ESTIMATES OF GENETIC PARAMETERS, GENETIC TRENDS AND OPTIMIZING COMMUNITY BASED BREEDING OF ABERA SHEEP BREED, ETHIOPIA

PhD DISSERTATION

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STATEMENT OF THE AUTHOR

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DEDICATION

This PhD work is dedicated to:

My beloved father **Alemayehu Abera Dulla**

My beloved mother **Tayech Aserse Terefe**

My only sister **Lidet Alemayehu**

My beloved daughters **Elon and Meba Demis**

ABBREVIATIONS AND ACRONYMS

AGG	Annual Genetic Gain
AMGG	Monetary Genetic Gain
ANOVA	Analysis of Variance
BW	Body Weight
AGR	Animal Genetic Resource
BWT	Birth Weight
BLUP	Best Linear Unbiased Prediction
c^2	Maternal Permanent Environmental Variance
CBBP	Community Based Breeding Program
CSA	Central Statistics Authority
CV	Coefficient of Variation
DP	Discounted Profit
DR	Discounted Return
EBV	Estimated Breeding Value
ECR	Estimated Conception Rate
ETB	Ethiopian Birr
F	Coefficient of Inbreeding
FAO	Food and Agriculture Organaztion of the United Nations
GDP	Gross Domestic Product
GLM	General Linear Model
h^2	Heritability
h^2a	Direct Heritability
h^2m	Maternal Heritability
h^2t	Total Heritability
HARC	Hawasaa Agricultural Research Centre
ICARDA	International Center for Agricultural Research in Dry Areas
ILRI	International Livestock Research Institute
ID	Animal identification
Kg	Kilogram
LRT	Likelihood Ratio Tests
LS	Litter Size
m.a.s. l	Meters Above Sea Level
MCBBP	Member Community Based Breeding Program
NMCBBP	Non- Member of Community Based Breeding Program
REML	Restricted Maximum Likelihood
r_g	Genetic Correlation
r_p	Phenotypic Correlation
SARI	Southern Agricultural Research Institute
SAS	Statistical Analysis System
SE	Standard Error
PWLS	Pre-Weaning Lamb Survival
SMWT	Six-Month Weight
SNNPR	Southern Nation Nationality and Peoples Region

SP	Selection Proportion
SPSS	Statistical Package for Social Sciences
SNP	Single Nucleotide Polymorphisms
WWT	Weaning Weight
YWT	Yearling Weight
σ^2_{am}	Maternal-Additive Genetic Variance
σ^2e	Residual Variance
σ^2p	Phenotypic Variance
σ^2_{pe}	Permanent Environmental Variance
χ^2	Chi-Square

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I. Amelmal Alemayehu, Tadele Mirkena, Aberra Melesse, Tesfaye Getachew, Aynalem Haile. 2021. Genetic Parameters and Trends of Growth Traits in Community-Based Breeding Programs of Abera Sheep in Ethiopia._Acta Agriculturae Scandinavica - Section A: Animal Science, https://doi/full/10.1080/09064702.2022.2067590.

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ESTIMATES OF GENETIC PARAMETERS, GENETIC TRENDS AND OPTIMIZING COMMUNITY BASED BREEDING OF ABERA SHEEP BREED, ETHIOPIA

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ABSTRACT

Three combined investigations were carried out with the objectives of 1) estimating the genetic parameters and genetic trends for growth traits of Abera sheep in six breeder cooperatives established under community-based breeding programs (CBBPs); 2) participatory basis of comparison of breeding objectives and selection criteria of farmers from CBBPs and farmers from traditional sheep breeding practices; and 3) optimization of CBBPs of Abera sheep targets to increase genetic gain and economical profits with nine different breeding alternatives, considering number of candidate breeding ram and male to female sex ratio. A total of 2901 birth weight (BWT) 2626 weaning weight (WWT), 2261 six-months weight (SMWT) and 1603 yearling weights (YWT) records were collected between the year 2013 and 2019 were used for the analysis. General linear model consisting of the fixed effects of sex, breeder cooperative, *season and birth type was used to analyze growth traits. As sheep in each CBBP is bred with by its own breeding ram, variance components and resulting genetic parameters were estimated, within each breeder cooperative, using univariate animal model based on restricted maximum likelihood method using WOMBAT software. Multivariate analysis was also employed to compute correlation estimates among growth traits. Six different models, by including or excluding maternal additive genetic effects, maternal permanent environmental effect, and covariance between direct-maternal additive genetic effects were fitted and the most appropriate model was selected based on a Log-Likelihood Ratio Test (LRT) and Akaike's Information Criterion (AIC) were then used to select the most appropriate univariate model for each trait, which was finally used to estimate the studied parameters. Results indicated that all fixed effects influenced ($P<0.05$) the growth traits. The overall least squares means for BWT, WWT, SMWT and YWT were 2.9, 15.5, 20.8 and 27.9 kg, respectively. Based on the best fitted univariate model, the direct heritability (h^2) for WWT and SMWT in the six breeder cooperatives were in the ranges of 0.12 to 0.38 and 0.20 to 0.49, respectively. Low to high (0.14 to 0.99) genetic correlations were observed for SMWT and other growth traits in all locations except negative association of SMWT with BWT and WWT in Abera Doko and Bonchesa Gobi communities. The WWT and SMWT showed positive genetic trends over the selection years in all breeder cooperatives/sites except Abera Doda breeder cooperative. Positive genetic progress was also achieved in most of the Abera sheep breeder cooperatives.*

Breeding objectives and selection criteria were defined using participatory own-flock ranking experiment and a structured questionnaire were under taken to assess sheep breeding practices of different sheep from community based breeding and traditional breeding practices of 3 sheep breed/type namely Doyogena, Abera and Dauwro from Sothern, Sidama and South-west regions *of Ethiopia. Farmers selected purposively from community based breeding program (CBBP) and traditional breeding practices, accessibly and sheep production experience. A survey and own flock ranking experiment involving 300 households and 360 head of sheep were used. Data on size and appearance, lamb growth, lamb survival and reproduction traits were recorded for each ewe. From survey study, qualitative and quantitative data were obtained from flock ranking measurements and significant ($p<0.05$) variation was observed on rank, breed and membership of community based breeding program (CBBP) on body weight and most of studied traits including price of ewe. Farmers from both member of CBBP and non-member community breeding program emphasized traits on body size and appearance, reproduction and mothering ability and body condition as their breeding objective. A simulation study was conducted to optimize for genetic progress and profitability of Abera sheep CBBP based on candidate number and sex ratio. Six-month weight (kg) were identified as selection criteria trait, 9 breeding alternatives or schemes were simulated and evaluated for Abera Bongodo breeder village based on different candidate number and sex ratio. The annual genetic gain (AGG) for SMWT ranged from 0.06 to 0.16 kg, annual monetary genetic gain (AMGG) ranges $ 0.27 to 0.64 and discounted profit per ewe ranges $-0.04 to 1.87. Scheme 9 is recommended over all other schemes. So, shifting the current male to female ratio 1:9 to 1:27 (Scheme 9) with increased number of proved lambs for selection up to 150 maximized the genetic progress and profitability of the breeding program than the former breeding scenario in Abera sheep CBBP.*

Keywords: *Community based sheep breeding, Genetic parameters, Genetic trends, Growth Traits, Estimated breeding value, Optimize selection intensity, Source of breeding ewe*

1. GENERAL INTRODUCTION

Ethiopia has the largest livestock inventory in Africa, including about 65 million cattle, 40 million heads of sheep, 51 million goats, 8 million camels and 49 million chickens in 2020 with wide distribution in the different agro-ecological zones of the country (CSA, 2020) Approximately 4.95 million goats and 4.75 million sheep population are found in Southern Nations and Nationalities Regional State of Ethiopia (CSA, 2020). The regional state is also known for its wide range of variations in climate conditions and topography as well as multi-ethnic diversity, representing a good reservoir of goat and sheep genotypes.

The vast indigenous animal genetic resources of Ethiopia provide a considerable economic base for smallholder farmers as well as for the country and contribute significantly to both food and nutritional security. In the country, agriculture plays a major role in the everyday life and livelihood of majority of Ethiopian citizens. The agricultural sector employs about 12 million smallholder farmers and 12 to 15 million pastoral and agro-pastoral communities and 45% of the gross domestic product (FAO, 2019). Among livestock products and by-products, meat, milk, honey, eggs, cheese, and butter are the front leaders. Animal protein also contributes to the improvement of the nutritional status of the society and livestock plays an important role in providing export commodities, such as live animals, hides, and skins to earn foreign exchanges to the country (CSA, 2017).

Fourteen traditional sheep populations are found in Ethiopia, (Gizaw, et al., 2007). Indigenous sheep and goat breed improvement programs were started around 1944 in Ethiopia through cross breeding indigenous sheep types with imported exotic sheep breeds such as Bleu du Maine, Merino, Rambouillet, Romney, Hampshire, Corriedale, Dorper and Awassi sheep, and Saanen, Anglo- Nubian, Toggenburg and Boer goats also, different government institutions (research organizations and universities), non-government institutions (e.g., Farm Africa) and projects (e.g., Chilalo Agricultural Development Unit and Ethiopia Sheep and Goat Productivity Improvement Program) implemented these introductions and cross-breeding of sheep (Tibbo, 2006). While the sustainability of the cross-breeding programs were questioned and the improvement programs produced no significant effects on sheep and goat productivity or on farmers' and pastoralists' livelihoods and the national economy at large because most crossbred sheep were not selected by farmers as they did not meet the preference of the farmers and were incompatible with the management of small-holder farmers (Gizaw and Getachew, 2009).

Some of the reasons for failure of these breeding programs also included lack of clear breeding strategies which are appropriate for different situations, lack of genetic improvement based on long-term vision and commitment, inefficient delivery of improved genetics, limited technical capacity at different levels, absence/lack of investment by the public and private sectors, limited application of modern biotechnology tools, lack of participation in the breeding programs and lack of monitoring and evaluation of the schemes (Haile et al., 2019).

The role of participation of sheep and goat producers in the implementation of breeding programs based on their trait preferences can determine the sustainability of the improvements audition (Gizaw et al., 2010). In 2009 community-based sheep breeding programs were implemented in three locations with three breeds (Bonga, Horro and Menz) with 8000 sheep (Haile et al., 2014). Following this, International Livestock Research Institute (ILRI), International Center for Agricultural Research in the Dry Areas (ICARDA) and University of Natural Resources and Life Sciences, Vienna (BOKU) in collaboration with Sothern Agricultural

Research Institute (SARI) initiated sheep CBBPs in different zones of Southern region of Ethiopia. The program was implemented with the aim of improving the productivity and income of small-scale farmers by providing access to improved animals that respond to improved feeding and management, facilitating the targeting of specific market opportunities used in domestic and /or export market (Haile et al., 2014). Currently, 40 sheep CBBPs are running in different zone of southern region of Ethiopia.

The success of any breeding programee depends greatly on definition of the breeding objective and choice of selection criteria during its establishment as takes the lead in sustainable continuity of the breeding program while, as in most of our community based breeding programs (for example Abera and Dawuro sheep) identification of breeding objectives and selection criteria were most often defined verbally in a loose manner allowing a considerable amount of scope for various interpretations of what the desired improvement might be and attention has been increasingly focused on the specific definition of breeding objectives for sheep from an economic point of view. Although participatory approach has recently been adopted and used to define breeding objectives for various sheep breeds (Getachew, 2010; Gizaw et al. 2010; Mueller et al., 2021) there is still a limited research effort to evaluate the breeding objectives and selection criteria of farmers in traditional breeding practices (Gizaw et al., 2013).

Classification of Ethiopian sheep population is based on tradition, ethnic community, as well as physical characters that is not satisfactory and consequently is not enough for the purpose of conservation and utilization of these resources for future use (Gizaw et al. 2007). Comprehensive knowledge and understanding of the genetic potential of the existing genetic diversity, a proper classification, as well as the population structure base specific sheep breed /population is very vital for rational planning of genetic improvement programs to enhance the productivity of indigenous breeds (Kijas et al., 2009; Uzzaman et al., 2014). Attention should be give in planning of new establishment and on-going selective breeding programs because, breeding programs do not yield the expected genetic improvement as a result of the following four reasons: I, the use of inappropriate models for breeding value estimation, for example when the models do not include systematic environmental effects that are present in the data; II, overestimation of the genetic parameters (e.g. h^2) resulting in biased estimated breeding values and over prediction of the expected response; III, preferential treatment among selection candidates resulting in selection of individuals that received "good treatment" instead of genetically superior individuals, and IV, unexpected correlated response in other traits (Hans et al., 2006).

The availability of more reliable phenotypic and genetic parameter estimates would enable in formulation of a more accurate selection index. Understanding of the genetic estimates can help to utilize results that obtained from evaluation of alternative improvement and dissemination schemes (Gizaw, 2008). Selection of parents over time /selective breeding leads to genetic improvement, i.e. there is an increase of average breeding value over time. This increase is referred to as ‘genetic trend’, and basically measures the success of breeding programs. The average of each generation is estimated by BLUP as the mean of the parents’ EBV, and since BLUP is also able to work out the difference between all animals and those selected as parents, BLUP can properly estimate the genetic change over time. The genetic trend is estimated from the average EBVs over time, i.e. the EBVs are plotted against the birth year of the animals so, based on the BLUP we were evaluated the genetic improvement that can be obtained from CBBPs.

A single index and hence a single breeding program might not satisfactorily meet the objectives of different systems and producers or farmer/pastoralist participatory approach for defining breeding objectives for Ethiopian sheep is very important. Any breeding program or breeding approach should meet the interest of small-scale sheep producers consequently; participatory approaches for evaluating the relative importance of traits in selection are rarely applied in animal breeding, whereas they are frequently used in plant breeding (Sölkner et al., 1998). Understanding the target production system and involving the farmers when defining breeding objectives is essential for designing sustainable breeding strategies and obtaining stable and visible outcomes from the breeding plans. This is particularly the case in traditional livestock management systems in which farmers and pastoralists have complex production and marketing objectives and strategies.

To optimize the design of breeding programs a full understanding of selection index theory to predict the outcome of performance recording, genetic evaluation and subsequent selection is required.

Evaluation of breeding programs: Once a breeding program is operational, it is essential to routinely evaluate the results. An evaluation may consist of comparing realized genetic improvement and rates of inbreeding with values expected when designing the breeding program. When there are clear differences between expected and realized selection response and inbreeding, then one needs to find the causes of those discrepancies and if possible improve the breeding program. This study provides, an estimation of genetic parameters and genetic trends resulting from confirmation and information of measurable genetic gains and the contribution of CBBPs to economical and social benefits for smallholder sheep farmers, information resulted from participatory identification of breeding objective and selection criteria among members and non-member of community based breeding programs and alternative breeding schemes to upgrade genetic gains resulted from selective breeding.

Thus, three different studies focusing on sheep populations in different regions of Ethiopia (Abera, Dawuro and Doyo gena) were performed. The study in the first paper provides evidence of measurable genetic gains resulting from community-based breeding programs in small-scale sheep farming of Abera sheep. The aim of the second paper was to review recent advances and to highlight a number of issues that arise when attempting to develop a breeding objective of small-holder farmers from community based breeding program and farmers in traditional breeding practices traditional breeders (NMCBBP) keep animals for multiple purposes and have undefined and complex breeding objectives. We used own-flock ranking experiments to identify breeding objectives of traditional and advanced (MCBBP) sheep breeders in different locations (Sidama, Kembata and Dauwro) to evaluate the impact of practicing community-based breeding program on breeders' preferences on attributes of sheep (production and reproduction traits) such as body size and appearance, reproduction traits and mothering ability (lambing interval and prolificacy), body condition and morphological characters (mainly coat color and horn). Thus, the objective of the current study was to identify breeding objective traits and selection criteria under different farmer's awareness level to investigate the impact of CBBP on targeting tangible identification of trait of breeding objective and selection criteria than traditional sheep breeders. The last study aimed to optimize the overall breeding structure based on candidate ram number and mating ratio to maximize genetic gain and discounted profit for Abera sheep community-based breeding program. Therefore, this study is initiated to address the following general and specific objectives.

General objective

To evaluate the genetic progress, comparative definition of breeding objective and selection criteria of small-holder farmers and to optimize and design sustainable community-based breeding for indigenous sheep breeds in Ethiopia.

Specific objectives

- To estimate the genetic parameters and trends of growth traits in a community-based breeding programs of Abera sheep in Ethiopia
- To identify breeding objectives and selection criteria of smallholder farmers in selected areas of southern Ethiopia using participatory approche.
- To optimize Abera sheep community-based breeding program by evaluating alternative breeding schemes.

2. LITERATURE REVIEW

2.1 Sheep Domestication and Introduction to Africa

The genus Ovis include all wild and domestic sheep, while domesticated sheep (*Ovis aries*) belong to the family Bovidae and sub-family Caprinae in the sub-order Ruminantia of the order Artiodactyla and Mouflon (*O. orientalis*) is the wild ancestor of the first grazing livestock species sheep (*Ovis aries*) and its domesticated 11,000 years ago the in the Fertile Crescent (Chessa et al., 2011). After domestication, sheep set apart and dispersed to Eurasia and Africa via separate migratory travelers. The current genetic path in the breeds raised from different agro-ecological zones and environmental pressure created phenotypic variation and morphological differences in sheep (Lv et al., 2014). Molecular genetics (endogenous retrovirus and mitochondrial DNA) confirmed that the maritime trade and colonization had a major influence on sheep movement in the Mediterranean areas (Chessa et al., 2011).

Archeological evidences and molecular genetics studies confirmed that selection of domestic sheep with desired secondary characteristics common to the modern breeds occurred first in South-West Asia and then spread successfully to Europe, Africa and the rest of Asia (Anne and Olivier, 2013). Sheep where adapted for meat in initial time while later specialization in to wool and milk and evolutionary forces of mutation, selective breeding, adaptation, isolation and genetic drift caused by human intervention along with the environmental influence has been the ability to create large number of local breeds (FAO, 2007).

The genetic material keeps raise and increased dramatically in the recent decades and sheep are among the widely distributed species among all livestock species. A recent report on livestock breed diversity stated that there were 7202 local breeds (breeds found in only one country), 509 regional trans boundary breeds (breeds found in different countries within one region) and 551 international trans boundary breeds (breeds found in different countries in different continents) (FAO, 2013). In addition, the widely practiced breed combination resulted in about 443 well documented composite sheep populations worldwide in 68 countries (Shrestha, 2005).

There is lack on information on study of African sheep compared to European and Asian sheep, the diversity of mitochondrial DNA (mtDNA) of African sheep has been less studied. Sheep population in Africa, Pakistan and China displayed a similarly homogenous retrotype pattern common to the population of South-West Asia, suggesting a direct migratory link of domestic sheep between these areas (Chessa et al., 2011).

The African sheep, mainly classified based on their tail type and most sheep in Africa categorized in fat-tailed and thin-tailed sheep types. The fat-tailed sheep are most widely distributed, being found in a large part of North Africa (from Egypt to Algeria) and in Eastern and Southern Africa (from Eritrea to South Africa) and the thin-tailed sheep are present mainly in Morocco, Sudan and in West Africa. The first domesticated sheep is believed to have been thin-tailed as the ancestors of domestic sheep are thin-tailed. Archaeological information supports separate introductions and dispersion histories for the African thin tailed and fat-tailed sheep (Anne and Olivier, 2013).

Horn of Africa and northeastern part of Africa is believed to be the first entrance place of fat-tailed sheep. Mitochondrial DNA analysis supports a common maternal ancestral origin for all African sheep, while autosomal and Y chromosome DNA analysis indicates a distinct genetic history for African thin-tailed and sub-Saharan fat-tailed sheep (Meadows et al., 2005).

2.2. Sheep Breed Classification in Ethiopia

Among developing regions, Ethiopia is known for its diversified and vast animal genetic resources numbering 70 million cattle and 42.9 million sheep and best place for studying the livestock resource (CSA, 2020). The country also can be considered as a center of livestock diversity: it is a route of sheep migration from Asia into Africa has large sheep population and diverse traditional sheep breeds spread across diverse ecology, communities and production systems (Gizaw, 2008). At the national level, sheep/goat account for about 90% of the live animal/meat and 92% of skin and hide export trade value (FAO, 2011). According to the data from 2017/18, Agriculture in general provides 80% food in the population and responsible for 34.9% of GDP and 83.9% of total exports while, the livestock sub-sector in particular contributes up to 25.6% of agricultural GDP and 10.5% of total Ethiopian foreign exchange (NBE, 2018).

In livestock production breed can be classified based on its utilization based on several different parameters such as suitability for meat or wool production (meat or wool type) or based on their breeding use as a specialized ram breed, a specialized dam breed or a dual purpose breed. Wool type breeds may be further classified according to the type of wool produced, hence fine-wool type, medium-wool type, long-wool type, coarse-wool type, carpet wool type and fur type (Ensiminger, 2002). Specialized sheep breed in any productive parameters and classification based on their importance is not common in Africa; rather sheep breeds are classified based on their tail form and hair type. In Ethiopia, at least six sheep breeds are found and these fall into three breed groups: the fat-tailed hair sheep, the fat-tailed coarse wool sheep and the fat rumped hair sheep (Ayalew et al. 2004). The review and characterization report of different scholars (Ayalew et al. 2004; Lemma, 2002; Abegaz, 2007) indicate the presence of long-thin tailed sheep breeds in North West and western part of the country on the border area with Sudan. Also in southern part of Ethiopia, around Dawuro zone and Konta special woreda sheep types where long fat tailed thoroughly (Alemayehu, 2011). Sheep breeds of the Amhara region of the country were also categorized into four groups based on agro-ecology and morphological characteristics. 1) The central highland sheep: include Farta, Tikur, Menz, Wollo, Shewa/Legegora, Sekota/Abergele sheep; 2) Rift valley: include Afar sheep; 3) North western highland: include Agew/Dangla sheep, Wegera sheep, Semien sheep; and 4) North western lowland sheep: include Gumuz/Shankila sheep (Lemma, 2002).

As shown based on morphological and molecular characterization of Ethiopian sheep breeds by targeting those sheep populations traditionally recognized by ethnic and/or geographic nomenclatures, the Ethiopian sheep breeds are classified into 14 traditional populations in 9 breeds within 6 major breed groups (Gizaw, 2008).

