteristics by taking into account each trait's contribution to the total variance in each PC, which could be useful in developing countries where economic weights are not always available. The larger the absolute value of the PCS, the greater the relative importance. The two PCS allows capturing the main information in predicted breeding value for the investigated early growth, feed efficiency-related traits and pre-weaning survival. Animals with a higher PCS1 could enhance weaning weight, weight gain, Kleiber ratio, growth efficiency and relative growth rate, whereas animals with a higher PCS2 could improve birth weight and kid survival. These selection indexes would be more important when economic weights for traits of interests are not available in time. The selection of the most appropriate and specific selection index is determined by the breeding goal or breeding objectives of farmers.

Table 6. Standardized score coefficients (V) of each standardized estimated breeding value for all traits in two PCs

Trait	V-PC1	V-PC2
BWT	-0.021	0.569
WWT	0.184	-0.083
ADG	0.235	-0.006
KR	0.235	0.045
GE	0.221	0.071
RGR	0.227	0.083
RR	-0.021	0.797

BW, birth weight; WW, weaning weight; ADG, pre-weaning weight gain; KR, pre-weaning Kleiber ratio; RGR, pre-weaning relative growth rate; RR, survival

Cluster analysis

Figure 2 displays the cluster analysis for the analyzed traits using the complete linkage approach. Seven traits were categorized into two major groups. The first group includes birth weight and pre-weaning survival. Traits such as weaning weight, weight gain, Kleiber ratio, growth efficiency and relative growth rate were included in the second group. Traits within the same cluster are regarded as more related to each other; thus, pre-weaning survival is associated with the birth weight of kids. Some other studies (Casellas et al., 2007; Abdelqader et al., 2017; Tesema et al., 2020b; Tesema et al., 2020c) also noted the positive association of birth weight with kid survival, i.e. the risk of mortality is reduced with the increase of birth weight. A clear distinction among traits could be important for farmers and breeders to consider important traits in the selection index and to improve other traits through indirect selection. Thus, easily measurable traits such as birth weight could be used as indirect selection for the survival of kids.

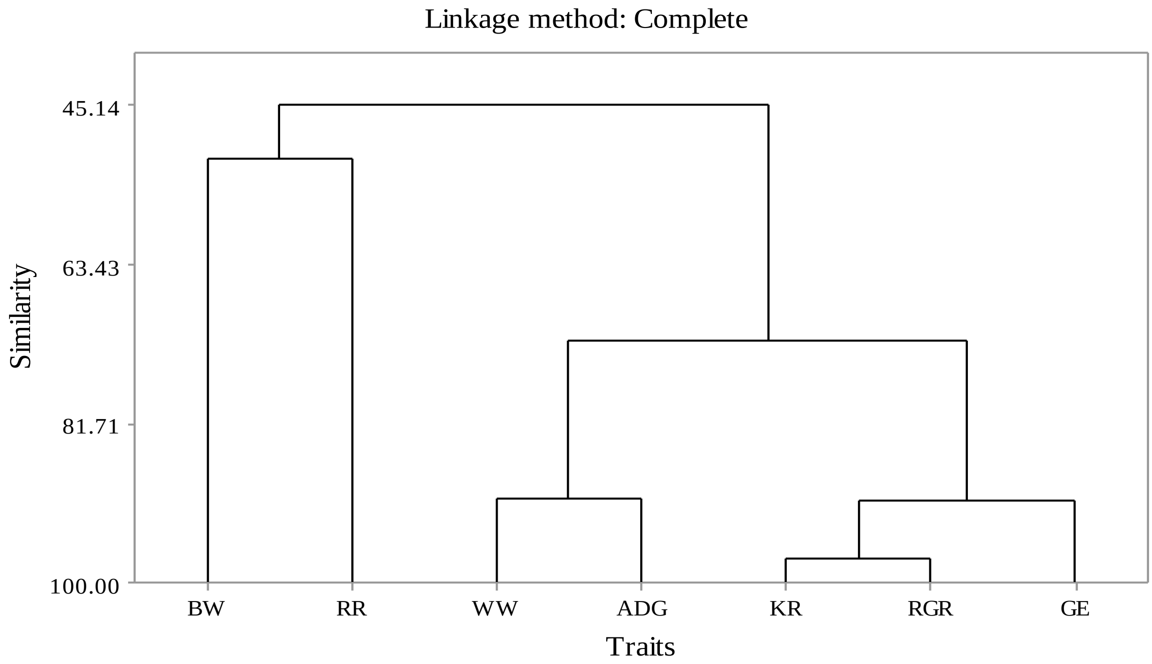

Figure 2. Dendrogram based on complete linkage methods for traits investigated

CONCLUSION

Principal component and cluster analysis are useful tools for determining the total variation originating in a group of correlated traits and reducing the number of traits to include in goat breeding programs' selection index. The variation in the breeding values of the analyzed traits could be explained by two principal components. PC1 could be considered as a new composite trait representing weaning weight, weight gain, Kleiber ratio, growth efficiency, and relative growth rate, whereas PC2 represents the birth weight and survival of kids. The choice of a specific PC is determined by the breeding objectives that could be used in the genetic improvement programs.

ACKNOWLEDGMENTS

The authors greatly acknowledge Amhara Agricultural Research Institute for their financial support. The authors would like to thank Mekonnen Shibeshi and Ali Hassen for their contribution to data collection.

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Effect of Different Types and Levels of Errors in Sire Pedigree on the Accuracy of Genetic Evaluation in Crossbred Goats

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ABSTRACT

The effect of different types and levels of error in sire pedigree on variance, heritability, inbreeding coefficient, estimated breeding value, the accuracy of breeding value and the genetic trend was evaluated. The proportion of interchanged sire (SIC) and progenies without sire (PWS) was varied in four steps from 25 to 100%. These eight pedigree files were compared to a pedigree file with complete pedigree information (CPI). The WOMBAT program fitting animal model was used to estimate genetic parameters. The correlations among estimated breeding values (EBV) resulting from different pedigree files were estimated using SAS. Except for 25-50%PWS, all pedigree files with sire pedigree error overestimated the genetic variance (σ^2_a) and direct heritability (h^2_a) compared to a pedigree file with CPI. The error in sire pedigree affects EBV, the accuracy of EBV and the rank of kids. The correlation estimate reduces with an increase in PWS and is similar for pedigree files with SIC. The magnitude of genetic reduction per year was lower for pedigree files with sire pedigree error compared to pedigree file with CPI. The mean inbreeding coefficient decreased (0.321 to 0.00%) with increasing the proportion of PWS. Pedigree files with sire pedigree error overestimated the direct heritability, total heritability, EBV, reduce the accuracy of EBV and genetic trend and underestimate the inbreeding level. However, the genetic parameter estimates derived from the pedigree files with SIC were near to estimates from the pedigree file with CPI. Improving the recording system and awareness creation about its impact is imperative for a successful genetic improvement program and accurate genetic evaluation.

Keywords: *Estimated breeding value, heritability, inbreeding coefficient, genetic trend, pedigree error*

INTRODUCTION

Genetic evaluation and estimation of genetic parameters for economically important traits are crucial for the definition and evaluation of breeding programs. Although there are various models for the estimation of genetic parameters, the animal model is the most widely used method (Ojango et al., 2011) and this model assumes that all genetic links discovered are true. The animal model considers individual animal performance as well as all known pedigree relationships (sire, dam, progeny, siblings, and other relatives) for the estimation of genetic parameters. Thus, for accurate genetic evaluation, it is vital to record all required pedigree information and the performance of traits.

Pedigree provides ancestral information and knowledge for predicting progeny performance (Nwogwugwu et al., 2020). Pedigree includes paternal and maternal information and missing sire pedigree is more harmful for genetic evaluation than missing dam pedigree information (Nilforooshan et al., 2008). According to Harder et al. (2005), there are two types of pedigree errors; these are wrong pedigree and missing (unknown) pedigree information. Wrong pedigree is more harmful than a missing pedigree (Sanders et al., 2006). The absence of proper sire identification or pedigree error could result in biased estimates of heritability, genetic progress and breeding value (Israel and Weller, 2000; Banos et al., 2001; Reid et al., 2014; Firth et al., 2015; Abbasi, 2019). Thus, the accuracy and completeness of pedigree information are essential features for genetic evaluation.

However, in the tropics where there is no proper animal recording and the type of goat production is extensive, multiple males are present and can mate with females indiscriminately, and thus it is difficult to identify the sires of the progenies (Carneiro et al., 2017). Thus, sire pedigree error has remained a severe problem. Indeed, markers of DNA, microsatellites and SNPs are used to assign true parents among candidates using a likelihood-based approach (Rupp et al., 2016). Nevertheless, the application of such molecular technologies especially in the tropics is not a viable option and is limited to characterization due to the cost of genotyping or sequencing and lack of trained personnel. Besides, although there are a lot of reports on dairy cattle (Israel and Weller, 2000; Banos et al., 2001; Harder et al., 2005; Sanders et al., 2006; Nilforooshan et al., 2008; Nwogwugwu1 et al., 2020), no information available on the impact of sire pedigree errors on genetic evaluation and genetic parameter estimates for small ruminants except for the report of Abbasi (2019) and Carneiro et al. (2017). Knowledge of the effect of the pedigree error is a base for designing alternative statistical approaches to reduce the impact of the problem. Therefore, this study aimed to evaluate the effects of paternal pedigree errors (wrongly assigned and missed sires) on genetic evaluation and to identify the type of error in sire pedigree, which had a more adverse effect on genetic evaluation of crossbred goat population.

MATERIAL AND METHODS

Data and pedigree files

Data in the current study were recorded from 2009 to 2018 at Sirinka Agricultural Research station, Ethiopia. Birth weight of Boer x Central Highland goat was selected for evaluation of the effect of misidentification on genetic evaluation. A kid's birth weight was measured within 24 hours after birth. The data set comprised 892 records for analyses of birth weight were edited for consistency of pedigree information and correct dates of kidding and weighing, and a final data set comprised of 875 records were used for analysis. The minimum and maximum birth weights were 1.0 kg and 4.20 kg, respectively with a mean value of 2.52 kg and 19.2% coefficients of variation. The number of sires, number of dams, progeny per sire and progeny per dam were 25, 238, 35 and 4, respectively. Data were cleansed to ensure that pedigree information was consistent and that the dates of kidding were correct. Records having dates and pedigree information that was inaccurate were discarded. A detailed description of the animal management, breeding procedure and data was shown in the previous study (Tesema et al., 2020). Selection has not been strong in the past. In this case, the pedigree relationship matrix does not have to account for selection based on EBV. In addition, the number of sires in this study was small and this should be in mind.

After having clean data, errors were introduced in the pedigree dataset by randomly allocating wrong sires to progenies and considering the sires of progenies unknown. Wrong sires were assigned to progenies considering the relationship of sires. Then, in addition to true sire identification, which used as a reference (benchmark), eight pedigree files were simulated by interchanging different proportions of sire in the flock and by missing different proportions of sire pedigree. The pedigree files evaluated in this study are presented as follow: (1) true sire pedigree information (CPI); (2) pedigree file with 25% randomly interchanged sires (25%SIC); (3) 50% randomly interchanged sires (50%SIC); (4) 75%

randomly interchanged sires (75%SIC); (5) 100% randomly interchanged sires (100%SIC); (6) pedigree file with 25% of progenies with unknown sire (25%PWS); (7) 50% of progenies without sire (50%PWS); (8) 75% of progenies without sire (75%PWS) and (9) 100% of progenies without sire (100%PWS) or sires set to unknown and attributing only knowledge of maternity.

Statistical analysis

The GLM procedure in the SAS program was used to detect the systematic effect of birth type (2 classes: single and multiple), season of kidding (3 classes: dry, short and main rainy season), sex of the kid (2 classes: male and female), parity of does (5 classes: 1 to ≥5), year of kidding (9 classes: 2009-2018), Boer blood level (four classes: 25, 50, 62.5 and 75%) and genotype (3 classes: F1, F2, and F3) on birth weight. Among these factors, birth type, sex of kid, parity of dam, season and year of kidding had a significant influence on birth weight of kids and considered for genetic evaluation. The WOMBAT program fitting animal model was used to estimate variance components and genetic parameters (Meyer, 2007). For a pedigree file with complete pedigree information, six univariate animal models were fitted:

$\mathbf{y = X\beta + Z_1a + \varepsilon}$

$\mathbf{y = X\beta + Z_1a + Z_2m + \varepsilon}$ with Cov ($\mathbf{a, m}$) = 0

$\mathbf{y = X\beta + Z_1a + Z_2m + \varepsilon}$ with Cov ($\mathbf{a, m}$) = $\mathbf{A}\sigma_{am}$

$\mathbf{y = X\beta + Z_1a + Z_2c + \varepsilon}$

$\mathbf{y = X\beta + Z_1a + Z_2m + Z_3c + \varepsilon}$ with Cov ($\mathbf{a, m}$) = 0

$\mathbf{y = X\beta + Z_1a + Z_2m + Z_3c + \varepsilon}$ with Cov ($\mathbf{a, m}$) = $\mathbf{A}\sigma_{am}$

Where $\mathbf{y}$ is the vector of records/ observations; $\boldsymbol{\beta}$, $\mathbf{a}$, $\mathbf{m}$, $\mathbf{c}$, and $\boldsymbol{\varepsilon}$ are vectors of fixed (fixed effects which had a significant effect), additive direct genetic, maternal additive genetic, permanent environmental effects of the dam and residual effects, respectively; $\mathbf{X}$, $\mathbf{Z_1}$, $\mathbf{Z_2}$ and $\mathbf{Z}_3$ are incidence matrices that relate these effects to the records**;** $\mathbf{A}$ is the numerator relationship matrix between animals; and σ_{am} is the covariance between additive direct and maternal genetic effects. With an assumption of direct additive genetic, maternal additive genetic, maternal permanent environmental effects, and residual effects are normally distributed with the mean zero. The (co)variance structure for the model was:

Var ($\mathbf{a}$) = $\mathbf{A}\sigma^2_a$, Var ($\mathbf{m}$) = $\mathbf{A}\sigma^2_m$, Var($\mathbf{c}$) = $\mathbf{I}_D c^2$, Var ($\boldsymbol{\varepsilon}$) = $\mathbf{I}_K e^2$ and Cov ($\mathbf{a, m}$) = $\mathbf{A}\sigma_{am}$,

Where $\mathbf{A}$ is the numerator relationship matrix between animals**;** $\mathbf{I}_D$ and $\mathbf{I}_K$ are identity matrices with orders equal to the number of dams and the number of kids, respectively. $\boldsymbol{\sigma}^2_{\mathbf{a}}$,

$\boldsymbol{\sigma^2_m}$, $\mathbf{c^2}$, and $\boldsymbol{\varepsilon^2}$ are the direct additive genetic variance, maternal additive genetic variance, permanent maternal environmental variance, and residual variance, respectively.

The significance of random effects was determined using the log-likelihood ratio test according to Meyer (1992). One optimized model was selected for each trait from the above six models as per the log-likelihood ratio test and this model was used for all pedigree files. The selected model was as follow:

$$\mathbf{Y = X\beta + Z_1a + Z_2m + \varepsilon \qquad Cov\ (a, m) = 0}$$

The correlations between EBV obtained from different pedigree files and correlations between ranks of animals were estimated using the Pearson correlation and Spearman rank correlation procedure of SAS, respectively. The multivariate relationship between pedigree files was analyzed through principal component analysis. The average EBVs were regressed on the year of birth to get genetic trends. The additive relationship matrix was used to extract the inbreeding coefficient (F) for individual animals.

Total heritability (h^2_t) was estimated according to Willham (1972):

$$h^2_t = \frac{\sigma^2_a + 0.5\,\sigma^2_m + 1.5\,\sigma_{am}}{\sigma^2_p}$$

Where σ^2_a is the additive genetic variance, σ^2_m is the maternal genetic variance, σ^2_p is the phenotypic variance, and σ_{am} is the covariance between additive direct and maternal genetic effects.

The additive coefficient of variation (CV_A) was computed as follow:

$$CV_A = \left(\sqrt{\frac{\sigma^2 a}{\tilde{n}}}\right) \text{x } 100$$

Where σ^2_a is the additive genetic variance and ñ is the sample mean.

The accuracy (r_{IH}) of EBV was computed as follow:

$$r_{IH} = \sqrt{1 - SE^2/\sigma^2 a}$$

Where SE is the standard error of EBV and σ^2_a is the additive genetic variance.

RESULTS AND DISCUSSION

Variance and heritability estimates

Particularly in the tropics where there is no proper animal recording and the type of goat production is extensive, multiple males are present and can mate with females indiscriminately, and thus it is difficult to identify the sires of the progenies (Carneiro et al., 2017). Thus, sire pedigree error has remained a severe problem. Consequently, knowledge of the effect of the pedigree error is quite important to reduce the impact of the problem through possible approaches. The variance and heritability estimates of birth weight derived from different pedigree files are presented in Table 1. The direct additive variance (σ^2_a) of birth weight from nine pedigree files varied from 0.05 to 0.09 kg. Likewise, the direct heritability estimate (h^2_a) varied from 0.22 to 0.39. The lowest and highest h^2_a were observed for pedigree files with 25%PWS and 75%PWS, respectively. The genetic variance and direct heritability estimates from pedigree files with interchanged sire (SIC) were overestimated compared to pedigree file with complete pedigree information (CPI). However, the estimates from pedigree files with SIC were found to be similar. The resemblance of genetic parameter estimates among different proportion of wrongly assigned paternity in this study could be due to a lack of pronounced genetic variation among sires and due to a small number of sires.

The h^2_a estimates from pedigree files with 25-50%PWS and 75-100%PWS were lower and higher, respectively compared to the estimate from pedigree file with CPI. In line with this result, Carneiro et al. (2017) noted that ignorance of real paternity overestimated the σ^2_a and h^2_a. Conversely, Abbasi (2019) noted that 50 to 90% of sire pedigree sequential deletion significantly reduces the estimate of genetic variance and heritability in sheep. Nevertheless, in the successive sire exclusion technique, an increase missing in a pedigree of sires did not significantly reduce heritability (Abbasi et al., 2011). The influence of pedigree error is affected by the magnitude of heritability estimates of a trait, i.e. the negative effect of the pedigree error is lower for high heritable traits (Nilforooshan et al., 2008) and makes more problems for traits with lower heritability and in the case of small progeny size per sire. This is because the similarity between parents and offspring is less apparent as the heritability decreases (Sapp et al., 2007). Thus, especially in the case of low heritability, increasing the number of progeny per sire decreases the influence of pedigree error (Sanders et al., 2006).

The maternal additive variance (σ^2_m) of birth weight among different pedigree files seems similar and the maternal heritability (h^2m) ranged from 0.16 to 0.18. Ignorance of sires of progenies had a small effect on maternal heritability estimates. The h^2m estimates from 50%PWS and 100%PWS were lower and higher, respectively than the estimate from a pedigree file with CPI. However, interchanging different proportions of sires had not a significant effect on the maternal heritability estimates. The non-significance of SIC on maternal heritability could be explained by the same information about dams and the absence of sufficient information about the sires to promote greater changes. The total heritability (h^2_t) was underestimated and overestimated by a pedigree file with 25-50%PWS and 75-100%PWS, respectively. Likewise, pedigree files with SIC overestimate the h^2_t estimate. The h^2_t replaces the h^2_a to estimate selection response from phenotypic selection when the maternal genetic effects are considered in the model (Abegaz et al., 2002; Tesema et al., 2020). Thus, the biased h^2_t could result in a biased selection response estimate and affect the genetic progress of a genetic improvement program.

Additive genetic coefficient of variation (CV_A) is a measure of additive genetic variation that is standardized by the trait mean and thus independent of other sources of variance, unlike heritability (Garcia-Gonzalez et al., 2012). Moreover, CV_A is used to measure the amount of genetic variation when there is a lot of residual error variance in traits (Ghafouri-Kesbi and Eskandarinasab, 2018). The CV_A resulted from a pedigree file with 25% to 50%PWS was lower compared to a pedigree file with CPI. Pedigree files with SIC, on the other hand, enhanced the CVA, even though the magnitude was not higher. These signify that pedigree error could bias (underestimate and overestimate) the coefficient of additive genetic variance. The biased CV_A estimate may affect the choice of breeding method (pure-breeding or crossbreeding) and the sources of information to be used for selection.

Pedigree error especially ignoring the sire of progenies influenced the standard error (SE) of h^2_a, which is a measure of precision. The SE of h^2_a estimates from 50-100%PWS was higher than the SE from a pedigree file with CPI. This finding is in line with the findings of Dong et al. (1988) and Abbasi (2019), who found that having an incomplete pedigree increases the standard error of estimations.

Table 1. Variance and heritability estimates from different pedigree files

Pedigree file	σ^2_a	σ^2_m	σ^2_e	σ^2_p	$h^2_a \pm SE$	$h^2_m \pm SE$	$e^2 \pm SE$	h^2_t	CV_A(%)
CPI	0.08	0.04	0.13	0.26	0.31±0.11	0.17±0.05	0.51±0.09	0.38	11.2
25% SIC	0.09	0.04	0.13	0.27	0.34±0.11	0.17±0.05	0.48±0.09	0.41	11.9
50% SIC	0.09	0.04	0.13	0.27	0.34±0.11	0.17±0.05	0.48±0.09	0.41	11.9
75% SIC	0.09	0.04	0.13	0.27	0.34±0.11	0.17±0.05	0.48±0.09	0.41	11.9
100% SIC	0.09	0.04	0.13	0.27	0.34±0.11	0.17±0.05	0.48±0.09	0.41	11.9
25% PWS	0.05	0.04	0.15	0.25	0.22±0.11	0.18±0.05	0.59±0.08	0.28	8.90
50% PWS	0.07	0.04	0.13	0.25	0.30±0.12	0.16±0.05	0.53±0.08	0.36	10.5
75% PWS	0.09	0.04	0.11	0.25	0.39±0.12	0.17±0.05	0.43±0.09	0.44	11.9
100% PWS	0.08	0.04	0.12	0.24	0.32±0.13	0.18±0.05	0.50±0.11	0.42	11.2

CPI, complete pedigree information; SIC, interchanged sire; PWS, progeny without sire; CV_A, additive genetic coefficient of variation

Estimated breeding value (EBV) and accuracy (r_{IH}) of EBV from different pedigree files

Estimating breeding value (EBV) closest to the true breeding value is a primary goal in genetic evaluation as the accuracy of breeding value directly influences the selection response. The mean EBV and the accuracy of EBV obtained from different pedigree files are presented in Table 2. Pedigree error had a negative relationship with the accuracy of EBV. The EBVs derived from pedigree files with sire pedigree error were lower compared to pedigree file with CPI. Likewise, pedigree files with different proportions of SIC and PWS had a lower accuracy of EBV compared to pedigree file with CPI. A similar observation has been made by previous studies (Israel and Weller, 2000; Wolak and Reid, 2017; Nwogwugwu et al., 2020). However, the accuracy derived from the pedigree file with SIC was near to the accuracy of pedigree file with CPI and this implies the likelihood of using one probable sire for estimation of EBV. In line with this result, Mueller et al. (2021) suggested that assigning the possible sire instead of missing uncertain sires could increase the accuracy of EBV, particularly in community-based breeding programs where the mating system is multi-sire. To do so, a mating probability should be assigned for each possible sire and models that consider paternal uncertainty (hierarchical and average numerator relationship matrix) should be used to reduce the prediction error variance and to obtain the nearest estimate with true pedigree information (Henderson, 1988; Carneiro et al., 2017; Mueller et al., 2021).

Table 2. The overall mean estimated breeding value of kids (n=875) and accuracy of estimated breeding value

Pedigree file	CPI	25% SIC	50% SIC	75% SIC	100% SIC	25% PWS	50% PWS	75%PWS	100%PWS
EBV(kg)	0.028	0.018	0.018	0.018	0.018	-0.009	0.020	-0.002	0.020
SE	0.222	0.240	0.240	0.240	0.240	0.200	0.222	0.252	0.251
r_{IH}	0.621	0.600	0.600	0.600	0.600	0.446	0.546	0.541	0.462

EBV, estimated breeding value; SE, standard error; r_{IH}, the accuracy of EBV; CPI, complete pedigree information; SIC, interchanged sire; PWS, progeny without sire

Rank correlation estimates of kids from different pedigree files

The rank and correlation of the rank of kids based on direct and maternal estimated breeding value was compared under nine pedigree files (Table 3). The estimated breeding value (EBV) derived from a pedigree file with CPI differed from those derived using PWS in different proportions. Pedigree files with different proportions of PWS had a moderate rank correlation with a pedigree file with CPI and a high correlation with a pedigree file with SIC. Despite the magnitude of correlation, pedigree error in sires affects the rank of kids, for example, the 2nd ranked kid by the pedigree file with CPI was ranked 3rd by a pedigree file with SIC (Table 3). Besides, a kid ranked 8th by a pedigree file with CPI was ranked 2nd and 5th by a pedigree file with 100%PWS and 75%PWS, respectively. Likewise, based on maternal breeding value, the kid ranked 2nd by a pedigree file with CPI ranked 8th, 5th and 4th by a pedigree file with 50%PWS, 75%PWS and 100%PWS, respectively. The influence of missing sire information on the ranking of the top bulls was noted in previous studies (Israel and Weller, 2000; Harder et al., 2005). Likewise, Carneiro et al. (2017) point out that the use of the pedigree file with a total uncertainty of paternity is detrimental to the ranking of the animals based on their breeding value. The effect of the pedigree error on EBV was higher for low heritability and young bulls (Harder et al., 2005). In any genetic improvement program, all breeding goats have not been maintained i.e. goats with the good EBV are retained as replacement flocks, and those with the poorest EBV are culled from the flock. In this situation, if there is a pedigree error, the wrong individual may be used as a parent in the next generation and progenies receives one-half of their genetic makeup from this individual. This can affect the genetic progress and thus the pedigree information must be recorded properly to select top individuals with high genetic merit and to improve genetic progress.

Table 3. Direct and maternal breeding value for birth weight of best ten animals and spearman rank correlations

Animal ID	CPI	25% SIC	50% SIC	75% SIC	100% SIC	25% PWS	50% PWS	75%PWS	100%PWS
DEBV									
16027	0.7495	0.8015	0.8015	0.8015	0.8015	0.5772	0.7406	0.7452	0.6362
16004	0.6394	0.6902	0.6902	0.6902	0.6902	0.4579	0.5936	0.5949	0.5322
16035	0.6375	0.7063	0.7063	0.7063	0.7063	0.4793	0.6447	0.6374	0.5470
16028	0.5487	0.6142	0.6142	0.6142	0.6142	0.4191	0.5552	0.5456	0.4612
16044	0.5129	0.5495	0.5495	0.5495	0.5495	0.3831	0.5139	0.3831	0.3505
16045	0.5048	0.5425	0.5425	0.5425	0.5425	0.3764	0.5048	0.3698	0.3427
16049	0.4777	0.5217	0.5217	0.5217	0.5217	0.3926	0.5041	0.4763	0.4146
18017	0.4279	0.4817	0.4817	0.4817	0.4817	0.3019	0.4192	0.4857	0.5552
16010	0.4191	0.4535	0.4535	0.4535	0.4535	0.3259	0.4102	0.1896	0.2100
16005	0.4042	0.4368	0.4368	0.4368	0.4368	0.3013	0.3714	0.2113	0.2247
r	-	0.988	0.988	0.988	0.988	0.939	0.988	0.867	0.685
MEBV									
9104	0.3326	0.3488	0.3488	0.3488	0.3488	0.3715	0.3322	0.3628	0.4059
9152	0.2587	0.2690	0.2690	0.2690	0.2690	0.1962	0.1725	0.1876	0.2314
13016	0.2349	0.2341	0.2341	0.2341	0.2341	0.2383	0.2632	0.2654	0.2447
9146	0.2274	0.2454	0.2454	0.2454	0.2454	0.1714	0.1849	0.1559	0.1691
16027	0.2265	0.2376	0.2376	0.2376	0.2376	0.2459	0.2191	0.3066	0.2993
9103	0.2236	0.2195	0.2195	0.2195	0.2195	0.1635	0.1630	0.1337	0.1421
17018	0.2207	0.2053	0.2053	0.2053	0.2053	0.2252	0.2136	0.2157	0.2242
9107	0.2143	0.2239	0.2239	0.2239	0.2239	0.2267	0.1894	0.1593	0.1848
9148	0.1991	0.2120	0.2120	0.2120	0.2120	0.1236	0.1232	0.0879	0.1102
13024	0.1982	0.1988	0.1988	0.1988	0.1988	0.1617	0.2110	0.1728	0.2050
r	-	0.903	0.903	0.903	0.903	0.636	0.406	0.576	0.636

CPI, complete pedigree information; SIC, interchanged sire; PWS, progeny without sire; DEBV, direct breeding value; MEBV, maternal breeding value; r, rank correlation coefficient between the ranks of animals in different pedigree error and the correct file.

Direct and maternal breeding value correlation of different pedigree files

The Pearson correlation coefficient estimates among pedigree files with complete pedigree information and other pedigree files with a pedigree error are illustrated in Table 4 and Figure 1. Pedigree files with different proportions of sire exclusion had a significant ($P<0.0001$) correlation with the pedigree file considering the real sire pedigree information. The correlation estimate among pedigree files with CPI and pedigree files with 75% and 100%PWS was relatively lower than other pedigree files. However, a model with 25-50%PWS had a higher correlation with a complete pedigree file. This indicates that the correlation estimate reduces with the increase in PWS and it is in agreement with Harder et al. (2005). Consistently, Nwogwugwu1 et al. (2020), noted that the introduction of error in pedigree slightly reduces the correlation estimate. Generally, the EBV resulted from pedigree files with SIC and with 25-50%PWS came closer to the pedigree file with CPI. The correlation between pedigree files with complete pedigree information and pedigree error based on maternal breeding value (MEBV) is illustrated in Table 4 and Figure 1. MEBV resulted from all pedigree files with a pedigree error was positively and highly correlated with a pedigree file with CPI. The proportion of SIC had not a significant effect on correlation estimates. Nonetheless, the strength of correlation was decreased with the increases in the proportion of offspring without a sire. However, the rank of top animals was under the influence of sire pedigree error and this may have an adverse effect on the genetic progress.

Table 4. Pearson correlation between complete pedigree and different pedigree files with sire pedigree error

Item	25% SIC	50% SIC	75% SIC	100% SIC	25% PWS	50% PWS	75%PWS	100% PWS
DEBV	0.97***	0.97***	0.97***	0.97***	0.98***	0.96***	0.88***	0.85***
MEBV	0.99***	0.99***	0.99***	0.99***	0.97***	0.95***	0.92***	0.91***

DEBV, direct breeding value; MEBV, maternal breeding value; SIC, interchanged sire; PWS, progeny without sire; ***, P<0.001

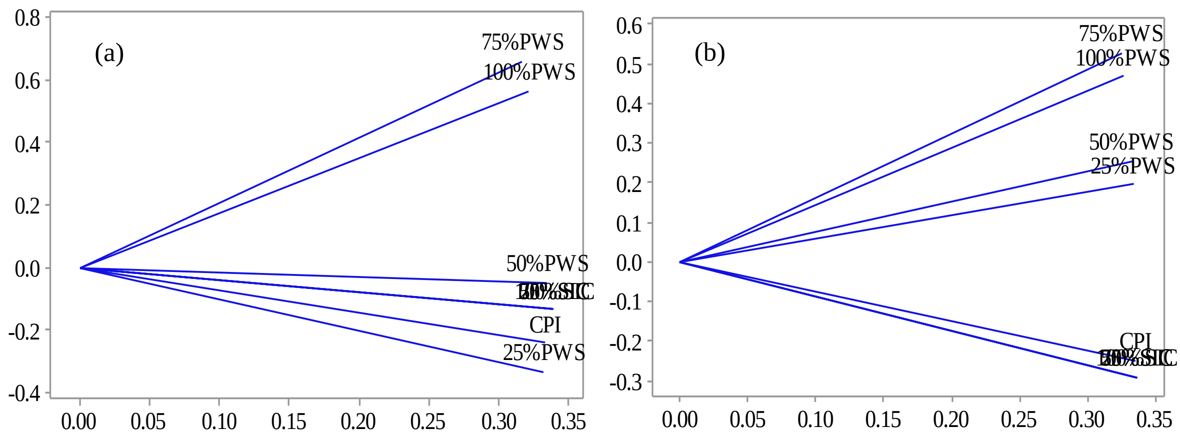

Figure 1. Multivariate relationship of pedigree files based on direct breeding value (a) and maternal breeding value (b); CPI, complete pedigree information; SIC, interchanged sire; PWS, progeny without sire

Genetic trend and inbreeding coefficient

The genetic trend is used for monitoring the efficiency of genetic improvement programs over time and implies the way forward. The genetic trend and inbreeding coefficient from different pedigree files are presented in Table 5 and Figure 2. Except for a pedigree file with 100%PWS, all pedigree files depicted that the birth weight of kids was reduced genetically by 0.0004 kg to 0.0114 kg year^{-1}. However, the reduction for most of the pedigree files was not significant (P>0.05). A positive genetic trend for birth weight was noted by Rout et al. (2018) for Jamunapari goats (0.037 kg year^{-1} increment) and Haile et al. (2018) for Awassi crossbred sheep (0.0001 kg year^{-1}). The lower genetic progress in this study could be explained by more environmental influence and the lack of a systematic selection scheme.

Pedigree files with different proportions of SIC showed similar genetic progress, probably because of the absence of marked genetic variation among sires and similar heritability estimates. The magnitude of genetic reduction from a pedigree file with SIC was lower than from a pedigree file with CPI. Likewise, the genetic trend derived from CPI differed from those derived from pedigree files with 25-100%PWS. The magnitude of genetic reduction of birth weight was lower for pedigree files with 25-75%PWS and a pedigree file with 100%PWS showed a positive genetic trend. The lower genetic progress in this study could be explained by more environmental influence and the lack of a systematic selection scheme. The effect of sire pedigree error on genetic trend concurs with previous studies (Banos et al., 2001; Visscher et al., 2002) which noted that wrong sire information reduced the genetic gain by reducing the heritability estimate. Israel and Weller (2000), Harder et al. (2005) and Sanders et al. (2006) point out that the downward influence of pedigree error is more pronounced in the case of low heritable traits than high heritable traits. In this study, the heritability estimate for birth weight was determined to be modest. This might be the reason for the overestimation of the regression coefficient or genetic trend of pedigree files with pedigree error in this study. Besides, according to Sell-Kubiak et al. (2018), incomplete pedigrees result in an underestimation of the inbreeding level of an individual and cause overestimation of its breeding value. This could be the other reason for the overestimation of the regression coefficient, especially for a pedigree file with 100%PWS compared to a pedigree file with CPI, as the inbreeding level for a pedigree file with 100%PWS was underestimated to zero. This implies that pedigree errors affect the decision of breeders and mislead the way forward due to overestimated genetic change. Especially for bucks of high and low genetic merit, the pedigree error or exclusion of these bucks has more effect on genetic trend or genetic progress. Therefore, improving the recording system through awareness creation is imperative for a successful genetic improvement program.

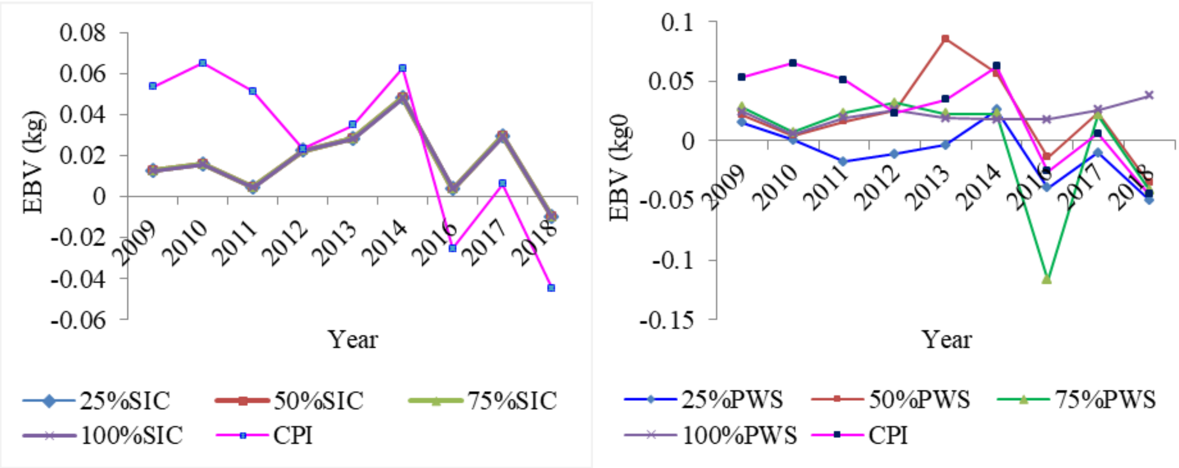

Figure 2. Genetic trend for SIC (left) and for PWS (right) pedigree files in relation to CPI pedigree file

EBV, estimated breeding value; CPI, complete pedigree information; SIC, interchanged sire; PWS, progeny without sire

The inbreeding coefficient measures the likelihood that two alleles at the same locus will be identical by descent (Lynch and Walsh, 1998). The inbreeding coefficient resulted from different pedigree files were given in Table 5. The mean inbreeding coefficient resulted from a pedigree file with CPI was 0.581%. This result is lower than the result (6.92%) reported by Teixeira Neto et al. (2013) and Pedrosa et al. (2010) for Santa Inês sheep population (2.33%). An increasing level of inbreeding causes inbreeding depression (Lal et al., 2013) and thereby increases susceptibility to diseases and unfavorable environmental conditions, increase the lethal genes (Sell-Kubiak et al., 2018), reduces animal reproductive and productive performance, as well as genetic change. However, the current estimate is below the acceptable inbreeding coefficient (6.25%) according to Ryan (2018).

In this study, pedigree files with different proportions of SIC had a lower inbreeding coefficient than pedigree files with CPI (Table 5). The mean inbreeding coefficient was decreased to 0.0% by increasing the proportion of PWS to 100%. Similarly, Mark et al. (2017) noted that the estimation bias increases with the increase of the proportions of unknown parents. The underestimation of the inbreeding coefficient due to pedigree error is in line with the findings of previous research (Lutaaya et al., 1999; Harder et al., 2005; Wolak and Reid, 2017; Sell-Kubiak et al., 2018). This underestimation is due to the reduction of the connectedness of individuals with their relatives. Underestimating an individual's inbreeding coefficient leads to an overestimation of its breeding value (Sell-Kubiak et al., 2018); this could result in a selection of pseudo-superior and genetically related animals as a parent for the next generation.

As a solution, Mark et al. (2017) suggested that the probability of detecting different pedigree configurations is taken into account to estimate the inbreeding rate from the incomplete pedigree. If not, the bias would increase with the number of unknown parents. Furthermore, assigning the mean inbreeding level from birth year to animals with unknown parents' results in an inbreeding level that is closer to the population's true value (Sell-Kubiak et al., 2018). This may also improve the accuracy of breeding value, allowing the breeder to make the best genetically superior animal selection decisions.

Table 5. The annual genetic gain (kg year^{-1}) and inbreeding coefficient (%)

Pedigree file	Genetic trend (kg year^{-1})		Inbreeding coefficient	
	b	P-value	N	F (%)
CPI	-0.0114	<0.0001	37	0.581
25%SIC	-0.0004	0.0521	39	0.357
50%SIC	-0.0004	0.0521	39	0.357
75%SIC	-0.0004	0.0521	39	0.357
100%SIC	-0.0004	0.0521	39	0.357
25%PWS	-0.0050	0.0027	33	0.321
50%PWS	-0.0033	0.6225	9	0.136
75%PWS	-0.0087	0.0003	7	0.128
100PWS	0.0017	0.0551	0	0.000

CPI, complete pedigree information; SIC, interchanged sire; PWS, progeny without sire; b, regression coefficient; R^2, coefficient of determination; N, number of inbred goats; F, inbreeding coefficient

Way of handling data with sire pedigree error

The accuracy and completeness of pedigree information are essential features for genetic evaluation. In this study, the genetic parameter estimates from the pedigree file with SIC were nears to estimates of the pedigree file with CPI. This indicates the possibility of assigning one more probable sire as a parent instead of missing sire information or exclusion of kids with unknown /uncertain sires to reduce the bias. Likewise, in a multi-sire mating scheme, Mueller et al. (2021) have suggested including up to three possible sires in the pedigree and recording the probability of mating. This could be one solution in multi-sire mating schemes with its limitations.

Assigning possible parents cannot completely fix all resulting problems. The effect of sire pedigree error could be solved by the use of genomic selection (Abdel-Shafy et al., 2020; Macedo et al., 2020). Nevertheless, the applicability of such technologies is limited particularly in the tropics due to financial and technical issues. To account for uncertain paternity, different statistical approaches such as iterative empirical Bayesian model, model based on the average relationship matrix, Bayesian hierarchical model, the use of genetic grouping, use of phenotypic information, and parentage probabilities have been suggested by several scholars (Sapp et al., 2007; Petrini et al., 2015; Carneiro et al., 2017; Shiotsuki et al., 2018; Macedo et al., 2020; Gómez et al., 2021; Mueller et al., 2021). However, this is not mean that these statistical approaches completely fix all resulting problems. Therefore, recording the pedigree information properly is the first option, if the pedigree file is uncertain, handling it with appropriate statistical approaches would be imperative to increase the accuracy of genetic evaluation.

CONCLUSION AND RECOMMENDATIONS

Error in sire pedigree has a significant impact on genetic evaluation in crossbred goats. It overestimate the direct heritability, bias the additive coefficient of variation, underestimate the estimated breeding value, reduce the accuracy of estimated breeding value, bias the genetic trend, affect the rank of top kids and underestimate the inbreeding level in the flock. Relatively, the impact of interchanged sire on genetic parameter estimates is lower than the effect of missed sire pedigree information. Thus, in multi-sire mating schemes and where there is no molecular information in place, assigning one more probable sire for offspring would be better with its limitations than missing sire pedigree information. Statistical approaches, which consider paternal uncertainty, could further improve the accuracy of genetic evaluation according to Carneiro et al. (2017) and Mueller et al. (2021). Furthermore, improving the recording system and awareness creation about its impact on genetic evaluation is crucial for accurate genetic evaluation and a successful genetic improvement program. This result would be more informative for the crossbred population.

ACKNOWLEDGMENTS

The authors appreciate Amhara Agricultural Research Institute for their financial support. The authors also express their sincere gratitude to Mekonnen Shibeshi, Ali Hassen, and Alemu Kefale who participated in the data collection.

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Growth Curves of Different Generations of Boer x Central Highland Goats Using Alternative Estimation Models

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ABSTRACT

This study aimed to find the best-fitted non-linear functions to provide a specific shape of the growth curve from birth to yearling age in three generations (F1, F2, and F3) of male and female Boer x Central Highland crossbred goats. The fitted models were Gompertz, Logistic, Brody, Von Bertalanffy, Monomolecular, Negative exponential, and Richards models. Root mean square error (RMSE), Bayesian information criterion (BIC), coefficient of determination (R^2), and Akaike's information criterion (AIC) were used to assess the goodness of fit of the models. The data were analyzed using the NLIN procedure of SAS. The Brody, Von-Bertalanffy, and Richard were the best-fit models with the lowest AIC, BIC and RMSE values, and the highest R^2 values compared to other models for F1, F2, F3, male, and female goats. The estimate of parameter A (asymptotic weight) from the best-fitted models were 28.47±1.08, 27.35±1.35, 22.85±0.81, 26.23±0.79, and 28.44±1.16 kg for F1, F2, F3, female and male goats, respectively. The asymptotic weight tended to decline with increasing filial generation, i.e. F1 had a higher value than F2 and F2 had a higher value than F3. The asymptotic weight for male goats was higher than for the female goats for all non-linear growth models. The estimates of parameter B from the best-fitted models were almost similar for all genotypes and sexes. The value of parameter K (maturity rate) tends to increase with the filial generation, and F1 had a slightly smaller value followed by F2 and F3. As per the best-fitted growth functions, both males and females had similar maturity rate. The Brody and Von-Bertalanffy models can be used for predicting mature live weight, maturation rate, and growth rate of Boer x Central Highland goats and can be used for formulating breeding and management strategies.

Keywords: *Boer goat, filial generation, growth curve, maturation rate, non-linear models*

INTRODUCTION

Goats provide both tangible (cash income, meat, milk, and manure for soil fertilizer) and intangible benefits (saving, prestige, insurance, cultural and ceremonial purposes) to the smallholder farming system (Legese et al., 2014). In addition, they are used as a source of risk mitigation during agricultural failures, because of their ability to adapt to harsh climatic conditions. Ethiopia is endowed with a huge goat population, with the number of goats estimated to be 50.50 million, with indigenous breeds accounting for 99.97% of the total (CSA, 2020). One of the most native goat breeds in Ethiopia is Central Highland goats. Despite their fitness and adaptability, their productivity and economic contribution are below their potential. As a result, many attempts have been made and are being made to enhance the productivity of indigenous goats through crossbreeding, within-breed selection, modification of nutrition, and veterinary service.

Growth is a very important characteristic of living organisms and is defined as an increase in weight and dimension over time (Kopuzlu et al., 2014). Modeling of growth curves provides information for assessing the genetic potential of animals for growth, ascertaining genetic variability of characteristics linked to growth and growth curve parameters can be used as selection and culling criteria in selective breeding programs. Besides, used for optimizing the management, determining nutritional requirements of animals, predicting the weight of animals at a specific age (Waheed et al., 2011; Lupi et al., 2016; Balan et al., 2017; Ghiasi et al., 2018). In addition, it can be an input for the modification of the growth curve shape of animals through selection. Thus, the modeling growth curve is important in animal production.

There are various types of growth models and, due to their sigmoid structure, nonlinear growth models are preferable to linear ones (Tariq et al., 2013) and provide the basis for an objective method of estimating growth potential (Kopuzlu et al., 2014). Non-linear models are suitable for unbalanced data, which is the characteristics of most breeding datasets, with different numbers of live weight records across different age, sex, and genotype classes of animals resulting from a declining number of records over time due to different factors such as death, slaughter, disposal and other factors. Using conventional methods for such types of data leads to bias in the estimated parameters (Wang and Zuidhof, 2004). In addition, non-linear models can describe the weight gain, evaluate the mature weight, the rate of maturing, as well as the rate of weight gain.

Modeling growth curves has been attempted for a few goat breeds or populations (Waheed et al., 2011; Gaddour et al., 2012; Raji et al., 2015; Ghiasi et al., 2018; Waiz et al., 2019; Wiradarya et al., 2020; Abdelsattar et al., 2021; Magotra et al., 2021; Rashad et al., 2022). Nonetheless, breed, flock size, clusters, management level, physical environment, and selective breeding practices (Akbas et al., 1999) influence growth curves. Thus, the best growth models for each breed and production system must be identified. Besides, no studies were found in the literature that describes the growth curve of Boer x Central Highland goats. Therefore, this study aimed to find the best-fitted non-linear functions to provide a specific shape of the growth curve from birth to yearling of age in Boer x Central Highland goats.

MATERIAL AND METHOD

Animals and Data

The data were obtained from Sirinka Agricultural Research Center shoat breeding station, northeastern Ethiopia. The breeding station is located at an altitude of 1850 m.a.s.l and at 11°45’00" N and 39°36’36" E. The area receives about 950 mm of annual rainfall on average. The area has a moderately warm climate, with average daily temperatures ranging from 13.7 to 26.4 °C. Goats were managed semi-intensively, i.e., allowed to graze/browse for about six hours per day on a natural pasture and supplemented with 0.10–0.40 kg of concentrate mixture consisting of wheat bran, Noug seed cake, and salt. The supplementation was based on physiology, sex and age of the animals. They were housed in semi-open concrete barns at night based on their age, physiology and sex (Tesema et al., 2021).

The data set used in this study comprised 6919 live weight-age records (3924 records on female kids and 2996 records on male kids; 3730 records on F1, 2085 records on F2, and 1106 records on F3 kids) from 875 kids that were born from 2009 to 2018 in Sirinka shoat breeding station. The numbers of F1, F2, and F3 kids were 434, 293, and 148, respectively. The weight of kids from birth to yearling age was considered in the present study. The live weight of kids was measured at birth and then monthly up to six months of age and at three-month intervals up to 12 months of age. For monthly growth stages where weights were not recorded (i.e., 7-, 8-, 10- and 11-month weights) weights were estimated using the following equation:

AdgWt = Bwt + [Cwt - Bwt)/ (ageCwt)] * ageEwt

Where AdgWt = Adjusted weight for a certain age (7, 8, 10, and 11 months), Bwt = birth weight of kids, Cwt = current weight of kids, ageCwt = the age in days at current weight and ageEwt = age in days for which weight is to be estimated.

Statistical analysis

Levenberg-Marquardt's iterative approach was used to determine non-linear growth curve model parameters using the NLIN procedure of SAS (2002). The weights of kids were fitted using seven non-linear models: the Gompertz, Logistic, Brody, Von Bertalanffy, Monomolecular, Negative exponential and Richards models. Each model was fitted to live weight records for males, females, F1, F2 and F3 kids. The mathematical forms of non-linear growth functions used to describe the growth curves of Boer x Central Highland goats are shown in Table 1.

Table 1. Models and parameters analyzed for estimation of growth curves for Boer x Central Highland goats

Model	Number of parameters	Equation	References
Gompertz	3	$W(t) = Ae^{-be^{-kt}} + \varepsilon$	Laird (1965)
Logistics	3	$W(t) = A/(1+be^{-kt}) + \varepsilon$	Nelder (1961)
Brody	3	$W(t) = A(1-be^{-kt}) + \varepsilon$	Brody (1945)
Von Bertalanffy	3	$W(t) = A(1-be^{-kt})^3 + \varepsilon$	Von Bertalanffy (1957)
Monomolecular	3	$W(t) = A/(1+e^{b-kt}) + \varepsilon$	Draper and Smith (1981)
Negative exponential	2	$W(t) = A(1-e^{-kt}) + \varepsilon$	Brown et al. (1976)
Richards	4	$W(t) = A(1-be^{-kt})^m + \varepsilon$	Richards (1959)

W(t), live weight at age t (month); A, asymptotic weight or mature weight; b, an integration constant related to initial animal weight. The value of b is defined by the initial values for W and t; k, the maturation rate, which is interpreted as weight change in relation to mature weight to indicate how fast the animal approaches adult weight; m, the inflection point of the curve

The non-linear models were examined for the goodness of fit using the Bayesian information criterion (BIC), Akaike's information criterion (AIC), coefficient of determination (R^2) and root mean square error (RMSE).

BIC was calculated using the following formula:

$$BIC = n\ln\left(\frac{RSS}{n}\right) + p\ln(n$$

Where n is the number of observations (data points), RSS is the residual sum of squares and p is the number of parameters in the equation. Smaller values of BIC suggest a better fit when comparing the models.

AIC was calculated using the following formula:

$$AIC = n \ x \ ln(RSS) + 2p$$

Where n is the number of observations (data points), RSS is the residual sum of squares and p is the number of parameters in the equation. Smaller values of AIC suggest a better fit when comparing the models.

RMSE was calculated as follow:

$$RMSE = \sqrt{\frac{RSS}{n - p - 1}}$$

Where n is the number of observations (data points), RSS is the residual sum of squares and p is the number of parameters in the equation. Smaller values of RMSE suggest a better fit when comparing the models.

The coefficient of determination (R^2) was computed as:

$$R^2 = 1 - \frac{RSS}{TSS}$$

Where TSS is the total sum of squares and RSS is the residual sum of squares.

RESULTS AND DISCUSSION

Descriptive statistics for growth traits

The mean, standard deviation, minimum, maximum, and coefficient of variation of monthly live weights from birth to yearling age are presented in Table 1. The range between the minimum and maximum live weight varied at different ages, which indicates the presence of variation. The coefficient of variation for the live weight of kids from birth to 12 months, which varied from 21.9 to 34.5%, also confirms the presence of variation within the crossbred population. Coefficient of variation shows the extent of variability of data in a sample in relation to the mean of the population, is a useful statistic for comparing the degree of variation between different data series, which in the current study is variation in weight traits measured at different ages. The coefficient of variation indicates that selection could be more effective in the trait with the highest CV. According to Owens et al. (1993), growth is measured as an increase in mass and includes cell multiplication, cell enlargement and incorporation of specific components from the environment. Although there are many variables that affect an animal's growth, they may be categorized into three basic groups: the animal's gene pool, the nutrients that it receives and its habitat (Pell et al., 1994). The influence of the most important environmental factors on the live weight of Boer x Central Highland crossbred goats was discussed well in the study of Tesema et al. (2021).

Table 1. Descriptive statistics for live weight of Boer x Central Highland goats

Trait	N	Mean	SD	Minimum	Maximum	CV%
Birth weight	875	2.52	0.57	1.00	4.20	22.9
1 month	794	5.05	1.35	2.26	9.73	26.8
2 month	725	7.52	2.38	3.26	15.5	31.7
3 month	674	9.98	3.44	4.00	21.2	34.5
4 month	653	10.1	2.38	5.26	17.3	23.5
5 month	628	12.0	2.93	6.13	20.6	24.4
6 month	537	13.9	3.48	7.00	24.0	25.0
7 month	452	14.4	3.16	7.44	21.9	21.9
8 month	452	16.1	3.59	8.22	24.6	22.3
9 month	452	17.8	4.03	9.00	27.4	22.6
10 month	351	17.4	4.30	10.2	29.8	24.7
11 month	351	18.9	4.73	11.1	32.5	25.0
12 month	351	20.3	5.15	12.0	35.2	25.3

N number of animals; SD standard deviation; CV coefficient of variation

Comparison of non-linear mixed growth models

Selecting a model with inadequate fit can result in growth rates, inflection points, and upper asymptote values that have no biological significance (Do and Miar, 2019). Consequently, picking a suitable development model is crucial for comprehending animal growth. The results of model comparison for the growth curve of F1, F2, F3, male and female Boer x Central Highland goats under the seven tested non-linear models considering the goodness of fit measures of AIC, BIC, RMSE and R^2 are shown in Table 3 and Table 4. The Brody, Von-Bertalanffy and Richard models provided the lowest AIC, BIC, and RMSE values and these growth functions had the highest R^2 value compared to other models for F1, F2, F3, male and female goats. Therefore, these models (Brody, Von-Bertalanffy and Richard) showed the best fit for genotype and sex groups. A further merit of the Brody and Von-Bertalanffy models is that interpretation of results is easier compared with Richards, which had four parameters. Besides, it is difficult to achieve convergence in the Richard function (Malhado et al., 2009; Rashad et al., 2022). On the other hand, the Negative exponential function supplied the worst fit of growth in Boer x Central Highland goats due to the highest AIC, BIC and RMSE values and lowest R^2 value.

In line with the current finding, Magotra et al. (2021) reported the Brody function as the best model while comparing various growth models in the Beetal goat breed. Waiz et al. (2019) estimated the growth curve of Sirohi goat by using five non-linear growth models viz., Brody, Logistic, Gompertz, Weibull and Richard, and selected Brody as a suitable model. Waheed et al. (2011) noted that Brody and Gompertz provided the best fit of growth curve estimates in Beetal goats. Similarly, Lupi et al. (2015) reported the von Bertalanffy and logistic models as the best models while comparing various growth models in Segurena sheep breed. Likewise, Freitas (2005) reported that Brody, Von-Bertalanffy and Logistic models were more versatile to fit the growth curve in sheep. Ghavi Hossein-zadeh (2015) evaluated six non-linear functions (Brody, Logistic, Richard, Negative exponential, Bertalanffy and Gompertz) and found that the Richard model was the best-describing growth in male and female Shall sheep. The result obtained in this study is consistent with Kopuzlu et al. (2014) who reported that Brody, Richards, and Janoschek models are best fitted. However, Raji et al. (2015) compared five different growth models (Brody, Gompertz, monomolecular, Richard, and Weibull) and found that Gompertz and monomolecular function was the best function for estimating the growth curve in Nigerian goats. On the other hand, Wiradarya et al. (2020) and Abdelsattar et al. (2021) reported that Gompertz growth curve was the best-fitted model for live weight in Kacang and Laiwu black goats, respectively. The variability of selected models among studies indeed is not surprising. Because the care of the animals, size or maturity weight, maturity rate, sample size, and data structure could all be factors in the difference of the chosen models among different studies.

Growth curve parameter estimates

The estimates of growth curve parameters under various models for F1, F2, F3, male, and female Boer x Central Highland goats are presented in Table 3 and Table 4. The growth model parameter A represents an asymptotic weight estimate or the mature weight of animals (Kopuzlu et al., 2014). The estimates of parameter A under best-fitted models in this study are higher than the value (17.97) reported for Raeini Cashmere goats using Gompertz model (Ghiasi et al., 2018) and the value (8.40 for males and 6.42 for females) noted for the nondescript goat breed (Raji et al., 2015). The current result is in line with the report of Waheed et al. (2011) for Beetal goats. However, Oliveira (2011) has reported a relatively higher result for Anglo-Nubian goats, in which the highest estimates for A were from the Richards (30.66), Brody (29.63), and von Bertalanffy (26.51), respectively. Likewise, Malhado et al. (2008) reported a higher value of parameter A for Anglo-Nubian goats (42.96 for the Richard, 42.58 for Brody, and 37.45 kg for the von Bertalanffy models). The breed difference, differences in the size of the skeleton, hormonal status, plane of nutrition (Owens et al., 1993), time unit and growth models used could be the reason for the variation of estimates among studies.

Parameter A was the largest for Brody, Von Bertalanffy and Richards in F1, F2, F3, male, and female kids. Rashad et al. (2022) also observed the largest value of parameter A. However, it was lowest for Logistics and monomolecular functions/models in both sexes and all filial generations. The A parameter tended to decline with increasing filial generation, i.e. F1 had a higher value than F2 and F2 had a higher value than F3. This result concurs with Gaddour et al. (2012), who noted that the mature weight and inflected weights of the F1 crossbred kids were higher than F2 genotype. The higher performance of F1 could be explained by the heterosis effect. The parameter A for male goats was higher than for the female goats for all non-linear growth models. Waiz et al. (2019) have reported a similar result for Sirohi goat breed. The hormonal and physiological differences could be the possible reason for the superiority of males.

The parameter B value in this study is comparable with the value (0.91) reported by Magotra et al. (2021) and lower than the result (0.98) noted for the Beetal goats using the Brody model (Waheed et al., 2011). The estimates of parameter B as per best-fitted models were almost similar for all genotypes and sexes. However, Magotra et al. (2021) noted a higher estimate for males than female goats for Beetal goats.

Parameter K indicates the speed of animal growth to arrive at the mature weight. A small value of parameter K indicates that the animal is late maturing, whereas large values specify late maturation (Ghavi Hossein-Zadeh, 2017; Waiz et al., 2019). The value of parameter K was different even for best-fitted growth functions and varied from 0.03 to 0.29. Richards growth model had a higher value followed by Brody and Von Bertalanffy model. The estimates for parameter K from all best-fitted models in this study were higher than the result noted for Raeini Cashmere goats (0.017) by Ghiasia et al. (2018) and lower than the estimate reported for Sirohi goats (Waiz et al., 2019). The estimate from Brody was in line with the values reported by Waheed et al. (2011) for Beetal goats and close to the estimate (0.13) reported by Magotra et al. (2021) for Beetal goats.

The value of K tends to increase with the filial generation, and F1 has s slightly small value followed by F2 and F3. This indicates that F3 goats arrive at asymptotic weight earlier than those with lower values of this parameter (F1 and F2). As per the best-fitted growth functions, both males and females had similar values of parameter K, which indicates the absence of difference in maturation rate among male and female goats. On the contrary, Waiz et al. (2019) noted that females achieved mature weight earlier as compared with male kids. The aim of crossing indigenous goats with Boer goats was to improve growth and meat production, thus, goats with high asymptotic or mature weight and early maturity would be preferred.

Table 3. Estimated growth curve parameters for different genotypes of Boer x Central Highland goats from different models

Genotype	A	B	K	m	BIC	AIC	R^2	**RMES**
F1								
Gompertz	21.87±0.36	1.86±0.02	0.23±0.007		11681	72838	0.941	3.16
Logistics	20.21±0.23	4.25±0.11	0.36±0.009		11821	72978	0.940	3.20
Brody	28.47±1.08	0.90±0.003	0.09±0.006		11562	72719	0.942	3.14
Von Bertalanffy	28.47±1.08	0.90±0.003	0.03±0.002		11562	72719	0.942	3.14
Monomolecular	20.21±0.23	1.45±0.02	0.36±0.009		11821	72978	0.940	3.20
Negative exp.	21.72±0.32	-	0.17±0.005		12397	73554	0.935	3.33
Richards	28.47±1.08	0.90±0.003	0.18±0.01	0.5±0.00	11562	72719	0.942	3.14
F2								
Gompertz	21.52±0.47	1.84±0.03	0.24±0.01		8480	69637	0.931	3.36
Logistics	20.04±0.31	4.16±0.14	0.38±0.01		8661	69818	0.929	3.40
Brody	27.35±1.35	0.89±0.005	0.10±0.008		8316	69474	0.932	3.32
Von Bertalanffy	27.35±1.30	0.90±0.005	0.03±0.002		8316	69474	0.932	3.32
Monomolecular	20.04±0.31	1.42±0.03	0.38±0.01		8661	69818	0.929	3.40
Negative exp.	21.17±0.40	-	0.19±0.007		9176	70334	0.923	3.53
Richards	27.35±1.30	0.90±0.005	0.20±0.01	0.50±0.00	8316	69474	0.932	3.32
F3								
Gompertz	19.81±0.38	1.82±0.05	0.30±0.01		3108	64265	0.931	3.36
Logistics	18.89±0.29	4.08±0.21	0.45±0.02		3327	64484	0.929	3.40
Brody	22.86±0.81	0.89±0.008	0.15±0.01		2927	64085	0.932	3.32
Von Bertalanffy	22.85±0.81	0.89±0.008	0.05±0.003		2927	64085	0.932	3.32
Monomolecular	18.89±0.28	1.41±0.05	0.45±0.02		3327	64484	0.929	3.40
Negative exp.	20.07±0.39	-	0.22±0.01		3685	64843	0.923	3.53
Richards	22.85±0.81	0.89±0.008	0.29±0.02	0.49±0.00	2927	64085	0.932	3.32

A, asymptotic weight or mature weight; and b, is an integration constant related to initial animal weight. The value of b is defined by the initial values for W and t; k, the maturation rate, which is interpreted as weight change in relation to mature weight to indicate how fast the animal approaches adult weight; m: inflection point of the curve

The mature weight and maturation rate are crucial in determining the appropriate slaughtering age for maximum muscle deposition and minimal fat, which might meet customer demands (Amaral et al., 2011). In this study, the correlation between maturation rate and mature weight was high (-0.98) and significant (P<0.001). This result is in line with the previous studies (Carneiro et al. 2009; Lupi et al. 2016; Kheirabadi and Rashidi 2019) for goats. This association indicates that the early mature crossbred goat are less likely to exhibit high mature weight and therefore selection only for increased mature weight will reduce the rate of maturing.

Table 4. Estimated growth curve parameters for male and female Boer x Central Highland goats from different models

Sex	A	B	K	m	BIC	AIC	R^2	RMSE
Female								
Gompertz	20.85±0.29	1.85±0.02	0.24±0.007	-	11286	72444	0.945	3.00
Logistics	19.43±0.19	4.20±0.10	0.38±0.009		11457	72614	0.944	3.03
Brody	26.23±0.79	0.90±0.003	0.10±0.005		11145	72302	0.946	2.97
Von Bertalanffy	26.23±0.79	0.90±0.003	0.03±0.001		11145	72302	0.946	2.97
Monomolecular	19.44±0.19	1.43±0.02	0.38±0.009		11457	72614	0.944	3.03
Negative exp.	20.86±0.26	-	0.18±0.004		11999	73157	0.939	3.16
Richards	26.23±0.79	0.90±0.003	0.20±0.01	0.48±0.00	11145	72302	0.946	2.97
Male								
Gompertz	22.32±0.41	1.85±0.03	0.24±0.009		11382	72540	0.931	3.45
Logistics	20.76±0.28	4.19±0.12	0.37±0.01		11551	72708	0.930	3.50
Brody	28.44±1.16	0.90±0.004	0.10±0.007		11226	72383	0.933	3.42
Von Bertalanffy	28.43±1.16	0.90±0.005	0.03±0.002		11226	72383	0.933	3.42
Monomolecular	20.76±0.28	1.43±0.02	0.37±0.01		11551	72708	0.930	3.50
Negative exp.	21.96±0.36	-	0.19±0.006		12062	73219	0.924	3.63
Richards	28.43±1.16	0.90±0.004	0.20±0.01	0.5±0.00	11226	72383	0.933	3.42

A, asymptotic weight or mature weight; and b, is an integration constant related to initial animal weight. The value of b is defined by the initial values for W and t; k, the maturation rate, which is interpreted as weight change in relation to mature weight to indicate how fast the animal approaches adult weight; m: inflection point of the curve

Predicted live weight

Predicted live weights (kg) as a function of age (months) obtained with different growth models for F1, F2, F3, male, and female kids are shown in Figure 1-6. The deviation of predicted from the actual growth curves for F2 crossbred goats was higher than for F1 and F3 generations. However, the actual and predicted growth curves in F1 and F3 seemed to match well. The predicted live weight of females after nine months was lower than the actual weight, while it was higher for males. The growth was not similar in all age intervals. Growth increased at an increasing rate for up to six months, then increased at decreasing rate for all genotypes and both sexes. However, the change in predicted live weight of F3 crossbred goats using different growth functions was very low compared to other generations. This result is consistent with Trangerud et al. (2007) who divide the growth curve into two phases, i.e., an early phase where the weight gain rate increases and a later phase where the weight gain rate decreases. This suggests that keeping crossbred kids that are over six months of age induces more production costs per kg of meat and thus keeping up to six months of age would be better. In general, the whole pattern of growth was somewhat like the so-called Sigmoid fashion. According to Waheed et al. (2011), growth curves are quite important to make culling and selection decisions.

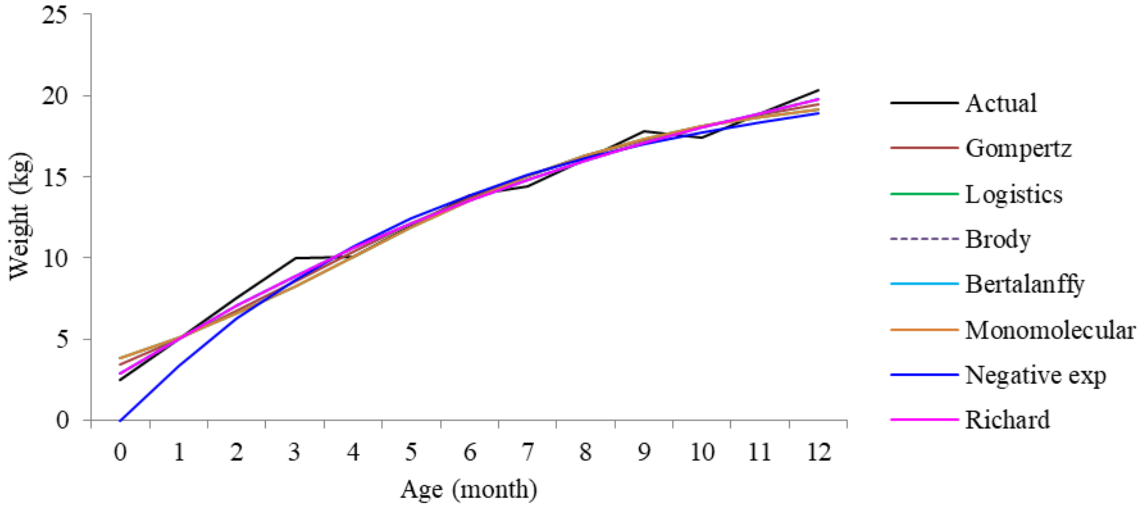

Figure 1. Actual and predicted live weights (kg) as a function of age (months) obtained with different growth models for F1 Boer x Central Highland goats

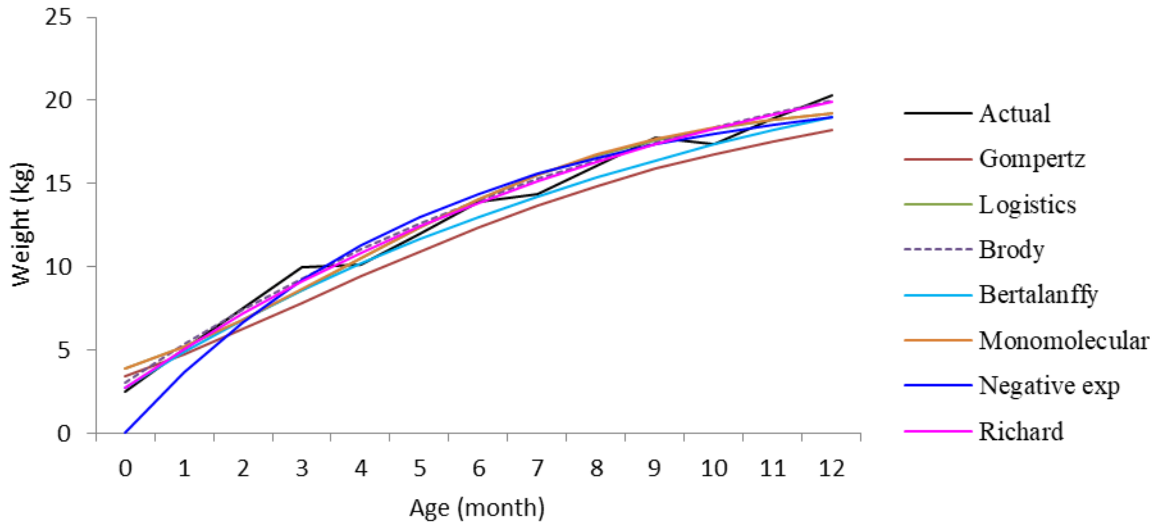

Figure 2. Actual and predicted live weights (kg) as a function of age (months) obtained with different growth models for F2 Boer x Central Highland goats

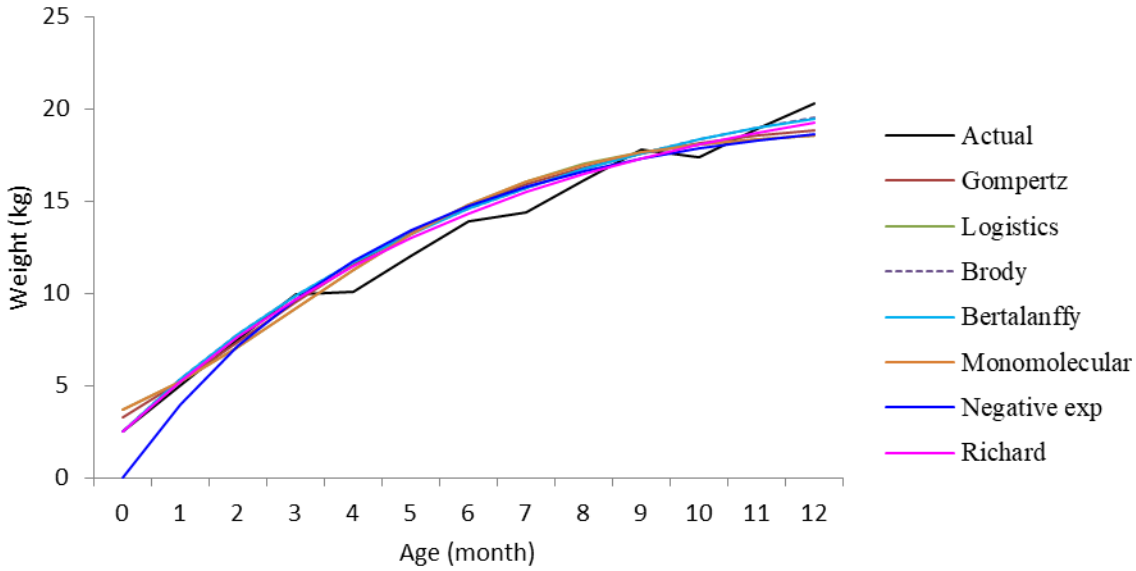

Figure 3. Actual and predicted live weights (kg) as a function of age (months) obtained with different growth models for F3 Boer x Central Highland goats

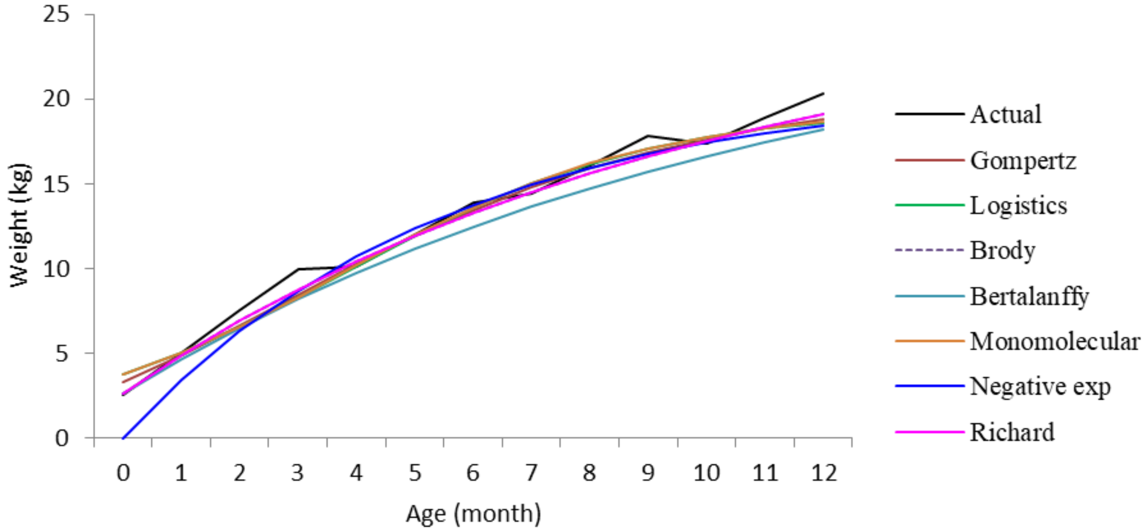

Figure 4. Actual and predicted live weights (kg) as a function of age (months) obtained with different growth models for female Boer x Central Highland goats

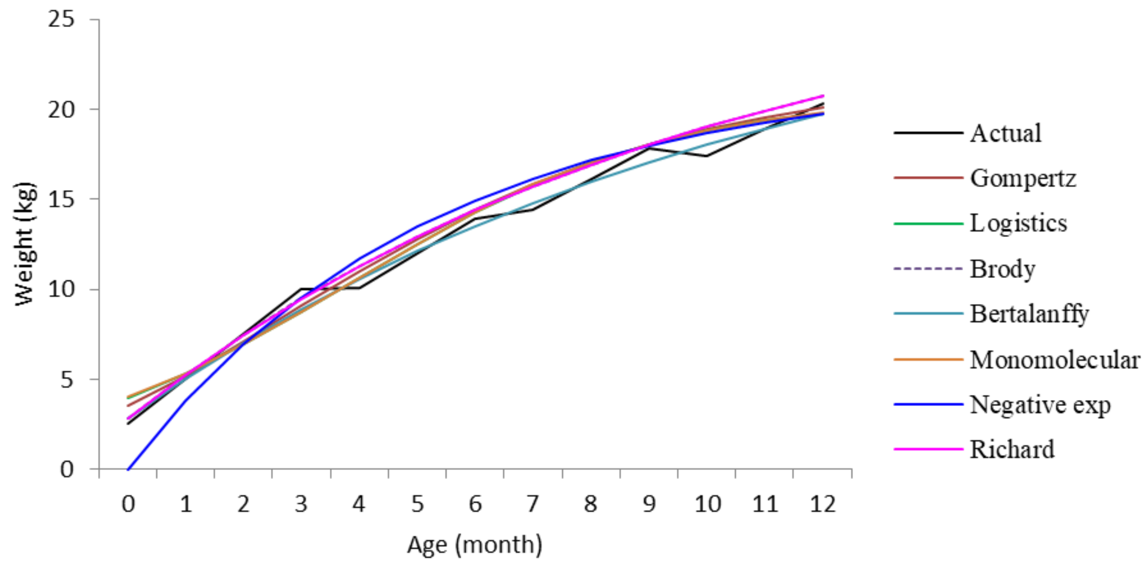

Figure 5. Actual and predicted live weights (kg) as a function of age (months) obtained with different growth models for male Boer x Central Highland goats

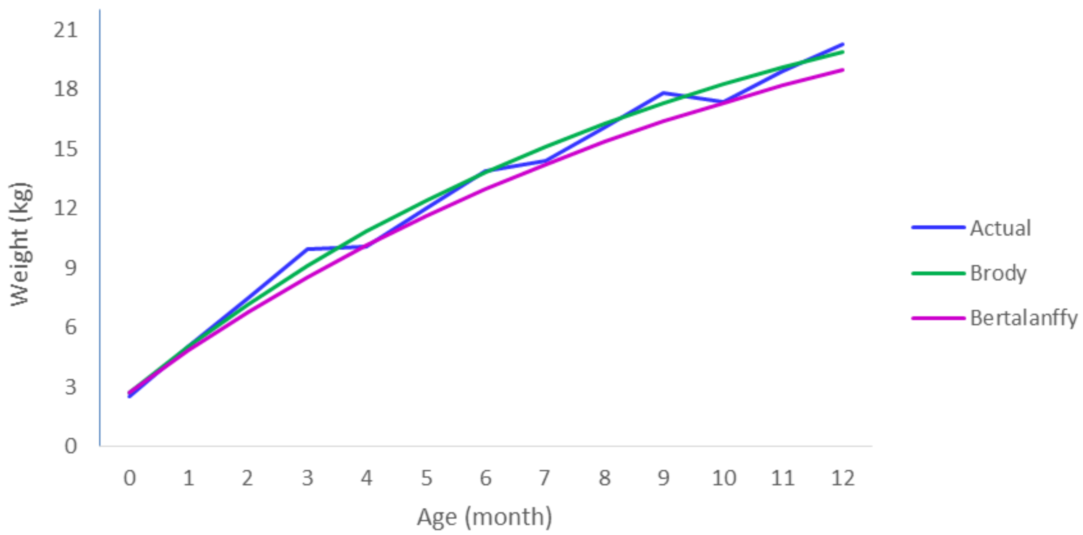

Figure 6. Actual and predicted live weights (kg) as a function of age (months) obtained with different growth models for the best model and actual curve, and all curves (genotypes and sexes) in one graph.