2.3 Sheep Breed Improvement

Improvement of the genetic competence of livestock species needs high input, intensive labor and long term plan and remains a challenge for developing countries due to lack of skilled resource personnel, supportive infrastructure and institutional arrangements. Genetics is the most important component of the management, use and development of animal genetic resources (Wurzinger et al., 2011). Genetic improvement could be implemented through selection within breed, selection between breeds or crossbreeding (Haile et al., 2019). The little research that has been undertaken in tropics found that there are highly productive indigenous breeds (FAO, 2005).

As indicated by Gizaw (2008), Ethiopia possess high phenotypic diversity for morphological characters on sheep and the significant within and between breed variation on growth and survival in Menz and Horro sheep breeds and moderate heritability for growth traits for Menz, Horro and Afar sheep breeds (Aebgaz et al., 2002; Gizaw et al., 2007). Genetic improvement program requires definition of wide-range breeding goal traits incorporating the specific need and social circumstances of the target group as well as environmental constraints. Description of the production system, breeding objectives, and traits to be selected, decision about breeding method, breeding population, and breeding plan has to be considered in designing breeding programs (Sölkner, et al., 1998; Kosgey and Okeyo, 2007).

Breeding goal is defined as a list of traits to be improved genetically. It should be in line with the National Agricultural development objectives, and appropriate for which it is defined and breeds suited to the production system. Breeding goals of traditional societies are far more multi-faceted than intensive productions systems and comprise many aspects other than high productivity with regard to cash products (Köhler-Rollefson, 2000). They can include aesthetic preferences, religious requirement and behavioral aspects, such as a complacent nature, good mothering instincts, herd ability, the ability to walk long distance and loyalty to the owner (Kosgy et al., 2004). The survival ability of animals in specific agro-climatic condition is very important before expecting it to produce high production (Gizaw, 2008).

2.4 Breeding Objectives and Importance of Sheep in Ethiopia

Sheep population in Ethiopia are not categorized as specialized sheep breed /type rather they are kept as indigenous unimproved breeds mainly created under the influence of natural selection and human intervention for morphological characteristics (Getachew, 2015). In the developing countries, livestock in general are kept for subsistence and multipurpose role (Wurzinger et al., 2011). Sheep are mainly reared by small-holder farmers and used mainly for income generation from the sale of live animals and food source (Duguma et al., 2010; Getachew et al., 2010; Alemayehu et al., 2011). Other intangible benefits like using sheep for insurance, means of saving and socio-cultural benefits are also well documented (Kosgy et al., 2004). Interest of farmers in the highland areas of Ethiopia were also documented for coarse wool, coat color, tail type and presence and absence of horn is (Gizaw, 2008; Getachew et al., 2010).

Farmers sold fast growing animals for their immediate cash income necessitate and the role of sheep is more definite in the extreme highlands of the country as such areas are less suitable for crop production as well as larger animals like cattle due to environmental difficulties further more specific sheep breed are more suitable for crossing breeding as immediate cash income, like Wollo, Menz, Tikur and Farta sheep breeds are among the short fat tailed coarse-wool populations in the sub-alpine areas has been targeted for Awassi crossbreeding (Getachew, 2015).

In the developing countries, acceptance of new breeds by farmers is influenced not only by their productive performances, but also by non-production traits like attractiveness and appearance of the animal (Wurzinger et al., 2011). Specific traits like coat color, tail type, horn and ear size of sheep can also have significant influence on price in the predominant live animal marketing (Tadesse, 2009). In the first step of importation of exotic breed in Ethiopia were aimed to improve wool and meat production (Getachew, 2015). While ignored the preference of farmers regards to sheep appearance and general phenotypic look led to low acceptance and resulted rejection of the exotic breeds (Duguma et al., 2011).

2.5 Characterization of Animal Genetic Resources

The refining of all knowledge which used to reliable prediction of genetic performance of an animal genetic resource in a definite environment and provides a basis for identification of different animal genetic resources and assessing available diversity and characterization includes a clear definition of genetic attributes of an animal genetic resource and the environments to which it is adapted (Ayalew et al., 2004).

Before starting to plan any breed or productivity improvement programs, it is very important to identify the class of indigenous Animal Genetic Resources (AnGRs) using different method of characterization.While, characterization should include physical description, reproduction and adaptations, uses, prevalent breeding system, population trends, predominant production system, description of environments in which it is predominantly found and an indication of performance levels (Ayalewet al., 2004). Generally, according to Nicholas (1987) breed characterization can be divided in to 3 main categories: phenotypic characterization, genotypic characterization and molecular taxonomic characterization.

2.5.1 Phenotypic Characterization

Phenotypic characterization of breeds is carried out based on morphological characters such as coat color, presence or absence of horn, tail type, body measurements and other specific and visible traits. Frequency of the most typical morphological characteristics can help to compare variations within breeds and distances between breeds. In general which needs describing the qualitative and quantitative traits of a representative sample of the breed usually in comparison with other breeds (CGRFA, 2011).

2.5.2 Genotypic Characterization

Genotypic characterization involves calculating genetic variances and co-variances, heritability and other quantitative genetic parameters of observable traits. The estimates of genetic parameters are helpful in determining the method of selection and the impact of selection that also helps to predict direct and correlated response to selection, choosing a breeding system to be adopted for future improvement as well as in the estimation of genetic gains (Safari et al., 2005)

2.5.3 Molecular Taxonomic Characterization

Since the beginning of the 1990s, molecular data have become more and more relevant for the characterization of genetic diversity (Groeneveld et al., 2010).

The Molecular Taxonomic Characterization needs establishment of the genetic distances between breeds and the genetic structure of breeds. Genetic characterization has recently been the method of describing and classifying livestock breeds using measures of genetic distances between populations (Nei, 1973).

Very recently, molecular characterization of farm animal genetic resource has received attention in Ethiopia (Getachew, 2004) and genetic characterization tools include biochemical (protein) polymorphisms and molecular polymorphisms. Biochemical markers lack the power to resolve differences between closely related populations because of low polymorphism of these markers (Meghen et al., 1994). Polymorphic molecular genetic markers include microsatellites, single nucleotide polymorphisms (SNPs), restriction fragment length polymorphisms (RFLPs), randomly amplified polymorphic DNA (RAPDs), mitochondrial DNA markers, Y-specific alleles, and amplified fragment length polymorphisms (AFLPs). Currently, microsatellites have become markers of choice for diversity study (Ruane, 1999). Microsatellites are also recommended markers by FAO for characterizing farm AGR (FAO, 2011).

2.6. Conservation of Animal Genetic Resources

Conservation of farm animal genetic resource has diverse pattern in the developed and developing world. While breed conservation is seen as the protection of rare breeds in developed countries (Windig et al., 2004), conservation in the context of developing countries can be appropriately defined as the rational use and protection of existing local genotypes from genetic introgression (Rege and Lipner, 1992).

The development of a national conservation program for animal genetic resources should start with an overview of the country's livestock production systems, including the species and breeds involved in providing different livestock functions and conservation of farm AGR thus incorporates preservation, maintenance, improvement and sustainable utilization (FAO, 2013).

Breed conservation needs to plan along with the improvement of management of animal genetic resource with for better utilization in apt breeding programs to conserve those at risk and to alter the loss of breeds (Barker, 1999). To conserve the diversity of animal genetic resource needs to include conservation of within-breed variation. Conservation of farm animal genetic resource has gained attention not in long ago while; it has become a major activity of regional and global bodies (FAO, 2013). In the same way, several studies addressing the theoretical and practical implementations of decision making in livestock conservation have recently been conducted. Two approaches on making conservation decision relating to issues of between-breed and within-breed diversity conservation (Eding and Meuwissen, 2001) have dominated the literature on livestock conservation.

The condition of farm animal genetic resources in Ethiopia including sheep resources have been reported as part of FAO global farm animal genetic resources survey (FAO, 2007). Regarding conservation efforts, purebred nucleus populations of few selected traditional sheep breeds are maintained in research centers, though these are not formally intended for conservation purposes. However, there is no comprehensive conservation program for the adapted indigenous sheep breeds of the country. There is also lack of research to support decision on conservation of sheep resources in Ethiopia.

2.7. Genetic Trend and Optimizing Design of Breeding Programs

Different parameters can be considered to design any breeding programs but in planning of breeding program, we often need a more dynamic approach that should help in getting optimal selection results. Such optimization is needed when optimizing decisions under current circumstances in a condition when a tactical decision is needed. Although such strategic planning in dynamic approaches that, help to reconsider design parameters when circumstances change (Hans et al., 2006).

Some traits are measured in specific age range, when a trait is measured at an earlier age, it would probably be more optimal to select younger animals, as they will have more accurate estimated breeding values so, selection accuracy and generation interval both change. In the design of a breeding program, many aspects that determine genetic response are mutually dependent, and changing one variable might result in different optimal values for other variables (Jack et al., 2004).

2.7.1 Genetic Trend

Selection of parents over time leads to genetic improvement, if there is an increase of average breeding value over time. This increase is referred to as 'genetic trend', and basically measures the success of breeding programs. The average of each generation is estimated by BLUP as the mean of the parents' EBV and since BLUP is also able to work out the difference between all animals and those selected as parents, BLUP can properly estimate the genetic change over time. The genetic trend is estimated from the average EBVs over time, i.e. the EBVs are plotted against the birth year of the animals (Hans et al., 2006).

Best Linear Unbiased Prediction (BLUP) can maximize the correlation between true and predicted breeding value or minimizes prediction error variance. Linear predictors are linear functions of observations. Unbiased estimation of realized values for a random variable such as animal breeding values, and of estimable functions of fixed effects is unbiased. True breeding value equals to those of the predicted breeding value. Prediction involves prediction of true breeding value (Henderson, 1949).

2.7.2 Optimization of Breeding Schemes and Inbreeding

The selection index theory has first been described for livestock breeders by Hazel (1943) a scientist from Iowa State University. Not much has changed, the formula for selection indices Hazel developed some 60 years ago are still valid, although Henderson (1973) has been shown that his mixed model equations (BLUP) are in fact Hazel's selection index, but make the calculation of selection indices computationally much easier (Hans et al., 2006).

The theory of selection index helps in optimization and designing breeding programs that can used to predict the outcome of performance recording, genetic evaluation, and succeeding selection.

Mating between closely related individual or inbreeding reduces genetic variation, which in turn reduces genetic gain. Furthermore, when inbreeding depression is present, fitness of the population may reduce to an extent where it affects the selection differentials, i.e. indirectly inbreeding may also reduce genetic gain. In the short term, inbreeding and genetic gain have an adverse relation, in the sense that maximizing short-term response by selecting fewer parents reduces long-term response and involves substantial risk (Hans et al., 2006).

The objective in optimized breeding strategies needs to be maximizing genetic gain while restricting inbreeding. Acceptable levels of inbreeding are difficult to determine and inbreeding depression is probably the most important issue. Though detailed knowledge of the relevant parameters to determine the level of the constraint is lacking, different approaches point towards values around 0.5 % and 1 % per generation. Different components of genetic gain (Bijma, 2000).

Alternative options for breeding programs need to be assessed, which can be done based on an analysis of the most important factors that determine rate of genetic gain: selection intensity, selection accuracy and generation interval, as in the Rendel and Robertson formula. It should be pointed point out that the different factors interact. For example, one could try to increase selection intensity, but the result is that breeding animals can be less rapidly replaced when fewer young animals are selected, and the generation interval is increased. The most important interactions are: Generation interval versus selection accuracy Selection young animals will not only lead to short generation intervals, but may also imply lower selection accuracy because young animals have generally less information available (no repeated records, maybe no own performance, no progeny test). If more young animals are retained as breeders, and a high replacement rate is applied, the generation interval may be shorter, but selection intensity will also be lower since more animals of the newborn generation are needed as replacements (Jack et al., 2004).

2.8. Small Ruminant Breeding Programs in Ethiopia

The approaches used to date for small ruminant breeding programs in Ethiopia are three: 1) crossbreeding and distribution of crossbred rams from stations/ ranches; 2) selective breeding involving central nucleus schemes; and 3) community‐based breeding programs (Haileet al., 2019).

The small ruminant breeding strategies adopted in Ethiopia over the last few decades largely focused on importing exotic breeds for cross‐breeding, and since the early 1960s, substantial efforts have been made however, these genetic improvement programmes produced no significant effects on sheep and goat productivity or on farmers and pastoralists livelihoods and the national economy at large (Tibbo, 2006).

The major limitation faced by livestock cross‐breeding programs in Ethiopia has been the lack of a clear and documented breeding and distribution strategy. There has been very little consideration of the needs of the farmers and pastoralists, their perceptions and indigenous practices. Additionally, they have had limited or no participation in the design and implementation of the breeding programs, leading to low commitment. Furthermore, the breeding programs lacked breeding schemes to sustain cross-breeding at the nucleus centers and at the village level (Gizaw and Arendonk, 2010). The distribution of the improved genotypes of these programs was indiscriminate and unplanned, resulting in failure of the breeding programs and threatened to dilute the sheep and goat genetic diversity in the country. not only in CBBP but also planning of sheep crossbreeding program needs optimized program in a way to exploit the available large genetic variation and stabilizing the current crossbred population to the levels found to be best for a particular location is the main suggestion as derived from the results of Getachew (2015).

2.9. Community-Based Breeding Program (CBBP)

Community-based breeding program is a small scale producers/farmer-participatory approach having common interest to conserve and improve their genetic resources under low-input production system and one way to genetically improve livestock genetic resources. CBBP focuses on indigenous stock and consider farmers' needs, views, decisions and active participation, from inception through to implementation, and have been identified as programs of choice (Haile et al., 2019).

As they possess a specialized livestock breed, breeding in developed countries was implemented with designed reproduction, controlled mating, large flock size, individual animal identification, progeny and performance testing and recording to identify superior parents and sophisticated data processing (Sölkner et al., 1998). Genetic improvement efforts attempted so far in developing countries were mainly focused on crossing of indigenous with the exotic sheep, did not bring the expected result in matching the interest of small-scale sheep producers (Workneh, 2002; Hassen et al., 2002).

In sheep production especially in crossbreeding different obstacles leads in the front mainly, lack of modern production like lack of clear idea which can lead to bring result, lack of recording at small holder level and lack of compatibility of existing environment and genotype (Workneh, 2000; Tibbo, 2006). Many attempts to improve indigenous sheep genotype based on pure breeding using technologies proved in developed world failed due to minimum participation of farmers, interruption of high governmental or other institutional subsidy, small flock size, single sire flocks, lack of animal identification, lack of performance and pedigree recording, low level of literacy and organizational paucity (Sölkner et al., 1998; Kosgey et al., 2006). However, community-based breeding schemes are to become viable options for genetic improvement programs of small ruminants in low-input, smallholder production systems (Sölkner et al. 1998; Kosgey and Okeyo 2007). The CBBP considers mainly the participation of small-scale farmers as they are working on the animals at their hand and within the existing environment.

The International Center for Agricultural Research in the Dry Areas (ICARDA), the International Livestock Research Institute (ILRI), University of Natural Resources and Life Sciences (BOKU) and the Ethiopian Agricultural Research System implemented a project on community based sheep breeding programs in eight communities of four districts (Afar, Bonga, Horro, Menz) in Ethiopia since 2009, involving more than 8000 sheep (Haile et al., 2014).

This new approach has been tested in a few places with promising results (e.g. with sheep and goat in Ethiopia, dairy goats in Mexico, llamas and alpacas in Bolivia and Peru, sheep in Argentina).The breeding programs in Ethiopia have achieved important outcomes/impacts. For example, the program covers 2,400 households in more than 30 villages with more than 14,000 people directly benefiting from the scheme. There is increased productivity (more births, better growth and reduced mortality), increased income from sheep production and increased mutton consumption. Additionally, the cooperatives have been able to build capital for buying rams/bucks and other investments, building on the initial revolving funds supported by the project (for example, Bonga cooperative has capital of around USD60,000) (Haile et al., 2018).

The aim were to put effort to improve the income of small-scale resource-poor sheep producers through improved animals that respond to improved feeding and management, facilitating the targeting of specific market opportunities and linkage. There is a governmental rural organization associated with each of the project sites. Different level of research organization were actively involved on community establishment, technical support and capacity building of the program and local enumerators were recruited for each community to help the research system in animal identification and recording. The indigenous knowledge of the community was considered at each phase of the project. For example, the community decides how rams were managed and how they are shared and used. The core in this project is to get community members working together in ram selection, management and use (Haile et al., 2014).

2.9.1 Selection tools in CBBP

2.9.1.1 Performance Recording

The first and most important selection tool is performance records. The magnitude and intensity of recording depends largely on the degree of organization, technical support of government or private institutions and it is often costly. We generally recognize two types of recording schemes (On-station and on-farm performance recording systems). The minimum requirements for either system are: 1. Individual identification of all animals 2. records on mating and lambing dates 3. live weight records of lambs at regular intervals (birth, weaning, six month and yearling weight). This basic recording structure can be adapted to the specific situation of different areas (Mavrogenis, 1995).

2.9.1.2 Estimation of breeding values

Genetic evaluation procedures should combine, in an optimum way, the performance of the individual and of his relatives (sire, dam, collaterals). Fixed factors effects should be considered. If the trait under selection pressure can be measured on the individual (live weight), mass selection is the best selection procedure. When milk yield is under selection, the use of relatives (dam sibs or progeny) becomes an integral part of the procedure, since it can be only be measured in one sex. When we aim for the simultaneous improvement of more than one trait, we must employ one of the following tools: 1. Independent culling levels 2. Tandem selection. 3. Selection based on total score (index). Evaluation procedure combines information on the individual with that of his relatives using Best Linear Unbiased Predictors (BLUP) under an "Animal Model (Mavrogenis, 1995).

3. SUMMARY OF MATERIALS AND METHODS

The studys conducted in three regional states (Sidama Regional State, Southern Nations Nationalities and People Regional State (SNNPRS), and South-West Regional State) of Ethiopia. The geographical location of the study areas are shown in Figure **1**. From Sidama regional state, the study was conducted in Dara Otelicho and Hulla woreda located on geographic coordinates of 38º 38'-38º 51' E longitude and 6º 36'-6º 54' N latitude with altitude ranging from 1200 to 2900 meters above sea level. Average annual maximum and minimum temperature of 28 ºC and 19 ºC respectively, with 1200-1700 mm ranges of total rainfall. From SNNPRS, the study was conducted in Kembata Tembaro zone, Doyo genaworda, Hawaera and Anicha village located on geographic coordinates of 7º 20'N latitude and 37º 50' E longitude with altitude range of 1900-2800 m.a.s.l, (midaltitude up to30 % of area and highland 70 % of area). Average annual maximum and minimum temperature of 27.76 ºC and 12.83ºC respectively. From South-West regionalstate, Dauwro Zone, Tocha worda, Medehaniyalem district were involved in the current study. The area is situated at an altitude ranging from 730 to 2850 m.a.s.l., longitude 37º09'E and latitude 7º 08 'N and the annual mean maximum and minimum temperature of the zone is 26.4 ºC and 14.9ºC, respectively (Agricultural office of the zone). The annual mean rainfall of the zone ranged from 1200 to 1800 mm.

3.1. Estimation of Genetic Parameters and Genetic Trends

Data collected over 7 years (2013 to 2019) by Hawassa Agricultural Research Center (HARC) were used to estimate genetic parameters and trend of growth traits resulted from the on-going selection program of Abera sheep from six different breeder cooperatives (Abera Gelede, Abera Atilla, Abera Doko, Abera Doda, Abera Bongodo and Bonchesa Gobi). Pedigree information and performance data were collected by enumerators at the time of incident (pedigree and BWT were recorded within 24 hours of lambing. WWT, SMWT and YWT were recorded between 85 to 95, 185 to 195 and at 355 to 360 days of age, respectively. Reliability and consistency of the pedigree data were checked using Pedigree Viewer Software (Kinghorn, 2015), and record errors like duplicated animal identification, and bisexual records were removed. Data was subjected to homogeneity of variances and normality test and outliers were excluded. Finally, 2901 records of BWT, 2626 records of WWT, 2261 records of SMWT, and 1603 records of YWT were included in the analysis.

The effects of fixed factors (year of birth, sex, breeder cooperative, season and birth type) on studied traits were analyzed using the "asremlplus" package in **R** statistical software (Brien, 2021).The statistical model used for the analysis of BWT, WWT, SMWT and YWT was:

$$y_{ijklm} = \mu + P_i + S_j + b_k + y_l + S_m + e_{ijklm}$$

Where y_{ijklm} is response of individual variables, μ is the overall mean, p_i = the effect of the i^{th} sex (i = 2, male, female), S_j= the effect of the j^{th} year (j= 6, 2014-2019), b_k = the effect of the k^{th} season grouped in to four classes based on the pattern of annual rainfall distribution in the area (k =4; September to November,spring; December to February, winter; March to May, Autumn and June to August, summer), $y_{l=}$ the effect of the $_l{}^{th}$ litter size (l=2, single, twin), S_m= the effect of m^{th} location (m=6; Abera Attila, Abera Gelede, Abera Doko, Abera Doda, Abera Bongodo and Bonchensa Gobi) and $e_{ijklm\ =}$ random error associated with each observation and assumed to be normality and independently distributed with mean zero variance $\sigma^2{}_{e.}$

Genetic parameters and (co)variance components for traits were estimated by fitting univariate animal model using Average Information Restricted Maximum Likelihood (AI-REML) model in

WOMBAT software (Meyer, 2012). All the fixed effects (lamb birth year, lamb birth season, sex, birth type, sex and site/location) considered in this study were found significant ($P< 0.05$) for all the traits and hence they were included in the model. The following six models were fitted to identify best fitting model for each trait by including or excluding maternal genetic or maternal environment effect.

Model 1: $y =\mathbf{X}_b + \mathbf{Z}_a + e$

Model 2: $y = \mathbf{X}_b+ \mathbf{Z}_a + \mathbf{W}_c + e$

Model 3: $y = \mathbf{X}_b + \mathbf{Z}_a + \mathbf{S}_m+ e$ with $cov\ (a,m) = 0$

Model 4: $y = \mathbf{X}_b + \mathbf{Z}_a + \mathbf{S}_m+ e$ with $cov\ (a,m)\neq 0$

Model 5: $y = \mathbf{X}_b + \mathbf{Z}_a + \mathbf{W}_c+ \mathbf{S}_m+ e$ with $cov\ (a,m) = 0$

Model 6: $y = \mathbf{X}_b + \mathbf{Z}_a +\mathbf{W}_c+ \mathbf{S}_m + e$ with $cov\ (a,m) \neq 0$

Where y is the vector of observations, b is the vector of fixed effects, a, m, c and e are the vectors of direct additive genetic effect, maternal genetic effect, maternal permanent environmental effect and residual (temporary environment) effect, respectively. **X, Z, W** and **S** are incidence relating individual records to b, a, c and m, respectively.

The (co) variance structure is as follows:

$$var \begin{bmatrix} a \\ m \\ c \\ e \end{bmatrix} = \begin{bmatrix} A\sigma^2 a & A\sigma^2{}_{am} & 0 & 0 \\ A\sigma^2{}_{am} & A\sigma^2 m & 0 & 0 \\ 0 & 0 & I\sigma^2 c & 0 \\ 0 & 0 & 0 & I\sigma^2 e \end{bmatrix}$$

Where, $A\sigma^2a$: additive genetic variance for direct effects of animal, $A\sigma^2am$: additive genetic covariance between direct and maternal effects, $A\sigma^2m$: additive genetic variance for maternal effects, $I\sigma^2c$: variance of maternal permanent environmental effects, $I\sigma^2e$, variance of remaining random effects, and A and I are matrices of relationships and identity matrices, respectively. The direct additive genetic, maternal additive genetic and maternal permanent environmental effects and residual effects were normal distributed with mean zero and variance $V(a) = A\sigma^2_{a,}V(m) = A\sigma^2_m$, $V(c) = I\ \sigma^2_c$ and $V(e) = I\ \sigma^2_e$ where I was identity matrix of order equal to the number of records.

Univariate animal model was used for each trait to select best-fited model. Log likelihood ratio test (LRT) were applied to choose the best model. A test statistics calculated as twice the difference between the log L of each model. The LRT was given by $D = 2\log(l_{R2}/l_{R1}) = 2[\log(l_{R2})-\log(l_{R1})]$, where l_{R1}=log-likelihood of restricted model and l_{R2}=log likelihood of the more general model.

To declare the significance of differences, the likelihood ratio was tested against the chi-square distribution with degrees of freedom being the difference in number of variance and covariance components in the models. If $2\Delta\log L$ values were not significantly different ($P>0.05$), then addition of a random effect did not improve the model hence model with lower number of random effect variances would then be chosen (Gilmour *et al.,* 2015). Finally, the model that has fewer parameters were selected as the most appropriate model.

Furthermore, the Akaike's Information Criterion (AIC) was also used for the selection of the best-fit model. When the two consecutive models have similar parameters, it makes the degree of freedom zero. Or, when, the difference between the full model and the reduced model log likelihoods value difference is negative, then the values of the difference with chi-square distribution become invalid, and more preferred by testing with AIC (Akaike, 1974).

AIC=−2 logL+2k

Where

Where logL is the log likelihood, and k was the parameter fitted for each model. A model with the lowest AIC was considered as the best-fit model for the traits (Akaike, 1974).

In In addition, depending on the model, total heritability were calculated according to the following equation (Willham, 1972).

$$h^2t = \frac{\sigma^2 a + 0.5\sigma^2 m + 1.5\sigma_{am}}{\sigma^2 p}$$

Genetic trend for each trait were estimated as regression of estimated breeding values obtained from the best model on year of birth using **R** software.

The WOMBAT software (Meyer, 2012) was used in the analysis of multivariate analysis to execute estimation genetic and phenotypic correlations. Genetic (r_G) and phenotypic (r_P) correlations between traits were estimated from variance and covariance components using the following formulae (Becker, 1984; Falconer and Mackay, 1996):

Genetic correlation (r_g) = $\frac{\sigma_{a12}}{\sqrt{\sigma^2 a_1 * \sigma^2 a_2}}$

Phenotypic correlation (r_p) = $\frac{\sigma_{a12}}{\sqrt{\sigma^2 a_1 * \sigma^2 a_2}}$

Where:

σ_{a12} = genetic covariance of traits 1 and 2,

σ^2_{a1} = genetic variance of trait 1, and

σ^2_{a2} = genetic variance of trait 2.

σ_{a12} = phenotypic covariance of traits 1 and 2,

σ^2_{a1} = phenotypic variance of trait 1, and

σ^2_{a2}= phenotypic variance of trait 2.

Correlation coefficient(r) were determined $0 < r < 0.3$ as weak correlation $0.3 < r < 0.7$ as moderate correlation, and $r > 0.7$ strong correlation as suggested by Ratner (2009).

3.2 Comparative and Participatory Identification of Breeding Objective and Selection Criteria

Own flock ranking (a method developd by Mirkena et al., 2010) and structured questionnaire were used to gather information from the selected households from member of community-based sheep breeding program and non-member of community based sheep breeding program. Selection of farmers were performed purposefully to investigate the outcome of participatory breeding program on identification of breeding objective and selection criteria.

Both sheep farmers from member of community-based sheep breed improvement program (CBBPs) and non- member (NCBBPs) from Doyogena, Abera and Dawuro were selected for the current study. Totally, 360 breeding ewes from (120 from Abera, 120 from Doyogena and 120 from Dauwro) were considered.

The structured questionnaire was focused on gathering information from the selected households from each CBBP and NCBBP members. Data on purpose of keeping sheep, ways of purchase and disposal from the farm, breeding practices and selection criteria used for breeding rams and ewes, rank of important traits, disease occurrence and lamb survival rate were collected. Inclusive list of traits was provided to each owner of sheep and asked to confirm its importance and the direction to improve it.

For the ranking experiment, each farmer from MCBBP and NMCBBP was asked to rank the top 2 and inferior (worst) ewes (1^{st}, 2^{nd} and 3^{rd}) within his own flock. The farmers were also asked to justify the reason for ranking the animals.

Data on body weight (BW), bodylength (BL), chest girth (CG), height at withers (HW), height at rump (HR), age (approximated through dentition), coat color type and pattern, reproductive performance and mothering ability (date of last lambing, parity, lifetime twinning, life time number of lambs born, life time number of lambs weaned, origin of ewe and sire (on farm or external), body condition score (BC) were recorded. The BC score was evaluated subjectively 1 to 5 as 1 very thin and 5 very fat.

Pre-weaning lamb survival (PWLS) was calculated for each ewe as ratio of lambs survived to weaning age to total number of lambs born in her lifetime. Twining rate (TR) was also calculated for each breeding ewe as ratio of lambs born to ewe parity. Economic value in terms of amount of money the owner is willing to pay (WTP) if the farmer were to buy the ewe for breeding purpose were recorded for each ewe. All recoding formats and questionnaire were tested before the actual survey to ensure clarity and accuracy.

The **R** software for statistical computing (**R** core team 2013) was used in all data analysis. Function in cross table (crosstable) in **R** using"gmodels" packages were used to create cross tabulations for qualitative data. Linear models were used to analyze the records for all traits. Regression in **R** package (Fox and Weisberg 2011) was used for the GLM (general liner model) analysis and the package lsmean was used for estimation of least squares means (Lenth, 2013).

The quantitative characteristics collected from the life history and linear measurement with fitting the rank, breed and participation level (PL) as fixed effects in the model as follows:-

$y_{ijl} = \mu + Rank_i + Breed_j + PL_l + e_{ijl}$

Where: -y_{ijl} is the trait of interest (body weight (kg), body length (cm), heart girth (cm), BCS (1-5), price (price if buying the ewe in ETB), μ is the overall mean for the traits$_j$, $Rank_i$ is the effect of the i^{th} rank of the ewe (i=1st, 2nd and 3rd); $Breed_j$ is the effect of j^{th} breed/type group (j = Doyogena, Abera, Dawuro); Participation level $(PL)_l$ is the effect of l^{th} participation level of CBBP (l=MCBBP and NM-CBBP); and e_{ijl} is the random residual effect.

Farmers from MCBBP and NMCBBP gave their reasons for the ranking of the ewes. Index based ranking was used to determine the relative importance of ranked traits. The reasons given by farmers were summarized in to groups and the groups were putted in categories based on the common characteristics.

The body size and growth traits categorized under reason related to live weight and lamb and ewe growth rate, body condition included reason related to body fat cover. The trait reproduction and mothering ability were grouped in the same group and included reasons referring to twining rate and lamb survival. Each farmer response of reasons were summarized by important with the assumption that farmers valuated the 1st, 2nd and 3rd reasons approximately in the same manner with same step length in between the numbered reasons. To calculate the weighted reason (WRi) of each trait (i) to be used for weighting of traits for sheep breed/type and location /site, the following equation from Bett et al.,(2009) were used to calculate the weighted reason (WR_i).

$$WR_i = \sum_{j=1}^{3} r_j X_{ji} / \left(\sum_i \sum_{j=1}^{3} r_j X_{ji} \right)$$

Where: - $\mathbf{X_{ji}}$ is the number of respondents giving reason with order j, j=1, 2, 3 to traits i, where i=body size and growth, body condition, reproduction and mothering ability, $r_j$is the weight analogous to Reason j. The weight is given by r_1=3, r_2=2 and r_3=1.

3.3. Optimizing Abera Sheep Community-Based Breeding Program

The study simulated Abera sheep CBBP to design the optimal breeding structure and economic return. Biological population, genetic parameters, and economic parameters from different sources (agricultural research and extension and ongoing CBBPs) were used as inputs to model the breeding scheme using ZPLAN+ software.

To represent the current system, 22 breeding rams and 200 breeding ewes were considered in the simulated CBBP. About 150 proven rams were produced with an estimated conception rate of 90 percent, a twinning rate of 1.26 lambs per ewe per lambing, a lambing interval of 0.61 year, and a sex ratio of 0.5, an estimated 85 percent of lambs survived to selection age and 5 percent of candidate rams were culled for physical appearances. Out of 150 rams proven, culling 5 percent for inferior performance, gives 53. breeding rams for the base population. The base size of 475 breeding ewes was then determined by the availability of rams for the base and the male to female ratio of 1:9.

Fixed costs included salaries for enumerators, supplies, and communication costs. The breeding program was panned for 10 years as to fit with panning period of agricultural development plans in Ethiopia. The economic value of trait of breeding objective indicate the increase in revenue related to one unit increment of the goal trait. Economic value were calculated number of expressions of the trait during one year per breeding ewe multiplied by marginal profit (Muller et al., 2021). Marginal profit also calculated as the difference between the total revenues and total costs per ewe per year. The current market price and cost of the traits of inputs in December 2021 were used to calculate revenue and cost. The economic value calculation assumed that, when the trait is increased by one-unit, other traits remain constant (FAO, 2015).

All costs related to community-based breed program for Abera sheep divided by number of CBBP(six) were considered and for Abera Bongodo village total $670.7 fixed costs (salaries for enumerator($340.63), capacity building, and training costs ($84.5) communication costs ($33.3) and cost for motorcycle for the organizer of data collection with consideration of its service year ($212.2) were considered. Fixed cost per breeding ewe per village $3.35 as calculated as Total fixed costs ($670.7)/Total number of breeding ewe in Abera Bongodo CBBP. Variable cost for animal treatment ($150), animal identification cost ($60), and breeding ram cost in traditional system ($100) were considered for 200 breeding ewe per year in CBBP that is equal to variable cost of $1.55 per ewe per year.

Abera sheep breeding program was simulated using ZPLAN+ software (Täubert et al., 2010). The breeding objective was to get improved genetic gain of the growth traits especially six-month weight (SMWT). The simulation of ZPALN+ is based on 9 breeding alternatives aimed to increase the genetic gain and profit of growth trait (SMWT). The genetic gain for single trait, annual genetic gain of breeding objective, cost, and profit from CBBP were used to test options to the current system.

As indicated in part I of this paper the genetic gain of growth traits were minimum in Abera sheep CBBP, so simulation aimed to divert genetic gain resulted from selective breeding were considered in the current method and the current simulation were planned to optimize the sex ratio of breeding animals and number of proven breeding lambs for selection.

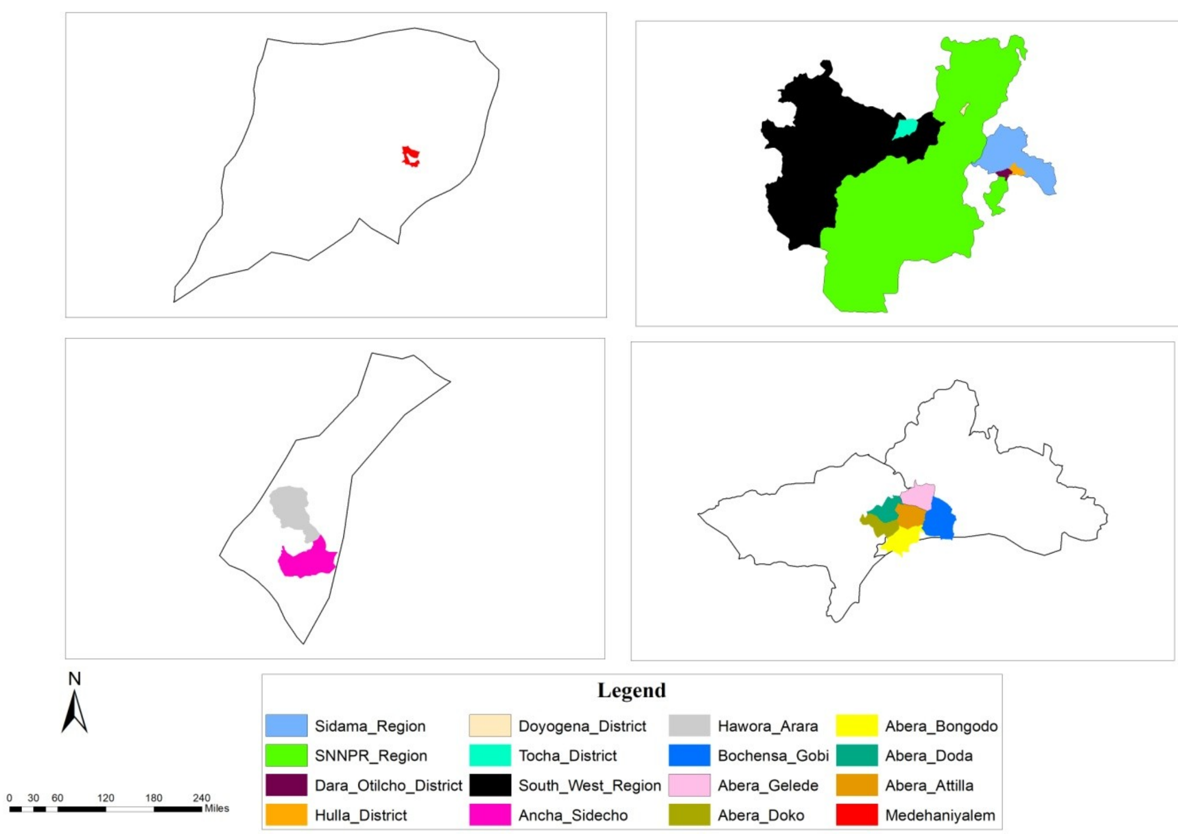

Figure 1. Geographical location of the study districts

4. SUMMARY OF RESULTS

4.1. Effect of Fixed and Genetic Factors on Growth Traits

4.1.1. Fixed Factors and Inbreeding

The overall LSM for BWT, WWT, SMWT and YWT were 2.90, 15.51, 20.8 and 27.9 kg, respectively. The traits were influenced ($p<0.01$) by sex, year, season, litter size, and location (Table 2; Paper I). The average coefficient of inbreeding trends (percentage per year) is illustrated in Figure 1; Paper I. Coefficient of inbreeding (F) showed different trends among CBBPs of Abera sheep ranging from -0.003 to 0.14 %. The trend of F in the current study demonstrated dissimilar (increasing, decreasing and stable) pattern between different breeder cooperatives.

4.1.2. Co (variance) Components and Genetic Parameter Estimates

Estimates of co (variance) components and genetic parameters for WWT and SMWT of Abera sheep in different breeder cooperatives are shown in Table 4; Paper I. The direct heritability (h^2) for WWT and SMWT in the six breeder cooperatives were in the range of 0.12 to 0.38 and 0.20 to 0.49, respectively. In the current study, very low permanent maternal environment effects (c^2) was recorded in all locations resulted from different models in WWT and SMWT of Abera sheep (Table 4; Paper I). Full model indicates less importance of additive maternal heritability (m^2) estimates in all breeder cooperatives except for that of Bonchensa Gobi. Additive maternal heritability (m^2) estimates were strong in SMWT than WWT traits. Total heritability estimate (h^2t) in current study for WWT and SMWT (Table 4; Paper I) was in the range of 0.04 to 0.68 and 0 to 0.48, respectively.

4.1.3. Correlation Estimates Among Growth Traits

The genetic and phenotypic correlations among growth traits (BWT, WWT, SMWT and YWT) for each breeder cooperative is presented in Table 5; Paper I. The genetic correlation between BWT and other post-weaning growth traits (SMWT and YWT) was low which indicates that the targeted selection to improve economically important traits would not increase BWT. High genetic correlations also exhibited between WWT and SMWT in all breeder cooperatives except in Bonchensa Gobi breeder cooperative (-0.15).

The SMWT and YWT had strong and positive genetic correlations in all breeder cooperatives ranging from 0.59 to 0.98. BWT had weak phenotypic correlation with other growth traits in most breeder cooperatives and the phenotypic correlation of WWT and SMWT were moderate to high and positive in all breeder cooperatives except in Bonchensa Gobi (-.0.07). The genetic and phenotypic correlation among different body weight traits in the current study were moderate to high and positive in most breeder cooperatives of CBBPs of Abera sheep

4.1.4. Genetic Trends

Genetic trends for the WWT and SMWT from six CBBPs are presented in Figure 2and Table 6; Paper I. The annual genetic trends were 0.02,0.03,0.19,-0.01,0.05 and 0.08 kg per year for WWT and 0.05, 0.03, 0.06,-002, 0.04 and 0.10 kg per year for SMWT at Abera Gelede, Abera Attilla, Abera Doko, Abera Doda, Abera Bongodo and Bonchensa Gobi breeder cooperatives, respectively. The WWT and SMWT showed significant genetic gain ($p<0.001$) during selection years in all breeder cooperatives except at Abera Doko for SMWT positive genetic gains were also observed for WWT at all breeder cooperatives except that of Abera Doda.

4.2 Breeding and Production Practices

4.2.1 Source of Breeding Sheep

Breeding ewes from NMCBBP in all locations were the result of natural selection and ingenious knowledge of sheep breeding while, breeding animals from MCBBP were the results of both natural selection and participatory selection of breeding animals. Born in the flock, born in the flock and purchase and purchase breeding ewes were found to be the sources of breeding sheep flock in all locations. Breeding sheep born in the flock were found to be the highest proportion of breeding ewe in both MCBBP (90%) and NMCBBPs (72%). Secondly, the flock of most farmers composed of both breeding ewe from born in the flock and purchased (8.3% in MCBBP) and (15% in NMCBBP) but farmers who keep only purchased breeding ewe were very small proportion (1.7% in MCBBP) and (12.5% in NMCBBP).

Practicing participatory breeding program had significant difference on source of breeding ewes ($p<0.05$) while, there was no association ($p > 0.05$) between location and source of breeding ewe (Table 2; Paper II)

All respondents (100%) from MCBBP in all locations reported that they had breeding ram in the flock while, majority of the respondents (73.3%) from NMCBBP reported that they had no breeding ram in the flock and only 26.7% respondents reported that they had at least one breeding ram in the flock. In all site in MCBBP, the most available breeding rams were born in the flock and appeared as the result of participatory selection while breeding rams in NMCBBP resulted from selection by farmers based on indigenous knowledge for preference traits (Table 3 Paper II).

4.2.2. Selection Criteria and Breeding Knowledge

Body Size and appearance of the animal, reproduction traits and mothering ability (lambing interval and prolificacy), body condition and morphological characters (mainly coat color and horn) were the main mentioned traits by farmers to select breeding ewes in the flock. Big size with good body condition, tall body frame, coat colors like red and brown (solid or light) and grey were the main criteria to select breeding ewes but, they were mentioned that there were null interest for black coat color in all sites.

4.2.3. Sheep Flock Size and Composition

The mean composition of breeding ram, breeding ewe, ram lamb, and ewe lamb were presents in Table 4. The overall mean flock size in the given sites was 6.28 heads, while, the three sites (Sidma, Kembata and Dawuro) mean flock size were not significantly different ($p < 0.05$). The average number of breeding ram were more available in member of community based breeding program than non-member. Mean of total flock size of sheep in Sidma (Abera), Kembata (Doyogena) and Dawuro were 13.3 heads, 12.3 heads and 11.8 heads, respectively both in MCBBP and NMCBBP. Kembata had larger sheep flock size than Dawuro while, Sidama had larger flock size than both Kembata and Dawuro.

4.2.4. Descriptive Statistics

The records on dentations showed that farmers selected ewes ranging from 1 to 8 years and with in an average of 3.2 years of age. Animals from both member of Community based sheep breeding program (MCBBP) and non-member community based sheep breeding programs (NMCBBP), ewes classified by farmers as best had higher mean values for the traits body weight, body length, chest girth, height at wither, body condition score and price than the animals classified as poor quality and the ewes chosen as being average quality in general had the mean values that were in between the best and the poor groups in both MCBBP and NMCBBP (Table 5; Paper II). Dawuro had higher body weight mean value than Abera and Doyogena sheep in both MCBBP and NMCBBP.

4.2.5. Effects of Site, Breed and Membership of CBBPs on body weight and all studied traits

There were significant effect of rank (Best, Average and Poor), Breed/site (Abera, Doyogena and Dawuro) and membership of community based sheep breeding, on body weight and all studied traits (Table 6; Paper II). The rank of breeding ewe based on farmers choice were significant ($p<0.05$) effect on the studied traits and the price of breeding ewes. Farmers' choices of Best, Average and Poor quality ewes were confirmed by the objective measurements (Table 7; Paper II). Ewes chosen as best were on average 2.63 kg heavier than the average ewes and 5.43 kg heavier than the poor quality ewes significant difference were observed between the best, average and poor ewes. The best ewes were scores the highest BCS then the averages and the poor ewes. Farmers expresses willingness to pay almost double as much for ewes classified as being best compared to the poor quality ewes and up to 17% more for best ewes than for an average ewes. Dawuro ewes were heaver than Abera and Doyogena ewes by 1.4 kg and 2.67 kg, respectively while, Abera and Doyo gena ewes had no significant difference in their body weight. BCS were slightly higher in Abera and Dawuro than Doyo gena ewes.