CONCLUSION AND RECOMENDATION

The result indicated that F1 goats had a higher mature weight than F2 and F3. However, the value of the maturation rate tends to increase with the filial generation, which indicates the early maturation of F3 goats with low mature weight. Males had a higher mature weight compared to their female counterparts, although no difference in maturation rate among male and female goats. The growth model could save time and cost as it enables the culling of goats based on early growth parameters and reduce the replacement costs or cost of maintaining poorly performed animals. The Brody and Von-Bertalanffy models can be used for predicting mature live weight and maturation rate of Boer x Central Highland goats and can be used for planning management and breeding strategies.

ACKNOWLEDGMENT

The authors are very grateful to Amhara Agricultural Research Institute.

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Body Mass Index as an Indicator of Meat Production Potential in Yearling Bucks

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ABSTRACT

This study aimed to evaluate the relationships among body mass index (BMI), meat traits, and body energy reserves in yearling bucks. Live weight (LW), heart girth (HG), neck girth (NG), paunch girth (PG), wither height (WH), rump height (RH) and body length (BL) were measured on twenty-four intact yearling bucks. Using these morphological traits and live weight, seven BMIs were computed as BMI1 = LW/HG^2, BMI2 = LW/PG^2, BMI3 = LW/WH^2, BMI4 = LW/RH^2, BMI5 = LW/NG^2, BMI6 = LW/BL^2 and BMI7 = ((LW/WH)/BL)/10. Data were analyzed using the general linear model procedure of Statistical Analysis System software. Meat traits and carcass primal cuts considered in this study were significantly ($P<0.001$) correlated with all BMIs ($r = 0.49$ to 0.86) except with BMI5. Back fat thickness (BFT) and all BMIs except BMI5 had a strong relationship ($r = 0.57$ to 0.67, $P<0.001$). The internal fat (IF) was moderately associated with BMI1, BMI2 and BMI3. The most important predictor variable for hot carcass weight was BMI7 ($R^2 = 0.748$, $P<0.0001$). BMI1 was the most important predictor variable for rib-eye muscle area ($R^2 = 0.542$, $P<0.0001$) and empty body weight ($R^2 = 0.719$, $P<0.0001$). The variation in leg weight was determined largely by a combination of BMI1 and BMI5 ($R^2 = 0.776$, $P<0.0001$). BMI7 was the most important variable for the estimation of most carcass primal cuts (thin, ribs and loin cut). A unit increase in BMI6 corresponds to a 0.68 mm increase ($P<0.0001$) in BFT. The combination of BMI2 and BMI3 was able to predict IF significantly. BMI can be employed as a phenotypic marker to determine meat productivity, primal cuts, and body energy reserves of bucks. Future research should investigate the relationships between different BMIs and goat body composition, reproductive performance, milk yield, and milk composition.

Keywords: *Buck, fat deposit, meat production, morphological traits, slaughter weight*

INTRODUCTION

Goats are a valuable genetic resource for meat, milk, skin, fiber production and they play an essential role in the socio-economic life of rural people in tropical and developing countries (Alade et al., 2010). Goat meat is a popular meat source in developing countries because of its low fat and cholesterol level, although it is less popular in developed countries (Webb, 2014). Goat meat provides enough protein, essential amino acids, vitamins and minerals particularly iron and potassium (Casey *et al*., 2003; Mazhangara *et al*., 2019). Consequently, the demand for this nutritious meat is increasing amazingly. This created tremendous opportunities for goat keepers and a significant number of younger goats are traded in formal, informal, subsistence, and small-scale agricultural systems (Webb, 2014; Mazhangara *et al*., 2019). However, goat producers and traders rely on eye judgment to estimate slaughter weight, carcass weight, and body energy reserves and to judge the nutritional status of goats. Modern techniques like X-ray computer tomography (Lambe *et al*., 2003), ultrasonic scanning (Bedhiaf Romdhani and Djemali, 2006) and dual X-ray absorptiometry (DEXA) allow us to estimate the carcass composition of living animals. Nonetheless, these approaches necessitate a high level of knowledge or need professionally trained personnel, specific equipment, and are costly and thus limited to developed countries. Body condition score (BCS) is employed for determining nutritional status and energy reserves; nevertheless, it is a subjective parameter (Phythian *et al*., 2012; Kenyon *et al*., 2014; McHugh *et a*l., 2019). Furthermore, without specialized equipment, body energy stores in the abdominal cavity, such as glycogen in the liver and intra-abdominal fat, cannot be effectively measured using BCS on live animals (Kenyon *et al*., 2014). Therefore, a quick and user-friendly objective parameter is necessary to estimate carcass features, carcass primal cuts, energy reserves and nutritional status of live goats.

The body mass index (BMI) is a widely used metric for determining how fat a person is (Kinge, 2016; Ortega et al., 2016). Likewise, in small ruminants, BMI has been associated with body mass, carcass composition and body fat reserves and has been suggested as a possible indicator of the nutritional status of small ruminants (Tanaka et al., 2012; Chavíra-Aguilar et al., 2016; Pta´cek et al., 2018). These studies have suggested that BMI can be used to predict carcass and carcass composition in small ruminants. However, research on the prediction of carcass features, primal cuts, and body fat reserves in bucks is scarce.

Body mass index (BMI) is commonly defined as BW (kg)/height^2 in humans. Likewise, this equation has been employed as a BMI for goats (Dønnem *et al.*, 2011; Randby *et al.*, 2015). Tanaka *et al*. (2012) calculated a BMI as {[BW/height]/body length}/10 as well. Recently, Liu et al. (2019) computed BMI from various volumetric measures, evaluated it as a predictor for growth traits in doelings and reveal a good association. Thus, like for growth traits, determining other highly suggestive BMI functions for carcass traits and energy reserves would have an immense economic contribution to goat production, management, breeding and marketing. Besides, important for carcass standardization and selling of goats based on the edible proportion yield. Even so, no study has yet been undertaken to analyze such BMI equations for meat production and body energy reserves in goats, except for Liu et al. (2019), who examined several BMI equations for growth traits of doelings. Therefore, the objective of this study was to identify relationships between different BMIs with the meat production and body energy reserves of yearling bucks.

MATERIALS AND METHODS

Location and animal management

The study was carried out at Sirinka Agricultural Research Center sheep and goat breeding station, which is located at an altitude of 1850 m.a.s.l and 11°45’ 00" N and 39°36’ 36" E. The mean annual rainfall is 950 mm. The area is a moderately warm temperature zone with mean daily temperature ranges of 16-21°C.

Twenty-four clinically healthy yearling bucks (12 Central Highland and 12 Boer x Central Highland) with a mean live weight of 27.5 kg were used. The experimental bucks were raised semi-intensively i.e. grazed/browsed on natural pasture for 6:00 hrs day^{-1} and supplemented with a concentration mix on average of 300 g day^{-1} when returned to their experimental pens in the afternoon. The experimental bucks were housed in individual pens (1.25×0.9 m) equipped with a feeding trough and watering bucket. Goats were vaccinated against common diseases in the area (Pasteurellosis, Sheep and goat pox, and Anthrax) before the commencement of the experiment. Experimental animals were monitored daily by visual appraisal; sick animals were identified and treated accordingly. All experimental protocols and animal care were in accordance with FASS (2010) and were approved by nutrition, health, and welfare researchers. This study is part of a previous study conducted by the same author (Tesema *et al*., 2018).

Morphological trait measurement

Live weight and six morphological traits were measured. The morphological traits were heart girth (HG), paunch girth (PG), neck girth (NG), body length (BL), wither height (WH) and rump height (RH). The morphological measurements were taken when 16:00 hrs left for slaughter using a flexible tape for length and using a graduated measuring stick for height, with the animals standing on a flat surface with their head held up. The morphological trait measurements were taken in the morning by the same person. The morphological traits measured are presented in Figure 1 and described as follow:

1. Heart girth (HG) was measured as a circumferential measure taken around the chest just behind the front legs and withers.
2. Paunch girth (PG) was measured as the circumference of the body immediately after the abdomen just before the hind legs.
3. Neck girth (NG) was measured as the circumference of the neck at the midpoint.
4. Body length (BL) was the distance from the point of the shoulder to the base of the tail.
5. Wither height (WH) was measured as the distance from the surface of a platform to the withers.
6. Rump height (RH) was measured as the distance from the surface of a platform to the rump.
7. Bucks' live weight (LW) was measured in the morning **b**efore they were fed using a suspended spring balance with a 50 kg capacity and 0.2 kg precision. The measurement of these morphological traits is demonstrated in Figure 1 for easy understanding.

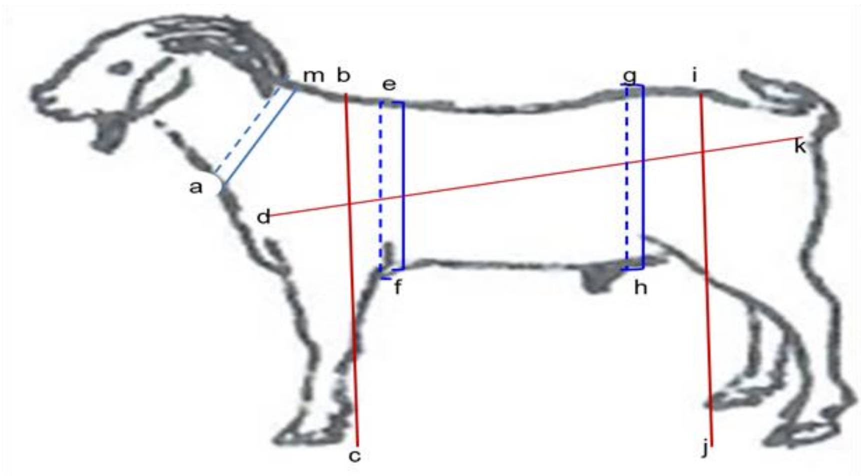

Figure 1. Measurements of morphological traits (a-m = Neck girth, b-c = wither height, e-f = heart girth, g-h = paunch girth, i-j = rump height, d-k = body length)

Body mass indexes (BMI)

Using morphological traits (wither height, neck girth, heart girth, paunch girth, rump height, and body length) and live weight seven body mass index (BMIs) were computed as follow: BMI 1 = LW/HG^2, BMI 2 = LW/PG^2, BMI 3 = LW/WH^2, BMI 4 = LW/RH^2, BMI 5 = LW/NG^2, BMI 6 = LW/BL^2 and BMI 7 = [(LW/WH)/BL]/10, where LW is the live weight, HG is the heart girth, PG is the paunch girth, WH is the wither height, RH is the rump height, NG is the neck girth and BL is the body length. Some of the functions were determined previously; for example, BMI3 was evaluated by other scholars (Dønnem et al., 2011; Randby et al., 2015), BMI7 was determined by Tanaka *et al*. (2012), and other functions such as BMI1, BMI3, and BMI4 were evaluated for growth traits of doeling by Liu et al. (2019), but not for carcass traits. However, BMI2, BMI5, and BMI6 were determined and evaluated in this study. Therefore, to the best of our knowledge, BMI1, BMI2, BMI4, BMI5, BMI6 and BMI7 were new combinations of morphological traits, which were evaluated for the prediction of carcass traits and body energy reserves in this study only.

Meat traits and carcass primal cuts

Goats fasted for 16 hours before slaughter with free access to water and slaughter weight (SBW) was measured immediately before slaughter. The animals were humanely slaughtered and dressed down using standard commercial techniques. After slaughter, the heads were removed at the atlanto-occipital joint, while the fore and hind legs were removed at the carpal and tarsal joints, respectively. The difference between SBW and the contents of the gastrointestinal tract is called empty body weight (EBW). Hot carcass weights (HCW) were measured immediately after slaughter and removal of non-carcass components. Dressing percentage (DP) was defined as the HCW expressed as a percentage of SBW. Rib eye-muscle area (REM) and back-fat thickness (BFT) were measured at the 12-13th rib position. Goats accumulate more internal fat, which is not associated with the carcass and thus internal fat (IF) is a sum of fats from the kidney, pelvic, heart, omental and mesenteric. After weighing, the carcass was partitioned into five primal cuts: loin, leg, thin cut, ribs and neck + shoulder + foreleg (Figure 2).

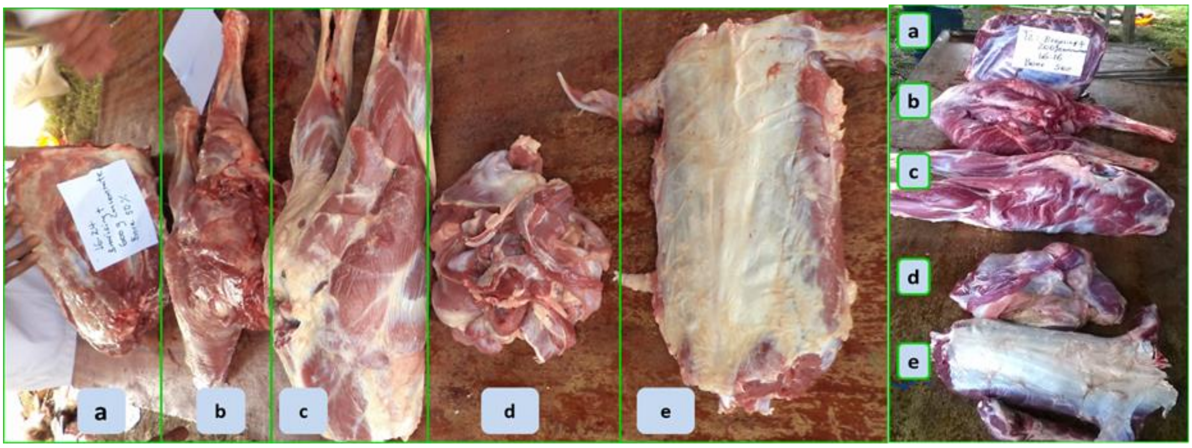

Figure 2. Description of carcass primal cuts (a = ribs, b = foreleg + shoulder + neck, c = leg, d = thin cut, e = loin)

Statistical analysis

The PROC MEANS procedure was used to calculate descriptive statistics for dependent and explanatory variables. The relationships of body mass indexes (BMI) with carcass traits and body energy reserves were computed via the Pearson correlation coefficient using the PROC CORR procedure in SAS (2002). The multivariate relationship between BMI, meat traits, carcass primal cuts, and body energy reserves was analyzed through a principal component analysis (PCA). Stepwise multiple regression procedure using PROC REG procedure in SAS (2002) with the inclusion P-value of 0.05 was used to predict meat traits, carcass primal cuts and body energy reserves from the explanatory variables (BMIs). Variables that did not significantly ($P > 0.05$) contribute to the model were eliminated. The goodness of fit of the developed equations was assessed by using a coefficient of determination (R^2). The regression model is presented as follow:

$$Y_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + e_i$$

Where,

Y_i is the response variable such as carcass traits, primal cuts and body energy reserves,

α is the intercept of the regression equation,

β_1, β_2, …., *and* β_7 are regression coefficient of the variables X_1, X_2 ....., *and* X_7;

X_1, X_2, and X_7 are the predictor variables or BMI1, BMI2, BMI3, BMI4, BMI5, BMI6 and BMI7, respectively, e_i is the residual random error.

RESULTS AND DISCUSSION

Description of carcass traits, primal cuts, body energy reserve and body mass index

The mean value of BMIs, carcass traits, carcass primal cuts, and body energy reserves are presented in Table 1. The mean value of slaughter live weight, empty body weight, carcass weight, and dressing percentage were 25.4±5.33 kg, 23.5±5.08 kg, 12.4±3.01 kg, and 48.4±2.41 %, respectively. Body energy reserves and carcass primal cuts showed a higher variability among individual animals relative to other traits. A similar observation has been made by Chavarría-Aguilar et al. (2016) for Pelibuey sheep and Fernandes et al. (2010) for cattle. Although BMI is a widely used metric for determining how fat a person is (Ortega et al., 2016), nowadays, it has been associated with body mass, carcass compositions and nutritional status of small ruminants (Tanaka et al., 2012; Chavíra-Aguilar et al., 2016; Pta´cek et al., 2018). The value of BMI could be affected by genetic factors, environmental factors, developmental factors, age and sex of animals.

Table 1. Descriptive analysis of BMI, carcass traits and body energy reserves of yearling bucks

Variables	Description	Mean ± SD	Minimum	Maximum	CV (%)
SBW	Slaughter body weight (kg)	25.4±5.33	16.0	36.2	21.0
HCW	Hot carcass weight (kg)	12.4±3.01	7.40	18.7	24.3
EBW	Empty body weight (kg)	23.5±5.08	14.4	33.7	21.6
DP	Dressing percentage (SBW) in %	48.4±2.41	43.9	52.9	4.98
REM	Rib eye muscle area (cm^2)	11.2±2.98	6.55	20.3	26.5
Thin cut	Thin cut (kg)	0.64±0.23	0.27	1.19	26.5
L+S+N	Fore leg + shoulder + neck (kg)	4.56±1.13	2.70	6.90	24.9
Ribs	Ribs (kg)	2.47±0.61	1.50	3.70	25.0
Loin	Loin (kg)	0.88±0.24	0.50	1.50	27.4
Leg	Leg (kg)	3.90±0.85	2.30	5.60	21.8
BFT	Back fat thickness (mm)	3.06±1.01	1.00	5.00	26.0
IF	Internal fat (kg)	0.14±0.08	0.02	0.32	28.1
BMI1	BMI-Heart girth (g cm^{-2})	5.96±0.69	4.88	7.40	11.6
BMI2	BMI-Paunch girth (g cm^{-2})	5.53±0.68	4.16	6.92	12.4
BMI3	BMI-Wither height (g cm^{-2})	6.47±1.33	4.57	9.18	20.6
BMI4	BMI-Rump height (g cm^{-2})	6.54±1.34	4.73	8.86	20.5
BMI5	BMI-Neck girth (g cm^{-2})	16.6±1.09	14.2	18.5	6.58
BMI6	BMI-Body length (g cm^{-2})	7.93±1.08	6.26	9.77	13.6
BMI7	BMI-Wither height and body length (g cm^{-2})	7.15±1.19	5.35	9.47	16.7

SBW= slaughter weight, HCW= hot carcass weight, EBW= empty body weight, DP= dressing percentage, REM= rib-eye muscle area, L+S+N= foreleg + shoulder + neck, BFT= back fat thickness, IF= internal fat

Relationship of BMIs to meat traits and body energy reserves

Different equations of BMI were evaluated in this study and their relationship with meat traits is shown in Table 2 and Figure 3. Meat traits and carcass primal cuts had a higher correlation ($r = 0.49$ to 0.86, $P<0.001$) with all body mass indexes except with BMI5. Likewise, in Figure 3, the angle between vectors of variables shows the correlation among them, i.e. the low and high angle between vectors indicates a strong and low correlation, respectively. In addition, the more parallel to a principal component axis is a vector, the more it contributes only to that principal component.

Since there is not enough information about the relationship between BMI and meat production in goats, particularly in bucks, information on sheep is used in part of the discussion. The positive association of BMI7 with meat production traits was noted in sheep in several studies (Chavarría-Aguilar *et al*., 2016; Pta´cek et al., 2018; Costa *et al*., 2020). The known equation for BMI is BW (kg)/height^2 in humans and this equation has been employed as a BMI for goats (Dønnem et al., 2011; Randby *et al*., 2015). Besides, Tanaka *et al.* (2012) calculated a BMI as {[BW (kg)/height (m)]/body length (m)}/10. Liu *et al.* (2019) also computed BMIs from other volumetric measures, evaluated them as a predictor of growth in goats and reveal good association. Likewise, other newly developed equations in this study were highly correlated to meat productivity and body energy reserves, besides the known equation. This suggests that various body mass indices could be used to predict meat traits in yearling bucks and thus can be utilized as a selection criterion and can help goat management, particularly in low-input production systems when there isn't enough performance data.

Among body energy reserve traits, back-fat thickness (BFT) was significantly associated with all BMIs ($r = 0.57$ to 0.67, $P<0.001$) except with BMI5 (Table 2). Likewise, internal fat (IF) was positively correlated with BMI1, BMI2 and BMI3. In line with this result, a significant relation between BMI7 and body energy reserves was reported in goats (Tanaka *et al*., 2012) and sheep (Chavarría-Aguilar *et al*., 2016; Pta´cek *et al.*, 2018; Costa et al., 2020). This moderate level of correlation indicates that body energy reserves can be predicted using a single or combination of BMIs.

Table 2. Correlation estimate among dependent and explanatory variables in yearling bucks

Variables	BMI1	BMI2	BMI3	BMI4	BMI5	BMI6	BMI7
Meat traits							
SBW	0.84***	0.77***	0.81***	0.81***	0.12^{ns}	0.84***	0.85***
EBW	0.85***	0.78***	0.80***	0.80***	0.15^{ns}	0.82***	0.83***
HCW	0.84***	0.76***	0.83***	0.83***	0.08^{ns}	0.86***	0.86***
DP	0.58***	0.49***	0.59***	0.61***	-0.18^{ns}	0.64***	0.63***
REM	0.73***	0.61**	0.67***	0.70***	0.09^{ns}	0.72***	0.71***
Carcass primal cuts							
Thin cut	0.81***	0.73***	0.83***	0.82***	0.13^{ns}	0.85***	0.86***
L+S+N	0.79***	0.73***	0.75***	0.78***	0.01^{ns}	0.81***	0.80***
Ribs	0.87***	0.83***	0.84***	0.86***	0.15^{ns}	0.86***	0.87***
Loin	0.80***	0.72***	0.79***	0.77***	0.12^{ns}	0.77***	0.81***
Leg	0.85***	0.77***	0.77***	0.79***	0.11^{ns}	0.84***	0.82***
Energy reserves							
BFT	0.58***	0.57***	0.60**	0.63***	0.10^{ns}	0.67***	0.64***
IF	0.35**	0.50***	0.45**	0.13^{ns}	0.12^{ns}	0.20^{ns}	0.15^{ns}

SBW= slaughter weight, HCW= hot carcass weight, EBW= empty body weight, BFT= back fat thickness, IF= internal fat, REM= rib eye muscle area

BMI1= BMI-Heart girth, BMI2= BMI-Paunch girth, BMI3= BMI-Wither height, BMI4= BMI-Rump height, BMI5= BMI-Neck girth, BMI6= BMI-Body length, BMI7= BMI-Wither height & body length

Ns= P>0.05, ***= P<0.001, **= P<0.01, *= P<0.05

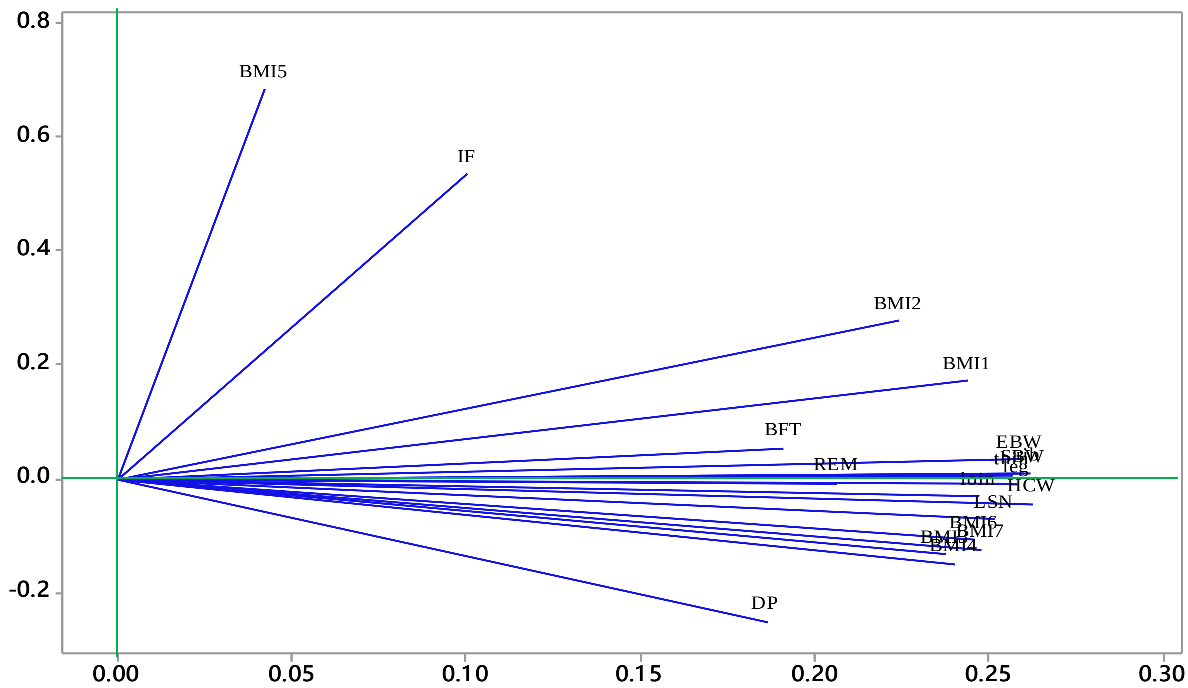

Figure 3. Multiple relations of evaluated traits of yearling bucks

SBW= slaughter weight, HCW= hot carcass weight, EBW= empty body weight, BFT= back fat thickness, IF= internal fat, REM= rib eye muscle area
BMI1= BMI-Heart girth, BMI2= BMI-Paunch girth, BMI3= BMI-Wither height, BMI4= BMI-Rump height, BMI5= BMI-Neck girth, BMI6= BMI-Body length, BMI7= BMI-Wither height & body length

Prediction of meat production and body energy reserves

Estimating a live animal's meat production potential is critical for marketing, management, and selection of goats where no advanced records exist. Indeed, modern technologies like X-ray computer tomography (Lambe *et al*., 2003), ultrasonic scanning (Bedhiaf Romdhani and Djemali, 2006) and dual X-ray absorptiometry (DEXA) allow us to estimate the carcass composition of living animals. However, these techniques are not applicable in developing countries due to technical and non-technical issues. Therefore, the prediction equations for meat production and body energy reserve were developed using easily measurable traits (Table 3). The most important variable for slaughter body weight (R^2 = 0.719, P<0.0001) and hot carcass weight (R^2 = 0.748, P<0.0001) were determined to be BMI7 which is a combination of wither height and body length. The inclusion of BMI1 in the model besides BMI7 increases the coefficient of determination (R^2 = 0.768) for slaughtered body weight. This result is in harmony with that of Chavarría-Aguilar et al. (2016), who noted that BMI7 could predict muscle tissue in Pelibuey sheep with a 0.66 coefficient of determination. Since there is not enough information about the relationship between BMI and meat production in goats, information on sheep is used in part of the discussion. Pta´cek et al. (2018) demonstrated the possibility of estimating *musculus longissimus lumborum et thoracis* depth in sheep using BMI7 (R^2 = 0.15). However, in this study, BMI1 was found to be the most accurate predictor variable for rib-eye muscle area (R^2 = 0.542, P<0.0001) and empty body weight (R^2 = 0.719, P<0.0001). This variation could be due to species differences. In this study, the BMI6 is the only variable that can predict the dressing percentage of bucks.

The need for meat cuts is varied among countries. The dorsal trunk, loin, and hind limb cuts are the most preferred cuts in Western countries. By contrast, the cuts from the breast region had a high preference in some African and Asian countries (Casey, 1982; Simela, 2005). It is worth noting that BMI7 was the single most essential variable, together with other variables, for accurately estimating most carcass primal cuts (thin, ribs and loin cut). According to Costa et al. (2020), BMI7 alone could not significantly predict leg weight. However, in this study, the variation in leg weight was determined largely by BMI1 alone (R^2 = 0.72, P<0.0001). Moreover, the accuracy of the prediction improved significantly when BMI1 was utilized in conjunction with BMI5. In this study, the most important variable for the foreleg + neck + shoulder cut was determined to be BMI6 (R^2 = 0.663, P<0.0001). Costa *et al.* (2020) demonstrated that BMI7 and its combination with body condition score could predict shoulder weight in sheep. These results indicated that BMI can be utilized to estimate the weight of carcass primal cuts in bucks.

In Ethiopia, lean meat is preferred in highland, semi-urban, and metropolitan areas, whereas meat with fat is preferred in lowland rural communities (Tesema *et al*., 2022). Therefore, estimating the fat deposit of live goats would be critical for consumers' preference and management of goats. Besides, it enables the goat keepers to finish bucks with more muscle and less associated fat. In fact, a minimal amount of subcutaneous fat is important for storage during chilling and good carcass presentation (Cadavez and Henningsen, 2012) as well as important organoleptic attributes of the meat are determined by fat content (Sinanoglou *et al*., 2013). The prediction of body energy reserve using BMI7 was noted in previous studies in goats (Tanaka et al., 2012), sheep (Chavarría-Aguilar *et al*., 2016; Pta´cek *et al*., 2018; Costa *et a*l., 2020) and humans (Ortega *et al*., 2016). Even so, BMI6 significantly predicted the back-fat thickness and when one point of BMI6 increase corresponds to a 0.68 mm increase (P < 0.0001) in back-fat thickness. This indicates that improvement in estimation is possible via the inclusion of the measure of length. Likewise, the combination of BMI2 and BMI3 could predict internal fat amount in bucks. These two BMI were not evaluated for estimation of body energy reserve in previous studies. This indicates that evaluation of BMI computed using height, circumference and volumetric measurements would be essential to estimate the body energy reserve of a live goat.

Table 3. Regression equation describing the relationship of BMI with meat production in bucks

	Traits	Model	R^2	P-value
Carcass traits	Slaughter body weight (kg)	-1.65 + 3.78*BMI7	0.719	<.0001
		-7.92 + 2.09*BMI7 + 3.37*BMI1	0.768	<.0001
	Empty body weight (kg)	-13.5 + 6.21*BMI1	0.719	<.0001
	Hot carcass weight (kg)	-3.20 + 2.17*BMI7	0.748	<.0001
	Rib eye muscle area(cm^2)	-7.61+ 3.16*BMI1	0.542	<.0001
	Dressing percentage (%)	37.0 + 1.43*BMI6	0.414	0.0007
Carcass primal cuts	Thin cut (kg)	-0.56 + 0.17*BMI7	0.745	<.0001
	Fore leg + Neck + Shoulder (kg)	-2.21+0.85*BMI6	0.663	<.0001
	Ribs (kg)	-0.77 + 0.45*BMI7	0.771	<.0001
		-1.64 + 0.29*BMI7 + 0.35*BMI2	0.837	<.0001
	Loin (kg)	-0.29 + 0.16*BMI7	0.656	<.0001
	Leg (kg)	2.32 + 1.04*BMI1	0.720	<.0001
		0.27 + 1.16*BMI1 – 0.20*BMI5	0.776	<.0001
Body energy reserve	Back fat thickness (mm)	-2.35 + 0.68*BMI6	0.448	<.0001
	Internal fat (kg)	-0.19 + 0.06*BMI2	0.251	0.0127
		-0.24 + 0.11*BMI2 – 0.03*BMI3	0.385	0.0061

BMI1= BMI-Heart girth, BMI2= BMI-Paunch girth, BMI= BMI-Wither height, BMI4= BMI-Rump height, BMI5= BMI-Neck girth, BMI6= BMI-Body length, BMI7= BMI-Wither height & body length

a= the intercept of the regression equation, β_1 and β_2= regression coefficient of explanatory variables, R^2= coefficient of determination

CONCLUSION

All BMIs except for BMI5 had a moderate to high correlation with meat traits, carcass primal cuts and body energy reserve. This favorable relationship of BMIs with meat production traits and body energy reserve showed it as a suitable selection marker to improve the meat productivity and management of goats. BMI7 was the most important variable for the estimation of most carcass traits and carcass primal cuts. BMI6 significantly predicted the back-fat thickness and a combination of BMI2 and BMI3 could predict the internal fat amount. Besides, BMI allows for a continuous evaluation of the body composition changes during goats growth period. Future research should be conducted to investigate the associations between different BMIs and body composition, reproductive performance, milk yield and milk composition of goats.

ACKNOWLEDGMENTS

The authors are very grateful to the livestock research directorate staff of Sirinka Agricultural Research Center and Debre Birhan Agricultural Research Center (Asfaw Bisrat, Ayele Abebe and Tesfaye Zewdie). Ethiopian Institute of Agricultural Research and Amhara Agricultural Research Institute financially supported this work. Thus, the authors would like to thank these institutions.

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Estimation of Genetic and Crossbreeding Parameters for Reproductive Traits of Boer x Central Highland Goats in Ethiopia

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ABSTRACT

Breed additive, heterosis, recombination effect, heritability and repeatability estimates for reproductive traits were estimated. Pedigree information and performance records of breeding females comprise of Central Highland (CH) and their crosses with Boer (B) goats were collected from 2009 to 2018. Least-squares means for genotype were obtained using a General Linear Model procedure of SAS by fitting genotype as a fixed group effect. For the estimation of crossbreeding parameters, breed additive, heterotic, and recombination effects were fitted as fixed covariates instead of genotypes. Variance, heritability, and repeatability estimates were estimated through AI-REML algorithm using WOMBAT software. Genotype did not have a significant influence on most of the reproductive traits except for gestation length (GL). The additive effect for litter size at birth (LSB), total litter birth weight (LBW), total litter weaning weight (LWW), litter size at weaning (LSW) and GL was estimated to be -0.004, 0.08, -3.18, -0.54, and 3.69, respectively. The contribution of heterosis to LSB, LWW and GL of crossbred goats was negative, while the estimates for LBW and LSW were positive. However, the heterosis effect and direct additive contribution of Boer goats on reproductive traits were not significant except for LSW. The recombination effect was not significant for all reproductive traits examined. The direct heritability estimate for LSB, LWB, LWW, LSW and GL were 0.050, 0.098, 0.086, 0.018 and 0.00, respectively. The repeatability estimates for LSB, LWB, LWW, LSW, and GL were 0.149, 0.116, 0.099, 0.086, and 0.061, respectively. Improvement in reproductive traits would not be expected by crossing Boer with Central Highland goat. Heritability estimates indicate that the improvement of reproductive traits through selection would be small and the repeatability

estimates indicate that multiple records would have to be used to make a decision of culling or selection.

Keywords: *Breed additive, heritability, heterosis, recombination effect, repeatability*

INTRODUCTION

Genetic improvement of indigenous goats through crossbreeding is a major way to enhance productivity quickly as it is used to exploit both additive and heterosis effects (Schiermiester, 2014; Williams *et al*., 2014). On account of this, milk-type exotic breeds such as Anglo-Nubian, Saanen, Toggenburg and meat-type Boer goats have been introduced to Ethiopia with the aid of different non-governmental and governmental institutions since 1975 (Tesema *et al*., 2022). Boer goat is known for their better growth rate and meat production. On the other hand, Ethiopian indigenous goats are resistant to disease, heat and drought. Thus, Boer goat was crossed with Central Highland, Abergelle and Woyito-Guji goat breeds of Ethiopia to combine productivity and adaptability through crossbreeding. These crossbreds were dispatched to smallholder farmers for crossing and improving productivity.

Genetic evaluation of the performances of crossbred animals is quite important for further expansion of that genotype or changing to the appropriate crossbreeding scheme or breeding system for the future (Tesema *et al*., 2020; Tesema *et al*., 2021). Differences among breed effects relative to magnitudes of heterosis and recombination effects are the major determinants of the efficiency of various crossbreeding systems (Gebrelul *et al*., 1994). For the planning of an effective crossbreeding program, information on the relative performances of breeds and their crosses, particularly under various environmental conditions, is also required (Haile et al., 2011). Indeed, estimates of genetic parameters for reproductive traits of different goat breeds have been reported by several scholars (Zhang *et al*., 2009; Rashidi *et al*., 2011; Kebede *et al*., 2012; Mohammadi *et al*., 2012; Mia *et al*., 2013; Menezes et al., 2016). However, the estimates are affected by breed, genetic composition in the population (Zhang *et al*., 2009) and environment. Besides, regarding Boer goats, the previous studies in Ethiopia are limited to performance evaluation, identification of non-genetic factors (Belay *et al*., 2014; Deribe *et al*., 2015; Tesema *et al*., 2020b; Tesema et al., 2021) and estimation of genetic parameter estimates for growth traits (Tesema *et al*., 2020a). A review of the literature by the authors showed that there is a lack of estimates of genetic and crossbreeding parameters such as additive, heterosis, and recombination effects for reproductive traits of

Boer x Central Highland goats. Therefore, the objective of this study was to estimate the crossbreeding and genetic parameters for the reproductive traits of Boer x Central Highland goats.

MATERIAL AND METHODS

Animals and management

The study was carried out at Sirinka Agricultural Research Center shoat breeding station, which is located at an altitude of 1850 m.a.s.l and at 11°45' 00" N and 39°36' 36" E. The mean annual rainfall amount is on average about 950 mm. The area has a minimum and maximum mean daily temperature of 13.7 and 26.4 °C, respectively, making it a moderately warm climate zone. A semi-intensive management system, which is defined by a moderate level of production inputs, was used to handle the animals. They were allowed to graze or browse on the natural pasture during the daytime approximately for six hours. In addition, goats supplemented with 0.10 to 0.40 kg concentrate mixture (consisting of wheat bran, *Noug* seed cake, and salt) depending on their age, physiological status, and sex. They were housed according to their sex, physiological status, sex, and health status. They received water *ad libitum* and were vaccinated against common diseases in the area, treated, de-wormed, and sprayed regularly. Each kid was given a unique identifying number, and within 24 hours of birth, the birth weight was determined. Kids were kept indoors for 3-5 days with their dams and after five days, dams were kept outside and kids were allowed to suckle three times a day until weaning age (90 days).

A single sire was assigned for 20–30 does for a service period covering two oestrous cycles. Indigenous Central Highland does were mated with pure Boer bucks to produce F1 crossbreds with 50% Boer level. F2 crossbreds were produced through *inter se mating* of F1 males and females. Female crossbred progenies with 50% Boer level were crossed with pure Boer bucks to upgrade to a high Boer level (75%). To create crossbreds with a 25% Boer level, pure female Central Highland goats and crossbred bucks with a 50% Boer level were crossed (Tesema *et al*., 2021). Tesema *et al*. (2020a) and Tesema *et al*. (2020b) have reported a detailed description of flock management.

Data and studied traits

Pedigree and performance records related to reproductive traits of 567 breeding female goats comprised of Central Highland (CH) and their crosses with Boer (B) goats were collected from 2009 to 2018. The crossbred does include four genetic groups: 50% F1 B x CH, 50% F2 B x CH, 25% BCH x CH and 75% B x BCH backcrosses. The number of goats in each genotype group is shown in Table 2. The dataset includes the animals, sire, dam, mating date, kidding date, kid sex, type of birth, parity of dam when kidding, and records of live weight of kids at different ages. The studied traits include litter size at birth (LSB), total litter birth weight (LBW), litter size at weaning (LSW), total litter weight at weaning (LWW) and gestation length (GL). LSB is the number of kids born per doe, LBW is the total weight of kids born per doe, LSW is the total number of kids weaned per doe, LWW is the total weight of kids weaned per doe and GL is the number of days between mating and kidding.

Statistical analysis

Least-squares means for the effect of genotypes were obtained using GLM procedure of SAS (2002) with fixed effects of genotype, year of kidding, season of kidding, birth type, sex of kids and parity of dam. The statistical model is presented as follow:

Model 1. Least-square mean estimation:

$$Y_{ijklmno} = \mu + A_i + B_j + D_k + T_l + G_m + F_n + e_{ijklmno}$$

Where $Y_{ijklmno}$ is the dependent variables, μ is the overall mean, A_i is the effect of i^{th} parity of doe (five classes: 1, 2, 3, 4 and ≥5), B_j is the effect of j^{th} genotype (five classes: CH x CH, F1 B x CH, F2B x CH, B x BCH, and BCH x CH), D_k is the effect of k^{th} year of kidding (nine classes: 2009-2018), T_l is the effect of l^{th} season of kidding (three classes: dry, main rain and short rain), G_m is the effect of m^{th} sex of kid (two classes: male and female), F_n is fixed effect of n^{th} birth type (two classes: single and multiple) and $e_{ijklmno}$ is random error term associated with each observation.

Multiple regression approach developed by Robison et al. (1981) was used to estimate the crossbreeding parameters. The coefficient of expected breed additive (g_i), heterozygosity (h_{ij}), and recombination (r_{ij}) effects were fitted as covariates to compute breed additive, heterosis and recombination loss. In addition to these covariates, the fixed effects in model 1 except genotype were fitted. The breed additive effect for Boer was estimated as deviations from the Central Highland goat breed. The expected coefficients used for crossbreeding parameter estimation for doe productive traits (Table 1) were derived according to the procedure of Dickerson (1973) and Wolf *et al*. (1995) as follows:

$g_i = 1/2(\alpha^s_i + \alpha^d_i)$

$h_{ij} = \alpha^s_i \alpha^d_j + \alpha^s_i \alpha^d_j$

$r_{ij} = 4g_ig_j - h_{ij}$

Where α^s_i and α^d_i denote the gene proportion of breed 'i' in the sire and dam of the animal, respectively. In addition, g_i is the breed additive effect, h_{ij} is heterosis, and r_{ij} is the recombination loss.

Without actually breeding the animals, it is crucial to estimate crossbreeding characteristics in order to predict the performance of untested genotypes, and thus enable to make a choice of breeding systems (Dickerson, 1973; Kinghorn and Vercoe, 1989; Demeke *et al*., 2003). Therefore, a prediction was made for each genotype examined for investigated traits according to Lynch and Walsh (1998) and Demeke *et al*. (2003):

$\bar{\boldsymbol{y}} = \boldsymbol{\beta a}$

Where $\bar{\boldsymbol{y}}$ is the predicted mean for each genotype, $\boldsymbol{\beta}$ is the matrix of expected genetic contribution (breed additive, heterosis, and recombination loss) and $\boldsymbol{a}$ is a vector of estimated crossbreeding parameters including the overall mean.

Table 1. Genetic coefficient used for crossbreeding parameter estimation for reproductive traits

Genetic group (S x D)	Generation and blood level	g	h	r
CH x CH	Indigenous	0.00	0.00	0.00
B x CH	F1 (50%)	0.50	1.00	0.00
B x BCH	BC1 (75%)	0.75	0.50	0.25
BCH x CH	BC1 (25%)	0.25	0.50	0.25
BCH x BCH	F2 (50%)	0.50	0.50	0.50

S, sire; D, dam; B, Boer goat; CH, Central Highland goat; F1, first filial generation, F2, second filial generation; BC1, back cross one; g, breed additive; h, hetrosis; r, recombination

Variance components, heritability and repeatability estimates were estimated through AI-REML algorithm using WOMBAT software (Meyer, 2007). Since the number of does with records for each genotype was inadequate, genetic parameters could not be estimated separately for each genotype. Heritability (h^2) = σ^2_a / σ^2_p and repeatability (r) = σ^2_a + σ^2_c / σ^2_p, where σ^2_a is the direct additive genetic variance, σ^2_c is the permanent environmental variance and σ^2_p is phenotypic variance. The animal model used for analyses of reproductive performance traits was the following:

$$Y = X\beta + Z_a a + Z_c c + e$$

Where **y** is the vector of observations for the dependent variable or reproductive traits (LSB, LBW, LSW, LWW and GL); **X** is the incidence matrix of fixed effects of reproductive traits and β is the corresponding vector of fixed effects; Z_a is the incidence matrix of the direct additive genetic effects; a is the vector of direct additive genetic effects associated with the Z_a incidence matrix; Z_c is the incidence matrix of the permanent effects of the dams; **c** is the vector of permanent environmental effects of dams associated with the Z_c incidence matrix; **e** is the vector of residual random effects associated with the observations.

RESULTS AND DISCUSSION

Genotype effect

The least-squares means of reproductive traits for different genotypes are presented in Table 2. The overall mean for LSB, LBW, LWW, LSW and GL were 1.54±0.02 kids, 3.90±0.05 kg, 14.0±0.35 kg, 1.37±0.02 kids and 148.1±0.31 days, respectively. Tesema *et al*. (2020b) have previously reported the least-squares means for various fixed effects (including year, season, birth type, and sex) and their effect on reproductive traits. Year of kidding, birth type, and parity of dam significantly influenced most of the traits considered in this study. However, genotype had no significant influence on most of the reproductive traits investigated except for GL. CH x CH dams had an extended gestation length than BCH x CH dams. In terms of LSB, LWB, LWW and LSW, indigenous goats (CH x CH) and crossbred does with 25% Boer level (BCH x CH) showed a tendency to perform better than other genotypes, although the difference was not significant (P>0.05). In line with this result, the absence of a significant difference in reproductive traits among indigenous and Boer crossbred dams was noted in several studies (Nguluma *et al*., 2013; Khanal, 2016; Mustefa et al., 2019). According to this result, the indigenous Central Highland dams tended to perform similarly in all traits to the crossbred dams, or crossing Boer goats with Central Highland goats had not improved the productive traits of the crossbred does.

Table 2. Least-squares means and their standard errors for doe productive traits

Genetic group (S xD)	N	LSB	LBW	N	LWW	LSW	N	GL
Overall mean	567	1.54±0.02	3.90±0.05	478	14.0±0.35	1.37±0.02	303	148.1±0.31
Significance		ns	ns		ns	ns		*
CH x CH	275	1.57±0.03	4.00±0.08	243	14.3±0.57	1.40±0.03	99	149.2±0.39[a]
B x CH	214	1.49±0.03	3.83±0.07	174	13.6±0.44	1.35±0.03	147	148.1±0.55[ab]
B x BCH	27	1.52±0.11	3.55±0.25	20	12.8±1.22	1.20±0.09	19	147.1±1.09[ab]
BCH x CH	19	1.73±0.10	4.08±0.31	17	15.4±2.58	1.47±0.12	12	145.2±0.53[b]
BCH x BCH	32	1.59±0.09	3.70±0.24	24	13.1±1.57	1.33±0.09	26	146.4±0.74[ab]

Means with different superscripts in each subclass within a column differ significantly ($P < 0.05$) from each other. Ns, non-significant ($P>0.05$); *, $P<0.05$; S, sire; D, dam; B, Boer goats; CH, Central Highland goats;N, number of observations; LBW, total litter birth weight; LSB, litter size at birth; LWW, total litter weaning weight; LSW, litter size at weaning; GL, gestation length

Crossbreeding parameter estimates

The estimates of additive and non-additive genetic effects (heterosis and recombination) are shown in Table 3. The additive effect for LSB, LBW, LWW, LSW and GL was estimated to be -0.004, 0.08, -3.18, -0.54 and 3.69, respectively. It was significant for LSW and the number of kids weaned was significantly reduced due to crossing. However, the direct additive contribution of Boer goats on other reproductive traits was not significant (P>0.05). This suggests that improvement in reproductive traits is not expected by crossing Boer with Central Highland goats. The failures of the Boer breeding females to express their potential under the existing management level could explain the lower and non-significant additive genetic contribution in this study.

The contribution of heterosis to LSB, LWW and GL of crossbred goats was unexpectedly negative, while the estimates for LBW and LSW were positive. However, the mean direct heterosis was significant only for LSW and the heterosis estimate for LSW was slightly superior to the parental breed, with 0.27 kids. The heterosis estimate obtained for LSB and LBW in this study is in agreement with Boujenane *et al*. (1991) and Atashi and Izadifar (2012), respectively. In contrast, a significant heterosis effect for LBW and LWW was noted in the crossbreeding program with Syrian and Turkish Awassi sheep strains (Haile *et al*., 2019). In addition, Fadili and Leroy (2001) reported a significant heterosis effect for LSW and LWW in the crossing of D’man and Timahdite sheep breeds. The negative heterosis effect indicated that the use of crossbred dams instead of pure Central Highland dams did not have any particular advantage in terms of heterosis for these traits. The expected increase in productivity due to heterosis depends on the genetic differentiation among parental breeds for a trait of interest. Heterosis increase when the difference in allelic frequencies between parental breeds increases (Dickerson, 1973; Atashi and Izadifar, 2012). Thus, the absence of significant improvement in most of the reproductive traits as a result of heterosis in the current study could be due to low genetic differences among parents for these traits. Therefore, the choice of the parental breeds for traits of interest is quite important to maximize the use of heterosis and to enhance the profitability of goat production. According to Thepparat *et al*. (2012), the degree of dominance in which heterozygous exceeds both homozygotes, the amount of homozygous recessives gene, and the level of epistatic interaction between non-allelic gene pairs are the determinants of the heterosis effect. In addition, a small number of observations that may not be sufficient to disentangle the genetics from the environmental effect could be the other factor.

The estimates of recombination effect for LBW and LSW of crossbreds were positive, while it was negative for LSB, LWW and GL. However, the recombination effect was not significant for all traits examined. This result is in agreement with Baas *et al*. (1992) for pigs and contrary to Haile *et al*. (2019), who noted a significant recombination effect for LBW and LWW in the crossbreeding program with Syrian and Turkish Awassi sheep strains (Haile *et al*., 2019). The non-significant recombination effect in this study suggests that there should be a non-significant difference in heterosis as recombination is a loss of heterosis. Besides, the magnitude and direction suggest the possibility of synthetic breed development, if there is enough advantage for crossbreeds. However, the magnitude of additive and heterosis effects in this study may not support this. Indeed, the negative recombination estimates for most of the examined reproductive traits in the crossbreds were not expected. As the Boer goat has not been selected for these traits, favorable epistatic interactions between genes in different loci may not be evolved. Hence, a crossing of Boer with unimproved Central Highland goats could not result in a significant loss of these interactions due to recombination.

Table 3. Estimate of breed additive, individual heterosis and recombination effect for reproductive traits

Trait	CH	gB	hBCH	rBCH
LSB (no.)	1.57±0.03	-0.004±0.07^{ns}	-0.03±0.04^{ns}	-0.02±0.08^{ns}
LBW(kg)	4.00±0.08	0.08±0.42^{ns}	0.14±0.23^{ns}	0.05±0.45^{ns}
LWW (no.)	14.3±0.57	-3.18±4.45^{ns}	-0.04±2.45^{ns}	-6.20±4.72^{ns}
LSW(kg)	1.40±0.03	-0.54±0.22*	0.27±0.12*	0.17±0.24^{ns}
GL (days)	149.2±0.39	3.69±3.34^{ns}	-2.62±1.82^{ns}	-4.31±3.63^{ns}

Ns, non-significant (P>0.05); *, P<0.05; gB, breed additive effect of Boer; hBCH, heterosis; rBCH, recombination effect; LBW, total litter birth weight; LSB, litter size at birth; LWW, total litter weaning weight; LSW, litter size at weaning; GL, gestation length

Predicted mean for different genotypes

Estimating crossbreeding parameters is essential to predict the performance of untested genotypes without actually producing the animals (Demeke et al., 2003). The expected reproductive performance as a function of genetic coefficients and crossbreeding parameters of each genotype is shown in Table 4. The LSB for indigenous goats was slightly higher than other genotypes. However, backcrosses (backcross with Boer and Central Highland) had a similar LSB. Likewise, the LSB for F1 and F2 crossbred does was found to be similar. Backcrosses with 75% Boer level and with 25% Boer level had a lower and higher LSW than other genotypes, respectively. Nevertheless, indigenous goats and F1 crossbreds had a similar LSW. In terms of LBW, the predicted means of F1s is higher than the other genotypes and is lower for CH than the other genotypes. The LWW of indigenous goats (CH) was greater by 12.8, 19.7, 38.1, and 49.1% compared with B x CH, BCH x CH, B x BCH and BCH x BCH, respectively. This indicates that LWW was decreased as a function of Boer level increases. The variation among genotypes in GL was negligible, which was less than two days.

Table 4. Predicted performance of doe productive traits

Genetic group (SxD)	Generation and blood level	LSB	LBW	LWW	LSW	GL
CH x CH	Local	1.57	4.00	14.30	1.40	149.20
B x CH	F1 (50%)	1.54	4.18	12.67	1.40	148.43
B x BCH	BC1 (75%)	1.55	4.14	10.35	1.17	149.58
BCH x CH	BC1 (25%)	1.55	4.10	11.94	1.44	147.74
BCH x BCH	F2 (50%)	1.54	4.14	9.59	1.35	147.58

LBW, total litter birth weight; LSB, litter size at birth; LWW, total litter weaning weight; LSW, litter size at weaning; GL, gestation length; S, sire; D, dam; B, Boer goats; CH, Central Highland goats

Heritability estimates

The variance components, heritability and repeatability estimates for reproductive traits of Boer x Central Highland goats are presented in Table 5. Error variances were the most important source of variation for reproductive traits, implying the significant influence of systematic factors on the expression of these traits. The direct heritability estimates for examined reproductive traits varied from 0.00 for GL to 0.098 for LWB. The heritability estimate for LSB obtained in this study is lower than those reported by Mia et al. (2013) for Black Bengal goats (0.08), Kebede *et al*. (2012) for Arsi Bale goats (0.075) and Zhang *et al*. (2009) for Boer goats (0.12). However, Mohammadi et al. (2012) reported a relatively lower estimate than the current result for Raeini Cashmere goats (0.04) and Menezes *et al*. (2016) for Boer goats (0.00). The estimated fraction of variance due to permanent environmental effects (c^2) obtained in this study is comparable with the report of Mohammadi et al. (2012) and higher than the report of Kebede et al. (2012). LSW is the other important trait in goat production and the heritability estimate was found to be low. The current estimate for this trait is higher than the estimate noted for Arsi Bale goats (0.005) by Kebede *et al*. (2012) and Markhoz goats (0.01) by Rashidi *et al*. (2011). On the other hand, a higher estimate than the current result was reported for the Black Bengal goats (0.13) by Mia *et al*. (2013), Boer goats (0.10) by Zhang *et al*. (2009), and Egypt Nubian (0.05) by Aboul-Naga *et al*. (2012). A meta-analysis (Jembere *et al*., 2017) result noted a weighted heritability estimate of 0.05 for LSB and 0.06 for LSW of goats.

A higher LBW heritability estimate for Raeini Cashmere goats (0.16), Boer goats (0.14) and Arsi Bale goats (0.126) than the current result were noted by Mohammadi *et al*. (2012), Zhang et al. (2009) and Kebede *et al*. (2012), respectively. However, the estimates in this study are comparable with the report of Mia et al. (2013) for Black Bengal goats and higher than the estimate reported by Rashidi et al. (2011) for Markhoz goats. The heritability estimate for LWW in this study is higher than the previous findings of Rashidi *et al*. (2011), Kebede *et al*. (2012) and Jembere *et al*. (2017), but lower than the result noted for pure Boer goats (Menezes *et al*., 2016). The heritability estimate for GL was lower and below the estimates for other goat breeds (Zhang *et al*., 2009; Mia et al., 2013). A variation of estimates among studies is explained by the difference in analytical models, data structure, genetic composition in the population (Zhang *et al*., 2009) and systematic factors examined. The magnitude of heritability estimates for a trait of interest indicates the magnitude of expected genetic progress through selection. Despite their economic importance, the improvement of reproductive traits through selection would be small as heritability and additive genetic variance estimates indicate. These estimates could be used to design breeding programs targeted at improving reproductive traits, as the estimates for such types of traits are scarce, particularly in the tropics.

Repeatability estimates

The repeatability estimates for LSB, LWB, LWW, LSW and GL were 0.149, 0.116, 0.099, 0.086 and 0.061, respectively (Table 5), which is found within a low range (<0.20). The repeatability estimate for LSB obtained in this study is in agreement with the findings of different scholars for different breeds (Aboul-Naga *et al*., 2012 Kebede *et al*., 2012; Mohammadi et al., 2012) and higher than the estimate found for pure Boer goats (Menezes *et al*., 2016). Higher repeatability estimates for LSW than the current estimate were reported for different breeds (Zhang et al., 2009; Kebede *et al*., 2012; Mohammadi *et al*., 2012) and a lower estimate (0.09) was noted for the Egypt Nubian goat breed (Aboul-Naga *et al*., 2012). Relatively high repeatability estimates for LBW and LWW were reported by Menezes et al. (2016) for Boer goats, Kebede *et al*. (2012) for Arsi Bale goats, Mohammadi *et al*. (2012) for Raeini Cashmere goats and Zhang *et al*. (2009) for Boer goats. The difference in sample size, breed, management conditions, a number of random factors and systematic factors considered in the estimation procedures could explain the variation of repeatability estimates among different studies. If the animal has a higher repeatability value for a certain characteristic, it can be decided whether to keep it or cull it based on the first record of observation; if it has a lower repeatability value, more than one observation on the same character is required. The finding of this study indicates multiple records would have to be used to make a decision of culling or selection.

Table 5. Heritability and repeatability estimates for reproductive traits of Boer x Central Highland goats

Estimate	σ^2_α	σ^2_c	σ^2_e	σ^2_p	h^2	c^2	e^2	r
LSB	0.001	0.002	0.017	0.0197	0.050±0.04	0.099	0.851	0.149
LWB	0.058	0.010	0.522	0.590	0.098±0.07	0.018	0.884	0.116
LWW	1.993	0.330	20.96	23.28	0.086±0.08	0.014	0.900	0.099
LSW	0.002	0.008	0.116	0.128	0.018±0.03	0.068	0.914	0.086

GL	0.001	1.766	27.11	28.88	0.000±0.06	0.061	0.939	0.061

LBW, total litter birth weight; LSB, litter size at birth; LWW, total litter weaning weight; LSW, litter size at weaning; GL, gestation length; σ^2_α, additive genetic variance; σ^2_c, permanent environmental variance, σ^2_e, residual variance; σ^2_p, phenotypic variance; h^2, heritability; $c^2 = \sigma^2_c / \sigma^2_p$, e^2, error variance; r, repeatability

CONCLUSIONS

The effect of breed additive, heterosis, and recombination was found to be non-significant for most of the reproductive traits. This result suggests that crossbred dams have no considerable advantage over Central Highland goats in terms of reproductive performance under the same environmental conditions. The low heritability estimates suggest that selection based on own performance may result in slow genetic progress and the repeatability estimates indicate that multiple records would have to be used to make a decision of culling or selection. Further studies should evaluate the role of both additive and non-additive effects on these reproductive traits and growth performance using a large data set.

ACKNOWLEDGMENT

We would like to express our sincere gratitude to Amhara Agricultural Research Institute for the financial support of this study.

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Breeding Objectives for Central Highland Goats Using Participatory and Bio-Economic Modeling Approaches

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ABSTRACT

The breeding objectives of Central Highland goats rearing under a low-input production system were defined through a participatory proportional piling method and bio-economic model. Additionally, the economic values and relative economic value of the breeding-objective traits were derived. A participatory proportional piling method was used to estimate the relative weights of farmers attached to a list of goat traits identified and the relative weights were statistically evaluated using a generalized multinomial logit model analysis. A bio-economic model was used to compute the economic values of the identified traits. The most important traits for selection of does according to farmer's preference were body size, coat color, post-weaning growth rate, and weaning rate with a relative weight (odds ratio) of 1.58, 1.38, 1.37, and 1.13, respectively. Goats with dark red followed by light red coat color were the most preferred (*P* <0.001) by goat keepers compared to white-colored goats. Farmers were more likely (*P* <0.001) to allocate higher scores for does-bearing twins than for single and triplet-bearing does. Using the bio-economic model (economic value and relative economic value), post-weaning growth rate, weaning rate, and six-month weight (body size) were identified as the most important traits and if the mean of these traits is changed by one genetic standard deviation, the change in profit will range from 2.06 to 3.03 \$ doe^{-1} year^{-1}. Therefore, the most important traits for the selection of Central Highland goats according to the economic-based method were post-weaning weight gain, weaning rate and body size (six-month weight). Besides, coat color was the second preferred trait by goat keepers next to body size. Thus, this aesthetical trait should be included in the designed breeding program besides economically important quantitative traits. The combination of the participatory proportional piling method and bio-economic model would give better insights to explore the

trait preferences of farmers and enhance profitability. The economic values of traits estimated in this study can be used for the construction of selection indices for Central Highland goats.

Keywords: *Bio-economic model, economic value, proportional piling, sensitivity analysis*

INTRODUCTION

Goats (*Capra hircus*) are among the most important livestock species, which contribute to the livelihoods of resource-poor farmers in developing countries, providing meat, milk, skin, fiber, manure, and short-term cash income (Mayberry *et al*., 2018). There are around 36.81 million goats (CSA, 2020) and they are categorized into eight genetically distinct groups (Alemu, 2004) in Ethiopia. Goat production is ideal for poverty alleviation due to their high multiplication rate, adapting to a wide range of agro-ecologies, including harsh climatic conditions, low capital investment, and ability to better utilize the limited as well as poor quality feed resources as compared to large ruminant (Abegaz *et al*., 2014).

Regardless of the aforementioned merits, the contribution of this sector to producers and the national economy is low (Abegaz *et al*., 2014). This low productivity is ascribed due to disease prevalence, feed shortage, absence of appropriate breeding systems, and poor institutional support. Therefore, to meet the ever-increasing demand for animal protein and thus contribute to economic growth, the genetic improvement of indigenous goats through selective pure breeding has been proposed as one of the major tools. Within-breed selection through a community-based approach is believed to be a more appropriate breeding program for a low-input production system with poorly developed infrastructures (Sölkner *et al*., 1998; Gizaw *et al.*, 2009; Mueller *et al.,* 2015). Defining breeding objective traits and their economic importance is a primary step in the development of a sound community-based breeding program (Abdollahy *et al*., 2012).

The breeding objective is defined as the traits to be improved, the cost, and the revenue related to a genetic change in each trait (Kosgey and Okeyo, 2007; Duguma et al., 2010). It can be identified through a participatory approach, such as participatory rural appraisal, ranking of animals, group discussion, and choice experiments (Duguma *et al*., 2010; Duguma et al., 2011; Haile *et al*., 2011; Gizaw *et al*., 2018). Identifying breeding objectives through a participatory approach provides insights into which traits are particularly important in their agro-ecosystem and how these can be incorporated into the design of sustainable breeding programs (Duguma *et al*., 2011). However, the relative importance of traits in economic terms in a given system cannot be derived using a participatory approach.

Besides identifying the relative weight of traits, defining these traits in economic terms (economic value) is imperative to define a profit-based breeding objective. The selection of multiple traits at the same time is possible through the selection index. In the selection index, the aggregate genotype may be defined as a linear function of additive genetic values of traits multiplied by their economic value (Hazel, 1943, Fuerst-Waltl and Baumung, 2009). Thus, economic values of traits are important for selection within a population, for evaluation of gene effects, and for designing optimum breeding programs. A bio-economic model is one of the very powerful tools used to estimate the economic value of traits (Amer, 2006; Gizaw *et al*., 2018) based on production (input and output), marketing (cost and revenue), genetic variation, and heritability information. Besides, it is used to investigate the robustness of these values to changes in the price of production inputs such as feed, management, and market prices (Kosgey *et al*., 2003; Haghdoost *et al*., 2008; Abdollahy *et al*., 2012).

Defining breeding objectives through a combination of the bio-economic model and preference-based method increases farmers' acceptance of the breeding objectives (Nielsen *et al*., 2014), enhances genetic progress (Gizaw *et al*., 2018), and enables to derive the economic value of traits. Besides, the economic values of traits for Central Highland goats have not been determined so far. Therefore, the objectives of this study were to identify the breeding objectives and to derive the economic value of important traits of Central Highland goats reared under a smallholder farming system.

MATERIALS AND METHODS

Description of breed and production system

The study was carried out in Kalu district of south Wollo, Ethiopia. Bati goats are genetically categorized within the Central Highland goat breed, which is distributed in the west of the rift valley escarpment in Wollo, central Tigray, Gonder and Shoa (Farm-Africa, 1996). Plain brown is a predominant coat color type. They have a predominantly straight facial and back profile, and have a straight horn shape (Gatew, 2014). Although these goats are reared for multiple purposes, they are known for best quality skin, and resistance to heat and drought stresses (Farm-Africa, 1996; Gizaw, 2009). The goat production system is mixed crop-livestock production and goats are predominant in number (50.9% of other livestock species) in the study area. Income generations by selling live animals as well as home meat consumption are the major reason for keeping goats (Gatew, 2014). Goats are raised on native shrub/pasture and depending on availability, supplemented with kitchen residues, homemade grain, local grain grinding house remains, and oilseed cake. Rivers/streams are the major sources of water. Most goat keepers have access to veterinary services within a 5 km distance (Gatew, 2014). Flock used uncontrolled natural mating and kidding occurring throughout the whole year. Bucks kept in the flock for 2.35 years on average (Gatew, 2014). Farmers sell goats during the entire year in times of cash need and feed scarcity. The mean ages of marketing for male and female goats are 6.21±0.23 and 6.35±0.23 months, respectively (Gatew, 2014).

Participatory approach (proportional piling method)

A proportional piling tool, which is one of the participatory approaches, was used to identify the preferences of farmers. This method was based on visualization and results were recorded numerically (Catley *et al*., 2013). In addition, it allowed farmers to give relative scores to a number of different items or categories according to one criterion (Hendrickx *et al*., 2011). Hence, this tool is easy for communicating trait preference studies with illiterate farmers, and results from this method are numerically meaningful and important for the ranking of traits and estimating the trait weights for constructing multi-trait selection indexes (Gizaw *et al*., 2018).

Forty-nine farmers were selected purposively based on their willingness and ownership of at least five goats. . The priority traits (seven traits for does and four traits for the bucks) were adopted from a previous production system study (Gatew, 2014). In addition, farmers were asked to mention any other traits, and they pointed out the tail shape of bucks. The identified traits and trait levels (Table 1) schematically depicted in Figure 1 to facilitate easy communication between the data collectors and respondents. The facilitator explained and demonstrated how to pile up beans proportionally to the relative importance of traits and trait levels.

For trait scoring, the participants were provided with 100 beans and asked to allocate the beans to each trait according to their preferences for the traits. The proportional piling exercise was done separately for buck and doe traits. Regarding trait level scoring, the maximum number of trait levels for investigated traits was three as indicated in Figure 1. Thus, to make the scoring simple for farmers, the number of beans was reduced to 10, and farmers were provided with 10 beans and asked to distribute the bean relative to the significance of each level of traits. Enumerators counted the beans given for each trait and trait level and farmers were asked the reason for their preferences.

Table 1. Buck and doe traits and trait levels

Traits	Levels of traits	Trait category
Coat color (buck and doe)	Dark red, light red and white	Type trait
Body size (buck and doe)	Large and small	Production trait
Growth rate (buck and doe)	Rapid (marketed ≤ 6 months) and slow (marketed > 6 months)	Production trait
Kidding interval (doe)	Short (3 kidding in 2 years) and long (2 kidding in 2 years)	Fitness trait
Prolificacy/litter size (doe)	Triple bearer, twin bearer and single bearer	Fitness trait
Weaning rate (doe)	Good (2 kids weaned/2 kids born) and poor(1 kid weaned/2 kids)	Fitness trait
Libido (buck)	Good and poor	Fitness trait
Milk yield (doe)	Two cups per milking and one cup of milk per milking	Production trait

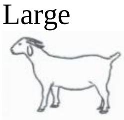
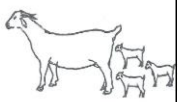
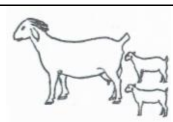
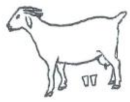
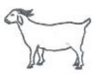
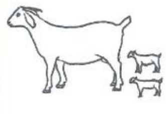
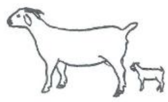
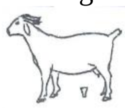
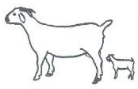
Level	Traits						
	Body size	Growth rate	Coat color	Kidding interval	Prolificacy/litter size	Weaning rate or kid survival	Milk yield
1	Large 	Rapid (marketed ≤ 6 month)	Deep red 	 3 kidding /2years	 Triple	 2kids weaned /2 kids	2 cup/ milking 
2	Small 	Slow (marketed > 6 month)	Light red 	 2 kidding /2years	Twin 	 1 kid weaned/2 kids	1 cup/ milking 
3	-	-	White 	-	Single 	-	-

Figure 1. Graphical representation of economically important trait levels

Bio-economic model and input parameters description

A bio-economic model is one of the very powerful tools used to estimate the economic value of traits (Amer, 2006; Gizaw *et al*., 2018) based on production (input and output), marketing (cost and revenue), genetic variation, and heritability information. This model assumes no variation among animals for the trait used to compute the economic values (Kosgey *et al*., 2003; Abdollahy *et al*., 2012; Gizaw *et al*., 2018). It also indicates the effect of production, management, and economic circumstances on the efficiency of the goat-production system. The bio-economic model combines both biological and economic variables. Table 2 and Table 3 present flock structure, production variables, input cost for the production system, revenue, phenotypic variance, and heritability estimates for investigated traits. The input parameters for the model were derived from a total flock size of 500 does and all calculations were carried out on a yearly basis. Information about flock structure was taken from data collected for nine years for Central Highland goats and their crossbred with Boer goats at Sirinka goat breeding station. Production variables (live weight and weight gain) were taken from the data collected through monitoring of Central Highland goats under a smallholder management system and from the report of Gatew *et al*. (2019).

The input cost includes feeding, veterinary services (vaccination, de-worming, spraying, treatment, and drug), management (labor for herding and feeding), marketing (personal expenses and marketing tax), and fixed costs (shelter, grazing land tax, repair costs, depreciation costs for buildings, and insurance). De-worming, spraying, and vaccination were set to be done three times per year. The treatment was set to be twice per year per animal. It was assumed that the market cost for all classes of goats was similar. The feeding regime for goat production in the area is entirely based on grazing and browsing in private and communal grazing/browsing areas. Thus, the price of grass hay was considered as an opportunity cost of communal grazing land according to Gizaw (2016). Supplementary feeding with concentrate (homemade grain and byproducts) was assumed for pregnant, lactating does, bucks during peak mating season, pre-weaning, and 6-12 month kids for sale. The dry matter, energy, and protein requirements for maintenance, pregnancy, lactation, growth, and mating/buck were calculated according to Kearl (1982). Revenues were derived from the sale of surplus buckling and goatling at six-month, surplus yearlings (male and female), culled does, and bucks (Table 2). It was assumed that the buck's lifetime service was 2.50 years, the mating ratio was 1:25, and 50% of kids born were males.

Table 2. Biological and genetic parameters input variables for the model

Biological input variables	Unit	Value	Traits	σ^2_p	h^2
Flock structure			**Genetic parameters**		
Conception rate	Prop	0.89	Weaning rate	0.076	0.09
Number of kids per birth	kid	1.56	Postweaning growth rate	0.0005	0.28
Kidding interval	days	240	Six-month weight	8.350	0.28
Survival from birth to 3 months (singles)	Prop	0.86	Prolificacy	0.188	0.05
Survival from birth to 3 months (multiples)	Prop	0.76	Mature weight	6.270	0.41
Survival from 3 to 6 months	Prop	0.92	Kidding interval	3846	0.06
Survival from 6 to 12 months	Prop	0.95			
Mortality (breeding does/bucks)	Prop	0.04			
Doe culling rate	Prop	0.22			
Buck culling rate	Prop	0.13			
Production variables					
WWT (M, single-born kids)	kg	10.5			
WWT (M, multiple-born kids)	kg	9.2			
WWT (F, multiple-born kids)	kg	9.92			
WWT (F, multiple-born kids)	kg	9.41			
WG1 (M single-born)	kg/day	0.057			
WG1 (M, multiple-born kids)	kg/day	0.054			
WG1 (F, multiple-born kids)	kg/day	0.052			
WG1 (F, multiple-born kids)	kg/day	0.051			
WG2 (female kid)	kg/day	0.046			
WG2 (male kid)	kg/day	0.042			
Mature weight of does	kg	34.0			
Mature weight of bucks	kg	41.0			

WWT= 3 month weight, WG1= weight gain from 3-6 month, WG2= weight gain from 6-12 months of age, F= female, M= male, Prop=proportion, h^2= heritability of traits, σ^2_p= phenotypic variance

The variability of goat performance and price across seasons were not considered in this study. Farmers were asked for the current price (February 2021) and the average prices collected through a formal interview were used in this study. Thus, price fluctuation across seasons was not considered in this study. The prices and costs were stated in Ethiopian Birr during data collection and the final result was changed in US dollars based on the exchange rate on the 10th of February 2021 (US$1.00 = 39.61 Birr).

Genetic parameters are the other important component of the bio-economic model. Estimates for phenotypic and genetic parameters are lacking for indigenous breeds in Ethiopia, except for the Arsi-Bale goats. Thus, the heritability estimate and phenotypic variance for investigated traits were taken from the literature and meta-analysis results (Kebede *et al.*, 2012; Bedhane *et al.*, 2013; Jembere *et al.*, 2017; Rout *et al.*, 2018) to calculate the genetic standard deviation.

Table 3. Economic input variables for the model

Economic variables		Unit	Value
Input cost	Feed cost	$/kg	0.08
	Management cost	$/head/year	0.04
	Marketing cost	$/head/ year	0.38
Health care cost	Vaccination	$/head/ year	0.23
	De-worming	$/head/ year	0.15
	Spraying	$/head/ year	0.04
	Treatments & drug	$/head/ year	0.40
Fixed cost		$/head/ year	0.76
Output/revenue	Buckling at six-month	$/kg	3.61
	Goatling at six-month	$/kg	3.56
	Buckling at yearling	$/kg	2.09
	Goatling at yearling	$/kg	2.05
	Culled does	$/kg	2.23
	Culled bucks	$/kg	2.16

$= US dollars = 39.61Birr.

Data analysis

Trait and trait level preference analysis

A generalized multinomial logit model was used to prioritize the traits and levels of traits by using SPSS (2007). The outcome variables were seven attributes in does and five attributes in breeding bucks. The score given for each trait and trait level were considered as predictor variables. The reference categories with which the results will be compared were identified based on the score and the least-scored category was used as a reference. For buck traits with five categories, consider the existence of five continuous variables Z_k (Z_1.... Z_5), in each case the propensity of farmers toward selecting a trait, with larger values of Z_k corresponding to greater probabilities of choosing that trait (assuming all other Z's remain the same). For doe traits with seven categories, there are seven continuous variables, Z_k (Z_1….Z_7), each of which can be thought of as the propensity of farmers toward selecting a trait, with larger values of Z_k corresponding to greater probabilities of choosing that trait (assuming all other Z's remain the same). The relationship between the Z's and the probability of a particular outcome is illustrated in the formula as follows:

$$\pi_{ik} = (e^{Z}{}_{ik}) / (e^{Z}{}_{i1} + e^{Z}{}_{i2} + e^{Z}{}_{i3} \ldots\ldots\ldots + e^{Z}{}_{ik}) \qquad (1)$$

Where π_{ik} is the probability the i^{th} farmer falls in category k, Z_{ik} is the value of the k^{th} unobserved continuous variable for the i^{th} farmer and $e^{Z}{}_{ik}$ is the exponential function with parameter z.

Derivation of economic values

The bio-economic model, which combines the biological and economic variables presented in Table 2 and Table 3, was used to derive the economic value of traits and to prioritize traits according to Gizaw (2016). A flock of 500 Central Highland breeding doe's rear under a low-input production system was simulated. Qualitative traits such as coat color, libido, and tail shape, do not have genetic parameter estimates and were not included in bio-economic modeling. The economic value of a trait is defined as the change in the flock profit resulting from a unit change in that trait, assuming all other traits are constant. Additive genetic standard deviation (σ_a) was calculated using the formula:

$$\sigma_a = \sqrt{h^2 \ x \ \sigma^2 p} \qquad (2)$$

Where h^2 is the heritability and $\sigma^2{}_p$ is the phenotypic variance.

Input costs, output/revenues, profits, and number of animals present relative to the number of does present in each category were calculated per doe per year based on biological and economic variables presented in Table 2 and Table 3. The profit was computed as a function of traits in the breeding objective:

$$P = \sum_{i=1}^{m} ni(Ri - Ci)ti - F \qquad (3)$$

Where *m* is the number of animal classes in the profit equation (kids, replacement female, replacement male, yearlings, breeding does, and breeding bucks), *n* is the number of expressions for a trait in the i^{th} class of animals (i.e. the proportion of animals in each category with respect to the total number of does present in the flock), *R* is the revenue per animal in the class of animals expressing the trait *t*, *C* is the variable cost per animal in the class of animals expressing the trait *t* and *F* is the fixed cost.

The number of animals present relative to the number of does present in each category was calculated based on biological variables presented in Table 2. Economic values were derived by multiplying the marginal utilities by the genetic standard deviations of the trait. The relative economic value of each trait was computed as follows:

$$REV\ (\%) = [(EV_i) / \sum^{n}_{i=1}(EVi)] \times 100 \quad (4)$$

Where EV and REV are the economic value and relative economic value of each trait, respectively.

The sensitivity of economic values to changes in different factors was analyzed by changing the base level of the price of feed, live animals, the cost of management and marketing by ±15%.

RESULTS

Proportional piling method

Trait preference

Farmer's preferences for traits of breeding does and bucks identified using a proportional piling method are summarized in Table 4. The traits, which had lower scores, were set as a reference (milk yield for does and tail shape for bucks) and traits with a higher score were identified as important traits.