The price the farmers were willing to pay for the breeding ewe were different across all sites ($p<0.05$). The largest price was recorded for Dawuro ewes (2357 ETB). Dawuro ewes were on average valued at 825.2 ETB and 1082.4 ETB more compared to Abera and Doyo gena ewes, respectively while, Abera ewes were cost more around 257.2 ETB than Doyo gena ewes.

Being member of participatory sheep breed improvement program had significant effect on all studded traits and price except BCS (Table 7; Paper II). Animals from MCBBP had higher body weight by 1.92 kg than NMCBBPs, also there were significant difference ($P<0.05$) in body length, chest girth and height at wither between MCBBP and NMCBBP. Ewes from MCBBP were on average more valued by 159.4 ETB than NMCBBP.

4.2.6. Weighted Reason

4.2.6.1. Weighted Reason for Farmers Choices of Breeding Ewes

Farmers from both MCBBP and NMCBBP across all sites, the weighted reasons for choice of best animals in the own flock of farmers are presented in Figure 2, Paper II. Both in MCBBP and NMCBBP, body size and appearance of ewes were considered as the most important traits in Abera and Dawuro farmers while, reproduction and mothering ability were weighted more in Doyogena sheep farmers.

Weighted reasons for farmers classifying ewes as poor quality ewes across sites, MCBBP and NMCBBPs are shown in Figure 3; Paper II. In MCBBP, in Abera and Doyogena sheep, reproduction, and mothering ability and in Dawuro sheep, body condition was most often mentioned as the reason for a breeding ewe being selected as poor quality. Similar with MCBBP farmers from NMCBBP also pointed out the trait reproduction and mothering ability and body condition to select ewes as poor quality in Abera and Dawuro sheep but in Doyogena sheep both body size and appearance and reproduction and mothering ability was most often cited as criteria for a ewe being selected as poor quality.

4.2.6.2. Weight Reason by Breed and Membership of CBBP

Trait preference for each trait group by breed within MCBBP and NMCBBP for best ewes are presented in Table 6; Paper II. In MCBBP, the best ewes, across breeds (Abera, Doyogena and Dawuro) were most preferred for traits related to body size and appearance and reproduction and mothering ability. While, in NMCBBP, best ewes were pointed out as best ewes because of the traits related to reproduction and mothering ability. Weighted reason in Abera, Doyogena and Dawuro sheep were 0.53 and 017, 0.08 and 0.13 and 0.23 and 0.13, respectively for MCBBP and NMCBBP for body size and appearance traits. Weighted reason in Abera, Doyogena and Dawuro sheep were 0.42 and 0.73, 0.78 and 0.75 and 0.55 and 0.78, respectively for MCBBP and NMCBBP for reproduction and mothering ability traits. Body condition was the last important trait in all breeds in MCBBP and NMCBBP.

4.3. Optimizing Abera Sheep CBBP

4.3.1. Genetic gain, Mating Ratio and Candidate Number for Breeding Objective Trait

The annual genetic gain (AGG) achieved per generation for SMWT in Abera Bongodo CBBP with nine different mating ratio and candidate alternatives are presented in Figure 2; Paper III. Relatively small genetic progress of 0.04 kg and 0.05 kg per year was observed in Abera Bongodo village for SMWT and WWT, respectively (Figure 1; Paper III). Consequently, current simulation were performed to divert and increase AGG gain of breeding objective trait (SMWT) with 9 alternatives considering number of candidate breeding rams and male to female sex ratio.

Small AGG registered in alternative 1 with 50 candidates breeding ram with 1 male to 9 females mating ratio. The highest AGG per ewe for SMWT is 0.16 kg with 150 candidate and 1:27 male to female ratio as indicated in alternative 9 then if we consider alterative 6 and 8 the AGG for SMWT registered around 0.15 kg. While, there would be around 91 g difference in AGG between alternative with highest gain (alternative 9) and alternative with the lowest gain (alternative 1). In general, in the current simulation the AGG was high at alternative 9 which is considered with 150 candidate of breeding ram with 1 to 27 male to female sex ratio.

4.3.2. Monetary Genetic Gain and Economic Benefit

The monetary genetic gain (MGG), discounted return (DR), discounted profit (DP) and selection proportion (SP) from nine alternative breeding schemes for current simulation are presented in Table 3; Paper III. Evaluation of the breeding program of Abera Bongodo breeder village, over the investment period, revealed that from use of 1:9 male to female sex ratio (alternative 1) generate minimum MGG of US$ 0.27 and from use of 150 candidates breeding ram with 27 female to one breeding ram sex ratio (alternative 9) generated maximum MGG of US$ 0.64. Evaluation of the breeding program, based on DP per ewe over the investment period, resulted the use of 150 candidate breeding ram with 1 to 27 sex ratio generate $1.87 DP per ewe over 10 years. Nevertheless, currently practiced breeding alterative with 1 breeding ram for 9 breeding ewe (alternative 1) registered rebuff DP.

5. GENERAL DISCUSSION

5.1. Factors Affecting Growth Traits

The overall least squares means of BWT, WWT, SMWT and YWT were 2.90, 15.51, 20.75 and 27.9 kg, respectively and sex, year of birth, season, birth type and location had significant ($p<0.05$) effect on growth traits (Table 2; Paper I). Different scholars also confirmed that most of fixed factors have been shown to be important source of variation in the growth performance of sheep (Momoh et al., 2013; Habtegiorgis et al 2019; Haile et al., 2020).

Six-month weight in our study were considered as breeding goal trait (Paper II) and the weight of Abera sheep (20.8 kg) were comparable with that of the Bonga sheep under community-based breeding program (Haile et al., 2020; Memeru, 2015). However, the SMWT of the current study are higher than those reported for Horro and Menz sheep breeds under CBBPs (Haile et at., 2020), local sheep breeds raised in Fentale district under farmers management (Worku et al., 2019) and Mecheri purebred sheep reared under dry land farming condition (Thiruvenkadan et al., 2009). This weight difference might have resulted from different factors including breed, environmental variations, management, and genetic improvement achieved due to the implementation of CBBPs.

5.2. Estimation of Genetic Parameters

The reason of genetic parameter estimation is to allow the efficient prediction of breeding value and selection procedures, which could be used as a basis for any sound livestock improvement program in addition being used to determine the selection criterion and future breeding strategies (Dolebo, 2020).

The heritability estimate for growth traits of sheep are usually moderate to high (Mekuriaw and Haile, 2014), and the heritability estimates in the current study fall within this range. The range of total heritability estimates for growth traits of Abera sheep from six breeder cooperatives (Table 4; Paper I) were in similar range of the sheep in Bonga and Horro CBBPs (Haile et. al., 2020) and Harni sheep (Lalit et al., 2016). However, the heritability estimates of growth traits in the current study are slightly higher than reported for Menz sheep (Haile et al., 2020), Iranian Karakul sheep (Talebi, 2019). The differences in heritability estimates of growth traits in the current study possibly due to varation in breed and environmental effects.

Low genetic association of birth weight (BWT) with other post-weaning growth traits in the current finding helps to avoid birth complication or dystocia and production loss due to increased BWT of lambs. Increasing BWT in different local sheep population also not recommended (Haile et. al., 2019; Areb et al., 2021).

The SMWT and YWT are most economically important growth traits as most sheep, which are marketed between this age intervals (Lalit et al., 2016). Selection based on those age ranges can increase the income of the farmers and selection based on post weaning traits in CBBPs could be considered important (Jembere et al., 2019). Similar with the current observation, positive genetic and phonotypic association between growth traits were reported for Horro sheep (Abegaz et al., 2010).

5.3. Estimation of Genetic Trends

The range of genetic gain for WWT (0.02 to 0.19 kg/year) as obtained from the current study was in the range of with those reported for sheep managed under CBBPs (Habtegiorgis, 2019; Mokhtari and Rashidi 2010). However, the range of genetic gain observed for WWT was higher than the report for Arman sheep (Mostafa et al., 2011) and Jordanian Awassi sheep (Jawasreh et al., 2018). The range of genetic gain in SMWT (0.03 to 0.08 kg/year) obtained in current study was coniststent with those reported by different scholars from CBBPs in Ethiopia (Habtegiorgis, 2019; Areb et al., 2021) while, it was slightly lower than reported by Haile et al. (2020) for Bongo and Horro sheep and Gizaw et al. (2013) for Menz sheep.

The possible reasons for the level of genetic gain in studied traits of indigenous breeds could be mainly dependent on the magnitude of its heritability estimate that depends mostly on phenotypic characteristics instead of additive genetic value and the breed difference, age and efficiency of CBBPs.

5.4. Breeding and Production Practices Among MCBBPs and NMCBBPs

Any breeding or conservation for animal genetic improvement programs should be planned based on preference and choice of farmers with the active involvement of them. Participation of farmers from planning to implementation of breeding programs are strongly advised by different scholars (Gizaw et al., 2010; Wurzinger et al., 2011). As clearly indicated in the current study, participation in community based sheep breed improvement programs had significant contribution to accurate identification of breeding objective and selection criteria of sheep. After launching CBBPs, significant body weight traits improvement and registered improved performance of sheep are reported in many part of the county and elsewhere (Getachew et al., 2010; Muller et al., 2019; Haile et al., 2020) and in west African Djallonké sheep breed (Yapi-Gnaoré et al., 2001) and in Inhamuns region, Ceará, Brazil (de Aguiar et al., 2020) and sheep from Morada Nova (Arandas et al., 2017).

Breeding ewes from NMCBBP in all locations were the result of natural selection and ingenious knowledge of sheep breeding while, breeding animals from member of community based breeding program (MCBBP) were the results of both natural selection and participatory selection of breeding animals. Membership of CBBPs had significant difference on source of breeding ewes as famers maintain breeding animals for long breeding season than NMCBBP. Similar findings were stated by Abebe et al. (2020) and Alemayehu et al. (2015) sheep in the northwest highlands and Dawuro and Konta sheep of south-west region of Ethiopia also confirmed that born in the flock and purchased sheep were the main source of their flock.

Shortage of breeding ram in the sheep flock also reported in different production system of the country. For instance, majority of respondents confirmed that the absence of breeding ram in the flock in mixed-crop production system (72%) and in Agro- pastoral sheep production system (58%) in central and eastern part of Ethiopia (Gebregziahear et al., 2019), also having only one breeding ram (48.3% in Tocha and 60% in Marka) in Dawuro zone and having no breeding ram(63.3%) in Konta special worda in mixed crop production system of Southern Ethiopia also reported (Alemayehu, 2011). As revealed in the current study, the awareness which had been created after launching CBBPs in all studied area, all small scale farmers keep their breeding ram for at least for two breeding years. Thus avoiding of early marketing of breeding ram totally solved the shortage of breeding ram in the flock and it had been played significant role in genetic improvement of the studied sheep.

The main sheep production objective of smallholder farmers from different part of Ethiopia is income generation (Alemayehu et al., 2015; Dossa et al., 2015; Haile et al., 2015; Abebe et al., 2020). Similarly in this study, early put on the market of male sheep as immediate income source resulted from lack of awareness is the critical problem and leads shortage of mating rams in

NMCBBP while, MCBBP were maintain their breeding ram until selection and the selected breeding rams serve in the community until two years.

Majority of participant smallholder farmers in the current study from MCBBP and NMCBBP areas have been practicing selection of breeding stock within their own sheep flock using their received (experience resulted from CBBP) and indigenous breeding knowledge, respectively. Body Size and appearance of the animal, reproduction traits and mothering ability (lambing interval and prolificacy), body condition and morphological characters (mainly coat color and horn) were the main mentioned traits by farmers to select breeding ewes in the flock. Big size with good body condition, tall body frame, coat colors like red and brown (solid or light) and grey were the main criteria to select breeding ewes but, they were mentioned that there were null interest for black coat color in all sites.

Being superior in morphometric traits in sheep worth higher value in sheep farmers to categorize them as best breeding animals. Similar with current result, ewes classified, as best had higher mean value for the studied traits in indigenous sheep in the northwest highlands of Ethiopia (Abebe et al., 2020) and Red Maasai and Dorper sheep in Kenya (Zonabend et al., 2016).
Variable body weight and different attributes in different rank groups of ewes from different experiment also reported in different (Afar, Bonga, Horro and Menz) sheep breed of Ethiopia (Mirkena, 2010; Duguma et al., 2011) and indigenous sheep in the northwest highlands of Ethiopia (Abebe et al., 2020).

Breeding sheep selection criteria mentioned by farmers from both MCBBP and NMCBBP in this study in general agreement with other studies in small holder farmers in different sheep farming areas (Arandas et al., 2017; Alemayehu, 2011; Melak et al., 2021) while, this study is not in line with the report of Haile et al., (2015) who reported that in TahtayMaychew (Basonawera) district farmers do not include body size and appearance as primary criterion for selecting breeding ewes. Rather, they selected twining ability as first ranked and farmers from Inhamuns region, Ceará, Brazil, selected and give priority for adaptation and disease resistance traits than size and appearance traits (de Aguiar et al., 2020). Lack of farmers preference for black coat color sheep might be associated with belief (taboo), low market demand and socio-cultural practices. Similar with the current result, culling or rejection to select sheep because of black coat color also reported by different scholars (Alemayehu, 2011; Edea et al., 2012; Tiesnamurti et al., 2021; Hamadou et al., 2019).

Farmers expresses willingness to pay almost double as much for ewes classified as being best compared to the poor quality ewes and up to 17% more for best ewes than for an average ewes. Dawuro ewes were heaver than Abera and Doyogena ewes by 1.4 kg and 2.67 kg, respectively while, Abera and Doyogena ewes had no significant difference in their body weight. BCS were slightly higher in Abera and Dawuro than Doyo gena ewes.

The price the farmers were willing to pay for the breeding ewe were different across all sites ($p<0.05$). The largest price were recorded for Dawuro ewes (2357 ETB). Dawuro ewes were on average valued at 825 ETB and 1082.4 ETB more compared to Abera and Doyo gena ewes, respectively while, Abera ewes were priced more around 257 ETB than Doyo gena ewes.

Being member of participatory sheep breed improvement program had significant effect on all studded traits and price except BCS (Table 7; Paper II). Animals from MCBBP had heavier body weight by 1.92 kg than NMCBBPs, also there were significant difference ($P<0.05$) in body length, chest girth and height at wither between MCBBP and NMCBBP. Ewes from MCBBP were on average more valued by 159.4 ETB than NMCBBP, this clearly indicate that CBBP can make noticeable change in performance of sheep and income of small-scale farmers.

5.5. Optimizing Selection Intensity

In the current simulation, improving the male to female ratio of 1:9 and increase the number of available breeding ram for breeding to obtain optimal genetic gain and economic return for breeding objective trait in Abera Bongodo breeder village. The optimal breeding alternative was selected based on the genetic gain per year, total discounted return and profit over 10 year investment period. In the current study, important increase in discounted profit per ewe ($1.87) which was achieved by increasing the number of female per breeding ram from 9:1 to 27:1(Table 3) were achieved and this finding agrees with the research of Getachew et al., 2022, who indicated the use of one breeding male for 25 female substantially increase the discounted profit per doe around 88.5% in Borna goat and higher selection intensity contributed in increment of discounted profit in Areb and Oromo goat populations in Ethiopia (Sheriff et al., 2022).

6. SUMMARY AND CONCLUSION

6.1. Summary

The study was carried out with the overall aim of evaluation of genetic progress, comparative identification of breeding objective and selection criteria of farmers from community based and traditional small scale sheep farmers and optimization of Abera sheep selection program.

The specific objective of the first study were estimation of the genetic parameters and trends of growth traits in community-based breeding programs of Abera sheep, The specific objective of the second study were to identifying the breeding objective and selection criteria of small holder farmers from community based breeding program and traditional sheep breeders and the last study were focused on optimizing selection intensity in Abera sheep community- based breeding program to plan sustainable breeding strategies.

Genetic parameters and trends of growth traits in community-based breeding programs of Abera sheep were conducted in Dara Otelicho and Hulla woreda of Sidama region from Six different breeder cooperatives (Abera Gelede, Abera Atilla, Abera Doko, Abera Doda, Abera Bongodo and Bonchesa Gobi) with 2901 records of birth weigh, 2626 records of weaning weight, 2261 records of six-month weight, and 1603 records of yearling weight.

General linear model consisting of the fixed effects of sex, breeder cooperative, season and birth type were used to analyze growth traits. Variance components and genetic parameters were estimated within each breeder cooperative following univariate animal model based on restricted maximum likelihood method using WOMBAT software. All fixed effects influenced ($P<0.05$) the growth traits. Multivariate analysis was also employed to compute correlation estimates among growth traits. Based on the best-fitted models, the direct heritability for WWT and

SMWT in the six breeder cooperatives were in the ranges of 0.12 to 0.38 and 0.20 to 0.49, respectively. Positive genetic progress also achieved in most of the Abera sheep breeder cooperatives.

Own-flock ranking experiment and a structured questionnaire were under taken to define breeding objectives and assess sheep breeding practices in member of community-based breeding program (MCBBP) and non-member of community-based seep breeding program (NMCBBP). Three sheep breed/type namely Doyogena, Abera and Dauwro from Sothern, Sidama and South-West regions, respectively were selected based on membership of community-based breeding program, accessibility and sheep production experience. A survey and own-flock ranking experiment involving 300 households and 360 heads of sheep were used. In own-flock ranking experiment, each farmer were asked to choose the first top two superior and the worst ewe with their own flock and to provide their reason for ranking the animals. Data on size and appearance, lamb growth, lamb survival and reproduction traits were recorded for each ewe. From questionnaire, qualitative and quantitative data were obtained from flock ranking measurements and significant ($p<0.05$) variation was also observed on rank, breed and membership of community based breeding program (CBBP) on body weight and all studied traits including price of ewe. Community- based breeding program reveled significant difference in price and body weight of sheep in all studied locations, ram and ewe from CBBP more valued than sheep from traditional farming. Therefore, CBBPs in all studied areas reveled positive impact on income of small-scale sheep farmers.

Farmers from both MCBBP and NMCBBP emphasized traits on body size and appearance, reproduction and mothering ability and body condition as their breeding objective.

A simulation study was conducted to optimize selection based on growth traits of village-based sheep breeding scheme of CBBP of Abera sheep type of Ethiopia. Six-month weight (SMWT, kg) were identified as selection criteria trait, 9 breeding alternatives or schemes were simulated and evaluated for Abera Bongodo breeder village. The schemes were as follows: scheme (1) 50 candidates with 1 male: 9 female sex ratio, scheme (2) 100 candidates with 1 male: 9 female sex ratio, scheme (3) 150 candidates with 1 male: 9 female sex ratio, scheme (4) 50 candidates with 1 male: 18 female sex ratio, scheme (5) 100 candidates with 1 male: 18 female sex ratio, scheme (6) 150 candidates with 1 male: 18 female sex ratio, scheme (7) 50 candidates with 1 male: 27 female sex ratio, scheme (8) 100 candidates with 1 male: 27 female sex ratio and scheme (9) 150 candidates with 1 male: 27 female sex ratio. The annual genetic gain (AGG) for six-month weight (SMWT) ranges 0.06 to 0.16 kg, annual monetary genetic gain (AMGG) ranges $ 0.27 to 0.64 and discounted profit per ewe ranges $-0.04 to 1.87. Scheme 9 is recommended over all other schemes.

6.2 Conclusion

The finding of the present study showed that fixed factors play an important role in influencing the growth performances of sheep. Positive and significant estimate of genetic trends in most breeder cooperatives for selection traits in the current study confirms that participatory sheep breed improvement program is a feasible option to improve growth performances in the low input production system. Moderate to high heritability estimate for body weight traits is indicative of the existence of genetic variability in the population and selection should be continued. Positive genetic correlation between SMWT and other growth traits suggests that use of these traits is useful in the selective breeding program. Different breeding scenarios were evaluated to optimize the breeding structure of Abera sheep community based breeding program of Ethiopia, with consideration of six-month weight as breeding objective trait. Shifting the current male to female ratio 1:9 to 1:27 with increased number of proved lambs for selection up to 150 maximized the genetic progress and profitability of the breeding program than the former breeding scenario. To enable factual genetic improvement program, considering improved management like health and feeds are crucial. Based on the result of the current study, design and implementation of Abera sheep CBBP using alternative 9 had an advantage over other schemes in termes of genetic gain and implemention cost.

Smallholder farmers from both MCBBP and NMCBBP emphasized traits on body size and appearance, reproduction, and mothering ability and body condition as their breeding objective. Sheep production challenges were more related to the lack of improved breeding ram in the flock, it is more common in NMCBBP than MCBBP.

Shifting the current male to female ratio of 1:9 to 1:27 with increased number of candidate lambs for selection up to 150 maximized the genetic progress and profitability of the breeding program than the former breeding scenario.

7. SCOPE FOR FUTURE WORK

1. The importance of maternal effect on growth traits reveal that maternal line selection needed to be initiated and the existence of correlations between WWT and SMWT permits selection at earlier age. It could also permit culling un-productive lambs at earlier age that also help the smallholder farmers to avoid unnecessary cost for unwanted breeding stocks.
2. As CBBPs revealed that better knowledge of identifying breeding objective and selection criteria, significant difference in price of breeding stock and significant difference in

growth traits than traditional sheep, scaling-up of the CBBP in neighboring districts as much as possible is crucial and recommended.

3. Advances in genetics and genome sequencing have contributed greatly to the understanding of genetic mechanisms of phenotypic traits in sheep and provide a basis for genetic improvements of economically important traits. Hence, identification and location of functional genes and variants associated with those growth traits helps facilitate and advance the current breeding techniques so, genomic selection, marker assisted selection or genome wide association studies should be exploited.

8. LIMITATIONS OF THE PRESENT WORK

1. The lack of quality, systematic and accurate records resulted from instability of data collectors in most CBBPs of Abera sheep because of different salary and promotion issue. Therefore, that leads the researcher to cost much time to clear and mange it.

9. RECOMMENDATIONS

1. Estimate of genetic progress indicated that, there was satisfactory genetic improvement in most of studied traits due to selective breeding of Abera sheep breed. Thus, improvement by selection of this breed under CBBP needs to be strengthened and continued.