Table 4. Farmer's weighting for traits using proportional-piling tool for Central Highland goats

Traits	Doe		Buck	
	Estimate(±SE)	Odds ratio (95% CI)	Estimate(±SE)	Odds ratio (95% CI)
Body size	0.46±0.05	1.58(1.42-1.76)***	0.60±0.07	1.83(1.58-2.11)***
Growth rate	0.31±0.05	1.37(1.24-1.51)***	0.39±0.06	1.48(1.31-1.67)***
Coat color	0.32±0.04	1.38(1.26-1.53)***	0.47±0.06	1.59(1.39-1.82)***
Weaning rate	0.12±0.04	1.13 (1.03-1.23)**	-	-
Kidding interval	0.07±0.04	1.07(0.98-1.17)ns	-	-
Prolificacy	0.07±0.04	1.07 (0.98-1.18)ns	-	-
Libido	-	-	0.02±0.04	1.02(0.94-1.11)ns
Milk yield	0	1.00	-	-
Tail shape & tail hair length	-	-	0	1.00

CI= confidence interval, SE= standard error, traits which had lower score were used as a reference, ns= P>0.05, **= P<0.01, ***= P<0.001

For selection of breeding buck, farmers were 1.83 times more likely to allocate higher weight to body size, 1.59 times to coat color and 1.48 times to growth rate than to tail shape. For doe, body size (odds ratio = 1.58, P<0.001), coat color (odds ratio = 1.38, P <0.001), growth rate (odds ratio = 1.37, P<0.001), and weaning rate (odds ratio = 1.13, P<0.01) were the most preferred traits relative to milk yield. This study revealed that farmers would give a similar score for prolificacy, kidding interval, and milk yield in does whereas for libido, and tail shape in bucks.

Trait level preference

The trait-level preferences of farmers are presented in Table 5. The odds of selecting a buck or doe with a rapid growth rate were 3.58 times higher than a buck or doe with a slow growth rate. Likewise, the breeding goat with a large body size is more likely preferred (odds ratio = 2.74, P< 0.001) compared with a small body size. Dark red color (odds ratio = 4.44, P<0.001) and light red color (odds ratio = 2.47, P <0.001) are the most preferred colors compared to white color. In terms of litter size, farmers are more likely to give the least score for single (odds ratio = 0.47, P<0.001) and triple (odds ratio = 0.44, P<0.001) compared to twins. High milk-producing does were highly favored over low milk-producing does. Breeding females who raised their kids until weaning had a chance of more than fourfold being preferred to the poor ones.

Table 5. Odds ratio estimates of the different trait levels against their reference categories

Traits	Trait levels[1]	Odds ratio (95% Wald CI)
Body size	Large vs small	2.74 (2.24 to 3.34)***
Growth rate	Rapid vs slow	3.58 (2.88 to 4.43)***
Coat color	Dark red vs white	4.44 (3.45 to 6.01)***
	Light red vs white	2.47 (1.84 to 3.33)***
Kidding interval	Long vs short	0.45 (0.37 to 0.54)***
Prolificacy	1 vs 2	0.47 (0.37 to 0.58)***
	3 vs 2	0.44 (0.35 to 0.55)***
Weaning rate	Good vs poor	4.10 (3.28 to 5.13)***
Milk yield	1 cup vs 2 cup	0.34 (0.28 to 0.42)***

CI= confidence interval, ***= P<0.001. [1] the last level is the reference category

Bio-economic model

Economic value of traits

The economic value and relative economic value of studied traits are presented in Table 6. Although all traits had a positive economic value, the highest economic value was obtained for post-weaning growth rate, weaning rate (number of kids weaned), six-month weight, and prolificacy. If the mean of these traits is changed by one unit, the change in profit will be ranged from 2.06 to 3.03 \$ doe^{-1} year^{-1}. A relatively small economic value was observed for mature weight. The economic value for prolificacy and kidding interval was almost similar.

Post-weaning weight gain, weaning rate and six-month weight had higher relative economic value per standard deviation improvement. Kidding interval and prolificacy had a close relative economic value per standard deviation improvement. However, the lowest relative economic value was observed for the mature weight of goats. In general, when comparing the relative emphasis of all traits considered, the highest relative importance was found for the post-weaning growth rate, weaning rate, and six-month weight, which contributed 23.75, 23.67, and 18.69%, respectively to the sum of the values of the standardized economic value over all traits.

Table 6. Mean, economic value ($ doe^{-1} year^{-1}), and relative economic value for traits of Central Highland goats

Traits	Unit	Mean	h^2	σ^2_p	σ_a	EV($/$\sigma_a$)	REV (%)
Weaning rate	Proportion	0.81	0.09	0.076	0.083	3.02	23.67
Post-weaning growth rate	kg/day	0.468	0.28	0.0005	0.012	3.03	23.75
Six-month weight	kg	13.3	0.28	8.350	1.529	2.39	18.69
Prolificacy/litter size	No. of kids	1.56	0.05	0.188	0.090	2.06	16.14
Mature weight	kg	34.0	0.41	6.270	1.603	0.24	1.840
Kidding interval	Days	240.0	0.06	3846	15.19	2.03	15.92

h^2= heritability of traits, σ^2_p= phenotypic variance, σ_a= genetic standard deviation, EV= absolute economic value, REV= relative economic value, $= US dollar

Sensitivity of economic values

The economic values for the traits considered and their sensitivity to price levels of production inputs and output with a constant number of does (breeding females) are shown in Table 7. Economic values for six-month weight, prolificacy, weaning rate, and kidding interval increased when feed cost was reduced and animal selling price increased. Increasing feed costs resulted in decreasing economic values for most of the considered traits. However, economic values for the post-weaning growth rate increased with increasing feed costs. An increase in a selling price of goats increased the economic value of all investigated traits. However, changes in veterinary and management prices did not affect the economic values of all investigated traits except for six-month weight. If output price decreased by 15% and input cost increased by 15%, the economic value of the six-month weight, mature weight, prolificacy, weaning rate, and kidding interval were very sensitive (reduced by 30.7 to 34.6%) than post-weaning growth rate which reduced by 12.8%.

Table 7. Economic values (\$ doe^{-1} year^{-1}) for traits for the base situation with changes in price levels of inputs and a constant number of does

Inputs/outputs	Price level (%)	Traits					
		SMWT	WG	MWT	PL	WR	KI
Feed cost	+15	2.17	3.06	0.22	1.89	2.77	1.86
	-15	2.64	3.00	0.26	2.25	3.31	2.22
Veterinary and	+15	2.36	3.03	0.24	2.06	3.02	2.03
Management cost	-15	2.41	3.03	0.24	2.06	3.02	2.03
Animal selling	+15	2.99	3.46	0.29	2.54	3.73	2.50
price	-15	1.79	2.60	0.18	1.58	2.32	1.56
If the output price decreased by 15% & input cost increased by 15%		1.56	2.63	0.16	1.43	2.09	1.41

SMWT= six-month weight, WG= growth rate, MWT= mature weight, PL= prolificacy, WR= weaning rate, KI= kidding interval, \$= US dollar

DISCUSSION

Breeding objectives identified through a participatory approach

Including farmers in the planning and designing of a community-based breeding program is vital for the successful implementation, sustainability, and profitability of the program. Breeding objectives identified through proportional piling are in line with the report of Gatew (2014) for Bati goats. Farmer’s preferences for body size and coat color for does in this study concur with previous studies (Gatew, 2014; Woldu *et al.*, 2016; Abebe *et al.*, 2020). According to Abraham et al. (2018), body size, twinning rate, milk yield, and kid survival rate were the most preferred traits for Begait goats. The attribute preference is influenced by the production system (Roessler *et al*. 2008; Duguma *et al*. 2011), agro-ecology, natural resources (Woldu *et al.*, 2016; Gizaw *et al*. 2018), and socio-cultural practices of farmers (Abebe *et al.*, 2020). Thus, identifying the breeding objective for each breed and each production system would be imperative. In general, body size, coat color, and growth rate were the most preferred traits for both does and bucks. However, the weaning rate is the other important trait for does. Thus, it would be imperative to select bucks based on measurements of the bucks’ female relatives to improve the weaning rate of the flock.

Concordantly, several scholars (Duguma *et al*., 2011; Mirkena *et al*., 2012; Woldu *et al*., 2016; Abebe *et al*., 2020) noted the preferences for large size sheep and goats. Usually, coat color is not incorporated in a selection index due to its categorical nature, but it is a very important trait. Thus, besides selection based on the breeding value of quantitative traits in the selection index, it is important to consider this trait through the participation of farmers in the selection decision. The least score for a triple-bearing does in this study could be explained by stunted growth and poor survival of kids because of doe poor access to feed to support triple kids according to farmers' responses. Coat color determines the price of goats and is associated with their culture. Goats with dark red and light red coat colors were the preferred coat colors in the community and believed to fetch high market prices.

Economic value of traits

The economic value is used for the construction of selection indices and for the calculation of monetary return from a breeding program when genetic gains for each trait obtained by this program are known. In addition, breeders use the relative economic value (standardized economic value) to make the first approximate assessment of the significance of traits in breeding (Komlósi *et al*., 2010). The economic value for the six-month weight and litter size of Begait goats noted by Abraham *et al.* (2018) is higher than the observed values in this study. However, the economic values for weight gain and kidding interval in this study are higher than the report of Abraham *et al*. (2018). The variation in the magnitude of economic values of traits among breeds is expected, as the input parameters are different for different breeds. In this study, the prioritized traits as per economic value are partly concurring with the report of Abraham *et al*. (2018) for Begait goats and partly agreed with the report of Gizaw *et al*. (2018) for Menz sheep. The number of kids weaned per doe (weaning rate) was the most important trait, which indicates the fitness and mothering ability of does (Zhang *et al*., 2009). Therefore, the improvement of this trait increases the number of kids sold and enhances profitability.

The small economic value and relative economic value for mature weight in this study are in agreement with the result obtained for Moghani sheep (Abdollahy *et al*., 2012), Horo sheep Gebre *et al.* (2012), and Begait goats (Abraham *et al*., 2018). In the future, due to a shortage of resources, the goat production system will be changed from extensive to semi-intensive in which feed intake of the doe can comprise most of the total feed costs. Therefore, any effort for enhancing mature weight would increase production costs. In such a situation, the selection of efficiently growing goats up to a certain age (e.g. market age) would be imperative and the change in profit per trait unit in this study demonstrates the importance of selection for growth rate than mature weight. In line with this study, the closer economic value for prolificacy and kidding interval also noted by Lobo *et al*. (2011), this indicates that these traits are altered by the system parameters in the same manner. Likewise, based on relative economic value the most important traits were post-weaning growth rate, weaning rate, and six-month weight, which contributed 66.1% to the sum of the relative (standardized) economic values over all traits. Due to the expected differing production and market payment methods, it is impossible to compare the economic values in this study with the earlier estimation.

Positive economic values for all studied traits indicated that genetic improvement in the trait would result in a positive effect on profitability. However, including these all traits in the selection index and selecting for these traits at the same time would result in slow genetic progress and make complex the breeding program. In selection programs, it is preferable to include a few of the most relevant traits in a breeding objective rather than complex combinations of traits (Philipsson *et al*., 2006). Likewise, the selection criteria should only be some important, easily measurable under field conditions, genetically correlated with other traits, and heritable (Kosgey and Okeyo, 2007; Haile *et al*., 2011).

According to the meta-analysis result noted by Jembere *et al.* (2017), the genetic correlation between six-month weight and post-weaning weight gain was 0.54. Likewise, the genetic correlation of weaning rate (litter size at weaning) with kidding interval was 0.59. These correlation estimates suggest that selection for one of them would result in a genetic change in the other trait. In addition, under an extensive management system, some production traits could also indicate adaptability and the best performing (e.g. fast-growing) animals are the best adapted to the prevailing condition (Haile *et al*., 2011; Mueller *et al*., 2015). Thus, considering traits with high biological and economic importance, more heritable and genetically correlated with other traits is imperative. In addition to growth traits, reproductive traits are also important traits, but these traits have little genetic variation and the inclusion of these traits in the selection index would result in little genetic change if there are no sufficient data or information sources for the estimation of breeding value. According to Mueller *et al*. (2015), traits associated with fertility, survival, longevity, and prolificacy could be compounded into the trait weaning rate which indicates fitness and mothering ability of does.

Therefore, traits such as six-month weight, kidding interval, and weaning rate would be important to enhance the genetic gain and profitability of the flock. However, the specific number of goal traits should be determined after evaluation of the index in terms of economic and genetic gain.

The increased economic value for the post-weaning growth rate with increasing feed cost is in line with the report of Gebre *et al*. (2012). Nevertheless, under a low input production system, the increment of feed cost to a large extent may not be affordable and needs a selection of animals for feed utilization efficiency. The non-significant influence of veterinary and management price variation on the economic values of most investigated traits is in line with the report of Haghdoost *et al*. (2008). This minimal influence could be explained by the extensive type of goat management, which is characterized by a small cost of production inputs.

The concordance of two methods

The most important traits that were stated for the selection through a participatory approach were body size, coat color, post-weaning growth rate, and weaning rate. Based on the bio-economic model, post-waning growth rate, weaning rate, and six-month weight (body size) would result in a better profit per standard deviation improvement. Likewise, post-weaning weight gain, weaning rate, and six-month weight received high emphasis. Other traits such as prolificacy, kidding interval, and milk yield seem to be equally preferred by farmers. Likewise, the economic value and relative economic value of prolificacy and kidding interval were almost similar. Quantitative traits ranked 1-4 through the participatory approach had high economic value and would result in a better profit if the mean of these traits changed by one unit through selection. Despite their order, a quantitative trait identified by the two methods (participatory approach and economic-based approach) seems to be concordant. In general, post-weaning growth rate, weaning rate, and six-month weight (body size) were the most important quantitative traits. Thus, alternative breeding schemes can be formulated using these traits and the coat color should also be considered during selection. The estimated economic values resulted from the bio-economic model would be necessary to construct the selection index.

Both approaches have their own merits and demerits. In the bio-economic model, the relative importance of traits is determined in monetary units, considers genetic variation and heritability of traits (Gizaw et al., 2018). Thus, these economic weights can be used as input for constructing a selection index if multiple traits are selected simultaneously and for the optimization of breeding programs. However, the identification of breeding objectives based on economic value tends to overstress selection for marketable production traits (Rauw *et al*., 1998), disregard the indirect value of subjective traits that may influence profitability (Rauw et al. 1998; Sölkner *et al*., 2008) and neglect farmers' objective (Gizaw *et al*., 2018). Some traits can be difficult to express in monetary terms. For instance, coat color is the second most important trait based on farmers' trait preference and so left out of the definition of breeding objectives if the prioritization is based on economic value. On the other hand, the relative weight of traits determined through a participatory approach considers cultural value, resource level, subjective traits such as coat color, and suitability for the existing environment. However, in the farmers' preference, the selection of traits may not be fully based on their economic contribution. It has been suggested to use a participatory approach and bio-economic model complimentary (Ragkos and Abas, 2015 and Gizaw *et al*., 2018) to overcome the above challenges. In this situation, the producers may still be maximizing monetary profit and non-monetary profit or the pleasure they obtain from the coat color of their goats. Therefore, complimentary use of these approaches would increase farmers' acceptance of the breeding objectives, used to define a profit-based breeding objective and thereby enhance the genetic progress.

CONCLUSION

Positive economic values for all studied traits indicated that genetic improvement in the trait would result in a positive effect on profitability. However, the most important traits for the selection of Central Highland goats according to economic-based method were post-weaning weight gain, weaning rate, and body size (six-month weight). Besides, coat color was the second preferred trait by goat keepers next to body size. Thus, the breeding program should consider coat color in addition to economically important quantitative traits. For genetically correlated traits including one of them would be imperative to make the breeding programs simple and for easy implementation. Farmers' preference could consider non-monetary profit such as cultural values and subjective traits whereas bio-economic modeling focuses on monetary profit. Thus, the combination of the farmer's preference and bio-economic model would give better insights to explore the trait preferences of producers and enhance profitability. The economic values of traits estimated in this study can be used for the construction of selection indices for Central Highland goats.

ACKNOWLEDGMENT

The authors greatly acknowledge Amhara Regional Agricultural Research Institute and Ethiopian Institute of Agricultural Research for their financial support.

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Determination of the inclusion level of Effective Microorganism treated wheat bran in broiler diets

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ABSTRACT

Poultry feed constitutes 60 to 70 per cent of the total cost of production. Hence, searching for alternative feed sources and feeding method is indispensable to produce poultry meat and egg. Different industrial byproducts such as wheat bran are among these alternative feed sources. This feeding trial was conducted to evaluate the effect of effective microorganism supplementation on broiler performance, determine the inclusion level of wheat bran on broiler feed and evaluate economic feasibility of EM supplementation in broiler die at Andassa Livestock Research Center. For this study, three hundred Cobb 500 unsexed day old chicks with an average initial body weight of 44.5 g was used. Chicks were equally and randomly distributed in five dietary treatment groups in a completely randomized design. Each dietary treatment group consisted of 60 broiler chicken distributed in three replicate pens with 20 chicks in each replicate. Treatments were the without EM and having 10 % wheat bran, and EM treated wheat bran with 15%, 20%, 25% and 30%. EM treated WB can be included up to 15% without affecting performance and daily gain of broiler. Beyond this level the body weight and daily gain was markedly decreased.

Keywords: *Broiler, Effective Microorganism, Supplementation, Wheat bran*

INTRODUCTION

Poultry feed constitutes 60 to 70 per cent of the total cost of production. Therefore, any attempt to reduce the feed cost may lead to a significant reduction in the total cost of production. Poultry lack fiber degrading enzyme for breakdown of complex carbohydrates like cellulose, hemicellulose and lignin (Thirumalaisamy *et al.*, 2016). There should be some methods of improvement on usage of fibrous feeds in poultry diets to make them digestible without adversely affecting production and health. Wheat bran is rich in dietary fiber containing 50.4% DM neutral detergent fiber (NDF), 16.7% acid detergent fiber (ADF) and lower amounts, 4% of acid detergent lignin (ADL).

The national poultry meat output in 2016 was estimated at about 13 000 tones. Ethiopia's share of the total poultry meat outputs in East Africa, Africa and the world in 2016 was only 2, 0.2 and 0.01 percent, respectively (FAO, 2019a). Poultry meat and egg consumption in Ethiopia is extremely low. By the year 2013, the per capita consumption of poultry meat in Ethiopia was estimated to be 0.66 kg, which is significantly lower than the annual per capita annual meat consumption of East Africa and Africa which is estimated to be 1.64 and 6.73 kg, respectively and the global average of 14.99 kg (FAO, 2019a).

Poultry feed is competitive with human food for both energy and protein sources. The cost of major feed ingredients like maize, soybean and others, are increasing from time to time. Hence, searching for alternative feed sources and feeding method is indispensable to produce poultry meat and egg. Different industrial byproducts such as wheat bran are among these alternative feed sources. The high fiber content in wheat bran limits its utilization in mono-gastric diets, particularly poultry due to ineffective fiber fermentation (Walugembe M., 2003). The inclusion level of wheat bran is lower in poultry diets since they do not have fiber degrading enzyme for breaking down complex carbohydrates like cellulose, hemicellulose and lignin (Thirumalaisamy et al, 2016).

The numbers of wheat milling factories in Ethiopia are around 300 out of which 140 are located in and around Addis Ababa (CSA, 2017). The annual total milling capacity of these factories is estimated to be 3.7 million tons. By-products are produced before milling and during the actual grinding process. During the milling process the production of 20–30 percent were by-products. Out of the total by-products produced, about 50–60 percent is wheat bran (*furushca*) and about 30 percent is wheat shorts/middling's (*furiskello*). In Amhara region a total of 47394 tons of dry matter wheat bran are produced with a total production of 1, 872 368 tones of dry matter in Ethiopia (FAO, 2019b).

Inclusion of wheat bran in broiler feed is not more than 10% (Boudouma, 2010). To use wheat bran in broiler diet improving the digestibility of its high fiber content through different method is mandatory. Supplementation of digestion booster additive Effective Microorganism is the most common method widely used for improving the digestibility of fiber. Effective microorganism (EM) is a combination of 70 to 80 different types of "good" and beneficial microorganisms contributing to the wide range of applications. EM contains five principal organisms namely, photosynthetic bacteria (phototrophic bacteria), lactic acid bacteria, yeasts, actinomycets and fermenting fungi. Lactic acid bacteria enhance the breakdown of organic matter such as lignin and cellulose, and ferment these materials without causing harmful influences arising from unrecompensed organic matter (Higa and Parr, 1994).

Hence, by adding EM in broiler diet containing wheat bran, with high dietary fiber content, the digestibility may be improved. With enhanced digestibility of wheat bran through supplementation of EM, it is possible to decrease cost of production by increasing the inclusion level of wheat bran in the diet in place of conventional feed ingredients like maize. The aim of this study is to determine the inclusion level of wheat bran by supplementing effective microorganism with water and feed in broiler diet and to evaluate economic feasibility of EM supplementation in broiler diet.

MATERIAL AND METHODS

Study area

The study was conducted at Andassa Livestock Research Center Poultry research and multiplication farm. The center is located 17 km away from Bahir Dar, capital of Amhara regional state. The center is located at 11º29' N latitude and 37º29' E longitude and 1730 meters above sea level. Annual rainfall, maximum and minimum annual temperature was 1330.4mm, 27.9ºC, and 13ºC, respectively (ARMA, 2018).

Experimental design and feed formulations

The research design was Completely Randomized Design (CRD). A total of 300 Cobb 500 unsexed day old chicks were purchased from Ellere private commercial chicken farm and transported to ALRC. Chicks were equally and randomly distributed in five treatment groups. Effective microorganism was obtained from bahir dar private seller. The application of the effective microorganism solution was both in the form of bokash and drinking water as 2 ml of EM solution per 1 liter of water (Wondimeneh *et al*., 2011). The treatments were complete feeds formulated from different ingredients (Table 1) and each treatment except the first one has EM.

Table 1. Feed formulation for broiler starter ration with different levels of wheat bran

No	Ingredients	T1	T2	T3	T4	T5
1	Maize	51	48	45	42	39
2	Wheat bran	10	15	20	25	30
3	Soya bean meal	18	19	20	21.5	21.5
4	Meat and bone meal	7.75	8	8.3	8.2	8.78
5	Nugseed cake	12.5	9.3	6	2.6	
6	Salt	0.5	0.5	0.5	0.5	0.5
7	Lysine	0.05	0.05	0.05	0.05	0.05
8	DL methionine		0.32	0.3		
Total		100	100	100	100	100
ME		3053.8	3053.9	3054.78	3059.8	3054.8
CP (%)		22	22	22	22	22

CP = crude protein and ME = Metabolizable Energy (kcal/kg)

The five treatments used for this study were;

Treatment 1 (T1): control group/ without EM and having 10 % wheat bran

Treatment 2 (T2): 15 % of wheat bran with EM

Treatment 3 (T3): 20% of wheat bran with EM

Treatment 4 (T4): 25% of wheat bran with EM and

Treatment 5 (T5): 30% of wheat bran with EM for both starter and finisher feed.

Table 2. Feed formulation for broiler finisher ration with different levels of wheat bran

No	Ingredients	T1	T2	T3	T4	T5
1	Maize	60	54.5	51.5	48.5	45.5
2	Wheat bran	10	15	20	25	30
3	Soya bean meal	20.5	19	20.5	18.5	17.5
4	Meat and bone meal	7.3	6.6	6	7	6.5
5	Nug seed cake	1.5	3.2	1		
6	Salt	0.5	0.5	0.5	0.5	0.3
7	Lysine	0.05	0.05	0.03	0.05	0.05
8	DL methionine	0.15	0.15	0.15	0.15	0.15
9	Premix			0.32	0.3	
Total		1000	100	100	100	100
ME		3160.4	3107.1	3098.58	3055.14	3033.91
CP (%)		20	20	20	20	20

CP = crude protein and ME = Metabolizable Energy (kcal/kg)

Experimental chicken flock management

The chicks were reared in well prepared brooding room bedded with 10 cm thick straw in deep litter system. One infra-red lamp which has a power of 150 watt was fitted for 20 chicks in each pen as a source of heat to maintain the temperature for the first 15 days. Feeders and waterers were set in each pen before chicks start to brood, and water were given *ad-libitum* to the chickens throughout the experiment period. The feeding experiment was conducted for 7 weeks (49 days). Birds were fed with the broiler starter ration up to the 4^{th} week of age (28 days) and followed by a finisher ration up to 7^{th} week of age (49 days). Scheduled vaccination against Newcastle (HB1 and lasota), Gumboro and fowl typhoid were given to prevent disease occurrence and all the bio-security safety procedures were under consideration.

Data collection and analysis

Dry matter intake, initial body weight and weekly base live weights were recorded using sensitive balance having 0.01sensitivity. Mortality data were recorded by flock attendants under close monitoring of researchers. The data were analyzed using General Linear Model of Statistical software (SAS, 2000). Differences between treatments means was tested by using Duncan multiple range tests at a significance level of 5%. The following linear model was used for analysis of quantitative data;

$$\mathbf{Y_{ij} = \mu + \alpha_i + e_{ij}};$$

Where; Y_{ij} = the observation in i^{th} treatment, μ = the overall mean measurement across all treatments, α_i = the effect of i_{th} treatment and e_{ij} = the random error.

Feed conversion ratio (FCR) was calculated to estimate the efficiency of feed utilization to produce meat. FCR calculated with the following formula;

$$FCR = \frac{\text{Total feed consumed by birds}}{\text{Total weight gained/bird in grams}}$$

The economic feasibility of the respective treatment diets were estimated through partial budget analysis by considering variable costs and income. All inputs cost, feed, medicament and EM purchasing cost and the income gained from selling of chicken were recorded.

RESULTS AND DISCUSSION

Feed chemical composition analysis

The protein and energy levels of the five dietary treatments used in the study were within the recommended levels for starter and finisher broiler chicks (Cobb500 Breed, 2015). The protein requirement is 19 - 22% CP for starter and 18-20% CP for finisher and the energy requirements is 3008-3086 for starter and 3167 for finisher.

Table 3. Proximate chemical composition of feed ingredients

Nutrient	Ingredients					
	Bokashi	WB	BMM	NSC	Maize	SB
DM (%)	91	92	96	94	93	95
Ash (%)	5.46	3.26	25.00	7.45	2.15	5.26
OM	85.51	88.74	71.00	86.55	90.85	89.74
CP	13.45	12.64	45.05	32.15	13.22	36.85
NDF	34.68	24.35	41.11	47.55	26.45	45.34
ADF	24.18	13.04	29.17	38.68	15.05	33.68
ADL	4.46	3.37	5.45	6.67	3.74	3.37

WB = wheat bran, BMM = bone and meat meal, NSC = Noug seed cake, SB = Soya bean meal, DM = Dry Matter, OM = organic matter, CP = Crude Protein, NDF = nitrogen Detergent Fiber, ADF = Acid Detergent Fiber and ADL = acid Detergent Lignin

Feed intake

The mean daily gain and total feed intake of broiler chicken at starter, finisher and overall period are presented in Table 4. Except at starter phase, TDMI and DDMI showed significance difference (P <0.05) among treatment groups. Whereas, there was no significant difference (P >0.05) among treatment groups in daily feed intake per bird during starter phase, there was significant difference (P < 0.05) among treatment groups in daily and total feed intake per bird at finisher phase and the overall period. It was evident that inclusion of WB up to 20% has no adverse effect on feed intake, while an inclusion level above 20% WB showed an adverse effect on feed intake of broiler chickens.

Table 4. Mean daily and total feed intake per bird during starter, final and overall period

Intake	Treatments					SEM	Sig	CV
	T1	T2	T3	T4	T5			
Starter phase (1-28 days)								
TDMI (g/bird)	1282	1181	1211	1161	1335	49.1	0.33	7.1
DDMI (g/bird)	45.8	42.8	43.2	41.5	40	2.5	0.33	7.1
Finisher phase (29-49 days)								
TDMI (g/bird)	2556[a]	2448[a]	2481[a]	2121[b]	2076[b]	58.7	0.001	3.07
DDMI (g/bird)	122[a]	117[a]	118[a]	101[b]	99[b]	2.8	0.001	3.08
Entire period (29-49 days)								
TDMI (g/bird)	3848[a]	3635[b]	3962[ab]	3282c	3212[c]	87.9	0.001	3.05
DDMI (g/bird)	78[a]	74[b]	75[ab]	67[c]	66[c]	1.8	0.001	3.05

*a, b, c mean across the row with different superscript statically significantly different (p < 0.05); TDMI = Total dry matter intake; DDMI = Daily dry matter intake; g = Gram; SEM = standard error of mean; sig = significant level; T1 = 10% WB; T2 = 15% WB; T3 = 20%; T4 = 25%WB; T5 = 30% WB and CV = coefficient of variation

Growth performance of Broilers

Total body weight gain, average daily gain and feed conversion ratio per bird during the starter, finisher and entire experimental period are presented in Table 5. There was significant difference (P < 0.05) between treatment in terms of total and daily body weight gains in starter, finisher and overall period. In starter phase inclusion of WB above 15% has adverse effect on total and daily body weight gains of birds. Similarly in finisher phase birds on T1 and T2 showed high total and daily body weight gain. In a similar fashion during the overall period birds performance on treatment T1 and T2 showed high body weight than other treatments having an inclusion level of above 15% WB. Hence, this study confirmed that effective microorganism treated wheat bran can be included up to 15% in broiler diet without adverse effect on growth performance. The study by Ali (2008) reported that feed additive supplemented wheat bran could be incorporated in broiler diet up to 30% without adverse effect. In contrast, Boudouma (2010) reported that wheat bran inclusion more than10% had adverse effect on broiler growth performance.

Table 5. Growth performance of broilers at starter, finisher and entire period fed different levels of EM treated wheat bran.

Parameter	Treatment					P value	SEM	CV
	T1	T2	T3	T4	T5			
Starter phase								
IBW	44.5	44.4	44.8	44.4	44.2	0.82	1.4	3.98
FBW	530.4	500.1	449.8	432.8	420.4	0.103	73.26	17.9
ADG	17.9	16.8	14.9	14.3	13.9	0.100	2.6	19.5
FCR	2.4	2.4	2.7	2.7	2.7	0.124	0.35	15.99
Fisher phase								
IBW	530.4	500.1	449.8	432.8	420.4	0.103	73.26	17.9
FBW	1272.4^{a}	1194.1^{ab}	1151.9^{bc}	1044.6^{c}	1049.6^{c}	0.04	127.1	12.6
ADG	26.5^{a}	25.1^{ab}	24.1^{b}	22.5^{b}	21.8^{b}	0.03	4.29	15.17
FCR	2.01	2.06	2.2	2.03	1.97	0.314	0.529	19.47
Entire phase								
IBW	44.5	44.4	44.8	44.4	44.2	0.82	1.4	3.98
FBW	1272.4^{a}	1194.1^{ab}	1151.9^{bc}	1044.6c	1049.6c	0.04	127.1	12.6
ADG	25.1^{a}	23.5^{ab}	22.6^{b}	20.5^{b}	20.4^{b}	0.04	2.59	13.12
FCR	3.03	3.04	3.4	3.04	3.15	0.25	0.258	10.44

IBW = Initial body weight; FBW = final body weight; ADG = average daily gain; FCR feed conversion ratio

Feed conversion ratio

The feed conversion ratio among treatments presented on Table 5. There was no significance difference ($P > 0.05$) on feed conversion ratio among treatments. This is comparable with the study by Ahmed (2004) and Wondimeneh *et al.* (2011) who reported that supplementing EM didn’t affect feed conversion efficiency.

Mortality

There was no significant difference among treatments on mortality of experimental birds. However, there was high mortality on T4 and T5. This is in line with the study by Yoruk *et al*. (2004) who reported mortality of hens fed with EM supplemented diet was no different from those fed without EM. Similarly, Wondimeneh *et al.*, (2011) reported that effective microorganism supplementation has no significant effect ($P < 0.05$) on mortality of chickens. On the contrary, Vicente *et al*., (2007) reported that probiotics supplementation significantly reduced mortality in chickens.

Table 6. Incidence of mortality in experimental birds across treatments

	Treatments							
	T1	**T2**	**T3**	**T4**	**T5**	**SEM**	**Sig**	**CV (%) (%) Mortality**
Mortality (%)	6.7	7.3	8.1	8.3	10.3	5.3	0.26	25

Partial budget analysis

The partial budget analysis of control and chicken fed with different level of EM treated wheat bran is presented in Table 7. The benefit cost ratio showed that the maximum return in raising broilers was obtained in chickens fed diets T1, T2 and T3 which contained 10, 15% and 20% of wheat bran, respectively. For an investment of a Birr, 2.7 and 2.6 birr return was earned in the first two treatments and T3, respectively. Treatment 4 and 5 shows relatively low benefit because of incidence of deformities and weak chicks that was sold with low price. This might be due to high inclusion of wheat bran in the diet. Therefore, this study revealed that T1 and T2 had better economic benefit in all economic parameters. In general, inclusion of EM treated WB above 15% in broiler diet had no cost advantage over the control diet (10% WB, not treated with EM).

Table 7. Partial budget analysis

Variables	**T1**	**T2**	**T3**	**T4**	**T5**
Income					
Selling price	176	173	163	145	125
Cost					
Purchasing cost	35	35	35	35	35
Feed cost	12.5	11.4	10.6	9.3	8.1
Total variable cost	47.5	46.4	45.3	44.3	43.1
Total Benefit	176	172	163	145	125
Net Benefit	128.5	126.6	117.9	100.7	81.9
Benefit/cost ratio	2.7	2.7	2.6	2.3	1.9

CONCLUSION AND RECOMMENDATIONS

In general, this study revealed that EM treated WB can be included to a level of 15% without affecting production performance of broilers. However, there was no difference in FCR among the treatments due to WB inclusion. There was also high return in T1 and T2 with 2.7 birr return for each 1 birr investment. Therefore EM treated WB can be included to a level of

15%, with similar rate of return to including 10% WB without EM treatment in broiler diets. Further study should be done on effect of EM supplementation on carcass quality of broilers.

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The effect of partial replacement of dried brewery grain with toasted soybean and noug seed cake on egg production, fertility and hatchability performance of Koekoek (Potchefstroom koekoek) chicken

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ABSTRACT

The objective of this study was to evaluate the egg production, fertility and hatchability performance of Koekoek chicken fed different levels of dried brewery grain (DBG), to determine the optimum inclusion level of DBG and, to evaluate the economic feasibility of feeding DBG to koekoek chicken. One hundred fifty hens and 15 cocks of 21 weeks old Koekoek chicken with average initial body weight of 1641.48 ± 23.92g were used for the experiment. Chicks were equally and randomly distributed in 5 dietary treatment groups in a completely randomized design. Each dietary treatment group encompassed 30 hens and 3 cocks distributed in 3 replication pens with 10 hens and 1 cock in each replicate. Treatment diets were formulated as Iso-nitrogenous and Iso-caloric Weight of birds was taken at the start of the experiment and egg production, feed offered and refusal was recorded daily. Egg fertility and hatchability were observed 3 times, at 31, 35 and 45 weeks age of laying phase. Data were analyzed using GLM procedure SAS software (SAS version 9, 2004). Significant difference between treatments means were separated with Duncan multiple range tests with 5% significance level. Daily and cumulative dry matter feed intake of birds showed significant difference ($P < 0.05$) with the increment level of DBG from T3 to T5. Similarly, there was significant difference in hen-day egg production (HDEP), hen-housed egg production (HHEP) and total number of eggs laid. However, total egg mass, average egg weight and FCR did not show significant difference ($P > 0.05$) among treatment means. No significant difference ($P > 0.05$) was observed among treatments in fertility and hatchability of eggs. The total mortality percentage of birds in the entire period of the study was 2.42%. The main reason for the mortality of birds was protrusion of vents resulting in cannibalism, which in turn lead to mortality. The highest benefit cost ratio was recorded for T4 (30% DBG). This study revealed that DBG could be used as a good alternative protein supplement for Koekoek layer chicken up to 30% inclusion level in partial substitution of Toasted Soybean (TSB) and Noug Seed Cake without negative effect on egg production, fertility and hatchability with optimum economic benefit. However, further works should be done to devise appropriate drying methods of the wet brewery grain to suit the transportation of brewery grain.

Keywords: *DBG, Feeding, Fertility, Hatchability, Koekoek*

INTRODUCTION

In Ethiopia the total chicken population is estimated to be 57 million and from the total chicken 78.9%%, 12%, and 9.1% were indigenous, hybrid and exotic breed, respectively (CSA, 2021). However; the economic contribution of the sector is still very low compared to this huge number; for instance the estimated egg and poultry meat production is about 40,000 and 60,480 tones, respectively (FAOSTAT, 2013). This is ascribed to the presence of many technical, organizational and institutional constraints (Fisseha *et al*., 2010).

Among the constraints, the availability and price of feed is the major problem to poultry production. Cereal grains, protein sources, vitamins and mineral supplements are required to formulate balanced poultry rations (Solomon, 2007). The prices of feed ingredients are the determining factors for the profit margins in poultry production. On the other hand, the high level of competition between human and poultry feed ingredients posed a great concern to nutritionists over the years particularly in developing countries. The fact that feed alone accounts for up to 70–80% of the production inputs in intensive poultry production urges nutritionists to search for alternative feed resources (Ravindran and Blair, 1992).

In this regard, dried brewery grains (DBG) and brewers dried yeast (BDY) by-products are alternative available cheap feed sources that can be obtained from brewery processing plants. DBG is cheap, available all year round, and has high nutritional value which is used as good sources of un-degradable protein and water soluble vitamins (Mussatto *et al.*, 2006). In Ethiopia, there is ample resource of brewery grain produced from about 12 brewery factories with annual production of 263,736 tons of wet brewery spent grain (roughly 22,140.64 tones on DM basis during 2015/2016; Amare, 2016).

Mafeni and Fombad (2001) found that DBG contained 27.7% crude protein and it was fairly rich in essential amino acids (0.9% lysine, 0.4% methionine, 0.4% tryptophan, 1.3% phenylalanine, 0.9% threonine and 1.6% valine). Gebremedhn *et al* (2019) reported that DBG can be included in layers ration up to 40% without affecting the production performance of birds. According to Mafeni and Fombad (2001), DBG has not significant effect on fertility and hatchability of breeder chicken and did not affect the quantity of semen produced by the cocks fed with 30% inclusion level. Hence, this study was designed with the following objectives.

- Evaluate egg production performance of koekoek chicken fed with different levels of DBG.
- Evaluate the fertility and hatchability of koekoek chicken fed with different levels of DBG.
- To determine the optimum inclusion level of DBG on koekoek layer chicken ration.
- Evaluate the economic return of feeding different levels of BDG to koekoek layer chicken.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Andassa Livestock Research Center (ALRC) poultry research facility. ALRC is located at 22 kilometers from Bahir Dar, the capital of Amhara Regional State. It is located at latitude and longitude, 11°29' N and 37°29' E, respectively with an altitude of 1730 meter above sea level.

Research design and ration formulation

The research design used was Completely Randomized Design (CRD). A total of 150 chicken and 15 cocks of koekoek breed chicken were used for this study. When pullets started egg laying or at the age of 21 weeks, the feeding experiment was started with a week acclimatization period. The average body weight of birds at the beginning of the experiment was 1644.00 ± 41.72 g. Those chicks were randomly distributed in 5 dietary treatment groups. Each dietary treatment groups consisted of 30 layers and 3 cocks, distributed in three replication pens with 1: 10 cock to hen ratio in each replica.

The wet brewery grain was purchased from Dashen brewery factory at Gondar and transported to ALRC. The wet brewery grain was available for sun drying by using polythene sheet on the ground for 5 consecutive days. The grain was frequently turned manually to avoid the formation of mold. After drying, the grain was stored in a well dried area waiting for subsequent feed formulation. The rest feed ingredients were purchased at Bahir Dar local market and Lysine, Methionine and premixes were purchased from Addis Ababa. The diet formulation for Koekoek layer chicken is shown in Table 1. Five closely iso-nitrogenous and iso-caloric diets were formulated for Koekoek layer chicken using feed win computer software based on their nutrient requirement. The treatment diet contains; T1= 0% DBG (control); T2= 10% DBG; T3= 20% DBG; T4= 30% DBG; T5= 40% DBG.

Table 1. Feed formulation for Koekoek layer chicken ration with different levels of DBG.

Feed ingredients	**Treatments**				
	T1	T2	T3	T4	T5
DBG	0	10	20	30	40
TSB	15	12.75	6.2	0	0
Noug seed cake	9.8	8	8	8	0
Maize	53.7	56.5	53	49.15	47
Wheat bran	11.5	2.75	2.75	2.75	2.75
Lime stone	9	9	9	9	9
Salt	0.5	0.5	0.5	0.5	0.5
Premix	0.5	0.5	0.5	0.5	0.5
Lysine	0	0	0.05	0.1	0.2
Methionine	0	0	0	0	0.05
Total (kg)	**100**	**100**	**100**	**100**	**100**
Calculated nutrient composition					
DM %	93.5	93.4	93.4	93	92.67
CP	16.54	16.54	16.49	16.55	16.58
Lysine	0.90	0.81	0.76	0.71	0.74
Methionine	0.28	0.27	0.27	0.27	0.27
EE	7.20	6.42	5.58	4.80	4.15
CF	6.24	6.93	7.58	4.8	4.15
ME kcl/kg	2870	2896	2901	2918	3040
Ca	3.69	3.70	3.71	3.72	3.73
P	0.39	0.38	0.37	0.36	0.34

DBG = Dried Brewery Grain; TSB = Toasted Soybean T1 = 0% DBG; T2 = 10% DBG; T3 = 20% DBG; T4 = 30% DBG; T5 = 40% DBG.

Chicken management

The experiment was conducted for 24 weeks in a deep litter system. The experimental pens were 1.5*2 meter wide. Whole units of the pens were cleaned and the concrete floor was bedded with well dried hay with 10 to 12 centimeter thickness. The house was disinfected with disinfectant using 37-40% formalin before three days placement of birds. Egg laying nest, feeders and waterers were placed in the pens 24 hours before the entrance of experimental birds.

Birds were fed with the prepared ration and the daily consumption of ration was given 3 times a day; early in the morning, mid-day and late in the afternoon. Clean and cool water was available all the time. The feed offered and refused were recorded every day for the calculation of feed consumption. Vaccines against Newcastle and Gumboro diseases were given as per the manufacturer's recommendations during the growing period of birds. Anti-stress in the form of vitamins (Vita chick) was given to the birds as deemed necessary.

Feed chemical composition analysis

Representative feed samples were taken from each of the feed ingredients and the analysis was conducted by Debre Birhan Agricultural Research Center Animal Nutrition Laboratory. The feed samples were analyzed based on recommended methods of proximate analysis of poultry feeds, Association of Official Analytical Chemists (AOAC, 1990), to determine the Dry Matter (DM), CP (Crude Protein), OM (Organic matter), NDF (Neutral Detergent Fiber, ADF (Acid Detergent Fiber, ADL (Acid Detergent Lignin, and Crude ash. The metabolizable energy (ME) contents of feed ingredients were calculated based on NRC (1994). The CP content was analyzed using the N analyzer by Kjeldahl method, in which % CP was estimated as % N x 6.25. The crude ash was obtained by combustion / burning the feed samples with the temperature of 550°C for more than 2 hours.

Data Collection

The total feed offered and refused in each morning was weighted and recorded with sensitive balance with 0.01g weighting capacity and the total and average daily feed intake/bird (g) and feed conversion ratio (FCR) were calculated. Feed conversion ratio was calculated as the total amount of feed consumed by the bird and dividing by the total weight of eggs produced. The egg production, egg weight, and hen housed (HHEP) and hen day egg production (HDEP) was calculated with the following formula:

$$\text{HHEP (\%)} = \frac{\text{Average daily number of eggs produced}}{\text{Number of hen housed}} \times 100$$

Where, HHEP = hen housed egg production.

$$\text{HDEP (\%)} = \frac{\text{Total number of eggs laid}}{\text{Average number of bird alive} \times \text{Number of days in lay}} \times 100$$

Where, HDEP = hen-day egg production

Egg fertility and hatchability

Hatching eggs were selected at 31, 35 and 45 weeks of age and kept for seven days in a freezer at < 18°C. Selection of hatching eggs was done based on uniformity in size, normal shape and cleanness of shells, and then finally disinfected with wet close dipped in disinfectant before stored. The hatching eggs were fumigated with 37- 40% formalin before setting.

A total of 1209 selected eggs were set in 3 batches at 31, 35 and 45 weeks of laying period. Both the setter and hatcher were washed and fumigated with 37- 40% formalin. Standard relative humidity, temperature and turning were programed both on the setter and hatcher. Eggs were candled on the 18th day of incubation to identify and remove the infertile eggs and the fertile eggs were transferred to the hatcher on the same day.

After 3 days in the hatcher, the hatcher was opened and the numbers of hatched chicks were counted as normal and weak chicks and un-hatched eggs and pips were counted separately as dead in shell in each batch. All weak chicks were discarded and the rest of the chicks were counted as normal and calculations were made for fertility, hatchability, dead in shell, normal and weak chicks.

Data analysis

Data collected from feed intake, egg HHEP and HDEP, egg mass, FCR, fertility and hatchability were subjected to ANOVA using the General Linear Model (GLM) equation of SAS software (SAS 9.0.). Duncan multiple range test was used to separate the means that are significantly different from each other at a significance level of 5%. The following linear model was used for the analysis of quantitative data;

$\mathbf{Y_{ij} = \mu + \alpha_i + e_{ij}}$; where; Y_{ij} = the observation in ith treatment, μ = the overall mean measurement across all treatments, α_i = the effect of ith treatment and e_{ij} = the random error.

RESULTS AND DISCUSSION

Feed chemical composition analysis

The chemical composition analysis result of feed ingredients used in the diet formulation is shown in Table 2. The CP content of DBG was comparable with the finding of Serena and

Knudsen (2007) who reported 22% CP for DBG and was within the range (19.5-31.9%) reported by Heuzé *et al*. (2016). On the other hand, the CP content was a bit lower compared to the values reported by Maertens *et al.*, (1990), Celus *et al.*, (2006) and Solomon (2007), which were, 25%, 26% and 24%, respectively.

The differences might be due to differences in the variety of barley used, time of harvest, malting, mashing conditions, adjuncts added and brewing technology used during brewing and production of DBG (Huige, 1994; Santos *et al*., 2003). Thus, DBG was able to meet the CP requirements of layer chicken and it could be suitable substitute for Toasted Soy bean (TSB) and Noug Seed Cake (NSC) in layer chicken diets.

Table 2. Proximate chemical composition of feed ingredients used for feed formulation in Koekoek layer chicken diet

Nutrients (% DM)	**Ingredients**				
	WTB	NSC	Maize	TSB	DBG
Dry matter	92	94	93	95	93
Crude Ashe	3.26	7.45	2.15	5.26	4.30
Organic Matter	88.74	86.55	90.85	89.74	88.70
Crude Protein	12.64	32.15	13.22	36.85	22.00
NDF	24.35	47.55	26.45	45.34	50.12
ADF	13.04	38.68	15.05	33.68	41.31
ADL	3.37	6.67	3.74	5.95	7.24
Metabolizable energy (kcal/kg)	3,009.02	1,223.62	3,052.38	2732.02	2,223.36

WTB = Wheat Bran; NSC = Noug seed cake; TSB = Toasted soybean; DBG = Dried Brewery Grain; NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin.

Feed intake and egg production of birds

The feed intake, egg production performance and FCR of Koekoek layer chicken fed with different level of DBG is presented in Table 3. Daily and cumulative dry matter feed intake of birds showed significant difference with the increment level of DBG from T3 to T5. Similarly, there were significant differences in HDEP, HHEP and total number of egg laid. Treatment 5 (40% DBG) was significantly lower than the control group (T1) and other treatment groups in HDEP, HHEP and total number of eggs laid. However, total egg mass, average egg weight and FCR did not show significant differences among treatment means.

The feed intake was comparable to the findings of John (2015) who reported that inclusion of over 15% DBG in the diets of laying quails resulted in significantly higher feed intake.

The total egg mass, average egg weight (AEGWT) and feed conversion ratio (FCR) reported in this study concurs with the finding of Gebremedhn *et al*. (2019) who reported non-significant difference in feeding of Bovans brown layers with a level of DBG ranging from 0-40%; while, the dry matter intake (DMFI), HDEP, HHEP and total number of eggs laid disagrees with the findings of the same author who reported non-significant result to those parameters. The result of egg production was also similar to the finding of John (2015) and Makinde *et al.* (2014) who reported that the inclusion level of 30% DBG in laying quail diets did not affect egg production and egg mass and, decreased the cost of production.

The higher feed intake by layer chicken feeding on the DBG could not be related to the energy levels of the rations, since the rations were nearly iso-caloric while, it is likely due to preferable aroma of the DBG. Even though higher feed intake was recorded for T3, T4 and T5, HDEP and HHEP were not affected in T3 and T4. Thus, the result revealed that inclusion of 30% DBG (T4) did not have negative influence on HDEP, total egg mass, average egg weight and FCR of Koekoek layer chicken.

Table 3. Feed intake, egg production and FCR of Koekoek layer chicken fed with different levels of DBG at 21-45 weeks.

	Treatments						
Parameter	**T1(0)**	**T2(10)**	**T3(20)**	**T4(30)**	**T5(40)**	**SEM**	**P val.**
ADDMFI (g/b)	94.00[d]	93.80[d]	99.91[c]	102.15[b]	104.58[a]	1.12	0.0001
CDMFI (kg/b)	17.29[c]	17.25[c]	18.28[b]	18.67[ab]	19.07[a]	0.25	0.0003
TNEGLEP	102.24[a]	100.38[ab]	106.10[a]	101.07[ab]	90.17[b]	5.45	0.0534
HDEP (%)	60.86[a]	59.75[ab]	63.15[a]	60.13[ab]	53.67[b]	3.24	0.0534
HHEP (%)	60.86[a]	59.24[ab]	63.15[a]	56.74[ab]	53.67[b]	3.24	0.0378
TEGMS (kg/b)	5.24	5.04	5.38	5.15	4.60	0.41	0.438
AEWT(g)	50.46	50.06	50.28	50.40	50.81	1.05	0.969
FCR	3.32	3.46	3.40	3.71	4.15	0.27	0.078

ADDMFIT = Average Daily Dry matter Feed Intake; CDMFI = Cumulative Dry matter Feed Intake; TNEGLYEP = Total Number of Egg Lay at Entire Period; HDEP = Hen Day Egg Production; HHEP = Hen Housed Egg Production; TEGMS = Total Egg Mass; AEGWT= Average Egg weight; FCR = Feed Conversion Ratio; b = Bird; T1, T2, T3, T4, and T5= 0%, 10%, 20%, 30% and 40% DBG respectively.

Egg fertility and hatchability

The egg fertility and hatchability results were shown in Table 4. Significant result was not observed (P > 0.05) between treatments in fertility and hatchability of eggs collected from birds fed different levels of DBG. Fertility of eggs were in agreement with the finding of Gebremedhn *et al*.(2019) who found non-significant differences (P > 0.05) in Bovans fed 0-40% DBG. Fertility of eggs recorded in this study were also similar to the figures reported by Meseret *et al*., (2012) in RIR chickens and Yimer (2019) in Koekoek chickens, that ranged from 79-88% and 78-82%, respectively.

In contrast, the fertility of birds in this study was lower than the value (92.2%) reported by Getnet *et al*. (2020) for Koekoek chicken. Fertility might be affected by several reasons, like general condition of the parents, mating rate, age, egg-storage duration and condition, weather conditions, and geographical location (Adu-Aboagye *et al,* 2020).

The hatchability of fertile eggs was in agreement with the study of Getnet, *et al*., (2020) who reported 86.7% hatchability for Koekoek chicken fed with commercial layer feed. The results were similar to the finding of Esatu, *et al.* (2011) who reported 83% hatchability from fertile eggs for koekoek but do not agree with the finding of Mafeni and Fombad (2001) who reported significant result for feeding of DBG >10% for ISA commercial breeder chicken.

In summary, the present study revealed that feeding of DBG up to 40% had no negative effect (P > 0.05) on the fertility and hatchability of Koekoek layer chicken.

Table 4: Fertility and hatchability of eggs laid by Koekoek chicken fed with different levels of DBG

Parameter	T1(0)	T2(10)	T3(20)	T4(30)	T5(40)	SEM	P Val.
F (%)	81.31	79.18	78.66	88.22	82.74	4.34	0.204
HS (%)	69.49	71.44	68.14	76.98	68.90	6.26	0.631
HF (%)	84.42	89.94	86.40	87.06	82.90	4.45	0.578
NCHK (%)	62.63	61.59	62.04	69.57	65.32	5.44	0.567
WKCHK (%)	6.86	9.85	6.10	7.41	3.58	3.44	0.493
DIS (%)	11.83	7.74	10.52	11.24	13.85	3.33	0.479

F = Fertility; HS = Hatchability from Set Eggs; HF = Hatchability from Fertile Eggs; DIS = Dead In Shell; NCHK = Normal chicken; WKCHK = Weak Chicken; SEM = standard error of mean; T1 = 0% DBG; T2 = 10% DBG; T3 = 20% DBG; T4 = 30% DBG; T5 = 40% DBG.

Mortality of birds

The mortality result is presented in Table 5. The total mortality of birds in the entire period (21-45 weeks) of the study was 2.42%. There was not a single case of mortality in treatments T1, T3 and T5, which is quite a remarkable observation on the adaptive attribute of the Koekoek chickens. A substantial level was recorded only for birds under T4 (30% DBG) where the main causes for mortality was ascribed to protrusion of vents which resulted in cannibalism and mortality. This result was closely comparable to the finding of Dawed *et al*. (2018) who reported 3.56% mortality for egg laying parent stock Koekoek chicken during the period of 17-60 weeks age at Debre Zeit Agricultural Research Center. This result was also similar to the report of Kegne *et al. (*2021) who found 3.70% mortality in Koekoek layer chicken feeding on processed cow pea at Andassa Livestock Research Center. The level of mortality recorded in this study was extremely low compared to the value (18.04%) reported by Dereje and Tesfaye (2018) for the same breed of chickens between 27-48 weeks of age at Bako Agricultural Research Center.

Table 5. Mortality of Koekoek chicken fed with different levels of DBG.

Parameter	**Treatments**					
	T1(0)	T2(10)	T3(20)	T4(30)	T5(40)	Total
Mortality (%)	0.00	3.03	0.00	9.09	0.00	2.42

T1 = 0% DBG; T2 = 10% DBG; T3 = 20% DBG; T4 = 30% DBG; T5 = 40% DBG.

Cost benefit analysis

The cost benefit analysis on birds fed with different levels of dried brewery grain is presented in Table 6. The benefit cost ratio increased with the increased inclusion level of DBG up to 30%, with a slight decline at 40%. Thus, feeding of DBG for Koekoek layer chicken with the level of 30% had a better economic benefit compared to the control group (T1) and the other treatment groups. However, this analysis should be taken with caution since some of the major costs associated to the transportation and drying of DBG, as well as costs related to the extra labor involved were not considered.

Table 6. Cost benefit analysis for Koekoek layer chicken fed with different levels of DBG

Costs	Treatments				
	T1(0)	T2(10)	T3(20)	T4(30)	T5(40)
Chick cost	26.00	26.00	26.00	26.00	26.00
Feed cost	225.75	201.55	177.79	145.15	134.49
Total cost	251.75	227.55	203.79	171.15	160.49
Income earned					
Income from the sale of eggs	460.08	451.71	477.45	454.82	405.77
Income from the sale of birds	200.00	200.00	200.00	200.00	200.00
Total income earned	660.08	651.71	677.45	654.82	605.77
Profit	408.33	424.16	473.66	483.67	445.28
Benefit to cost ratio	2.62	2.86	3.32	3.83	3.77

T1 = 0% DBG; T2 = 10% DBG; T3 = 20% DBG; T4 = 30% DBG; T5 = 40% DBG.

CONCLUSION AND RECOMMENDATION

In general, it can be concluded that DBG could be used as a good protein supplement for Koekoek layer chicken up to 30% inclusion level in partial substitution of TSB and Noug seed cake without negative effect on egg production, egg fertility and hatchability performances with a better economic benefit. However, further works are required to devise easier methods for drying the bulky wet brewery grains.

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Identification of Major Goat Health Problems through Participatory Epidemiology in Selected Goat Breeding Villages of Bahirdar Zuria District

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ABSTRACT

The study was conducted with the objectives of identifying and quantifying major goat health problems, determining the magnitude of goat mortality and case-fatality rates and identifying the seasonal occurrence of major goat disease and disease outbreaks in goat breeding villages of Bahirdar Zuria district. Participatory epidemiology tools were applied and 128 practicing in goat production were interviewed and two focus group discussions each group composed of 12 respondents were conducted. A total of 746 sera samples were also tested for antibody against PPR and FMD virus using Competitive Enzyme Linked Immuno-Sorbent Assay (C-ELISA). The informants ranked the livestock species based on their economic benefits for livelihood as goats, cattle, poultry, sheep and equine in their order of importance. Informants described Anthrax, Conjunctivitis, Diarrhoea, External Parasite, Internal Parasite, ORF, Pox, PPR and Mastitis were ranked as common diseases by proportional piling and which were the main causes of morbidity and case fatality for their goats. However, Pox, FMD, PPR, Diarrhoea and Conjunctivitis were the most priority goat disease problems ranked in the top through matrix scoring. Among those infectious diseases, sero prevalence of FMD and PPR were 12.98% (47) and 28.12% (108), respectively. The four recognized seasons of the year contribute differently to the occurrence of goat diseases in the study area and most cases were occurred during long and short-rainy seasons, i.e. Kiremt (June to August) and Tsedey (September to November), respectively. Therefore, effective disease control strategies like vaccination, and deworming should be implemented. Awareness creation for small ruminant producers in the community on the nature, economic loss and control of economically important goat diseases should be implemented.

Keywords: Bahir Dar Zuria, C-ELISA, FMD, Goat, Participatory epidemiology, PPR

INTRODUCTION

Ethiopia is home, to approximately 52.5 million goats (CSA, 2021). Though the population density of goats in mid- and low-altitude areas is high, they are produced across the country from the arid lowlands to the coolest highland areas (Solomon et al., 2014). In the country, it is estimated that 16.83 million skins are produced annually, of which 29.9% of goat skins are recovered from the market (CSA, 2014). The average carcass weight of Ethiopian goats is 10 kg, which is the second lowest in sub-Saharan Africa (Teshale and Kaleab, 2020; Solomon et al., 2014). Goat production accounts for 21.8% of the total meat supply (Gezahagn, 2022) and the average annual meat consumption per capita is estimated to be 9 kg/year which was lower than the global average meat consumption (77 kg/year) (Gezahagn, 2022).

The current contribution of goats to the country's economy and producers' livelihoods is still below the total potential production capacity (Solomon et al., 2014; Girma et al., 2000). With the presence of large population size, diverse breed type and wide distribution across various agroecologies and production systems, there is a huge potential to utilize goats to raise the socio-economic status of producers by improving goat productivity. First, however, some key limiting constraints have to be tackled through various research and development interventions. The major limiting factors those hinder the potential of the goat productivity are abundant livestock diseases, feed scarcity and poor genetic endowment. In this regard, Andassa Livestock Research Center had established goat monitoring villages to identify the potential and design a breeding program for central highland goat in selected villages of Bahir Dar Zuria district, Northwestern Ethiopia (Assemu et al., 2020). Exploiting the full potential of goat production is however constrained by many diseases. Formulating an effective animal health intervention program is fundamental for a successful goat breeding program. However, the type of goat diseases prevailed and the associated risk factors are not yet determined in such goat breeding villages. Hence, based on the above evidences, the objectives of this study were to identify and quantify major goat health problems in the study areas; to determine the magnitude of goat mortality and case-fatality rates and to identify the seasonal occurrence of major goat disease and disease outbreaks.

MATERIALS AND METHODS

Description of the study area

The study was conducted in selected Wondata and Dehinamariam Kebeles of Bahir Dar Zuria district, where goat production is the main practice and source of livelihood. Bahir Dar Zuria district is found around Bahir Dar city which is the capital city of the Amhara region, Ethiopia. The District's area covers 1443.37 km^2 (CSA, 2011). Bahir Dar Zuria is part of the West Gojjam Zone, which is bordered by Yilmana Densa, Mecha, and Abay River, which separates from North Achefer; to the South, South West and North West, respectively. It is situated on the southern shore of Lake Tana. The topographic features of the district indicate that approximately 48% can be defined as rolling, 32% hilly, 13% mountainous, and 7% as valleys. Agriculture is the mainstay of the prop in the study area as it contributes about 100% of the population’s economy (CSA, 2016). The major crops grown in the area are wheat, barley, millet, teff and maize. The city is located approximately 565 km north-northwest of Addis Ababa, having a latitude and longitude of 11°36′ N and 37°23′ E coordinates, and an elevation of 1840m above sea level. Its temperature ranges from 10 to 32^0C. The area receives a mean annual rainfall of 800 to 1250 mm (Yemiamerew et al., 2022).

Questionnaire survey

Initially, a questionnaire survey was carried out to get baseline information about the common goat diseases in the study areas. All farmers (128) practicing in goat production were interviewed from the two kebeles. Others, who have good knowledge or experience in goat herding and goat diseases were included in the interview. In this phase, the respondents listed major goat diseases by their local names and their clinical symptoms and allow them to rank the diseases based on the frequent occurrence or severity of each listed disease using open-ended questions (SSI). The top five ranked diseases were selected to be studied in detail using participatory epidemiology. Respondents also describe and categorized major goat diseases in different age group. The ages of individual goats were categorized into three groups as kids, young and adults.

Participatory epidemiological study

In this phase, the actual participatory epidemiology of the major goat disease was carried out using two independent groups whereby each group was composed of 12 respondents. Explicitly, two groups were interviewed per kebele and informants who were members of the goat breeding program were considered. The investigation was carried out using selected participatory epidemiology (PE) tools including proportional pilling (matrix scoring, pairwise ranking), seasonal calendars and semi-structured interviews (SSI).

Scoring of Goat diseases

The top five ranked goat disease were prioritized using proportional pilling, which is a semi-quantitative method for determining community priorities. The local name of the disease, which represents the selected diseases mentioned, was written on the top of the flip chart. Then, the respondents were asked to pile sand in proportion to the importance of the diseases. Twenty-five (25) beans were used to make the technique more reproducible. The number of beans placed on the name of each disease was counted. The scores were recorded after summarizing and crosschecking their ranking by probing.

Estimation of goat morbidity and case fatality

The Proportional pilling technique was employed for flock morbidity and case fatalities. The participants were asked to divide the sands into two, a pile representing the proportion of goats that became ill in the last year and the other representing the proportion that remained healthy over the same period. This was given an overall proportion of goats that became ill over the year. The participants were then asked to give reasons that could explain the scores given. The pile representing the proportion of animals that became ill was further subdivided into six piles corresponding to the proportion of animals that got each of the five diseases identified through pair-wise ranking. The final step in this exercise was sub-dividing the piles representing individual diseases into the proportion of animals that recovered and those that died from each disease to determine case fatality rates (Bett et al., 2009).

Temporal Dynamics of Goat disease and disease outbreaks

Seasonal calendars were used in this study to understand local perceptions of seasonal variations in goat diseases, disease vectors and time of outbreak occurrences. A visualization method called a 'seasonal calendar' has been widely used by veterinarians and other livestock workers to illustrate seasonal variations in disease incidence (Konde, 1993; Hadrill and Yusuf, 1994), and disease vectors (Catley and Ahmed, 1996).

Seasonal calendar classifications

Four recognized main seasons contribute differently to the occurrence of goat diseases in the study area. These results were obtained from the discussion with informant groups and identifying seasonal calendars according to the local perceptions were recorded. Seasonality mainly depends on rainfall, sun intensity and flood retreats were the informants' main factors for classification. Therefore, the seasonal calendar is categorized as Tsedey which means spring has a cold climate with light rain that include months of September, October and November; Meker which means autumn crop harvesting season including December, January and February; Bega which was a sunny and dry season of the year including March, April and May and Kiremt which is characterized by heavy rainfall season including June, July and August.

Semi-structured interviews (SSI)

Following the scoring of the proportional pilling and seasonal calendar, the results were discussed with the participants using open and probing questions using SSIs. The informant groups were mainly probed on the top-ranked diseases about the seasonal occurrence, impact, age group affected and predisposing factors.

Blood Sample collection and serological test

Blood sample was collected from non-vaccinated goats above 6 months of age to confirm and support the appraisal information through serological result using non-heparinized vacutainer tube and 6ml blood sample was drawn from jugular vein of the animal. The serum was extracted from the collected blood in 12 hours by putting the tube in slanted position. Serological test performed for FMD and PPR anti-body by using ID.Vet ID Screen® FMD NSP Competition and ID.Vet ID Screen® PPR Competition, Montpellier, France antibody test kit, respectively.

The sample size was calculated based on the Thrusfield formula

$$N = \frac{1.96^2 P\exp(1 - P\exp)}{d^2}$$

Where, N = sample size, Pexp = expected prevalence, and d = absolute precision 5% absolute precision and 95% confidence interval were used to determine the sample size. Accordingly, the minimum sample size calculated was 384 samples. However, 362 serum sample of FMD were tested out 384 the remaining serum sample was haemolysed during blood sample transportation.

Data management and Analysis

All data collected were organized and fed into Microsoft Excel spreadsheets and coded appropriately using SPSS and STATA statistical software. Agreement between informant groups was assessed using Kendall's coefficient of concordance (W) and Logistic regression to quantify the association between disease, mortality and the associated risk factors, respectively.

RESULT AND DISCUSSION

Major goat production constraints

The main constraints in goat production identified and ranked by respondents in both peasant associations were diseases, labour shortage and predators according to their order of importance (Table 1). According to the majority of respondents, there has been high disease prevalence in both peasant associations. It was reported that farmers only got disease control service and there was lack of disease prevention strategy due to lack of governmental veterinary clinics and lack of infrastructures like refrigerators in the clinics to maintain the cold chain of the most abundant and infectious viral disease vaccines.

Table 1. The rank of major livestock production constraints

Constraints	**Ranks**							
	R1	R2	R3	R4	R5	Sum	Index	Score
Disease	205	24	36	4		269	0.366	1
Feed and grazing land shortage	10	40	42	18		110	0.150	4
Labour shortage	60	72	9	12	2	155	0.211	2
Predator	20	64	24	24	2	134	0.183	3
Marketing problem		8		12	6	26	0.035	6
Lack of credit	10	12	18			40	0.054	5

Disease outbreak and knowledge of respondents on existing diseases

Based on the questionnaire survey result, goat-rearing farmers mostly used hand dug-well as a source of water for their goats during the dry and wet seasons. From all 37% of respondents faced goat disease outbreaks and most of them did not recognize the disease (Figure 1). However, those respondents who can recognize the disease know the root cause of the disease. As they point out that the major reasons for the disease outbreak were introduced from the market, increased temperature of the area and drinking of communal stagnant water.

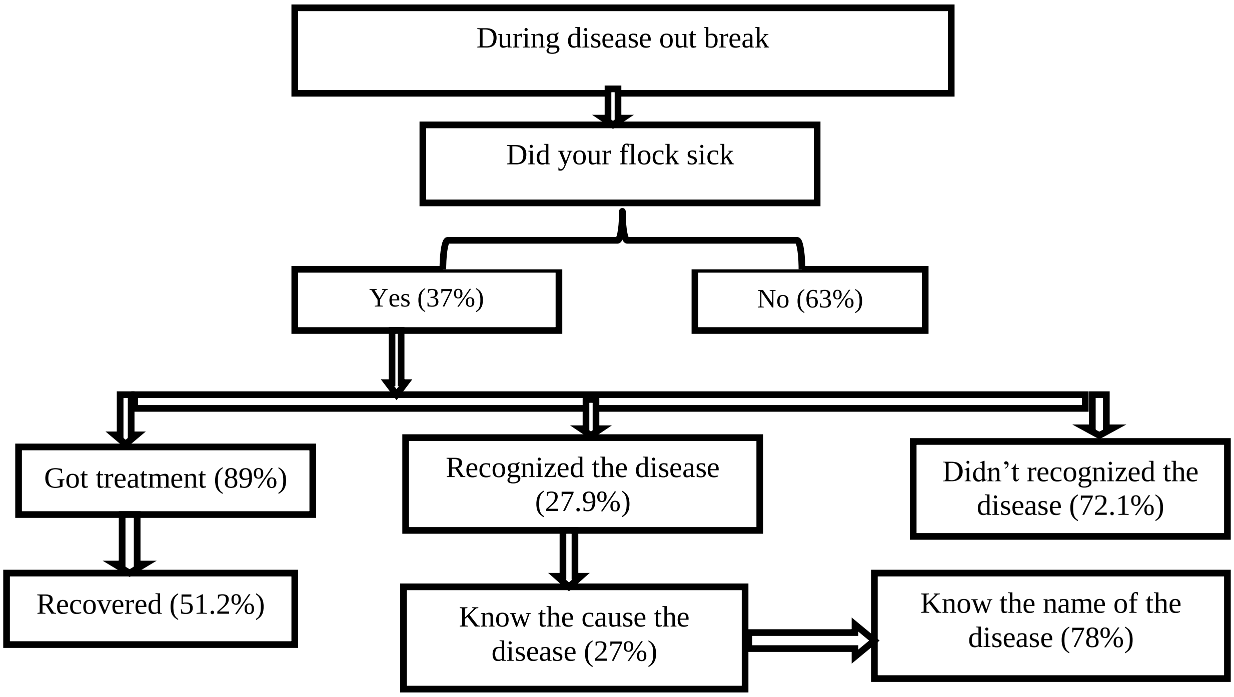

Figure 1. Disease outbreak and knowledge of respondents on existing disease chart

Common goat diseases, morbidity and case fatality across age groups of goats

Ranking of listed diseases using proportional piling across age groups showed that the top three diseases of goats were PPR, Pox and Diarrhoea (Table 2). The informants declared that in the kids' age group PPR, diarrhoea and internal parasite are the first, second and third diseases, respectively, diseases responsible for high morbidity and case fatality. Even if Pox had relatively lower morbidity than the top three diseases, it had effect for case fatality like internal parasite. PPR and Pox were the respective first and second causes of morbidity and case fatality in younger age groups of goats. Respondents also confirmed that PPR, Pox and Diarrhoea were the most common diseases responsible for morbidity and case fatality in adult goats.

Table 2. The rank of common diseases, morbidity and case fatality across age goats using proportional piling

	Kids		**Young Goat**		**Adult Goat**	
	Morbidity	**Case fatality**	**Morbidity**	**Case fatality**	**Morbidity**	**Case fatality**
Anthrax	4	6	2	7	2	2
Conjunctivitis	10	7	12	11	9	8
Diarrhoea	17	21	10	11	13	17
External Parasite	3	3	-	-	-	-
Internal Parasite	14	12	12	13	18	10
ORF	2	2	8	5	6	3
Pox	11	12	18	21	19	26
PPR	39	37	38	32	31	34
Mastitis	-	-	-	-	2	-
Total	100	100	100	100	100	100

Matrix Scoring for Disease characteristics

During the focus group discussion participants agreed there were five most important goat diseases which were responsible for the production and reproduction traits of their goat flocks. The association between diseases based on their characteristics and consequence was also assessed using the matrix scoring method. Simple matrices were constructed on the flip chart. Farmers recognized that goats triggered high mortality associated with PPR diseases (Table 3). FMD had high transmission rates across goat flocks, and Pox and Diarrhoea had a higher score as causes of abortion. Conjunctivitis is also responsible for reduced appetite and had a relatively short recovery period than other diseases. Regarding loss of body condition, diarrhoea accounts for a higher score than other diseases.

Table 3. Summarized matrix scoring of disease signs based on group discussion

Major Disease	**Mortality**	**Transmission**	**Abortion**	**Recovery**	**Reduced appetite**	**Loss of body condition**
Pox W=0.162***	4.5 (4-9)	5.5 (7-8)	3.75 (3-5)	4.25 (4-5)	1.5 (0-2)	1.5 (1-2)
FMD W= 0.08***	5 (5-6)	6 (7-9)	3.25 (3-4)	3.75 (4-5)	1.25 (1-2)	1.75 (2-2)
PPR W= 0.137***	5.5 (5-8)	5.25 (5-7)	2 (2-3)	2.75 (3-3)	3.5 (3-5)	2 (2-3)
Diarrhoea W= 0.561	3.5 (3-4)	5 (5-8)	3.75 (3-7)	3.5 (2-5)	1.5 (1-3)	3.75 (3-7)
Conjunctivitis W= 0.110***	3.75 (3-5)	3.5 (4-5)	1.25 (1-2)	5.25 (5-8)	5.5 (6-7)	1.75 (1-3)

W=Kendall's coefficient of concordance (***P<0.001). The minimum and maximum scores are shown in parentheses.

Season of major goat disease occurrence

According to responses from informants the seasonal variation in the occurrence of "Kiremt" was also noted by the community during the matrix scoring, most cases occurred during long and short-rainy seasons, i.e. Kiremt (June to August) and Tsedey (September to November), respectively. Proportional piling showed that PPR had a higher score during Kiremt and Tsedey, whereas FMD highly occurred during Tsedey (Figure 3).

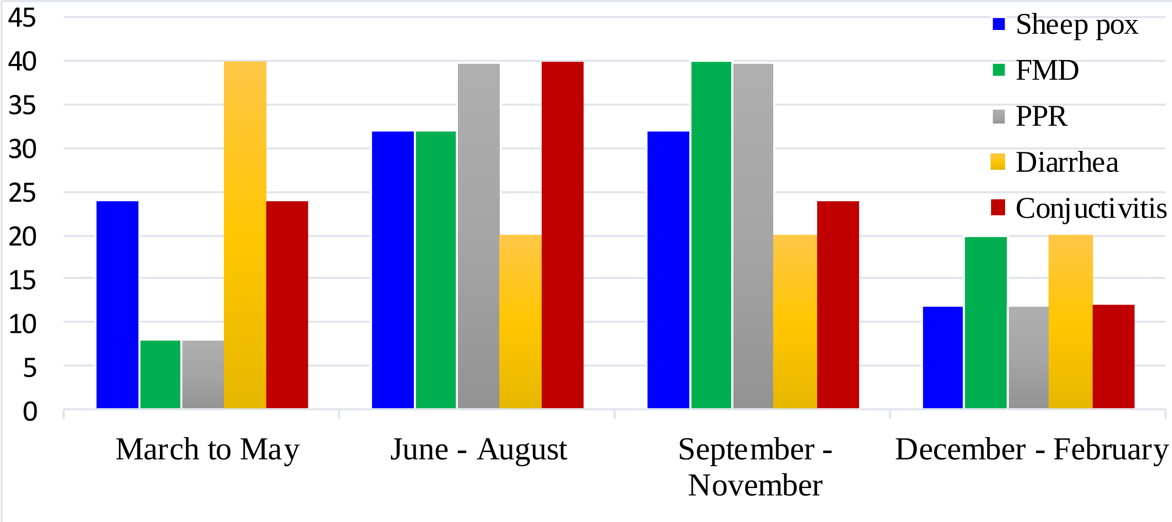

Figure 3. Seasonal occurrence of major goat diseases

Sero-Prevalence of PPR

Out of the total (n=384) number of samples collected, the overall seroprevalence of PPR was 28.12% (108). Based on location 82(41.2%) from Dehinamariam and 26(14.05%) from Wondata kebele were found positive. The prevalence of PPR varies significantly (P < 0.00) between study locations (Table 4).The present study was comparable with some previous reports, conducted in a different part of Ethiopia under an extensive goat production system; 28.6% of unvaccinated goats in Eastern Amhara (Biruk, 2014); 26.3% of non-vaccinated goats in Gambella (Bekele et al., 2011). Conversely, the present finding was relatively found higher than 2.3% and 2.28% in Awash Fentale District (Faris et al., 2011; 2012), and 3.49% in Bench Maji Zone (Tamirat et al., 2017). It is also relatively lower than the reports of Berihun et al. (2014) 46.53% in Tigray, Bekele et al. (2011) 38.3% in Afar and Kibrom et al. (2018) 41.8% in South Omo.

Risk factors investigated against PPR seropositivity

Higher seropositivity was also recorded in females (33.5%), adults (33.19%) and medium herd size (35.04%) than their counterparts (Table 4). Study kebeles, sex, and herd size were found significantly (P<0.05) associated with PPR seropositivity based on multivariable logistic regression. Those goats found at Wondata kebele were 0.22 times less likely to be infected with PPR disease than Dehina Mariam. Male goats were 0.51 times less likely to have PPR disease than females. Based on the result all risk factors except age had statistically significant (P < 0.05) association with seropositivity (Table 4).

Table 4. Risk factors associated with PPR seropositivity using multivariable logistic regression analysis

Risk factors		N	Positive	Prevalence (%)	Odds ratio	95% Conf. Interval of OR	P-value
Kebeles	Dehina M.	199	82	41.20	1.0	-	-
	Wondata	185	26	14.05	0.22	0.13 - 0.37	0.000
Sex	Female	194	65	33.50	1.0	-	-
	Male	190	43	22.63	0.51	0.30 - 0.85	0.009
Age	Young	158	33	20.89	1.0	-	-
	Adult	226	75	33.19	1.42	0.83 - 2.44	0.199
Herd size	Small	51	7	13.72	1.0	-	-
	Medium	117	41	35.04	2.57	1.05 - 7.01	0.048
	Large	216	60	27.78	1.97	0.84 - 5.19	0.138

Sero-Prevalence of FMD

Out of the total (362) number of samples collected overall seroprevalence of the FMD virus was 12.98% (47). It was also observed that 10.29% (18) and 15.51% (29) were positive at Dehinamariam and Wondata kebele, respectively. The prevalence of FMD varies significantly (P <0.00) between study locations (Table 5).

Risk factors investigated against FMD seropositivity

Higher seropositivity was also recorded in females (19.05%), above three age groups (21.85%) and medium herd size (14.63%) than their counterparts (Table 5). Study kebeles, sex, and age group were found significantly (P<0.05) associated with FMD seropositivity based on multivariable logistic regression. Those goats found at Wondata kebele were 1.9 times likely to be infected with FMD disease than Dehinamariam. Male goats were 0.40 times less likely to have FMD disease than females. Based on the result all risk factors except herd size had statistically significant (P <0.05) association with seropositivity (Table 5).

Table 5. Risk factors associated with FMD seropositivity using multivariable logistic regression analysis

Risk factors		**N**	**Positive**	**Prevalence (%)**	**Odds ratio**	**95% Conf. Interval of OR**	**P-value**
Kebeles	Dehina M.	175	18	10.29	1.0	-	-
	Wondata	187	26	15.51	1.90	0.94 – 3.86	0.050
Sex	Female	189	36	19.05	1.0	-	-
	Male	173	11	6.36	0.40	0.17 - 0.92	0.031
Age group	≤1 year	148	17	11.49	1.0	-	-
	1yr<x< 2 years	69	1	1.45	0.12	0.01 – 0.93	0.043
	2yrs≤x< 3 years	26	3	11.54	0.82	0.21-3.19	0.780
	≥3 years	119	26	21.85	1.51	0.69-3.28	0.292
Herd size	Small	114	15	13.16	1.0	-	-
	Medium	123	18	14.63	1.50	0.68 – 3.31	0.304
	Large	125	14	11.20	0.89	0.39 – 2.01	0.791

CONCLUSION AND RECOMMENDATIONS

Infectious diseases like Anthrax, parasites, conjunctivitis, ORF, PPR and diarrhea were declared by informants as common goat diseases of study area. However, PPR, Pox and Diarrhoea were the top three goat diseases which were important causes of morbidity and case fatality in younger age groups of goats. June to August and September to November were important disease-occurring seasons. There was a higher seroprevalence of PPR and FMD in goats in the study area. Study kebeles, sex, age group and herd size were significant risk factors for the occurrence of PPR and FMD in goats. Therefore, effective disease prevention by vaccinating FMD and PPR before June and control strategies like deworming should be implemented in the study area. Awareness creation for small ruminant producers in the community on the nature, economic loss and control of economically important goat diseases should be implemented. Even though, scientifically they are not diseases, respondents included diarrhoea and parasites as major diseases of their goats. Therefore, further study should be conducted to identify those diseases caused by parasite and diarrhoea.

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Species Identification and Habitat Suitability Modeling of Major Ixodid Ticks Infesting Livestock in Wag-Lasta Area

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ABSTRACT

A cross-sectional study was employed (April 2020 to June 2021) to identify prevalent ticks at genus and species level and delineate their spatial distributions in Waghimra, Ethiopia. Ticks species identification was determined based on their morphological patterns. Three agro ecologies and Georeferencing was performed while samples were collected, and seven bioclimatic variables and three individual models were utilized to develop the ensemble model. Three genera, Rhipicephalus, Amblyomma and Hyalomma were identified in cattle, goats, and sheep with distribution rates of 52.5%, 40.7% and 6.9%, respectively. Nine different tick species were found with varying levels of abundance, including A. variegatum, R. pravus, R. decoloratus, A. cohaereneces, and R. evertsi, H. truncatum, R. pulchellus, H. rufipes and H. marginatum. According to this study, female animals were more vulnerable than male ones, and adults were more vulnerable than young and old animals. The male-to-female and adult-to-nymph stage ratios for the tick genus were found to be 1:1 and 1:6, respectively. Precipitation of the driest Month, Precipitation of the Warmest Quarter, Isothermality, Precipitation of the Wettest Quarter and Temperature, Annual Range has contributed the highest for the ensemble model. The models indicated that A. Variegatum was dominated the highlands and midlands of Sekota and Dehana districs; R. pravus was more prevalent in the lowlands of Abergelle, Ziquala and Sahala districts. Overall the study sites were highly suitable for both A. variegatum and R. pravus with vast variety of tick species presence.

Keywords: *Tick, spatial distribution, ensemble modeling, Waghimra*

INTRODUCTION

Ethiopia has the largest livestock in Africa that provides livelihood to the poor and foreign income source to the country through the export of live animals, meat, offal and partial or finished leather products. However, the sector generates little profit than its actual potential due to widespread diseases, feed shortage, and low genetic potential of breed available (CSA, 2020). In tropical countries, tick and tick-borne diseases are among significant livestock production constraint (Kouam & Dongmo, 2018). The likely consequences of tick infestation include losses in milk and meat production, tick-borne disease morbidity and mortality, hide and skin deterioration and expenses for control and prevention measures. They are the most important vectors of pathogenic agents affecting livestock, humans, pets and wildlife (Adane et al., 2018; Kouam & Dongmo, 2018; Lovis et al., 2013; Nogueira Domingues et al., 2012). Ticks are vectors responsible for many illnesses, such as babesiosis, theileriosis, ehrlichiosis and borreliosis. Tick is the second most common vector of human infectious diseases after mosquitoes (Bellgard et al., 2012).

There are two families of ticks, Ixodidae (hard ticks) and Argasidae (soft ticks). Studies on the prevalence of tick infestation in Ethiopia revealed that there are four primary tick genera (Amblyomma, Rhipicephalus (Boophilus), Haemaphysalis, and Hyalomma) whose prevalence fluctuates from location to location and across time (Gashaw et al., 2018). At least 800 species of ticks globally and 47 in Ethiopia have been reported to date (Bekalu, 2016).

Species distributions models (SDMs), also commonly referred to as ecological niche Models (ENMs) are becoming routinely used in vector-borne disease systems to model the potential geographic distribution of risk. Broadly, this is accomplished by correlating locations where a species of interest is known to occur with the underlying environmental characteristics (e.g., climate, elevation, and land cover). The resulting model can then be projected to unstapled areas on the landscape, providing a spatial prediction of areas that are ecologically suitable for species presence.

Spatial and temporal conditions determine the distribution of ticks for the completion of their life cycles. The local climate may support or inhibit several crucial components of their life cycles. Temperature and relative humidity control the survival of eggs and larvae. Ecoclimatic variables are commonly used as predictive variables for tick distribution and are sensitive to high temperatures and drought. Data layers describing vegetation characteristics are predictive variables because vegetation patches can provide local sheltered habitats for ticks when climatic conditions are too harsh (Remesar et al., 2019; Sungirai et al., 2018). The approach developed to check factors creating favorable conditions for tick survival are an interpolation of a weather station and remotely sensed data. While weather station data produce biologically meaningful climate-related variables, remotely sensed data provide broader diversified environmental descriptors, including information on vegetation cover. These biological and weather variables determine the existence of ticks in time and space. Hence, habitat models using variables that have plausible relation to the tick's survival in a particular location and time are a reliable source of information in predicting the probable occurrence of tick species for a wider area using presence-only data from accessible places.

Although ticks remain a problem, little is known about their distribution and occurrence in Waghimra. Data on the prevalence and type of ticks are essential for the development of an effective control strategy for ticks (Nasero & Roba, 2020; Riet-Correa et al., 2018). Also, habitat suitability models are an excellent source of information to delineate all possible suitable territories of ticks in which these models were not available for the study area. Therefore, the objectives of this study were to identify a suitability model for major tick species in Waghemira and Lasta area.

MATERIALS AND METHODS

Description of Study Sites

This study was carried out in three agroecological areas of Waghimra zone of the Amhara region, Ethiopia. Waghimra is located at 12° 23"N and 13° 16" N degrees of longitudes and 38° 44’’E and 39° 21" E degrees of latitudes and altitudes ranging from 989 to 4043m above sea level. The area is characterized by unimodal and erratic annual precipitation patterns ranging from 350 to 650 mm and recurrent droughts. The zone has eight districts and two administrative towns. The main rainy season (summer) starts from late June to early September in the highlands and midlands and from early July to mid-August in the lowland area (Adane et al., 2018). Cattle and Abergelle breed goats are the major livestock reared in the area.

Study population and study design

A cross-sectional study with a simple random sampling method was conducted (April 2020 to June 2021). Animals of all species brought to local veterinary clinics (three from each district) were our target populations for this study. In fact, during the peak season for tick populations, animal owners brought their animals to local veterinary clinics for the sake of prevention from ticks and other cutaneous diseases. The study animals were categorized as young, adult, and old based on their age, while physically grouped into poor, medium, and good (Adane et al., 2018). A data recording format was developed and detailed records of the host species, age, sex, body condition, and district, and geo reference were recorded. Animals were restrained, and feeding ticks were carefully detached and maintained in universal bottles containing 20 ml of 70% ethanol. Collected specimens were immediately transported to the laboratory and stored at +4°C for further investigation. Stereomicroscope, manual and color pictures of various ticks were used to assign ticks at the genus and species levels. The laboratory species and genus identification was carryout at Kombolcha animal health regional laboratory, Amhara Region, Ethiopia.

Data analysis and model development for R. pravus and A. variegatum

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 25 (IBM Corp. Armonk, NY). Host-related demographics and tick infestation abundance in different districts were summarized using descriptive statistics. Tick species suitability modelling was performed using the R software, USDM package. Suitable localities were delineated using ArcGIS version 10.17 of overlay analysis tools.

Tick species occurrence data

Ticks were collected from domestic animals across the three agroecology of the area. Animals from these agroecologies were brought to at least three nearby local veterinary clinics, which were the sites where we attained samples. In the study areas, one veterinary clinic is mandated to serve at least three Kebeles so that we attain the agroecology variations. This agroecology was highland, midland and lowland to capture any species variation based on climate and weather. The collected tick species were morphologically identified at the species level with a stereomicroscope. Accordingly, we collected 203 ticks that belong to three Ixodid tick genera comprising nine tick species. The species identified were R.pravus, A.variegatum, R.decoloratus, A.cohaerenece, R.evrtsi, H.truncatum, R.pulchus, H.marginatum, and H. rufipes with varying degrees of prevalence. Among these, R.pravus and A.variegatum were the most dominant, with equal prevalence of 31%. Hence, we decided to develop a predictive model for the two tick species. Along with the tick species, specific localities of the host animal and tick were recorded along with other information. Georeferencing was done with Google earth.

Bioclimatic variables

A high resolution (30 arc-second) Bioclimatic variables that determine the occurrence and adaptation of insect vectors were used to develop the model. Initially, 23 were proposed but later trimmed to seven variables due to multicollinearity issues. These variables were downloaded from the worldclim 2.1 databases. The list of variables used is listed in Table 1.

Table 1. Bioclimatic variables used to develop a predictive model

Variable code	Name
wc2.1_30s_bio_3	Isothermality
wc2.1_30s_bio_7	Temperature Annual Range
wc2.1_30s_bio_14	Precipitation of Driest Month
wc2.1_30s_bio_15	Precipitation Seasonality
wc2.1_30s_bio_16	Precipitation of Wettest Quarter
wc2.1_30s_bio_18	Precipitation of Warmest Quarter
wc2.1_30s_bio_19	Precipitation of Coldest Quarter

Model development

Before the model development, the raster datasets in GeoTIFF format were clipped to the study area extent in QGIS software and converted to asci grid cells. Then, the datasets were checked for multicollinearity in R software. Variables with more than a 0.7 correlation coefficient were trimmed. Accordingly, out of 23 variables, 16 of them had multicollinearity issues. Hence, we used seven bioclimatic variables to develop the model.

The model was developed using an ensemble modeling algorithm in R software. Three individual models, including General Linear Model, Artificial Neural Network and Maxent, were selected to develop the ensemble model. These models were selected because of previous reports of performance in handling model overfitting.

The presence-only occurrence data was used to generate random background pseudo absence for the two selected tick species. Using the actual occurrence and the pseudo absence, the model was adjusted to run three-fold for the three selected models, making nine individual model outputs. These outputs were ensembled using true skill statistics evaluation metrics of 0.75 performances. The mean value of each output was used to estimate the suitability gradient of the final model. True skill statistics, roc and kappa value were used to evaluate the accuracy of the model. The output of the algorism in grid raster data was exported to QGIS.

The suitability level was mapped from 0-1000, 0 being unsuitable and 1000 being perfectly suitable and the rest in between the two.

RESULTS AND DISCUSSION

Tick species distribution

The three major genera of ticks identified were *Rhipicephalus*, *Amblyomma and Hyalomma*, with distribution rates of 52.5%, 40.7% and 6.9%, respectively. This finding was in contrast with those report by (Ayana et al., 2021) in Borena, Ethiopia, which were 78.3%, 13.5%, and 1.2%, respectively. Ticks belonging to the following nine species were identified: *A.cohaerenece* (9.9%), *A.variegatum* (31%), *H.marginatum* (1%), *H.rufipes* (1%), *H.truncatum* (5%), *R.decoloratus* (10.3%), *R.evertsi.evertsi* (9.3%), *R.pravus* (31%) and *R.pulchellus* (2%). Pastoralists in the lowlands frequently move their livestock to nearby areas for water and grazing. Thus, locality data for tick collections rarely represent the habitat in which most of the developmental cycles of the specimen or species have occurred.

Amblyomma was evenly dispersed throughout the body, while *Rhipicephalus* mainly attached around the ears and perineum, which agrees with the report of (Ayana et al., 2021). On the legs, belly, dewlap, and scrotum, hardly any genera were observed. Besides, *H.mareiginatum* and *H.rufipes* were only observed in Dehana and Sekota; the data were insufficient for a meaningful comparison of their distribution patterns. Female animals were found more vulnerable than males. Adult animals were more frequently infected (59.8%) than young (23.0%) or old (17.2%) animals (Table 2). In the study area during the harsh season, only adult animals in good body condition were allowed to graze, which may have contributed to the increased prevalence of this finding. In contrast to this, young and old animals, especially poorly conditioned animals, are kept at home so that there is less chance of contracting diseases from the local communal grazing land. Tick infestation was more prevalent in animals with good body condition (50.3%) than poor (29.7%) and medium (21.0%), which is substantially in contrast to the reports of 86.7%, 90.9% and 75.3% for animals with poor, medium, and good body condition (Nasero & Roba, 2020), respectively.

Table 2. Descriptive characteristics of ticks collected across different variables

Variables	Category level	N	%
District	Abergelle	50	24.5
	Dehana	55	27.0
	Sekota	98	48.5
Species	Cattle	43	21.0
	Goat	138	67.6
	Sheep	22	11.3
Sex	Female	121	59.3
	Male	82	40.6
Age	Adult	122	59.8
	Old	35	17.2
	Young	46	23.0
Predilection site	Perineum	58	28.8
	Chest	16	7.9
	Ear	90	44.1
	Inguinal	30	14.8
	Leg	10	4.4
	Good	102	50.3
Body Condition Score	Medium	42	20.7
	Poor	59	29.0
Sex of ticks	Female	103	50.7
	Male	100	49.3
Developmental stage	Adult	125	61.58
	Nymph	78	38.42

The dominant genus in Sekota and Dehana was *Amblyomma,* the least abundant in Abergelle district. The distribution of *A.variegatum,* known for its wide host range, in relatively high rainfall areas agrees with the report (Pegram, 1981). In contrast, *Rhipicephalus* was more abundant in the lowlands of Abergelle (45%) than in Sekota (35%) and Dehana (20%) districts (Table 3). In particular, *R.pravus* was more prominent in the lowlands of Abergelle, where the optimal rainfall for the species to maintain was up to 750mm, which was in line with the report (Pegram, 1981).

Table 3. Tick species identified by the study district

Tick species	Sekota	Dehana	Abergelle	Total (%)
A.cohaerenece	7	12	1	20(9.9)
A.vartiegatum	45	17	1	63(31)
H.marginatum	0	2	0	2(1)
H.rufipes	2	0	0	2(1)
H.truncatum	5	4	1	10(5)
R.decoloratus	1	2	19	21(10.3)
R.evrtsi	15	2	2	19(9.3)
R.pravus	20	16	27	63(31)
R.pulchus	3	1	0	4(2.0)
Total	**98(48.53)**	**55(26.96)**	**50(24.51)**	**204(100)**

Table 4. The distribution of tick species along body parts

Tick species	Predilection sites					
	Chest	Head	Inguin	Leg	Perineum	Total
A.cohaerenece	4	6	5	1	4	20
A.variegatum	6	17	16	5	19	63
A.variegatum	0	1	0	0	1	2
H. rufipes	1	0	0	0	1	2
H. truncatum	1	1	2	1	5	10
R.decoloratus	0	19	1	0	1	21
R.evertsi.evertsi	2	6	3	0	8	19
R.pravus	2	39	3	3	16	63
R.pulchellus	0	1	0	0	317	4
Total	**16**	**90**	**30**	**10**	**58**	**204**

During the peak tick breeding season of drought, well-conditioned animals are more likely to travel long distances in search of food and water, increasing the risk of being infected. In contrast, poorly conditioned animals are more likely to be kept indoors or to cover only a short distance, making them less vulnerable. The average sex ratio of 1:1 was detected in ticks of all genera, and the tick-stage nymph-to-adult ratio was 1: 1.6.

Suitability localities for *A.variegatum* and *R.pravus*

The ensemble model outperformed the individual models regarding the evaluation metrics used. The ROC evaluation had the highest score for both species and KAPP had the lowest estimation (Table 5).

Table 5. The performance of the model for both Amblyomma *variegatum* and *Rhipicephalus pravus*

Evaluation metrics	*A.variegatum*	*R.pravus*
	Testing data value	Testing data value
TSS	0.944	0.935
ROC	0.991	0.988
KAPPA	0.591	0.463

Temperature variables can influence the occurrence of insects and vectors in an environment. Hence, the Annual Temperature Range (Bio_7) contributed most for both species models. Precipitation of the Warmest Quarter (Bio_18), Isothermality (Bio_03), and Precipitation of the Wettest Quarter (Bio_16) contributed significantly to the model (Table 6).

Table 6. Variable percent contribution to the model

Variables used	***Amblyomma variegatum***	***Rhipicephalus pravus***
	% Contribution	**% Contribution**
TemperatureAnnual Range	32.6	27
Precipitation of the Warmest Quarter	15.3	16.9
Isothermality	14.9	14.2
Precipitation of the Wettest Quarter	13.5	14
Precipitation of the driest Month	9.8	10.8
PrecipitationSeasonality	8.4	8.6
Precipitation of the coldest Quarter	5.6	8.5

Temperature variables are known to determine the occurrence of ticks in a particular place. When the temperature of the area is above threshold, like Abergelle district, their occurrence is limited to districts like Sekota, and Dehana in which their average temperature is lower. Suitable localities for *A.variegatum* were in the midlands of Sekota, Gazgibla, and Dehana districts, whereas the lowlands of Abergelle, Ziquala, and Sahala were unsuitable for this tick species. Besides, the Lasta district was unsuitable for ticks (Figure 1). This can be because factors other than agroecology also play a role in determining its existence. Also, the major determinant variables like Temperature, annual range of temperature and Precipitation are moderate and close to the normal range compared to the lowland areas where a high-temperature range and low precipitation are expected. Hence, the midlands being suitable are plausible to these tick species that were dominantly prevalent in the midlands.

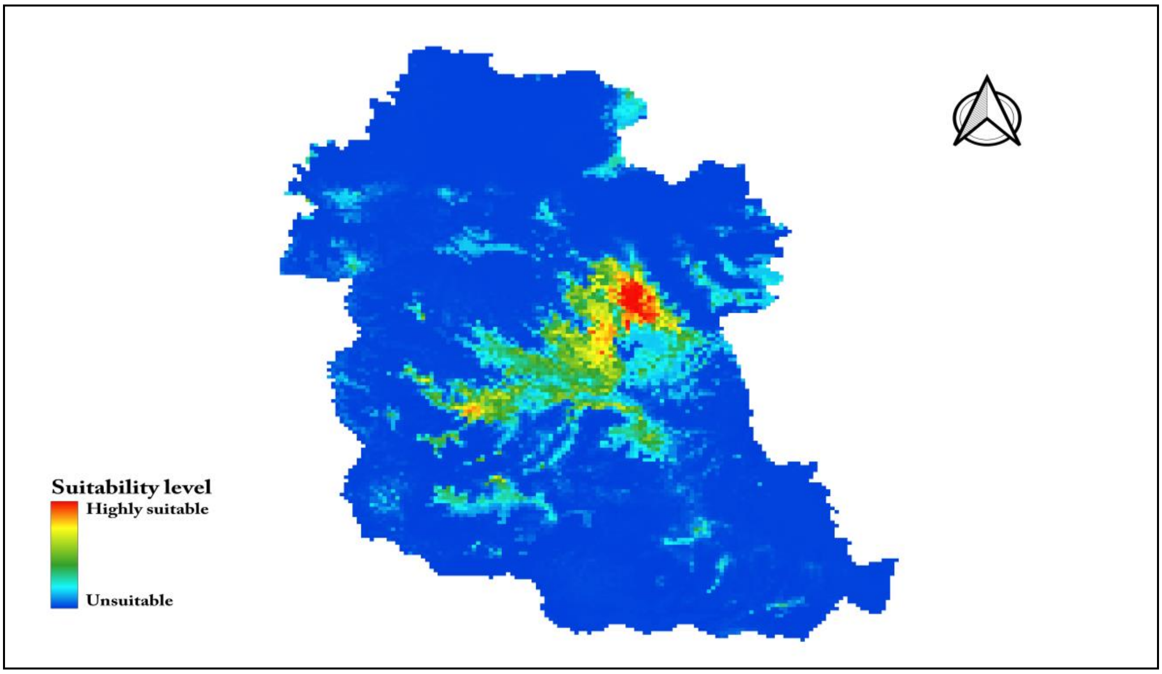

Figure 1. Predicted geographical distribution of suitable territories of *Amblyomma variegatum* in Waghemira and Last area

Unlike *A.variegatum, R.pravus* has widely distributed suitable territories. The lowlands of Abergelle, in the midlands of Dehana and Sekota districts, were the prominent suitable niche localities. Besides, the Ziquala, Sahala, and Bugna districts were also moderately suitable (Figure 2).

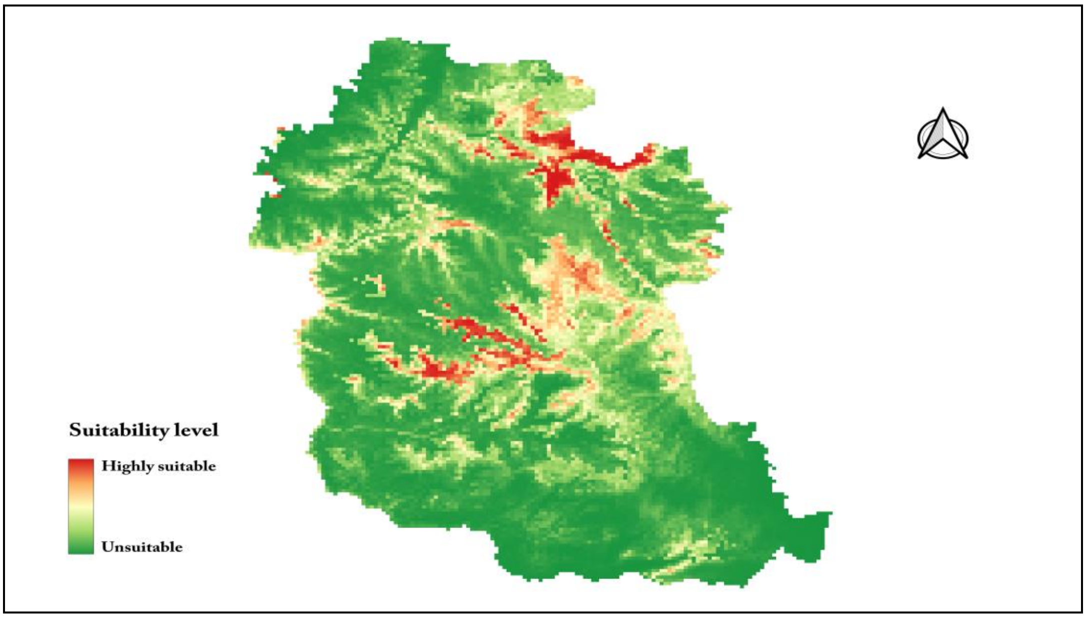

Figure 2. Predicted geographical distribution of suitable territories *Rhipicephalus pravus* in Waghemira and Lasta area

CONCLUSION AND RECOMMENDATIONS

This study revealed a wide range of tick species are available, affecting livestock production in the study area. The two most abundant tick species were found *to be A. variegatum* and *R. pravus*. Overall, nine tick species were detected in this study, of which suitability modelling was attempted for only the two abundant species. Accordingly, the model predicted that the midland areas of Waghemira and Lasta are more suitable for A. variegatum than the hot and dry lowland areas. In contrast, the hot and arid lowlands of Waghemira were highly suitable for *R. pravus*. Further studies on ticks and tick-borne diseases with advanced molecular techniques to better understand their distribution in time and space are highly advised.

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Acaricidal Efficacy Evaluation of Amitraz and Diazinon against Amblyomma Variegatum Tick Species in Waghimra Zone, Northern Ethiopia

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ABSTRACT

Ticks pose a substantial economic burden associated with production loss and treatment costs globally. Ethiopia has tremendous livestock resources, but its productivity is hindered by various animal health challenges in which ticks are the top priority, with a limited response to acaricidal treatments. Hence, this paper was designed to evaluate the effectiveness of commercially available chemicals (amitraz and diazinon) against the widely distributed tick species (A. variegatum) in Waghimra zone. Ticks were collected from animals admitted to veterinary clinics with no history of treatment with acaricides. Adult Immersion Technique (AIT) was employed to detect acaricidal resistance, and the mean percent control and antiparasitic effectiveness were used to estimate tick susceptibility with a completely randomized laboratory-based trial (CRD). The mean weights of eggs laid by ticks subjected to amitraz and diazinon indicated that amitraz had a better egg-laying-inhibition effect than diazinon. The mean control percentages of amitraz and diazinon were 92.8%±2.8 and 69.7%± 1.55, respectively, with a highly significant difference (P = 0.0002). The antiparasitic effectiveness of the two drugs were 57.5±0.48 and 37.5%±0.48 for amitraz and diazinon, respectively, which revealed that amitraz was better than diazinon in killing adult ticks (P =0.026). In general, ticks treated with diazinon showed evidence of resistance development, and amitraz is relatively the most effective acaricide. We recommended the use of amitraz in the study area and other locations with similar settings.

Keywords: *Acaricidal; Adult Immersion Test; Amblyomma variegatum; Amitraz; Diazinon*

INTRODUCTION

Tick infestations are a major problem for animal production in tropical areas where prevention and control remain deficient (Rosa et al., 2016). There are seven hard ticks genera, four are prevalent in Ethiopia: *Amblyomma*, *Rhipicephalus* (*Boophilus*), *Haemaphysalis*, and

Hyalomma (Gashaw et al., 2018). More than 800 species of ticks globally and 47 in Ethiopia have been reported to date (Bekalu, 2016; Pegram, 1981).

Control and prevention measures for tick infestations include acaricide treatments, tick-resistant animals, vaccination of animals against tick, and management interventions. Chemical acaricides such as synthetic pyrethroids, organophosphates, and amitraz are the only choice for fighting tick infestation (Yessinou et al., 2016). However, improper, inadequate and excessive use of these substances encourages the emergence of drug resistance which is a change in the target species' susceptibility to synthetic insecticides (Rosado-Aguilar et al., 2010).

Drug resistance is a growing issue that poses serious dangers to livestock sectors. A lack of standardized techniques for diagnosing acaricide resistance appears to be the main difficulty in creating and maintaining a tick resistance monitoring system. The most commonly used tickcidal resistance evaluation techniques are Adult Immersion Test (AIT), Larval Packet Test (LPT), and Larval Immersion Test (LIT) (FAO, 2004). Even though ectoparasites, particularly ticks, are major animal health problems in the Waghimra zone (Bahiru & Assefa, 2020), little is known about their efficiency and also, there are signs of resistance by ticks against commonly used acaricides. Therefore, the objective of this study was to evaluate the efficacy of commonly used chemicals against the most common tick species in the Waghimra zone.

MATERIALS AND METHODS

Description of the study area

The tick identification study was conducted in the Waghimra zone, Amhara Regional State, Ethiopia. A suitability model for *A. variegatum* and *R. pravus* distribution in Waghimra and Lasta area, Amhara Regional State, Ethiopia, was developed. The elevation of the area ranges from 989 to 4043 meter above sea level. It is characterized by unimodal and erratic annual precipitation patterns ranging from 350 to 650 mm. The Zone had eight districts and two administrative towns. The main rainy season (summer) starts from late June to early September in the highlands and midlands and from early July to mid of August in lowlands areas (Adane et al., 2018). The area is characterized by more massive livestock production than agriculture due to recurrent draught in which local zebu cattle and Abergelle breed goats are the main livestock types reared. A recent survey showed widespread ticks in all species of animals in which *Amblyomma variegatum* was found to be the dominant species in all agroecologies of the area. Tick species were collected from animals admitted to vet clinics found in the area and the experiment was conducted in Sekota Dry land Agricultural Research Centre Laboratory.

Experimental setup

Tick species: Fully engorged female ticks on infested animals, not being sprayed within one month, were collected and taken to a research laboratory in clean, dry and labeled plastic bottles with holes at the top for proper aeration. The collected ticks were distinguished microscopically with the help of keys at the species and genus levels. Only *A.variegatum* species were screened for this experiment.

Acaricides: The test acaricides were amitraz 12.5% (Hebei Veyong Animal Pharmaceutical Co., China) and diazinon 60% (Kafer El Zayat Pesticides & Chemicals Co., Egypt). Amitraz and diazinon were diluted in 1:1000 and 1.6:1000 in distilled water, with a final volume of 1000 ml, respectively.

Invitro acaricidal efficacy determination: The Adult Immersion Test (AIT) technique was used to evaluate acaricides sensitivity assay and water with four replications as described by (FAO, 2004). A completely randomized design (CRD) was employed to evaluate the efficacy of amitraz and diazinon against *A.variegatum*. Samples were first washed with water to remove feces, eggs, and debris and allowed to dry on a paper towel. About 120- ticks of equal weight were randomly drawn into 12 groups (10 ticks per group) and weighed. Each assigned group of ticks was subjected to amitraz, diazinon and water treatments (immersion) with four replications in 100 ml plastic containers and shacked for one minute. Acaricides were discarded through the sieve and the ticks were placed on absorbent paper to dry. Once dried, each tick per group was stuck in Petri dishes ventral side up with double-sided adhesive tape. Finally, samples were placed in a large plastic box and incubated at 27 °C with a dampened sponge.

The oviposition and death status was checked daily at regular 12-hour interval in the daytime. After seven incubation days, live and dead ticks were counted, and the weight of eggs laid per treatment and control groups were weighed. A group of 10 engorged female ticks of equal size were weighed and recoreded on a sensitive balance that was able to measure weights of about 100 grams. The Egg-Laying Test (ELT) was used to compare the mass of eggs laid by acaricide and water-treated ticks and finally estimate the percentage of control as described by (Ayana et al., 2014).

Percent control = $\frac{MEC-MET}{MEC}$ x 100, Where (MEC) is the mass of eggs laid by control ticks, and (MET) is the mass of eggs laid by treatment ticks

The Antiparasitic efficacy was also evaluated as

AE = [B – T] / B

Where B = the Mean Survival of ticks of control groups, T = Mean Survival of ticks of treatment groups, and AE is antiparasitic efficacy (killing effect of chemicals) as described by (Petros et al., 2015).

Statistical analysis

The statistical analysis was done using Statistical Package for Social Sciences (SPSS) version 25 (IBM Corp. in Armonk, NY). Simple descriptive statistics like mean, standard deviation and counts were calculated. An independent t-test was used to compare the mean effectiveness of the two acaricides. A P-value less than 0.05 were considered significant with a 95% CI.

RESULTS AND DISCUSSION

All ticks in the control group survived (40), while amitraz-treated ticks survived the least (17), and those treated with diazinon were 25. On average, 10 and 4.25 and 6.25 ticks per group survived for the control, amitraz and diazinon, respectively (Figure 1). On the other hand, out of 40 ticks treated with amitraz and diazinon, 23 and 15 were found dead at the end of the study period, respectively.

Immersed ticks with both acaricides caused the death of many ticks and the surviving ticks laid the list egg weights indicating the chemicals still got their acaricidal potential. The mean weight of eggs oviposited by ticks treated with amitraz, diazinon and water were 0.07, 0.29 and 0.97 grams, respectively (Table 1). This indicated that amitraz was superior in egg-laying inhibition than diazinon and water. The reason might be associated with the high sterilization effect of amitraz compared to diazinon (Petros et al., 2015).

Table 1. Mean survival and oviposition of ticks after treatment

	N	Amitraz	Diazinon	Control
Average weight in grams of immersed ticks	40	19.94	21.012	20.98
The average number of ticks that survived	40	4.25	6.25	10
The average weight of Eggs laid in grams	40	0.07	0.29	0.97

Table 2. Analaysis of Varianvce for the Egg Laying Inhibition Effect of Treatments

Source of Variation	**SS**	**DF**	**MS**	**F**	**P value**
Treatment	1.758	2	0.8790	F (2, 9) = 305.7	P<0.0001
Residual	0.02588	9	0.002875		
Total	1.784	11			

Table 3. Mean Comparison of tick survival for the two chemical preparations (t-test).

Treatment	MaS	MiS	MS	SE	t-value	p-value	AE (%)
Amitraz	5	3	6.25	0.48	2.94	0.026	57.5
Diazinon	7	5	4.25	0.48			37.5

MS= mean survival of ticks, SE= standard error, MaS=Maximum survival of ticks,MiS=Minimum survival of ticks

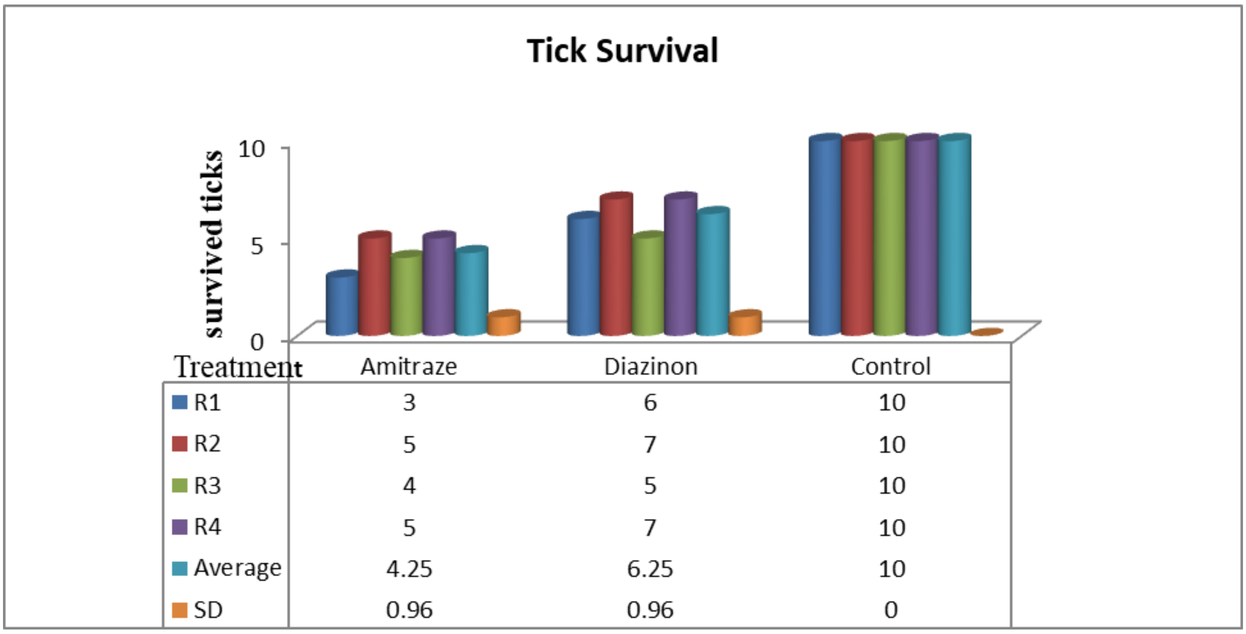

Figure 1. Immersed Tick Survival (R=Replication, SD= Standard Deviation)

However, the acaricides are not as effective as they should be. The estimated antiparasitic efficacy of amitraz was 57.5%±0.96 (Table 3) which was much lower than the report of 100% (Ayana et al., 2014) in Borena and higher than 33.33% (Gashaw et al., 2018) in Sebeta Ethiopia. Gashaw et al. (2018) also confirmed a 100% mortality of ticks by diazinon, which was not in line with 37.5%±0.96 (Table 3) of this finding. The superiority of amitraz acaricidal property over diazinon was also supported by the finding of Petros et al. (2015), who reported 99.1% to 85.2% for amitraz and diazinon. The other reason for these efficacy deviations by the corresponding drug could be differences in the test ticks, inconsistencies in the sample size, the study location, and uncontrolled use of acaricides which promote the development of resistance in ticks.

Table 4. The mean control percentages for amitraz and diazinon

Treatment	Max	Min	SE	t-value	p-value	C%± SE
Amitraz	98.53	86.67	2.8	8.9	0.0002	92.80±2.8
Diazinon	73.55	67.21	1.55			69.72±1.55

C%= Control Percent, Max=Maximum C %, Min=minimum C% SD= Standard Deviation

Amitraz and diazinon overall mean percent of oviposition inhibition effect were calculated by comparing the mean egg mass laid by ticks treated with each acaricide versus the mean egg mass of untreated control groups, and its standard deviation was calculated from mean percent control at each replication. Accordingly, the mean control percentages for amitraz and diazinon were 92.7% ±2.8 and 69.72% ± 1.55, respectively. Lower egg mass was laid in amitraz-treated groups than in diazinon-treated ticks with a highly significant difference (P=0.0002) (Table 4) indicating amitraz is better than diazinon in controlling *A. Variegatum* tick species and perhaps others as well in the study area and also other parts of the world that have closely similar settings. Overall, this result indicated that amitraz treatment significantly reduced the mass of eggs laid compared to diazinon (Figure 2).

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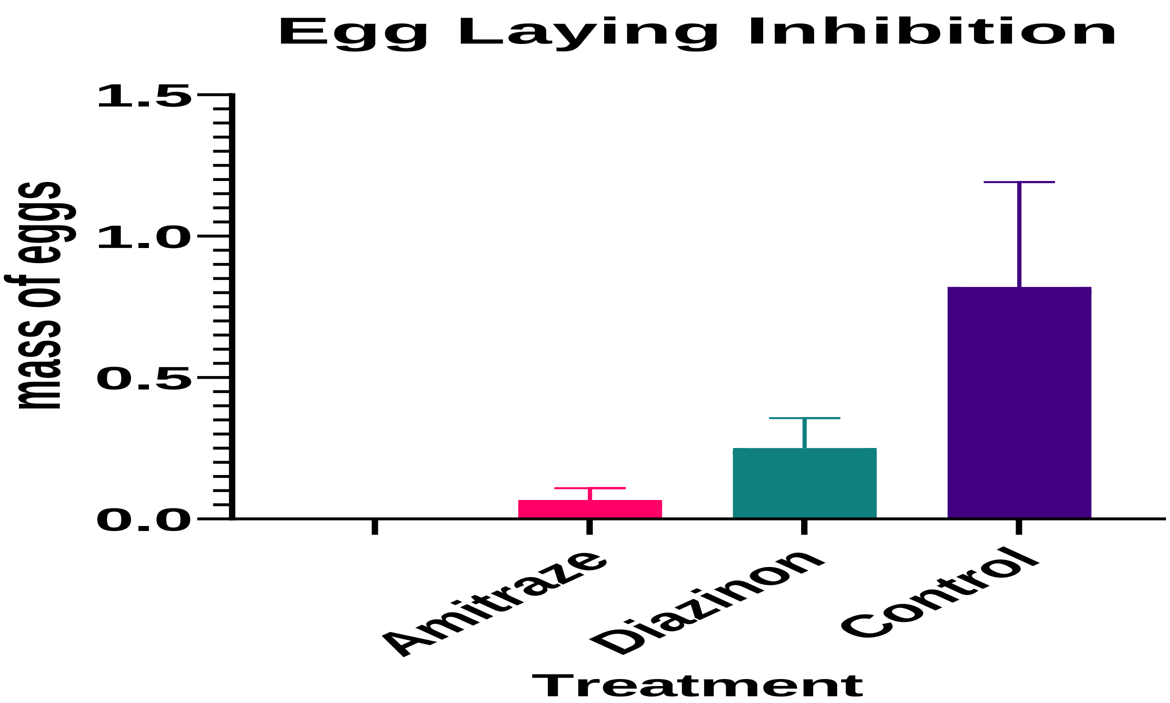

Figure 2. Mass of Eggs laid by Ticks

CONCLUSION AND RECOMMENDATIONS

The result indicated that drug resistance is developing by A.variegatum tick species against commonly used acaricides in the study area. It is alarming that continuing indiscriminate use of these chemicals by non-professionals without considering resistance development may facilitate complete inefficacy sooner than later. Hence, control and prevention approach should paramount the responsible use of these acaricides. Amitraz performed better than diazinonin both Antiparasitic and egg-laying inhibition effects hence, it should be used as first-line treatment against ticks in the study area.

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Determinants of Exotic Chick Morbidity and Mortality Kept in Small Scale Commercial Chicken Farms in Bahir Dar, Northwest Ethiopia

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ABSTRACT

A longitudinal study was conducted on exotic chicks ‘morbidity and mortality in small-scale chicken farms of Bahir Dar, Ethiopia. A total of 10006 exotic chicks from five small-scale farms were monitored for clinical health problems from 0-45 days old age. Data on potential risk factors were collected using personal observations, postmortem examination, and laboratory analysis. Survival analysis was employed to model the presumed explanatory variables. The overall crude exotic chicken morbidity and crude mortality risk rates were 6.58% and 6.4%, respectively. The incidence and risk rate of chicken diseases were spraddle leg (15.08%, 0.99%), cannibalism (7.54%, 0.51%), ascites (6.77%, 0.46%), omphalitis (4.77%, 0.32%), avian salmonellosis (2.46%, 0.19%), avian mycoplasmosis (1.08%, 0.10%), respectively. Among the risk factors investigated, the experience of the chick care taker (HR= 2.45, P= 0.000), source of day old chick (HR= 2.64, P= 0.000), chick caretaker (HR= 0.41, P= 0.000) and breed (HR= 2.35, P=0.000) were found significantly associated with the incidence of crude morbidity and mortality. “Avian salmonellosis and avian *Mycoplasma galisepeticum* 30.7% and 14.8%, respectively, were confirmed based on serological tests. In conclusion, the morbidity rate and mortality rate of chicks were found to be higher than the economically tolerable level. Therefore, it is advised that further interventions be made against the identified pathogens and risk factors for chicks’ morbidity and mortality that have been discovered.

Keywords: *Incidence, Risk rate, Survival analysis*

INTRODUCTION

Livestock production in Ethiopia contributes 15 to 17% of the total gross domestic product, 35 to 49% of agricultural GDP, and 37 to 87% of the household incomes (EGDP 2017).

However, the contribution of poultry to the Ethiopian economy is only 2-5% of the potentiality from 56.06 million chickens (Dawit *et al.*, 2017). Currently, in Ethiopia, there is a high demand for chicken meat and egg due to a substantial increase in the price of beef, mutton, and a growing population that can't be achieved by local chickens (Tadelle etal, 2013). As a result, the livestock master plan of the Ministry of Agriculture has been targeted to upgrade village chicken production by using exotic chickens to raise chicken meat production from 2.9 thousand tons to 10.2 thousand tons, an egg from 258 million to 894 million (ELMP, 2015).

Exotic chicken breed affected by various types of diseases makes the situation worse, which is susceptible to several diseases that plague the chicken industry today (Tewodros 2019). According to CSA, 2020, chicken mortality and morbidity in Ethiopia due to disease is 34% and 42.04%, respectively, (CSA, 2020). In this regard, different researchers have investigated numerous determinant factors in chicken morbidity and mortality such as pullorum (Markos & Nejash 2016), Avian mycoplasma (Adamu *et al*., 2017; Jibril *et al*., 2018), fowl typhoid considered to be the most important chickens disease reported in different parts of Ethiopia

Amhara National Regional State government has given great attention to exotic chicken production to stabilize food security and increase job opportunities through organizing youth groups under small-scale chicken production systems. However, the expansion of small-scale chicken farms was intercepted as a result of the widespread occurrence of chicken diseases within poultry farms (Mohamed *et al*., 2018; Gebrewahd *et al*., 2017). A comprehensive study on epidemiological determinants of exotic chicken morbidity and mortality using longitudinal study design has been scarce, especially in the present study area, where scale small-scale exotic chicken production is flourishing. Therefore, , the objective of this study is to determine the prevalence of major economically important chicken diseases, determine the incidence rate, morbidity rate and mortality rate of exotic chicken from day old to 45 days of age, investigate determinant factors influencing exotic chicken morbidity and mortality rates in a small-scale production system

MATERIALS AND METHODS

Study area description

The study was conducted in Bahir Dar City, Northwestern Ethiopia, which is the capital of the Amhara National Regional State. The area is located at latitude 11.5936° to 11° 35' 37.1" North, longitude 37.3908° or 37° 23' 26.8" East, about 578-kilometer Northwest of the Ethiopian capital, Addis Ababa. It is located at an altitude of 1,820 meters (5,970 ft) above sea level, which receives an annual rainfall of 1200-1600 mm with an average temperature from 10 to 38^{0}C. Bahir Dar is known for its wide avenues lined with palm trees and a variety of colorful flowers and is surrounded by Lake Tana and the Blue Nile (CSA, 2007).

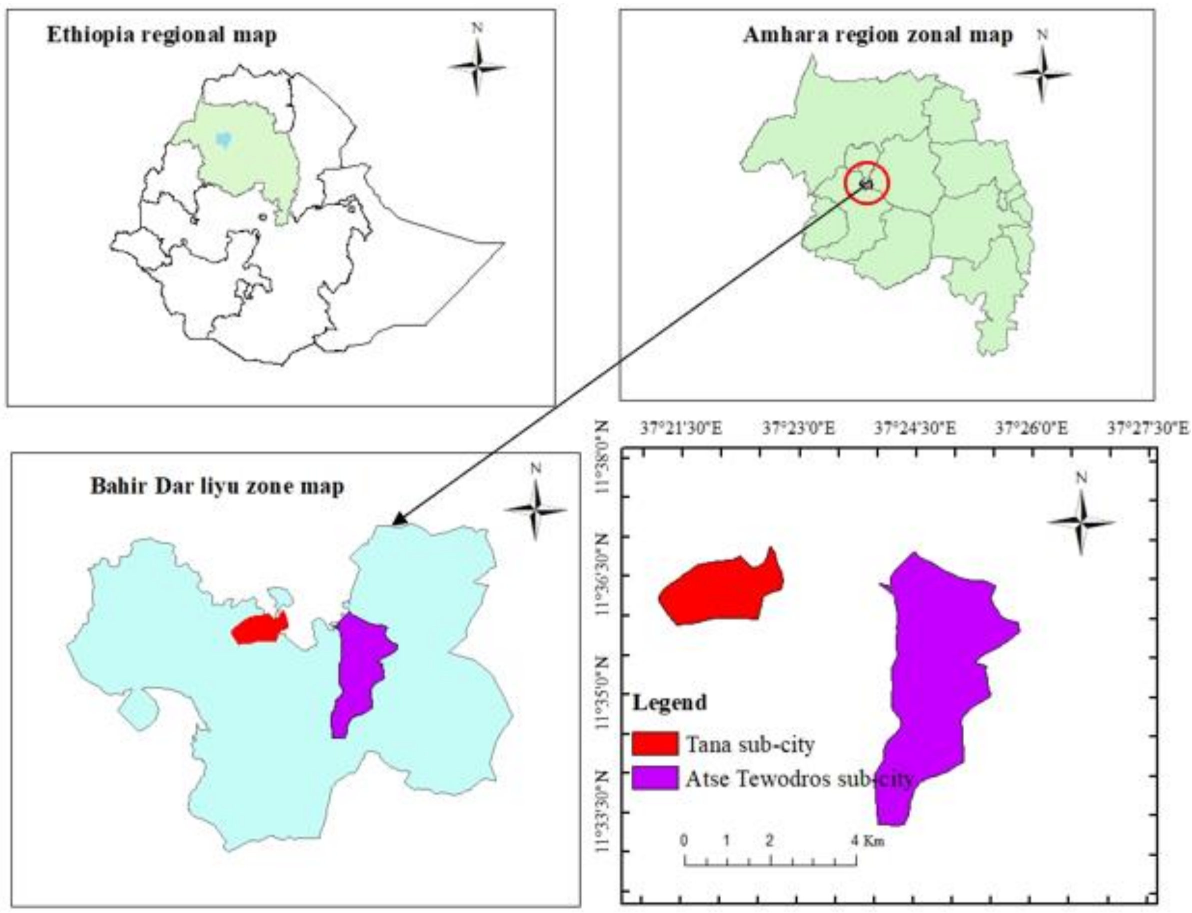

Figure 1. Map of the study area

Selection of study farms

A total of five small scale farms were enrolled and followed for approximately eight weeks on actively engaged chicken producer organized youth groups. The organized youth groups were received training on chicken production before starting exotic chicken rearing by the Bahir Dar City administration Micro and Small Enterprises Development Office.

Study population and sampling technique

The study population was 10006-day old exotic chicks reared under a small-scale production system in Bahir Dar City. Day-old refer to the age group up to 72 hours old while chicks were > 72 hours to 8 weeks old age (EIAR, 2014). A list of small-scale chicken farms was obtained from Bahir Dar City Administration Small and Micro Enterprise Development Office. For this study, purposive sampling procedures were employed to select representative farms based on the availability of small-scale chicks' farms and willingness of chicken producers for the frequent follow-up study.

Study design

Longitudinal study design

The sampling units (chick) were identified individually by leg band and monitored throughout the study period. All five farms were regularly visited daily to record management practices and occurrence of health problems. Observed chick health problems during the follow-up period were individually recorded based on their clinical signs, postmortem finding, and laboratory investigation. Chick was withdrawn from the unfollow-up when they completed their 45 days study period and when the chick loss happened during the follow-up period, the date, and reason for the loss was recorded.

Data collection method

Chick morbidity is defined as a sickness that has recognizable clinical manifestation and mortality as the death of a chick at the age of 0-8weeks old age. Follow-up data collection was conducted for 45 days. Daily data collection formats were given to farm attendants to record any event exhibited by each chick in the respective study farms such as flock size, health problems, the number of sick and dead chick', additions, and withdrawals of chicks.

Diagnosis of chicken disease observed in sick and dead chick during the follow-up period was, examined using case history, clinical sign, and laboratory analysis. Blood was collected from diseased chicken by plucking few feathers from the ventral surface of the humeral region of the wing and wiping the site with cotton damped with alcohol, approximately 2ml of blood samples were being collected from brachial veins using a syringe with 23-Gauge hypodermic needles. The syringe was labeled verified before drawing the blood from the chicken and set tilted on a table overnight (24 hrs). At room temperature to allow clotting for easily separating the plasma (Pires et al., 2012). Then sera were filled in cryovials tubes with a specific code number for each chicken and kept frozen at – 20ºC until analysis. A total of 99 (52 salmonellosis and 47 Avian mycoplasmas) suspected serum samples were transported in a cold chain container to National Veterinary Institute (NVI) for SAT and ELISA tests respectively. The slide agglutination test (SAT) using undiluted polyvalent salmonella antiserum was used to diagnose salmonella by depositing the same 25µl volume of serum and antigen per test. Then after mixing the two liquids exactly for 2 minutes by using agitator, reading was done within 30 seconds. Visible aggregates were indicative of positiveness. ELISA test was used to detect specific antibodies against M. gallisepticum. A final serum dilution of 1:100 was used, according to the instructions of the manufacturer. All serum samples collected from each chicken were run on the same test plate to prevent conclusion errors that could be due to day-to-day variation in the test Positive and negative reference controls provided by the manufacturer were also used in each test run, for quality control and to confirm the results. Optical density values were set at a wavelength of 405 nm, using an ELISA reader.

Data management and analysis

Univariate and multivariable cox-regression was employed using Stata Statistical Software: Release 14 to examine and quantify the association between explanatory variables with chicken morbidity and mortality. The associations between explanatory variable and outcome variables were done by Cox's proportional hazard model. Incident density was calculated by dividing the number of diseases cases or deaths to the number of chick days at risk (Muraguri *et al*., 2005). Number of chick days at risk was calculated by adding the number of days that each chick stayed in the study group excluding days obtaining a new case in each chick or the days of removal from the study group. As directly taking true rate results tend to overestimate morbidity, mortality and other specific disease conditions were converted into risk rates based on the formula $RR=1-e^{-\text{True Rate}}$ (Martin *et al*., 1987,Gitau *et al*., 2010; Yeshwas, 2015; Wudu 2007).

Besides the number of exotic chicks in a population that test positive for a specific disease based on a serum sample was estimated dividing the number of "seropositive exotic chick to number of exotic chicks examined. In determining crude morbidity rate, a chick completely recovered from an illness was considered to be at risk for another illness and even to the same type of illness. As far as the second occurred after the disappearance of the clinical sign of the first disease condition were considered as different cases in calculating the incidence rate. In this case, the days in which the chick stayed ill were not counted as days at risk for the second occurrence.

Survival analysis and investigation of risk factors

First, the Kaplan–Meier method was employed to estimate the hazard function of observed hazard differences for different explanatory variables with morbidity and mortality. However, Kaplan–Meier graph doesn't allow to say, with any confidence, whether or not there is a real difference between the groups (Hosmer and Lemeshow, 1999). As a result, the probability of obtaining the observed hazard curves was evaluated by the Log-rank test at $P<0.05$.

Furthermore, Cox's proportional hazard model was used to evaluate and quantify the association between explanatory variables. Investigation of risk factors related to chick health problems were done by considering a total of 16 potential risk variables. The responses of all variables were dichotomized carefully to make the cut-off points reasonable, facilitate analysis and interpretation of results. In the analysis, only the first occurrence of cases was considered. Initially, the association of individual risk factors with an outcome variable was screened. Those variables significantly associated with the outcome variable at a 5% significance level in the univariate analysis were selected for multivariable analysis using Cox regression to ensure their independent effect. In the multivariable analysis, a model was fitted for each outcome variable by stepwise backward elimination of insignificant variables ($P>0.05$).

RESULT AND DISCUSSION

Chick morbidity and mortality

During the study period, a total of 10,006 chicks were followed from five (5) small-scale chick farms, in Bahir Dar City. The only chicken health service provided for scale small-scale chicken producers during rearing chicken was vaccine availability against Newcastle disease and infectious bursal disease from day-old chicken distributer organization. Among, total chick followed, 4490 (44.90%) were Koekoek, 3300 (32.98 %) Bovans Brown, and 2216

(22.15%) SassoT-44. About 93.5% of chick was completed the follow-up period and the remaining (6.37%) lost the follow-up due to death. Among total chicks observed, 650 chicks (6.5%) were sick. Of the total 650 sick chicks, 637 (98%) were died and only 2% of sick chick recovered from disease during the follow-up period. This indicates the probability of sick chick between 0 to 45-day old age to be recovered from the disease is very low.

The present study revealed that the crude exotic chick morbidity and mortality rates in the study area were 6.5% and 6.3 %, respectively (Table 1).The present incidence of crude morbidity and mortality findings were found higher than the Western standard, normal (≤ 1.2%) or high (> 1.2%) (Pereira *et al*., 2010) as well as the expected level of mortality rate in African standards of ≤ 2.5% in broiler and 2 to 5% in layer chicken that chicken that can be achieved through good chicken health management (Boulianne *et al*., 2013).

The present morbidity and mortality finding was lower when compared to other previous findings in Ethiopia (Hailu *et al*., 2012)and abroad (Uddin et al 2012; Muhammad et al 2010). For instance, Hailu *et al*. (2009) has reported the highest 45% and 29.9% of chicken mortality in sixteen districts of Amhara National Regional State and, in Andassa Poultry Farm, respectively. Uddin *et al*., (2012) has reported 32.38 % and 21.3% morbidity and mortality respectively in the cage system in India, and (Muhammad *et al*., 2010) has reported 11.41% mortality under the small scale production system in Nigeria. The variation observed among the studies might be associated with variations in the source of day-old chicken, management of chick, type of chick breed, and production system. For instance, poor health management of sick chick and extended time of day-old chicken transportation was observed in the present study of chick farms and source of day-old chick, respectively.

The morbidity and mortality variations observed among the present and previous studies might be associated with variations in chicken production systems, breed type used, management practice, and locations. The major chicken diseases diagnosed in the present study were mismanagement (36.77%), unknown (25.54%), spraddle leg (15.08%), cannibalism (7.54%) ascites (6.77%), omphalitis (4.77%) avian salmonellosis (2.46%) and avian mycoplasmosis (1.08%) (Table 1).

Table 1. Causes of exotic chick morbidity and mortality across breeds under a small-scale commercial farms

Causes of morbidity	Bovance Brown		Koekkoek		SassoT-44		Overall (%)
	N	%	N	%	N	%	
Ascites	6	5.17	28	6.36	10	10.64	6.77
Omphalitis	4	3.45	17	3.86	10	10.64	4.77
Spraddle Leg	10	8.62	63	14.31	25	26.59	15.08
Avian Mycoplasmosis	1	0.86	1	0.23	5	5.32	1.08
Avian Salmonellosis	11	9.48	5	1.14	0	0	2.46
Cannibalism	11	9.48	31	7.05	7	7.45	7.54
Mismanagement	50	43.10	157	35.36	32	34.04	36.77
Unknown	23	19.83	138	31.36	5	5.31	25.54

Major chicken health problems found in the present study were consistent with other previous studies in Ethiopia and abroad (Selam and Kelay, 2013; Mishamo 2019; Kassaye *et al.*, 2010; Farooq *et al.*, 2002; Rahman and Samad2003, Muhammad *et al.*, 2010; Uddin et al2012; Tirunesh and Girma 2016); Hailu *et al.*, 2012); Tadesse, 2017).higher magnitude of morbidity and mortality was recorded in Koekoek as compared to Bovance Brown and SasoT-44. The incidence of morbidity for Bovance Brown, Koekoek, and SasoT-44 was 3.5%, 9.8%, and 4.24%, respectively. Likewise, the prevalence of mortality for Bovance Brown, Koekkoek, and SasoT-44 was 3.4% 434 9.67%, and 4.15%, respectively.

The hazard function curve for chick morbidity and mortality indicates that the median age for chick morbidity and mortality was in 10 days. The cause of chick morbidity and mortality found in these findings were relatively comparable with various previous findings in chicken (Mishamo 2019; Kassaye *et al.*, 2010; Rahman and Samad, 2003; Muhammad *et al.*, 2010); Uddin *et al.*, 2012).The incidence of crude morbidity and crude mortality rates under small-scale farming in the study areas were 6.58% and 6.48%, respectively. The incidence of chick health problems diagnosed during the follow-up study period was spraddle leg (0.99%) followed by cannibalism (0.51%), ascites (0.46%), omphalitis (0.32%), avian salmonellosis (0.19%), avian mycoplasmas (0.10%).

Table 2. The incidence of disease conditions and causes for exotic chicks' morbidity, and mortality on small scale commercial farms

Variables	N	Chick days at risk	Chick 45 days at risk	Incidence Rate	
				True	Risk (%)
Crude morbidity rate	650	430772	9572	0.0679	6.58
Crud morality rate	637	430785	9573	0.0665	6.48
Cannibalism	49	431317	9584	0.0051	0.51
Ascites	44	431310	9584	0.0046	0.46
Omphalitis	31	431353	9585	0.0032	0.32
Spraddle Leg	98	431151	9581	0.0102	0.99
Avian Mycoplasmosis	7	431391	9586	0.0013	0.10
Avian Salmonellosis	16	431326	9585	0.0016	0.19

Risk factors

The present study tried to investigate the determinant factors affecting exotic chick morbidity and mortality that were recorded from direct observation. Among sixteen (16), initially considered potential risk factors for exotic chick morbidity and mortality, only (7) explanatory variables were P<0.05 associated with chick morbidity and mortality based on univariate Cox regression analysis. Additional job (HR= 0.66, P=0.000), ownership of chick caretaker (HR= 0.68 P =0.002), experience chick caretaker (HR= 1.46, P=0.002), source of chick (HR= 1.52, P=0.021), season of chick hatching (HR= 1.29, P=0.021)breed (HR= 2.35, P= 0.00) and arrival time (HR= 0.56, P=0.004) variables were associated with chick morbidity and mortality based on Univariate Cox regression.

However, when those significant variables at univariate cox regression were allowed to fit the multivariable cox-regression, only four (4) explanatory variables were found significant for the final model. These include the experience of chick caretaker, source of the chick, breed, and the ownership of chick caretaker have a strong significant relationship with exotic chick morbidity and mortality.

Table 3. Potential variables significantly associated with chick morbidity and mortality based on Univariate Cox regression

Risk Factors	Categories	Morbidity			Mortality		
		HR	95% CI	P-Value	HR	95% CI	P-Value
Additional Job	No vs Yes	0.66	0.52 - 0.83	0.000	0.64	0.51 - 0.81	0.000
Ownership*	Owner vs Hired	0.68	0.53 - 0.86	0.002	0.64	0.49 - 0.81	0.000
Experience*	≤ 2 yrs vs ≥2yrs	1.46	1.15 - 1.87	0.002	1.49	1.17 - 1.91	0.001
Source of chicken	Ethiochicken vs Hawassa	1.52	1.21 - 1.91	0.000	1.56	1.23 - 1.97	0.000
Season of hatching	Autumn vs Winter	1.29	1.04 - 1.60	0.021	1.31	1.03 - 1.66	0.025
Arrival time	Day vs Night	0.56	0.37 - 0.83	0.004	0.54	0.36 - 0.81	0.003
	SassoT-44	Ref					
Breed	Koekkoek	2.35	1.90-2.94	0.000	2.39	1.90-2.99	0.000
	Bovance Brown	1.10	0.94-1.19	0.351	0.99	0.87-1.14	0.453

* Chicken caretaker; ref = reference; yrs= Years; HR = hazard rate

The hazard of chick morbidity was 2.35 times higher in the Koekoek breed as compared to the SassoT-44 breed (Table 4). Experience of chick caretaker (HR= 2.45, P= 0.000), breed (HR= 2.35, P =0.000) and source of chick (HR= 2.64, P= 0.000) were found the most determinant factors of chick morbidity. Based on the final model, the hazard for morbidity is 2.45 times higher in those chick caretakers who had below two years of farm management experience as compared to those who have more than two years of experience (Table 4). The hazard of chick morbidity was 2.64 times higher in those chicks coming from Hawassa as compared to those sourced from Ethio chicken.

Table 4. Potential variables that were significantly associated with chick morbidity based on multivariable Cox regression

Risk Factors	Categories	Morbidity		
		HR	95% CI	P-Value
Experience*	≤ 2 Years Vs ≥ 2 years	2.45	1.94 – 3.11	0.000
Source of chicken	Ethiochicken Vs Hawassa	2.64	2.23 - 3.11	0.000
Ownership*	Owner Vs Hired	0.41	0.32 - 0 .52	0.000
Breed	SassoT-44	Ref		
	Koekoek	2.35	1.90-2.94	0.000
	Bovance Brown	0.82	0.62-1.07	0.154

* Chicken caretaker; ref= reference; HR = hazard rate

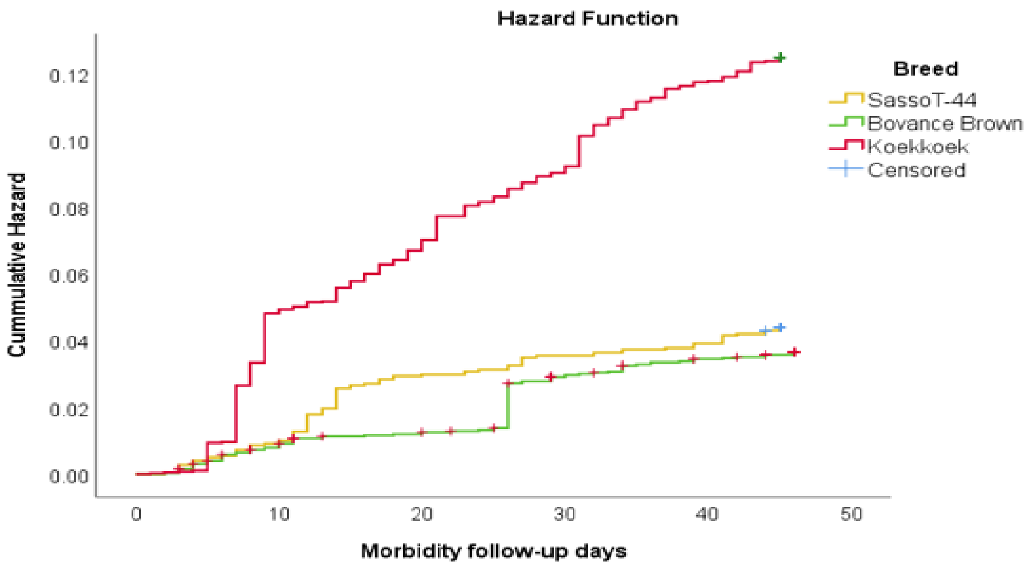

Figure 2. Hazard functions based on breed factor, of morbidity across exotic chick, breed under small scale chicken production

Experience of chick caretaker (HR= 2.51, P= 0.000), breed (HR=2.39, P= 0.000) and source of chick (HR= 2.70, P= 0.000) were found the most determinant factors of chick mortality. According to the final model, the hazard for mortality was 2.51 higher in those chick caretakers who had below two years of farm management experience when compared to those who have more than two years of experience (Table 5. Potential variables that were significantly associated with crude mortality based on multivariable Cox regression.The hazard of chick mortality was 2.39 times higher in the Koekoek breed as compared to SassoT-44. Likewise, the hazard for experiencing mortality is 2.70 times higher in those chicks that sourced from Hawassa as compared to Ethiochicken (Table 5).

Table 5. Potential variables that were significantly associated with crude mortality based on multivariable Cox regression

Risk Factors	Categories	Mortality		
		HR	95% CI	P-Value
Experience*	≤ 2 Years Vs ≥ 2 years	2.51	1.98 - 3.19	0.000
Source of chicken	Ethiochicken Vs Hawassa	2.70	2.28 - 3.18	0.000
Ownership*	Owner Vs Hired	0.40	0.31- 0 .50	0.000
	SassoT-44	Ref		
Breed	Koekkoek	2.39	1.90-2.99	0.000
	Bovance Brown	0.80	1.61-1.06	0.132

* Chicken caretaker; ref= reference

Those chicks sourced from Hawassa were more likely at risk for morbidity and mortality as compared to Ethiocicken (Mekelle). This could be associated with an extended time of travel and mismanagement of day-old chicken during loading and unloading during night times, as flock level survey results revealed that those DOC chicks sourced from Hawassa were frequently arrived at night times due to extended time of travel. This justification is supported by Caffrey *et al. (*2017), who reported that the risk of chicken mortality increased as the duration of the journey increased. As reported by Whiting *et al.* (2007) the longer duration between loading and unloading of day-old chicken, the higher variation in the mortality risk. Moreover, the significant association between chick farm experience and ownership with chick morbidity and mortality in the present finding was not found in other previously published studies. However, such association has been reported in other species of animals. For instance, low calf mortality was observed in farms managed by more experienced managers (Heinrichs and Radostits, 2001). This suggests that owners might be motivated sufficiently to provide the care necessary to ensure high survival (Wymann *et al*., 2006).

Serological investigation

A serological investigation was conducted to confirm the causes of chick morbidity and mortality. Those suspected, active clinical cases during the follow-up period were partially subjected to further laboratory Analysis. About 52 and 47 serum samples from salmonella and Mycoplasma suspected cases were collected for laboratory analysis, respectively. Accordingly, the prevalence of avian Salmonellosis was 30.7% (16/52). This finding was relatively consistent with other previous studies from apparently healthy chicken in Ethiopia

Genet *et al*., 2014) and lower than other some previous reports in Ethiopia and abroad (Tadesse, 2018); Minte *et al*., 2010; Uddin *et al*., 2012).

Similarly, the prevalence of avian mycoplasmosis was 14.8% (7/47).This finding was found relatively small as compared to some previous reports in Ethiopia and abroad (Yasmin *et al*., 2018; Muhammad *et al*., 2010; Rahman and Samad, 2003). The discrepancy between the present and previous reports on the prevalence of avian salmonellosis and mycoplasmosis might be associated with variations in various epidemiological factors; chicken breed, chicken health management, location, pathogen detection techniques, sample size, the health status of chicken, and chicken management practices.

CONCLUSION AND RECOMMENDATION

Small-scale chicken production plays a great role as a means of job opportunity mainly to organized Youth Groups in Bahir Dar city. However, this study revealed that morbidity and mortality are the major bottlenecks affecting the production and productivity of chickens in such production systems. The overall prevalence and incidence risk rate of chicken morbidity and mortality found in this study were found higher than the economically tolerable set by both the Western and African standards. Spraddle leg, cannibalism, ascites, omphalitis, avian salmonellosis, and avian mycoplasmas were the major chicken diseases observed during the study period. Chicken caretaker, breed, the experience of chicken caretaker, and source of chicken have investigated the significant potential determinant factors affecting chicken morbidity and mortality. Moreover, more than half of chicken farms in the study area lack the required knowledge about the role of biosecurity, as they didn't follow proper disposal of dead chickens. As the magnitude of chick morbidity and mortality in the study area was higher than economically tolerable, tailor-made subsequent intervention towards the identified diseases & significant determinant factors is suggested to improve exotic chicken health. Careful handling and good health management during transportation, loading, and unloading of DOC is suggested to reduce chick morbidity and mortality. As significantly higher morbidity and mortality rates were observed from Koekoek breed as SassoT-44 and Bovance Brown, further breed specific study is suggested to verify the association between breed, morbidity and mortality. As laboratory confirmation was done only for Avian salmonellosis and avian Mycoplasmosis, additional laboratory investigations are suggested to confirm other diseases of chicken. Sustainable technical training towards manipulating the identified risk factors, prevention, and control of the identified economically important chicken diseases is warranted to improve the production and productivity of chicken

ACKNOWLEDGEMENT

The authors acknowledge Mehari Ayalew, Gedamu Endalamaw, and Dr. Belayneh Lulie for their kind cooperation and chicken farm owners for allowing us to use their farms as well as chicken for sample collection and regular monitoring. We would like to extend sincere thanks to Amhara Agricultural Research Institute for granting the financial support and National Veterinary Institute for kind technical assistance during laboratory analysis.

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Effectiveness of different foot rot treatments at Metema Gumuz sheep station

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ABSTRACT

This experimental finding was conducted to evaluate the effectiveness of different treatments for foot rot in sheep. Thirty-six acute foot rot infected Gumuz sheep breeds were randomly divided into nine groups of sheep, each group having four sheep. Different treatment regimens were assessed for their comparative effectiveness as follows: group 1 treated with Oxytetracycline at 20mg/kg IM group 2 with formalin (5% foot bath), group 3 Copper sulphate (10% foot bath), group 4 Copper sulphate (10% foot bath), Group 5 Penstrip (1ml/10kg IM), group 6 Oxy tetracycline and Formalin, group 7 Oxytetracycline and Copper sulphate, group 8 Penstrip and Formalin and group 9 Penstrip and Copper sulphate were treated with Oxytetracycline at 20mg/kg IM, Penstrip and Copper sulphate, and Farmers practice (Salt solution plus Hog plum bark foot bath), respectively. Sheep feet were inspected for twenty-eight days and foot rot lesions and treatment response were recorded. This study revealed that 10% copper sulphate was the most effective footbath against foot rot among the treatment regimens. Parenteral administration of antibiotics significantly ($p<0.001$) had low mean treatment response rate to the management of acute foot rot in sheep compared to other treatments. In conclusion, this finding revealed that all treatment regimens had mean (%) treatment response against acute foot rot in sheep but 10% copper sulphate was the most effective footbath against foot rot among the treatment regimens.

Keywords: *Effectiveness*, *Foot rot*, *Gumuz Sheep*

INTRODUCTION

Lameness is one of the greatest concerns for poor welfare in sheep. Economic losses to the sheep and goat rearing industry due to lameness are considerable (Wani *et al*., 2015). Foot diseases are major causes of lameness in small ruminants and responsible for great economic losses, due to reduced forage intake, less body weight gains and milk production, decreased reproduction rates, and premature culling of animals (Aguiar *et al*., 2011). Foot rot is one of the most frequent foot diseases in goats and sheep (Kaler and Green, 2008). The primary agent of the disease is *Dichelobacter nodosus;* however, for the occurrence of infection it should exist as a synergistic action with *Fusobacterium necrophorum*. The latter bacterium is a natural inhabitant of soil and feces. It causes an interdigital dermatitis that allows invasion by *D. nodosus* (Wani and Samanta, 2005). *D. nodosus* is an obligate bacterium of ruminant digit and cannot survive longer than seven days in the environment (Green and George, 2008). Feet exposure for extended periods at ambient and wet pasture, feces and urine predisposes to infection and disease transmission between animals (Egerton, 2002).

In the past few years foot rot has become one of the biggest challenges for sheep in Metema Gumuz sheep station and on private farms. The main predisposing factors to foot rot infection include muddy pastures, frequent rains and injury to feet (Asif *et al*., 2011) and other factors include low land farms, high stocking densities, winter housing, routine foot trimming, and inadequate treatment and failure to isolate the affected sheep (Whittington,1995). Administration of parenteral antibiotics and analgesics in association with footbath is highly effective treatment for the foot rot in sheep. This is likely to improve welfare and give economic benefits to the poor farmers (Dar *et al.*, 2015). Foot rot is a serious and frequently occurring infectious disease of sheep in our station. It affects the reproductive and productive performance of sheep. Therefore, the objectives of the study were to evaluate the effectiveness of different treatment combinations for foot rot in sheep.

MATERIALS AND METHODS

Study area description

Metema is located between12˚40'N and 36˚8'E. It is situated at an altitude ranging from 500 to 1608 m.a.s.l. It has a uni-modal pattern of rainfall (June to September); with annual rainfall ranging from 850 to 1110 mm with a minimum and maximum average temperature of 22˚C and 43˚C, respectively (Solomon *et al*., 2011)

Study animals

Thirty-six acute foot rot infected gumuz sheep breeds were selected from the herds of Metema gumuz sheep conservation and research station. The identity, age, and sex of the selected animals were recorded at the beginning of the study for easy identification. The animals were divided into nine groups of four sheep per treatment group. The selection of sheep for this experiment is dependent on the severity of foot rot and sheep that have not received any antibiotics treatments at least one month from the commencement of the trial.

Naturally, foot rot infected sheep greater than 6 months of age were selected and randomly divided into nine groups of sheep, each group having at least 4 sheep. Selected sheep were subjected for different treatments (Table 1).

Study design and treatments

This experiment was arranged in a completely randomized block design (RCBD) with nine treatments and four replications. Experimental animals were assigned based on severity of foot rot (score) and randomly allocated into nine treatment groups by considering an equal severity of foot lesions based on visual observation and clinical analysis. Experimental animals in treatment 1 and 4 were applied to 20mg/kg oxy-tetracycline and 1ml/10kg pen-strip, respectively intramuscular (IM) injection for 3 days. Animals in the treatments of 2, 3 and 9 were subjected to 5% formalin, 10% copper sulphate and farmers practice (salt solution andHog plum bark powder), respectively foot bathing for seven days.

Anti-foot rot Application procedures

The affected interdigital tissue was cleaned, debrided and disinfected. Topical applications (footbath) were applied daily for five minutes of seven days and sheep inspected for twenty-eight days and parenteral administration of drugs were given intramuscularly for three consecutive days and inspected for twenty-eight days. The efficacy of the treatment combination was evaluated based on clinical response.

Table 1. Treatment arrangements of the study

Treatments	Treatment combination	Dose and Route	Duration (days)
1	Oxytetracycline	20 mg/kg IM	3
2	Formalin	5% foot bath	7
3	Copper sulphate	10% foot bath	7
4	Penstrip	1ml/10kg IM	3
5	Oxytetracycline	20 mg/kg IM	3
	Formalin	5% foot bath	7
6	Oxytetracycline	20 mg/kg IM	3
	Copper sulphate	10% foot bath	7
7	Penstrip	IM	3
	Formalin	5% foot bath	7
8	Penstrip	IM	3
	Copper sulphate	10% foot bath	7
9	Farmer practice	Salt solution plus Hog plum bark foot bath	7

Data management and analysis

All collected data were entered into a Microsoft Excel spreadsheet and subjected for analysis of variance (ANOVA) by using the general linear model (GLM) procedure in Statistical Analysis System (SAS) (2002) version 9.0. When the difference was significant, the LSD (least significant difference) test at a 5% probability level was used to locate differences between the treatment means.

RESULT AND DISCUSSION

The present study was conducted to evaluate the comparative effectiveness of different treatment regimens for the management of acute foot rot in sheep. All treatment regimens had mean (%) treatment response against acute foot rot management in sheep. All the sheep in different groups after treatment had reduced clinical lameness, as reflected in the reduction in the number of foot rot-affected feet. Significantly high ($p<0.001$) mean (%) treatment response rates were recorded on the treatment 3 and 6. This study agrees with the report of Teixeira *et al*., (2010) who reports that copper sulphate significantly outperformed the management of acute foot rot in sheep.