2. Routine data recording and ample peedgree information on production and reproduction performance of small ruminant is very much limited in traditional small ruminant production system of Ethiopia. While, community based breeding program revealed that it is possible to record production and reproduction data as routine activity, data from community based programs needs to be accurate, adequate and reliable. To realize this, skilled data collectors and

awareness of small-scale farmers are extremely needed. Moreover, routine data recording, data management and interpretation require standardized format monitoring by national data base system. Thus, the responsible governmental body should establish standard national routine sheep herds/flocks performance recording and data capture, evaluation and feedback system in traditional sheep production in general and community based breeding programs in particular.

10. REFERENCES

Abebe, A., Banarjee, S., Goshmie, S., Bisrat, A., Abebe, A., Besufikad, S., Zewdie, T., Gizaw, S., 2020. Selection efficiency for growth performance of Menz sheep in a community-based breeding program. Livestock Research for Rural Development. Volume 32, Article #152. http://www.lrrd.org/lrrd32/9/ascha32152.html.

Abegaz, S., 2007. In situ characterization of Gumuz sheep under farmer's management in North West lowlands of Amhara region. An MSc Thesis presented to the School of Graduate Studies of Alemaya University of Agriculture, Dire Dawa, Ethiopia.

Abegaz, S., Duguma, G., Negussie, E., Gelmesa, U., Terefe, F., Rege, J.E.O., 2002. Factors affecting reproductive performance and estimates of genetic parameters of litter size in Horrosheep. Journal of Agricultural Science, Volume 139(01): Pages 78–85. doi:10.1017/S0021859602002265.

Abegaz, S., Van Wyk, J.B and Olivier, J.J., 2010. Estimation of Genetic and Phenotypic Parameters of Growth Curve and their Relationship with Early Growth and Productivity in Horro sheep. Leibniz-Institute for Farm Animal Biology, Dummerstorf, Germany.

Ajmone, M. P., and Globaldiv Consortium, T., 2010. A global view of livestock biodiversity and conservation – GLOBALDIV. Animal Genetics 41, 1-5.

Alemayehu, A., 2011. Phenotypic characterization of indigenous sheep types of Dawuro zone and Konta special woreda of SNNPR, Ethiopia. An M Sc Thesis presented to the School of Graduate Studies of Haramaya University, Dire Dawa, Ethiopia.

Alemayehu, A., Mekasha, Y., Abegaz, S., Jimma, A., 2015. Description of sheep production system, husbandry practices and assessment of major constraint in Dawuro zone and Konta special wereda of south region of Ethiopia. Global Journals of science frontier research (USA), Volume 15 Issue 6 Version 1.0:49-50. https://journalofscience.org/index.php/GJSFR/article/download/1619/1480/.

Ann, W., L. Gegner and R. Earles., 2000. Sustainable Sheep Production. NCAT Agriculture Specialists. 138p.

Arandas, JKG., Alves, ÂGC., Facó O., Belchior, EB., Shiotsuki, L., de Arruda Leite, PMB., Ribeiro, MN., 2017. Do traditional sheep breeders perform conscious selection? An example from a participatory breeding program of Morada Nova sheep. Tropical Animal Health Preproduction. doi: 10.1007/s11250-017-1350-4. PMID: 28756554.

Awgichew, K., 2000. Comparative performance evaluation of Horro and Menz sheep of Ethiopia under grazing and intensive feeding conditions. Humboldt-University, Berlin, Germany, 159 pp. (Ph.D. thesis).

Banik , S., Pankaj, P., Naskar, S., 2015. Climate Change: Impacts on Livestock Diversity in Tropical Countries. Livestock Production and Climate Change 6, 162.

Barker, J., 1999. Conservation of livestock breed diversity. Animal Genetic Resources Information, 25, 33-43. doi:10.1017/S1014233900005770.

Becker, W.A., 1984. Manual of Quantitative Genetics, 4th Edition. Students Book Corporation, Pullman, Washington D.C. Pp 31-118.

Bijma, P., Van Arendonk, J.A.M., Woolliams, J. A., 2001. Predicting rates of inbreeding for livestock improvement schemes. Journal of Animal Science. Volume, 79, pages, 840–853. https://doi.org/10.2527/2001.794840x.

CGRFA., 2011. Commission on Genetic Resources for Food and Agriculture. Thirteenth Regular Session. Draft Guidelines on Phenotypic Characterization of Animal Genetic Resources. http://www.fao.org/3/am651e/am651e.pdf.

Chessa, B., Pereira, F., Arnaud, F., Amorim, A., Goyache, F., Mainland, I., Kao, R.R.J., Pemberton, M., Beraldi, D., Stear, M., Alberti, A., Pittau, M., Iannuzzi, L., Banabazi, M.H., Kazwala, R., Zhang, Y.-P., Arranz, J.J., Ali, B.A., Wang, Z., Uzun, M., Dione, M., Olsaker, I., Holm, L.-E., Saarma, U., Ahmad, S., Marzanov, N., Eythorsdottir, E., Holland, M.J., 22, 23, Ajmone-Marsan, P., Bruford, M.W., Kantanen, J., Spencer, T.E., Palmarini, M., 2011. Revealing the history of sheep domestication using retrovirus integration. Science. 324, 532– 536.

Chipman, J., 2003. Observations on the potential of Dangila sheep for improved food security around Quairit and Adet, West Gojjam, Northwestern Ethiopia. A field study. Hosted by International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia.

CSA (Central Statistical Agency)., 2014/15. Federal Democratic Republic of Ethiopia, Central Statistical Agency. Agricultural Sample Survey, Volume II.

CSA (Central Statistical Agency)., 2016/2017(2009 E.C). Federal Democratic Republic of Ethiopia, Agricultural sample survey, Report on livestock and livestock characteristics. Statistical Bulletin 585. Addis Ababa, Ethiopia.

CSA (Central Statistical Agency)., 2020/2021(2013 E.C) Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey. Volume II. https://www.statsethiopia.gov.et/wp-content/uploads/2021/05/REVISED_2013.LIVESTOCK-REPORT.FINAL-1.pdf.

De Aguiar, A.L., da Silva, R.R., Alves, S.M., 2020. Breeding objectives and selection criteria of a participatory community-based breeding programme of goats and sheep. Tropical Animal Health Production 52, 1933–1943. Available at https://doi.org/10.1007/s11250-020-02209-6.

Dolebo, A., 2020. Phenotypic, Genomic and physiological basis of fecundity traits in Bonga Sheep of Ethiopia. PhD dissertation. Hawasaa University, Hawassa, Ethiopia.

Dossa, L.H., Sangaré, M., Buerkert., 2015. Production objectives and breeding practices of urban goat and sheep keepers in West Africa: regional analysis and implications for the development of supportive breeding programs. SpringerPlus4, 28. https://springerplus.springeropen.com/track/pdf/10.1186/s40064-015-1075-7.pdf.

Duguma, G., Mirkina, T., Haile, A., Ally Mwai, O., Tibbo, M., Barbara, R., Solkner ,J., Wurzinger M., 2011. Identification of Small Holder Farmers and Pastoralists' For Sheep Breeding Traits choice Model Approach. Available at: https://www.researchgate.net/publication/221969311.pdf.

Duguma, G., Mirkina, T., Haile, A., Iñiguez, L., Okeyo, A.M., Tibbo, M., Rischkowsky, B., Sölkner, J., Wurzinger, M., 2010. Participatory approaches to investigate breeding objectives of livestock keepers. Livestock Research for Rural Development. Volume 22, Article 64.

Duguma, G., Tadesse, T., Kumsa, T., Abegaz, S., 2007. Evaluation of the impact of plane of nutrition on growth and carcass traits of Horro lambs castrated at different ages. pp. 13-22. Proceeding of the 15th Annual Conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, October 4-6.

Edea, Z., Haile, A., Tibbo, M., Sharma, A.K., Assefa, D., Sölkner, J., Wurzinger, M., 2010. Morphological characterization of Bonga and Horro indigenous sheep breeds under smallholder conditions in Ethiopia. Ethiopian Journal of Animal Production 9(1): 117–133.

Edea, Z., Haile, A., Tibbo, M., Sharma, AK., Sölkner, J., Wurzinger, M., 2012. Sheep production systems and breeding practices of smallholders in western and south-western Ethiopia: Implications for designing community-based breeding strategies. Livestock Research for Rural Development. Volume 24, Article #117.http://www.lrrd.org/lrrd24/7/edea24117.htm.

Excoffier, L., Laval, G., and Schneider, S., 2007. Arlequin (version 3.0): an integrated software package for population genetics data analysis. Evolutionary Bioinformatics Online. Volume :1; pages 47-50. PMID: 19325852; PMCID: PMC2658868.

Falconer, D., and Mackay, T.,1996. Introduction to quantitative genetics. London: Longman Group Ltd.

FAO, 2007. The State of the World's Animal Genetic Resources for Food and Agriculture.

FAO, 2011. Molecular Genetic Characterization of Animal Genetic Resources. FAO Animal Production and Health Guidelines. No. 9. Rome.

FAO. 2013. In vivo conservation of animal genetic resources. FAO Animal Production and Health Guidelines. No. 14. Rome.

FAO. 2019. The world is off-track to meet most food and agriculture –related sustainable development Goals, Rome.

Galal, E.S.E., 1983. Sheep germplasm in Ethiopia. Animal Genetic Resources Information1:412.available at: ftp://ftp.fao.org/docrep/fao/012/q7426t/q7426t00.pdf.

Getachew, T., 2015. Genetic diversity and admixture analysis of Ethiopian fat-tailed and Awassi sheep using SNP markers for designing crossbreeding schemes. Dissertation for obtaining a doctorate degree at the University of Natural Resources and Life Sciences, Vienna, Austria.

Getachew, T., Haile, A., Tibbo, M., Sharma, A.K., Kifle, A., Terefe, E., Wurzinger, M., Sölkner, J., 2009. Morphological characters and body weight of Menz and Afar sheep within their production system. Ethiopian Journal of Animal Production 9(1): 99–115.

Getachew, T., Haile, A., Tibbo, M., Sharma, A.K., Sölkner, J., Wurzinger, M., 2010. Herd management and breeding practices of sheep owners in a mixed crop-livestock and a pastoral system of Ethiopia. African journal of agricultural research, volume 5(8), pp: 685-691. https://academicjournals.org/article/article1380964803_Getachew%20et%20al.pdf.

Getachew, T., Rischkowsky, B., Rekik, M., Mueller, J., Tessema, T., Solomon, D., Haile, A., 2022.Optimizing breeding structures and related management in community-based goat breeding programs in the Borana pastoral system of Ethiopia. Livestock Science, Volume 256, ISSN 1871-141, https://doi.org/10.1016/j.livsci.2021.104819.

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

Gilmour, A. R., Gogel, B. J., Cullis, B. R., Welham, S. J., Thompson, R., 2002. ASREML user guide, release 1.0. VSN International Ltd, UK.

Gizaw, S and Getachew, T., 2009. The Awassi x Menz Sheep Crossbreeding Project in Ethiopia: Achievements, Challenges and Lessons Learned. Proceedings of the Mid-Term Conference of the Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP), Hawassa, 13-14 March 2009, 53-62.

Gizaw, S., 2008. Sheep resources of Ethiopia: genetic diversity and breeding strategy. Wageningen University, Wageningen, The Netherlands, 145 pp. (Ph.D. thesis). https://edepot.wur.nl/122006.

Gizaw, S., Abegaz, S., Rischkowsky, B., Haile, A., Mwai, A.O., Desse, T., 2013. Review of sheep research and development projects in Ethiopia. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Gizaw, S., Komen., H., van Arendonk, J. A. M., 2010. Participatory definition of breeding objectives and selection indexes for sheep breeding in traditional systems. Livestock Science, 128, 67–74. https://doi.org/10.1016/j.livsci.2009.10.016.

Gizaw, S., van, A. J. A. M., Komen, H., Windig, J .J. Hanotte, O., 2007. Population structure, genetic variation and morphological diversity in indigenous sheep of Ethiopia. Animal Genetics 38:621-628.

Goudet, J., 2001. FSTAT, a program to estimate andtest gene diversities and fixation indices (version 2.9.3). http://www.unil.ch/popgen/softwares/fstat.htm.

Groeneveld, L. F., Lenstra, J. A., Eding, H., Toro, M. A., Scherf, B., Pilling, D., Negrini, R., Finlay, E. K., Jianlin, H., Groeneveld, E., Weigend, S., 2010. Genetic diversity in farm animals, A review. Animal Genetics 41, 6-31.

Habtegiorgis, K., 2019. Estimation of genetic parameters and genetic trends for productive and reproductive traits of Goyogena sheep in southern Ethiopia. M.Sc thesis. Jimma University, Jimma, Ethiopia. Pp 41-45.

Haile, A., Desse, T., B, Rischkowsky., 2014. Performance of indigenous sheep breeds managed under community-based breeding programs in the highlands of Ethiopia: Preliminary results. Addis Ababa: ICARDA.

Haile, A., Getachew, T., Merkena, T., Duguma, G., Gizaw, S.,Wurzinger, M., Soelkner, J., Mwai, O., Desse, T., Abebe, A., Abate, Z., Jemebere, T.,Rekik, M., Lobo, R., . Mwacharo, J.,Terfa ,Z., Kassie, G., Mueller, G and Rischkowsky, B., 2020. Community-based sheep breeding programs generated substantial genetic gains and socioeconomic benefits. Animal, Volume 14, Issue 7, Pages 1362-1370, ISSN 1751-7311. https://doi.org/10.1017/S1751731120000269.

Haile, A., Gizaw, S., Getachew, T., Joaquín P, M., Peter, A., Mourad, R., Barbara, R., 2019. Community-based breeding programmes are a viable solution for Ethiopian small ruminant genetic improvement but require public and private investments. Journal of animal breeding and genetics, volume 136, page: 319-328.

Haile, A., Mwacharo, J.M., Rekik, M., Wamatu, J., Solomon . and Tesfahun, G., 2018. SmaRT Ethiopia achievements. Workshop and field day on Small Ruminant .Community Based Breeding Program (held in Hosaena, Ethiopia, 27-28 March 2018).

Haile, D., Gizaw, S., Kebede, K., 2015. Selection criteria and breeding practice of sheep in mixed crop livestock farming system of North Shoa, Ethiopia, Journal of Biology, Agriculture, and Healthcare. https://core.ac.uk/download/pdf/234661801.pdf.

Hamadou, I., Moula, N., Siddo, S., Issa, M., Marichatou, H., Leroy, P., Antoine-Moussiaux N., 2019. Valuing breeders' preferences in the conservation of the Koundoum sheep in Niger by multi-attribute analysis. Archives Animal Breeding, Available at: -https://aab.copernicus.org/articles/62/537/2019/aab-62-537-2019.pdf.

Hans, G., John, J and J van der Werf., 2006. Optimal Designs of Breeding Programs. Armidale Animal Breeding Summer Course.

Hazel, L.N., 1943. The genetic basis for constructing selection indexes. Genetics, volume 28, pages 476-490. https://doi.org/10.1093/genetics/28.6.476.

Henderson, C.R., 1973. Sire evaluation and genetic trends. Journal of animal science, volume 1973, pages 10-41. https://doi.org/10.1093/ansci/1973.Symposium.10.

Jack, C, M., John P, G., PiterBijma and Johan A.M. van Arendonk., 2004. Design and optimisation of animal breeding programmes. for ANS 652 A and B, S05, Iowa State University. https://media.gradebuddy.com/documents/2876069/69d2f8fc-3e42-4edc-a1af-a5b2ff272b21.pdf

Jawasreh, K., Ismail, ZB., Iya, F., Castañeda-Bustos, VJ., Valencia-Posadas, M., 2018. Genetic parameter estimation for pre-weaning growth traits in Jordan Awassi sheep. veterinary world. volume 11(2), pages 254-258. www.veterinaryworld.org/Vol.11/February-2018/27.pdf.

Jembere, T., Rischkowsky, B., Dessie, T., Habtegiorgis, K., Okeyo, A., Mirkena, T., Haile, A., 2019. Genetic and economic evaluation of alternative breeding scenarios for community based productivity improvements of three indigenous goat breeds in Ethiopia. Small Ruminant Research. https://doi.org/10.1016/j.smallrumres.2019.07.017.

Joost, S., Bruford, M. W., Curik, I., Kantanen, J., Lenstra, J. A., Sölkner, J., Andersson, G., Baret, P. V., Buys, N., Roosen, J., Tixier-Boichard, M., Marsan, P. A., 2016. Advances in Farm Animal Genomic Resources. Frontiers in Genetics, volume 6. DOI: 10.3389/fgene.2015.00333.

Kijas, J.W., Townley,D., Dalrymple, B. P., Heaton, M.P., Maddox, J. F., McGrath, A., Wilson, P., Ingersoll, R., McCulloch, R., McWilliam, S., Tang, D., McEwan, J., Cockett, N., Oddy, V., Nicholas, F., Raadsma, H., 2009. A Genome Wide Survey of SNP Variation Reveals the Genetic Structure of Sheep Breeds. PLOS ONE: volume, Pages 1-13. https://doi.org/10.1371/journal.pone.0004668.

Kocho, T., 2007. Production and marketing system of sheep and goat in Alaba, Southern Ethiopia. Msc thesis. Hawassa University, Ethiopia.

Köhler-Rollefson, I., 2000. Management of Animal Genetic Diversity at Community Level. GTZ, Eschborn, Germany. http://hdl.handle.net/10568/3679.

Kosgey, I.S., and Okeyo, A.M., 2007. Genetic improvement of small ruminants in low-input, smallholder production systems: Technical and infrastructural issues, Small Ruminant Research,Volume 70, Issue 1,Pages 76-88, https://doi.org/10.1016/j.smallrumres.2007.01.007.

Kosgy, I. S., 2004. Breeding objective and breeding strategy for small ruminant in tropics. Ph.D, thesis, Animal Breeding and Genetics Group, Wegeningen University, with references-with Summary in English and Dutch.

Lalit, M. ZS., Dalal, DS., Dahiya, SP., Patil, CS and Dahiya, R., 2016. Genetic analysis of growth traits in Harnali sheep. Veteranary World: pages 128-32. www.veterinaryworld.org/Vol.9/February-2016/4.pdf.

Legesse, G., Abebe, G., Siegmund-Schultze, M., Valle Zarate, A., 2008. Small ruminant production in two mixed-farming systems of Southern Ethiopia: Status and prospects for improvement. Experimental agriculture, volume 44, pages 399–412.

Lemma, S., 2002. Phenotypic classification and description of indigenous sheep types in the Amhara National Regional State of Ethiopia. M.Sc thesis, Department of Genetics, University of Natal, Pietermaritzburg, South Africa, Page 104.

Lv, F.H., Agha, S., Kantanen, J., Colli, L., Stucki, S., Kijas, J.W., Joost, S., Li, M.-H., Ajmone Marsan, P., 2014. Adaptations to Climate-Mediated Selective Pressures in Sheep. Molcular. Biology. Evolution. 31, 3324–3343.

Mavrogenis A. P., 1995. Breeding systems and selection strategies for sheep improvement in Cyprus. In: Gabiña D. (ed.). Strategies for sheep and goat breeding. Zaragoza: CIHEAM, pages 17-26.

Meghen, C., MacHugh, D.E., Bradley, D.G., 1994. Genetic characterization of West Africa cattle. World Animal Review: Volume 78: pages 59–66.

Mekuriaw, S and Haile, A., 2014. Genetic parameter estimates for growth and reproductive trait of sheep for genetic improvement and designing breeding program in Ethiopia: A review. Open access library journal, 1: e589. http://dx.doi.org/10.4236/oalib.1100589.

Melak, A., Hailu, A., Assefa, A., Aseged, T., Sinkie, S., Tsion, S., 2021. Characterization of the production system and breeding practices of sheep producers in TahtayMaychew District, Northern Ethiopia. International Journal Tropical Dry lands, volume 5, pages 5-11.https://smujo.id/td/article/view/7960/4821.

Melesse, A., Banarjee, S., Admasu, L., Fekadu, M., Fsahatsion, H., Shimelis, T., Tafesse, M., 2012. Morphological characterization of indigenous sheep in Southern Regional State, Ethiopia. Animal genetics resources, volume 52, pages 39-50. Doi: 10.1017/S2078633612000513.

Memeru, M., 2015. On-farm performance evauation and community based traditional selectio methods of Bonga sheep in Adiyo Kaka woreda, Southern Ethiopia. M.sc thesis. Hawasaa University, Hawassa, Ethiopia.

Meyer, K. 2012. WOMBAT, a program for Mixed Model Analyses by Restricted Maximum Likelihood (User Notes. Animal Genetics and Breeding Unit). Armidale, AU: University of New England.

Mirkena, T., 2010. Identifying breeding objectives of smallholders/pastoralists and optimizing community-based breeding programs for adapted sheep breeds in Ethiopia. A PhD thesis, University of Natural Resources and life sciences, Veinna.

Mokhtari, M. and Rashidi, A., 2010. Genetic trends estimation for body weights of Kermani sheep at different ages using multivariate animal models. Small Ruminant. Research, 88:23-26. https://doi.org/10.1016/j.smallrumres.2009.11.003.

Momoh, O.M., Rotimi, E.A and Dim, N.I., 2013. Breed effect and non-genetic factors affecting growth performance of sheep in a semi-arid region of Nigeria. Journal of Applied Biosciences 67:5302 – 5307. ISSN 1997–5902. https://dx.doi.org/10.4314/jab.v67i0.95053.

Mostafa, L F., Hedayatollah, R., Saeed, A., Kourosh, M and Khalil, M., 2011. Genetic Trends Estimation for Some of the Growth Traits in Arman sheep. Journal of Animal and Veterinary Advances, 10:1801-1803.

Muigai, A.W.T., Hanotte, O., 2013. The Origin of African Sheep: Archaeological and Genetic Perspectives. African Archaeolgy. Rev. 30, 39–50.

Muller, JP., Haile, A., Getachew, T., Rekik, M., Rischkowsky, B., 2019. Genetic progress and economic benefit of community-based breeding programs for sheep out- and up scaling options in Ethiopia. Small Ruminant Research, 177, pp. 124-132.

Naskar, S., Gowane, G., Chopra, A., 2015. Strategies to Improve Livestock Genetic Resources to Counter Climate Change Impact. In Climate Change Impact on Livestock: Adaptation and Mitigation (ed. V. Sejian, J. Gaughan, L. Baumgard and C. Prasad), pp. 441-475. Springer India.

NBE (National Bank of Ethiopia), 2018. Annual report 2017/2018. Addis Ababa, Ethiopia.

Nei, M., 1973. Analysis of gene diversity in subdivided populations. Procceeding of the national academy of science of united satates of America, volume, 70 (12): pages 3321 – 3323. https://doi.org/10.1073/pnas.70.12.3321.

Nicholas, F. W., 1987. Veterinary genetics. Oxford [Oxfordshire] : New York : Clarendon Press. Oxford University Press, http://www.loc.gov/catdir/enhancements/fy0640/85008928-t.html.

Nigussie, H., Mekasha, Y., Kebede, K., Abegaz, S., Kumar Pal S., 2013. Production objectives, breeding practices and selection criteria of indigenous sheep in eastern Ethiopia.Livestock research for rural development, volume 25. http://www.lrrd.org/lrrd25/9/nigu25157.htm.

Quinton, M and Smith, C., 1995. Comparison of evaluation-selection systems for maximizing genetic response at the same level of inbreeding, Journal of Animal Science, Volume 73, Issue 8, August 1995, Pages 2208–2212, https://doi.org/10.2527/1995.7382208x.

Ratner, B., 2009. The correlation coefficient: Its values range between +1/−1, or do they? Journal of targeting, measurement and analysis for marketing, 17(2) :139-142.

Rege, J. and Lipner, M., 1992. Animal genetic resources: Their characterisation, conservation and utilisation. African Proceedings of the research planning.

Rousset, F., 2008. Genepop'007: a complete re-implementation of the genepop software for Windows and Linux. Molecular ecology resources, volume 8(1): pages 103-106.

Ruane, J., 1999. A critical review of the value of genetic distance studies in conservation of animal genetic resources. Journal of Animal Breeding and Genetics, volume 116: pages 317–323.

Rutten, M.J.M., Bijma, P., Woolliams, J.A., Van Arendonk, J.A.M., 2002. Sel Action: Software to predict selection response and rate of inbreeding in livestock breeding programs. Journal of Heredity, Volume 93, Pages 456–458, https://doi.org/10.1093/jhered/93.6.456.

Safari, E., Fogarty, N.M., Gilmour, A. R., 2005. A review of genetic parameter estimates for wool, growth, meat and reproduction traits in sheep. Livestock Production Science, 92(3), pp.271-289.

Sambrook, J., Fritsch, F., Maniatis, T., 1989. Molecular cloning: A laboratory manual. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York, USA.

Sheriff, O., Wondimagegn, K., Haile, A., Getachew, T., Wacharo, J., 2022. Genetic and economic evaluation of alternative breeding schemes for two indigenous goat populations of Ethiopia. Journal of Applied Animal Research, volume 50(1): pages 80-85:DOI:10.1080/09712119.2021.2023549.

Shrestha, J.N.B., 2005. Conserving domestic animal diversity among composite populations. Small ruminant research: the journal of the International Goat Association, Volume: 56, pages 3-20.https://doi.org/10.1016/j.smallrumres.2004.06.014.

Singh H., Pannu U., Narula HK., Chopra A., Naharwara V. and Bhakar SK., 2016. Estimates of (co) variance components and genetic parameters of growth traits in Marwari sheep. Journal of applied animal research, volume 44(1): pages 27-35. https://www.tandfonline.com/doi/pdf/10.1080/09712119.2014.987291.

Sölkner, J., Nakimbugwe, H., Valle-Zárate, A., 1998. Analysis of determinants for success and failure of village breeding programmes. In Proceedings of the 6th World Congress on Genetics Applied to Livestock Production, 12–16 January 1998, Armidale, Australia. http://www.wcgalp.org/system/files/proceedings/1998/analysis-determinants-success-and-failure-village-breeding-programmes.pdf.

Tadesse, F., 2009. Price and performance analysis of indigenous sheep breed marketing in Menz districts of Ethiopia. MSc thesis. Haramaya University, Ethiopia.

Talebi, E., 2019. Heritability estimates for some growth traits and kleiber ratios in karakul sheep. Islamic Azad University, Darab, Fars, 74817–83143. Iran. https://en.engormix.com/sheep/articles/heritability-estimates-some-growth-t43169.htm.

Thiruvenkadan, A.K., Karunanithi, K., Murugan, M., Arunachalam, K., & Narendra Babu, R., 2009. A comparative study on growth performance of crossbred and purebred Mecheri sheep raised under dry land farming conditions. South African Journal of Animal Science, *39*(5), 121-125.http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0375158920090005000029&lng=en&tlng=en.

Tibbo, M., 2006. Productivity and health of indigenous sheep breeds and crossbreds in the central Ethiopia highlands. Ph.D Dissertation. Department of Animal Breeding and Genetics, Faculty of Veterinary Medicine and Animal Sciences, Swedish University of Agricultural Science (SLU), Uppsala, Sweden.

Tiesnamurti, B., Anwar., Destomo, A., Febresiana, A., 2021. Coat cover characteristics of sheep in North Sumatera, Indonesia. IOP Conference Series: Earth and Environmental Science. https://iopscience.iop.org/article/10.1088/1755-1315/788/1/012009/pdf.

Uzzaman, MR., Edea, Z., Bhuiyan, MS., Walker, J., Bhuiyan, AK., Kim, K., 2014. Genome-wide Single Nucleotide Polymorphism Analyses Reveal Genetic Diversity and Structure of Wild and Domestic Cattle in Bangladesh. Asian-Australas Journal of al Science. volume;27(10):pages 1381-1386. doi:10.5713/ajas.2014.141602014.

Vigne, J. D., 2011. The origins of animal domestication and husbandry: A major change in the history of humanity and the biosphere. Comptes Rendus Biologies, Volume: 334, Pages 171-181.doi: 10.1016/j.crvi.2010.12.009. Epub 2011 Feb 2. PMID: 21377611.

Weir, B. S., and Cockerham, C. C., 1984. Estimating F-statistics for the analysis of population structure. Evolution. 1358-1370.

Woolliams, J. A., Bijma, P., Villanueva, B.,1999. Expected Genetic Contributions and Their Impact on Gene Flow and Genetic Gain, Genetics, Volume 153, Issue 2, 1 October 1999, Pages 1009–1020, https://doi.org/10.1093/genetics/153.2.1009.

Woolliams, J.A., Bijma, P., 2000. Predicting rates of inbreeding in populations undergoing selection. Genetics.Volume: 154(4): Pages:1851-64. doi: 10.1093/genetics/154.4.1851. PMID: 10747074; PMCID: PMC1461013.

Workneh, A., van Dorland, A., Rowlands, J., 2004. Design, execution and analysis of the livestock breed survey in Oromia Regional State, Ethiopia. Addis Ababa and Nairobi. OADB (Oromia Agricultural Development Bureau) and ILRI.

Worku, A., Alemu, T., Gudeto, A., Gurru, M., Messele, F., and Dadi, G., 2019. Growth performance evaluation of sheep breeds under farmers' management at Fentale District, Oromia Regional State, Ethiopia.

Wurzinger, M., Sölkner, J., Iñiguez, L., 2011. Important aspects and limitations in considering community-based breeding programs for low-input smallholder livestock systems. Small Ruminant Research. Volume, 98, pages 170–175.

Yapi-Gnaoré, C.V., Dagnogo, B., Oya, B.A., 2001. Community-based livestock improvement and conservation: experiences from open-nucleus breeding programmes in West Africa. http://www.fao.org/3/y3970e/y3970e09.htm#TopOfPage.

Yaro, M., Munyard, K. A., Stear, M. J., Groth, D. M., 2016. Molecular identification of livestock breeds: a tool for modern conservation biology. Biological Reviews. doi:10.1111/brv.12265.

Zonabend König, E., Mirkena, T., Strandberg, E., Audho, J., Ojango, J., Malmfors, B., Okeyo, A.., Philipsson, J., 2016. Participatory definition of breeding objectives for sheep breeds under pastoral system in the case of Red Maasai and Dorper sheep in Kenya. Tropical Animal Health Preproduction 48, 9–20. https://doi.org/10.1007/s11250-015-0911-7.

11. INDIVIDUAL PAPERS

Paper I

Genetic parameters and trends of growth traits in community-based breeding programs of Abera sheep in Ethiopia (published)

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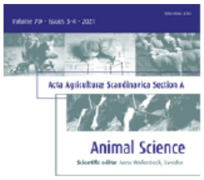

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Genetic parameters and trends of growth traits in community-based breeding programs of Abera sheep in Ethiopia

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ABSTRACT

The objectives of the current study were to estimate the genetic parameters and genetic trends for growth traits, and to assess inbreeding levels of Abera sheep under community-based breeding programs (CBBPs) in Ethiopia. General linear model consisting of the fixed effects of sex, breeder cooperative, season and birth type was used to analyze growth traits. Variance components and genetic parameters were estimated within each breeder cooperative following univariate animal model based on the restricted maximum likelihood method. All fixed effects influenced ($P < 0.05$) the growth traits. Multivariate analysis was also employed to compute correlation estimates among growth traits. Based on the best fitted models, the direct heritability for weaning weight (WWT) and six-month weight (SMWT) in the six breeder cooperatives were in the ranges of 0.12 ± 0.12–0.38 ± 0.17 and 0.20 ± 0.10–0.49 ± 0.01, respectively. Range of positive genetic progress in WWT (0.15–0.44 kg) and SMWT (0.21–0.57 kg) was achieved in Abera sheep breeder cooperatives during selection years.

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SMWT; selection; heritability; CBBP; genetic gain

Introduction

Despite a vast diversity of indigenous sheep breeds/types, well-organized, successful and sustainable breeding programs under smallholder, sheep farming situation are rare (Kosgey et al., 2006). Previous attempts to develop and implement small ruminant breeding programs based on crossbreeding of locally adapted populations using exotic breeds and selective breeding based on central government farms were not successful in many developing countries (Haile et al., 2018). Community-based breeding programs (CBBPs) are a major way to improve the genetic performance of livestock in developing countries (Muller et al., 2015). The launched CBBPs in the country have been attracted national genetic improvement strategies of small ruminant from small-scale farming system and the program revealed that visible and encouraging genetic improvement which is leading to positive impact on small-scale sheep farmers (Haile et al., 2014).

Community-based sheep breeding programs are being implemented in Ethiopia starting from 2009 in three locations with three breeds (Bonga, Horro and Menz) involving more than 8000 sheep (Haile et al., 2014). International Centre for Agriculture Research in dry areas (ICARDA), in partnership with Southern Agricultural Research Institute (SARI), launched a community-based sheep breed improvement project in different districts of the Sothern region of Ethiopia. Hawassa Agricultural Research Center (HARC) adopted the CBBP on Abera sheep in six different villages since 2013.

Abera sheep breed is known with long fat tail ending with a straight tip with plain and patchy hair coat color type. The common hair type of sheep in all studied zones is short and smooth and sheep from Sidama-Gedeo are devoid of wattle and ruff (Melesse et al., 2013).

Effectiveness of selective breeding program can be assessed by change in breeding value of each selection interest traits which are expressed as a proportion of expected theoretical change of mean of breeding values resulted from selection (Mokhtari & Rashidi, 2010). In participatory sheep breeding program, genetic improvement of growth traits was mainly dependent on its heritability and genetic correlation with its economic importance, which can attract small-scale sheep farmers. Heritability estimate in each trait of interest is very much important to plan capable breeding program that can lead to optimize the selection response of growth traits (Berkana, 2019). Traits of interest which are identified by Abera sheep small-

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scale farmers were mostly depend on growth traits, which can be explained by weight of the animals in different ages. So, the current study target was to learn more about the growth traits in Abera sheep. The aspiration any CBBP in small-scale farmers, especially framers from sub- Saharan African country is to make them economically benefited from selective breeding and growth is economically important trait of farm animals which can interpreted scientifically as increment in growth or weight is directly related to increment of income so, data generated under Abera sheep CBBP for the last six years have not been systematically analyze to evaluate possible genetic progress of growth traits; therefore, the current study was taken up with the objective of estimating genetic parameter, genetic trend and inbreeding level to generate information for optimization of the ongoing CBBP in six cooperatives of Abera sheep.

Materials and methods

Study area description

The investigation was conducted in Dara otelicho and Hulla woreda of Sidama region located on geographic coordinates of 38° 38′–38° 51′ E longitude and 6° 36′–6° 54′ N latitude with altitude ranging from 1200 to 2900 meters above sea level. Average annual maximum and minimum temperature ranges 28°C and 19°C respectively, with 1200–1700 mm ranges of total rainfall. The district is characterized by mixed-crop livestock production system as agricultural practice.

Breeding animals and description of the breeding program

The breeding program has been implemented with the full participation of farmers, researchers and extension following the guidelines for implementation of participatory breeding programs (Haile et al., 2018). Six different breeder cooperatives (Abera gelede, Abera atilla, Abera doko, Abera doda, Abera bongodo and Bonchesa gobi) were involved. An enumerator selected from the community is responsible for animal identification, data collection and recording and follow-up of the community flocks. Selection of rams was carried out twice a year across flocks within cooperatives. Six-month weight (SMWT) was used as selection criteria to improve market weight. Estimated breeding values of the candidates for weaning weight (WWT) was considered as pre-screening and final approval of breeding ram was handled by the representative of the community considering community's preference in morphological characters like coat color, confirmation, tail type and horn. The top 10% selected rams were used to serve the community flocks. Around 60% of next best rams were used to serve flocks outside the community and those not fitting for breeding were culled and marketed for meat.

Data and traits recorded

Pedigree information and performance data were collected by enumerator at the time of incident (pedigree and birth weight (BWT) recorded within 24 h of lambing. Since weaning weight (WWT), six-month (SMWT) and yearling weights (YWT) were recorded on fixed dates, these records were adjusted for fixed age at 90, 180 and 360 days of age. Reliability and consistency of the pedigree data were checked using pedigree viewer software (Kinghorn, 2015), and record errors like duplicated animal identification, and bisexual records were removed. Data were subjected to homogeneity of variances and normality test and outliers were excluded. Finally, 2901 records on birth weight (BWT), 2626 records on weaning weight (WWT), 2261 records on six-month weight (SMWT) and 1603 records on yearling weight (YWT) were included in the analysis. Details of data used and pedigree structure are presented in Table 1.

Statistical analysis

Effect of fixed effects

The effects of fixed effects on studied traits were analyzed using the 'asremlplus' package in **R** statistical software (Brien, 2021). The statistical model used for the analysis of BWT, WWT, SMWT and YWT was

$$y_{ijklm} = \mu + P_i + S_j + b_k + w_l + S_m + S_n + e_{ijklm}$$

where y_{ijklm} is response of individual variables, μ is the overall mean, p_i = the effect of the ith sex (i = 2, male,

Table 1. Details of data size and pedigree structure.

	Type of trait			
No of	BWT	WWT	SMWT	YWT
Total record	2901	2626	2261	1603
Animal in pedigree	4153	4258	3410	2744
Animal without offspring	1252	2575	1864	1567
Animal with offspring	1782	1683	1546	1177
Sire	527	501	467	360
Sire with records and progeny in data	300	0	245	–
Dam	1255	1182	1079	817
Dam with records and progeny in data	230	52	152	36
Animal with paternal grand sire	1682	0	1093	–
Animal with paternal grand dam	1682	0	1093	–
Animal with maternal grand sire	446	95	282	78
Animal with maternal grand dam	446	95	282	78

Notes: BWT = birth weight, WWT = weaning weight, SMWT = six-month weight and YWT = yearling weigh.

female), S_j = the effect of the jth year (j = 6, 2014–2019), b_k = the effect of the kth season grouped in to four classes based on the pattern of annual rainfall distribution in the area (k = 4; September to November, spring; December to February, winter; March to May, autumn and June to August, summer), w_l = the effect of the lth litter size(l = 2, single, twin), S_m = the effect of mth location (m = 6; Abera attila, Abera gelede, Abera doko, Abera doda, Abera bongodo and Bonchensa gobi) and e_{ijklm} = random error associated with each observation and assumed to be normality and independently distributed with mean zero variance $\sigma^2_{e.}$

Genetic parameter estimates

Genetic parameters and (co)variance components for traits were estimated by fitting a univariate animal model using Average Information Restricted Maximum Likelihood (AI-REML) model inWOMBAT software (Meyer, 2007). All the fixed effects (lamb birth year, lamb birth season, sex, birth type, sex and site/location) considered in this study were found significant (P<0.05) for all the traits and hence included in the model. The following six different models were fitted to identify the best fitting model for each trait by including or excluding maternal genetic or maternal environment effect:

Model 1: $y = X_b + Z_a + e$

Model 2: $y = X_b + Z_a + W_c + e +$

Model 3: $y = X_b + Z_a + S_m + e$ with cov (a, m) $= 0$

Model 4: $y = X_b + Z_a + S_m + e$ with cov (a, m) $\neq 0$

Model 5: $y = X_b + Z_a + W_c + S_m + e$ with cov (a, m) $= 0$

Model 6: $y = X_b + Z_a + W_c + S_m + e$ with cov (a, m) $\neq 0$

where y is the vector of observations, b is the vector of fixed effects, a, m, c and e are the vectors of direct additive genetic effect, maternal genetic effect, maternal permanent environmental effect and residual (temporary environment) effect, respectively. **X, Z, W** and **S** are incidence relating individual records to b, a, c and m, respectively.

The (co) variance structure is as follows:

$$var\begin{bmatrix} a \\ m \\ c \\ e \end{bmatrix} = \begin{bmatrix} A\sigma^2 a & A\sigma^2_{am} & 0 & 0 \\ A\sigma^2_{am} & A\sigma^2 m & 0 & 0 \\ 0 & 0 & I\sigma^2 c & 0 \\ 0 & 0 & 0 & I\sigma^2 e \end{bmatrix}$$

where $\boldsymbol{A\sigma^2 a}$ is the additive genetic variance for direct effects of animal, $\boldsymbol{A\sigma^2{}_{am}}$ is the additive genetic covariance between direct and maternal effects, $\boldsymbol{A\sigma^2 m}$ is the additive genetic variance for maternal effects, $\boldsymbol{I\sigma^2 c}$ is the variance of maternal permanent environmental effects, $\boldsymbol{I\sigma^2 e}$, variance of remaining random effects and A and I are matrices of relationships and identity matrices, respectively. The direct additive genetic, maternal additive genetic and maternal permanent environmental effects and residual effects were normal distributed with mean zero and variance **V(a)** $= \boldsymbol{A\sigma^2 a}$,**V(m)** $= \boldsymbol{A\sigma^2 m}$, **V(c)** $= \boldsymbol{I\sigma^2 c}$ and **V(e)** $= \boldsymbol{I\sigma^2 e}$ where I was identity matrix of order equal to the number of records.

Univariate animal model were used for each trait to select the best fit model. Log likelihood ratio test (LRT) was used to choose the best model. The loglikelihood ratio=2 times maximum likelihood for full model minus maximum likelihood for reduced model and chi-square (χ 2) with degree of freedom equal to the difference between the two model being compared. The LRT was given by $D = 2\log(l_{R2}/l_{R1}) = 2[\log(l_{R2}) - \log(l_{R1})]$, where l_{R1} = log likelihood of restricted model and l_{R2} = log likelihood of the more general model.

To declare the significance of differences, the likelihood ratio test was tested against the chi-square distribution with degrees of freedom being the difference in number of variance and covariance components in the models. If 2ΔlogL values were not significantly different ($P > 0.05$), then addition of a random effect did not improve the model hence model with lower number of random effect variances would then be chosen (Gilmour et al., 2015). Then, the model that has fewer parameters was selected as the most appropriate model. Depending on the model, total heritability was calculated according to the following equation (Willham, 1972):

$$h^2 t = \frac{\sigma^2 a + 0.5\sigma^2 m + 1.5\sigma_{am}}{\sigma^2 p}$$

Genetic trend for each trait was estimated as regression of estimated breeding values obtained from the best model on year of birth using R software.

Results

Fixed effects

The overall LSM for BWT, WWT, SMWT and YWT were 2.90, 15.51, 20.8 and 27.9 kg, respectively. The traits were influenced ($p < 0.01$) by sex, year, season, litter size and location (Table 2).

Inbreeding

The average coefficient of inbreeding trends (percentage per year) is shown in Figure 1. Coefficient of inbreeding (F) shows different trends among CBBPs of Abera sheep ranging from −0.003 to 0.14%. The trend

Table 2. Least squares mean (LSM ± SE) for growth traits of Abera Sheep.