The bacteriostatic effect of CuSO4 is a consequence of the reaction of Cu++ with protein thiol groups in targeted organisms (Epperson and Midla, 2007). Dar *et al*. (2015) reported 100% percentage recovery rate of Oxytetracycline + Esgipyrin-NE + Copper sulfate in India. This variation might be due to the analgesic effect of Esgipyrin-NE. There were not significantly ($P >0.001$) mean treatment response rate differences recorded among the treatments of 2, 5, 7, 8, and 9. Parenteral administration of antibiotics significantly ($p<0.001$) low mean treatment response rate to the management of acute foot rot in sheep compared to other treatments. However; Yeshimebet and Biruk (2014) reported that antibiotics spray had the best result compared to formalin for the management of foot rot in sheep.

The farmers' practice (application of Salt solution and Hog plum bark powder) had promising effect on the foot rot treatments compared to conventional treatments of antibiotics. The therapeutic effect of hog plum against foot rot due to its antimicrobial properties (Plabon *et al*., 2021). On the other hand, salt solution (sodium chloride) is an ionic compound consisting of positive ions (cations) and negative ions (anions) to form neutral compounds that can provide a healing effect on wounds (Samidah *et al*., 2021). Herbal preparations are inexpensive, easily available, easy to prepare and so juicy/ointments of indigenous medicinal plants may play a direct role in the sustainable treatment and control of foot rot infections (Yeshimebet and Biruk, 2014).

Table 2. Mean (percentage) treatment response of the effectiveness of different formulations against foot rot.

Treatments	Treatment response (%)
Oxytetracycline	62.5[d]
5% Formalin	81.25[bc]
10% copper sulphate	100[a]
Penstrip	62.5[d]
Oxytetracycline & 5% formalin	75 [cd]
Oxytetracycline &10% copper sulphate	93.75[ab]
Penstrip & 5% formalin	75 [cd]
Penstrip & 10% copper sulphate	81.25[bc]
Salt solution & Hog plum bark powder	68.75 [cd]
Mean	77.78
CV	15.9
LSD (0.05)	18.07
LS	***

[a,b,c,d] = means within column having different superscript letters are significantly different at ***= P<0.001; CV= coefficient of variation; LS= level of significant; LSD= least significant difference.

CONCLUSION AND RECOMMENDATIONS

From our study, we concluded that the administration of 10% copper sulphate footbath alone for seven days is highly effective to treat sheep lameness with acute foot rot. This is likely to improve welfare and give economic benefits to the ranch. 5% formalin and Salt solution plus Hog plum bark powder footbath were the second and third drug of choice respectively. Parenteral administration of antibiotics for acute foot rot management in sheep had low treatment response rate. To reduce/eradicate the frequent occurrence of foot rot in the ranch; good farm management practice and initial treatments of acute foot rot infected sheep with copper sulphate should be advisable.

ACKNOWLEDGEMENT

We would like to thank the Amhara Agricultural Research Institute for the financial support.

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Participatory Evaluation of Napier (Pennisetum purpureum) and Desho (Pennesitum praucifolium) in the High Lands of Amhara region

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ABSTRACT

A participatory study was conducted to evaluate the performance of selected Napier (Pennisetum Purpureum) and Desho (Pennesitum praucifolium) grass varieties in the highland area of Amhara region for two countinous years (2020 - 2021). Five Napier ILCA-16791 (T1), ILCA-15743 (T2), ILCA-16794 (T3), ILCA-16813 (T4) and ILCA-14984 (standard check) and four desho (Kindo Kisha#591, KindoKisha-DZF#590, KindoKisha-DZF#589 and Kulumesa 592) at researcher and farmers management condition were evaluated in the study. Biological data (plant height, tiller number and dry matter yield) and social data (farmers forage selection criteria and their preference) were collected in irrigation and rain fed conditions. Biological data were analyzed by general linear model (GLM) in SAS software (SAS, version 9.0) while social data was calculated in MS Excel. The mean annual dry matter yield of five Napier and four desho grass varieties were 23.54 and 8.0 ton DM/ha, respectively. The effect of variety was observed ($P<0.05$) on plant height and tiller number on both Napier and desho grasses. But its effect on dry matter yield was observed significant ($P<0.05$) on Napier varieties than Desho grass ($P>0.05$). Napier varieties 16791 and 15743 overperformed ($P<0.05$) in dry matter yield than the other three varieties while significant difference was not observed ($P>0.05$) in desho varieties. Tiller number, plant height, palatability and leaf width are major farmers' forage variety selection criteria. The overall agronomic performance of forage varieties in this trial corresponded with the farmers preference triats recorded on the forages. Based on agronomic performance and farmers' preference Napier varieties (16791 and 15743) and desho varieties (DZF#590 and K kosha591) were found productive and hence, are recommended for wider utilization in the study areas and similar agro-ecologies.

Keywords: *Desho, Dry Matter Yield, Farmers Preference, Napier*

INTRODUCTION

The available feed resources in Ethiopia are characterized by marked seasonal fluctuations in quality, particularly in digestibility and protein content. Reasonable levels of increases in body weight of animals gained during the wet season are lost dramatically during the long dry season. To satisfy the ever-increasing demand for livestock products, the existing subsistence livestock production should be shifted to semi-intensive and intensive systems. Among the technical options for system shift, introduction and utilization of high yielding improved forage varieties and upgrade household availability and quality of feed is the major one. Improved forage crops can play an important role in sustaining the livelihoods of small and medium-scale livestock producers, via their positive effects on livestock productivity and advanced family income and nutrition. Though some promising cultivars of forage grasses, legumes and shrubs are identified, their contribution as livestock feed and their coverage remained small. Adaptation trials of improved forage were conducted for limited agroecologies which were not well fitted in the wider ecological conditions and farming systems of the country. This fact calls for testing and verification of potential improved forage germplasm under different ecological and farming system conditions.

Napier (Pennisetum purpureum) grass is fast growing perennial grass that is adapted in areas having altitude up to 2500 m and rainfall 600-1000 mm. It is also palatable for animals, tolerates considerable drought period and rapidly recovers from stagnation of growth with the onset of rains after extended dry periods (Deribe et al., 2017). Similarly, Desho (Pennesitum graucifolium**)** is a perennial grass and is palatable to cattle, sheep and other herbivores (Ecocrop) (FAO, 2010). The grass can recover after water stress even under severe drought conditions (Butt et al., 1993). Both of the species have relatively better performance in mid altitude areas of the Amhara region. Though there are many research reports on the potential of the two species under field condition in the mid land of Amhara region, informations are scanty in high land areas of the region. Besides, evaluation of the varities needs to be confirmed with farmer’s preference. Preference ranking is one of the methods to assess the acceptability of innovations. It can be used for validating or evaluating the acceptability of existing technology and also for designing technology development. The use of preference ranking for technology validation involves asking farmers to rank from best to least an already available set of technological options such as treatments in an on-farm trial to find out which option the farmers find most acceptable (Guerrero et al., 1993). Therefore, this study was conducted to evaluate the productivity of Napier and Desho grass varieties under small scale irrigation in the highland area and to assess farmers' perception and preferences for Napier and Desho grass varieties.

MATERIAL AND METHODS

Site selection and description of the study area

The study was conducted at Goncha Siso Enese district of Amhara Region. The specific site (Guza Yemerat kebele) was selected due to it is the project area for International Fund for Agricultural Development (IFAD) and availability of year round irrigation water and access to year round road. The area is located between $38^0$0’12.2” and $38^0$23’46.2” E longitudes, and $10^0$46’11.6” and $11^0$9’31.9” N latitudes. The elevation ranges from 1400m to 3400 meters above sea level, and the exact altitude of the experimental site was 2600 m.

Farmers Research and Extension Group (FREG) Organization

Before the implementation of the study, FREG was organized to increase the adoption of selected technologies and help to easily capture the perception of farmers. Twenty five farmers interested for improved forage development were selected and training was given about the aim of the study, importance of FREG, improved forage and livestock production for income generation.

Experimental design and treatments

The study included two sets of experiments. The first set of experiments was evaluation of five Napier varieties while the second was evaluation of four Desho grass varieties. The variety selection was conducted in a mother-baby trial protocol of ARARI (Alemayehu et al., 2018). The mother trial was laid on by randomized complete block design (RCBD), while the baby trial was conducted on four farmers in a single block.

In the first set of experiment five Napier grass varieties namely ILCA-16791 (T1), ILCA-15743 (T2), ILCA-16794 (T3), ILCA-16813 (T4) and ILCA-14984 (standard check) were considered due to their better performance in upper altitudes of midlands (Gezahegn et al., 2016 and Wondimeneh et al., 2016). The plot size was 4m * 5m, with 1 m distance between plots and blocks. Root splits were planted by row distanced 1m and 0.5m between plants. The Plot size was 4m*5m with spacing of 50cm between and within a row. The second set of experiment evaluated four Desho lines i.e Kindo Kisha#591, KindoKisha-DZF#590, KindoKisha-DZF#589 and Kulumesa 592 on four replications on both mother and baby trials. The Plot size was 4m*5m with spacing of 50cm between and within a row.

Management of mother and baby trials

Both mother and baby trial plots were planted by researchers during irrigation season. The mother trial was managed by researchers from planting to the end of the experiment. Irrigation was applied every week using furrow irrigation method. NPS fertilizer was applied at a rate of 100 kg/ha during plantation and nitrogen (urea) was applied at a rate of 100 kg/ha after each harvest. After plantation, the baby trials were allowed to be managed by host farmers, on different irrigation, weeding and fertilization (particularly manure) levels. The agronomic and yield data were collected on both trials when the plant reached on average 1 and 0.8 m height for Napier and Desho, respectively.

Preference ranking

In preference ranking members of FREG have participated in the selection process on their criteria. First, they were allowed to list important criteria for the selection of given forage varieties. Then they were asked to rank the criterion based on their importance using a pairwise matrix. After that farmers choosen their preference in each criterion independently and the farmers' count was recorded for each variety in each criterion.

Data collection and analysis

Performance data was collected for plant height at harvest, number of tillers per plant and dry matter yield. The data were collected for two series years (2020 and 2021) both in the irrigation and rainy seasons. In each case, sampling was done from the middle rows excluding the guard rows. Immediately after forage sampling, the fresh samples were weighed by using a Salter balance having a sensitivity of 0.1 kg for green biomass yield estimation and used for calculating dry matter yield. A minimum of 500g individual samples of forage was taken for DM% analysis, which was oven-dried at 65^{o}C for 72 hrs until a constant weight was obtained. In each plot, five plants were randomly taken from the middle rows and measured for plant height and tiller number.

Social data of farmers' selection criteria and their preferences were also collected using the pairwise ranking method while results were calculated by preference matrix ranking (Ceccarelli, 2012). Biological data were analyzed using GLM modle of SAS package (version 9, 2002). Analysis of variance (ANOVA) was employed and the least significance difference (LSD) at 5 % was used for mean separation. The analysis model was Yijkl = µ + $V_i + M_j + S_k + E_{ijkl}$. Where Y_{ijkl} = agronomic performance of the variety; µ=over all mean; V_i = effect of variety; M_j = effects of management; S_k = effects of season and E_{ijk} = random error.

RESULTS AND DISCUSSION

The performance of Napier varieties

Plant height and tiller number

Plant height and tiller number were significantly (P < 0.05) affected by variety of Napier grass (Table 1). The effect of variety on plant height was also reported by Gezahegn et al. (2016). But unlike the current result effect of variety on tiller number was not observed in Napier grass in mid-altitude areas (Wondimeneh et al., 2020). Napier variety 14984 was growing faster and hence showed higher plant height (P <0.05) in both researcher and farmer's management conditions though no difference was observed (P >0.05) between management systems. The current result was similar to the results of five locations performance evaluation study that reported 14984 recorded superior performances in plant height (Gezahegn et al., 2016). In contrast to this 16791 and 15743 performed similarly with 14984 in plant height at the mid-latitude of Amhara region (Wondimeneh et al., 2016). The varity 16791 showed higher tiller number ability than other varieties except with 15743 in farmers-managed plots.

Dry Matter Productivity of Napier varieties

Five Napier varieties produce about 16.56 and 30.52 total annual dry matter yield (ton/ha) in the first and second year of plantation, respectively (Table 2). This result is higher as compared with values of 10 and 16.8 ton/ha (Elkana et al., 2010) in the first and second year, respectively in Kenya. However, apart from location, a difference in studied cultivars and the use of irrigation in the current study could be reasons for the difference.

Table 1. Mean plant height (cm) and tiller number of Napier varieties under researcher and farmers management condition

Variety	N	Researcher managed		Farmers managed		Combined	
		PH (cm)	Tiller no	PH (cm)	Tiller no	PH (cm)	Tiller no
16791	8	99.23 bc	117.55 a	100.86 b	55.18 a	100.04 b	86.36 a
15743	8	104.07 b	105.29 b	98.29 b	53.69 a	101.18 b	79.49 a
16794	8	72.66 d	86.58 c	93.70 b	40.12 b	83.18 c	63.35 b
16813	4	97.90 cd	87.11 c	97.67 b	33.81 b	97.78 b	60.46 b
14984	8	122.44 a	75.19 d	108.63 a	54.20 a	115.53 a	64.69 b
Mean	36	99.26	94.34	99.83	50.79	99.54	70.87
CV		3.97	7.23	4.89	13.84	5.12	10.78
LSD		6.08	10.50	7.53	10.11	8.53	11.05

Values in a column and under the same factor with different superscripts significantly differ at P <0.05; CV= cofficient of variance; LSD= least significant difference; PH= plant height

There was a significant difference in the dry biomass productivity of Napier varieties in irrigation, rain and total annual dry matter yield (P <0.0001). There was no significant difference (P > 0.05) between 15743, 16791 and 16984 in the first establishment irrigation period. But after establishment 16791 and 15743 gave significantly higher yield (P <0.0001) in rainy and irrigation periods, respectively. Incontast of other findings 16813 in this study has performed poorly in all periods and growing years than other varieties (Gezahegn et al., 2016).

Table 2. Annual forage dry matter yield (ton/ha) of five Napier Varieties across years

Napier varieties	2020			2021			Combined		
	DMYI	DMYR	TDMY	DMYI	DMYR	TDMY	DMYI	DMYR	TDMY
16791	7.35 a	15.96 a	23.32 a	16.14 b	22.93 a	39.07 a	11.75 b	19.44 a	31.19 a
15743	8.21 a	15.96 b	21.57 a	18.57 a	20.87 b	39.45 a	13.39 a	17.12 b	30.51 a
16794	4.50 b	9.14 d	13.64 c	9.77 b	15.44 c	25.21 c	7.13 c	12.29 d	19.42 c
16813	2.19 c	3.46 e	5.65 d	8.72 b	8.57 d	17.29 d	5.45 d	6.02 e	11.47 d
14984	7.29 a	11.32 c	18.60 b	14.81 b	16.77 c	31.58 b	11.05 b	14.04 c	25.09 b
Mean	5.91	10.65	16.56	13.60	16.91	30.52	9.76	13.78	23.54
CV	15.79	11.45	11.55	10.63	10.75	8.78	9.78	9.21	8.17
LSD	0.95	1.24	1.95	1.47	1.85	2.73	0.97	1.29	1.96

Values in a column and under the same factor with different superscripts significantly differ at least P < 0.05; CV= cofficient of variance; DMYI=dry matter yield in irrigation; DMYR=dry matter yield in rain; LSD= least significant difference; TDMY= Total annual dry matter yield

The effect of variety of Napier was observed (P <0.0001) in both researcher and farmer's management conditions. But, there was no significant difference (P >0.05) in Napier varieties under researchers and farmer's management systems.

Table 3. Mean dry matter yield of Napier varieties under management systems and across years

Variety	N	2020		2021		Combined mean	
		Researcher managed	Farmers managed	Researcher managed	Farmers managed	Researcher managed	Farmers managed
16791	8	24.26 [a]	22.51 [a]	38.28 [b]	39.86 [a]	31.27 [a]	31.19 [a]
15743	8	22.64 [b]	20.38 [a]	42.14 [a]	35.26 [ab]	32.39 [a]	27.82 [ab]
16794	8	14.00 [d]	12.94 [c]	26.69 [d]	23.72 [c]	20.35 [c]	18.33 [c]
16813	4	5.73 [e]	5.58 [d]	19.22 [e]	15.35 [d]	12.48 [d]	10.46 [d]
14984	8	19.33 [c]	17.38 [b]	32.20 [c]	30.94 [b]	25.77 [b]	24.16 [b]
Mean	36	17.19	15.76	31.71	29.03	24.45	22.39
CV		5.46	12.20	7.15	11.26	4.52	11.41
LSD		1.45	2.91	3.49	4.96	1.68	3.87

Values in a column and under the same factor with different superscripts significantly differ at least P < 0.05; CV= cofficient of variance,LSD= least significance difference

Performance of Desho varieties

Plant height

The mean plant height of desho grass lines was not significantly (P>0.05) different among lines both in researcher and farmers managed plots (Table 4). This finding disagreed with the result of Denbela et al. (2020). Even though there was no difference, the analysis for plant height ranged from 67.3 to 71.35cm with a mean of 68.73 cm in researcher managed and 75.91 to 81.58cm in farmers managed. Generally, KindoKisha-DZF#589 gave the highest mean plant height which was 71.35 cm followed by K kosha591 with a value of 67.35cm at harvest. The current finding also disagrees with the finding of Teshale et al. (2021) who reported that a significant difference (P<0.05) was observed in plant height at harvest and the highest height was observed by Kindo Kosha DZF No# 589 (102.6cm). This difference might be due to location and management differences.

Tiller Number per Plant

Tillering performance is an important morphological characteristic to be considered during the selection of appropriate forage crops to improve production and productivity. The mean tillering performance of the tested grass is indicated in Table 4. Tiller density is an important attribute of grasses as it increases the chances of survival and the amount of available forage (Laidlaw, 2005). The overall analysis indicated that there was a significant (P<0.05) variation among the desho grass cultivars in tiller number in researcher managed trial. The current finding agrees with the finding of Teshale et al. (2021), who works on desho grass lines evaluation. The highest number of tillers (225.69) was recorded by KindoKisha-DZF#590.

Table 4. Mean plant height (cm) and tiller number of desho grass varieties under researcher and farmers management condition

Variety	N	Researcher managed		Farmers managed		Combined	
		PH (cm)	Tiller no	PH (cm)	Tiller no	PH (cm)	Tiller no
K kosha591	4	67.3	217.64[a]	75.91	189.60	71.61	203.62
KindoKisha-DZF#590	4	67.85	225.69[a]	81.58	208.57	74.72	217.13
KindoKisha-DZF#589	4	71.35	218.63[a]	79.61	149.04	75.48	183.84
Kulumesa 592	4	68.4	182.54[b]	78.82	172.13	73.61	177.34
Mean	16	68.73	211.13	78.98	179.83	73.86	195.48
CV		6.38	5.19	9.7	34.7	6.45	16.049
LSD		7.0085	17.53	12.26	99.874	7.62	50.19
P-value		0.5849	0.0015	0.77	0.59	0.69	0.32

Values in a column and under the same factor with different superscripts significantly differ at least P <0.05; CV= cofficient of variance

Dry Matter Yield

The effect of desho grass lines on dry matter yield is indicated in Table 5. In the current study, dry matter yield was significantly (P<0.05) affected by grass lines in researcher managed trial. Tessema (2022) also found a significant difference among different lines of desho grass lines. The highest value of dry matter yield was measured from Areka K kosha591 (10.5 t/ha). Teshale et al. (2021) also found highest dry matter yield with the same desho grass lines. The second yield was found by KindoKisha-DZF#590 (9.03t/ha). The lowest dry matter yield was measured from Kulumesa 592 with a yield of 6.7 t/ha. This finding agreed with the finding of Denbela et al. (2020). The previous studies reported by different scholars demonstrated that the wider range of dry matter yield differences between desho grass varieties could be attributed due to differences in the genetic potential of the varieties (Bimrew, 2016; Tekalegn, 2017).

Table 5. Annual forage dry matter yield (ton/ha) of four Desho grass Varieties across years and management systems

Variety	N	2020		2021		Combined means	
		RM	FM	RM	FM	RM	FM
K kosha591	4	9.75	6.74	11.26	8.77[a]	10.5[a]	7.77
KindoKisha-DZF#590	4	10.35	6.59	7.7	7.32[b]	9.03[ab]	6.96
KindoKisha-DZF#589	4	7.68	7.01	7.08	7.4[ab]	7.38[ab]	7.21
Kulumesa 592	4	7.99	8.59	5.4	7.95[ab]	6.7[b]	8.27
Mean	16	8.9	7.23	7.87	7.86	8.4	7.55
CV		30.50	20.50	46	11.1	27.41	15.8
LSD		4.36	2.37	5.87	1.39	3.68	1.88
P-value		0.46	0.27	0.22	0.014	0.016	0.142

Values in a column and under the same factor with different superscripts significantly differ at $P < 0.05$; CV= cofficient of variance; RM = researcher managed; FM = farmers managed

Farmer's selection

Forage variety selection criteria

During farmers variety selection farmers listed four selection criteria i.e. tiller number, plant height, palatability and leaf width in decreasing order of importance (Table 6). Tiller number and plant height are correlated with yield parameters while palatability and leaf width have related to the quality parameters of forage.

Table 6. Pair-wise ranking matrix of selection criteria

Criteria	TN	PH	PY	LW	Total	Rank	Weighted Value
Tiller number	*	TN	TN	TN	3	1	4
Plant height		*	PH	PH	2	2	3
Palatability			*	PY	1	3	2
Leaf width				*	0	4	1

TL = tiller number; PH = plant height; PY = palatability; leaf width

Farmer's selection for Napier varieties

Based on the above criteria, farmers select 15743 and 16791 as first and second respectively, as both were the two top dry matter yielding varieties in biological data (Table 7). This showed that farmer's selection was in line with the biological performance of the varieties.

Table 7. Farmers selection on Napier grass cultivars based on their criteria

Farmer selection criteria	Napier varities				
	15743	16791	14984	16794	16813
Tiller number	184	176	80	76	84
Plant height	129	129	90	69	33
Palatability	88	76	52	18	66
Leaf width	41	40	15	15	39
Total weighted scores	442	421	237	178	222
Rank	1	2	3	5	4

Farmer's selection for Desho Varieties

Acoording to the response of participant farmers in desho varity trial, they preferably select Areka-DZF# 590, KK1-DZF#591, Kulumsa-DZF#592 and KK2-DZF-589, in their order of importance (Table 8).

Table 8. Farmers selection on Desho grass cultivars based on their criteria

Farmer selection criteria	Areka-DZF# 590	KK1-DZF#591	Kulumsa-DZF#592	KK2-DZF-589
Tiller number	124	108	80	88
Plant height	105	105	48	42
Palatability	48	50	50	52
Leaf width	22	22	28	28
Total weighted scores	299	285	206	210
Rank	1	2	3	4

CONCLUSIONS AND RECOMMENDATIONS

Napier varieties give reasonable dry matter yield in the study area but showed differences among varieties in which 16791 and 15743 varieties gave better dry matter yield while unlike other areas variety 16813 poorly perform in high land areas. Farmer's varietal preferences are in line with agronomic performance of the evaluated varieties. Therefore, Napier varieties are best performed in high land areas and hence recommended for further utilization. Similarly, among desho varieties, KindoKisha-DZF#590 and K kosha591 were found best performed in terms of tiller number and dry matter yield than the other two varieties. Resembling the biological performance farmers selected KindoKisha-DZF#590 and K kosha591 as first and second priority, respectively. Generally, the studies verify the biological performance of varieties was parallel with farmers' selection criteria. Hence, Napier varieties (16791 and 15743) and desho varieties (KindoKisha-DZF#590 and K kosha591) are recommended for further promotion and utilization as improved forage to Goncha area and other similar agro-ecological zone.

ACKNOWLEDGMENT

The authors would like to acknowledge International Fund for Agricultural Development (IFAD) for funding this activity.

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Evaluation of Bracharia grass cultivars productivity in lowland of North Shewa zone of Amhara Region, Ethiopia

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ABSTRACT

The study was conducted at Ataye research site, Efiratana Gidim district of North Shewa zone, Amhara region in 2020/2021 to evaluate the biomass yield and chemical composition of 10 Brachiaria grass cultivars. The experiment was designed in Randomized Complete Block Design (RCBD) with three replications. Nitrogen, phosphate & sulfur (NPS) at 100kg/ha was applied during planting, while urea fertilizer was added at 50kg/ha after establishment and after each harvest. Supplementary irrigation was done once per week after the onset of dry season through a furrow irrigation system. Plant height, Dry Matter Yield (DMY), chemical composition and Crude Protein Yield (CPY) varied ($P < 0.01$) among 10 Brachiaria cultivars tested. *Brachiaria hybrid Mulato I* and *Brachiaria hybrid Mulato II* were produced greater biomass and crud protein yield compared to the rest Brachiaria cultivars tested. The fiber concentration measured for all Brachiaria cultivars was too high that could limit digestibility. Therefore, further study required to improve Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) concentration and animal evaluation to evaluate effect of Brachiaria grass feeding on overall performance of ruminants.

Keywords: *Brachiaria, dry matter yield, chemical composition, crude protein yield*

INTRODUCTION

Livestock production is one of the most important agricultural land use systems in the world, with grasslands covering 25% of land surface and contributing to the livelihoods of more than 800 million people (Steinfeld *et.al.* 2006). However, in Ethiopia livestock production has been mainly constrained by inadequate supply and poor quality of livestock feeds. According to CSA (2017) report, the major feed resources in the country are green fodder (54.59%), crop residue (31.6%), hay (6.81%) and agricultural by product (1.53%) which have poor quality and in short supply during dry season. To alleviate feed shortage and to improve feed quality, introduction and evaluation of improved forages have been conducted by different organizations. Consequently, a number of forage crops have been recommended for different agro-ecologies.

Among forage crops introduced in Ethiopia, Napier grass (Pennisetum sp.) is affected by the emergence of stunt and smut diseases (Mureithi and Djikeng, 2016). Therefore, looking for alternative forage crops that are disease resistant, have greater biomass yield and improved quality is an important step to sustain livestock production in the country. Interest on *Brachiaria* research was spurred by the exceptional performance of livestock production on *Brachiaria* pasture in South America. Millions of hectares of land were covered by *Brachiaria* spp. in South and Central America with estimated 99 million hectares in Brazil alone (Jank *et al*., 2014) that support highly vibrant beef industry. Grasses in the genus *Brachiaria* have advantage over those in other genera including adaptation to drought and low fertility soils, ability to sequester carbon; increase nitrogen use efficiency through biological nitrification inhibition (BNI) and arrest greenhouse gas emissions. Africa is the center of origin of *Brachiaria* grasses and is thus adaptable in Ethiopia and can be well integrated in the existing farming systems. Studies have shown high farmers' preference of *Brachiaria* species and cultivars in Rwanda based on real or perceived attributes of palatability and improved lactation performance (Mutimura and Everson, 2012).

Despite the immense benefits demonstrated of these grasses in South America and well started in some parts of Africa like Kenya and Rwanda, the potential of improved *Brachiaria* grass in Ethiopia to address the challenge of livestock feed scarcity remain unexploited. Although there were studies conducted in western Amhara region under different agro ecologies, there is lack of information for the lowlands area of North Shewa like Ataye. Therefore, the objective of this study is to evaluate productivity and nutritive value of various *Brachiaria* grass cultivars in low land areas of North Shewa, Amhara region, Ethiopia**.**

MATERIALS AND METHODS

Description of the study area

The study was conducted at Ataye research site, Efiratana gidim districts of North shewa zone, Amhara region in the year 2020/2021. The Ataye research site is located at10^{0}17'27"N latitude and and 39^0 54'27''E longitude, at an altitude of 1487 meters above sea level. The mean annual maximum and minimum temperatures are 27.7 °C and 11.5 °C, respectively. The mean annual rainfall is 1018 mm, with peak rainfall in August. The soil is clay loam with good water holding capacity.

Treatments and experimental design

For the current study 10 brachiaria grass cultivars namely *B. brizantha cultivars Marandu (acc. no. 16550), B. brizantha cv. la libertad (acc. no. 16551), Brachiaria brizantha wild (acc. no. 13726), Brachiaria brizantha wild (acc. no. 13755), Brachiaria brizantha wild (acc. no. 13777), Brachiaria brizantha wild (acc. no. 13809), Brachiaria decumbens, Brachiaria mutica (DZF 483), Brachiaria hybrid cv. Mulato I,* and *Brachiaria hybrid cv. Mulato II* were used. The experimental design used in the current study was a randomized complete block design (RCBD) with three replications. Brachiaria roots split were planted at 50 cm between rows and 30 cm between plants as recommended by Negasu *et al*. (2020). The plot size was 3m x 2m (6 m^2) and the space between plots and blocks was one meter. NPS fertilizer at 100 kg/ha was applied at planting and urea was top dressed at 50kg/ha after establishment and just after each harvest. Weeding and other management practices were done manually, as required. Supplementary irrigation was done once per week after the onset of dry season through a furrow irrigation system.

Sampling, data collection, and chemical composition analysis

Plant height at harvest, the number of tillers per plant, leaf to stem ratio and forage biomass yield (t/ha^{-1}) were measured/counted. Morphological parameters were measured or counted on 10 randomly selected plants from the middle rows of each plot when grass starts heading. Samples were taken at each cut to estimate herbage and dry matter yield. Two cuts were harvested each year with supplement irrigation and harvesting was done by hand with a sickle, leaving a 7-8 cm stubble height. Harvesting was done at the middle three rows, excluding the border rows. The fresh herbage yield was measured immediately after harvest using a portable balance with a precision of 0.01g and 500g of fresh samples were taken for laboratory analysis. Samples were dried in a forced-air draft oven at 65°C for 72 hours to calculate partial dry matter (DM). The DM yield was then determined using the partial dry matter content of the samples. During harvesting, five plants were chosen at random from each plot, dried in a paper bag, and the leaves were then carefully stripped from the stems to determine the leaf to stem ratio. The ratio was obtained by dividing the leaf percentage by the stem percentage.

Statistical analysis

Data on plant height, tiller number, dry matter yield, crude protein yield, and chemical composition were subjected to the analysis of variance (ANOVA) using the general linear model (GLM) of SAS software (SAS version 9.4, 2009). Mean separation was done using LSD and significance was declared at ≤ 5%.

RESULTS AND DISCUSSION

Plant height, dry matter yield, and crude protein yield were varied ($P < 0.01$) among the Brachiaria cultivars tested, however, number of tillers per plant and leaf stem ratio were similar ($P > 0.05$) (Table1).

Plant height, number of tillers per plant and leaf to stem ratio

Brachiaria mutica DZF 483 had greater plant height (128.3 cm) than the rest of cultivars tested, which was followed by *Brachiaria hybrid Mulato I* (115.9 cm), *Brachiaria hybrid Mulato II* (114.6 cm) and *Brachiaria brizantha wild 13777* (104.3 cm), while *Brachiaria decumbens* (65.2 cm) had the least value. The plant height observed in the present study for *Brachiaria mutica DZF 483*, *Brachiaria hybrid Mulato I*, *Brachiaria hybrid Mulato II* and *Brachiaria brizantha wild 13777* was greater than the value reported by Alemu *el al. (*2022), however, the plant height measured for the rest cultivars was in agreement with the value reported by Wubetie *et al.* (2019), Solomon *et.al* (2022), Alemu *et al. (*2022). The greater plant height observed in the present study could be related to clay loam soil type and temperature of the study area. In contrast to the current study, number of tillers per plants and leaf to stem ratio were varied among Brachiaria cultivars (Wubetie *et al*., 2019 and Negasu *et al*., 2020).

Table 1. Dry matter yield and yield related traits of Bracharia grass cultivars under supplementary irrigation condition at Ataye research site

No	Bracharia lines	PH	NTPP	DMY (t_ha1)	LSR	CPY
1	*B. brizantha Marandu Acc no. 16550*	80.7[cd]	57.89	5.23b[c]	0.55	0.48[bcd]
2	*B. brizantha wild 13777*	104.3[abc]	54.99	3.18d[c]	0.47	0.27[de]
3	*B. mutica DZF 483*	128.3[a]	45.11	9.65a[b]	0.40	0.65[abc]
4	*B. brizantha wild 13809*	99.4[bc]	58.42	3.68d[c]	0.52	0.36[cde]
5	*B. hybrid. Mulato I*	115.9[ab]	63.07	10.10[a]	0.52	0.87[a]
6	*B. brizantha la libertad Acc no. 16551*	88.2[bcd]	55.22	4.96d[c]	0.49	0.37[cde]
7	*B. hybrid Mulato II*	114.6[ab]	63.20	11.79[a]	0.62	0.89[a]
8	*B. brizantha wild. Acc no 13755*	91.0[bcd]	37.31	0.39[d]	0.57	0.03[e]
9	*B. brizantha wild. Acc no 13726*	98.8[bc]	36.44	5.09[bc]	0.46	0.46[bcd]
10	*B. decumbens*	65.2[d]	62.76	7.73[abc]	0.55	0.73[ab]
	Over all mean	98.64	53.44	6.18	0.52	0.51
	CV	16.60	30.55	44.26	26.08	40.17
	LSD	28.093	28.009	4.692	0.2306	0.3525
	LS	***	NS	***	NS	**

PH= Plant height; NTPP=Numbers of tiller per plant; DMY=Dry Matter Yield; LSR= Leaf Stem Ratio; CPY= crude protein yield; CV=coefficients of variation; LSD= least square difference; LS= level of significant

Dry matter and crude protein yields

Dry matter yield (DMY) and crud protein yield (CPY) were varied ($P < 0.01$) among *Brachiaria* cultivars tested. Brachiaria hybrid cultivars Mulato II and Brachiaria hybrid cultivars Mulato I had greater DMY and CPY than *B. brizantha* Marandu Acc no. 16550, *B. brizantha* wild 13777, *Brachiaria mutica DZF 483, B. brizantha* wild 13809, *B. brizantha* la libertad Acc no. 16551, *B. brizantha* wild Acc no. 13755, *and B. brizantha* wild Acc no. 13726, and *B. decumbens* had an intermediate value. The dry matter yield observed in the present study is lower than the value reported for same cultivars for different agro-ecologies of Amhara region (Tiruneh *et al*., 2022), which is attributed to lower number of harvest (2 Vs. 5). Though Brachiaria hybrid cultivars Mulato I and Brachiaria hybrid cultivars Mulato II had lower CP concentration than other cultivars, they had greater CP yield because of greater biomass yield.

The chemical composition of Brachiaria grass cultivars is shown in Table2. Organic matter, crud protein, neutral detergent fiber, acid detergent fiber and acid detergent lignin percent was varied ($P < 0.001$) among the tested Brachiaria cultivars. *B. mutica* DZF 483 and

Brachiaria hybrid cultivars Mulato II had greater OM% than *B. brizantha* Marandu Acc no. 16550, *B. brizantha* wild 13809, *B. decumbens,* and *B. brizantha* la libertad Acc no. 16551, *B. brizantha* wild 13777, Brachiaria hybrid cultivars Mulato I, *B. brizantha* wild Acc no. 13726 and *B. brizantha* wild Acc no. 13755 had an intermediate value. *B. brizantha* wild 13809 had greater CP% than *B. brizantha* Marandu Acc no. 16550, Brachiaria hybrid cultivars Mulato I, *B. brizantha* la libertad Acc no. 16551, Brachiaria hybrid cultivars Mulato II, *B. brizantha* wild Acc no. 13755, *and B. brizantha* wild Acc no. 13726, and *B. brizantha* wild 13777, *B. mutica DZF 483,and B. decumbens* had an intermediate value.

Brachiaria brizantha Marandu Acc no. 16550 and *B. brizantha* wild Acc no. 13755, had the lowest NDF% than *B. mutica DZF 483,* Brachiaria hybrid cultivars Mulato II, *B. brizantha* wild Acc no. 13726, and *B. decumbens, and B. brizantha* wild 13777, *B. brizantha* wild 13809 Brachiaria hybrid cultivars Mulato I and *B. brizantha* la libertad Acc no. 16551 had an intermediate value. *B. brizantha* la libertad Acc no. 16551 had the lowest ADF% than *B. brizantha* wild 13777, *B. mutica DZF 483*, Brachiaria hybrid cultivars Mulato I, Brachiaria hybrid cultivars Mulato II, *B. brizantha* wild Acc no. 13726, *and B. decumbens,* and *B. brizantha* Marandu Acc no. 16550, *B. brizantha* wild 13809, and *B. brizantha* wild Acc no. 13755 had an intermediate value.

Table 2. The chemical composition of Bracharia grass cultivars under supplementary irrigation at Ataye research site

No	Bracharia lines	DM%	OM%	CP%	NDF%	ADF%	ADL%
1	*B. brizantha Marandu* Acc no. 16550	91.33	89.5[b]	5.37[f]	57.48[c]	41.59[bc]	7.33[cd]
2	*B. brizantha* wild 13777	92.67	89.8[ab]	9.94[ab]	60.41[bc]	45.41[b]	8.00[cd]
3	*B. mutica DZF 483*	93.00	90.8[a]	9.77[abc]	64.42[a]	55.69[a]	9.93[a]
4	*Brachiaria brizantha* wild 13809	91.67	88.8[b]	10.53[a]	58.80[bc]	42.50[bc]	7.68[cd]
5	*Brachiaria hybrid Mulato I*	92.33	90.0[ab]	6.24[ef]	59.98[bc]	44.88[b]	7.74[cd]
6	*B. brizantha la libertad* Acc no. 16551	91.33	90.0[ab]	9.22[bcd]	57.87[bc]	37.95[c]	7.07[d]
7	*Brachiaria hybrid Mulato II*	92.00	91.0[a]	7.28[e]	66.12[a]	52.16[a]	9.12[ab]
8	*B. brizantha* wild Acc no 13755	92.33	89.9[ab]	8.41[d]	57.46[c]	40.56[bc]	7.34[cd]
9	*B. brizantha* wild Acc no 13726	92.00	90.0[ab]	8.88[cd]	64.72[a]	51.06[a]	9.70[a]
10	*B. decumbens*	91.67	87.3[c]	9.79[abc]	60.95[b]	45.15[b]	8.32[bc]
	Over all mean	92.03	89.7	8.55	60.82	45.69	8.22
	CV	0.92	1.47	7.18	3.14	6.82	7.59
	LSD	1.447	2.065	1.053	3.284	5.343	1.070
	LSg	NS	***	***	***	***	***

DM= Dry matter; OM= Organic matter; CP= Crude protein; NDF= Neutral detergent fiber; ADF= Acid detergent fiber; ADL= Acid detergent lignin

The CP and NDF concentration reported for B. brizantha, B. mulato and B. mutica are comparable with the current findings; however, ADF% was greater than previous report (Mustaring *et al*., 2014). The greater fiber concentration observed for Brachiaria cultivars could limit digestibility; therefore, further study required to improve the fiber content through different agronomic practice. The same Brachiaria cultivars in the present study had different chemical composition compared to the value reported for different district in the Amhara region (Tiruneh *et al*., 2022). Different chemical composition for the same cultivars might be attributed to soil fertility (Kaur & Goyal, 2017) and environmental condition (Radkowski *et al*., 2020).

CONCLUSION AND RECOMMENDATIONS

Dry matter yield and chemical composition varied among the 10 Brachiaria cultivars tested. *Brachiaria hybrid Mulato* II and *Brachiaria hybrid Mulato* I produced greater biomass and crud protein yield. Though the CP concentration was lower for these 2 cultivars, CP yield was greater due to the greater biomass yield they produced. The NDF and ADF concentration measured for all cultivars tested were greater that could limit digestibility. Therefore, further study is required to reduce fiber content of Brachiaria through agronomic practice and evaluation the effect of feeding Brachiaria on the overall performance of ruminants.

ACKNOWLEDGEMENT

The authors would like to thank Agricultural Growth Program -II and Amharic Region Agricultural Research Institute for their financial support to accomplish the field experiment. The authors would also thank Dr.Wubetie and Gondar Agricultural Research center for supply planting materials.

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Comparative evaluation of pasture improvement interventions on herbage yield, quality, economic performance and farmer's perception at Ferenji- Wuha Watershed, Central Gondar zone, Ethiopia

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ABSTRACT

The study was conducted to evaluate the response of degraded pasturelands to the application of pasture improvement interventions, and to estimate the profitability of pasture improvement practices. The interventions were: treating the pastureland with urea fertilizer, pastureland over-sowing with Vetch, application of cattle manure and untreated pasture as a control. All the treatments were applied in all the mother and baby trials. Mother trial was laid down in a Randomized Complete Block Design (RCBD) with four replications, while baby trials were applied at each farmer's field without any replication. Data such as plant height (cm), fresh biomass yield (t ha^{-1}), dry matter yield (t ha^{-1}), crude protein yield (t ha^{-1}) and chemical composition of feeds were recorded and analyzed from the mother trial to assess the potential of pastureland improvement interventions. All data were analyzed by analysis of variance, and differences in treatment means were compared by the LSD (Least Significant Difference) at 5% while descriptive statistics were used for preference ranking using mean scores. The results revealed that herbage dry matter (DM) yields increased from 2.09 to 6.51 t ha^{-1} with the application of urea fertilizer. The herbage crude protein content increased from 45.8 to 136.4g kg^{-1} with Vetch over sowing. Remarkable crude protein yields (from 0.61 to 0.69 t ha^{-1}) were achieved as Urea fertilizer and manure were applied. Of the interventions, Urea fertilizer application as an effective intervention contributed to fetching the highest net return (16,975.30 ETB) from the direct sale of pasture hay with an attractive marginal rate of return (MRR) (2.86 ETB). Urea fertilizer application as pastureland improvement intervention was found attractive and highly preferred technology among tested options by the farmers. It is, therefore, Urea fertilizer application as a pasture improvement option that can significantly improve pasture land productivity, and quality and is found economically feasible which makes highly attractive and preferable technology that enables rural farmers to benefit from their land resources.

Keywords: *grazing land, manure, pastureland, urea fertilizer, vetch*

INTRODUCTION

Ethiopia is the largest livestock producer in Africa, with 70.29 million heads of cattle, 42.92 million sheep, 52.46 million goats, 10.79 million donkeys, 2.15 million horses, 0.38 million mules, 8.15 million camels, and 56.99 million poultry (CSA, 2021). Although the country has a large livestock population, the production and productivity per head are very low which in turn is associated with the major hindrances being the shortage of feed resources in terms of quantity and quality (Selamawit *et al.*, 2017; CSA, 2021). Livestock feed in the country is based on natural pastures, fallow grazing, stubble grazing, and crop residues (CSA, 2021). The natural pasture resource consists of grass-dominated which is followed by legumes and other herbaceous species. More than 85.67% of the livestock feed in Ethiopia comes from crop residues and natural pasture out of which 36 – 41.6% is estimated to be from private grazing land (CSA, 2021). However, the availability and quality of these feed sources cannot satisfy effective livestock production even for maintenance because of low digestibility and low intake of livestock for the whole year round, as a result, body weight gains obtained during the wet season may be lost totally or partially in the dry season (Alemayehu, 2006).

The productivity of natural pasture or grasslands in most parts of Ethiopia is extremely very low which may not exceed 2 t ha^{-1} (Gezahagn *et al.*, 2016). It is characterized by very minimal investments, little or no pasture improvement, and no fertilization, leading to very low yields (Ndambi *et al.*, 2018). The availability and quality aspect of forages from native pastures are governed by different factors such as poor grazing land management; most of the grazing lands are located either in waterlogged and highly degraded areas (Yadessa *et al.*, 2016). Besides this low productivity as a result of the increased human population, there is a critical conversion of grazing lands into croplands. As a result of shrinkage in grazing lands, few management interventions and assigning large herds on small grazing lands caused overgrazing and land degradation that leads to low productivity due to its continuous heavy grazing, invasion by unpalatable plant species and mismanagement practices (Abule, 2015; Gezahagn *et al.*, 2016). This is the scenario that practically faced the Ferenji- Wuha watershed and the surroundings.

The observed grazing land degradation ultimately alarms grazing land improvement measures. Different actors (research organizations, livestock development sectors and NGOs) have tested different pastureland management interventions for degraded grazing lands through the application of organic and inorganic fertilizers and over-sowing of grazing lands by using legume forages and they have obtained a remarkable improvement in different areas outside the watershed (Tesfaye *et al.*, 2015).

Numerous previous studies conducted in Ethiopia and other countries give empirical evidence that the application of organic and inorganic fertilizers and also over-sowing with legume forages could significantly improve the productivity and quality of pasturelands. Despite the availability of improved pastureland interventions in the country, there is no information and farmers do not validate grassland improvement practices in the current watershed. This problem necessitates testing alternative pastureland improvement intervention options by participating farmers in the watershed. The objectives of this study, therefore, were to evaluate improved pastureland improvement interventions and their role in enhancing degraded pasturelands, to evaluate the level of intervention options in improving the quality of pasture resources, to estimate the profitability of pastureland improvement interventions through partial budget analysis and to assess farmer’s perception and reaction towards pastureland improvement interventions in the watershed.

MATERIALS AND METHODS

Description of the study area

The experiment was carried out at the highlands of Gondar Zuria district, Manterno Kebele, Ferenji- Wuha watershed, which represents the upper catchment of Mozgie. The study area (Ferenji- Wuha) is located between 12° 19’ 36’’ N latitude and 37° 35’ 28’’ E longitude, at an elevation of 1991 m.a.sl. The area has a moist tropical cl0imate with monthly maximum temperature ranging from 25.3 to 32.6 ºC (mean 29.0 ºC) and monthly minimum temperature from 11.1 to 16.9 ºC. Based on 10 years (2012-2021) data, annual rainfall is strongly seasonal, variable and unreliable with a mean of 1,052 mm (range 641 to 1,678 mm). The soil types are predominantly Cambisols and Leptosols, which are found in the upper and central parts of the watershed, whereas Vertisols are found in the lower catchment area. The topography of the area ranges from gentle slopes to very steep slopes. From the feed resources available in the watershed natural pasture is the second major feed source which is used especially during the rainy season.

Selection of participating farmers

A total of 6 farmers who have grazing land in the watershed and are willing to allocate 3.75 ha of grazing land with an average steepness of 5% were selected and used for the field experiment. All the participating farmers were used for the application of all the grazing land improvement interventions.

Treatments and experimental design

The experiment was conducted in a mother-and-baby trial fashion. To take appropriate measurements in each treatment from the participating farmers' one farmer's field that represents the real command area of the watershed was purposively selected and used for the application of the mother trial. Four pastureland improvement interventions (pastureland treated with urea fertilizer, pastureland treated with cattle manure, and pastureland over-sown with legume forage Vetch (*Vicia villossa*)) and untreated pastureland as a control were used as a treatment. A mother trial plot was laid down in Randomized Complete Block Design (RCBD) with four replications. The plot size was 5m X 5m and the space between the block and the plot was 2m. The total experimental area had an area of 289 m^2 (26 m x 26 m). Baby trials were conducted at all the participating farmers' fields. All the treatments were applied at each participating farmer as a baby trial.

Method of treatment application

For the urea-treated pasture plots urea fertilizer at the rate of 150 kg ha^{-1} was used immediately after the rain becomes continuous. For the manure-treated plots, well-rotten cattle manure at the rate of 5 t ha^{-1} was applied immediately after the rain started. For the over-sown pasture plots, Vetch (*Vicia villossa*) at a seeding rate of 12 kg ha^{-1} was used at the beginning of the rainy season, while untreated pastureland plots remained untreated. Both the urea and manure were applied wholly at a prescribed time. The experimental grazing land was enclosed from July to the end of November to protect it from external disturbances. The determination of species composition and harvesting was done at the end of November, 2021.

Forage sampling and processing

When the pastures on the experimental plots reached approximately 50% flowering stage, their performance was evaluated for plant height at forage harvest, forage biomass yield (t ha^{-1}), dry matter percent (%), and dry matter yield (t ha^{-1}). The vegetation from each treatment was sampled using a quadrant with a size of 1 m^2 (1 m x 1 m) during a predetermined sampling period using a hand-operated sickle, at about 5 cm above the ground. The quadrant was randomly thrown five times per plot (four at the corner and one at the center) and the average weight of each quadrant harvest per plot was used for the determination of pasture yield, quality, and botanical composition. After harvesting, the total fresh weight of the forage sample from each plot was weighed immediately using a portable digital balance with a sensitivity of 0.01g.

A 500g individual fresh sample was taken and the sample of each plot was further categorized into different botanical fractions (grass, herbaceous legume, and forbs). Each botanical component was weighed separately and dried in a forced air draft oven to determine the contribution of each component to the total dry matter (DM) yield of the pasture. The DM yield of each botanical component in each plot was determined by drying the samples in an oven at 60 °C for 72 hours. The DM yield of each botanical component was calculated separately and summed up to provide the total DM yield of the plot, and the final DM yields were reported as tonnes per hectare. The morphological parameters (plant height) were measured from ten spot areas that were randomly selected from the corner and center of each plot at harvest and it was measured in centimeters from the ground surface to the top of the main stem (then the average was taken).

Botanical composition

From the sample taken at each plot, all species were listed, recorded, and identified based on their leaf and stem structure and floristic (flowering) characteristics. The botanical composition concerning the relative proportion of the grasses, legumes, and weeds/forbs in the treatment plots on a weight basis was determined by relating the weights of each group to the weight of the whole samples. Identification of the species was undertaken with the assistance of local farmer’s in situ, experienced researchers from Gondar agricultural research center, and an identification field guide, and then the nomenclature was undertaken following (Edwards *et al.,* 2000).

Forage quality analysis

Chemical analyses of forage samples were carried out by taking representative samples from different harvests of respective fields. The feed samples were dried in a forced air draft oven at 60^{0}C for 72 hrs for partial dry matter (DM) determination. Dried samples of feeds were milled using a laboratory mill to pass through a 1 mm screen. Milled samples of feeds were taken to Debere Birhan Agricultural Research Centre and stored at room temperature pending chemical analysis. Dry matter (DM), crude protein (CP), and ash in the feed samples were determined according to the procedure of (AOAC, 2000). Nitrogen (N) was measured using the micro-Kjeldahl procedure (AOAC, 2000). Crude protein was determined by multiplying nitrogen content with 6.25 factors. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were analyzed according to the procedures of (Van Soest *et al.*, 1991).

Partial budget analysis

To know the profitability of pastureland improvement interventions partial budget analysis was done following the procedure of Upton (1979). The economic analysis included the variable costs and benefits of pasture hay production. Average prices in Ethiopian Birr (ETB) for pasture hay, Urea fertilizer, cattle manure, Vetch seed, labor for Urea fertilizer application, labor for manure application, labor for vetch under sowing, labor for hay harvesting were considered for the analysis taking the prevailing price into account. These were: 3,250.00 ETB t^{-1} for pasture hay, 18,000.00 ETB t^{-1} for Urea fertilizer purchase, 500.00 ETB t^{-1} for manure purchase, 40.00 ETB kg^{-1} for Vetch seed purchase, 50.00 ETB ha^{-1} for Urea fertilizer application, 90.00 ETB t^{-1} for manure transportation and application, 50.00 ETB ha^{-1} for vetch under sowing and 50.00 ETB t^{-1} for hay harvesting.

The gross field benefit was taken at the final sale of the biomass. Net Income (NI) was calculated as the amount of money left when Total Variable Costs (TVC) are subtracted from gross field benefit or Total Return (TR):

$NI = TR - TVC$

The change in Net Income (Δ NI) was calculated as the difference between changes in Total Return (ΔTR) and the change in Total Variable Costs (ΔTVC), and this is to be used as a reference criterion for the decision on the adoption of technology.

$\Delta NI = \Delta TR - \Delta TVC$

The Marginal Rate of Return (MRR) that measures the increase in Net Income (ΔNI) associated with each additional unit of expenditure (ΔTVC) were calculated and expressed as a ratio:

$MRR = \Delta NI / \Delta TVC$

Farmer's perception

Development of selection criteria

The criteria used by farmers in the selection of pastureland intervention options were identified through focus group discussions (FGDs) following the procedure described by Krueger (2002). Groups of participating and non-participating farmers in the watershed and the surrounding were purposefully selected. With the guidance of researchers and extension workers, farmers listed criteria that they consider important for the selection of pasture improvement interventions. A pairwise ranking matrix was used to determine the most important criteria which were then applied in the evaluation and selection.

Evaluation and selection of pastureland improvement intervention

Volunteer farmers have participated in the evaluation and selection of pastureland improvement intervention options at Ferenji- Wuha Watershed two weeks before the pasture harvested. Attributes that could not be directly observed in the field such as high milk yield and tolerance to water-logged conditions were dropped. The final criteria included height at harvest, early maturity, high biomass yield, better preference by animals, high legume species composition, and absence of weedy plants. For each criterion, farmers' opinions on individual intervention options were recorded in an evaluation form using a Likert scale of 1 to 4 where, 1 =poor, 2=fair, 3=good and 4=very good following the procedure outlined by Krueger (2002).

Statistical analysis

The data collected on DM yield, crude protein yield, and species compositions were analyzed using the Generalized Linear Model (GLM) procedure of SAS 9.1 (SAS Institute, 2003). Where a significant effect of treatments was found, the least Significant Difference (LSD) test was employed to separate means at $P \leq 0.05$.

The linear model used was: $Y_{ij} = \mu + t_i + b_j + e_{ij}$

Where Y_{ij} is the response variable (the observation in j^{th} block and i^{th} treatment mean), μ is the overall, t_i is the treatment effect, b_j is the block effect (gradient), and e_{ij} is the random error. While, descriptive statistics were employed for preference ranking using mean scores.

RESULTS AND DISCUSSION

Pasture botanical composition

Twelve plant species were identified across the experimental plots, which included 6 grass species, 4 forbs, and 2 legumes (Table 1). The majority of grass species identified were Paspalum scrobiculatum (Gaja), (Sardo) Cynodon dactylon (L.) Pers, (Tucha) Pennisetum thunbergii, (Koke sar) Acroceras zizanioides (Kunth) Dandy, (Engicha) Cyperus esculentus L. and (Gagirda) Echinocloa colona (L.). The legumes identified in the study include *Trifolium decorum* Chiov (Wajema), and (*Yemno guwaya*) *Vicia villosa.* Grasses were the dominant species in all the treatments in the study area as compared to legumes and forbs/weeds. Species diversity in natural pasture or grazing land is a desirable attribute in terms of pasture quality, quantity, and persistence. Hence, the presence of desirable perennial and annual grasses species in the study area would indicate the degree of persistence of these species against recurrent drought, frost, and high pasture pressure consistent with the harshness of the prevailing climatic biotic factors (Nebi *et al.*, 2021). In terms of life form, 66.7% of plants were annuals, while the rest were perennial species (Table 1).

Table 1. Major Grass, legume and forb/weed species observed in different pastureland improvement intervention areas at Ferenji- whuha watershed

Scientific name	Local name (Amharic)	Life form	Species presence in each treatment			
			T1	T2	T3	T4
Grasses						
Paspalum scrobiculatum	*Gaja*	Annual	✓	✓	✓	✓
Cynodon dactylon (L.) Pers	*Sardo*	Perennial	✓	✓	✓	✓
Pennisetum thunbergii	*Tucha*	Annual	✓	✓	-	✓
Acroceras zizanioides (Kunth) Dandy.	*Koke sar*	Annual	✓	✓	✓	✓
Cyperus esculents (L.)	*Engicha*	Perennial	✓	✓	✓	✓
Echinocloa colona (L.) Link	*Gagirda*	Perennial	✓	✓		✓
Legumes						
Trifolium decorum Chiov.	*Wajema*	Annual	✓		✓	✓
Vicia villosa	*Yemno guwaya*	Annual			✓	
Forbs/weeds						
Commelina subulata Rott.	*Yewhaankur*	Annual	✓	✓	✓	✓
Polygonum nepalense Meisn.	*Yetija siga*	Annual	✓	✓	✓	✓
Hygrophila auriculata (Schum) Heine	*Ameykela*	Perennial	✓	✓	✓	
Commelina benghalensis L.	*Yeayitabish*	Annual	✓		✓	

*T1= Untreated pastureland (Control); T2= Pastureland treated with Urea fertilizer (150 kg ha^{-1}); T3= Pastureland over sown with Vetch (12 kg ha^{-1}); T4= Pastureland treated with cattle manure (5 t ha^{-1}).

Proportion persistence of species

About 66.67% of the grass species were decreasers and the remaining were increasers. In the case of legumes, 100% of the species were decreasers. On the other hand, 25% of the forb species were decreasers, 50% of forbs were increasers, and 25% invaders (Table 2).

Table 2. Proportion of decreasers, increasers, and invaders among pasture plants

Category	Grasses	Legumes	Forbs/weeds
Decreasers	66.67	100	25.00
Increasers	33.33	-	50.00
Invaders	-	-	25.00

Decreasers= most palatable and desirable plants that decrease in a site when overgrazed, Increasers= less palatable plants that tend to increase in a site when overgrazed, Invaders= least desirable plants, mostly exotic which invade a site when overgrazed (Hurt et al., 1993).

Plant height, dry biomass, and total Crude Protein (CP) yield (t ha^{-1})

As indicated in Table 3 in the control treatment, grasses contributed about 89.64% of the biomass yield, but that contribution decreased ($P < 0.05$) to 80.60, 62.42 and 64.17% with the application of chemical fertilizer, pasture over sown with vetch, and pasture treated with cattle manure, respectively which is in disparity with the results of (Nebi *et al.*, 2021). This could be mainly due to the increased proportion of legumes and weeds/forbs with the application of manure and Urea fertilizer and also over sowing of vetch. The contribution of legumes to the total herbage mass increased ($P < 0.05$) with the application of vetch over sowing (27.96%) and pasture treated with cattle manure (17.77%) as compared to the control (9.03%). On the other hand, the application of cattle manures also increased ($P < 0.05$) the proportion of weeds/forbs from 15 to 1.32%, with the lowest proportion being recorded for the control/untreated pasture.

As expected, the control plots had the lowest pasture growth, biomass, and crude protein yield (79.65 cm height, 2.09 t DM ha$^{-1,}$ and 0.11 t CP ha^{-1}) and there was an improvement ($P < 0.05$) in pasture growth, biomass, and total CP yield with the application of Urea fertilizer, pasture treated with cattle manure and pastureland over sown with Vetch. The highest plant height, biomass, and crude protein yield were observed with Urea fertilizer (107.80 cm, 6.51 t DMha$^{-1,}$ and 0.69 t CP ha^{-1}), followed by manure (93.95 cm, 5.16 t DM ha$^{-1,}$ and 0.61 t CP ha^{-1}), and Vetch over sowing (90.80 cm, 3.63 t DM ha$^{-1,}$ and 0.51 t CP ha^{-1}) (Table 3).

In general, pasture improvement interventions are expected to have a direct positive impact on the yield and quality of pasturelands (Tessema *et al.*, 2010). The three-fold increase in herbage DM and CP yield, as a result of Urea fertilizer and cattle manure application, is considerable given the critical feed shortages in areas where remarkable pasture exists (Gebremedhin *et al.*, 2009). The pasture yield recorded in the present study is generally in line with previous reports (Tessema *et. al.*, 2010). The highest pasture yield response observed with the chemical fertilizer application can be related to the availability of N for plant growth. In the present study, it can be observed that the application of fertilizer not only improved the yield performance but also favored the growth of desirable pasture species. The increased total CP production (t ha^{-1}) in the case of Urea fertilizer and manure-treated pasture plots could be expected to contribute to the improvement in biomass production and CP percentage since total CP production (t ha^{-1}) is a function of total biomass produced and CP percentage. This result was per the findings of Nebi *et al.* (2021) who reported a significant total crude protein production that ranges from 0.59 to 0.71t ha^{-1} with Urea fertilizer and manure application.

Table 3. Mean effect of pastureland improvement interventions on herbage and crude protein yield and other plant species composition

Treatment	**PH (cm)**	**GBC** (%)	**LBC** (%)	**FBC** (%)	**FBY** (t ha^{-1})	**DM** (%)	**DMY** (t ha^{-1})	**CPY** (t ha^{-1})
Untreated Pastureland	79.65[c]	89.64[a]	9.03[b]	1.32[b]	11.09[c]	18.86	2.09[d]	0.11[c]
Urea fertilizer treated	107.80[a]	80.60[ab]	7.73[b]	11.66[ab]	29.79[a]	21.86	6.51[a]	0.69[a]
Over sown with Vetch	90.80[bc]	62.42[b]	27.96[a]	9.60[ab]	19.76[b]	18.37	3.63[c]	0.51[b]
Manure treated	93.95[b]	64.17[b]	17.77[ab]	15.00[a]	26.59[a]	19.42	5.16[b]	0.61[a]
Mean	93.05	74.21	15.62	9.39	21.8	19.63	4.28	0.47
CV (%)	6.27	11.31	22.00	22.10	7.74	10.26	8.75	19.42
LSD (0.05)	12.88	18.53	14.50	10.82	7.46	ns	1.67	0.42

*a,b,c,d= means within column having different superscript letters are significantly different at ($P>0.05$); ns= non-significant at ($P>0.05$); CV= coefficient of variation; CPY= crude protein yield; DMP= dry matter percent; DMY= dry matter yield; FBC= forbs botanical composition; FBY= forage biomass yield; GBC= grass botanical composition; LSD= least significant difference; LBC= legume botanical composition; PH= plant height.

Nutritional quality of pasture resources

In addition to biomass yield increases, CP contents were higher than the control in all of the pastures with the highest values reported for pasture over sown with vetch followed by manure, and Urea fertilizer applications (Table 4). The increased proportion of legumes in the case of pasture overs own with vetch, manure, and Urea fertilizer applications could be expected to contribute to the improvement in the CP content and reduction in fiber fractions of the pasture compared to untreated pasture (Aydin and Uzun, 2005; Brum *et al.,* 2009). The CP content of the pasture produced in treated pasture plots was well above the nutritional requirements of ruminant livestock under grazing conditions and can be classified as high quality (Bezabih *et al.,* 2013). Similarly, ash and OM contents were slightly higher than the control, with the highest values reported following pasture over sown with vetch, manure, and Urea fertilizer applications, respectively. Increases in ash content may have resulted from increased availability for root assimilation of mineral nutrients in the treated pasture plots (Wilson *et al.,* 2010). However, DM contents were almost similar in all the treatments. On the other hand, the fiber contents (NDF, ADF, and ADL) were lower following manure application, pasture over-sown with Vetch, Urea fertilizer application, and untreated pasture. Hay obtained at different pasture improvement interventions, fiber contents were below 72, 40, and 10% for NDF, ADF, and ADL, respectively, which indicates they have no negative effect on feed intake and digestibility. Nussio *et al.* (1998) also reported that forage with or more than 72% NDF, 40% ADF and 10% ADL shows low intake and digestibility.

Table 4. Chemical composition (%DM) of natural pasture treated at different pastureland improvement interventions at Ferenji- wuha watershed in the year 2021/22

Treatment	**Chemical compositions (% DM)**						
	DM	**OM**	**Ash**	**CP**	**NDF**	**ADF**	**ADL**
T1	90.40	89.73	9.81	4.58	65.70	38.82	3.88
T2	89.28	91.71	12.80	10.60	64.21	36.16	3.58
T3	87.03	95.66	14.06	13.64	62.98	35.24	3.44
T4	88.15	93.68	13.10	11.70	61.70	35.91	3.35

*ADF = acid detergent fiber; ADL= acid detergent lignin; CP = crude protein; DM= dry matter; NDF = neutral detergent fiber; OM = organic matter; T1= Untreated pastureland (Control); T2= Pastureland treated with Urea fertilizer (150 kg ha^{-1}); T3= Pastureland over sown with Vetch (12 kg ha^{-1}); T4= Pastureland treated with cattle manure (5 t ha^{-1}).

Partial budget analysis

The result of the partial budget analysis was shown in Table 5. The result of the partial budget analysis revealed that Urea fertilizer applied plots resulted in a higher profit margin than the rest of the pasture improvement options and the control. Urea fertilizer-treated pasture plots also had the highest net return. The observed higher profit margin and net return at Urea treated pasture plots may be associated with improved hay biomass production. The analysis also showed that farmers can triple their income by applying commercial fertilizer as a promising pastureland improvement option compared to the control (untreated pasture). Manure with its slow rate of nutrient release short-term economic benefit from the application of cattle manure to the pastureland was not as attractive as urea-treated pasture. Long-term benefits were not captured in this analysis due to differences in the rate of nutrient release into the soil system; however, chemical fertilizers are quick to release nutrients with immediate effect on plant growth. Although pastureland overs own with Vetch forage produced a relatively lower biomass yield than Urea fertilizer and manure-treated pastures due to its lowest total variable cost it provided the highest marginal rate of return 4.81 ETB. However, Urea fertilizer and manure-treated pastures are also still profitable by providing MRR of 2.86 and 1.75 ETB, respectively. This indicates that to produce the required hay biomass yield, each additional unit of 1 ETB increment per 1 ha of pastureland to purchase inputs for pasture improvement resulted in a profit of 4.81 ETB for pastureland over sown with Vetch, 2.86 ETB for Urea fertilizer treated pasture and 1.75 ETB for manure treated pasture, respectively.

Table 5. Partial budget analysis results of pastureland improvement interventions at Ferenji-whuha watershed in the year 2021/22

Variables	**Treatments**			
	T1	**T2**	**T3**	**T4**
Amount of hay produced (t ha^{-1})	2.09	6.51	3.65	5.16
Amount of inputs used				
Amount of Urea fertilizer used (t ha^{-1})	-	0.15	-	-
Amount of manure used (t ha^{-1})	-	-	-	5.00
Amount of Vetch seed utilized (kg ha^{-1})	-	-	15.00	-
Total variable cost (ETB)	459.00	4,182.20	1,333.00	4,085.20
Price for Urea fertilizer purchase (ETB t^{-1})	-	18,000.00	-	-
Price for manure purchase (ETB t^{-1})	-	-	-	500.00
Price for Vetch seed purchase (ETB kg^{-1})	-	-	40.00	-
Labor for hay harvesting (ETB t^{-1})	220.00	220.00	220.00	220.00

Labor for input application (ETB ha^{-1})	-	50.00	50.00	450.00
Total return (ETB)	6,792.50	21,157.50	11,862.50	16,770.00
Net return (ETB)	6,333.50	16,975.30	10,529.50	12,684.80
ΔTVC	-	3,723.20	874.00	3,626.20
ΔNI	-	10,641.80	4,196.00	6,351.30
MRR (ratio)	-	2.86	4.81	1.75

*ΔNI= change in net income; ΔTVC= change in total variable cost; ETB= Ethiopian Birr; MRR= marginal rate of revenue; T1= Untreated pastureland (Control); T2= Pastureland treated with Urea fertilizer (150 kg ha^{-1}); T3= Pastureland over sown with Vetch (12 kg ha^{-1}); T4= Pastureland treated with cattle manure (5 t ha^{-1}).

Farmers' selection criteria

Results from participatory criteria identification showed that farmer's largely desired pastures that produce better biomass yield, are highly preferred by animals, and have better growth (Table 6). Other attributes were legume species composition, the relative absence of weedy plants, and early maturity. Farmers' prioritized preferences indicate their expectation for forages that have better biomass and a better grass composition as highlighted by Kidake *et al.* (2016). Identification of these preferences by farmers at varied intervention options is essential for the wider adoption of degraded pastureland improvement. This is because consideration of farmer criteria would essentially ensure that recommended pasture improvement intervention meets farmers' requirements and their opportunities, thus they have better prospects to adapt as earlier reported by Nkongolo *et al.* (2008) on improved forages in Kenya.

Table 6. Pairwise ranking matrix of farmers' selection criteria for the pastureland improvement interventions evaluated at Fernji- Wuha watershed

Key attributes considered	**HBY**	**HH**	**AP**	**LSC**	**AWP**	**EM**	**Total Score**	**Rank**
High biomass yield (HBY)		HBY	HBY	HBY	HBY	HBY	5	1
Height at harvest (HH)			AP	HH	HH	HH	3	3
Animal preference (AP)				AP	AP	AP	4	2
Legume species composition (LSC)					LSC	LSC	2	4
Absence of weedy plants (AWP)						AWP	1	5
Early maturity (EM)							0	6

Farmer's Perception on pastureland improvement interventions

Results in Table 7 show differences in mean scores among the four pastureland improvement interventions based on key selection criteria. The study revealed that farmers in Ferenji-whuha watershed of Gondar zuria district preferred Urea fertilizer as the best pasture improvement option which was followed by manure application. This is because Urea fertilizer in its direct release of nutrients to the soil favored the production of better hay biomass which corresponds with the biological data. This finding is consistent with Nebi *et al.* (2021) who found differences in farmer preferences for pastureland improvement intervention options with a better preference for Urea fertilizer application at Adami Tulu Jido Kombolcha and Arsi Negelle districts of Oromia Region.

Table 7. Farmers' scores for the pastureland improvement interventions evaluated at Ferenji-Wuha watershed

Pastureland improvement interventions evaluated	High biomas	Height at harvest	Animal preference	Legume spp. composition	Mean scores	Rank
Untreated pastureland	1.27	1.62	2.82	1.92	1.91	4
Pastureland treated with Urea	3.58	3.46	2.98	2.06	3.03	1
Pastureland over sown with	2.78	2.92	2.25	2.82	2.69	3
Manure treated pastureland	3.00	3.14	2.83	2.96	2.98	2
Mean	2.66	2.79	2.72	2.44	2.65	-

CONCLUSION AND RECOMMENDATIONS

From this study, it can be concluded that the application of Urea fertilizer to degraded pasturelands can lead to a tripling of native pasture yield with improved nutritional quality. Compared to the other pastureland intervention options use of Urea fertilizer was found more economical in obtaining a higher profit margin and net income with a modest marginal rate of return. Though pasture overs own with Vetch produced a relatively lower biomass yield it was potentially profitable. Recognizing farmers' expectations and being responsive to their preferences for new technology or improved intervention is central to its successful promotion and acceptance in the farming community. Using the farmer's own defined criteria on forage amount, height at harvest, livestock preference, and legume-to-grass species composition; pasture treated with Urea fertilizer was the most preferred intervention. Hence, according to the results of this study, a better pasture improvement application of Urea fertilizer to degraded pasturelands was a biologically efficient, potentially profitable, and highly acceptable intervention. It is thus important that further long-term soil fertility improvement effects of organic fertilizer in improving pasture productivity should be further studied. In addition, for wider adoption of such pasture improvement practices, strong extension support and a series of demonstrations to livestock producers will be important.

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Participatory Evaluation of Perennial Forage Grasses and Tree Forage Legumes Integrated on Soil Bund Structures and Farmer's Perception at Ferenji- Wuha Watershed, Central Gondar Zone, Ethiopia

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ABSTRACT

The study was conducted to determine potential perennial grasses and tree forage legumes suited for integrating with soil bund structures and to assess farmers' perceptions towards the introduced technologies. The evaluated grasses species were Napier (ILRI- 16791), Desho (Areka DZF# 590), and Brachiaria grass (Brachiaria mutica); and perennial tree legume species were Sesbania sesban and Cajanus cajan. Grass and tree legume species were independently planted alternately along the soil bund structures with a randomized complete block design. Data on morphological and biomass parameters including Plant Height (PH), Green Biomass Yield (GBY), Dry Matte Yield (DMY), and Leaf to Stem Ratio (LSR) for both perennial grasses and tree legume species; Survival Rate (SR) and Number of Branches per Plant (NBPP) for tree legume species and Number of Tillers per Plant (NTPP) for the perennial grasses were collected. Farmers' perceptions were assessed based on a key identified criteria by using a Likert scale of 1-4 (where 1= poor and 4= very good). The biological data were analyzed by SAS (2003) and descriptive statistics was used for preference ranking using mean scores for both perennial grasses and tree legumes. The results revealed that the highest forage dry matter yield (24.78 t ha^{-1}) was obtained from Napier grass (ILRI- 16791) than other grass species and from the perennial tree legume species the highest forge biomass yield (7.46 t ha^{-1}) was obtained from Sesbania sesban. Based on the overall farmer's selection criteria Sesbania sesban from perennial trees and Napier grass (ILRI- 16791) were selected as the most promising and highly preferred forage species. Based on the result of this study, it was concluded that Napier grass (ILRI- 16791) showed outstanding potential and was the highly preferred perennial grass followed by Desho (Areka DZF# 590), and from the perennial tree legume species Sesbania sesban was the best preferred to improve biomass supply for enhanced production from livestock and the best form of soil conservation those could be scaled out to other similar areas.

Keywords: *biomass yield, farmer, perennial grass, perennial tree legume, soil bund, watershed*

INTRODUCTION

Ethiopia is an agriculture-based country where the majority of the population is engaged in subsistence mixed crop-livestock production (Zerihun and Getachew, 2013). In the country livestock production has been contributing substantially to the livelihoods of rural households, but the overall productivity from the sector is very low due to poor livestock feed supply in quantity and quality (Selamawit et al., 2017; Tahir et al., 2018; CSA, 2021). Similarly, in central Gondar zone, livestock husbandry system is extensively based on natural pasture, which is greatly influenced by biomass supply and nutritional dynamics of pasture forages (Tessema, 2005). The animal fed on poor-quality diets could not realize the dietary nutrient requirement. This is making livestock take too long to attain optimum production and reproduction performances (Uday et al., 2017; Tahir et al., 2018; CSA, 2021). To combat these nutritional constraints, the use of locally available and introduced forage species adapted to the local agroecological conditions is recommended. The cultivation of high-quality forages with high herbage yield and adaptability to biotic and abiotic environmental stresses is one of the options to increase livestock production under smallholder farmers' conditions (Tessema, 2005).

Fast-growing forage species like Desho, Brachiaria, Napier, Sesbania, Luciana, and Pigeon pea are therefore increasingly used to provide strategic sources of high-quality fodder for supplementing livestock fed on poor-quality roughage diets in semi-arid environments (Negasu et al., 2020; Denbela, 2022). These forage species provide more forage per unit area but also ensure regular forage supply due to their perennial nature. The grasses can recover after water stress even under severe drought conditions (Tessema, 2005). Perennial forage species are used in a variety of agroforestry systems all over the world for fodder production and soil conservation. These species are also among the useful multipurpose grasses that could have an increasing role as a home-grown feed (Rudel *et al.*, 2015).

Due to the competition of land between food and forage crop production, the parcel of land allotted for sole forage production is very low in the highland areas of the country. On the other hand, poor soil management and land use practices are the causes of severe soil erosion in Ethiopia in general and at Ferenji- Wuha Watershed in particular. The Ferenji- Wuha Watershed covers 375 ha of land that is facing soil degradation and loss of land productivity in the Amhara Region. The farmers settled in the watershed suffer from the impacts of severe erosion of their farmlands. To alleviate this problem, several soil and water conservation measures have been undertaken by the government, although their success is highly questionable. However, there was no practice of strengthening the physical structures with biological soil conservation practices with special emphasis to forage grasses and legumes. This condition calls for the integration of improved forage that could have several advantages over conventional feed resources. Though improved forages were being introduced as biological soil conservation measures and animal fodder in government intervention areas of the watershed, little is known about how farmers perceive the production and utilization of such forages. This necessitates the introduction and evaluation of adapted and best-fit perennial tree legumes integrated with soil and water conservation structures, particularly on soil bunds. Thus, the objectives of the study were to determine potential perennial grass and browse legume forages suited for integrating with soil and water conservation structures and to asses' farmer's perception and reaction towards the technologies.

MATERIALS AND METHODS

Description of the study area

The field experiment was conducted at Ferenji wuha watershed of Gondar zuria district in the Central Gondar zone of the Amhara during 2021 cropping season. The study area (Ferenji wuha watershed) is located 698km North West of Addis Ababa at a geographical location between 12^{o}19'38'' N latitude and 37^{o}35'33'' E longitude, at an elevation of 2000 m.a.sl. The area has a moist tropical climate and the monthly maximum temperature ranges from 25.3ºC to 32ºC with a mean value of 28.5ºC, while the monthly minimum temperature ranges from 10.6ºC to 16.1ºC with a mean value of 13.6ºC. Based on 10 years (2012- 2021) data, the total annual rainfall ranges between 641 mm and 1678 mm with a mean value of 1052 mm. The rainfall in the area is small in amount, unpredictable in onset and cessation, and poorly distributed. The topography of the area ranges from a gentle slope to a sharp steep slope (Yonas et al., 2010).

Participant farmer's selection

At the beginning of the experiment, discussions were made with livestock experts for the selection of participant farmers who are hosted in the watershed. All farmers having cropland in the watershed (28 farmers) of which 22 males and 6 females were purposively selected based on their willingness to allocate land with conservation structures for Desho, Brachiaria, and Napier grass and 15 farmers of which 12 males and 3 females for perennial forage legume production and evaluation.

Extension method used to introduce the technology

To introduce the selected forages, and disseminate and diffuse the technology farmers' research and extension group (FREG) was organized and used as a group extension method. Participatory theoretical and practical training was given to 45 farmers, and 3 development agents before grass planting and during managing planted forages. The content of the training was focused on grass production, management, hay preparation, and utilization. Besides the training, to increase their awareness about the technology production and utilization flayers were prepared and distributed for all training participants. Field days were organized at the farmer's field and a set of farmers, kebele extension workers, district and zonal level livestock experts, and a multidisciplinary team of researchers were participated and invited to conduct a result demonstration and create linkage for further scaling of the technology. In the field days 128 farmers (34 females), 5 kebele extension workers (2 females), 9 district and zonal level livestock experts (1 female), and 11 researchers from Gondar Agricultural Research Center participated. Joint field visits and experience sharing with farmers, extension workers, and researchers were done to hold method demonstrations, especially on Desho, Brachiaria, and Napier grass plantation, management, and hay preparation.