	BWT (kg)		WWT (kg)		SMWT (kg)		YWT (kg)	
Source of variation	*N*	Mean ± SE	*N*	Mean ± SE	*N*	Mean ± SE	*N*	Mean ± SE
Overall	2919	2.90 ± 0.01	2626	15.51 ± 0.09	2274	20.75 ± 0.18	1603	27.89 ± 0.16
CV%		10.18		11.36		12.00		8.05
Birth year		**		**		**		**
2013	163	2.83±0.01^{f}	166	15.55±0.15^{bc}	160	NA	160	NA
2014	252	2.90±0.01 ^{f}	250	16.27±0.08^{a}	249	22.03±0.15^{a}	245	29.33±0.13^{a}
2015	584	2.88±0.01^{e}	577	15.46±0.07^{b}	544	21.60±0.11^{ab}	303	29.33±0.14^{a}
2016	362	3.09±0.15^{d}	256	15.20±0.09^{bc}	198	20.71±0.24^{cd}	144	28.30±0.20^{bc}
2017	754	3.28±0.01^{c}	745	15.12±0.07^{c}	710	20.71±0.13^{d}	388	27.35±0.13^{c}
2018	630	3.33±0.01^{b}	505	16.50±0.10^{a}	299	20.24±0.19^{de}	287	26.97±0.13^{d}
2019	174	3.49±0.03^{a}	130	16.04±0.13^{a}	114	19.27±0.24^{e}	76	29.15±0.28^{ab}
Sex		**				NS		*
Male	1734	3.18±0.01^{a}	1575	15.78±0.05^{a}	1385	21.18±0.08^{a}	999	28.30±0.08^{a}
Female	1185	3.09±0.01^{b}	1051	15.46±0.06^{b}	899	20.78±0.10^{a}	604	28.01±0.09^{b}
Cooperative		**				**		**
Abera Gelede	569	3.23±0.02 ^{a}	574	15.63±0.06^{c}	570	20.35±0.12^{d}	524	28.68±0.11^{b}
Abera Attila	466	3.21±0.02^{a}	421	16.09±0.07^{a}	345	21.91±0.12^{bc}	188	28.89±0.17^{b}
Abera Doko	477	3.03±0.02^{d}	421	15.74±0.15^{b}	368	21.30±0.16^{c}	172	28.84±0.17^{a}
Abera Doda	269	2.99±0.02^{d}	226	14.26±0.09^{d}	224	16.54±0.22^{e}	86	27.51±0.23^{c}
Abera Bongodo	522	3.15±0.01^{c}	375	15.73±0.63^{b}	297	21.90±0.11^{ab}	108	28.54±0.19^{b}
Bonchensa Gobi	616	3.17±0.02^{b}	612	15.76±0.07^{b}	470	22.54±0.09^{a}	525	27.29±0.11^{c}
Season		**				*		NS
Kerimet (Summer)	729	3.10±01^{a}	777	15.74±0.07^{a}	709	21.26±0.11^{a}	403	28.20±0.13^{a}
Beleg (Autumn)	802	3.12±0.0^{a}	698	15.51±0.07^{c}	648	20.77±0.13^{b}	415	28.34±0.13^{a}
Bega (winter)	681	3.17±0.0^{b}	548	15.88±0.08^{ab}	388	21.14±0.15^{ab}	392	28.09±0.12^{a}
Tseady (spring)	707	3.19±0.01^{a}	606	15.48±0.08^{bc}	529	20.92±0.14^{ab}	393	28.14±0.20^{a}
Birth type		**		*		NS		NS
Single	2005	3.21±0.0^{a}	1804	15.72±0.05^{a}	1581	20.96±0.08^{a}	1041	28.14±0.08^{a}
Twin	898	3.01±0.0^{b}	807	15.49±0.06^{b}	684	21.14±0.11^{a}	551	28.32±0.11^{a}
Triplet	16	2.68±0.0^{c}	18	16.02±0.38^{ab}	9	NA	11	NA

Notes: Mean values with different superscripts across columns are significantly different ($P < 0.05$); LSM: least square means; SE: standard error; *N*: number of observations; BWT: birth weight; WWT: weaning weight; SMWT: six-month weight and YWT: yearling weight, kg: kilograms;** highly significant ($p < 0.01$), *significant ($p < 0.05$) NA: non applicable and; NS: nonsignificant ($p > 0.05$).

of F in the current study demonstrated dissimilar (increasing, decreasing and stable) patterns between different breeder cooperatives.

Model comparisons

Log likelihood values of all different models on the selection traits considered are presented in Table 3.

Variance and covariance components and genetic parameter estimates

Estimates of co (variance) components and genetic parameters for WWT and SMWT of Abera sheep in different breeder cooperatives are shown in Table 4.

The direct heritability (h^2) for WWT and SMWT in the six breeder cooperatives were in the range of 0.12 ±

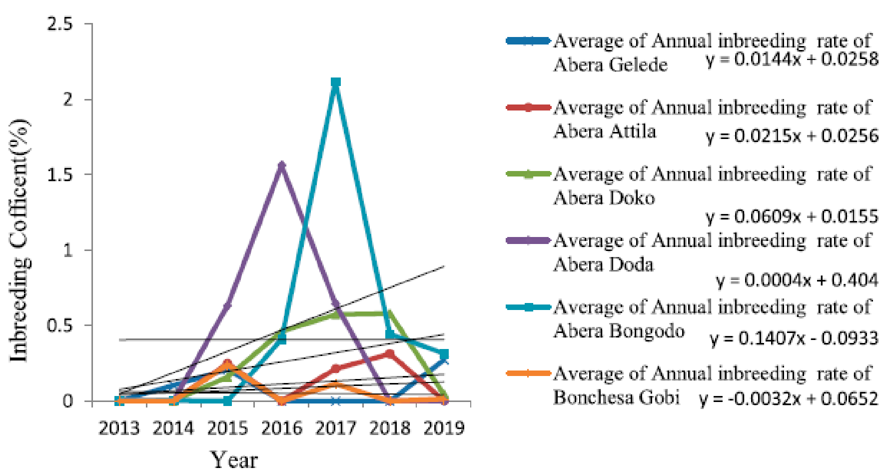

Figure 1. Annual mean of inbreeding of each breeder cooperative of community-based breeding program of Abera sheep.

Table 3. Log likelihood values from univariate analyses for each breeder cooperative (best model is highlighted in bold font).

		Model					
Breeder cooperatives	Traits	1	2	3	4	5	6
1	WWT	−459.51	−459.52	−459.52	**−458.01**	−459.54	−458.01
	SMWT	−788.15	**−788.15**	−788.16	−779.78	−788.27	−779.78
2	WWT	−329.72	−317.8	−317.22	−317.08	−317.23	**−317.08**
	SMWT	**−108593**	−346691	−96480	−96604	−95237	−95266
3	WWT	−550.55	−550.56	−550.56	−541.57	−550.56	**−541.71**
	SMWT	−570.92	**−570.71**	−570.91	−567.93	−570.72	−567.8
4	WWT	−183.15	−183.16	−183.16	**−182.56**	−183.17	−182.55
	SMWT	−337.48	−335.67	−335.68	−341.85	−335.67	**−336.02**
5	WWT	−253.44	**−253.32**	−253.42	−253	−253.35	−252.94
	SMWT	−287.42	−284.92	−285.48	−284.72	−284.92	**−284.92**
6	WWT	−513.83	−510.15	−509.9	−509.46	−509.9	**−509.46**
	SMWT	−509.11	−498.2	−498.3	−498.23	−498.01	**−498.01**

Notes: WWT = weaning weight and SMWT = six-month weight and (Breeder cooperative 1 = Abera Gelede, Breeder cooperative2 = Abera Attilla, Breeder cooperative 3 = Abera Doko, Breeder cooperative 4 = Abera Doda, village 5 = Abera Bongodo and village 6 = Bonchensa Gobi).

Table 4. Estimates of co(variance) components and genetic parameters for weaning and six-month weight of Abera sheep in different breeder cooperatives.

Cooperative/trait	Model	σ^2_a	σ^2_m	σ^2_c	σ^2_e	σ^2_p	σ_{am}	h^2	m^2	c^2	c_{am}	h^2t
1												
WWT	4	0.67	0.43	–	1.21±0.22	1.77±0.11	−0.54	0.38 ± 0.17	0.24±0.27	–	−0.99	0.04
SMWT	2	1.28	–	0.02	4.4±0.52	5.7±0.35	–	0.22 ±0.09	–	0.05	–	0.22
2												
WWT	6	0.37	0.42	0	1.05±0.18	1.71±0.13	−0.13	0.21 ±0.14	0.25±0.29	0	−0.34	0.23
SMWT	1	0.16	–	–	0.16±0.00	0.33±0.00	–	0.49 ±0.01	–	–	–	0.48
3												
WWT	6	7.4	0.95	0.01	0.01±1.00	5.73±0.49	−2.66	0.29 ±0.23	0.17±0.77	0	−0.99	0.68
SMWT	2	2.58	–	0.4	6.14±1.02	9.13±0.74	–	0.28 ±0.13	–	0.04	–	0.28
4												
WWT	4	0.62	0.16	–	1.31±0.36	1.78±0.17	−0.32	0.35 ±0.29	0.09±0.54	–	−0.99	0.12
SMWT	2	0.01	–	1.19	6.27±1.08	7.46±0.74	–	0.20 ±0.03	–	0.14	–	0
5												
WWT	2	0.16	–	0.04	1.13±0.16	1.34±0.10	–	0.12 ±0.13	–	0.03	–	0.12
SMWT	6	0.97	0.16	0.63	1.24±0.42	2.62±0.24	−0.38	0.37 ±0.22	0.06±0.50	0.24	−0.95	0.18
6												
WWT	6	0.68	0.13	0.01	1.02±0.19	2.13±0.14	0.29	0.32 ±0.14	0.06±0.86	0	0.99	0.55
SMWT	6	1.45	0.55	0.49	1.19±0.34	3.65±0.29	−0.03	0.39 ±0.15	0.14±0.31	0.13	−0.04	0.46

Notes: σ^2_a = direct additive genetic variance; σ^2_m = maternal additive genetic variance, σ^2_c = maternal permanent environmental variance; σ^2_e = residual variance, σ^2_p = phenotypic variance; h^2 = direct heritability; m^2 = maternal heritability; c^2 = ratio maternal permanent environmental variance to phenotypic variance; c_{am} = correlation between direct maternal additive genetic effects; and h^2t = total heritability(breeder cooperative 1 = Abera Gelede, 2 = Abera Attilla, 3 = Abera Doko, 4 = Abera Doda, 5 = Abera Bongodo and 6 = Bonchensa Gobi).

0.13–0.38 ± 0.17 and 0.20 ± 0.03–0.49 ± 0.01, respectively. In the current study, very low permanent maternal environment effects (c^2) was recorded in all locations resulted from different models in WWT and SMWT of Abera sheep (Table 4).

Full model indicates less importance of additive maternal heritability (m^2) estimates in all breeder cooperatives except for that of Bonchensa Gobi. Additive maternal heritability (m^2) estimates were high in SMWT than WWT traits. Total heritability estimate (h^2t) in the current study for WWT and SMWT (Table 4) was in the range of 0.04–0.68 and 0–0.48, respectively.

Correlation estimates among growth traits

The genetic and phenotypic correlations among growth traits (BWT, WWT, SMWT and YWT) for each breeder cooperative are presented in Table 5. The genetic correlation between BWT and other post-weaning growth traits (SMWT and YWT) was low which indicates that the targeted selection to improve economically important traits would not increase BWT. High genetic correlations also exhibited between WWT and SMWT in all breeder cooperatives except in breeder cooperative #6 (−0.15).

Genetic correlations between SMWT and YWT had high and positive genetic correlations in all breeder cooperatives ranging from 0.59 to 0.98. BWT had weak phenotypic correlation with other growth traits in most breeder cooperatives and the phenotypic correlation of WWT and SMWT was moderate to high and positive in all breeder cooperatives except in # 6 (−0.07). The genetic and phenotypic correlation among different body weight traits in the current

Table 5. Estimates of genetic (above diagonal) and phenotypic (below diagonal) correlations between growth traits in multi-trait analysis in breeder cooperatives of Abera sheep.

Cooperatives	Traits	BWT	WWT	SMWT	YWT
1	BWT	_	0.964	0.43	0.438
	WWT	0.191	_	0.535	0.499
	SMWT	0.147	0.569	_	0.979
	YWT	0.095	0.338	0.146	_
2	BWT	_	0.915	0.137	−0.886
	WWT	0.791	_	0.376	0.678
	SMWT	0.114	0.271	_	0.336
	YWT	−0.885	−0.587	0.279	_
3	BWT	_	0.193	−0.1	−0.3
	WWT	0.073	_	0.397	0.341
	SMWT	0.035	0.261	_	0.953
	YWT	−0.13	0.286	0.702	_
4	BWT	_	0.644	0.659	0.769
	WWT	0.535	_	0.99	0.984
	SMWT	0.588	0.747	_	0.987
	YWT	0.766	0.821	0.884	_
5	BWT	_	−0.125	0.126	0.639
	WWT	−0.073	_	0.967	0.681
	SMWT	0.097	0.691	_	0.843
	YWT	0.506	0.499	0.82	_
6	BWT	_	0.579	−0.391	0.25
	WWT	0.246	_	−0.159	0.409
	SMWT	−0.123	−0.071	_	0.597
	YWT	0.006	0.14	0.151	_

Notes: BWT = birth weight; WWT = weaning weight; SMWT = six-month weight and YWT = yearling weight, Village: 1 = Abera Gelede, 2 = Abera Attilla, 3 = Abera Doko, 4 = Abera Doda, 5 = Abera Bongodo and 6 = Bonchensa Gobi.

study were moderate to high and positive in most breeder cooperatives of CBBPs of Abera sheep.

Genetic trends

Genetic trends for the WWT and SMWT from each breeding year data and the average estimated breeding values during the selection years from six CBBPs are presented in Figure 2. The annual genetic trends were 0.02,0.03,0.19,−0.01,0.05 and 0.08 kg per year for WWT and 0.05, 0.03, 0.06,−002, 0.04 and 0.10 kg per year for SMWT at Abera gelede, Abera Attilla, Abera doko, Abera doda, Abera bongodo and Bonchensa gobi breeder cooperatives, respectively. The traits, WWT and SMWT showed significant genetic gain ($p < 0.001$) during selection years in all breeder cooperatives except at Abera Attilla and Abera doko. Positive genetic gains were also observed for WWT at all breeder cooperatives except that of Abera doda.

Discussion

Factors affecting growth traits of Abera sheep

CBBPs were technically feasible to improve the growth traits of Abera sheep in the current result. The BWT of Abera sheep (2.90 ± 0.01 kg) in the current result was similar to that of CBBP improved Menz (2.75 kg) and Horro (2.51 kg) sheep as reported by Haile et al. (2020). On the other hand, BWT of Menz sheep (2.23 kg) and West African Dwarf (Djallonke) sheep (1.74 kg) both on station flock as reported by Getachew et al. (2020) and Ampong et al. (2019) exhibited less BWT compared to the current study so this shows a comprehensible improvement due to the implementation of CBBPs. As the establishment of Bonga sheep CBBPs was older than the current CBBPs, the BWT of Bonga sheep (3.29 vs. 3.10 kg) in the Sothern part of Ethiopia was heavier than Abera sheep in this study (Haile et al., 2020; Areb et al., 2021).

The WWT of Abera sheep found in this study (15.51 ± 0.09 kg) was higher than most of the unimproved indigenous sheep breeds of Ethiopia reported in the range of 11.0–13.5 kg (Ayele & Urge, 2019), which shows the impact of the CBBP program on the genetic improvement of Abera sheep. In view of the fact that, the community-based sheep breed improvement program has been show significant improvement in WWT of sheep in the country, for example, Bonga sheep improved up 15.5 kg (Memeru, 2015) and Doyogena sheep up to 14.8 kg under CBBP (Habtegiorgis, 2019).

The SMWT in the current study (20.75 ± 0.18 kg) with CV of 12% was comparable with the SMWT of Bonga sheep under CBBPs (Memeru, 2015; Haile et al., 2020). However, the SMWT of the current study is higher than those reported for Horro and Menz sheep breeds under CBBPs (Haile et al., 2020), local sheep breeds raised in Fentale district under on-farmers management (Worku et al., 2019) and Mecheri purebred sheep reared under dry land farming condition (Thiruvenkadan et al., 2009), this weight difference from difference scholar could be resulted from different factors including breed, environmental variations, management and genetic improvement achieved due to the implementation of CBBPs.

As shown in Table 2, the effect sex on body weight was significant ($p < 0.01$). Accordingly, males were heavier than females for BWT, WWT, SMWT and YWT. This difference in the current result is may be due to sexual size dimorphism (SSD) that could be caused by different factors such as specific selection pressure, sex-biased phenotypic and genetic variation (Badyaev, 2002). Sexual difference as a factor of growth performance variation in sheep has been also reported in different local sheep breeds (Haile et al., 2020).

Year of birth had influenced the studied traits ($P < 0.05$). The main reason for year and season variation might be due to the availability of feed related to the annual rainfall fluctuations in the study area (Matewos & Tefera, 2019). Season of birth was also significant ($p < 0.05$) source of variation in growth traits of Abera

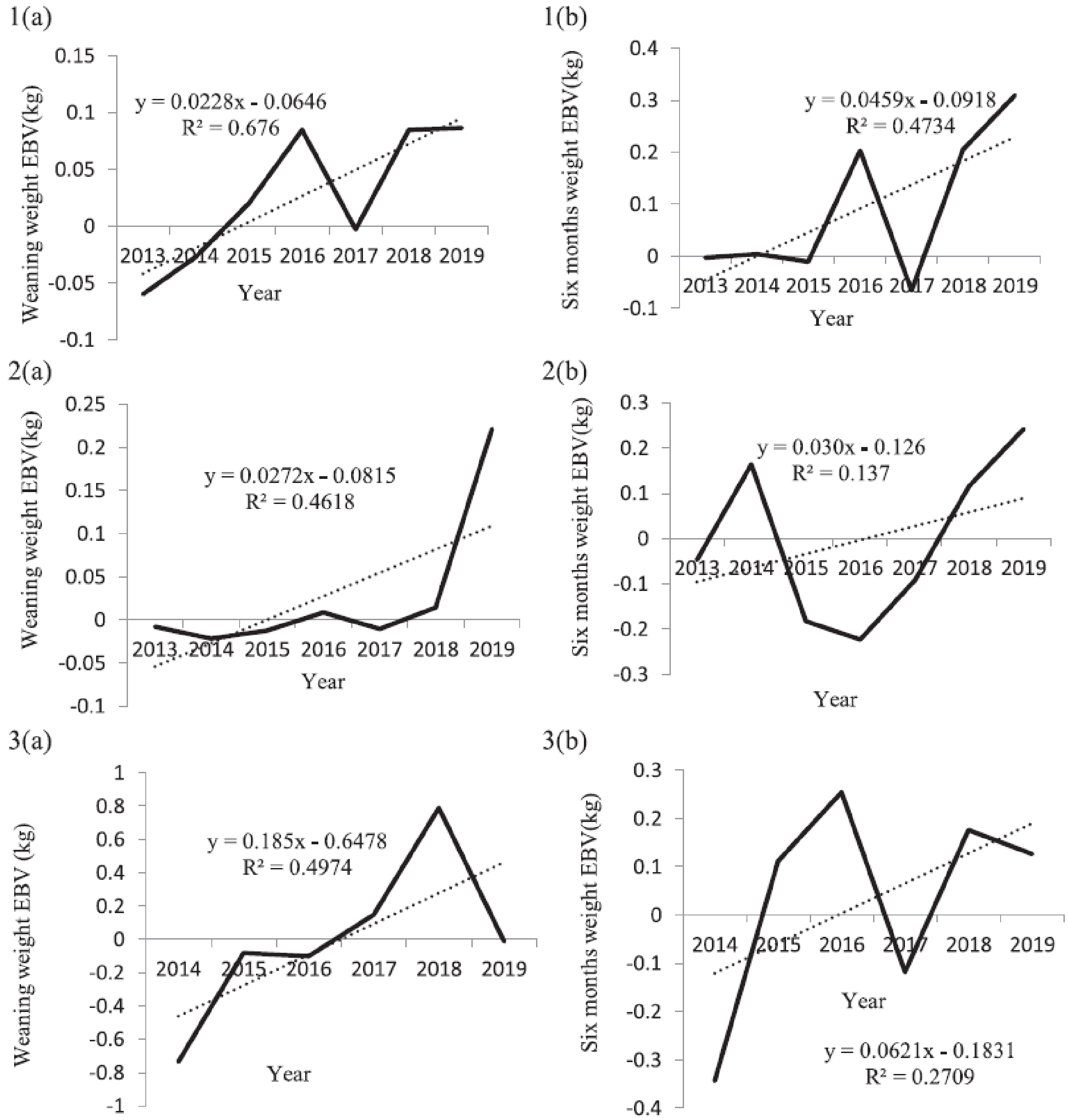

Figure 2. Genetic trend of estimated breeding values (EBV) for weaning weight (a) and six-month weight (b) in six CBBPs (1, 2, 3, 4, 5 and 6) of Abera sheep.

sheep. Accordingly, the values for WWT and SMWT were higher in winter and summer seasons. However, there were no significant differences observed ($p > 0.05$) in YWT and BWT of Abera sheep in all seasons. Such seasonal differences could be related to the severity of the climatic conditions (the amount of frost and cold), the availability of good quality and quantity feed. The availability of feed resources will enable ewes to produce better quality and quaintly of milk resulting in improved weight gain for lambs born during such season. Similar seasonal influence on body weight traits of sheep was also observed in Horro sheep (Haile et al., 2020) and Menz sheep (Abebe et al., 2020).

In the current study, birth type had significant effect ($p < 0.05$) on BWT, WWT and SMWT. Least squares mean of SMWT for single, twin and triplet births were 21.0, 21.2 and 19.1 kg, respectively. Single born lambs had greater BWT and WWT than twins and triplets, but there were no significant difference among twins and single born lambs while triple born lambs were inferior

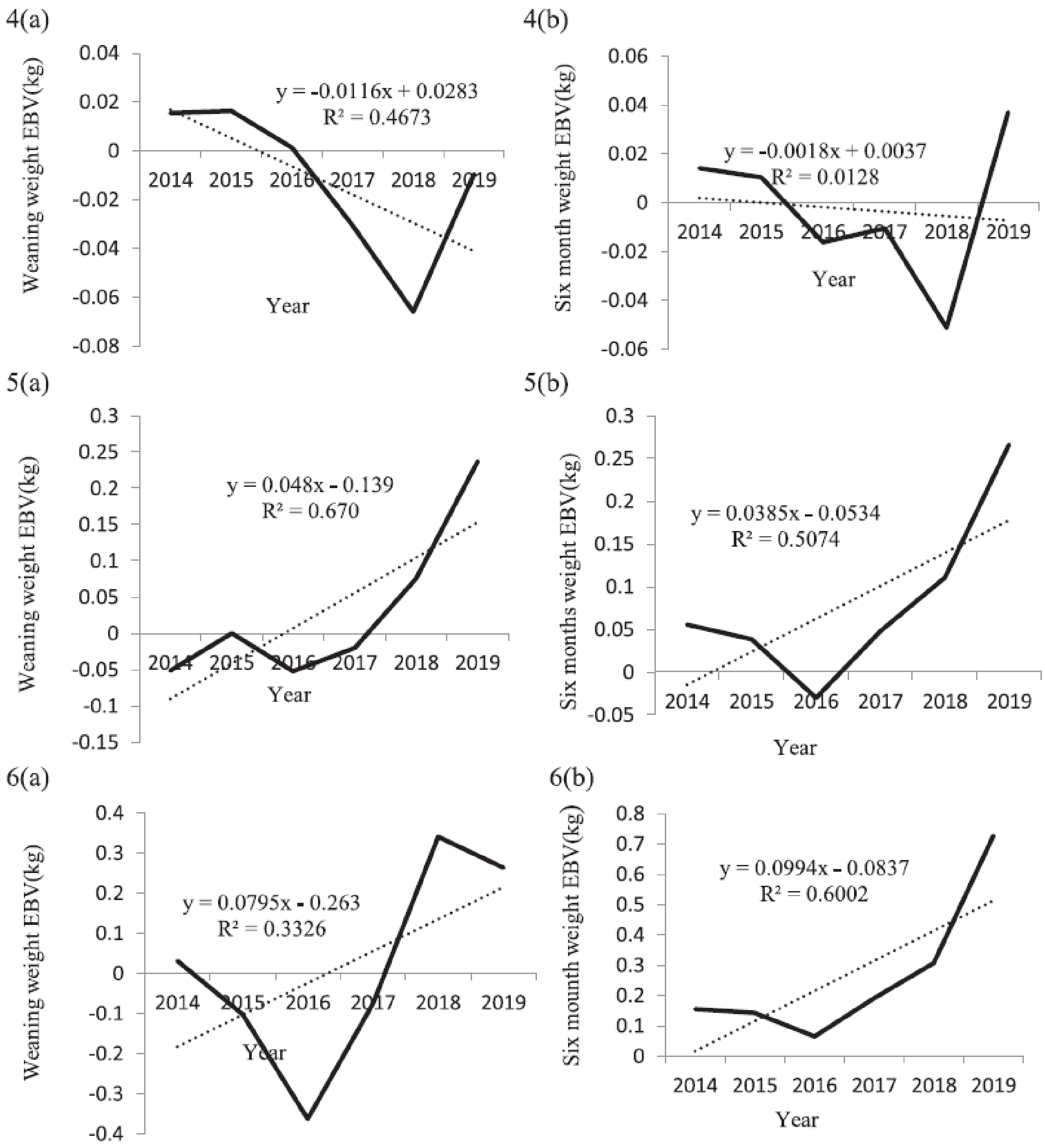

Figure 2 *Continued*

in SMWT and YWT. Difference in birth type might be as resulted from the capacity of the demand the fetus for the reason that of the regulation of fetal development in sheep and it is depend on interaction between the inherent capacity of the fetus for growth and the maternal environment, i.e. carrying multiple fetuses leads a decline in lamb birth weight (Gootwine et al., 2007).