Treatments and experimental design

The experiment was conducted in two sets. Participatory evaluation of perennial forage grasses (set 1) and tree forage legumes (set 2) integrated with soil bund structures and farmer's perception. Three improved perennial grass species (Napier grass (ILRI- 16791), Desho grass (Areka DZF# 590), and Brachiaria grass (Brachiaria mutica) with their production package were used. Two improved perennial tree legumes namely Sesbania sesban variety DZF- 405 and Cajanus cajan variety Tsegab (ILRI-11566) with their production package were used for the experiment. For ease of treatment application, the watershed was divided into two and these halves were further divided into upper, middle, and lower watersheds considering gradient difference to catch the soil fertility differences at different slop. All the treatments were equally applied at each half at different slops. All the perennial grasses and tree legumes were planted at equal distances at each contour.

The experimental materials were laid down in Randomized Complete Block Design (RCBD) with nine replications. The experimental sites were harrowed to crash clods and leveled out to maintain a well-prepared seed bed. For the forage integration work about 22,000 Desho, 18,000 Napier, and 2,000 Brachiaria grass root splits and 5 kg Sesbania and 8 kg Pigeon pea seed were used as planting material. Planting was done along the soil bund structures and these species were alternately planted at random as a replication. Each species were planted at a spacing of 0.2m between plants, giving 250,000 plants ha^{-1}. For the perennial grasses establishment and growth, Nitrogen fertilizer at a rate of 46 kg ha^{-1} was applied half at planting and half at the vegetative stage of plant growth; and for the perennial tree forage legumes 100 kg ha^{-1} NPS fertilizer was applied at planting. About 7.0 km of soil bund structures were planted with perennial grass forage species and 2.8 km of soil bund structures were covered with perennial tree forage legume species. The weeds on planted soil bund structures were effectively controlled by hand hoeing throughout the growing season.

Grass establishment and management

The forage introduction work was a continuation of previous Desho, Brachiaria, and Napier grass adaptation experiments conducted since the 2016 cropping season outside the watershed with the same agro ecology. The root splits were planted at the beginning of the rainy season on well-prepared soil bunds. All farm operations were carried out by farmers based on the recommendation with close assistance and supervision from development agents and researchers. Grass species hay was harvested and properly cured when grass showed a sign of heading for the Desho and Brachiaria, and for the Napier reaching a 1-meter height.

Forage sampling and processing

The overall performance of grasses and forage legumes was evaluated using visual estimation and proceeded measurements of plant height at forage harvest, number of tillers/branch per plant, forage biomass yield (t ha^{-1}), dry matter percent (%), dry matter yield (t ha^{-1}) and leaf to stem ratio. A hand-operated sickle was used for clipping the plants, at about 7 cm above the ground. Plant height was measured by averaging the natural standing height of ten plants per measured area from the entire rows. The main tiller number was an average of primary tillers on the stem of ten plants. The main branch number of perennial forage legumes was an average of primary branches on the stem of ten plants. Grass and legume forage harvested for herbage and dry matter yield were following their predetermine stage for harvest. Sampling was done from the middle rows. Immediately after forage sampling the fresh samples were weighed by using a salter balance having a sensitivity of 0.1kg for green biomass yield estimation. A minimum of 500g individual samples of grass forage were taken for DM% analysis, which was oven dried at 65^{0}c for 72 hours until a constant weight was obtained. For leaf-to-stem ratio determination, when the middle row was harvested five plants were taken at random, dried in a paper bag and the leaves then were carefully stripped from the stems. The ratio was obtained by dividing the weight of the leaf by the weight of the stem.

Farmer's perception

Development of selection criteria

Both participating and non-participating farmers convened at Ferenji wuha watershed in October 2021, where they were briefed on the need to develop the criteria to evaluate and select the most suitable perennial grass. To avoid gender bias and possible dominance in the process, participants were disaggregated by gender, and youth were also considered. The criteria used by farmers in the selection of the species were identified through focus group discussions (FGDs) following the procedure described by Krueger (2002). With the guidance of researchers and extension officers, each group listed and ranked 10 key criteria for each perennial forages. The identified criteria were presented in a plenary by the leader of each group. And these criteria were then ranked in order of priority using a pairwise ranking matrix. Entries of criteria were counted in the entire matrix and the criteria having the highest score ranked first. Where criteria tied, farmers were requested to break the tie by comparing each pair and selecting the priority criterion between them.

Evaluation and selection of suitable perennial grass

Farmers participated in the evaluation and selection of perennial grasses at Ferenji- Wuha Watershed two weeks before the first harvest. Attributes that could not be directly observed in the field such as high milk yield, soil erosion control, easy to establish, height at harvest, and pest resistance were dropped. The final criteria included the perennial grasses' ease to establish, drought tolerance, height at harvest, early maturity, leafiness, high biomass yield, high re-growth after cutting, and palatability while, for perennial tree forage legumes drought tolerance, branching ability, leafiness, high biomass yield, high re-growth after cutting, and palatability were included. For each criterion, farmers' opinions on individual grass species were recorded in an evaluation form using a Likert scale of 1 to 4 where, 1 =poor, 2=fair, 3=good and 4=very good (Krueger, 2002).

Statistical analysis

The data collected for perennial grasses on plant attributes were analyzed using the General Linear Model (GLM) procedure of SAS 9.1 (SAS Institute, 2003). Where a significant effect of treatments was found, the Least Significant Difference (LSD) test was employed to separate means at $P \leq 0.05$. The data collected on perennial tree forage legume attributes were analyzed using paired T-test procedure of SAS 9.1 (SAS Institute, 2003) for equality of variance, while, descriptive statistics were employed for preference ranking using mean scores.

RESULTS AND DISCUSSION

Yield and yield-related performance

Perennial tree legume species survival rate

The mean value of growth traits and phenology parameters of perennial grasses and forage tree legumes are shown (Table 1 and 2). Data regarding plant survival rate at the first harvest stage was presented in Table 2. The results from this study revealed that a significant ($P < 0.01$) difference was observed among the perennial fodder tree species. Sesbania sesban (DZF- 405) performed best survival (92.33%) compared with Cajanus cajan (ILRI-11566) (69.33%) indicating Sesbania sesban (DZF- 405) was more adaptable to the midland agroecologies of the watershed. The observed highest survival rate in species Sesbania sesban (DZF- 405) could be attributed to the genetic difference that caused a difference in suitability of the environment for the specific species. This result lined with the result obtained in one year of plant survival of a grand mean of 94.02% in Sesbania sesban accessions tested as reported by Negasu and Gizahu, (2019). Orwa et al. (2009) obtained a relatively lower survival rate (56.09- 83.24%) from Sesbania accessions at the first harvest. The reason might be associated with differences in the genetic makeup, environmental conditions (soil type and fertility, temperature, and altitude), and management practices applied to the plant.

Plant height (cm)

The result of plant height as affected by perennial grass forage species is shown in Table 1. Plant height significantly differed ($P < 0.05$) for different perennial grass specie at forage harvest. The highest mean value of plant height was measured from Napier grass (ILRI-16791) (181.78cm), followed by Desho grass (Areka DZF# 590) (119.89cm) with the least (49.33cm) from Brachiaria grass (Brachiaria mutica). These results are higher than the result reported by Bimrew et al. (2017) (39.4 cm) when Brachiaria grass was planted under irrigation conditions in Northern Ethiopia and harvested at 90 days intervals. The plant height recorded for Napier grass in this experiment was lower than the value (2.78m) reported by Aman and Diribi (2021) for Napier grass under supplementary irrigation at Wondo Genet. This variation could be due to the difference in evaluated genotypes and environmental conditions of the study areas. However, the mean plant height of Napier grass (ILRI- 16791) obtained in this study was higher than the value reported by Gezahagn et al. (2016) for the same accession evaluated under rain-fed conditions. This result might be due to the advantage of supplementary irrigation and differences among the experimental years in temperature and variation in both amount and distribution of annual rainfall. Plant height recorded by Desho grass (Areka DZF# 590) was higher than a result reported by Birmaduma et al. (2019) for adaptation work done on different desho.

Regarding plant height for perennial tree legume species, the combined analysis result showed that there was no statistically significant (P> 0.05) difference observed between the perennial legume forage species in plant height at harvest (Table 2). The mean plant height of perennial legume forages was 133.98 cm which was in conformity with the results of Negasu and Gizahu (2019) who reported plant height that ranges from 124.26 to 142.01 cm for the Sesbania accessions tested.

Number of tillers per plant

Number of tillers per plant for perennial grasses showed a significant (P <0.05) difference among evaluated species (Table 1). The highest mean number of tillers per plant was observed by Brachiaria grass (Brachiaria mutica) followed by Desho grass (Areka DZF# 590) that ranges from 39.77 to 43.55, while the smallest (16) NTPP was obtained from Napier grass (ILRI- 16791). The variations could be because as a result of genetic variation as the plant leaf width becomes wider and longer in the case of Napier grass, it is attributed to high competition for light between plants which resulted in better plant growth which ultimately limits the number of tillers per plant. The mean number of tillers per plant was in disagreement with the previous results of Mustaring et al. (2014) who reported the ranges from 64.74 to 98.91 for the Desho (Areka DZF# 590) and Brachiaria grass (Brachiaria mutica), respectively. Wondimagegn et al. (2021) also reported several tillers per plant from 83 to 106 from Desho grass (Areka DZF# 590) and Brachiaria grass (Brachiaria mutica), respectively.

Number of branches per plant for perennial tree legumes

Number of branches per plant for perennial legume forages is shown in Table 1. Significantly (P <0.01) more branches per plant (21.90) were recorded for Sesbania sesban (DZF- 405) compared with (12.78) for Cajanus cajan (ILRI-11566) which is contributed by differences in the genetic makeup of the species. This has been confirmed by the report of Negasu and Gizahu (2019), who observed great differences among perennial legume forage species. The mean number of branches per plant was in disagreement with the previous results of Denbela et al. (2020b) who reported the ranges from 26 to 79 for the Cajanus cajan variety DZ-00420 and DZ-16555, respectively. Variations in the number of branches per plant could be attributed to differences in the level of soil fertility, climatic zones, seasons, agronomic practices adopted, and differences in cultivars used in different study areas.

Table 1. Mean biomass yield and yield components of perennial grasses tested at Fernji-Wuha watershed in 2020 and 2021 growing seasons

Treatment	PH	NTPP	GBMY (t ha^{-1})	DMP	DMY (t ha^{-1})	LTSR
Napier grass (ILRI- 16791)	181.78^{a}	16.00^{b}	84.66^{a}	31.73	24.78^{a}	1.01^{c}
Desho grass (Areka DZF# 590)	119.89^{b}	39.77^{a}	64.73^{a}	29.33	19.50^{b}	1.27^{b}
Brachiaria grass (*Brachiaria*	49.33^{c}	43.55^{a}	10.80^{b}	22.40	2.36^{c}	1.62^{a}
Mean	117.00	33.11	53.40	27.8	16.88	1.29
CV (%)	19.44	16.34	14.48	24.32	11.60	8.59
LSD (0.05)	44.31	6.96	44.29	ns	14.89	0.14

*a,b,c= means within column having different superscript letters are significantly different at (P>0.05); CV= coefficient of variation; DMP= dry matter percentage; DMY= dry matter yield; GBMY= green biomass yield; LSD= least significant difference; NTPP= number of tillers per plant; PH= plant height

Green biomass yield (t ha^{-1})

The combined analysis results for different harvests for perennial grasses show a significant (P <0.05) difference among them for green fodder yield (Table 1). Napier grass (ILRI-16791) ranked top in average green biomass yield by producing 84.66t ha^{-1} followed by Desho (Areka DZF# 590) (64.73t ha^{-1}) and Brachiaria grass (Brachiaria mutica) (10.80t ha^{-1}). The differences in fresh forage yield among perennial grasses could be attributed to the performance and potential of different cultivars grown in the same condition. Compared with the current finding, higher result (47.22 to 96.18t ha^{-1}) for different Brachiaria grass cultivars was reported (Mustaring et al., 2014).

The combined analysis (at 9 month) done for the perennial tree legume species indicated a significant (P <0.01) difference for green fodder yield (Table 2). Sesbania sesban (DZF- 405) ranked top in average green biomass yield (24.33 t ha^{-1}). On the other hand, relatively the lowest green fodder yield (11.99 t ha^{-1}) was obtained from the species Cajanus cajan (ILRI-11566). Negasu and Gizahu (2019) recorded that, there was a considerable variation in the performance of cultivars for green forage yield, and this variation was due to varietal potential. Compared to the current results a relatively higher fresh fodder yield (22.06 to 36.18 t ha^{-1}) for different pigeon pea species was reported (Denbela et al., 2020b); and lower yield for Sesbania species (24.33 t ha^{-1}) was reported (Denbela, 2022).

Dry matter content

The combined analysis indicated a non-significant (P> 0.05) difference among the perennial grass species in dry matter content (Table 1). The mean dry matter percentage of perennial grasses was 27.8% which conformed with the results of Wubetie et al. (2019) who reported a dry matter percentage that ranges from 25.06 to 30.02 % for Brachiaria cultivars. Among the tested perennial browse tree species, Cajanus cajan (ILRI-11566) recorded a significant (P <0.05) dry matter percentage than Sesbania sesban (DZF- 405) (Table 2). This could be due to the differences in the amount of water in their meristematic tissue. The mean value for the dry matter content was 31.78%, which is lower than the Sesbania species reported by Denbela (2022). Variations in the dry matter percent could be attributed to the varietal difference and also agro ecological and edaphic divergence with study areas.

Dry biomass yield (t ha^{-1})

The result of the combined analysis showed that forage dry matter yield was significantly (P <0.05) affected by species (Table 1). Napier grass (ILRI- 16791) had better (P <0.05) dry matter yield than the other grass species. Desho grass (Areka DZF# 590) has a better dry matter yield (P <0.05) than Brachiaria grass (Brachiaria mutica). These results are in line with those of Mustaring et al. (2014) who reported the dry matter yield of Napier grass from 10.52 to 34.01t ha^{-1} under rain-fed conditions, and lower result (10.51 t ha^{-1}) was reported for Napier grass (Gezahagn et al., 2016) under rainy season and (17.36 t ha^{-1}) (Aman and Diribi, 2021) under supplementary irrigation.

The results of the analysis of variance indicated that Sesbania sesban (DZF- 405) produced significantly (P <0.05) higher dry matter yield (7.46 t ha^{-1}) than Cajanus cajan (ILRI-11566)

(Table 2). The variation in dry matter yield might be due to the differences in yield-related components like plant height, number of branches per plant, and differences in green biomass yield within the forage species. Megerssa and Feyisa (2016) and Negasu and Gizaw (2019) reported different forage biomass production due to variations in the genetic potential of the forage species. These results are in line with those of Wubshet et al. (2021) who reported the dry matter yield of Sesbania sesban (7.79 t ha^{-1}); and was in contrary to the report by Denbela (2022) who reported 17.66 t ha^{-1} dry matter yield for Sesbania sesban (DZ-32) under irrigation.

Leaf-to-stem ratio

As indicated in Table 1, leaf to steam ratio (LSR) was significantly (P <0.05) influenced by different perennial grass species and Brachiaria grass (Brachiaria mutica) had recorded to have a significantly (P <0.05) higher LSR than others which is attributed to difference between the nature of the plants. The mean LSR of the current study was contrary to the previous results of Ramírez de la Ribera et al., (2008) for Brachiaria decumbens and Desho grass (Areka DZF# 590) that are tested in Cuba. This could be due to the cultivar differences used and other edaphic and environmental differences within the study areas. There was no significant (P> 0.05) variation in leaf to steam ratio (LSR) among the perennial fodder tree species (Table 2). The mean leaf-to-steam ratio was 1.12 which was in disagreement with the results of Denbela (2022) who reported 1.27 for Sesbania sesban (DZ-2002).

Table 2. Mean performance of perennial browse tree species integrated and tested under soil and water conservation structures at Fernji- Wuha watershed

Variables	Browse tree species tested		SD	Prob.
	Sesbania sesban	Cajanus cajan		
Number of samples taken	30	30		
Survival rate (%)	92.33	69.33	6.44	0.0012
Plant height (cm)	139.61	128.34	13.84	0.2136
Number of branches	21.90	12.78	2.86	0.0053
Fresh biomass yield (t ha^{-1})	24.33	11.99	2.20	0.0054
Dry matter percent (%)	30.67	32.88	2.29	0.0153
Dry biomass yield (t ha^{-1})	7.46	3.94	0.54	0.0039
Leaf to stem ratio (ratio)	1.13	1.11	0.28	0.9188

SD= standard deviation; Prob. = probability.

Farmers' selection criteria for perennial grasses

Results from participatory selection criteria identification showed that farmers largely desired forages that give high biomass yield, high re-growth after cutting, highly palatable, easy to establish and early maturing as an important criterion (Table 3). Other attributes were leafy, drought tolerant, better growth, contributing to better milk yield, and essentiality for soil erosion control. Farmers prioritized preferences based on multiple benefits to meet their needs and are tolerant to biotic and abiotic stresses as highlighted by Kidake et al. (2016). Identification of these preferences by farmers at the evaluation stage is essential for the wider adoption of perennial grasses.

Table 3. Pairwise ranking matrix of farmers' selection criteria for the perennial grasses species evaluated at Fernji- Wuha watershed

Key attributes	HBY	ETE	P	DT	HRG	L	HH	EM	MY	SEC	Total Score	Rank
HBY		HBY	P	HBY	HBY	HBY	HBY	HBY	HBY	HBY	8	1
ETE			ETE	ETE	HRG	ETE	ETE	EM	ETE	ETE	5	4
P				P	P	P	P	EM	P	P	6	3
DT					HRG	L	HH	DT	DT	DT	4	7
HRG						HRG	HRG	HRG	HRG	HRG	7	2
L							L	L	MY	L	4	6
HH								EM	HH	HH	3	8
EM									EM	EM	5	5
MY										MY	2	9
SEC											0	10

DT= drought tolerance; EM= Early maturity; ETE= Easy to establish; HH= Height at harvest; HBY= High biomass yield; HRG= High re-growth after cutting; L= Leafiness; MY= Milk yield; P= Palatability; SEC= Soil erosion control.

Farmers' selection criteria to browse legume forage species

Results from participatory selection criteria identification showed that farmers largely desired forages that give high biomass yield, highly palatable, drought tolerant, branching ability, leafier, and high re-growth after cutting (Table 4). Other attributes were easy to establish; pest resistance; contributing to better milk yield and essentiality for soil erosion control. Identification of these preferences by farmers at the evaluation stage is essential for the wider adoption of perennial fodder tree species; which is also confirmed by Tewodros and Meseret (2013).

Table 4. Pairwise ranking matrix of farmers' selection criteria for the browse tree legume species evaluated at Fernji- Wuha watershed

Key attributes	HBY	ETE	P	DT	HRG	L	BA	PR	MY	SEC	Total Score	Rank
HBY		HBY	HBY	HBY	HBY	HBY	HBY	HBY	HBY	SEC	8	1
ETE			ETE	DT	HRG	L	BA	ETE	ETE	ETE	4	7
P				P	P	P	P	P	P	P	7	2
DT					DT	DT	BA	DT	DT	DT	6	4
HRG						HRG	BA	HRG	HRG	HRG	5	6
L							L	L	L	L	5	5
BA								BA	BA	BA	6	3
PR									PR	PR	2	8
MY										MY	1	10
SEC											1	9

HBY= High biomass yield; ETE= Easy to establish; P= Palatability; DT= drought tolerance; HRG= High re-growth after cutting; L= Leafiness; BA= branching ability; PR= pest resistance; MY= Milk yield; SEC= Soil erosion control.

Farmers' preference for perennial grasses

The pairwise result below also indicated that Napier grass (ILRI- 16791) is ranked first followed by Desho grass (Areka DZF# 590) (Table 5). Napier grass was found extremely superior to the other introduced perennial grass species in terms of different farmers' criteria. Discussions with farmers showed that Napier was highly valuable in producing forage biomass besides soil bund stabilization and was also reported as it is not invasive and can be managed easily. Dinku and Nedessa (2012) reported that in addition to soil and water conservation benefits, Napier and Desho grasses have superior value in promoting livestock productivity and improving the livelihood of the beneficiaries. This implies that improving the productivity of conservation structures using multi-purpose grasses can provide opportunities for enhancing the adoption of the technologies.

Farmers' preference to perennial tree legume forages

The pairwise result indicated that the fodder tree Sesbania sesban (DZF-405) is ranked first followed by Cajanus cajan (ILRI-11566) (Table 6). Discussions with farmers showed that the fodder tree Sesbania sesban (DZF-405) was highly valuable in producing forage biomass besides soil bund stabilization. According to their response, they select the plant based on all their pre-settled criteria's. Denbela et al. (2015) reported that in addition to other benefits, Sesbania sesban (DZF-405) had superior potential in promoting livestock productivity. This implies that improving the productivity of conservation structures using multi-purpose perennial fodder tree species can provide opportunities for enhancing the adoption of the technologies.

Table 5. Farmers' scores for the perennial grasses species evaluated at Fernji- Wuha watershed

Perennial grasses Species used	HBY	ETE	P	DT	HRG	L	HAH	EM	Mean score	Rank
Napier grass (ILRI- 16791)	3.04	2.88	3.08	3.36	3.17	3.30	3.09	2.94	3.11	1
Desho grass (Areka DZF# 590)	3.18	2.90	3.17	3.18	2.09	3.45	2.77	2.72	2.94	2
Brachiaria grass (Brachiaria mutica)	2.33	2.81	1.23	1.69	1.93	2.46	2.43	1.97	2.11	3
Mean	2.85	2.86	2.49	2.74	2.41	3.07	2.76	2.54		

DT= drought tolerant; EM= early maturity, ETE= easy to establish, HAH= height at harvest, HBY= high biomass yield, HRG= high re-growth, L= leafiness, P= palatability.

Table 6. Farmers' scores for the perennial browse tree legume species integrated and evaluated under soil and water conservation structures at Fernji- Wuha watershed

Browse tree species used	High biomass yield	Palatability	Drought tolerance	High re-growth	Leafiness	Branching ability	Mean scores	Rank
Sesbania sesban	3.58	2.76	2.95	3.09	2.30	2.72	2.90	1
Cajanus cajan	3.24	3.02	1.67	2.13	3.45	3.12	2.77	2
Mean	3.41	2.89	2.31	2.61	2.875	2.92	2.83	

CONCLUSION AND RECOMMENDATIONS

The higher biomass yield was obtained from Napier grass (ILRI- 16791) followed by Desho grass (Areka DZF# 590). From the perennial tree legume forages, higher biomass yield was harvested from Sesbania sesban (DZF-405). Recognizing farmers' expectations and being responsive to their preferences for new technology or improved perennial grasses and perennial tree legume forages is central to its successful promotion and acceptance in the farming community. Using farmer's own identified criteria farmers select Napier grass (ILRI-16791) as the most preferred perennial grass followed by Desho grass (Areka DZF# 590) when integrated with the soil bund structures. Based on the set criterion for perennial trees species, farmers also selected Sesbania sesban (DZF-405) as the most promising fodder tree and this was also supported by the biological data. From this study result, we recommend for targeted promotion of these productive and most farmer-preferred Napier grass (ILRI- 16791) as the first and Desho grass (Areka DZF# 590) as the second alternative for successful uptake where as Sesbania sesban (DZF-405) as superior forage plant to adapt in tested watershed than other species. Integrating these forage species with the existing soil and water conservation effort should be up-scaled at wider. In addition, further study should be done on the performance of animals fed with these grass species to reach firm recommendations.

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Pre-Scaling up of Koekoek Chicken under Farmers Management in Burie District, Western Amhara, Ethiopia

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ABSTRACT

The study was conducted with objectives of promoting, disseminating and creating wider demand on Koekoek chicken and to assess farmer's perception on the breed in Burie district of the Amhara region. Twenty five unsexed, 45 day old chickens were provided to the 27 participant farmers. Participants have gained different skills and experience, mainly feed preparation from locally available ingredients, construction of chicken houses from locally available materials and they were aware about the management of chicken and importance of record keeping though one day training and continuous door-to-door monitoring. The average body weights of chicken were 1292.8 g and 1576.8 for females and males at 20 week and 1684.9 g and 2217.4 g for females and males at 45week of age, respectively. The average age at first egg-lay was 22 weeks and egg production was 180/hen/year. The participants said that adaptability, growth performance and scavenging ability of koekoek were good; however, the diseases resistance ability and market preference due to its black plumage color was lower. The participants earned an average profit of 2797birr/head. Therefore, to exploit Koekoek's adaptability, scavenging ability and good egg production in semi scavenging system scaling up and introduction of Koekoek chicken to the rural area should be done. However, further extensions works should be done to develop awareness on the taste and quality of Koekoek chicken meat to alleviate the market problems due to its black plumage color.

Keyword: *Bure district, Koekoek, Pre scaling up*

INTRODUCTION

In sub-Saharan Africa, the majority of the rural population (85%) keeps chicken; and contributes as source of affordable animal protein and household cash income (Van Der Zijpp et al., 2007). In Ethiopia, the poultry sector is among the ones that have due attention for food security and poverty alleviation. Chicken production is an important and integral part of most households in rural, urban and peri-urban areas like other developing countries (Habte et al, 2017). The backyard small-scale chicken production is characterized by low input-output scavenging, with minimal investment in housing, feeding and health care, and hence weak biosecurity, high offtake rates and high mortality rates (Gezahegn and Karl, 2010).

The chicken population in Ethiopia is estimated at about 57 million on which 78.9%, 12%, and 9.1% were reported to be indigenous, hybrid and exotic, respectively (CSA, 2021). Although there is huge chicken population their production potential is limited. This low production performance of indigenous chickens has led to introduction of exotic breeds. For the last several decades different exotic breeds have been imported to the country, to improve the production and productivity of chicken and raise its socio economic contribution. The Ministry of Agriculture and Rural Development of Ethiopia has introduced, multiplied and disseminated several exotic chicken breeds to the farmers over the last 50 years (Solomon, 2008). Among these breeds, Koekoek is one of the well-known breeds for its convenience to scavenging ability which is typical feature of the rural production system.

Koekoek has some specific characteristics like; free ranging, dual-purpose breed adaptable to smallholder production systems, lays brown shelled eggs (196 eggs/bird/year) withan average weight of 55.7g, has sex-specific feather color and pattern with a possible application in breeding programs, reaches early sexual maturity (130 days) and reaches an average weight of 3-4kg for males and 2.1kg for females (Taddele and Fassil, 2016). Koekoek breed was studied very well in Ethiopia and showed different performance at different agro-ecologies. The demonstration and evaluation conducted in eastern and southern Tigray showed that this breed could lay up to 210 eggs per hen per year (Shumuye et al., 2018). Similarly, the study conducted in Lume district of East showa zone by Dessalew et al. (2012) reported 187 egg/hen/year under farmer’s management. Whereas similar study in Dale and Shebedino woreda of Sidama revealed that this breed laid 109 eggs per hen per year (Tekalign et al., 2019). Thus, this breed is well adapted and convenient under farmer’s management around different parts of Ethiopia in general and Amhara region in particular. Though, the objective of this study was to promote and disseminate Koekoek chicken in Burie district of western Amhara Region, to create wider demand on the breed and to comprehend the farmers’ perception to the breed.

MATERIAL AND METHODS

Description of the Area

The study was conducted in Burie Zuria district of West Gojam zone, Amhara region. Burie district is located 165 km away from Bahirdar, the capital of the region. The district covers 587.95 square km and has 19 rural and one urban kebeles. Rainfall ranges from 1500 to 2000 mm per annum and 13.3% of the district is Kola, 66% is Woina Dega, and 20.7% of the area is Dega. Denbon and Wohine durbete kebeles were the study kebeles among these 19 rural kebeles

Study area and participant Selection

The study area was selected purposively by accessibility to inputs such as cereal grain for supplementation and convenience to market for chicken products. Convenience to market mainly related with linkage with Burie agro-processing industry as the industry required huge amount of chicken eggs. Participant farmers were selected in collaboration with district livestock production and veterinary expertise based on their willingness to participate and ability to construct chicken house and ability to cover the feed cost and willingness to collect data and a total of 27 households were selected and technical support in house construction, feed preparation, management of chicken and data collection was provided by researchers.

Chicken Management

A total of 675 unsexed 45 day old Koekoek chicks, 25 chicks for each participant were distributed. The chicks were hatched and reared up to 45days at Andasa Livestock Research Center by fulfilling adequate requirements. Drinkers and feeders were prepared by the participant farmers with locally available materials.

Disease Prevention and Control

Scheduled vaccination against common poultry diseases was provided by veterinarians and during some disease occurrence treatments were administered. Birds were vaccinated against poultry diseases such as Marek’s at day one, New castle/HB1 at day three, and Gumboro at day fourteen and twenty-one, Newcastle/Lasota at 28, 63 and 112 days and fowl typhoid at 45 days of age. The vaccines were purchased from National veterinary institute and brought by ice box and handled as per the recommendation.

Housing and Feeding

Each participant built chicken house with 3*4 meter dimension. The house was built with locally available materials like wooden material and mud. The house was bedded with dry wheat straw with 5-8 cm thickness. The house with bedding material was disinfected with 37-40% formalin. Communal laying nest and perches were constructed in the house to spend overnight. Since farmers practiced a semi-intensive production system, the house had run an area which was built adjacent to each house. In addition to scavenging in the backyard the chicken were offered supplementary feed two times a day, in the morning and afternoon. From day one of delivery to two months, participants bought the rearing feed from Admas farmers union at Injibara town for their chicken. The feed has nutritional composition of 2750 k/cal of metabolizable energy and 16% crude protein. After two months the participants started to prepare feed by their own by using locally available ingredients with maize and wheat and by purchasing ingredients like Noug seed cake, wheat bran and salt from Burie district market.

Data Collection and Analysis

The required data were collected by hired enumerators and monthly follow up by the researchers with data recording sheet. The farmer's perception was collectedby using an interview with participant farmers. Biological data's like age at first lay (when 5% of the total hens started laying), egg production, egg weight at 5%, 50% and peak lay, body weight at 5th and 11th month, mortality, cost of feed and medicament, income from sale of cock, hen, eggs and home consumption. The collected data was analyzed by simple descriptive statistics using MS-Excel. Likert scale with the scale of Very Poor, Poor, Neither, Good and Very good was employed to assess the perception of participants. To estimate the economic benefit of the study cost benefit ratio was employed. The change in net income (ΔNI) was calculated as the difference between the changes in total return (ΔTR) and the change in total variable costs (TVC). Out of 27 selected participants from only 22 participants was data collected and analyzed, the rest 5 participant's drop out due to loss of birds by selling and predator.

RESULT AND DISCUSSION

Average Body Weight

The average body weight of chicken at 20 week was 1.29 and 1.57 kg for females and males, respectively (Table 1). This result is higher than the reported by Tekalign (2019) as 1.23 and 1.43kg for females and males under farmer's management, respectively and Aman et al.

(2016) who reported 1.5kg for males and 1.1kg for females under farmer's management with semi scavenging system. Kasa and Saba (2016) also reported 1.34 and 1.03kg for males and females Koekoek breed, respectively, which is lower than the result of this study. The average body weight of chicken at 45 week was 1.68 and 2.2kg for females and males, respectively. Tekalign (2019) found that the yearling body weight of Koekoek chicken was 1.6 and 2.5 kg, for females and males, respectively. The female body weight is almost similar but the male body weight was slightly higher than that recorded in this study. The difference in body weight might be due to the presence of management differences in different study areas.

Table 4. Average body weight of Koekoek chicken at different age across participants

Participants	20 week BW(g/bird)		45 week BW(g/bird)	
	Female	**Male**	**Female**	**Male**
1	991	1162	1575	2639
2	1166	1358	1768	2082
3	1143	1364	1659	2749
4	1090	1629	1919	2248
5	1607	2228	1651	2763
6	1114	1477	1829	1905
7	1470	1393	1567	1649
8	1278	1376	1622	2484
9	1359	1368	1518	2039
10	1189	1833	1659	2235
11	1147	1769	1439	1985
12	1361	1422	1889	2369
13	1376	1455	1689	2125
14	1434	1983	1240	1902
15	1211	1653	1923	2203
16	1367	1702	1796	2045
17	1411	1819	1756	1985
18	1313	1734	1527	2125
19	1414	1596	1721	2367
20	1257	1489	1897	2203
21	1442	1582	1849	2216
22	1396	1953	1576	2465
Average	**1292.8**	**1576.8**	**1684.9**	**2217.4**

Egg production

The average number of eggs produced was 180per hen per year (Table 2). Tekilemariam (2020) reported similar result (176 eggs/hen/year) for the Koekoek chicken under farmer's condition with semi scavenging management. Similarly, the study conducted in East Showa zone, Lume district under farmer's management condition by Desalew et al. (2013) reported 187 eggs per hen per year. On the contrary, Tekalign et al. (2018) reported 109 eggs per hen per year for the same breed under farmer's management condition. The differences in egg production might be due to the differences in management like feeding and housing.

Table 5. Average egg production/hen /year

Participants	Egg production/year	Participants…	Egg production/year
1	178	13	184
2	179	14	184
3	183	15	179
4	169	16	181
5	179	17	179
6	186	18	171
7	187	19	179
8	185	20	183
9	173	21	183
10	177	22	188
11	180		
12	176	**Average**	**180**

Age at first lay and Egg weight

The results revealed that the average age at first lay was 154 days (22 week) (Table 3). This result was higher than the value reported by Aman et al. (2016) in the southern part of Ethiopia which was 142 days of age at first egg laying. A similar study in Ada'a and Lume districts by Desalew et al. (2012) reported age at first laying of Koekoek chicken was 153.3±6 days under farmer's management condition.The differences in average age of first lay were not substantial. The average egg weight of the current study was 40.1 ±1.2g, 44.3 ±2.06g and 47.5 ±2.97g at 5%, 50% and peak laying stages, respectively (Table 3). Tekalign et al. (2019) reported average egg weight for Koekoek chicken at 5%, 50% and peak production to be 43.81g, 47.42g and 51.49g, respectively. Kasa and Saba (2016) also found similar results, with average egg weight at 5%, 50% and peak production of 41.72, 44.65 and 47.9g at farmer's management condition. There are reports indicating egg weight at first lay of 40.2g (Aman et al., 2016), 48.8g (Desalew et al., 2012) in different parts of Ethiopia. The difference in egg weight may be due to the type and quality of feed provided to chicken; since feed is an important factor determining the quality and size of eggs.

Table 6. Average age at first lay and average egg weight at different age of Koekoek chicken

Participants	Age at first lay (weeks)	Egg wt at 5%	Egg wt at 50 %	Egg wt at peak laying
1	24	39	44	53
2	23	40	42	52
3	21	41	43	48
4	24	39	40	46
5	19	40	42	45
6	20	41	45	46
7	21	40	44	45
8	22	39	46	46
9	23	41	43	45
10	22	42	45	47
11	21	38	46	49
12	24	39	45	54
13	20	41	47	47
14	20	40	47	51
15	24	38	41	42
16	25	40	42	46
17	23	39	45	46
18	21	41	44	48
19	22	40	46	46
20	20	41	47	48
21	25	42	44	45
22	20	41	47	50
Average	**22**	**40.1 ±1.2**	**44.3±2.06**	**47.5±2.97**

Mortality Rate

The average mortality of chickens, from the total 25 chicken provided to each participant, was 16.23% (Table 4). Out of this 10.9% was during the 20 weeks of age and the remaining 5.33% was after 20 weeks to the end of the experiment. Loss of birds happened because of two reasons that were disease 10% (though it was not confirmed by laboratory), predator and unknown reasons accounted for 6.23% of the mortality. This shows that the majority of the loss of bird's occurred during the early age of the chicken. The level of mortality recorded in this study could be considered as favorable compared to the various reports from around the country on the same breed under farmers' management conditions. The figures were generally variable across the country; 10.9% and 8.6% (Mulualem and Mezgeb, 2021), 35.9% (Kasa and Saba, 2016), 20.2% (Aman et al., 2016) and 34.7% (Shumuye et al., 2018). The reason for good survival rate on this study may be the good management of participant households and provision of scheduled vaccination against common poultry diseases.

Table 7. Mortality rate of Koekoek chicken per household at Burie district

Participants	Mortality up to 20 weeks (%)	Mortality after 20 weeks (%)
1	4	2
2	3	0
3	3	1
4	5	4
5	7	0
6	2	2
7	1	0
8	2	1
9	4	3
10	0	2
11	3	3
12	2	1
13	3	0
14	6	2
15	5	3
16	3	0
17	5	4
18	2	4
19	1	1
20	1	1
21	2	1
22	1	0
Overall	**74 (10.9%)**	**36 (5.33%)**

Perception of Participants

Participant farmers have different perception regarding the performance of Koekkoek chicken. Based on different criteria's participant farmer's perception for koekoek in comparison with the different exotic breeds which were introduced previously was summarized in Table 5. Criteria used for comparison were adaptability, scavenging ability, disease resistance, egg production, growth performance and market preference. Out of 22 participants 93.75% of the participants said that Koekoek chicken was good in adaptability, whereas 6.25% responded that they had poor adaptability to the environment and the management system. Similarly, most of the participants agreed that the Koekoek showed good scavenging ability, egg production and growth performance with respective percentage of 93.75%, 62.75% and 68.25%. On the other hand, disease resistance and market preference were moderate, 56% and 57.25%, respectively. Koekoek's relatively moderate market preference was because of its black plumage color, that red and white are the predominant color preferred by farmers.

Table 8. Perception of participants on koekoek chicken compared to other exotic breeds

Criteria	Very Poor	Poor	Neither	Good	Very good
Adaptability		6.25		50	43.75
Scavenging		6.25		43.75	50
Disease resistance		56.25		31.25	6.25
Egg production	6.25	31.25		50	12.5
Growth performance		37.5		50	18.75
Market preference	18	39.25		43.75	

Technology Dissemination

The participants were trained and technically supported on chicken management and data recording. They have benefited by different means, like as a source of income by selling egg and cocks and by hatching their egg using local hens. Twelve participants have hatched 131 chicks using local hens and 15 non participant farmers purchased 165 eggs for incubation. Since there were cocks more than the sex ratio they sold extra cocks to their neighbors and local market. This enabled non-participants to have access to improved genetics. Participants have acquired knowledge and skill of feed preparation mainly with locally available ingredients. Participants acquired skills on building poultry house including laying nest. They were aware about the whole management of chicken and the importance of record keeping.

Cost benefit analysis

Koekoek chicken contributed to smallholder farmers for food security as protein source and income source from selling of egg, hen and cocks. Since it has good characters like good scavenging and hatchable eggs it is among the preferable chicken breeds by farmers. Keeping chickens, however, entails important costs like house construction, feed and medication. In calculating the partial budget analysis the feed, medication, chicken shelter construction or maintenance were considered as variable costs whereas the sale of live chicken, eggs and the existing chicken till the time of this data collected were used as an income source. Based on this the average income of a participant was 4769 birr while the average variable cost was 1972 birr (Table 6).

$\Delta NI = \Delta\,(TR - TVC)$
$\Delta NI = 104925 - 43405$
$\Delta NI = 61570$

61570/22= 2797

The average profit earned by a participant was 2797 Birr. There are other higher or lower profit margins reported elsewhere from eggs produced using Koekoek chickens. For example, Kasa and Saba (2016) reported an average profit of 2731.02 Birr, whereas Aman et al. (2016) reported a profit margin of 1048.90 Birr per participant farmers.

Table 9. Cost benefit analysis

Participant	Sale of cock	Sale of hen	Sale of egg	slaughtered	Consumed egg	Total income	House	Media	Feed	Total expense	Benefit
1	800	600	1400	400	200	3400	150		800	950	2450
2	1600		800		800	3200	1000		700	1700	1500
3	1400		1000	1400	1000	4800		40	600	640	4160
4	1000	1400	1000	1000	800	5200	1800	50	200	2050	3150
5	2250	1400	2250	800	250	6950	2500		850	3350	3600
6	1600	1980	1750	800	2000	8130	1800		1000	2800	5330
7	1200		2600	800	1000	5600	1500		900	2400	3200
8	1400	1350	400	600	600	4350	2600		800	3400	950
9	2250	840	2000	250	250	5590	2000	50	800	2850	2740
10	2400	600	1760	200	300	5260	2000		550	2550	2710
11	1920		280	200	1200	3600	200		600	800	2800
12	2500	1000	1500	200	250	5450	2000		800	2800	2650
13	1045	600	2800		600	5045		65	950	1015	4030
14	1800	1000	600	360	200	3960	1000		300	1300	2660
15	950	760	1200		40	2950	950	50	500	1550	1450
16	1520	600	1900	180	200	3800	1440		950	2390	1410
17	1250	700	780	650	250	3630	900		850	1750	1880
18	2200	800	1540	400	550	5490	1250		1150	2400	3090
19	1800	1400	800	500	250	4750	850		950	1800	2950
20	1600	1000	1050	40	450	4500	1100	60	1250	1410	3090
21	2000	800	1450	600	460	5310	750	50	1100	1900	3410
22	1800	600	650	400	410	3960	650		950	1600	2360
						104925				**43405**	**61570**

CONCLUSION AND RECOMMENDATION

The participant farmers have benefited from selling of egg and chicken. Koekoek was well adapted and good scavenger to the farmer'smanagement condition. Moreover, the participant farmers obtained important skills on improved chicken management. Wider demands were created for Koekoek chicken in the study area. In conclusion, it is necessary to exploit

Koekoek's adaptability, scavenging ability and good egg production by introducing the breed to the rural community and scaling up the best practices and lessons obtained in the current study. However, to alleviate market problems relating to its plumage color further extension efforts should be made on the farmers' awareness.

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Diagnostic Survey of Honeybee Diseases and Pests in Western Amhara, Ethiopia

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ABSTRACTS

The diagnostic survey of honeybee diseases and pests wasdesigned to identify the types, prevalence, and potential risk factors associated with honeybee diseases and pests. Different methodologies, including survey and laboratory analysis were applied, and has addressed 3 zones, namely East Gojjam, Awi and South Gondar, ninedistricts, 27 localities, 103 beekeeper respondents, 90 apiary sites, and 409 honeybee colonies were examined for the presence of honeybee pests, external parasites, and diseases. The collected data werecoded and stored using Microsoft Excel spreadsheets and analyzed using descriptive statistics, frequency, rank index formula, and chi-square (x^2) tests with the Statistical Package for the Social Sciences (SPSS) version 16. According to the diagnostic survey results, pests and predators (24.47%) were the main challenges to the beekeeping industry in the study areas. Regarding honeybee pests and predators, the rank index confirmed that the most important pests and predators affecting honeybee colonies identified were ants (24.15%), spiders (19.08%), bee-eater birds (18.1%), wax moth (15.44%), varroa (6.88%), death's head hawk moth (3.88%), small hive beetle (2.26%), honey bager (2.26%), mice (2.02%), bee lice (1.83%), lizards(1.62%), prey mantis(1.35%) and snakes(0.83%) in their decreasing order of economic importance. Different local control methods have also been identified by respondents for each disease, pests and predators.In the laboratory diagnosis results, out of 409 honeybee samples, the overall prevalence of varroa miteon adults, on broods, bee lice, nosemaapis, and amoeba was 61.6%, 51.64%, 16.4%, 14.91%, and 14.91%, respectively, with different risk factors. There was statistically significant ($p<0.05$) variation in the overall prevalence of varroa mite and nosemaapis infestation among agro-ecology, hive type, and seasons ($p<0.01$). However, amoeba disease and bee lice infestations were statistically significant at $P<0.05$ in hive type and study location. Moreover, tracheal mites were not found throughout the study period and no clinical symptoms of bacterial diseases (American Foul Brood and European Foul Brood), fungal (Chalk brood) observed in the study period. In general, it is possible to increase production and productivity by protecting honeybees from

diseases and enemies. Therefore, it is appropriate to strengthen the colonies to have their own (natural) defense against honeybee parasites and pathogens. Awareness should be created for beekeepers to monitor their honeybeecolonies for diseases and pests frequently. Further attention should be given to the study of effective prevention and control methods against the identified honeybee enemies and pests.

Key words: *Amoeba, Honeybee diseases, Nosema, Parasite, Pests, varroa, bee lice*

INTRODUCTION

Apiculture is a promising off-farm business that contributes both directly and indirectly to smallholders' income and the overall economy of the country (Ajabush, 2018). It has an important role in creating and diversifying the income of subsistence smallholder farmers, mostly small land owners and landless people (Gezahegn, 2001). Honeybees pollinate wild flowers, numerous agricultural crops, and horticulture while foraging for nectar and pollen, as well as creating honey and bee wax. Ethiopia has the potential to produce 500,000 tons of honey and 50,000 tons of wax per annum. The recent production is only 129,301 tons of honey and 5300 tons of bees wax (CSA, 2021). Similarly, in Amhara Region, beekeeping is a deep-rooted household activity and an integral part of the life style of the farming communities documented to own more than 1,380,048 honeybee colonies. During the production season the Amhara Region has produced about 18,122 tone of honey (CSA, 2021).

Asone of the subtropical countries, Ethiopia is known for its diverse agro-climatic conditions and biodiversity, favored the existence of a diverse honeybee flora and a large number of honeybee colonies (CSA, 2021). The land is not only favorable to honeybees but also to different kinds of honeybee pests and predators that interact with the lives of honeybees (Desaleng, 2001).

In Ethiopia, several surveys have been conducted on the existence of honey bee diseases such as protozoan (Nosema and Amoeba), fungus (chalk brood), parasitic mite (varroa), insects (small and large hive beetles, wax moth, ants, wasps, Death Head Hawk moth, birds (bee-eater birds), mammals (Honey badger), and reptiles (frogs and toads, snakes) (Amssalu *et al*., 2012; Dessalegn, 2015). The presence of bacterial and viral diseases, which are the most contagious ones, has not been reported in the country so far. The occurrence of the above mentioned diseases and pests and the non-existence of bacterial and viral diseases were reported before eight years. As a rule, monitoring of honeybee diseases and pests must be conducted at least in five years interval unless outbreak has been reported (VanEngelsdorp *et al*., 2013). On the other hand, the loss of honeybee colonies in Ethiopia has increased from time to time and reports are coming from different parts of the country, and specifically in the Amhara region (Addisu and Desalegn, 2021, Alemu *et al*., 2015).

The essential and valuable contributions of honeybees depend upon the healthy population of honeybees (FAO, 2012). The health of honeybees has been one of the most important topics in apiculture research in recent years (Genersch, 2010). Honey bee diseases, pests, and predators are major bottlenecks for the sector and are causing a significant economic loss in honey bees and their products. This is because if it once occurs in the colony, it causes partial or total loss of colonies and most of them spread very quickly and are difficult to treat (Desalegn and Yosef, 2005). Therefore, proper conservation of honeybees in Ethiopia through the implementation of early detection and monitoring of honeybee diseases and pests must be ensured so that colony losses and food safety problems experienced in other parts of the world are not repeated in Ethiopia.

For that reason, generally, it is important to determine the current status of existing, occurrence and prevalence of honeybee diseases, pests and its associated honey bee health risk factors and manage them as early as possible. Therefore, the objectives of this study are

- To determine the occurrence and prevalence of honeybee diseases and pests
- To identify potential risk factors associated with honeybee disease and pests
- To generate base line information for control/prevention strategies of major bee pests and pathogens

MATERIALS AND METHODS

Description of the study area

The diagnostic survey of honeybee diseases and pests was designed to be carried out at a national level, in which AndassaLivestock Research Center takes the responsibility of conducting the study in Western part of the Amhara national regional state. Accordingly, the study was conducted in three zones of Western part of the Amhara regional state (Awi, East Gojam, and South Gonder) using a pre-structured questionnaire to identify the types, distribution, and prevalence of honeybee diseases and pests. A purposive multistage sampling procedure was employed to select zone, district, and sample respondents. In the first stage, three administrative zones were selected using purposive sampling based on their beekeeping potential. In the second stage, three representative districts were selected based on their potential for beekeeping and agro-ecological representativeness (high land, mid-land, and low land). In the third stage, from each district, three rural kebeles were sampled using purposive sampling based on their representativeness and transport accessibility. In the fourth stage, beekeepers and honeybee hives were sampled from all rural kebeles using a simple random sampling technique. Accordingly, 103 experienced beekeepers were interviewed, and a total of 409 honeybee colonies were diagnosed.

Honeybee and brood sampling

In order to examine the prevalence and infestation rates of honeybee diseases and pests, four to sixhoneybee colonies were randomly inspected from each apiary site both externally and internally for the occurrences and infestation of honeybee diseases and pests. Accordingly, a total of 409 honeybee colonies werediagnosed from 1009 visited honeybee colonies. From each sampling localities, adult honeybee and sealed brood samples were taken from sampled honeybee colonies. In the absence of sealed brood, empty old brood combs were taken to see the remnant symptoms of disease attacks. Moreover field observations were carried out on the presence of pests and the necessary records were carried out. The sample size required for the study were determined based on sample size determination in random sampling methods using 50% expected prevalence with 95% confidence interval at 5% absolute precision, according to Thrusfield (2005) as follows:

$$n = \frac{1.96^2 X P_{exp} X(1 - P_{\exp})}{d^2}$$

Where; n = required sample size Pexp= Expected prevalence (50%) d= Desired absolute precision (5 %). Accordingly, a total of 409 diagnosed honeybee colonies were used as sample size for the study.Finally, prevalence for apiary level and infestation/infection for colony level was calculated using (Van Englesdorp *et al*., 2013) protocols.

$$\text{Prevalence} = \frac{\text{Noofpositivecases}}{\text{TotalNoofsampledpopulation}} \text{X100}$$

Laboratory Examination Procedures

Tests for brood diseases, varroa mites, and adult honeybee diseases were taken in the respective districts of the Animal Health Clinic. Interviews and laboratory works were done during the day, and inspection, adult and brood sample collection were conducted during the night for the entire period of the study field trip.

Diagnosis for honeybee Ecto-parasites

Examination for Varroa mite and bee lice

The study followed the standard methods for Varroa detection (Dietemann *et al*., 2013). Samples of adult honeybees were collected from honeybee colonies hived in traditional, transitional and movable frame hives. From each honeybee colony, about 250-300 adult worker honeybees were brushed off from the entrance of the hive, and from the brood comb directly into a wide mouth plastic container.To dislodge mites, 10 ml of 1% detergent-water solution (10 ml detergent in 1000 ml water) was added immediately and vigorously shaked for oneminute. The mites were collected filtering the solution through sieve (8 to 12mm mesh) that hold the worker honeybees back after washing and let out the mites with the solutions. The sieve was turned down to white paper on which the presence/absence of the varroa mite and honeybee lice was examined and counted.

Moreover, brood examinations were done by cutting off 5 X 5 cm^2 brood comb areas from drone and/or worker pupae broods. About 100 pupae were removed from their cells using forceps and checked for the presence of varroa mites on the worker and/ or drone pupae. At the end, number of varroa mites per diagnosis sample was recorded.

Examination for Tracheal mite

For the examination of tracheal mites, samples of 20-30 adult honeybees were collected randomly and examined according to Sammataro *et al*. (2013). The sampled worker honeybees were preserved in 70% alcohol. The head and first pair of legs of honeybees were removed using forceps and scissor. Transverse-section thoracic disks were sliced and placed directly in a small dish containing 10% potassium hydroxide (KOH). The sliced thoracic disks in KOH were heated and stirred gently near to boiling point for approximately 10 minutes until the soft internal tissues dissolved to expose trachea rings. The trachea ring sections were retrieved through filtration and washed with tap water. Then the disk- trachea suspension was examined for infested part and *Acrapiswoodi* under a dissecting microscope at 10 magnification power.

Examination forProtozoal diseases (Nosama and Amoeba)

Examination of Nosema and Amoeba diseases caused by protozoan agent that affects the abdominal contents of adult honeybees, their sampling and diagnostic techniques werealmost the same. Therefore, a sample of 20-30 adult worker honeybees were collected from the hive entrance randomly and examined according to Fries *et al*. (2013) procedure. The sample worker honeybees were preserved in 70% ethanol alcohol until laboratory analyses. The abdomen of honeybees from each sample was cut using scissors. The cut abdomens were placed and grounded in mortar containing 5-10 ml distilled water until an even suspension is formed using pestle. The mortar and pestle were thoroughly cleaned before being used again. A loop of suspension was placed on microscopic slid with cover slips and examined under the light microscope using 40-magnification power for the presence of Nosema spores and Amoeba cyst.

Examination for fungal diseases (Chalk brood)

Both inside and outside of the hive were examined for clinical confirmation of chalk brood. Dry scales with white to dark colored molds and chalk brood mummies were visible when one looked closely at the comb cells and bottom boards of the hives.

Examination for bacterialdiseases

Observation of clinical symptoms was made during the study period. Brood examinations were done by cutting off 5 X 10 cm brood comb areas and checked for the presence of clinical symptoms of bacterial (AFB and EFB) honey bee diseases. Typical clinical symptoms such as irregular brood arrangement, sunken and dark capping with puncture holes, dead and decayed larvae with dark “scales” and slight to pronounced odor were examined for the occurrence of AFB in the brood. Similarly, twisted larvae with creamy-white guts visible through the body wall, melted and yellow white larvae with unpleasant sour odour and loosely-attached brown scales were directly observed for the infected brood by EFB.

Data management and statistical analysis

The collected data was organized, coded, stored andanalysedusing Microsoft Excel spreadsheets version 2007 for data management. Analysis of the survey and laboratory data collected was done using SPSS software version 16. The statistical analysis used in the study varied depending on the type of variable and information obtained. The questionnaire survey data was analyzed using descriptive statistics and the ranking of the different types of beekeeping constraints obtained in the study was done by using the rank index formula as described by Musa *et al*. (2006). A chi-square test was used to assess the association of the risk factors for the major parasitic and honeybee disease andlogistic regression was also used to assess the strength of association among different factors**.**Statistical significance was set at $p<0.05$. Summarized data was presented in the form of tables and figures.

RESULTS AND DISCUSSIONS

Household characteristics of the respondent

From the total of 103 sample households interviewed, about 93.2% were male-headed and the rest, 6.8%, were female-headed. This is in agreement with the findings of many authors (Tessega, 2009; Sisay *et al.*, 2015; Bizuayehu *et al.*, 2020), who have indicated that agricultural activities in general and beekeeping in particular are mainly the duties of males, and females are mainly engaged in house duties.

The majorities (about 92.3%) of the beekeeper respondents were in the age range of 21–65 years old (Table 1). This result shows economically active age group actively engaged in beekeeping activities. Age and expertise play a significant role in identifying beekeeping constraints and honeybee behaviors that defend against pests and predators. This result concurs with the findings of (Tewodros *et al.*, 2015; Sintayehu, 2016), who stated that beekeeping is learnt through generation and practiced by all economically active age groups (15–65 yrs).

In terms of marital status, about 94.2% of beekeepers were married (Table 1). Marriage helps farmers to sustainably engage in agriculture in general and beekeeping practices in particular to ensure the livelihood of their families. This result is in line with Tessega (2009); and Alemu *et al*. (2015), who reported that the majority of the beekeepers (97.5%and 95.8%) were married in Burie district and Eastern Amahara region respectively.

About 78.7% of beekeepers had gone through basic education to college levels. This result indicates that most of the beekeepers are more educated. Education in farmers' households is very important to identify their problems with agricultural activities and seek appropriate solutions on time, thereby improving the productivity and production of their agricultural activities. This is in line with Alemu et al. (2015); Guesh (2015); and Amsalu (2020), who stated that 63.3%, 77.6% and 63.6% of the respondent beekeepers attended primary and junioreducation in Eastern Amhara, Tigray and East Wellega zones. Education affects beekeeping technology adoption, household income, and socio-economic status of a family.

Table 1. Sex, age, marital states and educational level of the respondent

Socio economic variables	Category	Frequency	%
Sex	Male	96	93.2
	Female	7	6.8
Age	<20	1	0.97
	21-65	95	92.2
	>66	7	6.8
Marital status	Single	4	3.9
	Married	97	94.2
	Divorced	2	1.9
Educational states	Illiterate	21	20.4
	Read and Write	25	24.3
	Primary	19	18.4
	Junior	21	20.4
	Secondary	15	14.6
	College	1	1.0
	Others	1	1.0

Table 2. Family size and beekeeping experience

Socio economic indicators	N	Minimum	Maximum	mean	Std. deviation
Family member	103	1	11	6.07	2.01
Beekeeping experience	103	4	54	20.72	13.19

The average family size of beekeepers in the study area was 6.07±2.01 (Table 2). The majority of beekeepers said that labor is one of the most crucial elements in their beekeeping practices. Adebabay *et al*. (2008) stated that beekeepers with large family size were most benefited to carry out various beekeeping tasks like hive inspection, settling swarms, providing water and feed, helping the household during honey harvesting. The beekeepers had an average experience of 20.72± 13.19 ranging from 4–54 years (Table 2). These result showedthat beekeepers have long experience in honey production and have a rich knowledge of identifying the problems they encounter in beekeeping practice. This result concurs with the findings of (Gichora, 2003; Tessega, 2009), who stated that the level of beekeeper beekeeping experience was taken to be the number of years that an individual was continuously engaged in beekeeping.

Beekeepers perception on trends of honey production and honeybee colony

Majority (75.7%, 83.5%) of beekeeper respondents declared that the trend of honey bee colony and honey production had decreased respectively and some beekeepers also responded to (19.4%, 13.6%) honey bee colony and honey production is increasing trend respectively (Figure 1). The major causes for the decrease in the number of honeybee colonies and productivity of honeybee colonies as mentioned by the respondents were: Pests and predators,un-wise use of pesticides and herbicides, lack of honeybee forage are the major causes. The results were similar with different scholars (Alemu *et al.*, 2015; Addisu and Desalegn, 2017; Bizuayehu *et al.*, 2020).

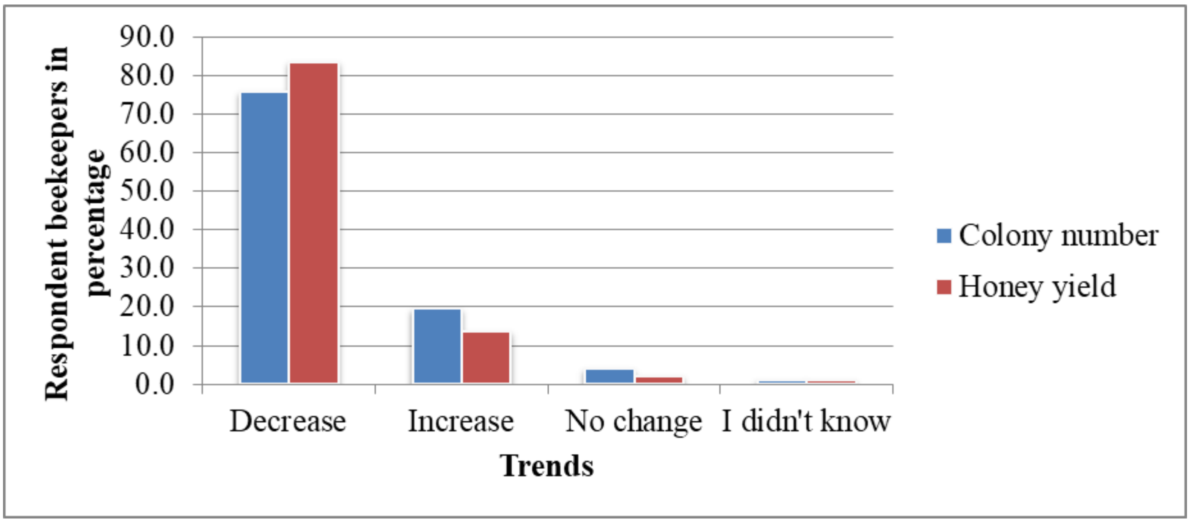

Figure 1. Beekeepers perception on trends of honeybee colonyand honey yield

Major beekeeping constraints

According to the survey results, beekeepers in Western part of the Amhara region listed out about fourteen major beekeeping constraints that hampered the production of beekeeping in order of their importance (Table 4). These identified constraints were also reported in different parts of Ethiopia by different studies even though the level of importance varies from place to place (Goush, 2015; Teklu, 2016; Amsalu, 2020).

Table 4. Major beekeeping constraints in Western part of the Amhara region

Problems	Index	Rank
Pests and predators	0.24	1st
Un-wise use of pesticides and herbicides	0.19	2nd
Lack of bee forage	0.18	3rd
Absconding	0.15	4th
Lack of improved beekeeping skill	0.07	5th
Increased cost of production	0.04	6th
Drought	0.02	7th
Disease	0.02	7th
Weather	0.02	7th
Migration	0.02	7th
Death of colony	0.02	7th
Lack of water	0.01	8th
Luck of credit	0.01	8th

Index = sum of (8*ranked 1st+ 7*ranked 2nd+6*ranked 3rd+5*ranked 4th+4*ranked 5th+3*ranked 6th+2*ranked 7th+1*ranked 8th) for individual reasons divided by the sum of (98*ranked 1st+ 7*ranked 2nd+6*ranked 3rd+5*ranked 4th+4*ranked 5th+3*ranked 6th+2*ranked 7th+1*ranked 8thh) for over all Constraints

Honeybee pests and predators

According to the results of the current study, the existence of pests and predators is a major challenge to the honeybees and beekeepers in the western part of the Amhara region. After having identified the major pests facing the beekeeping activities, beekeepers were requested to rank them in order of importance and the results indicated that, ants, spiders, birds, wax moth, varroa, death's head hawks moth, beetle, honey bager, mice, bee lice, lizards, prey mantis, and snakes, were the most harmful pests and predators in order of importance (Table 5). In Ethiopia, more than 15 honey bee pests and predators have been identified (Desalegn, 2001; Desalegn and Amssalu, 2006). The result is in agreement with Tesega (2009); Guesh (2015); Alemu *et al*. (2015); and Bizuayehu *et al*. (2020).

Table 5. Major pests and predators of honey bees

Major Pests and predators	Index	Rank
Ants	0.24	1st
Spiders	0.19	2nd
Birds	0.18	3rd
Wax moth	0.15	4th
Varroa	0.07	5th
Death's Head Hawks Moth	0.04	6th
Beetle	0.02	7th
Honeybagers	0.02	7th
Mice	0.02	7th
Bee lice/mite	0.02	7th
Lizards	0.02	7th
Prey mantis	0.01	8th
Snake	0.01	8th

Season of occurrence for pest and predator

The results showed that the majority of the pests and predators listed by the sample beekeepers were present throughout the year. In particular, ants, wax moths, varroa, bee-eater birds, hamagot, death's head hawks moth, and mice were more common from January to September (Figure 2).

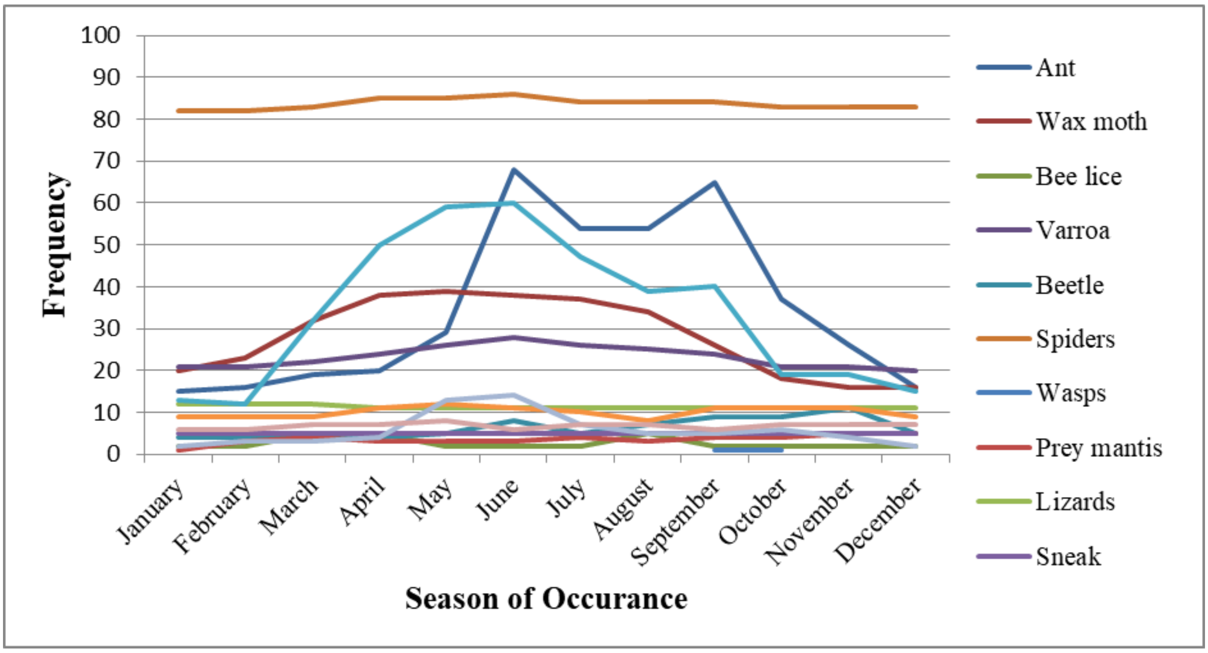

Figure 2. Attacking (occurrence) season of major honeybee pest and predator

The majority of respondens (about 80%) stated that weak honeybee colonies were more susceptible to pest attacks and honeybee diseases than medium and strong colonies (Figure 3).

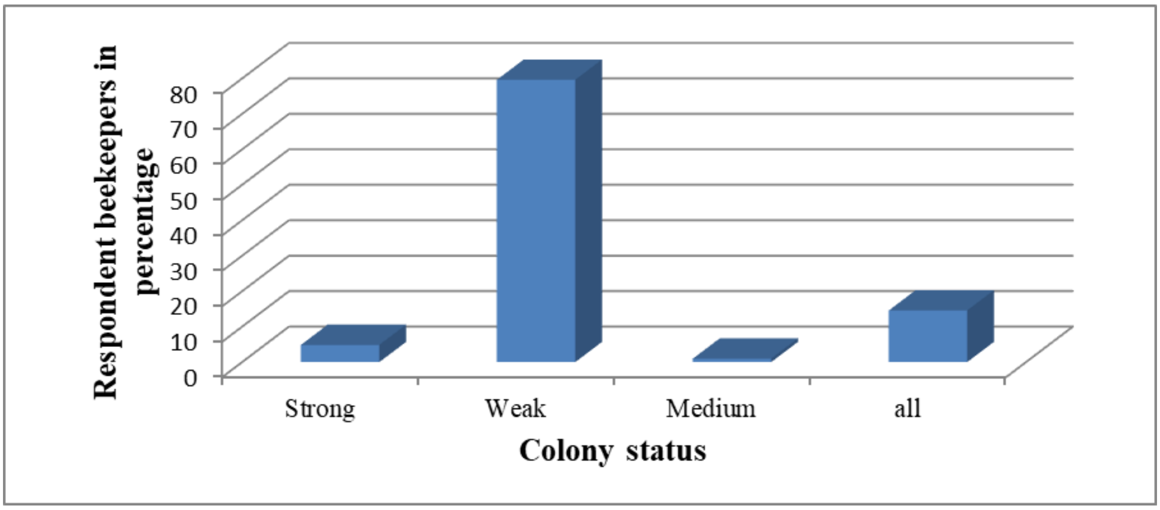

Figure 3. Strength status of honeybee colonies and pest and predators effect

In comparison to other types of behavior, the majority of respondents (about 77%) claimed that honeybee colonies with very aggressive behavior had more defense capacity against diseases and pest attacks (Figure 4).

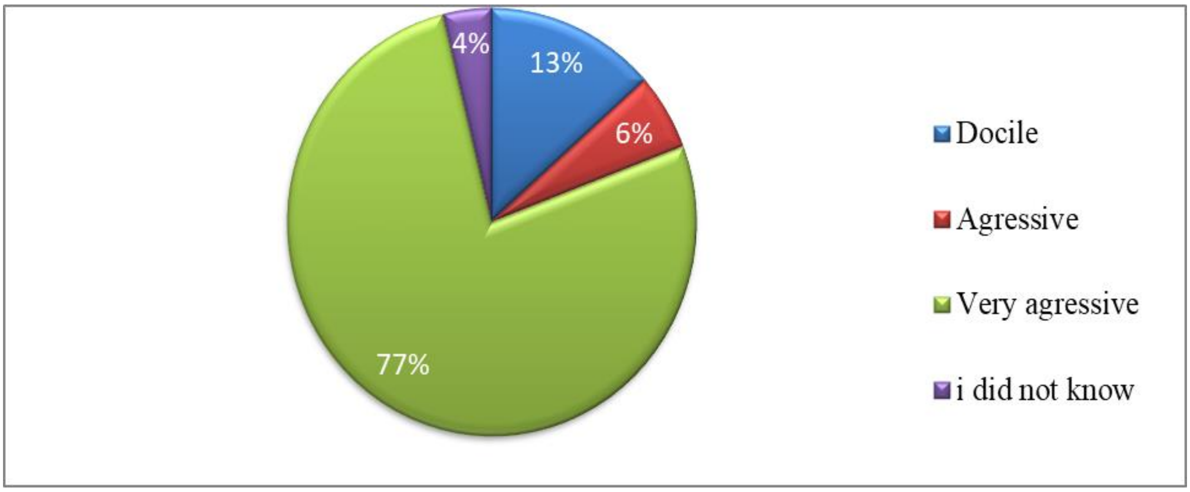

Figure 4. Honeybees and their defensive behavior against pests, predator and disease

The respondents replied that ant (both black and red) and wax moth are major causes for the absconding of honeybee colonies (about 63%), (about 54%) respectively. Moreover, based on the beekeepers responses, major causes for honeybee colonydwindling arespider (about 75%) and bee-eater birds (about 71%) (Figure 5).

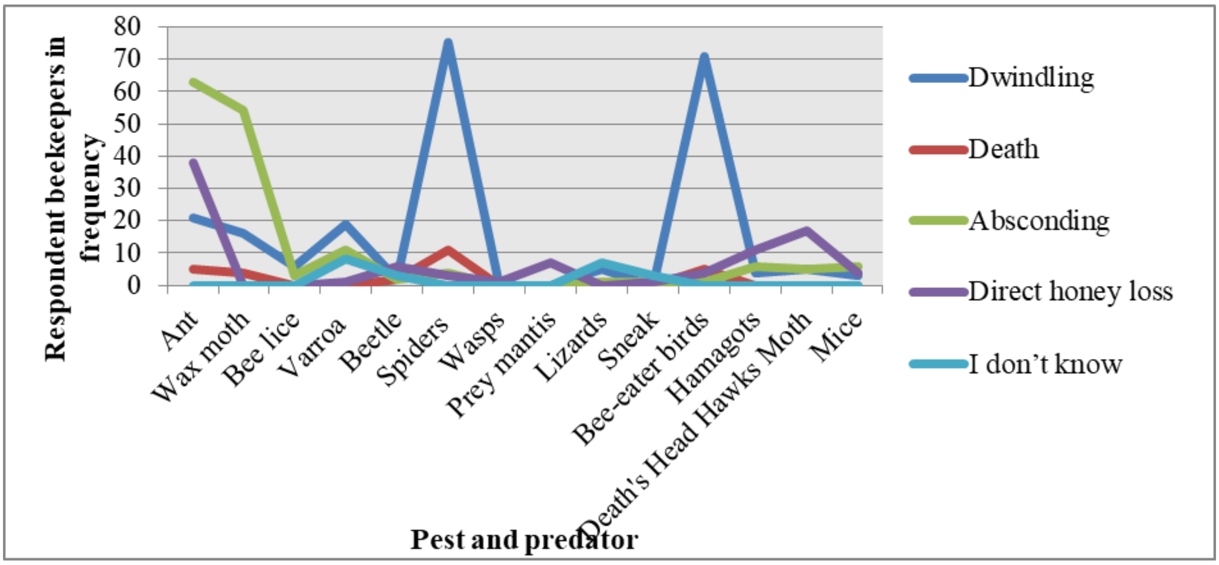

Figure 5. Effects of pest and predator on honeybees

Beekeepers indigenous knowledge on pests and predators controlling mechanisms

Beekeepers have always used different traditional prevention techniques, but they have not always been successful in reducing these pests and predators, which need to develop strong preventative techniques in order to avoid them. Respondents were asked how to traditionally control honeybee pests and predators in their locality and most of the respondents reported as it is indicated in Table 6; this is in line with Tesega Balie, 2009 and Teklu Gebretsadik, 2016.

Laboratory Diagnosis of Honeybee Disease and Parasitic Mites

Under this examination, the major honeybee parasitic mites (varroa mites, bee lice and tracheal mites), adult honeybee diseases (Nosema and Amoeba) and brood diseases (Chalkbrood, AmericanFoul Brood and European Foul Brood) werediagnosed.However, tracheal mites were not found throughout the study period andno clinical symptoms of bacterial (American Foul Brood and European Foul Brood) and fungal (Chalk brood) diseases were observed in the study period.

Table 6. Honey bee pest and predator local controlling measures

Pest and predators	Controlling measures
Ant	Applying ash (49%), Cleaning apiaries, hive stands and hives(14.7%), Applying different insecticides and boiled water in ant nests(10.2%), Smoking pepper(10.2%), White Eucalyptus leaf (5.1%), Appling soap(3.2%), Appling used vehicle oil and Greace (2.6%), Destroying their nest (2.6%) and Do not use any controlling measures (1.9%)
Spider	Cleaning apiaries, hive stands and hives (95.7%) and Killing (4.3%)
Bee-eater birds	Chasing (80.2%), Do not use any controlling measures (9.3%), Killing (4.7%), Trapping (3.5%), Destroying their nest (2.3%)
Wax moth	Removing infested, empty and old combs (53.5%), No use of any measures (27.6%), Clean apiaries, hive stands and hives (8.6%), Smoking pepper (3.5%), Remove old hive (3.5%), and feed the colony to strengethen (3.5%)
Varroa	Do not use any controlling measures (90.6%), Smoking pepper (6.3%), Strengthen the colony by feeding (3.1%)
Death's Head Hawks Moth	Killing (85.0%), Minimize hive entrance (10%), Cleaning apiaries and hive stands and hives (5%)
Beetle	Killing (42.9%), Cleaning the hive (14.3%), Minimize hive entrance (7.9%) and Smoking pepper (7.9%)
Hamagots	Chasing by dog (36.4%), Trapping (36.4%), Fencing the apiaries with torn (13.6%), killing (13.6%)
Mice	Killing (80%), Minimize hive entrance (10%), No use of any measure (10%)
Bee lice/mite	Do not use any controlling measures (100%)
Lizards	Do not use controlling measures (83.9%), Killing (38.5%), Chasing (7.6%)
Prey mantis	Killing (85.7%), Close the hive openings (14.3%)
Snake	Killing (80%) and Do not use any controlling measures (20%)

Prevalence of varroa mite with its associated risk factor

Based on the result obtained from the laboratory diagnosis the overall prevalence of varroa mite was 61.6% (Table 7). The present result was found to be lower than earlier research findings of varroa mite prevalence by Desalegn (2015) 82% in Tigray Region; Alemu *et al.* (2015) also reported 85.9% prevalence in the eastern parts of the Amhara Region. Bizuayehu *et al*. (2020) reported that 78.35% varroa prevalence in East and West Gojjam Zone of Amahara Rigion. However, slightly lower prevalence was reported by Guesh Godifey (2015) which is 62.1% during honey flow and 53.4% during dearth periods in Tigray Region. Different African countries reported different result on varroamite prevalence: about 78.6% in Nigeria (Akinwand *et al.*, 2013), 100% in South Africa (Strauss *et al.*, 2013), about 83% in Kenya (Muli *et al.*, 2014) and about 92% in Tanzania (Mumbi *et al.*, 2014).

The current result indicated that higher varroa mite prevalence was observed in the frame hives (about 69.4%) and traditional type of hive (about 60.3%) than in intermediate types of hives (about 42.4%) and there was a statistically significant difference among these hive types ($\chi2$=8.459; *P*<0.05) (Table 7). This result partially agrees with Alemu *et al*. (2015), who reported about 94.2%, 84.8%, and 79.85% in movable frame hives, intermediate, and traditional hives, respectively, in the eastern parts of the Amhara Region. Bizuayehu *et al*. (2020), who reported about 88.89% intermediate, 85.89% in movable frame hives, and 71.96% traditional hives in East and West Gojjam Zone of Amahara Rigion. In terms of agro-ecology, varroa mite prevalence was higher (75%) in low land than in highland (55.3%) and mid-land (53.9%) agro-ecology. There was a statistically significant difference ($\chi2$=16.184; p<0.05) among the three agro-ecologies. The higher prevalence of varroa mite (71.6%) was observed in the build-up period than in the dearth period (51.9%). Based on this outcome, seasonal differences were found to be statistically significant ($\chi2$=16.805; p<0.05) (Table 7). This result agrees with Amsalu (2020), who reported that 69.6% during dry and 60.9% during wet season in East Wolega Zone Oromia region. It was shown that varroa was prevalent in Awi (78.1%), East Gojam (68.8%), and South Gondar (39.5%). Between the three zones, there is a significant difference in the total prevalence of varroa ($p < 0.05$), with a higher prevalence in Awi and East Gojam than in South Gonder (Table 7).

Table 7. Prevalence of varroa mite with it is associated risk factor

Observed risk factors	**Categories**	**No of hives examined**	**Varroa prevalence**		**Chi square**	**p- value**	**Odds ratio**
			Positive	**%**			
Hive types	Traditional	252	152	60.3	8.459	0.015	1
	Intermediate	33	14	42.4			1.206
	Frame	124	86	69.4			2.571
Agro Ecology	Highland	141	78	55.3	16.184	0.000	1
	Midland	128	69	53.9			2.230
	Lowland	140	105	75.0			2.367
Seasons	Build up period	208	108	51.9	16.805	0.000	1
	Dearth period	201	144	71.6			2.297
Study location	Awi	105	82	78.1	43.371	0.000	
	East Gojam	170	117	68.8			
	South Gondar	134	53	39.6			
Total		**409**	**252**	61.6			

Prevalence of bee lice with its associated risk factors

From the total (409) colonies examined for the presence of bee lice, the laboratory diagnosis confirmed that about 16. 4% were found to be infested with bee lice (Table 8). This result was lower than the rate reported by Gizachew *et al*. (2013), who reported 42% of colonies infested with bee lice at Holeta and its surrounding areas. Guesh (2015) reported 27.5% and 5.73% during the honey flow and dry seasons, respectively, in the Tigray Region. Amsalu reported 26.1% and 13.0% prevalence rate during the dry and wet seasons, respectively, in East Wollega Zone, Oromia region. However, the current finding was found to be higher than the bee lice prevalence reported by Adeday *et al*. (2012), which was about 5.5% in the adult honeybee in Wuqro district, Tigray region. Bezuayhu *et al*., 2021 found 11.34% prevalence of bee lice in the Amhara region's East and West Gojjam zones.

The results indicated that frame hives had the highest frequency of bee lice (24.2%), followed by traditional hives (14.3%), and that intermediate hives had the lowest prevalence (3%) of bee lice. With this, statistically significant difference was seen between the three hives ($\chi2=10.627$; $p<0.05$). This result is in line with the findings of Alemu *et al*. (2015), who reported that bee lice prevalence was higher in movable frame hives (46.5%) than in intermediate hives (31.9%) and traditional (17%). Bezuayhu *et al*. (2020) also reported that the highest bee lice prevalence (12.82%) was in movable frame hives rather than intermediate (11.11%) and traditional hive types (10.28%). Contrary to our results, Gizachew *et al*.(2013) have reported that the highest bee lice prevalence (48.5%) was observed in traditional hives at Holleta and Guesh Godifey (2015) reported 29% bee lice prevalence in traditional bee hives at Tigray. Segni (2017) reported that the highest bee lice prevalence (50.9%) was observed in traditional hives in the Ejere District.

The investigation result revealed that higher prevalence of bee lice in lowland (22.1%) than midland (14.1%) and highlands (12.8%) (Table 8). The difference might be due toagroecology, which might affect the multiplication or survival of bee lice. With this, there was no statistically significant difference between agro-ecology ($\chi2=5.247$; $p>0.05$).The result also indicated that bee lice prevalence was slightly higher in the dearth period (17.4%) than in the build-up period (15.4%). Despite this, there was no statistically significant change between the two seasons ($\chi2=0.307$; $p>0.05$). There was also difference in bee lice prevalence between study locations 23.5% in East Gojjam; 11.4% in Awi and 11.2% in South Gondar zone.

Table 8. Prevalence of bee lice with its associated risk factor

Observed risk factors	Categories	No of hive examined	Bee lice prevalence		Chi square	p- value	Odds ratio
			Positive	%			
Hive types	Traditional	252	36	14.3	10.627	0.005	1
	Intermediate	33	1	3			1.790
	Frame	124	30	24.2			10.127
Agro Ecology	Highland	141	18	12.8	5.241	0.073	1
	Midland	128	18	14.1			1.884
	Lowland	140	31	22.1			1.664
Seasons	Build up period	208	32	15.4	0.307	0.580	1
	Dearth period	201	35	17.4			1.073
Study location	Awi	105	12	11.4	14.332	0.004	
	East Gojam	170	40	23.5			
	South Gondar	134	15	11.2			
Total		409	67	16.4			

Prevalence of Nosema disease with its associated risk factor

Four hundred nine (409) honeybee colonies were assessed for the presence of nosema disease. The overall prevalence of Nosema diseasein the Western part of the Amhara region was 14.9 %. The present investigation indicated that honeybee nosema disease was higher in the traditional type of hive (19.8%), followed by the frame hive (8.9%). However, Nosema was not found in the intermediate type of hive during the study period. With this, a statistically significant difference was seen between the hive types ($\chi2=14.174$; $p<0.05$). The highest prevalence of *Nosema apis* observed in traditional hive might be due to the difference in the management practice. Traditional beehives are difficult to easily manipulate and control honeybee pests and diseases and would become susceptible to thepests and disease. This result agreeswith the findings of Guesh (2015) and Segni (2017), who reported that *Nosema apis* was higher in traditional hives than in both movable frame and intermediate hive types. However, our result contradicts the findings of Bizuayehu *et al*. (2020), who reported that *Nosema apis* prevalence was higher in movable frame hive followed by intermediate and traditional hive types (62.82%, 44.44% and 42.99%), respectively in Bure Zuria, and Awabel districts.

The results also indicated that Nosema disease was more prevalent in highland agro-ecology (20.6%) followed by midland agro-ecology (18.8%) and the least prevalence wasobserved in lowland agro-ecology (5.7%). With this, there was a statistically significant difference among agro-ecology ($\chi2=14.373$; $p<0.05$) (Table 9). This might be due to the effect of humidity that affected the spread of Nosema disease. The result is in linewith Guesh (2015); Segni, 2017; and Bizuayehu *et al*. (2020), who stated that Nosema disease was more prevalent in high land agro-ecology than in mid and low land agro-ecology.

In terms of season, the prevalence of nosema was higher during the buildup period (23.6%) than during the dearth period (6%). There was a statistically significant difference ($\chi2=24.916$; $p<0.05$) with respect to season. The result also indicated that East Gojam zones have the highest prevalence of Nosema (30%), followed by Awi zones (9.5%) and Nosema was not found in the South Gonder zone. With this result, a statistically significant ($\chi2=56.380$; $p<0.05$) difference was observed in *Nosema disease* prevalence between the study zones (Table 9).

Prevalence of amoeba disease with its associated risk factor

The laboratory diagnostic result confirmed that the overall prevalence of amoeba disease was 14.9%. The present result was found to be lower than previous research findings of amoeba prevalence rates in different regional states of Ethiopia, such as; Oromia region, with a prevalence rate of 88%; Amhara region (95%); and 60 % in Benishangul-Gumuz (Aster *et al.*, 2010).

Table 9. Prevalence of Nosema with its associated risk factor

Observed risk factors	Categories	No of hive examined	Nosema prevalence Positive	%	Chi square	p- value	Odds ratio
Hive types	Traditional	252	50	19.8	14.174	0.001	1
	Intermediate	33	0	0			0.471
	Frame	124	11	8.9			2.006
Agro Ecology	Highland	141	29	20.6	14.373	0.001	1
	Midland	128	24	18.8			0.246
	Lowland	140	8	5.7			0.257
Seasons	Build up period	208	49	23.6	24.916	0.000	1
	Dearth period	201	12	6.0			0.175
Study location	Awi	105	10	9.5	56.380	0.000	
	East Gojam	170	51	30			
	South Gondar	134	0	0			
Total		**409**	**61**	14.9			

The result indicated that the highest prevalence of amoeba disease (18.7%) was observed in traditional hives compared to improved frame hives (11.3%), and no amoeba disease was observed in the intermediate hive type, and this difference was statistically significant ($\chi 2=9.840$; $p<0.05$). Our results agree with the findings of Segni (2017) who stated that Amoeba disease prevalence was higher in traditional hive (84.9%) than in intermediate (79.81%), and modern (77.8%) type of hives at Ejere district. Bizuayehu *et al*. (2020) also reported that the prevalence of amoeba disease was higher in traditional hive (100%) than in intermediate (88.89%), and modern (98.72%) type of hives reported from Awabel and Burie Zuria district.In the case of agro-ecology, amoeba prevalence was higher in midland (18.8%) than in highland (14.2%) and low land (12.1%) agro-ecology. When the prevalence of Amoeba disease was calculated based on season, the highest prevalence of amoeba (16.4%) was observed in the dearth period, while the lowest prevalence (13.5%) was observed in the buildup period. However, the difference in prevalence of amoeba disease was not statistically significant among the two seasons ($P>0.05$) (Table 10). Regarding the study zones, Awi (29.7%) had the highest prevalence of the honeybee amoeba disease, followed by East Gojjam (17.6%), and no amoeba disease was observed in the South Gonder zone. Moreover, a statistically significant difference between the study zones was found ($\chi 2=42.149$; $p<0.05$) (Table 10).

Table 10. Prevalence of Amoeba with its associated risk factor

Observed risk factors	Categories	No of hives examined	Amoeba prevalence		Chi square	p- value	Odds ratio
			Positive	%			
Hive types	Traditional	252	47	18.7	9.840	0.007	1
	Intermediate	33	0	0			0.567
	Frame	124	14	11.3			2.023
Agro Ecology	Highland	141	20	14.2	2.391	0.303	1
	Midland	128	24	18.8			0.921
	Lowland	140	17	12.1			0.631
Seasons	Build up period	208	28	13.5	0.704	0.401	1
	Dearth period	201	33	16.4			1.179
Study location	Awi	105	31	29.5	42.149	0.000	
	East Gojam	170	30	17.6			
	South Gondar	134	0	0			
Total		409	61	14.9			

CONCLUSION AND RECOMMENDATION

Based on laboratory and survey results, honeybee pests and predators were the major constraints for beekeeping in the Western part of the Amhara region. Major honeybee pests and predators detected in the study area include ants, spiders, birds, wax moth, varroa, death's head hawks moth, beetle, hamagots, mice, bee lice, lizards, prey mantis, sneaks, and wasps in order of importance. The findings of the disease investigation revealed that varroa, bee lice, nosema, and amoeba were found major honeybee parasites and diseases. Honeybee diseases like AFB, EFB, chalk brood, stone brood, and tracheal mites were not confirmed in the study period. Finally, hive type, agro-ecology, and season were identified as risk factors for honeybee parasites and diseases.

The following recommendations are made based on the aforementioned findings.

- Honeybee colonies should be strengthened so they can defend themselves against viruses and parasites that affect honeybees.
- Beekeepers should be awared of the need to regularly checking their honeybee colonies for the prevalence of diseases and pests, which cause the majority of honeybee illnesses and thus boost productivity.
- The investigation of efficient prevention and control options against the identified honeybee pests and enemies should receive more focus.

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Determination of an Optimum Honeybee Colonies Carrying Capacity in Northeast Dry Land Areas of Amhara region, Ethiopia

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ABSTRACT

The study aimed to investigate the nectar secretion dynamics and nectar sugar of major honeybee flora species and to determine the optimum honeybee colony carrying capacity in northeast dry land areas of the Amhara region. Acacia asak, Acacia etbaica, Acacia tortolis, Becium grandiflorum, and Cordia africana honeybee floral species were considered for this study. Floral nectar was collected through micropipette and washing techniques based on the flower nature of the species and nectar sugar was measured by a honey refraco-meter. Hence, A.asak, A.etbaica, A.tortolis, B.grandiflorum, and C.africana could have been estimated to produce 10.2±6.4mg, 5.3±4.6mg, 2.6±1mg, 3.7±2.1mg, and 5.7±3.2mg/flower head of nectar sugar, respectively. In a single tree of A.etbaica, A.asak, A.tortolis, B.grandiflorum, and C.africana a mean of 0.15kg, 0.15kg, 0.06kg, 0.01kg, and 0.03kg of honey yield was expected to produce, respectively and similarly in a hectare of land a mean of 49.9kg, 128.9kg, 5.6kg, 5.5kg, and 2.2kg of honey was estimated to harvest in the respective trees. In a hectare of land a sum of 57.5kg, 57.5kg, and 128.9kg of honey in highland, midland, and lowland locations, respectively was estimated to produce during the main harvesting season of the area. Based on this, the mean number of honeybee colonies introduced in the lowland have estimated to be 18 traditional, 6 transitional, and 5 frame hives; in the highland 12 traditional, 6 transitional, and 5 frame hives whereas in the midland 8 traditional, 5 transitional, 3 frame hives in a hectare of land. The study indicated that despite the limited rainfall and high temperature in the study area; the studied species secrete a significant amount of nectar sugar and are very potential for beekeeping. Overall in the lowland areas during the flowering time of A.asak, a higher number of honeybee colonies could be introduced in a hectare of land than the midland and highland agro-ecologies due to the higher honey production potential of the species.

Keywords: *Carrying capacity, honey, honeybees, nectar, sugar*

INTRODUCTION

Apiculture is a promising off-farm enterprise, which directly and indirectly contributes to smallholder income generation in particular and the nation's economy in general. It has a significant role in generating and diversifying income of subsistence Ethiopian smallholder farmers mainly the small landholders and landless (Gezahegn, 2001). Ethiopia has the largest honeybee population in Africa with over 10 million honeybee colonies, out of which about 6.9 million are estimated to be hived while the remaining exist in the wild (CSA, 2021). The annual honey production of Ethiopia is estimated to be 129 million kilograms which make the country to rank the first honey-producing country in Africa and ninth in the world. Of this, the greater portion is harvested from traditional hives (CSA, 2021). Moreover, Ethiopia's beekeeping system is characterized as low input- low output system mainly carried out by rural smallholder beekeepers.

Success in beekeeping depends on the availability of floral resources (honeybee forage) and is a very important field for most beekeepers in the world (Rucker et al., 2002). Hence, beekeeping is more dependent on the existing natural resources of an area than any other livestock activity. In areas, where beekeeping is not suitable, other improved management skills and advanced technologies alone cannot make beekeeping successful. For this reason, the availability of adequate bee forage is considered to be one of the most important elements in the beekeeping industry (Al-Ghamdi et al., 2016). Most of the methods for obtaining information about plants utilized in an area are based on direct field observations of foraging honeybees on flowers.

Ideally, a good beekeeping area is one in which nectar and pollen plants grow abundantly and with a relatively long blooming season. Such potential areas are however not always available or easy to find. Not all honeybee floras are equally important for honeybees rather it is better to think about the food source they contain either in pollen and nectar production potential and the blooming duration of the plant. Variations in the date and duration of flowering periods among regions and seasons influence the type of pollen or nectar production. Beekeepers must know the time and duration of the blooming season of every major honey plant including the environmental factors affecting them and the carrying capacity of the area, which includes the number of colonies that can be put for maximum production (Rajan, 1980). Understanding the optimum carrying capacity of an area with the estimation of the nectar amount for each species is a very important step in the establishment of an apiary

Considering the above realities, it was crucial to provide information on the amount of nectar and honey production potential, and carrying capacity of beekeeping sites to have sustainable beekeeping in the area. Therefore, the objectives of the study were to investigate the nectar secretion dynamics and nectar sugar of major honeybee flora species of the target area and to determine optimum honeybee colony carrying capacity based on yield potential and distribution of bee forage plants. The implementation of this study was also allowed to prepare the actual beekeeping potential and to suggest the number of honeybee colonies to be introduced in specific beekeeping areas of the Waghimra zone, Amhara region, Ethiopia.

MATERIAL AND METHODS

Description of the Study Area

Waghimra zone is located at 12° N latitude and 38° E longitudes at an altitude of 500-3500 m.a.s.l with an annual rainfall of 150-700 mm which is an erratic type of rainfall. The annual average temperature ranges from 15°C to 40°C. Cattle, small ruminants, poultry, and equines are the major livestock species kept in the zone. About 408,352 cattle, 595,054 goats, 222,089 sheep, 11,038 equines (Donkey and Mule), 40,687 poultry, and, 130,771 honeybee colonies in the study area were reported (CSA, 2020).

Sampling Procedures

Stratified and purposive sampling techniques were used for this study to have a simple studying village from the vast geography of the area. From the total of seven districts in the Waghimra Zone, three stratified districts were selected based on their agro-ecology and beekeeping potentials and three kebeles were selected from each sample district.

Data Collection Methods

Nectar Collection Methods and Nectar sugar Estimation

Five selected major honeybee flora species (*Acacia asak,* Acacia *etbaiaca*, *Acacia tortolis, Becium grandiflorum, and Cordia africana)* of the area were considered in nectar collection, honey yield estimation, and honeybee colonies carrying capacity determination (Figure 1).

a. *Acacia asak* b. A. *etbaiaca* c. *Acacia tortolis*

d. *Becium grandiflorum* e. *Cordia africana*

Figure 1. Major bee floras of the study area

Nectar Collection Methods

Honeybee flora species which their flower morphology is suitable for directly extracting and measuring the nectar volume; the volume of nectar was determined by directly removing the nectar from the flower using graduated capillary tubes and/or micropipette (Nuru et al., 2017). In this case, the nectar of *B. grandiflorum* and *C. africana* was collected by this procedure. The technique for extracting floral nectar using micropipettes is often unsuited to flowers where nectar is produced in very small volumes and/or where nectar is highly viscous. An alternative technique developed by Mallick (2000), is the washing of the viscous nectar to those species having very small inflorescence and low amounts of nectar. Hence, two washes with a known volume of distilled water removed 95% of total floral sugar and it provided information on nectar production in this species that could not have been obtained using a standard micropipette extraction method (Mallick, 2000). Hence in the present study, the nectar of *Acacia* species was collected through this method.

Nectar Sugar Estimation

The concentration of the nectar sugar was measured using a digital honey refracto-meter according to Bolton et al. (1979) and, the mass of total soluble sugar per volume was estimated following the above-described procedure. Nectar TSS was estimated as per plant species or hectare. The nectar collection, as well as sugar concentration measurement, was performed in five hours intervals of a day at 6:00, 10:00, 12:00, 15:00, and 18:00. From each plant and sampling time, the nectar volume was measured from an average of five flowers and repeated for three consecutive days as a replication.

- Nectar sugar/tree = number of flowers/tree*nectar sugar/flower
- Nectar sugar/ha = number of trees of species "1" /ha* nectar sugar of species "1" + number of trees of species "2" /ha* nectar sugar of species "2"+ number of species "x"/ha* nectar sugar species "x"

Expected honey estimation

The average number of flowers per tree was obtained by multiplying the average number of flowers in $1m^3$ by the average surface area or volume of the canopy of the species. A quadrant method was employed to get the number of trees of a species in a hectare of land using 20mx20m and 5mx5m for trees and shrub-type species, respectively. The average amount of honey that can be obtained from a single plant is estimated from the average number of flowers per plant and the average mass of the nectar total soluble sugar per flower. Given that 1 kg of honey with 18% moisture content contains 820 g total dissolved sugar and assuming that all factors remain constant, to harvest 1kg of surplus honey, the colony has to consume a further 1kg of honey for survival, brood rearing, and as fuel energy to foragers (Kim et al., 2011). Therefore,

- Expected honey yield /plant species = Nectar sugar per tree/2/0.82
- Expected honey yield /ha = Nectar sugar/ ha /2/0.82

Determination of honeybee colonies carrying capacity

The optimum honeybee colony caring capacity was estimated as per one plant species and/ or per 400 hectares of beekeeping areas shown below.

- Optimum colony's caring capacity = Optimum honey yield expected (kg/colony/harvest)/Optimum honey productivity of the area (kg/colony/harvest) by type of hives.

Statistical analysis

Analysis of variance (ANOVA) and t- Test were used to compare the mean amount of nectar volume and sugar amount per flower with different factors and the result was presented in table form. Mixed effect analysis of variance was employed in which plant species, time of the day, and agro ecology was fixed factor, and individual tree as a random factor. A pairwise correlation analysis was performed between the environmental factors (temperature and relative humidity of the area) and the volume of nectar and mass of sugar secreted per flower or inflorescence.

RESULTS AND DISCUSSION

Characteristics of major honeybee flora species

Phenology of selected honeybee floras

The flowering period distributions of the honey-source plants varied from one species to another (Table 1). Most of the species had a blossoming season during spring with little extension in early summer while only *A.tortolis* flowered in autumn. Therefore, *A.tortilis* was observed to flower in the dry season during the leafless stage, but when rain occurred, the flowers aborted and initiated new leaves. In the midland and lowland agro ecologies, *B. grandiflorum* was observed in flowers during August and September months.

Table 1. Flowering period distribution of the study species

Species	**Months of the year**											
	Aug	Sept	oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July
Acacia etbaica		X	X	X						X	X	
Acacia asak	X	X	X	X								
Acacia tortolis								X	X	X		
Beciumgrandiflorum	X	X										
Cordiaafricana			X	X								

Note: Bars with different colors indicate the flowering duration of each species

Floral density and flower biomass

The mean number of flowers per tree of A.etbaica, A.tortolis, A.asak, B.grandiflorum, and C.africana were estimated to be 23810.7, 18786.6, 11489.3, 2692.1, and 4400.1, respectively (Table 2). In a hectare of land, a mean of 325.9 trees of A.etbaica, 97.9 trees of A.tortolis, 859.4 trees of A.ask, 455.5 trees of B.grandiflorum, and 69.8 trees of C.africana was recorded.

Table 2. Canopy volume, number of flowers/trees, and number of trees /ha

Species	Flowers/m^3	Canopy volume (m^3)	Flowers/tree	Trees/ha
A.etbaica	2767.3	8.4	23810.7	325.9
A.tortolis	2358.8	8.2	18786.6	97.9
A.asak	2079.3	5.6	11489.3	859.4
B.grandiflorum	2692.1	-	2692.1	455.5
C.africana	537	8.27	4400.1	69.8

Nectar Secretion Potential of Selected Species

Mass of nectar sugar of Acacia species

Daily average nectar sugar of 10.2±6.4mg, 5.3±4.6mg, and 2.6±1.4mg /flower head was recorded for A.asak, A.etbaica, and A. tortolis, respectively (Table 3). Hence the highest amount of nectar sugar was recorded in the A. asak species which is only available in the lowlands of Waghimra. In Saudi, a mean of 3.8, 1.6, and 2.0mg/flower head was reported for A.asak, A.etbaica, and A.tortolis, respectively (Nuru et al., 2017). Therefore, the nectar sugar amount of the species in the present study was higher than Saudi, which might be due to the agro ecological and soil characteristics difference that affect the species' nectar properties.

Table 3. Nectar sugar amount (mg/ flower) of *Acacia* species in different agro-ecologies

Location	A.tortolis	A.etbaica	A.asak
Highland	2.4±1.4	4.470±3.9b	-
Midland	2.6±1.5	6.039±5.0a	-
Lowland	2.7±1.3	-	10.2±6.4
Overall mean	2.6±1.4	5.3±4.6	10.2±6.4
Sign.	NS	**	

Means with the different letters are significantly different from each other (P<0.01); NS non-significant difference (P>0.05)

Nectar volume and sugar amount of B.grandiflorum and C.africana

The mean nectar volume per flower, sugar concentration percentage, and total sugar mass per flower of B.grandiflorum was 9.8 ±4.8µl, 38.0 ±12.4%, and 3.7 ±2.1mg flower per head, respectively; and for C.africana was 16.5 ±6.9µl, 34.5 ±14.5%, and 5.7 ±3.2mg/flower head, respectively (Table 4). In this regard, the nectar volume of C.africana is higher than

B.grandiflorum while the B. grandiflorum nectar was more concentrated than C. Africana. The observed nectar volume per flower for both species is lower than S.abyssinica and higher than C.macrostachyus with 17.7µl and 3.6µl volume per flower head, respectively (Tura et al., 2020). The nectar volume, as well as the nectar sugar concentration variation of the species, might be the nature of the plant.

Table 4. Nectar volume (µl/flower) and nectar concentration (%/flower) of B.grandiflorum and C.africana

District	B.grandiflorum			C.africana		
	Nectar volume (µl)	Concentration (%)	Nectar Sugar (mg)	Nectar volume (µl)	Concentration (%)	Nectar sugar (mg)
Highland	9.7±4.6	37.7±12.2	3.7±2.1	16.5±6.6	33.3±14.0	5.5±3.1
Midland	9.9±4.9	38.3±12.7	3.7±2.1	16.5±7.2	35.8±15.0	5.8±3.4
Mean	9.8±4.8	38±12.4	3.7±2.1	16.5±7.0	34.5±14.5	5.7±3.2
Sign.	NS	NS	NS	NS	NS	NS

Nectar sugar secretion starts in the morning at 6:00 with 3.5±3.1, 6.7±4.9, and 6.7±4.9mg/ flower head for A.etbaica, A.tortolis, and A.asak, respectively. The peak nectar sugar amount was observed in the afternoon from 12:00 to 15:00 hours with 7.6±4.8, 4.2±1.0, and 15.1±5.8mg/flower head for A.etbaica, A.tortolis, and A.asak, respectively (Figure 2). Moreover, the nectar sugar secretion dynamics of the studied species showed an increasing trend early in the morning, peaking toward mid-day, followed by a decline trend. The finding is in line with Nuru (2016) who proved, the amount of sugar over time increased for A.ehrenbergiana and A.tortilis in Saudi Arabia.

As shown in Figure 2, the nectar secretion dynamics of both species started lower and peak immediately and decreased as the day becomes sunny and the temperature increased. This supports the general truth of plants needs a moderate sunrise and temperature for nectar secretion by supporting photosynthesis. At the start of nectar secretion time, the volume became higher due to the humidity of the area and decreased as temperature increased and vice versa for nectar concentration. This indicates that peak nectar volume and concentration secretion time are different due to environmental factors.

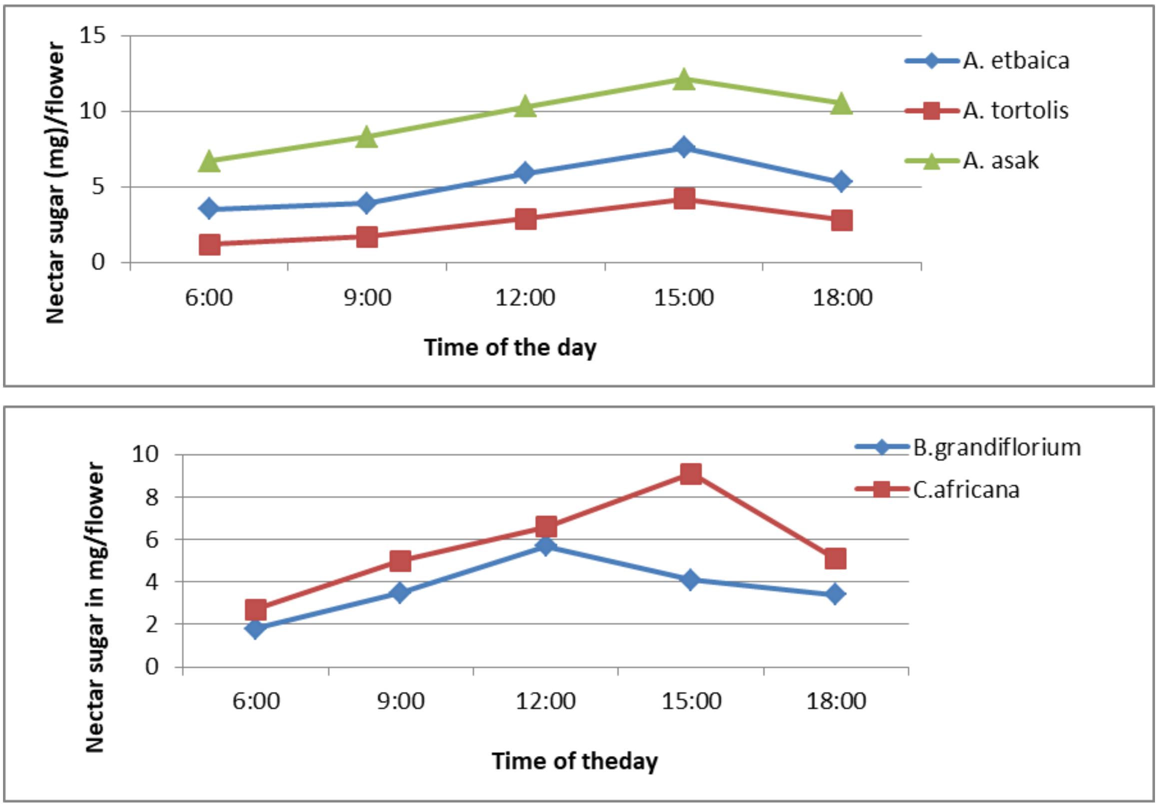


Figure 2. Nectar sugar amount (mg) per flower over the time of the day

Association between nectar secretion and weather Condition

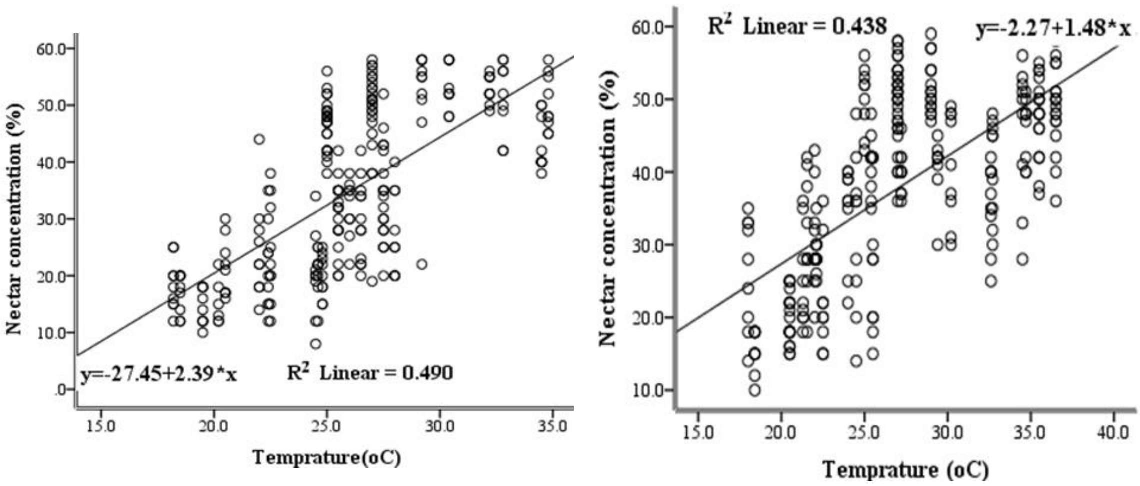
Effect of temperature and humidity on the nectar sugar of Acacia species: The temperature and humidity range of the study area during data collection was 18-36.5^{0}C and 20-43%, respectively. According to Jakobsen and Kristjánssonf (1994), nectar secretion and sugar concentration are temperature dependent plants for their biological activities. On this side, the present study revealed temperature had a significant positive correlation with the nectar sugar amount of Acacia species (Table 5). Hence the result was in line with Nuru et al. (2017), the ambient temperature had a significant positive correlation with nectar values (volume/flower, TSS content, and concentration in Acacia species of Saudi Arabiya), which may indicate the adaptations of the species to higher temperatures. The presence of a positive correlation between the temperature and nectar secretion was observed for A.ehrenbergiana and A.tortolis species under Saudi conditions (Nuru et al., 2016). The effect of humidity on the nectar sugar amount of Acacia species was negatively correlated at P<0.01. In advance, the effect of air moisture on nectar sugar amount had a highly significant negative correlation (Table 5). This indicates the air moisture either dilutes or vapors the nectar sugar amount of study plants.

Table 5. Correlation between nectar sugar amount and temperature and humidity of the air in *Acacia* species

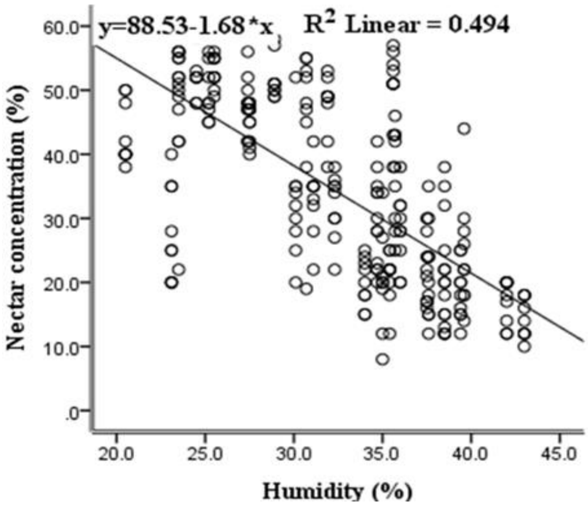
Species	Temperature (^{0}C)	Humidity (%)
Acacia etbaica	0.32**	-0.32**
Acacia tortolis	0.73**	-0.69**
Acacia asak	0.40**	-0.87**

Note: The value ** denotes the variables were significant at P<0.01.

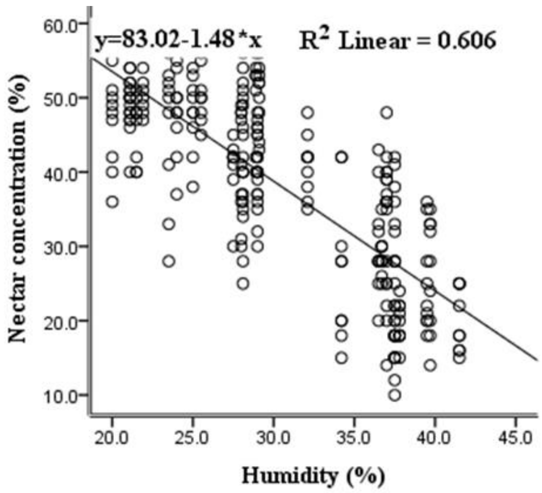
Effect of temperature and humidity on the nectar sugar concentration of B.grandiflorum and C.africana: Nectar concentration has a strong and direct relationship with temperature and an indirect relationship with air humidity (Figure 3). This was in agreement with the study conducted by Nuru et al (2012) on Z.spina-Christi reported that there is a positive correlation between temperature and nectar concentration. Similarly, Nuru et al. (2015) reported that the amount of nectar per flower of two lavender species significantly increased with an increase in temperature in southern Saudi Arabia. The refractometer reading showed the highly concentrated nectar of B.grandiflorum and C.africanawas to be at 29^{0}C and 30.4^{0}C respectively. The linear regression model indicated that temperature had affected the nectar sugar concentration of B.grandiflorum, and C. Africana species by 43.8%, and 49%, respectively, and humidity also affected the nectar sugar concentration of B.grandiflorum and C.africana species by 60.6%, and 49.4% respectively (Figure 3). Much more pronouncedly, temperature affected the nectar concentration of S.absisinica by 63.4% and C.macrostachyus by 72.3% (Tura et al., 2020).



(A) *C. africana* (B) *B. grandiflorum*



(C). *C. africana*



(D). *B. grandiflorum*

Figure 3. The effect of humidity on the nectar concentration of C. africana and B. grandiflorum plant species

The honey yield of major honeybee flora species

Among the species, a single tree of A.etbaica has produced relatively higher nectar sugar (0.15kg) followed by A.asak (0.12kg), A.tortolis (0.05kg), C.africana (0.03kg), and the least B.grandiflorum (0.01kg)/tree (Table 4). In this regard, the potential for A.etbaica was similar with the finding of Nuru et al (2017) being 0.15kg/tree but for A.asak, A. tortolis was 0.2kg, and 0.4kg/tree, respectively which is higher than the present investigation. Mainly it is because this plant species in the Saudi Arabiya had large canopy volumes of 20m^3, and 22.8m^3, respectively (Nuru et al., 2012). The present finding is also lower than C.macrostachyus and S.abyssinica plants in Ethiopian that can produce a nectar sugar amount of 3.2 kg, and 8.85 kg per tree, respectively that is because these trees have large crowns that hold huge numbers of small flowers of 483,840 and 676541floweres/ tree, respectively (Tura et al., 2020). Despite the limited rainfall and high temperature in the study area; the studied species secrete a significant amount of nectar sugar and are very potential for beekeeping.

Given that one kilogram of honey with 18% moisture content (wt. /wt.) contains 820g total dissolved sugar. Hence the mean amount of honey produced by a single tree of A.etbaica, A.asak, A.tortolis, B.grandiflorum, and C.Africana was estimated to produce 0.18kg, 0.15kg, 0.061kg, 0.012kg, and 0.037kg, respectively in ascending order (Table 6). Therefore, the plants in the genus Acacia produce more honey than that of B.grandiflorum, and C.africana because of their large number of small flowers with a large canopy of a tree.

Table 6. The mean expected nectar sugar and honey in kg/ tree

Plant species	Mass of nectar sugar per tree (kg)	Amount of expected honey yield per tree (kg)
Acacia etbaica	0.125	0.153
Acacia asak	0.120	0.150
Acacia tortolis	0.047	0.057
Becium grandiflorum	0.010	0.012
Cordia africana	0.025	0.031

The actual nectar and honey production potential of the species in a hectare of land has been calculated based on the abundance of the plants in the area. In this regard, A.asak could have produced the highest amount of honey (128.90kg/ha) than other species while the lowest was recorded for A.tortolis (2.16kg/ha) (Table 7). Under ideal environmental conditions, the estimated average amount of honey that can be obtained from the study plants per hectare area is lower than the amount of honey yield reported per hectare for some annual crops and trees like milkweed (500-600 kg/ha) (Zsidei, 1993); red clover with an estimated sugar yield of 883 kg/ha/flowering period (Szabo and Najda, 1985), and various lime species (90 - 1200 kg/ha) (Crane et al., 1984). In some species, the amount of nectar sugar per flower was high, but the amount of honey per tree or hectare of land was low because honey production potential also depends on the number of flowers per unit area or volume and the canopy of the plant.

Table 7. The mean expected sugar and honey in kg/ hectare

Species	Expected nectar yield (kg/ha)	Expected honey yield (kg/ha)
Acacia etbaica	40.74	49.86
Acacia asak	103.13	128.90
Acacia tortolis	6.60	5.58
Becium grandiflorum	4.56	5.47
Cordia africana	1.75	2.16

Total expected honey yield

Depending on the abundance and the nectar production difference of each species, the amount of honey produced in a hectare of land was also varied in each agro-ecology. The study showed the flowering time of the species matters the total harvestable honey of a specific area in the specific period in each study location. Plants with the same flowering period help to harvest maximum honey in specific beekeeping areas.

Hence, based on this 57.49 kg/ hectare of honey yield in the highland and midland and 128.91kg/hectare in the lowland agro-ecologies was expected during the main harvesting season (Table 8). Therefore, in the lowland localities high honey productivity has been expected due to the abundance of A.asak species which contributed for higher honey yield production. Honey in the highland and midland was estimated to be the sum of A.etbaica, B.grandiflorum, and C.africana while in the lowland from A.asak only.

Table 8. The maximum harvestable honey (kg/ha) of land in each agro-ecology

Agroecology	**Expected honey yield (kg/ha)**
High land	57.49
Midland	57.49
Low land	128.91

Optimum Honeybee Colonies Carrying Capacity

Based on the survey result, the average productivity of traditional, intermediate and movable frame hive was 9.7kg, 13.3kg and 19.3kg, respectively in the northeast dry land areas of the Amhara region. Hence, 7kg, 10kg, and 15kg per hive per one harvesting season were reported in the highland and 10kg, 15kg, and 18kg of honey has produced in traditional, intermediate, and movable hives, respectively in the midland agro-ecology. Regarding the lowland, a maximum of 12kg, 15kg, and 25kg honey has been harvested from traditional, intermediate, and movable hives, respectively (Table 9).

The total expected honey yield was used to estimate the optimum honeybee colonies to be introduced in a hectare of beekeeping areas in each agro-ecology. Hence it could be estimated by dividing the expected honey production potential of the species by the maximum honey productivity of honeybee colonies in each hive type. Therefore, the number of honeybee colonies to be placed in a specific beekeeping site depends on the expected honey yield of the area and the types of beehives. Depending on this, a relatively large number of honeybee colonies could be introduced in the lowland agro ecology (18, 9, and 5 traditional, intermediate, and movable hive honeybee colonies, respectively). Relatively minimum honeybee colonies (8, 5, and 3 of traditional, transitional, and frame hives, respectively) could be introduced in the midland agro ecology. In an investigation conducted by Tura et al.

(2020) on S.abyssinica, and C.macrostachyus forests in Arsi, Jimma, and Southwest zones of the Oromiya regional state, a maximum of 24 traditional, 16 intermediate, and 9 movable hives, and 56 traditional, 36 intermediate, and 20 frame hives were estimated to be introduced in a hectare of forest area, respectively. In this regard, the variation with the present finding is due to the nectar production potential of the species.

Table 9. The optimum number of honeybee colonies to be introduced in a hectare of beekeeping sites within different agro-ecology

Agro-ecology	Honey yield(kg)/hive type			Honey yield expected (kg)/ha	The optimum number of hives/ha		
	Trad. hive	Interm. hive	Movab. hive		Trad. hive	Interm. hive	Movab. hive
Highland	5	10	12	57.49	12	6	5
Midland	7	12	18	57.49	8	5	3
Lowland	7	15	25	128.91	18	9	5

CONCLUSION AND RECOMMENDATIONS

The study indicated that despite the limited rainfall and high temperature in the study area; the studied species secreted a significant amount of nectar sugar which is a potential for beekeeping. A hectare of beekeeping site in the lowland of the Waghimra zone could produce relatively higher honey yield than highland and midland agro-ecologies due to the more abundance and higher nectar secretion potential of A.ask flora species. In lowland areas during the flowering time of A.asak, a higher number of honeybee colonies (18 traditional hives, 9 intermediate and 5 movable hives) could be introduced in a hectare of land than the midland and highland agro-ecologies due to the higher honey production potential of the species. Above all, the information generated in this study is believed to be useful in apiary site selection and to estimate the honey bee colony carrying capacity of an area. According to the result of this study, some of the suggested issues that required consideration by beekeepers and any development organizations are indicated:

- Due to the high honey production potential of the study bee floras, propagation and conservation are recommended for sustainable honey production and environmental conservation;

- Other than these studied species in the study area, there are some other honeybee plants to be estimated for honey production, therefor such investigations shall be done in the inclusion of the rest of important honeybee floras especially shrubs and herbs.

ACKNOWLEDGMENT

The authors acknowledged the Ethiopian Institute of Agricultural Research (EIAR) for financing this research project.

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The Efficiency of Different Propolis harvesting Techniques from Frame Hive

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ABSTRACT

Propolis is a resinous substance collected by honeybees from leaf buds and exudates of trees and conifers. Propolis harvesting could potentially produce extra income for the beekeepers. Raw propolis can be harvested by scraping propolis built up from hive parts, and hive entrances using specially constructed screens. In this study, the experiment was done at Andassa livestock research center during the period from April 2020 to march 2021. The effect of harvestingtechniques (1×1mm openings meshwire, 4×4mm openings meshwire and 3×3mm openings plastic screens) and seasonsof the year on propolis harvestingwerestudied. The propolis samples were analyzed based on the least squares method. In the analysis, the General Linear Model /GLM/ procedure available in SAS software was used. The result showed that differences in harvesting techniques (used in this experiment) and harvesting season's variations have significantly affected the propolis harvest. Harvesting from October to December using a 3mm×3mm openings plastic screen gave the highest amount of raw propolis yield. Although the current results highlighted the possibility of harvesting techniques and seasons for sustainable propolis production, more research is needed on quality, chemical composition, and market linkage.

Keywords: *propolis, zander hive, honeybees, harvesting technique, seasons*

INTRODUCTION

Propolis is a resinous substance collected by honeybees from leaf buds and exudates of trees and conifers. Propolis harvesting could potentially produce extra income for the beekeepers. Raw propolis can be harvested by scraping propolis buildup from hive parts, and hive entrances using specially constructed screens (Pereira *et al*., 2000). The composition of propolis varies dependingon the encircling plants. Variations in color, odor, and chemical compounds are observed reckoning on the source and also the season of gathering (Tsagkarakis *et al*., 2017). Moreover, some colonies appear to show a lot of avid behavior on the propolis collection. The quality and quantity of propolis made are coupled to seasonal differences, techniques of harvesting (Inoue *et al*., 2007; Toreti *et al*., 2013), geographical diversity, plant sources, and bee species (Mello and Hubinger, 2012). Factors that affect propolis production are the botanical origin of the resin, honey bee genetics, hive structure, food availability, environmental factors, and disease (Ruby *et al.*, 2021).Because propolis isn't usually held on in massive quantities within the colony, as is honey, beekeepers induce its production to get quantities that let its commercialization. One method for inducing the production of propolis is placing a plastic screen between the top and the nest, which stimulates the covering of the screen with propolis. The foremost usually used collection techniques employ special traps placed on top of a hive, below the covers, or next to lateral walls within the hives so bees don't combine wax with the propolis and no contamination happens throughout harvesting (Clay, 2002).

Propolis productivity can vary from 300 to 1,450 g/hive/year if proper production techniques are implemented (Souza *et al*., 2016). The common annual production of propolis per colony has been delineated as 10 to 300g. However, the yield depends on the climate, the forest resources, and the harvesting techniques (Pujirahayu *et al*., 2014). Abu Fares *et al*. (2008) and Ghisalberti (1979) rumored that annual productionis around 50-150 g per colony in European conditions and 50 to 600g for various honey bee races respectively. Manrique and Soares (2002) have reported that propolis production and honey production are positively correlated. Biotic and abiotic factors that favour the production of honey will also favor propolis production too. Six identified factors as being determinants to propolis production: the botanical origin of the resin, honey bee genetics, hive structure, food availability, environmental factors, and disease (Ruby *et al*., 2021). Simple induction of colonies for more propolis production in both traditional basket and Langstroth hives is possible; no significant effects on honey yield between induced and control groups for either hive type. Significant propolis yield variations within groups and between seasonswere also observed (Nuru *et al.*, 2002).

Introducing a propolis trap into the hive increased the amount and quality of propolis produced and also amount of honey produced increased as a result propolis production has a positive effect on honey production. Propolis production did not adversely affect hive size over the period, besides has a positive correlation between honey production and propolis production (Jager *et al.*, 2002). Propolis production was found to increase during times of honey production when harvestedusing a propolis trap. Honey and pollen stores were significantly and positively correlated with propolis production (Nicodemo *et al.*, 2013). Honeybees value more highly to fill with propolis firstly the top part of the hive, wherever the most temperature loss is occurring. Generally, temperature loss is a great force for honeybees to collect and store propolis. Slightly opened covers over the traps are used as a technique for this reason (Tsagkarakis *et al.*, 2017).

Propolis dissolved into a solutionis used as an ingredient in cosmetics, medicine, and natural preservatives (Krell, 1996). Studies also showed that propolis' composition has antifungal, antiviral, "antibacterial, antioxidant, anti-inflammatory, hepatoprotective, and antitumor" characteristics making it a more desired substance (Bankova, 2005). Components like minerals and flavonoids cause raw propolis to have these characteristics. Allergies, cancer, skin irritations, weakened immune systems, burns, and acne are treated by propolis products (Krell, 1996). While some medical uses are scientifically proved, alternative medical treatments are solely hypothesized and practiced by individuals who believe it to successfully treat their desires.

Uses of propolis have been discovered over time. Currently, propolis is mainly used to create an extract that is sold in a tincture at varying concentrations (Suran *et al.*, 2021). Propolis tinctures are sold for nearly seven times the price of honey (Dirina and Bugina, 2012). Propolis has a high commercial value of all hive products because of its potential use in apitherapy. Beekeepers who actively maintain more than 10 hives can make $2000-$3000 per year from honey alone. However, beekeepers that make other products can supplement their earnings by creating a more diverse market. By producing royal jelly, propolis, candles, and beeswax cosmetics beekeepers can increase profitability in some situations by 50% (Dirina and Bugina, 2012). Although there is no local market for propolis, products are sold to foreign markets. Propolis is the highest bee product sold to the international market next to honey and beeswax. The demand for raw propolis products has been increasing throughout the whole world (Bankova *et al*., 2000).

In Ethiopia beekeepers are generally unaware of the number of alternative products produced by honeybees, besides the normal functions associated with honey and wax production as a means of generating additional income from beekeeping. One of these relatively unknown products produced in the honeybee colony is propolis. In Ethiopia, propolis production is not reported in any part of the country (Kassa, 2021). In this paper, we give an overview of the available trapping methods for harvesting propolis usingdifferent harvesting materials.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Andassa Livestock Research Center (ALRC) in Amhara National Regional State (ANRS), Ethiopia. It is located south of Bahir Dar city and 22 km far on the way to Tis Abay. The center is situated at 11029'N latitude and 37029'E longitude at an altitude of 1730m above sea level. The mean annual rainfall is 1434 mm and the temperature ranged from 13.1 to 27.9^{o}C and humidity ranges from 95% throughout the rainy season to 35% during the dry season. The topography of the study area varies from gentle slope grassland to river valley plain. In general, the area is characterized by dark clay soil, which is seasonal water-logged.

Experimental Design, Treatment Setup, and Colony Management

Completely Randomized Design was utilized on 18 colonies of honeybees kept in Zander hives. Inspected honeybee colonies were selected based on the worker bee population with the total internal hive area (number of combs) covered by the honeybees. Chosen colonies were headed by similar in their strength, with 5 frames brood, 3 frames honey, 2 frames pollen,and covered with 8-10 combs of honeybees. Similar hive manipulation was carried out for each colony as needed. Honeybee colonies were randomly assigned to each of the treatments to produce propolis; thus each of the treatments was replicated six times and a total of eighteen improved frame hives colonized by Apismellifera L. honeybee were used for the experiment at a 2m distance from each other.

Each hive was placed on a wood hive stand 50 cm from the ground with the entrance of the hive being positioned in a northeast direction to protect the hive from the prevailing wind and rain. The honeybees during this study were settled within the same place and picked up resins within the same area; thus, they were exposed to identical plants or floral resources and weather conditions. Honeybees collect resins from various plant sources throughout the year. Harvesting of propolis was carried out in every three months interval (April-June, July-September, October-December, and January-March) for one year. The three propolis harvesting techniques used during propolis harvesting experiment were; 1mm×1mm square openings s mesh wire/Treatment 1, 4mm×4mm square openings s mesh wire/Treatment 2, and Plastic screen 3mm×3mm square openings/Treatment 3.

Propolis-harvesting materials placed with 8mm spacing under the lid (cover) of the hive were used to harvest propolis from the inside of the hives. In the attempt of closing the holes in propolis trap, honeybees plastered it with propolis. The plastered propolis was harvested and extracted.

Statistical Analysis

The propolis samples produced in three harvesting techniques and during four different periods were analyzed based on the least squares method. GLM tests were used to compare the propolis yields using SAS software.

RESULTS AND DISCUSSIONS

Effect of Treatments on Honeybee Propolis Yield

The annual average yields of propolis harvested using different propolis traps was 209.62 ±4.53 g, 221.15 ±8.68 g, and 253.58 ±3.16 g per hive using 1mm×1mm square openings mesh wire, 4mm×4mm square openings s mesh wire and 3mm×3mm square openings s plastic screen respectively. Relatively least amount of propolis was collected from 1mm×1mm square openings mesh wire followed by 4mm×4mm square openings mesh wire . The 3mm×3mm square opening splastic screen produced the highest amount of propolis with a highly significant difference (LSD = 24.743, P = 0.0003). But there was no statistical significance difference between Treatment 1 and Treatment 2.

The results showed the interference ofpropolis harvesting material used with the propolis yield. This is promising research result compared to the previous studies in Ethiopia which gives yield of 24.2 ± 22.5 g/hive (Nuru *et al.*, 2002). Abu Fares *et al*. (2008) reported that in Europe the annual productions of propolis per colony were around 50-150g. On the other hand, the average production of propolis per colony per year has been 10-300g; the large variation was due to the effect of climate, forest resources, and the trapping mechanism (Pujirahayu *et al*., 2014). The propolis yield wasalso varied depending on the breeds of honeybee; Sahinler & Gul (2005) reported that Caucasian (A. m. caucasica), Carniolan (A. m. carnica), Italian (A. m. ligustica), and Anatolian (A. m. anatolica) honeybee breeds yield about 27.34 g, 29.63 g, 26.12 g, and 39.67 g propolis, respectively. Similarly, hive type has also affected the yield of honeybee propolis (Nuru *et al*. 2002).The propolis production using frame hives and local basket hives within 19 months from *A. m. bandasi* was 24.2 ±22.5g and 12.7 ±8.6g, respectively. Only a few studies indicated a contrasting result (high yield) compared to our findings. One of the timeworn studies showed that annual propolis yield ranged from a minimum of 50 grams to a maximum of 600 grams for different honey bee races (Ghisalberti, 1979). Higher yields were also reported in other studies ranging from 300 to 1,450 g/hive per year (Tsagkarakis *et al*., 2017). The annual propolis yield in each treatment is presented below (Figure1).

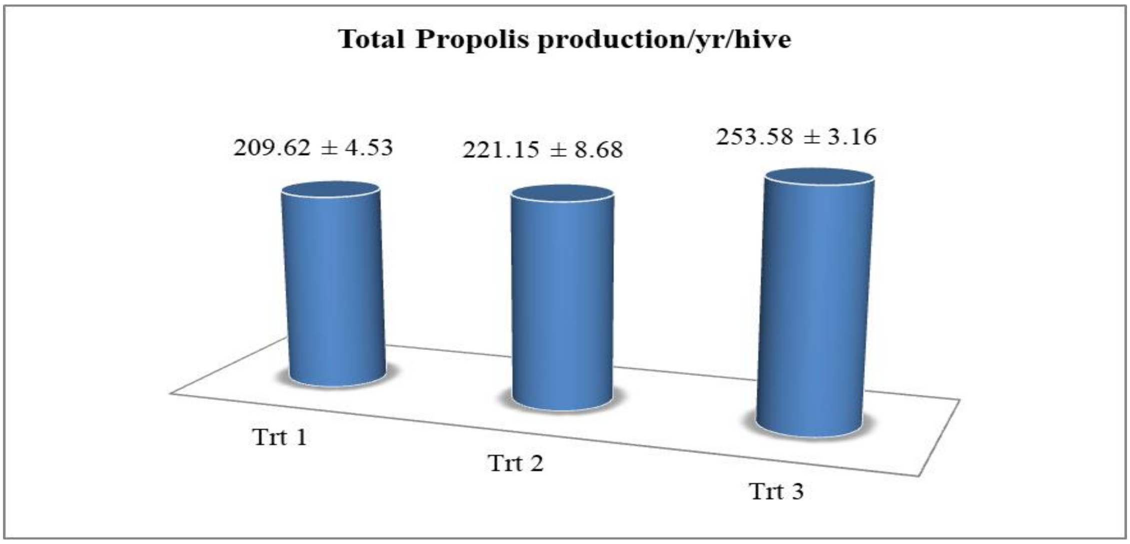

Figure 1. Total propolis production per year using different techniques

Effect of Collection Period on Honeybee Propolis Yield

The effect of different collection months on the propolis collection is presented in Table 1. The averageyield of 52.72 ±3.06g, 54.49 ±1.40g, 64.60 ±3.85g, and 56.31 ±3.38g of propolis were obtained from April to June, July to September, October-December, and January to March respectively. The amount of propolis harvested has significantly varied monthly (LSD = 8.6516, p = 0.0393) and relatively more propolis was harvested between October-December.As the production period affects propolis production, the highest yield wasobtained in late autumn and early winter (Jager*et al*., 2002; Karlıdag & Genc, 2007; Abu Fares *et al*., 2008). Kiziltas & Erkan (2020) reported that the highest propolis production was observed in the post-season /the season after the honey harvest. The amount of propolis produced is linked to seasonal variations (Toreti*et al*., 2013). Significant propolis yield variations were observed between different months (Nuru. A *et al* 2000). In rainy seasons, *A. Mellifera* and other insects show an increased attraction to plants, resulting in a collection of greater amounts of resin and also some plants produce more resins in certain periods (Bastos *et al*., 2011).

There was a decrease in the amount of propolis collected from April to June for Treatment 2 & Treatment 3. A little increase occurred from July to March. But a large increase in the amount of propolis collected was noticed from October to December in the two treatments. The yield of Treatment 1 was opposite to the two treatments. For Treatment 1, a large yield was recorded from April to June. However, the total mean yield was high from October-December as food availability and environmental factors directly affect the propolis production (Ruby M. *et al.,* 2021). Abu Fares *et al*., 2008, reported that propolis production decreased from September to December; it was different from thisresult may be due to difference in botanical origin of the resine (Ruby M. *et al.,* 2021).

Table 1: Effect of the collection period on honeybee Propolis yield

Types of traps	Collection Periods				
		April-June	July-September	October-December	January-march
	N	LSM	LSM	LSM	LSM
1×1mm openings Mesh wire	6	68.44	58.05	43.65	39.48
4×4mm openings Mesh wire	6	43.72	47.38	71.23	58.82
3×3mmopenings plastic Screen	6	46.00	58.03	78.92	70.63
Total	18	52.72^{b}	54.49^{b}	64.60^{a}	56.31^{ab}
SE		3.06	1.40	3.85	3.38

LSM = Least square means, LSD = 8.6516, CV= 22.80721, Means with different letters in the same rows are significantly different ($p<0.05$).

Some plants can produce resins that contain different mineral content (Huang, 2014). The absorption of nutrients in the soil varies according to climate conditions, the requirements of each plant species, and their development (Bankova *et al*., 2016). In addition, as pollen represents approximately 5% of the final composition of propolis; the pollen content in propolis could interfere with the study results (Huang *et al.*, 2014). Due to the botanical origin the pollen present in propolis may vary (Freitas *et al*., 2011). Compositely, the mineral composition of propolis can be influenced by these factors. Therefore, the results obtained herein could, possible differ in the resin collected due to plant diversity or the preference of honeybees for a certain plant species during a specific season.

Interaction between Treatments and Months on Propolis Yield

The effect of the interaction between treatments and different months on propolis collection is presented in Figure 2. The monthly production varies from treatment to treatment. Treatment 1/ mesh wire 1×1mm square openings s collect a high amount of propolis from April-June; whereas Treatment 2 and Treatment 3 collected a high amountof propolis yield from October-December. This shows treatments by themselves depend on the collection period and the yield variation was highly significant. Interaction combination of 3×3mm square openings s plastic screen X October to December produced the highest amount of propolis with a mean of 78.92 ± 2.81g.

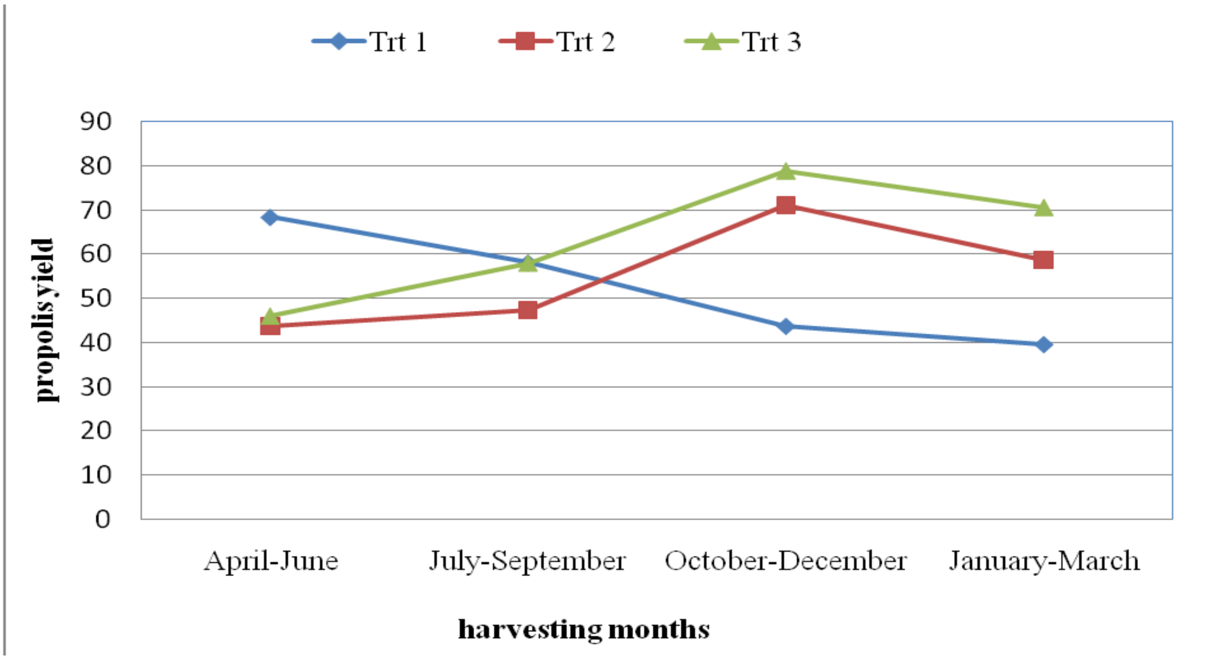

Figure 2. Treatments and months effect on yield of honeybee propolis

CONCLUSION AND RECOMMENDATION

From the current study, it was observed that propolis harvesting techniques and collection seasons variations had significantly affected the production of propolis. The 3×3mm square openings plastic screen during October-December produced the highest amount of propolis. In general, the study showed a promising result from each harvesting technique and collection seasons as compared to the previous studies.

Even though propolis can be harvested at any season throughout the year using one of the three trapping techniques from October to December using a 3×3mm plastic screen gives a high propolis yield as compared to other combinations. Therefore, beekeepers are advised to collect propolis during the peak flowering season using a 3x3 plastic screen. The current results highlighted the possibility of propolis harvesting using different techniques. This result need to be demonstrated at beekeepers level. Moreover, further study is required on the quality, chemical characteristics, and use of propolis for export in order to ensure sustainable production.

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Identifying and Evaluating the Effect of Poisonous Plants to Honeybee Colonies in East Amhara, Ethiopia

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ABSTRACT

The study was conducted to identify and evaluate the effect of poisonous plant on honeybee colonies in Eastern Amhara. Two beekeeping potential zones, South Wollo and Waghimra were selected purposively. Using multistage sampling technique a total of six districts and 18 local kebeles were addressed in this survey. A total of 225 sample beekeepers selected purposively based on their experience in beekeeping and data was collected through interview. The result indicated that about 15.6% of the respondents had awareness about the existence of honeybee poisonous plant in their locality. According to the present finding a total of 11 plant species were identified as a poisonous plant. These include Helianthus anus, Agave spps, Aloea spps, Parthenium hysterophorus, Euphorbia tirucalli, Ranunculus mustifidus, Euphorbia spps, Guizotia scarab, Acacia saligna, Lanthana camara, and Nicotiana glauca. The effect of the poisonous plants might be either direct physical damage to honeybees or causing internal abnormality which can leads to death. Some plants were repellent and honeybee killer while others weakened and responsible for the dwindling of colonies during their flowering period. The other plant species were reported to cause vomiting, allergic, headache, diarrhea, and bad taste to the consumers by irritating consumers' throat. The identified poisonous plant species were located abundantly in the home garden, fence and watershed areas of the study area where apiaries are existed. Though these plants had no value to the honeybee, beekeepers did not try to remove the plants from the area were honeybee colonies are available. Moreover, by this survey the identified poisonous plants may or may not be poisonous plant unless checked by critical investigation of chemical analysis or by feeding of honeybees. Hence it could be recommended that a detailed chemical analysis of these identified plants should be conducted to devise and implement appropriate control and prevention measure.

Keywords: *Beekeepers, Eastern Amhara, Honeybees, Poisonous plant*

INTRODUCTION

Honeybees are well known for their commercial products playing increasing roles in income generation, healthy food, and medicinal values (Nuru and Hepburn 2001). However, the recent reduction of the bee population rises from different angles and became great concern for global food security and environmental stability. It is multistage factors that lead to the decline of the bee population worldwide. An outbreak of pathogens and pests, exposure to pesticides, shortage of forage, and global climate change are the known factors commonly responsible for the loss and death of honeybee colonies (Henry et al., 2012; Potts et al., 2010; Desneux et al., 2009; 2007; Adler, 2000). Exposure to poisoning substances from natural and chemical is considered a prime cause of honeybee deaths and colony reduction. It is difficult to differentiate between plant and pesticide poisoning; some reports describe that honeybee death following visits to some plant species (Jaeger, 1961; Crane, 1978). This can be supposed to be the biochemical effects of some active ingredients in their pollens and nectars that may be toxic to bees and other humans and animals.

Accordingly, recommended plant species such as Aesculus californica, Clematis hirsutar, Clematis simensis, Croton macrostachyus, Datura stramonium, Euphorbia abyssinica and Justicia schimperiana were reported as poisonings plants (Nuru and Hepburn 2001; Adler 2000; Majak et al., 1980; Mussen, 1979). Honeybees occasionally encounter sources of such toxic nectar, but the predominating nectar sources provide great dilution of any toxic nectar collected. These specific stress conditions seem to occur repeatedly in most cases of poisoning and they affect the dose of poison the bees receive. When good nectar source plants are scarce to honey bees in the surrounding area, especially soil moisture, reduce good nectar sources plant became to reduce the bee is forced to forage from the poisonous plants because it is the only food available. Most of those poisonous plants' symptoms are limited to the blooming period. If the poison is in the pollen, the symptoms may stay longer as long as the pollen remains in the combs. There is no clear-cut method for differentiating between plant poisoning and pesticide poisoning. The effects of plant poisoning are usually more gradual and last longer than the effects of pesticide poisoning. Plant poisoning usually occurs in the same geographical areas at the same time each year, whereas pesticide poisoning is indiscriminate (Jaeger, 1961; Crane, 1978).

In different countries, plants that are poisonous to honeybees and man are identified and important cautions are exercised. In our country, there are many oral reports about plants that are poisonous to honeybees and also honey which is poisonous to man. Therefore poisonous plants that have economic importance to honeybees in the Wag-himra and south Wollo zones of the Amhara Region should be investigated and studied to take the right cautions. With these backgrounds the objectives of this study was to identify and prioritize important honeybee poisonous plants and determine the distribution and to generate baseline information in minimizing these poisonous plants.

MATERIALS AND METHODS

A survey questionnaire was prepared to comprise mainly of the types of poisonous plants. In the present survey two beekeeping potentials zones of Eastern Amhara (South wollo and Waghimra) were selected and addressed in data collection. From each zone, three districts and from each district three rural kebeles were selected through multistage sampling approach. Thus, a single household respondent is used as a sampling unit, and the total households included in this study were determined according to the formula given by Yamane (1967) with a 95% confidence level. The respondents were selected based on their experience in beekeeping, knowledge of locally available honeybee forages, and honeybee colony ownership. Hence a total of 225 respondent beekeepers were selected from total beekeepers.

$n = N/1+N (e) 2$

Note, n=Sample size; N = population size; e=the desired level of precision.

Data Analysis

The social data was analyzed using descriptive statistics (percentage, frequency, mean, and standard deviation) with SPSS Version-23. The result was presented in table form.

RESULTS AND DISCUSSION

In the present study, the concept of poisonous plant for honeybees from the beekeepers mind and experience is mentioned accordingly. Hence 15.6% of respondents reported the presence of poisonous plants and 84.4% of the interviewed beekeepers said no poisonous plants in their locality. According to the interviewed beekeepers the existence of poison for honeybees and/or honey resulted from the nectar and pollen of the source plant. In other ways some plants reported as a poisoned may cause damage of honeybees. Moreover in the study area as beekeepers argument, some plant species which can cause honeybee colony lose by their poisonous nature on their pollen and nectar.

According to the respondents, a total of 11 poisonous plant species were identified during the survey (Table 1; Figure 1). Hence, Helianthus annuus and Agave spps were produced after which the honeybees get stuck and damaged and sometimes exposed the foragers to birds attack. Lanthana camara and Nicotiana glauca plant species was repellent and honeybee killer while Acacia saligna plant weakened and responsible for the dwindling of colonies during their flowering period. The other plant species like Euphorbia spp, Partheniumhy sterophorus, Euphorbia tirucalli, Aloea berhana, and Ranunculus mustifidus were reported to cause vomiting, allergic, headache, diarrhea, and bad taste to the consumers by irritating consumers' throat while consuming the honey from these sources.

Some of the identified poisonous plant in the present study was reported in different parts of the country by different authors Keralem (2002) reported Cassia slamea, Croton macrostyches, Aloea brahana, Ziziphus macronata, Phytolacica dodecandra and Suspania spps as plants toxic to honeybees at Amaro and Enebse districts. Tewodros (2010) also reported the existence of toxic plants like Helliantus anus, Verbena officinalis, and Euphorbia tirucalli in Sekota district. Assemu (2013) also reported Crton macrostachy, Hellianthus annus, Ephorbia spps, Simiza, Justitia schemperina, Acacia decurrens were the major honeybee flora known by their poisonous effect in western Amhara.

Table 1. Plants known for their poisoning effect, their flowering month, effects and symptoms to bees and humans

No	Local name	Scientific name	Family name	Flowering month	Plant type	Effects on	Symptoms and causes
1	Bahir suf	HelianthusHelianthus anus	Asteraceae	Oct-Nov	Cultivated crop	Bees	Produce a tar which bees get stuck
2	Chiret	Agave spps	Agavaceae	Dec-Apr	Shrub	Bees	Produce a tar in which bees get stuck and exposed to bird attack
3	Eret	Aloea spps	Aloeaceae	Sept-Nov	Shrub	Human	Irritating the throat
4	Kinche	Parthenium hysterophorus	Asteraceae	Year-round	Herb	Human	Irritating the throat
5	Kinchib	Euphorbia tirucalli	Euphorbiaceae	Nov	Shrub	Human	Irritating the throat
6	Kuliza	Ranunculus mustifidus	ranunculus mustifidus	Sept-Oct	Shrub	Human	Irritating the throat
7	Kulkual	Euphorbia spps	Euphorbiaceae	May-June	Shrub	Human	Irritating the throat
8	Mech	Guizotia scaraba	Poaceae	Sept-Nov	Herb	Human	Bitter taste
9	Saligna	Acacia saligna	Fabaceae	Oct-Nov	Tree	Bees	Weakened colonies
10	Yewof kollo	Lanthana camara	Verbenaceae	Year-round	Shrub	Bees	Repellent
11	Tobbacco	Nicotiana glauca	Nicotiana glauca	Year-round	shrub	Bees	Repellent and bee killer

In the present investigation the effect of poisonous plant was in both live bees and the honey that they produced and finally it could be poisonous for humans. In this regard, honeybees are poisoned from the pollen and the nectar of the plant and/or direct physical damage during flower visitation or/and cause paralysis, abnormality and even death. According to this 44% of the respondent said that the symptom of the poisonous plant was sticking their wings and legs of honeybees while 16% of the interview beekeepers said poisonous plant could have cause a diarrhea (Table 2). Moreover this study showed that knowledge of beekeepers about the effect of poisonous plants on honeybees was limited unless designed poisonous plant validation experiment was done.

Table 2. Symptoms of the poisonous plant shown in honey bees and humans

Symptom	Frequency	%
Paralysis	9	4
Diarrhea	36	16
Vomiting	9	4
Irritating	20	9
Allergic	20	9
Headache	9	4
Sticky	99	44
Bad taste of honey	23	10

Even if the main source of pollen and nectar of honeybees is from the flower part of the plants, honey bees may contacted with the leaf, bark, and latex of the flowering plants. During this the poison part of the plant might be have damage and/or death. In this regard, 58% of the respondent believe that mostly the poisonous part of the plants was their flower and the bees were forced to exploit the nectar and pollen from those poisonous plants during the dearth period when the best honey bee plants were absent in the locality. According to the beekeepers, the location of these poisonous plants was mostly in and around home garden, fences and watershed areas of the study area and therefore honeybee colonies are presented nearby these plants and highly exposed for damage (Table 3).

Table 3. Location of the poisonous plants restricted

Location	Frequency	%
Home garden	31	70
Farmland	5.8	13
Fence	32.2	72
Watershed area	27	61
Other	4	9

Concerning to the measure those beekeepers taken to control honeybees from the damage causing from this poisonous plants, most (91.1%) of the beekeepers said no took any measure on it (Table 4). Because they said this identified plants had advantages as fence, water and soil conservation purpose and some of them are used for animal feed and fuel. In this regard they did not try to remove on their locality near to their backyard apiary.

Table 4. Measures taken to prevent colonies from getting poisonous plants

Measures	Frequency	Percent
Burning	8	3.6
Weeding	11	4.9
Placing the hive far from the poisonous plant	1	0.4
No measure taken	205	91.1

Kulkual

Ager atfi

Parthenium hysterophorus

Acacias aligna

Azadirachata indica eem

Figure 1. Photo of the some poisonous plants

CONCLUSION AND RECOMMENDATION

The survey results indicated that most of the respondents did not know the presence of poisonous plants rather few experienced beekeepers had awareness about this plants. The poisonous plant might have either direct physical damage to honeybees or causing internal abnormality which can leads to death. Some plants were repellent and honeybee killer while others weakened and responsible for the dwindling of colonies during their flowering period. The other plant species were reported to cause vomiting, allergic, headache, diarrhea, and bad taste to the consumers by irritating consumers' throat. The identified poisonous plant species were located abundantly in the home garden, fence and watershed areas of the study area where apiaries are existed. Duo to additional advantages of the plant species beekeepers did not try to remove the plants from the area were honeybee colonies are available. Moreover by this survey the identified poisonous plants may or may not be poisonous plant unless checked by critical investigation of chemical analysis or by feeding of honeybees. Hence it could be recommended that a detailed chemical analysis of these identified plants should be conducted to devise and implement appropriate control and prevention measure.

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Response of Apis Mellifera Monticala Honeybee Race to Different Queen Rearing Techniques in Waghimra, Ethiopia

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ABSTRACT

The study was carried out to investigate the responses of local races of honeybees to different queen-rearing techniques. A total of 15 local races of honeybee colonies in standard Zander hives were assigned to Splitting, Miller, Overcrowding, and Grafting techniques of queen rearing using a randomized complete block design (RCBD). The experiments were done during the main flowering periods of the year. Accordingly, splitting technique of queen rearing gave significantly more number of queens than miller and overcrowding ($P<0.05$). The grafting method had no response in producing queen cells. It was also found that there was a significant difference ($P<0.05$) between the Splitting and overcrowding methods but not with the miller method. A mean of 10.4, 7.4 and 5.6 queens have emerged in splitting, miller and overcrowding techniques, respectively. As the result of the present study, to rear honeybee colonies, splitting was found to produce more queens and suitable techniques for the local bees and conditions. It was also found that 1/4th of multiplied honeybee colonies were absconded and 11.7kg of honey was harvested in the same year of splitting while in the next year after splitting it was recorded 13.8kg of honey. Therefore splitting technique is the best for the Apis mellifera monticola race and can be used in the area having in mind that dearth period supplementation and proper colony management are the basic activities to be carried out.

Keywords: *Apis mellifera monticola, honeybees, splitting, rearing, Queen*

INTRODUCTION

The basic sources of honeybee colonies for beekeeping beginner farmers around the Wag-Lasta area are those wild bees (feral bees) found in areas where human rich is limited due to different reasons. Since artificial queen rearing was not practiced and reported before in the area, beekeepers are expanding their apiaries and number of bee colonies simply by following the bees' natural reproduction pattern. At present, due to various factors, the honeybee colony population is in a state of continuous decline. Absconding is also becoming a major problem in beekeeping development and is known to be a peculiar characteristic of the area. As the result, it is becoming more difficult to obtain adequate swarms every year to start and expand an apiary and beekeeping practice (Nuru and Dereje, 1999). In most cases, farmers in the area are also complaining that they are facing a serious shortage of honeybee colonies. Moreover, there is a high demand for honeybee colonies mainly due to the involvement of agricultural offices, individuals, and different NGOs in beekeeping development. Consequently, the price of honeybee colonies is becoming too costly for beekeepers to expand their honeybee farms and engage in sector.

Beekeepers in the area and other parts of the country believed that the rapid deforestation of honeybee plants around the area is the primary reason for the diminishing number of honeybee colonies. Moreover, the drought existed for many years due to the shortage of rainfall is the other reason to aggravate the problem (Abebe et al., 2014). In this area, where reproductive swarming tendency is low, one of the major problems of apiculture is obtaining swarms either to start or to increase the existing stock. Thus, evaluation of different queen-rearing techniques in the local honeybee race would be very important and of these, splitting, overcrowding, miller, and grafting queen-rearing methods have been rated as better in their simplicity for local conditions. However, honeybees have their breeding strategies which are very dependent on the potential of the queen and the general activeness of the worker bees in a colony (Laidlaw and Eckert, 1962). These days, man has highly involved in facilitating and managing the breeding strategies of the colony (Snelgrove, 1981). Even though the commercial lifespan of a honeybee queen is two years, beekeepers in the study area are not replacing their queens at this stage; rather they merely left the colony to replace the queen after she ends her actual life span through the natural queen-rearing process (Graham, 1992; Jim and Jeanne, 1984). Nevertheless, having an old queen could result in the decline of the colony's productivity since the old queen couldn't administrate the colony efficiently (Snelgrove, 1981). Thus, mitigating the satisfaction of the increasing demand for the honeybee population by different newly emerging stakeholders through increasing the declining honeybee population using artificial queen-rearing techniques is very critical at this moment (Jim and Jeanne, 1984). This led to evaluation of different queen-rearing techniques in the local honeybee race concerning honeybee colony multiplication in frame hives under apiary sites. And the objective of this study was to evaluate the performance of Apis mellifera monticola honeybee race to different queen-rearing techniques.

MATERIAL AND METHODS

Experimental Management and Design

A total of 15 Apis mellifera monticola honeybee colonies were arranged for the experiment purpose at the Jinkaba beekeeping site. The colonies were then transferred into standard frame hives and arranged in RCBD design by considering honeybees' population strength with five replications with enough space between colonies. Regardless of the experimental honeybee colonies used, other basic management practices were made reasonably uniform.

Treatment Setup

The queen-rearing methods were considered as a treatment during the experimental period. Hence three queen-rearing techniques (treatments) were evaluated in this experiment. The techniques were:

Splitting: Combs with eggs, young larvae, pollen, and honey were put in the supper of the hive and rearranged. A Queen excluder was placed in between the bottom and the supper to separate them. Splitting of the colonies was done the next day carefully by pushing many worker bees to be in the queen-less supper (above the queen excluder) using smoke through the entrance. Then the queen rights splits were moved 300 meter away from the original place, while the queen less was left in their original place. On the third day of splitting, inspection was carried out to see the raising of queen cells. Then the number of queen cell built was recorded. On the 9th day of splitting when the queen pupae were ripe, the mature queen pupae were recorded and harvested, and equal numbers of nuclei colonies were formed.

Miller**:** The foundation sheet was printed and fixed to standard frames. The frames were placed between the two brood nests in the best colony by removing the already existing brood. After about a week the comb was taken from the colony and the lower edge of the comb was trimmed in a zigzag fashion to expose several larvae/ eggs about to hatch toward the bottom edge of the comb and given to a queen less colony. The recipient colony was De-queened 24 hours before receiving the trimmed combs (After Nine or ten days sealed queen cells were harvested, kept in the queen cages and return to the same colony).

Overcrowding: The idea is that when there are a lot of bees, the sense for the queen was decreased so overcrowding may create superseded queens. So colonies assigned to this technique were overcrowded by reducing the supers as well as by preventing spurring when they required additional space. The inspection was made nine days after removing the super to observe the construction of queen cells. The technique can be effective during the flowering period when there is a high population of bees and abundant forage (Nuru and Dereje, 1999).

Data collection and analysis

The collected data were the number of queen cells produced, the number of queens that emerged, the adaptability of newly established honeybee colonies, and the honey yield of the mother and daughter colonies. In data was analysed with Analysis of Variance (ANOVA) for Random Complete Block Design (RCBD) using R studio and least significant difference (LSD) values were worked out to determine the significance of differences among the mean values at a 5% level of significance.

RESULTS AND DISCUSSION

Queen Cell and Queen Production

From the experiment, the A. mellifera monticola colonies assigned to splitting, miller, and overcrowding techniques gave an appropriate number of emerged queens. This, in turn, has elaborated that A. mellifera monticola colonies have the potential to the available queen-rearing techniques and are active to understand the replacement of missed queens rather than absconding in case of death of queens in the area. The total number of queen cells developed from mother colonies, during the first 6 – 9 days, has indicated that in from A. mellifera monticola colonies more queens could be developed, and have a possibility of having more colonies split from a single mother colony in the area.

In the present experiment Apis mellifera monticola honeybee race was highly responded to splitting queen rearing method so that in a single mother colony a mean of 10.4±3.57 new daughter queens had emerged. While in miller and overcrowding methods the local A. mellifera monticola produced 7.4±1.34 and 5.6±1.67 virgin queens, respectively (Table 1). Hence splitting and overcrowding queen-rearing techniques had a significant difference ($P<0.05$) in queen cell production and queen emergency while splitting and miller, and miller and overcrowding had no significant difference at $P<0.05$ (Table 1).

The number of queen cells constructed during brood-rearing season was not showed statistically difference among honeybee colonies rearing techniques. While the number of queens emerged during brood-rearing season was showed statistically difference ($P<0.05$) among honeybee colonies queen-rearing techniques. Moreover, the number of queens produced through splitting was higher (10.4±3.57) than miller (7.4±1.34) and overcrowding (5.6±1.67) techniques (Table 1). Therefore, for these facts rearing queens using splitting was better in queen rearing response of Apis mellifera monticola than overcrowding and miller techniques. This result was in line with Abebe et al. (2014), verification experiment on splitting technique for Apis mellifera monticola who stated an average of 8.6 queen cells were developed through the splitting of Apis mellifera monticola. The maximum number of queens produced by splitting, miller, and overcrowding are given in Table 1. Hence from this, it is observed that splitting queen rearing technique was the best in achieving the maximum number of queens in mass honeybee colony multiplication.

Table 1. Number of queen cells produced and queens emerged in different queen-rearing methods

Queen rearing methods	No. of queen cells produced			No. of queens emerged		
	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum
Splitting	13.4±4.04[a]	7	17	10.4±3.57[a]	7	15
Miller	9.6±2.30[ab]	7	13	7.4±1.34[ab]	6	9
Overcrowding	7.6±1.86[b]	5	10	5.6±1.67[b]	3	7
Overall mean	10.2±3.65			7.8±3.03		
F-value	4.218			5.8997		
p-value	0.056			0.026		

Treatments with the same letter are not significantly different at Alpha: 0.05; DF Error: 8

Adaptability multiplied honeybee colonies

The experiment confirmed that out of the total colonies in (mother and daughter), about 33.3% (1/3rd) have absconded 6 months after establishment by miller and overcrowding methods, and about 26.7% of multiplied honeybee colonies with the splitting method was absconded (Figure 1). In the Wag-himra splitting verification experiment, of the total 30% and 50% of mother and daughter colonies were absconded after splitting (Abebe et al., 2014). The difference in absconding rate might due to the initial size of worker bees, implies that queens produced by splitting were responsible for quality queen production having strong colony build up capability.

In present experiment in all queen-rearing methods, the rate of absconding of experimental colonies (mother and daughter) was considered to be high. It has been understood that a strong dearth might be brought pest infestation harder and resulted in considerable colony absconding. Even in areas where honeybee feed shortage is of paramount importance and the prevalence of long dearth periods and absconding is a peculiar character to the beekeeping sub-sector, colony multiplication could be an activity to be carried out and used as a means of alleviating serious colony shortage. Of course, colony management is the most and foremost important thing that we have to understand.

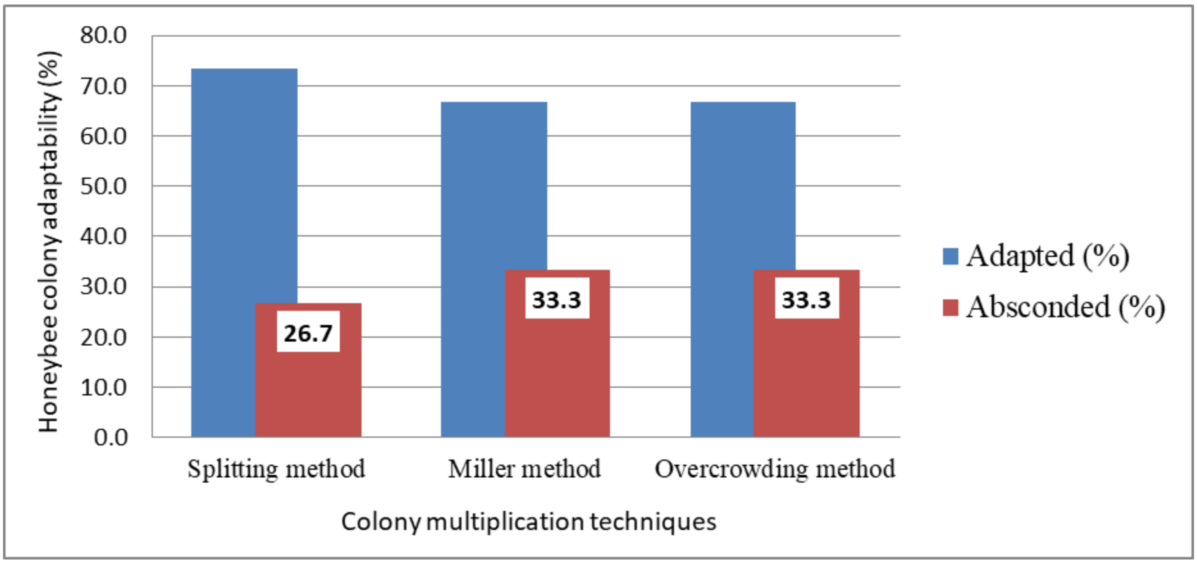

Figure 1. Honeybee colonies' adaptability after newly established honeybee colonies

Honey yield of multiplied honeybee colonies

Regarding honey yield, honey produced from mother colonies after multiplication has revealed that honey production in the same year of multiplication was impacted more. As indicated (Table 2) honeybee colony had a honey yield of 11.7kg in the same season of splitting (year 1), then increase to 13.8kg in the coming year. Hence the result showed that about 14.8% of honey yield difference was observed in the first and second years after multiplication. Therefore, present experiment has confirmed that, even if multiplication could decrease honey production at that particular period, colonies were able to compensate in the coming honey flow season and afterward. Honey yield at year 1 and year 2 represents the honey yield of mother colonies in the first and second year after splitting, respectively (Table 2).

Table 2. Honey yields of honeybee colonies immodestly after multiplication and after a year

Queen rearing methods	Honey yield (Kg)		Honey yield difference (%)
	Year 1	Year 2	
Splitting	12.2	15.8	22.8
Miller	11.8	12.4	4.8
Overcrowding	11	13.2	16.7
Overall mean	11.7	13.8	14.8

CONCLUSION AND RECOMMENDATIONS

Apis mellifera monticola colonies found to give an appropriate number of queens under different queen-rearing methods. This, in turn, has elaborated that A. mellifera monticola colonies have the potential for queen rearing techniques and are active to understand the replacement of missed queens rather than absconding in case of death of queens in the area. In the present experiment, three fourth of daughter colonies were able to adapt to the local environmental conditions of the area while one-fourth absconded. Splitting queen rearing has shown 14.8 % reduction in immediate honey yield but it could have compensated by the next honey harvesting season. From this study, splitting queen-rearing technique is suggested as the best queen rearing technique in that the maximum number of queen cells emerged from the starter colonies of Apis mellifera monticola race. Based on the results of this experiment, it can be recommended that;

- Colony multiplication using the splitting queen rearing technique can be used considering dearth period supplementation and proper colony managements as the basic activities to be carried out.
- Sufficient training on practical queen-rearing techniques and preconditions should be given due attention during colony multiplication in the area.
- Scaling up could be done through different beekeeping farmers and small interest/business groups in different localities across existing production systems

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Evaluation of locally formulated feed on the growth performance and survival rate of Nile Tilapia (Oreochromis niloticus) in an aquarium

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ABSTRACT

A 90-day feeding trial was conducted to provide a nutritionally optimized feed formulated from locally available feed ingredients and to determine its effect on the growth and survival of Nile tilapia (*Oreochromis niloticus*). Three test diets were prepared from soybeans (*Glycine max*), Sweet Lupine (*Lupine luteus*), and cowpea (*Vigna unguiculata*) and compared with a commercial diet. These include. A total number of 168 mixed-sex *O. niloticus* fingerlings weighed on average 17.23 ± 0.32g were divided into 3 groups in triplicates and stocked in 12 rectangular glass aquariums (90 x 45 x 44 cm) or 180 litres in a recirculating system free from a bottom substrate. Fourteen fish were stocked per aquarium and fed with 5% of their body weight twice a day at 9:00 AM and 3:00 PM. The fish were sampled every two weeks and mortality was recorded daily. Our results showed the existence of a significant difference (P <0.05) in the growth rate of *O. niloticus* under different tested diets. The study indicated that locally available nutrients can replace up to 100% of commercial feeds without adversely affecting the growth performance and percentage survival of *O. niloticus*. Cowpea meal-based feed in this experiment had shown the best performance.

Keywords: *Glass aquaria, Growth, Lupine luteus, Soybean meal, survival*

INTRODUCTION

Fish is an important source of food for many, if not all, of the world. Over the past five decades, global per capita fish consumption has increased from 9.0 kg in 1961 to 20.2 kg in 2015 (FAO, 2018). This increasing demand for protein is attributed to various factors such as overpopulation explosion, health benefits derived from consuming fish and aquaculture development (Rosa *et al*., 2007). Freshwater and marine aquaculture products are increasing continuously unlike the capture fisheries production with slowed and steady supply of fish products (FAO, 2021). Aquaculture is believed to be one of the key solutions to global food security by increasing fish production (HLPE, 2020).

In the world, many tropical and subtropical countries mostly preferred culturing Nile tilapia (*Oreochromis niloticus*) fish species. Nile Tilapia is generally considered to be an economically viable freshwater fish species in terms of rapid growth, breeding and low feed conversion efficiency, high resistance to disease and harmful water conditions, and consumer acceptance (Munguti *et al***.,** 2014; Sousa *et al*., 2013). Tilapia production in developing countries cultured in semi-intensive freshwater ponds with low stocking densities, fertilization, and /or supplementary feeding mainly cereals brans, however, the recent intensification of aquaculture practices requires the use of well-formulated feeds (Tacon, 1993; El-Saidy *et al*., 2005). Fish feed is important in fish farming and covers more than 60% of operating costs (Munguti *et al*., 2009).

Decreasing the price of fish feed helps to reduce the cost of production. The fish feed used to grow fish in Ethiopia is produced by Alema Koudijs Animal Feed Processing PLC. The prior purpose of the company was to produce chicken feed but later, they began producing pellets for fish. However, the price is high because the company imports some of the ingredients which are not locally available. There is no locally based aquaculture feed manufacturers and also no feed producer companies for fries and fingerling. One of the major challenges in the aquaculture sector is to reduce feed costs and produce high-quality feed for all growth stages. Fish feed research plays a key role in promoting the aquaculture sector to support sustainable aquaculture development. Thus, the current study was designed to provide a nutritionally well-formulated feed for Nile tilapia from locally accessible feed ingredients, and to determine the effect of formulated feeds on the growth and survival rate of Tilapia larvae in glass aquaria.

MATERIALS AND METHODS

A total of 168 mixed-sex Nile tilapia fingerlings with an average initial body weight of 17.23 ± 0.32g and an average total length of 10.04 ± 0.07 cm were obtained from BFALRC. The length of each fish was measured to the nearest one mm using a measuring board and also the weight of individual fish was taken using an OHAUS Switzerland-made electrically powered SKX2201 model electronic balance with a precision of 0.1 g. Prior to the experiment, fish were stocked in 3 glass aquaria (0.25 m^3) in the center indoor recirculating system and acclimatized for seven days during this time they were offered the control diet.

This experiment was conducted for 90 days from October to December 2021. At the beginning of the experiment, fish were starved for 24 hrs. Fish fingerlings were assigned randomly using the lottery method into 12 rectangular glass aquaria (90 x 45 x 44 cm) (180 l) recirculating system free of a bottom substrate at a stocking density of 14 fish per aquarium. The four feed treatments (three test and one control) assigned to each aquarium randomly in triplicate. Water from the Lake Tana was filtered in a filtration system before being used and the water was recirculated.

The fish were grown under a temperature range of 23-25.8 ºC controlled by an electrical thermo-regulating device (Tetratec HT 100 heaters). Dissolved oxygen was kept at 7-8 mg/ l with continuous aeration using an air pump (Hailea model HAP 200 Hi-blow Diaphragm) at an air flow rate of 200 L/min as part of the recirculating system. Each aquarium was provided with oxygen from the system through an air tube fitted with air stones attached at the tip of the tube. Every two days, waste was siphoned from each aquarium and 5-10 l of rearing water was replaced with water taken from Lake Tana filtered and UV-treated within 24 hours. Physico-chemical parameters such as temperature, dissolved oxygen (DO), salinity, TDS, conductivity, and pH were monitored weekly using the HANNA Multiparameter probe model HI 9829.

Experimental design and feed processing

The experiment was designed in a completely randomized design of four diets replicated three times and conducted in a recirculating indoor aquarium. Totally, 168 *O. niloticus* were randomly divided into 12 groups, weighed, and transferred to glass aquaria. Fingerlings were acclimatized for one week by feeding commercial floating fish feed prior to distribution. Initial stocking densities remain within recommended levels to avoid physiological stress on tilapia which is < 18 g / 180 lit aquaria (Liti, *et al*., 2005; Manduca *et al*., 2020). During the experimental periods of 90 days, the fish were fed with 5% of their body weight twice a day, at 9:00 Am and 3:00 pm.

Diet formulation for feeding experiment

Three dietary treatments with a control group were used. The choice of ingredients was based on the content of essential dietary nutrient, their availability and price. The experimental feeds were prepared using fishmeal, maize (*Zea mays*), wheat bran (*Triticum aestivum*), Noug (*Guizotia abyssinica*) cake, soybean (*Glycine max*), Sweet lupine (*Lupine luteus*), cowpea

(*Vigna unguiculata*), premix, and oil. The control feed (Alema koudijs feed plc) was purchased from the manufacturer at Debre Zeit, Ethiopia.

Proximate analysis of the ingredients except the fish meal used in the experiment was taken after Shigdaf Mekuria (2018), whereas the fish meal proximate analysis was done by the National Fishery and Aquatic Life Research Center (NFALRC) feed laboratory according to AOAC (1990) (Table 1). The proportions of the feedstuffs were calculated using the Pearson square method in an excel sheet (Table 2).

Table 10. Proximate composition of local ingredients (Shigdaf Mekuria, 2018)

Nutrients	***Fish meal**	**Wheat bran**	**Niger seed cake**	**Maize**	**Soybean**	**Sweet lupine**	**Cowpea**
Dry matter, %	94	89.4	91.1	90.4	93.5	90.2	89.7
Crude protein, %	52	15.5	30.3	9.2	35.7	32.9	21.8
Crude fiber, %	4.45	9.8	25.5	3.3	12	19.3	7.8
Lipid, %	12.5	2.6	9	4.5	20.5	5	0.6
Ash, %	12.68	3.9	7.6	1.7	5	3.1	4.2
Metabolizeable energy	3320	1980	2338	3139	3803	2970.0	2800

* Proximate analysis made by Laboratory of NFALRC.

All ingredients including the premix and oil were weighed to exact proportion (Table 2), ground into powder, mixed, and made into clumpy powder with a sprinkling tiny amount of water on it and processed into a dry meal. Finally, a fish feed pelletizer machine was used to pelletize the meal (pellet size 1mm). There were three experimental feed groups and a control group; Soybean based feed (Feed 1), Sweet Lupine-based feed (Feed 2), and cowpea-based feed (Feed 3). The control group is the commercial floating feed from Alema Kjoudays PLC with a CP content of 35%.

Sampling and data collection

The amount of formulated feed required to feed fish was determined based on the average weight of fish in each aquarium. Daily feed weight rates were adjusted to account for changes in fish weight during each sampling period (i.e., biweekly). The weight data were collected from the entire fish samples every two weeks in different experimental settings to evaluate the growth performance and to adjust feeding ration. Fish were counted per aquaria and recorded.

Table 11. Ingredients used and their proportions for the formulation of experimental diets

Ingredients	**Feed 1**	**Feed 2**	**Feed 3**
Soybean toasted	29	-	-
Sweet lupine	-	28.5	-
Cowpea	-	-	17
Fish meal	24.7	29	36
Niger seed cake	17.6	13.5	20.5
Maize	13.2	13.5	11.5
Wheat bran	15	15	14.5
Premix	0.3	0.3	0.3
Oil	0.2	0.2	0.2
Total	**100**	**100**	**100**

Analytical process and calculations

The final individual weight of the fish was used to determine how much they had grown (g). Growth parameters including daily growth rate (DGR), weight gain (WG%), specific growth rate (SGR), length gain (LG), survival rate (%), feed conversion ratio (FCR), and feed efficiency (FE) in each dietary treatment of the experiment was calculated according to Adebayo *et al* (2004).

$$\text{Daily growth rate (g/day)} = \frac{\text{Final weight (g)} - \text{Initial weight (g)}}{\text{Culture time}}.$$

$$\text{Body Weight gain (g)} = \text{Final weight (g)} - \text{Initial weight (g)}$$

$$\text{SGR (\% day}^{-1}) = \frac{100 \times [\ln(\text{Final body weight (g)}) - \ln(\text{Initial body weight(g)})]}{\text{no.of days}}$$

$$\text{LG (cm)} = \text{Final length (cm)} - \text{Initial length (cm)}$$

$$\text{FCR} = \frac{\text{Total feed consumed (g)}}{\text{Total weight produced (g)}} \quad \text{and FE} = 1/\text{FCR}$$

$$\text{Total weight produced (g)} = \text{Final weight of fish (g)} - \text{Initial weight of the fish (g)}$$

$$\text{Percentage Survival (\%S)} = \frac{\text{Number of fish harvested}}{\text{Number of fish stocked)}} \text{x} 100$$

Data collected were subjected to the homogeneity test, followed by one-way ANOVA to test for differences in growth response and survival rates of stocked fish fed different diets. The Tukey-HSD post-hoc test ($P < 0.05$) was used to determine the pairwise direction between diets. All statistical analysis was performed using MS Excel and IBM Statistical Package for the Social Sciences (SPSS) program (version 23). Values were expressed as means ± SE.

RESULT AND DISCUSSION

Growth performance indices

The initial body weight of individuals varied between 16.35±0.93g to 18.3 ±1.08g, but not statistically significant (P > 0.05). After 90 days of feeding, the fish grew from an initial minimum average weight of 16.35±0.93g to a maximum final average weight of 52.23±1.59g. Variations in growth performance, percentage survival, and mean feed utilization efficiency were observed between fishes that received different feed groups (Table 3). Although, the final body weight varied between 46.55±2.38g to 52.23±1.59g, the difference was not statistically significant (P >0.05). The fish showed a nonstop linear growth in time which indicated that the experimental feeds was fulfilling the requirement of *O. niloticus* juveniles to grow (Figure 1).

The mean total length gain (cm) of Soybean based feed (Feed 1) and the commercial feed (control) received fishes was 4.38±0.42 and 4.13±0.36, respectively (Table 3). Whereas the least mean total length gain was observed in those fishes fed with Cowpea-based (3.90±0.86 cm) feed (Feed 3). The difference in length gain was found to be non-significant (P >0.05).

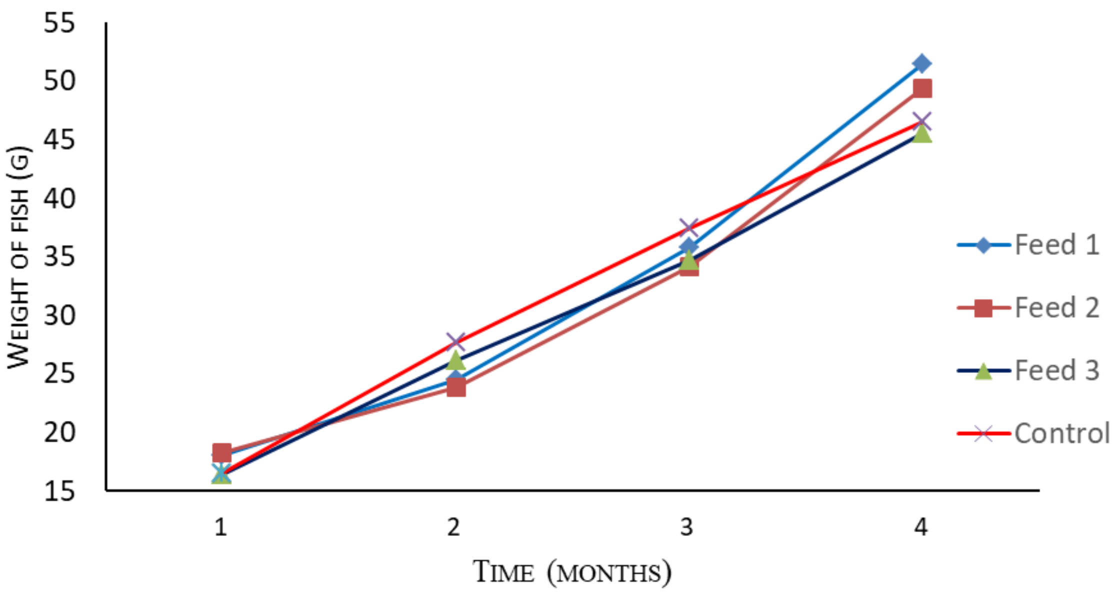

Figure 3. Growth curves of O. niloticus fed with test and commercial feeds for 90 days (Month 1=Start, Month 2= day 30, Month 3=day 60, and Month 4= day 90).

Fishes that relied on Cowpea-based feed (Feed 3) and commercial feed (control group) showed higher DGR, and SGR than toasted Soybean (Feed 1) and sweet lupine (Feed 2). The lower performance of fish depending on Soybean based might be due to its lower amino acid profile especially that of methionine (Cruz and Ridha, 2001). The fish fed the Cowpea based feed (Feed 3) showed the highest mean body weight gain (21.33±7.87 g) followed by those in the control group (20.76±2.59g). This is mainly due to the higher proportion of lysine, the most limiting amino acid for finfish found in cowpea (Elhardallou *et al*., 2015). Fish that were fed sweet lupine-based feed showed the least mean body weight gain (17.48±3.99 g). Protein is the most expensive part of fish diets and supplies essential amino acids for energy, growth, and protein synthesis, and as substrates for key metabolic pathways (Anderson *et al*., 2016; Craig and Helfrich, 2017). The digestible lysine requirement of *O. niloticus* fingerlings is 15.21 g/kg or 5.41 g/100 g of digestible protein (Furuya *et al*., 2012). The lower growth of fish fed with sweet lupine-based feed might be due to the anti-nutritional factors present in it. However, the difference in mean body weight gain among the dietary treatments was not statistically significant (P >0.05).

In the experimental diets, the mean SGR of an individual was comparable and varied between 1.01±0.08 and 1.42±0.08 %/day. The mean SGR of a fish that fed commercial feed was higher (1.42±0.08 %/day) than the treatment groups. The lowest specific growth rate of a fish was recorded in Feed 1 and Feed 3 which were 1.01±0.88%/day and 1.11±0.12 %/day, respectively. On the other hand, the mean percentage survival of *O. niloticus* at different feed types ranged from 95.24±4.76 to 97.62±2.38 in which the fish fed experimental feeds 2 and 3 and the control feed showed relatively lower percentage survival but those relied on Soybean based feed showed the maximum survival percentage. The mortalities might not be diet related but due to stresses caused during handling. But the difference in SGR and percentage survival was not statistically significant (P >0.05).

The feed conversion ratio (FCR) was calculated to evaluate the utilization of feed. The expected FCR for tilapia ranges from 1.5 to 2.0 (Watanabe *et al*., 2002; Rana and Hassan, 2013) and the FCR in the present study fell in this range indicating that the experimental feeds were consented by *O. niloticus* fingerlings. The best FCR and FE values were observed in Feed 3 (1.78 and 0.59) followed by the control feed (1.80 and 0.59). The FE value was 0.57 for those *O. niloticus* juveniles that depend on feeds 1 and 2, respectively.

Table 3. Mean ±SE for growth parameters of O. niloticus fed on different experimental feeds

Parameter	Experimental groups (feeds)			Control group	F-value	P-value
	Feed 1	Feed 2	Feed 3			
Initial BW(g)	18.07±1.4	18.30±1.08	16.35±0.93	16.49±0.51	0.994	0.444
Final BW(g)	51.48±3.9	49.35±4.57	52.23±1.59	46.55±2.38	0.316	0.814
Initial TL (cm)	10.18±0.32	10.25±0.30	9.81±0.25	9.90±0.16	0.667	0.596
Final TL (cm)	14.56±0.46	14.20±0.45	13.23±1.09	14.03±0.22	0.773	0.541
TLG (cm)	4.38±0.42	3.95±0.30	3.90±0.86	4.13±0.36	0.170	0.914
DGR	0.29±0.04	0.26±0.04	0.34±0.02	0.35±0.03	1.548	0.276
SGR (%)	1.11±0.12	1.01±0.08	1.31±0.24	1.42±0.08	1.619	0.260
%S	97.62±2.38	95.24±4.76	95.24±4.76	95.24±4.76	0.077	0.971
FCR	1.96±0.25	1.96±0.27	1.78±0.15	1.80±0.16	0.867	0.497
FE	0.57±0.05	0.57±0.05	0.59±0.04	0.59±0.04	0.984	0.447

According to the observed comparable results of fish growth, SGR, %S, and FCR the formulated feeds from local ingredients (experimental feeds) potentially replaced the available commercial feed. The FCR obtained in this experiment seems to be very high in comparison to other studies (El-Saidy and Gaber, 2005; Omasaki *et al*., 2017; Mengistu *et al*., 2020). But the difference in FCR was not statistically significant (P > 0.05) and similar to other scholars (Muin *et al*. (2017), Devic *et al*. (2018) and Toriz-Roldan *et al*. (2019).

CONCLUSION AND RECOMMENDATION

The local ingredients used as protein sources in this experiment were Soybean, Sweet Lupine, and cowpea which are legume species that can easily be produced. The local fish producers already know their agricultural practice to cultivate them and also process them into flour. This is an opportunity for the local farmers to get an ingredient to formulate feeds. The study indicated the possibility of formulating *O. niloticus* juvenile feed from local ingredients and replacing the commercial feed without affecting the growth performance and percentage survival. The use of plant protein sources that are easily been cultivated by the farmers can potentially reduce feed cost in particular and cost of production in general. It is hence concluded that farmers can use legume species as an alternative ingredient to formulate fish feed. For ease of feeding, research efforts are required to bring a technique to make formulated feed prepared from these ingredients to float.

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Effects of Stocking Density on the Growth Performance of male Nile Tilapia (Oreochromis niloticus) in Concrete Ponds

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ABSTRACT

The research was conducted to investigate the effect of stocking density on the growth performance and production of male O. niloticus in pond culture. Male fingerlings were sorted manually by examining the genital papilla and stocked at three level of stocking densities: 3, 5, and 7 fingerlings/m^2 in triplicates. Experimental fingerlings' with an average weight of 26.31 ± 0.06g were reared for six months in a 10m^2 concrete pond. The fish were fed a commercial feed at 3 up to 5% of their body weight based on their growth stage twice a day. The result of this study showed final mean weight ranged from 182.58 ± 0.39 - 153.57 ± 0.34 g and the mean daily growth rate ranged from 0.9 - 0.73 g per day. The growth performance of fish showed a significant difference with increasing stocking density ($P<0.05$). The gross yield obtained at the end of the experiment ranged from 0.51 ± 0.01 - 0.98 ±0.01 kg/m^2. The higher stocking density (7 fingerlings/m^2) showed the uppermost biomassand net profit. The overall results indicated that even if a higher growth rate was obtained at the lower stocking densities, the highest stocking density gave a significantly higher yield/m^2 and can be very useful to give good returns for local consumption and efficient utilization of resources. Therefore further study should be conducted to investigate better stocking density for improved fish yield and economic gain. Moreover, there is a need to establish optimum management levels for increased stocking densities.

Keywords: Growth performance, O. niloticus, Pond culture, Production, Stocking density

INTRODUCTION

The production of fisheries in the major lakes of Ethiopia is decreasing at an alarming rate and failed to meet the ever-growing demand for fish (Mulugeta et al., 2013). The current increasing market demand for fish protein in Ethiopia can be met only when the capture fishery is supplemented by aquaculture (Ashagrie et al., 2008). However, aquaculture in Ethiopia remains more potential than actual practice because, currently, there was not this much plentiful production of aquaculture in the country, and didn`t benefit from this sector (Natea, 2019). Aquaculture development in Ethiopia has been very limited and the practice mainly consisted of stocking fish fingerlings (Lema and Zenebe, 2009). The problem of overpopulation in ponds caused by uncontrolled reproduction is a major limitation for further development of the aquaculture sector. Mostly, small-scale aquaculture is implemented with mixed-sex O. niloticus fishes (Erkie et al., 2019).

Due to precocious maturity and uncontrolled reproduction of females, overpopulation in ponds is evitable which results in stunted fish and failure to get market-sized fish (Ashagrie et al., 2008). In the Amhara region, most of the farmers' ponds became overcrowded by fish fingerlings with stunting growth and seem like multiplication ponds than production (Erkie et al., 2019). The culture of all-male O. niloticus is well established for increased production potential and low management requirements in a semi-intensive pond culture system since there is no energy to be utilized for reproduction and there exists no competition with younger fish (Adamneh et al., 2013).

Apart from using all male O. niloticus, stocking density is another key factor to achieve optimum production because it has a direct effect on the growth performance and total production of the fish, nutrition, and type of culturing system (Islam et al., 2006). This is because the growth rate of fish progressively increases at lower stocking densities. The reason is that a lesser number of fish in a pond of a similar size helps fish to get more space and food at the same time (Hasan et al., 2010). But, if the stocking density is too low, the fish grow faster and reach larger sizes but, the per-unit area production is also low (Ashagrie et al., 2008). On the other hand, male mono-sex culture permits the use of higher stocking rates (Nahid et al., 2012). High stocking densities reduce individual growth rates, but yields per unit area are greater (Ashagrie et al., 2008). However, excessive stocking densities produce fish below marketable size and fish yields are not improved (Jha and Barat, 2005). Furthermore, fish intensification by increasing stocking density is also found suitable to overcome the problem of land shortage (Khattab et al., 2001) and increase the profitability of the farm.

Therefore, proper stocking density is considered one of the most important variables in aquaculture because it directly influences the growth and production of fish and the profitability of the farm. However, information related to the effect of stocking density on the growth performance and production of male O. niloticus in pond culture conditions has not been well studied in Ethiopia. Therefore, this study aimed to compare the growth performance and production of male tilapia at various stocking densities in pond culture and generate baseline information for improving fish production in pond farming.

MATERIALS AND METHODS

Description of the Study Area

The pond experiment was conducted at Bahir Dar Fisheries and Other Aquatic Life Research Centre (BFALRC) located at a distance of 563 kilometers from Addis Ababa, the capital of Ethiopia.

Experimental setup and design

The trial was conducted in concrete ponds with a dimension of 5x2x1 m ($10m^2$) for a period of six months i.e., from February to August 2021. The ponds were first arranged randomly and assigned to each treatment group. The ponds were covered by fine-meshed nylon nets to prevent the entrance of frogs and other predators. The experiment was carried out by using three treatments (different stocking densities) using male O. niloticus fish in triplicate. The treatments were labeled as T1, T2, and T3 for the corresponding stocking density of 3, 5, and 7 fingerlings/m^2, respectively. The total number of experimental fishes (fingerlings) stocked at T1 was 30 fingerlings/pond, 50 fingerlings/pond for T2 and 70 fingerlings/pond for T3.

Sex Identification and Stocking

A total of four hundred fifty O. niloticus fingerings were collected from fish multiplication ponds using a beach seine net with a mean length of 11.42± 0.12 cm, and the mean weight of the fingerlings was 26.31 ± 0.06. There was no significant difference ($p > 0.05$) between treatments in terms of initial weight and length of the fingerlings at stocking. Before stocking, sex identification was done manually through the inspection of their genital organs visually and with the aid of magnifying hand lens. The experimental fish fingerlings were acclimatized in ponds for two weeks before starting the actual experiment.

Feed and feeding of the experimental fish

The feed used during the experiment was commercial feed bought from Alema Koudijs's animal feed factory. The feed was administered to fish at a rate of 5% of their body weight up to they attained an average weight of 102 grams and then reduced to 3% of their body weight until the end of the experiment (Craig et al., 2017). The ratio was split into two portions and fed twice a day morning at 9:00 PM and afternoon at 3:00 AM (Chapman, 2000) for 6 months. Feeding was done by hand at a constant place and time as this method enables regular inspection of the fish. The daily ration was then calculated and adjusted regularly according to the body weight gain of the fish every month.

Sampling of the Experimental Fish

Experimental fishes were sampled every month using a seine net to observe and record their growth. During the period of sampling, the water level in each pond was first lowered and then, the fingerlings were caught using a scoop net and stocked in a bucket till their weight was recorded. According to the previous suggestions made (Zenebe et al., 2012), 30% of the experimental fishes were sampled from each pond. The sampled fish were handled carefully to avoid stress and their weight and length were recorded using an electronic weighing balance (WAGTEGH Model SKX2201) with 0.01 g precision and a measuring board with 0.01 cm and recorded in a recording sheet. Once the relevant record was taken from individual fingerlings were gently returned to their pond. At the end of the experiment, a harvest was made and the total fish produced in each pond was taken and calculated the total biomass of the fish between different stocking densities.

Growth parameters

The growth performances of fish were determined and feed utilization was calculated as cited by (Ridha, 2006; Alhasan et al., 2012) as follows;

Weight gain (WG) = Final weight (g) – Initial weight (g)

Daily growth rate (DGR) = $\frac{\text{weight gained (g)}}{\text{Culturing days}}$

Specific growth rate/day (SGR) = $\frac{\text{In (final weight)- ln (Initial weight)}}{\text{Culturing period}}$

Percentage weight gain (%WG) = $\frac{\text{Final weight} - \text{Initial weight (g)}}{\text{Initial weight}}$

Food Conversion Ratio (FCR) = $\frac{\text{The total feed is given (g)}}{\text{Total Weight gain (g)}}$

Total biomass and yield

Total biomass (BM) = Number of fish produced × Mean weight of fish

Productivity or yield = NW/SA, Where N = average number of fish produced, W= mean weight of fish, and SA = surface area of the pond in m^2.

Partial Budget Analysis

A partial budget analysis was performed to estimate the net profit from this culture operation. The fingerling price and feed costs were calculated. But, facility (fixed) costs and labor were not included in the analysis, because they were common for all experimental ponds. The selling price for the harvested fish was based on retail prices. Net profit for each treatment group was estimated using the following formulas:

Net profit (P) = GI – TC

Where (TC) =Total costs of production = cost of fingerlings + cost of feed and

(GI) =Gross income = total fish output × sales price

Statistical Analysis

SAS software was used to compute descriptive statistics and plot graphs. One-way Analysis of Variance (ANOVA) at $\alpha = 0.05$ was further used to test the significant difference among mean values of the different stocking densities of male O. niloticus on the various parameters and Fisher's LSD test was used to separate the means.

RESULTS

The different growth parameters in all of the treatments at different stocking densities were presented in Table 1. The results showed that the different growth parameters of male O.niloticus fingerling were significantly affected by stocking density ($P < 0.05$). In all growth parameters, the highest value was attained at a density of 3 fingerlings/m^2 followed by 5 and 7 fingerlings/m$^{2.}$

Table 1. Summary of different growth parameters during culturing time

Growth parameter	Experimental group/ stocking densities		
	T1	T2	T3
Mean initial length(cm)	11.42± 0.12^a	11.44±0.04^a	11.47±0.06^a
Mean final length(cm)	23.46±0.03^a	21.56±0.21^b	20.23±0.07^c
Mean length gain (cm)	12.03±0.1^a	10.11±0.25^b	8.77±0.14^c
Mean initial weight(g)	26.31±0.06^a	26.28±0.08^a	26.33±0.1^a
Mean final weight(g)	182.58±0.39^a	163.33±0.78^b	153.57±0.34^c
Mean weight gain(g)	156.26±0.41^a	137.05±0.83^b	127.23±0.29^c
Percentage weight gain (%)	593.95±2.3^a	521.53±4.4^b	483.19±1.8^c
Daily growth rate(g/day)	0.9±0.01^a	0.79±0.005^b	0.73±0.001^c
Specific growth rate	1.11±0.002^a	1.05±0.004^b	1.01±0.001^c

Means within a column followed by a different letter (s) are significantly different at $P<0.05$, LSD test.

Total Fish Harvested at the End of the Experimental Period

The total biomass (kg) harvested from the treatment ranged from 4.9 kg to 10.2 kg. The mean total fish harvested in 3 fingerlings/m^2 was 5.11±0.11 kg; and 7.57±0.22 kg and 9.78±0.14 kg for the stocking density of 5 fingerlings/m^2 and 7 fingerlings/m^2, respectively. There existed a significant difference (P < 0.05) among treatment groups in the total fish harvest. The mean fish yield was 0.51 ± 0.01 kg/m^2, 0.75 ± 0.02 kg/m^2 and 0.98 ±0.01 kg/m^2 for 3, 5 and 7fingerlings/m^2, respectively. The mean yield varied between treatment groups and the difference was statistically significant (P< 0.05) (Table 2).

Table 2. Production of O. niloticus during the culturing time

Total fish harvested	Experimental group/ stocking densities		
	T1	T2	T3
The total biomass kg/treatment	5.11±0.11^c	7.57±0.22^b	9.78±0.14^a
Yield kg/m^2	0.51±0.11^c	0.76±0.02^b	0.98±0.01^a

Means within a column followed by a different letter (s) are significantly different at p<0.05, LSD test

Total feed provided for the experimental fish and feed conversion ratio

The total feed provided in the stocking density 3, 5, and 7 fingerlings/m^2 was 13,061.22 g 19,854.59 g, and 25,555.11 g, respectively (Table 3). The total feed provided by O. niloticus fingerlings during the culturing period was affected by stocking densities. The feed conversion ratio (FCR) obtained from O. niloticus fishes at different stocking densities during the culture period ranged from 2.91 to 3.18. The lowest (best) means feed conversion ratio (2.98 ± 0.04) was obtained at the stocking density of 3 fingerlings/m^2 and the highest (poorest) mean feed conversion ratio (3.15 ± 0.01) was observed at the highest stocking density of 7 fingerlings/m^2. The experiment revealed that the food conversion ratio was affected with stocking density and the difference was significant (P < 0.05).

Table 3. The total amount of feed provided and food conversion ratio

Variables	Treatment			P-value
	T1	T2	T3	
Total feed provided (g)	13,061.22^a	19,854.59^b	25,555.11^c	<0.0001
The feed conversion ratio	2.98 ± 0.04^b	3.12± 0.02^a	3.15 ± 0.01^a	<0.01

Partial Budget Analysis

At the end of the experiment total net profit was highest (1151.65 Birr) in 7 fingerlings/m^2 (919 Birr) in 5 fingerlings/m^2 and (650.85 Birr) in 3 fingerlings/m^2, respectively. It was also observed that the net profit/m^2/6 months was highest (38.39 Birr) with a stocking density of 7fingerlings /m^2 while the lowest net profit/m^2/6 months (21.69 Birr) was obtained with a stocking density of 3fingerlings/m^2 (Table 4). Regarding the profit contribution, 7 fingerlings/m^2 contribute the highest (42.31%) followed by 5 fingerlings/m^2 (33.76%) and 3 fingerlings/m^2 (23.91%), respectively.

Table 4. Partial budget analysis of male O. niloticus fingerlings at different stocking densities

Parameter	T1	T2	T3
Production period (day)	174	174	174
Stocking density/10m^2	30	50	70
Cost of fingerlings (Eth. Birr)	30	50	70
Cost of feed used (Eth. Birr)	391.8	589.5	768.2
The total cost of production (Eth. Birr)	421.8	639.5	838.2
Total production (kg)	5.11	7.57	9.78
The selling price of fish/kg (Eth. Birr)	125	125	125
Gross income from the fish sale (Eth. Birr)	638.75	946.25	1222.5
Net profit (gross income-total cost) (Eth. Birr)	216.95	306.75	384.3
Net profit/m^2/6 months (Eth. Birr)	21.69	30.63	38.43
Net profit contribution (%)	23.9	33.75	42.35

DISCUSSIONS

Growth performance

The growth performance of individual fishes decreased as the stocking density increased indicating an inverse relationship between stocking density and growth of male O.niloticus fingerling. Because the growth of tilapia (O.niloticus) depends on the stocking density, feed quality, and others (Khattab et al., 2001). The lower growth performance of tilapia exhibited at higher stocking density could have been caused by energy expenditure because of competition for feed and living space and increased stress. It has been reported that high stocking density of O.niloticus fingerlings might lead to 'social stress' which eventually leads to impaired fish growth (El-Sayed, 2002). In line with the present study, different scholars, Herrera (2015) studied the effects of stocking density on growth performance and production of male tilapia in the three different densities (3, 3.2, and 3.5fingerlings /m²), Diana and Lin (2004) stocked male tilapia at 3, 6, and 9fish/m^2, and Sophia et al. (2010) all those scholars abstracted that the highest weight of fish was attained at a density of 3fish/m^2 than the other density of fish/m^2. Fish stocked at the lower density (3fish/m^2) had significantly higher (156.27±0.38 g) mean weight gain than higher stocking density. These results were similar to the finding of Hasan et al. (2010) that reported mean weight gain of 155.0 g in the stocking density of 3.7 fish/m^2, and the finding is in line with different scholars (Ridha, 2006; Chakraborty and Banerjee, 2010; Opiyo, 2010).

Daily growth rates and Specific growth rates observed in this study increase as the stocking density decrease and the growth rates were affected by the density of fish in the pond. Because, increased stocking density results in competition for space, food, and increase activity levels, and fish use more energy deriving in high metabolic rates and then a growth decrease (Ellis et al., 2002). This is in agreement with Gillian-Klanian and Arámburu-Adame's (2013) tose reported a daily growth rate of lower density (0.96 g day-^{1}) higher than higher density (0.73 g day-^{1}). Islam and Begum (2019) also reported that the lowest stocking density had a significantly higher mean weight, daily growth rate, and specific growth rate than the higher density treatment, and the growth of O. niloticus fish was found to be density-dependent. Similar growth scenarios were also obtained with many other culturing systems with similar species (Ashagrie et al., 2008; Abou-Zied and Ali, 2012; Yakubu et al., 2013; Daudpota et al., 2014).

Yield /Production

There was a strong trend for a total production increase with increasing stocking density. The highest productivity was obtained in T3, followed in decreasing order in T2 and T1, respectively i.e. high stockingdensity (7fish/m^2) was given significantly higher biomass yield per pond than lower-density. This might be due to a higher number of individuals contributing to the final harvest. Herrera (2015) studied the effects of stocking density on growth performance and production of male GIFT tilapia in three different densities 3, 3.2, and 3.5 fish /m^2; Sophia et al. (2010) studied the stocking density of 3 and 5 fish/m^2, Hasan et al. (2010) stocked 3.7, 4.9, 6.2/m^2 and Ribera et al. (2009) stocked 2, 4, 6, 8/m^2 all those scholars abstracted that the production of fish increased with increasing stocking density and the production of the fish was affected by the stocking density of the fish in the pond.

In the present study, the lower stocking density (3fish/m^2) obtained a high individual growth rate, but the total production per pond was lower than other stocking densities. This is confirmed by Ashagrie et al. (2008) stocking density is too low, the fish grow faster and reach larger sizes but, the per-unit area production was low. In contrast, with a higher stocking density of 7fish/m^2 individual growth rate of fish decreases, but yields per unit area was greater. This result also inagrement with (Nahid et al., 2012; Ashagrie et al., 2008). In the present study male O.niloticus fingerlings stocked at 7fish/m^2 was the best stocking density to obtain maximum production. Herrera (2015) reported that the optimum stocking density is the level where the maximum yields are reached. This is indicated that stocking density is one of the most important factors in determining the production of a fish farm.

Feed Utilization

The total feed provided to the experimental fish was positively related to stocking density, the total feed offered increased with an increased stocking density. This result is in agreement with (Sophia et al., 2010) feed offered was based on average live weights in each pond multiplied by the number of fish at the beginning; those with the highest density received more feed. The ability of fish to convert feed given to biomass (Feed convertion ratio, FCR) was affected by increasing stocking density. The best FCR was obtained with a lower stocking density than higher densities, which might be feed computation during feeding. This is proven by Thorarensen and Farrell (2010) under cultural conditions, the fish obtaining feed increase their swimming speed; these activities require energetic cost, which increases due to agonistic interactions. This contributed to lower growth performance in the higher stocking density. In the present study, the growth performance of fingerlings decreases with increasing stocking density due to poor feed utilization. Because daily weight gain and specific growth rate generally decreased with increasing stocking density indicating the decreasing feed utilization ability. This was in agreement with different scholars who reported by reducing the initial stocking density from higher stocking density to lower stocking density, the growth performance of tilapia fish was higher and the feed conversion rate was better (Hasan et al., 2010; Garcia et al. 2013; Herrera, 2015) .

Partial Budget Analysis

When the stocking densities of the fish increase the net profit also increases indicating a positive relationship between stocking densities and net profit. This might be due to a higher number of individuals contributing to the highest net profit. This result was in agreement with Islam and Begum (2019) reported that the higher density could be more profitable for tilapia than the lower density in terms of cost-effectiveness and meet the demand for large-scale fish production. In the lower stocking density i.e. 3fish/m^2 individual growth rate was higher but after the end of the experiment, the total production and the net profit contribution (23.91%) were lower relatives to other stocking densities. This indicated that in the lower stocking density individual growth rate of the fish was high, but the product obtained per pond was very low due to difficulties to compensate production cost and the profitability of the farm is decreased.

On the other hand, the higher stocking density 7fish/m^2 obtained maximum production and contributed to the highest net profit (42.31%). Khattab et al., (2001) also proved the present result, increasing the stocking density of fish within limited area results in full utilization of space for maximum fish production and can improve the profitability of the fish farm. This result indicated that stocking density is one of the important variables to determine the profitability of the fish farm.

CONCLUSION AND RECOMMENDATIONS

The overall results of this study indicate that even if a higher growth rate was obtained at the lower stocking densities, a higher stocking density of 7fish/m^2 gave significantly higher yield or production per meter square and contribute the highest percent of net profit than lower stocking densities which is useful to give good returns for local consumption and ensure efficient utilization of resources. Therefore, stocking density is an important indicator that determined the production and profitability of male tilapia fish farm. This was important as baseline information on male O.niloticus culture and stocking density of pond fish farming to improve food security, reduce poverty and nutrition deficiency and maximize the contribution of aquaculture to the economy of the country. Therefore further study should be conducted to investigate better stocking density beyond 7fishes/ m^2 and whether it will be possible to get more yields per unit area. Moreover, it is important to establish optimum management levels (quality feed and secured water supply) are necessary to fish growth under high-density systems.

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The Potential Fish Yield and Some Physico-Chemical Properties of the Rib, Shumbrite, and Koga Dams in Amhara Region, Ethiopia

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ABSTRACT

This study was conducted from 2020 to 2021 in Rib, Shimburit and Koga dams to estimate potential fish yield and physicochemical parameters of water for proper recommendation. Both fisheries and water quality data were collected and analyzed following standard procedures. Morpho-edaphic index and area-based models were used to predict potential fish yield. Fish samples, physico-chemical and limnological parameters were sampled in wet and dry seasons. The result showed that conductivity and total dissolved substances (TDS) ranged from 75.5 to 155 (µS/cm) and 55 to 145 (g/l), with the highest conductivity values 155 (µS/cm) in Koga and TDS of 145 (g/l) in Rib dam, respectively. Dissolved oxygen (DO) and pH values ranged from 6.34 to 6.76 (mg/l) and 7.74 to 8.33, respectively, with the highest DO value 6.76 mg/l in Rib dam and the highest pH value 8.33 at Koga dam. This study revealed that the mean annual potential fish yields (kg/ha) were 372.95, 302.24 and 303.88 for Rib, Shumbrite and Koga reservoirs, respectively. The total mean annual fish production potential is estimated at 38.3, 20.3 and 25.53 tones /year for Rib, Shimburit, and Koga, respectively. A continuous monitoring, periodic fish yield assessment and stock enhancement for sustainable fish production and resource management of the reservoirs was mandatory.

Keywords: *Dams, fish diversity, fish yield, Morpho-edaphic index, water quality*

INTRODUCTION

Dams and lakes are crucial elements of the contemporary aquatic ecosystem with a significant economic and environmental resource that Ethiopia and many other nations benefit greatly. Dams significantly contribute to both global and fresh water production in a number of West African countries (Dugan, 2003). The most significant inland water bodies are reservoirs, which have a big potential to significantly increase the nation's inland fish production. Fishery development in reservoirs has multiple advantages including job creation, income generation and is environmental friendly in addition to its primary uses like irrigation, electricity generation, and supply of water for cities and industry (Kutty et al., 2008). Fishery production from inland water bodies have reportedly suffered in Africa due to environmental deterioration, heavy fishing pressure from increasing human populations, inadequate fishery data, and ambiguous property rights (Khan et al., 2004). The physical and chemical heterogeneity of the physico-chemical and biological limnology and type of dam/reservoir are the main drivers to determine the biotic structure (Vinebrooke et al., 2004). Fish potential yield can be estimated from hydro-morphological parameters, which can then be approved using known sampling, experimental and statistical estimation techniques (Punt, 2003).

However, the majority of the data in the literature on the nation's capability for producing fish from reservoirs is inconsistent, and in some cases even contradictory. The potential of dams, reservoirs and, in some cases, even rivers, was not taken into account in the majority of the designs. However, because they are very simple to maintain and could be a source of protein and employment in areas where both are in scarce supply, a few water bodies are significant for a number of reasons and should receive more attention from fishery planners and developers (Marshall and Maes, 1994). Additionally, they are simple to incorporate with other agricultural activities, which might even improve all farm activities without incurring a lot of additional costs. Physico-chemical properties, plankton, morphometry are a few characteristics of the reservoir that might affect fish productivity and production. The development and management of freshwater fisheries, particularly in Africa, heavily depends on the methods for projecting prospective fish output in lakes, dams, and reservoirs (Baigun et al., 2006).

There are several ways to estimate a stock’s current condition, including directly through research, and indirectly through information on catch volumes, age composition, and effort levels to capture those volumes (Punt, 2003). Therefore, the current study aimed to investigate fish production potential, some physico-chemical and biological limnology for sustainable fish production and resource utilization of Rib, Shumburite and Koga reservoirs.

MATERIALS AND METHODS

Study area

The study was conducted in Rib, Shumbrite, and Koga dams. Rib dam is constructed by damming the river rib in the south Gonder zone, on the east side of the sub basin of Lake Tana. The rib river, about 130 km long, has a drainage area of about 1790 km and an annual average discharge of 14.6331 m^3/s. There are 685 km^2 of the catchment area on the dam. The dam is located at 12º15'61" N and 38º06'39" E at an altitude of 1973 m. Koga dam is located 12º11'55"N and 37º28'31"E at an elevation of 1935m above sea levels. Koga Dam was an earth filled structure that stored 85 cubic meters of water from the Koga River, which has a basin area of 266 km^2, and snowmelt from southern Steep Mountain, 64 km from its source. The southern part of the irrigation area has an elevation of 2000m while its northern part has an elevation of 1865m above sea levels (Gebreyohannis et al., 2009).

Shumbrite micro earth fill dam is located in the eastern part of Gojjam, Debre Elias woreda at particular kebele of Yegdad and Yekomit. The dam is located at 10º22'44.42" N and 37º24'11.32" E at an altitude of 2124m above sea level. Debre Markos is the nearest city about 30km and the dam is constructed for irrigation. The crest length of the dam was 312.5m and the maximum dam height was 16m (Amanuel et al., 2022). The reservoir support fishery as important activities after its establishment (Amanuel et al., 2022).

Data collection and analysis

In 2020 and 2021, seasonal samples of fish and water were collected from three dams at convenient sampling locations that represent the dams. Different mathematical models, including the area-based model and the morpho-edaphic index, descriptive statics, and methods for assessing the potential fish yield were applied.

Physical parameters

Surface water samples were collected using the water sampler from 1 m below the surface and put into sample vials that had already been cleaned. Temperature, pH, conductivity, and dissolved oxygen levels were measured in-situ (indicate the name of the probe used). Conductivity, total dissolved solids (TDS), turbidity and PH also measured in-situ and are the variables to be measured.

Fish sampling

Fishes were sampled in wet and dry seasons from strategically selected and accessible sites for two years (from 2020 to 2021). Multi filament gill nets with mesh size ranging from 6 –14 cm were employed overnight, from 5:00 PM to 6:00 AM. The fish samples were identified and categorized in accordance with species guidelines (Paugy et al., 2003). Each fish samples were weighed to the nearest 0.1gm using electrical scale balance while standard length (SL), fork length (FL), and total length (TL) were measured to the nearest 0.1 cm using measuring boards.

Morpho – edaphic index (MEI)

The MEI technique has a reputation for being able to quickly assess potential fish yield and estimate fish production in lakes and reservoirs throughout the world. The mean conductivity (µS cm-1) or mean total dissolved solids (mg/l) of the water body are multiplied by the mean depth (m) of the water body to determine the MEI (Henderson and Welcome, 1974; Ryder et al., 1974).

$$\mathbf{MEI} = \frac{Conductivity\ (\mu s/cm)}{Mean\ depth\ in\ m} - - - - - - - -\ (\text{Ryder et al., 1974})$$

Estimation of potential and actual yield

The potential fish yield generation of the water bodies was evaluated using the morpho-edaphic index and area-based models developed by several scientists. The potential fish yield of the water bodies was calculated using the mean of the conductivity measurements made according to the seasons (rainy season and dry season). For estimating the potential fish yield the following models were applied.

Model 1: Y=14.3136 MEI $^{0.4681}$…………………….. (Henderson and Welcome, 1974)

Where: Y is the potential fish yield in kg/ha and MEI is the Morpho Edaphic Index

Model 2: In (Yt) = 3.57 + 0.76 In (Ao)…………………….. (Marshall, 1984)

Model 3: Yt = 8.32 Ao 0.920 (R2 = 093) ………………….. (Crul, 1992)

Model 4: Log (Y) = 1.407 + 0.3697 Log (MEI) – 0.00004565 Ao …… (Teows and Griffith, 1979)

Where: Yt is the total yield in tons per years and Ao is the lakes area in square kilometers.

Fish yield (FY)

The area of the reservoir in hectares was multiplied by the probable fish yield in kg per hectare, and the result was converted to tons per year. As a measure for exploitation level, the relative yield index (RYI) was used. The ratio of the estimated potential fish production to the actual catch is known as the RYI.

RYI = Yobs /Yest * 0.75

Where: Yobs = observed Yield (which was obtained from the total weighted fish samples obtained in the field). Yest = estimated potential fish yield (obtained using MEI). The expression catch kg/ ha = 14.3136 MEI $^{0.4681}$ describes the relationship for lakes which are approaching or have reached their maximum level of exploitation.

RESULTS AND DISCUSSION

Physico-chemical parameters

The Physico-chemical parameters measured in this study were within the acceptable range for freshwater quality (Table 1). The values of pH and DO showed good water quality suitable for the growth and survival of fishes. A decreased transparency during the rainy season might be associated with heavy flood that transport silt, debris, and organic matter in to the reservoirs (Table 2). The rainy season at this time coincides with periods of reduced temperature. The highest transparency at this time may be due to the debris settling in the dry season. The conductivity and Total Dissolved Substances (TDS) values indicated a significant ionic content in each dam. The dams' mean conductivity (115 µS/cm) was higher than that of the shallowest reservoirs in Africa (Namara et al. 2010); which might be caused by rainfall, runoff from the nearby water, and weathering of the underlying rocks and soils. On the basis of physico-chemical parameters measured, all dams have good water quality and suitable for enhanced fish production as it was indicated by Ranta and Lindstrom's (1998) in theory of lakes.

Table 1. Mean of some physical parameters in the three study dams

	Sampling reservoir		
Parameters	Rib	Shimubrit	Koga
Secchi (cm)	40.25	52.6	24.5
Conductivity (µS/cm)	155	75.5	113
TDS (g/L)	145	55	119
pH	8.22	7.74	8.33
T (^{o}C)	22.5	21.1	21.59
DO (mg/l)	6.76	6.34	6.55
Salinity (%)	0.08	0.05	0.07

TDS -total dissolved solids, T-temperature, DO, dissolved oxygen

Table 2. Seasonal variations of Conductivity, TDS, pH and DO values in the study dams.

Parameter	Wet season			Dry season		
	Rib	Shimubrit	Koga	Rib	Shimubrit	Koga
Conductivity (mg/l)	155	75.5	113	109	40.5	120
DO (mg/l)	6.58	6.50	6.72	6.45	6.32	6.21
pH	6.82	7.74	8.33	8.1	7.4	8.1
TDS (mg/l)	145	55	119	122	44	110

Cond (conductivity), TDS (total dissolved solids); DO (dissolved oxygen)

Fish species composition

The fish species composition in Rib dam was composed of L. barbus (n =116), O. niloticus (n =109), C. garpinus (n =16) and Cyprinus carpio (n =11) samples. *Generally, Rib dam consist of* 11 species in 3 families, Shumbrite dam 5 species in 3 families and Koga reservoir 7 species in 3 families (Table 3).

The similarity index of species composition among the dams ranged from 0.1 to 0.19. Two common species was found in the entire three dams although some species were in each dams. The low similarity index of species composition indicates that the environmental factors or human disturbances among the three water systems varied to some extent. Family Cyprinidae constituted the largest portion of the fish community with the highest number of species, i.e., 23 spp, followed by family Cichlidae and Claridae each with one species. The most abundant species were L. barbus species, O. niloticus and C. garpinus.

Table 3. The species composition and number of individual found in the study dams

Family	Species	Number of Individual	Site		
			Rib	Shimburit	Koga
Cyprinidae	L. Intermedius	22	*	-	*
	L. Nedgia	16	*	-	*
	L. Macrophtalmus	5	*	-	-
	L. platydorsus	8	*	-	-
	L. truttiformis	11	*	-	-
	L. surkis	7	*	-	-
	L. crassibarbis	9	*	-	*
	L. megastoma	20	*	-	*
	V. beso	18	*	*	*
Total		116			
Cyprinidae	C. carassius	6	-	*	-
	C. cuvieri	5	-	*	-
Cichlidae	O. niloticus	109	*	*	*
Claridae	C. garpinus	16	*	*	*
Total		252			

Potential fish yield

The estimated potential fish yield (kg/ha) of Rib, Shumbrite and Koga dam from the morpho – edaphic indexes (MEI) were 372.95, 302.24 and 303.88, respectively. The mean potential fish yield estimate for Rib dam was the highest followed by Shumbrite and Koga dam. This study revealed that Koga dam has the highest MEI values with 6.01 followed by 3.15 in Shumbrite dam and 2.51 in Rib dam. This estimates show that Rib dam recorded 29.46 kg/trip which is the highest, and the least (17.20 kg/trip) was recorded in Shumbrite dam. The highest (372.95 kg/ha) and lowest (302.24 kg/ha) potential yield estimated was calculated for Rib dam and Shimburit dam, respectively. The observed harvest yield show Rib dam has the highest harvest, followed by koga dams. The least harvest was recorded in Shumbrite dams (Table 4). Total dissolved salts (TDS) and alkalinity are positively and strongly connected with the potential fish yield (PFY), meaning that as these parameters increase, PFY increase as well, demonstrating the favorable influence these factors have on PFY. The inverse nature of the relationship between PFY and the physical parameters is indicated by the fact that PFY is strongly negatively linked with total hardness and DO and that as these parameters increase PFY increases.

The high conductivity value and low mean depth of the study dams, as measured by the morpho-edaphic index, could be attributed to the high potential fish yield of Rib, Shumbrite, and Koga dams. According to Balogun and Aduku (2005), the fisheries potential of smaller, shallower dams with a reasonable high concentration of dissolved solids is often higher and the dam is extremely productive when employing the MEI. In this regard, small shallow reservoirs around the country, such as Lugo Lake, Tekeze, and Geray reservoir, the estimated fish yield of the research dams was comparable. The three study dams in the Amhara region have fish potential that ranged from 20 to 115 kg; the average of this distribution is 55 kg. The potential fish yield in three dams agreed with Mustapha (2009) who showed shallow tropical reservoirs are more productive than deeper lakes. For example the fish yield from the Rib, Shumbrite, and Koga dams is relatively higher than Botanga (86.90 kg/ha) and Libga (97.19 kg/ha) deeper reservoirs in Ghana and the Oyun reservoir in Nigeria (Mustapha, 2009). However, the fish potential yield of Rib, Shumbrite, and Koga dams were relatively higher than that of other tropical reservoirs like Kubani (38kg/ha) and Kainja dam (Balogun and Aduku, 2005; Ibrahim and Balogun, 2009). Therefore, the high potential yield might be as a result of high conductivity with low salinity in addition to its tropic location as compared with temperate region (Edward, 2013). Moreover the area-based models and the morpho edaphic index might show higher values in the study dams compared with Tekeze dam (60 kg/ha) (Goraw et al., 2009).

Table 4. The potential fish yield for the study reservoirs

Parameters	Sampling reservoir		
	Rib	Shumbrite	Koga
Latitude	12º15'61"N, 38º 06'39"E	10˚22'44.402" 037˚24'01.132"	11˚ 35' 55" 37˚ 14' 31"
Altitude (m)	1973	2124	1935
Mean surface area (ha)	1000	48	1750
Mean depth	9.5	5.71	8.5
TDS (mg/l)	145	55	119
Conductivity in (µS/cm)	155	75.5	113
Morpho Edaphic Index (MEI)	2.51	3.15	6.05
Potential Fish Yield (kg/ha)	29.46	17.30	26.22
Potential Yield (ton / year)	225.3	10.8	383.01
RYI	0.57	0.29	0.24
Relative Yield Index (%)	57	29	24

Relative yield index (RYI) and (% RYI) revealed that Rib dam has the highest value with 0.57 and 57 %, Koga dam recorded the least with 0.24 and 24 %, respectively (Table 5). The potential fish yield is translated in to fish yield of 38.3 yield ton per year, 20.3 yield ton per year and 25.53 yield ton per year in Rib, Shumbrite and Koga dam, respectively. The Relative yield index (RYI) variation in potential fish yield and fish yield value patterns at all three study dams with the highest values in Rib and the lowest value in Koga dams were recorded (Table 5).

Table 5. The mean potential fish yield and the RYI of the dams

RYI	Yobs (kg)	Yest (MEI)	RYI = Yobs/Yest x 0.75
Rib	29.46	2.51	0.57
Shumbrite	17.30	3.15	0.29
Koga	26.22	6.01	0.24

YI = Relative Yield Index; Yobs = Yield observed; Yest = Yield estimated

Length Frequency distribution

A total of 252, L.Barbus (n=116), *O. niloticus* (n=109), C .garpinus (n=16) and *Cyprinus carpio* (n=11) individuals were caught during the study period. The total length (TL) of O.niloticus ranged from 16 to 36 cm and Total forked length (FL) for C. garpinus and Cyprinus carpio ranged from 18 to 60 cm. In this study, the length frequency distribution of both species indicated that the fish population showed normal fish population distribution with no apparent problems of over exploitation (Figure 1 and 2).

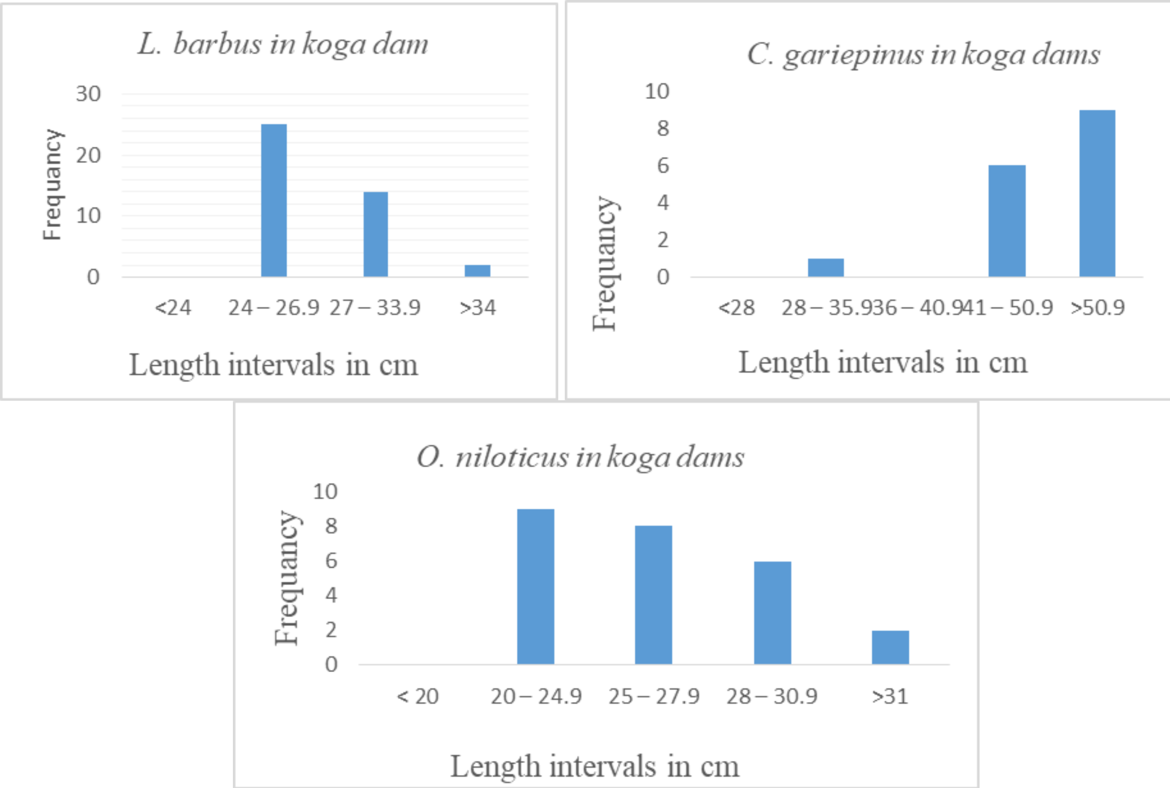
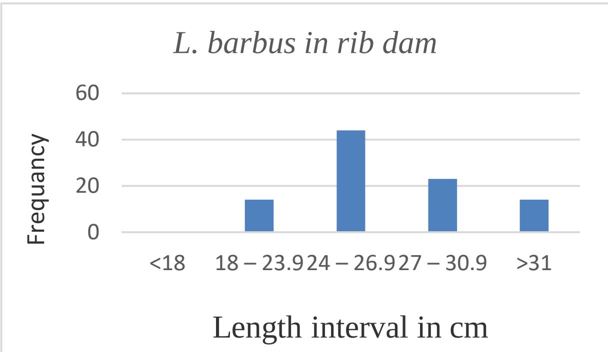
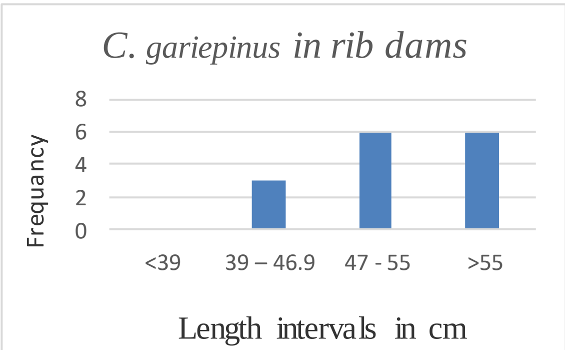
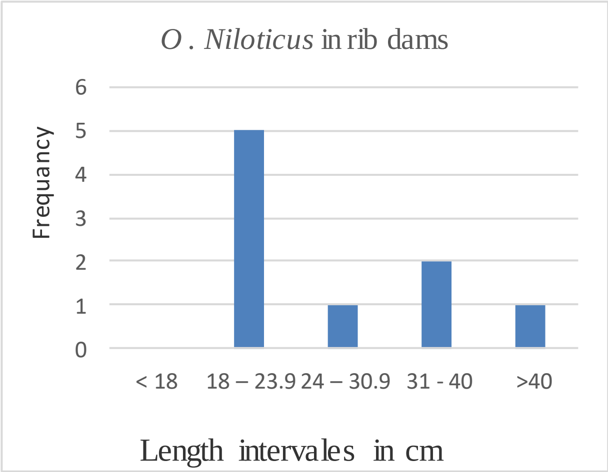


Figure 1. The length intervals and the frequency of the dominant fish spp in Koga dams







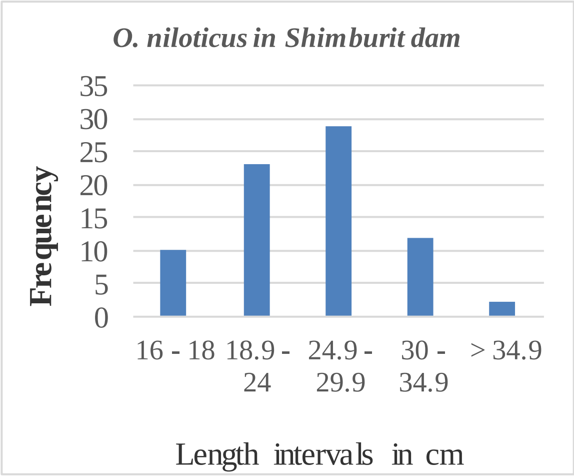


Figure 2. The length intervals and the frequency of the dominant fish spp in Rib and Shimburit dams

Length-Weight relationship: Total Weigth of the dominant fish species (Labeobarbus, Oreochromis niloticus and Clarious gariepinus) showed curvilinear relationship with total length and was statistically significant (P< 0.005) (Figure 3, 4 and 5). The relationship between length and total weight of the dominant commercial fish specious (Labeobarbus, Oreochromis niloticus and Clarious gariepinus) was curvilinear and the line fitted to the data was described by the regression equation. The regression coefficients for most of the dominant species were near to the cube value (b = 3). In fishes, the regression coefficient b = 3 describes isometric growth which mean that weight increases at a rate of about a cube of increase in length (Froese, 2006). However, fishes may also have “b” value less than or greater than 3 in a condition of allometric growth (Froese, 2006). In agreement with Anteneh (2005) in Rib, Shimburit and Koga dams showed nearly isometric growth. Similar result has been reported in lake Hawassa (Demeke, 2000), in River Sanja (Tesfaye, 2006), in the head of Blue Nile River (Omer, 2010) for L. barbus, O. niloticus and C. garpinus.

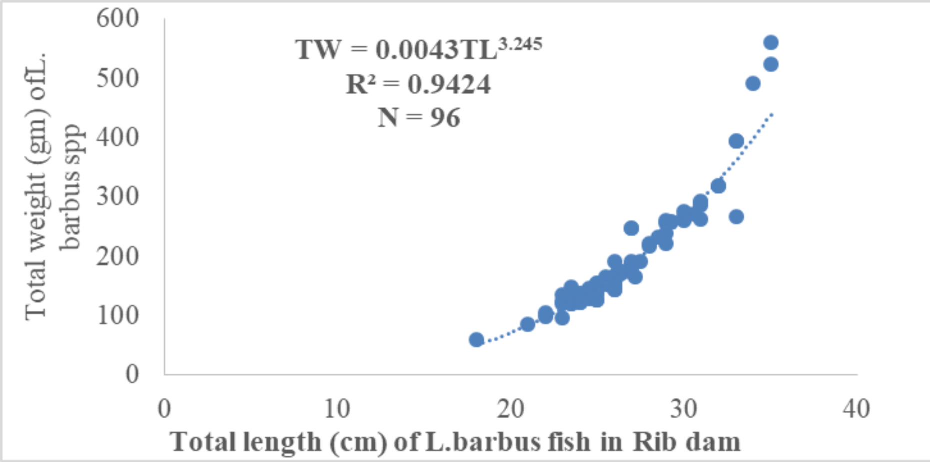


Figure 3. The length weight relationship of L. barbus fish in Rib dam

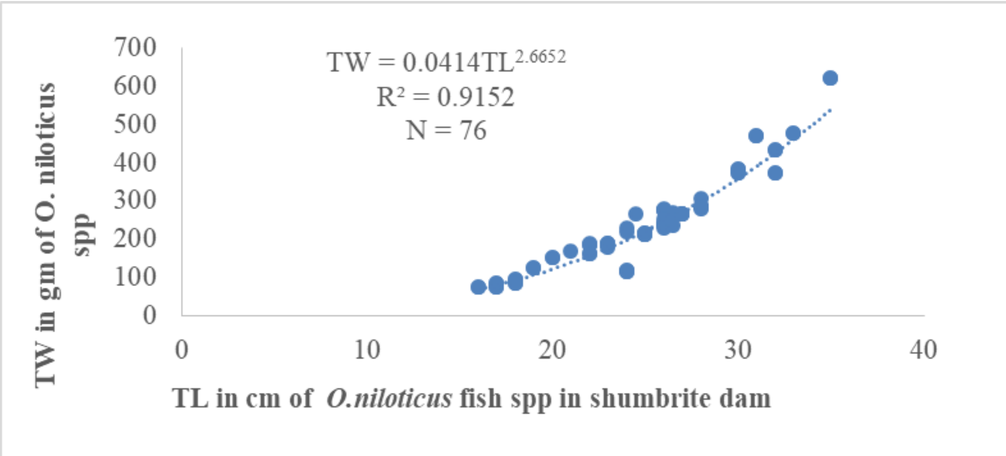


Figure 4. The length weight relationship of O. niloticus fish in Shimburit dam

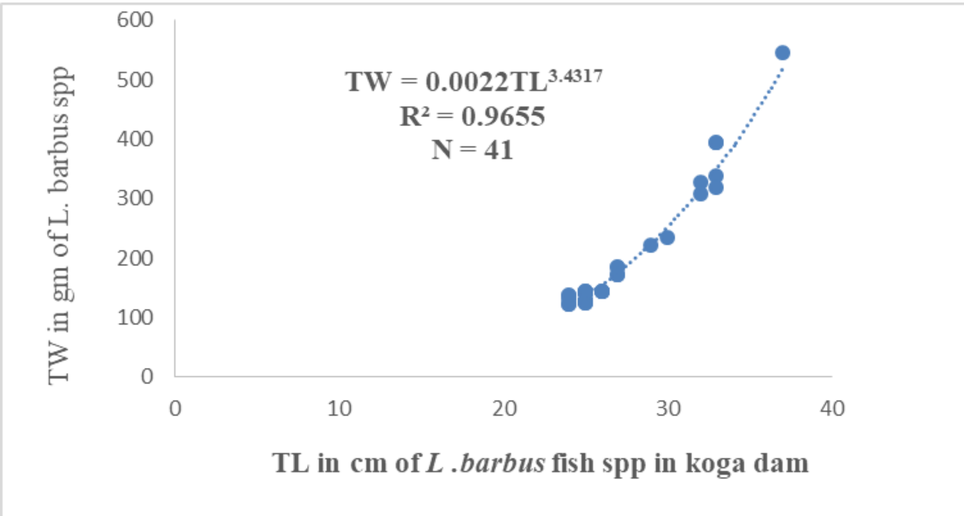


Figure 5. The length weight relationship of L. barbus fish in Koga dam

CONCLUSION AND RECOMMENDATION

The morpho edaphic index (MEI) and area based models indicated the study water bodies had high fish potential yield which suggests sustainable exploitation of fish resource. The potential yield were 372.95 Kg/ha, 302.24 Kg/ha and 303.88 Kg/ha in Rib, Shimburit and Koga dam, respectively were observed, and this yield converted to 38.3 yield ton per year, 20.3 yield ton per year and 25.53 yield ton per year, respectively. This implies that the study dam has good prospects for fish populations with only moderate exploitation. The physico-chemical characteristics of the research dams at the time of sampling were also within acceptable limits. A fish stock that has been slightly exploited has a RYI value less than one. The least one activity in the catchment area of the study area is the conventional command and control technique of management. Therefore, it appears that there is a general dearth of knowledge and scientific information in the locality where this practice is carried out. Continuous fisheries monitoring and yield assessment program for proper fishing and stock enhancement activities in all study dams was found to be mandatory.

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