Location had also significantly ($p < 0.05$) affected growth trait of Abera sheep. The highest BWT was found in Abera gelede breeder cooperative with values of 3.23 kg, followed by Abera attila (3.21 kg). As the sheep rearing skills and follow-up of the breeding program varies between different breeder cooperatives and member of CBBPs, the highest SMWT weight were observed in Bonchensa gobi and the lowest in Abera doda. Variation in growth traits of Abera sheep from different CBBPs might be due to the difference in flock management practices, availability of feed and commitment of each data collector and smallholder farmer.

Inbreeding

Even though estimated F in the current study was not beyond the critical level (6.25%), the visible increasing trend in most CBBPs could be an indicator of designing and implementing a systematic mating plan. The most likely reason for inbreeding increment in Abera bongodo CBBP could be the selection of superior breeding rams and high interest of farmers to bred their rams with ewes without seeing their detail pedigree. Minimizing the occurrence of inbreeding through the use of selected breeding rams for unrelated breeding ewes, ram regular change, and minimizing the service of breeding ram for just only two service years for ongoing CBBPs of Abera sheep are some of the options to be implemented. Various studies in Ethiopian sheep breed at CBBP level had reported inbreeding coefficient which is in the range of the current study. Haile et al. (2020) reported inbreeding coefficient values of −0.34, 0.32 and 0.24% for Bonga, Menz and in Horro sheep breeds, respectively.

Genetic parameter estimates and genetic gain

Range of direct heritability estimate (h^2) for WWT of Abera sheep in all breeder cooperatives in the current study, is found higher than the range 0.20–0.29 for black head Somali sheep (Yacob, 2008), 0.27 for Marwari sheep (Singh et al., 2016) and slightly lower (0.48) than Menz sheep (Haile et al., 2020). Similar h^2 estimate for WWT was also reported for Sabi sheep (0.38) in Zimbabwe (Assan et al., 2002). The direct h^2 estimate of SMWT reported by Haile et al. (2020) for Bonga sheep (0.49) was consistent with the current findings. However, the h^2 estimate for SMWT(0.49 ± 0.01) in the current study was higher than those reported by Haile et al. (2020) for Menz sheep (0.06), Areb et al. (2021) for Bonga sheep (0.22), Singh et al. (2016) for Marwari sheep (0.28).

This low permanent maternal environment effects (c^2) in the current result indicates that good care of maternal environment or management (feeding /health care) had significant effect on pre-weaning traits than post-weaning traits. Moderate to low permanent maternal environmental estimates in SMWT were also reported by different scholars (Singh et al., 2016, Habtegiorgis, 2019).

Both additive and maternal heritability estimates in the current result indicate that the scope of genetic improvement in Abera sheep through selection should be continued. The current result revealed that additive maternal heritability were more important at early age of lambs than at post-weaning growth ages and the models rejected the additive material heritability effect to estimate the best fitted model in SMWT than WWT.

Maternal heritability of SMWT in the current study (0.06–0.14) were lower than Bonga sheep (0.41), Horro sheep (0.15) and higher than Menz sheep (0.003) (Haile et al., 2020) while, the maternal heritability of SMWT in the current study is in the range of the report by Yacob (2008) 0.04–0.23 in Afar sheep and 0.12–0.23 in black head Somali sheep.

The heritability estimate for growth traits in sheep are usually moderate to high (Mekuriaw & Haile, 2014) and the heritability estimates in the current study fall in this range. Phenotypic response from selection could be predicted from estimate of total heritability. The range of total heritability estimates for growth traits of Abera sheep from six breeder cooperatives were in similar range of the sheep in Bonga and Horro CBBPs (Haile et. al., 2020) and Harni sheep (Lalit et al., 2016). However, the heritability estimates of growth traits in the current study are slightly higher than those of reported for Menz sheep (Haile et al., 2020), Iranian Karakul sheep (Talebi, 2019).

Low genetic association of BWT with other post-weaning growth traits in the current finding helps to avoid birth complication or dystocia and production loss due to increased BWT of lambs. So, increasing BWT in different local sheep population of Ethiopia also not recommended (Haile et al., 2019; Areb et al., 2021).

The SMWT and YWT are the most economically important growth traits as most sheep are marketed between this age interval (Lalit et al., 2016). Selection based on those age ranges can increase the income of the farmers and selection based on post-weaning traits used as suitable criteria in CBBPs is important (Jembere et al., 2019). Similar to the current result, positive genetic and phonotypic association between growth traits were reported for Horro sheep (Abegaz et al., 2010).

The range of genetic gain for WWT (0.02–0.19 kg/ year) that obtained in current study were in the range of those reported for sheep managed under CBBPs (Mokhtari & Rashidi 2010; Habtegiorgis, 2019; Areb et al., 2021). However, the range of genetic gain observed for WWT was higher than those reported for Arman sheep (Mostafa et al., 2011) and Jordanian Awassi sheep (Jawasreh et al., 2018). On the other hand, Jeichitra et al (2015) reported 0.85 kg/year for Mecheri sheep and Zishiri et al. (2010) 0.34 kg/year for Ile de France sheep breed which was higher than the observation of the current study.

The range of genetic gain in SMWT (0.03–0.08 kg/ year) obtained in current study was in the range of those reported by different scholars (Habtegiorgis, 2019; Areb et al., 2021) while it was slightly lower than reported by Haile et al. (2020) for Bongo and Horro sheep and Gizaw et al. (2013) for Menz sheep. The possible reasons for different genetic gains in studied traits of indigenous breeds can be the breed difference (the gain were more pronounced in lager breeds than smaller), age and efficiency of CBBPs and dedication of researchers, farmers and data collectors.

The main reasons for the achievement genetic gain in most breeder cooperatives of Abera sheep were due to the integration of breeders with small-scale sheep farmers on selection of breeding rams and effective utilization of breeding rams, good data collection and keeping scheme and increment of farmers income. This lack of annual genetic improvement in WWT and SMWT Abera doda breeder cooperatives are may be due to different factors such as lack of settlement of data collectors in that particular CBBP and lack of accuracy of recording and/or data quality and management.

Conclusion

Positive and significant estimate of genetic trends in most breeder cooperatives for selection traits in the current study confirms that participatory sheep breed improvement program is a feasible option to improve growth performances in the low input production system. Moderate to high heritability estimate for body weight traits is indicative of the existence of genetic variability in the population and selection should be continued. Positive genetic correlation between SMWT and other growth traits suggests that the use of these traits is useful in the selective breeding program. Poor or downward genetic progress was observed in some of the breeder cooperative's flocks. Small genetic progress might be attributed to the variation in successful implementation of breeding program. So, those corrective measures should be taken in breeder cooperatives that showed less genetic performance along with optimization of selection routine in regard to both economically important and productive reproductive traits using automated digital database system is suggested to evaluate actual genetic improvement of Abera sheep. Nevertheless, the result in the current cooperatives revealed that the participatory sheep breed improvement program could add genetic progress in the growth traits of sheep under small-scale sheep breeders.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Abebe, A., Banarjee, S., Goshmie, S., Bisrat, A., Abebe, A., Besufikad, S., Zewdie, T. & Gizaw, S. (2020). Selection efficiency for growth performance of Menz sheep in a community-based breeding program. *Livestock Research for Rural Development*, 32, Article #152. Accessed 19 September 2020, available at: http://www.lrrd.org/lrrd32/9/ascha32152.html.

Abegaz, S., Van Wyk, J. B. & Olivier, J. J. (2010). Estimation of genetic and phenotypic parameters of growth curve and their relationship with early growth and productivity in Horro sheep. Dummerstorf: Leibniz-Institute for Farm Animal Biology. p. 91.

Ampong, E., Obese, F. Y. & Ayizanga R, A. (2019). Growth and reproductive performance of west African dwarf sheep (Djallonké) at the Livestock and Poultry Research Centre, University of Ghana. *Livestock Research for Rural Development*, 31, Article #8. Accessed 1 June 2021, available at: http://www.lrrd.org/lrrd31/1/fyobe31008.html

Areb, E., Getachew, T., Kirmani, M. A., Abate, Z. & Haile, A. (2021). Estimation of (co)variance components, genetic parameters, and genetic trends of growth traits in community-based breeding programs of Bonga sheep. *Animal*, 15(5), 100202. doi:10.1016/j.animal.2021.100202

Assan, N., Makuza, S., Mhlanga, F. & Mabuku, O. (2002). Genetic evaluation and selection response of birth weight and weaning weight in indigenous Sabi sheep. Matopos Research Station, Zimbabwe. Available at: https://www.ajas.info/upload/pdf/15_268.pdf

Ayele, S. & Urge, M. (2019). Productive and reproductive performances of indigenous sheep in Ethiopia: A review. *Open Journal of Animal Sciences*, 9, 97–120. doi:10.4236/ojas.2019.91009

Badyaev, A. (2002). Male and female growth in sexually dimorphic species: Harmony, conflict, or both? Available at: http://eebweb.arizona.edu/faculty/badyaev/papers/47.pdf.

Berkana, K. (2019). *Performance progress of Horro sheep managed under community-based breeding in Horro district compared to on-station performance at Bako Agricultural Research Centre.* MSc thesis, Wollega University, Nekemte, Ethiopia. Available at: https://fliphtml5.com/zryme/tdip/basic

Brien, C. (2021). Asremlpus: Augments 'ASReml-R' in fitting mixed model and packages generally in exploring prediction differences R package ver version 4.2-32.zip. Available at: https://cran.r-project.org/package=asremlPlus

Getachew, T., Abebe, A., Gizaw, S., Rischkowsky, B., Bisrat, A. & Haile, A. (2020). Coat colour alterations over the years and their association with growth performances in the Menz sheep central nucleus and community-based breeding programs. *Tropical Animal Health and Production*, 52, 2977–2985. doi:10.1007/s11250-020-02315-5

Gilmour, A. R., Goge, B. J., Cullis, B. R., Welham, S. J. & Thompson, R. (2015). ASReml user guide release 4.1 functional specification, VSN International Ltd, Hemel Hempstead, HP1 1ES, UK. Available at: www.vsni.co.uk

Gizaw, S., Getachew, T., Haile, A., Rischkowsky, B., Sölkner, J. & Tibbo, M. (2013). Optimization of selection for growth in Menz sheep while minimizing inbreeding depression in fitness traits. *Genetics Selection Evolution*, 45(1), 20. doi:10.1186/1297-9686-45-20

Gootwine, E., Spencer, T. & Bazer, F. (2007). Litter size dependent intrauterine growth restriction in sheep. *Animal*, 1(4), 547–564. doi:10.1017/S1751731107691897

Habtegiorgis, K. (2019). *Estimation of genetic parameters and genetic trends for productive and reproductive traits of Doyogena sheep in southern Ethiopia*. M.Sc thesis, Jimma university, Jimma, Ethiopia. p. 44.

Haile, A., Desse, T. & Rischkowsky, B. (2014). Performance of indigenous sheep breeds managed under community based breeding programs in the highlands of Ethiopia.

Haile, A., Getachew, T., Merkena, T., Duguma, G., Gizaw, S., Wurzinger, M., Soelkner, J., Mwai, O., Desse, T., Abebe, A., Abate, Z., Jemebere, T., Rekik, M., Lobo, R., Mwacharo, J., Terfa, Z., Kassie, G., Mueller, G. & Rischkowsky, B. (2020). Community-based sheep breeding programs generated substantial genetic gains and socioeconomic benefits. *Animal*, 14 (7), 1362–1370. doi:10.1017/S1751731120000269. ISSN 1751-7311.

Haile, A., Getachew, T. & Rischkowsky, B. (2019). Community-based sheep breeding programs in Ethiopia generated substantial genetic gains and socio- economic benefits-preliminary results. Technical report for CGIAR Research Program on Livestock Agri-Food Systems, ICARDA, Beirut, Lebanon.

Haile, A., Wurzinger, M., Mueller, J., Mirkena, T., Duguma, G., Rekik, M., Mwacharo, J., Mwai, O., Sölkner, J. & Rischkowsky, B. (2018). *Guidelines for setting up community-based sheep breeding programs in Ethiopia*. ICARDA, Tools and Guidelines No.1. Aleppo, Syria: ICARDA.

Jawasreh, K., Ismail, Z. B., Iya, F., Castañeda-Bustos, V. J. & Valencia-Posadas, M. (2018). Genetic parameter estimation for pre-weaning growth traits in Jordan Awassi sheep. *Veterinary World*, 11(2), 254–258. Available at: www.veterinaryworld.org/Vol.11/February-2018/27.pdf

Jeichitra, V., Ramanujam, R., Rahumathulla, P. S. & Karunanithi, K. (2015). Genetic and phenotypic trends for growth traits in Mecheri sheep. *Indian Journal of Small Ruminants*, *21*(1), 96–99. https://www.researchgate.net/publication/276394686

Jembere, T., Rischkowsky, B., Dessie, T., Habtegiorgis, K., Okeyo, A., Mirkena, M. & Haile, A. (2019). Genetic and economic evaluation of alternative breeding scenarios for community based productivity improvements of three indigenous goat breeds in Ethiopia. *Small Ruminant Research*, 178, 46–54. doi:10.1016/j.smallrumres.2019.07.017

Kinghorn, B. & Kinghorn, S. (2015). Pedigree viewer version 6.5f. Available at: http://bkinghor.une.edu.au/ pedigree.htm

Kosgey, I. S., Baker, R. L., Udod, J. A. M. & van Arendon, J. A. M. (2006). Successes and failures of small ruminant breeding programmes in the tropics: a review. *Small Ruminant Research*, 61, 13–29.

Lalit., Malik, Z. S., Dalal, D. S., Dahiya, S. P., Patil, C. S. & Dahiya, R. (2016). Genetic analysis of growth traits in Harnali sheep. *Veterinary World*, 9(2), 128–132. Available at: www.veterinaryworld.org/Vol.9/February-2016/4.pdf

Matewos, T. & Tefera, T. (2019). Local level rainfall and temperature variability in drought-prone districts of rural sidama, central rift valley region of Ethiopia. *Physical Geography*, 41 (1), 36–53. doi:10.1080/02723646.2019.1625850

Mekuriaw, S. & Haile, A. (2014). Genetic parameter estimates for growth and reproductive trait of sheep for genetic improvement and designing breeding program in Ethiopia: A review. *Open Access Library Journal*, 1, e589. doi:10.4236/oalib.1100589

Melesse, A., Banerjee, S., Lakew, A., Mersha, F., Hailemariam, F., Tsegaye, S. & Makebo, T. (2013). morphological characterization of indigenous sheep in southern regional state, Ethiopia.

Memeru, M. (2015). *On-farm performance evaluation and community based traditional selection methods of Bonga sheep in Adiyo Kaka Woreda, Southern Ethiopia*. M.sc thesis, Hawasaa university, Hawassa, Ethiopia.

Meyer, K. (2007). WOMBAT: A tool for mixed model analyses in quantitative genetics by restricted maximum likelihood (REML). *Journal of Zhejiang University Science B*, 8(11), 815–821. doi:10.1631/jzus.2007.B0815

Mokhtari, M. & Rashidi, A. (2010). Genetic trends estimation for body weights of Kermani sheep at different ages using multivariate animal models. *Small Ruminant Research*, 88, 23–26. doi:10.1016/j.smallrumres.2009.11.003

Mostafa, L. F., Hedayatollah, R., Saeed, A., Kourosh, M. & Khalil, M. (2011). Genetic trends estimation for some of the growth traits in Arman sheep. *Journal of Animal and Veterinary Advances*, 10, 1801–1803.

Mueller, J., Rischkowsky, B., Haile, A., Philipsson, J., Mwai, O., Besbes, B., Valle-Zarate, A., Tibbo, M., Merkena, T., Duguma, G., Solkner, J. & Wurzinger, M. (2015). Community based and livestock breeding programs: essentials and examples. *Journalof Animal Breeding and Genetics*, *132*(2), 155–168. doi: 10.1111/jbg.12136. PMID: 25823840.

Singh, H., Pannu, U., Narula, H. K., Chopra, A., Naharwara, V. & Bhakar, S. K. (2016). Estimates of (co) variance components and genetic parameters of growth traits in Marwari sheep. *Journal of Applied Animal Research*, 44(1), 27–35. Available at: https://www.tandfonline.com/doi/pdf/10.1080/09712119.2014.987291

Talebi, E. (2019). *Heritability estimates for some growth traits and Kleiber ratios in Karakul sheep*. Islamic Azad University, Darab, Fars, Iran. Available at: https://en.engormix.com/sheep/articles/heritability-estimates-some-growth-t43169.htm

Thiruvenkadan, A. K., Karunanithi, K., Murugan, M., Arunachalam, K. & Narendra Babu, R. (2009). A comparative study on growth performance of crossbred and purebred Mecheri sheep raised under dry land farming conditions. *South African Journal of Animal Science*, 39(5), 121–125. Accessed 3 June 2021, Available at: http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0375-15892009000500029&lng=en&tlng=en

Willham, R. L. (1972). The role of maternal effects in animal breeding: iii. biometrical aspects of maternal effects in animals. *journal of Animal Science*, 35(6), 1288–1293. doi:10.2527/jas1972.3561288x

Worku, A., Alemu, T., Gudeto, A., Gurru, M., Messele, F. & Dadi, G. (2019). Growth performance evaluation of sheep breeds under farmers' management at Fentale District, Oromia Regional State, Ethiopia.

Yacob, Y. (2008). Environmental and genetic parameters of growth, reproductive and survival performance of Afar and blackhead Somali sheep at Werer Agricultural Research Centre, Ethiopia.

Zishiri, O. T., Cloete, S. W. P., Olivier, J. J. & Dzama, K. (2010). Genetic trends in South African terminal sire sheep breeds. *South African Journal of Animal Science*, *40*(5), 455–458. https://www.sasas.co.za/wp-content/uploads/2012/09/Zishiri40Issue5Congress_1.pdf

Paper II

Comparative and Participatory Identification of Breeding Objective and Selection Criteria of Small Holder Farmers in Southern Ethiopia (Ready for submission for publication in Tropical Animal Health and Production).

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Abstract

Own-flock ranking experiment and a structured questionnaire were under taken to assess sheep breeding practices to make comparison among member of community-based breeding program(MCBBP) and non-member of community-based program(NMCBBP) or traditional sheep breeders, breeding objective/selection criteria difference among communities in different sites to modify breeding objective. Three sheep breed/type namely Abera, Doyogena and Dauwro from Sidama, Sothern and South-West region of Ethiopia, were level of participation of farmers like MCBBP and NMCBBP, and the selected famers had, as much as possible, 3 or more breeding ewe within their own flock, each farmer identified three ewes representing the best, average and poorest rank. A survey and own flock ranking experiment involving 300 households and 360 head of sheep were used in the current study. In own flock ranking experiment, each farmer were asked to choose the first top two superior and the worst ewe with their own flock *and to provide their reason for ranking of the animals. Data on size and appearance, lamb growth, lamb survival and reproduction traits were recorded for each ewe.*

Qualitative and quantitative data were obtained and body weight (BW) and other linear measurements recorded from every farmer and animal. Significant ($p<0.05$) variation were observed on rank, breed and membership of community based breeding program (CBBP) on body weight and all studied traits including price of ewe. Farmers from MCBBP more focused on traits of related on body size and appearance, while NMCBBP farmers emphasized on reproduction and mothering ability and body condition as their breeding objective.

Keywords: *Selection, flock ranking, traits of interest, traditional sheep farmers, weighted reason, Dawuro.*

Introduction

Sustainability of successful sheep breeding plan or strategy broadly depends on the trait preference of small-scale farmers and the genetic passing ability of the preferred trait, which can be link with the existing biodiversity of the farming environment. Synthetic breed creation/breed substitution and cross breeding program with introduction of temperate breeds are not to be considered as successful due to lack of matching the genotype with the small holder farmers or pastoralist breeding objective and the production systems.while, participatory within breed selection program involving indigenous breeds more to be sustainable and successful and compatible compared with breed substitution and cross breeding (Kosgy, 2006; Haile et al., 2018). Mixed crop-livestock and pastoral systems is broadly known production system in developing region of Africa while not only traditional production system but also traditional marketing where common in the Ethiopia (Legesse et al., 2008). In the country, agricultural activities, where mostly used for survival and farmers keep small ruminants for trade and meat consumption in household level where gross income is determined by the size of the flock number raised by the owners rather than their production (Gemeda et al., 2007).

Purpose of sheep keeping or breeding objective of the smallholder farmers/ pastoralist in Ethiopia may show a discrepancy and mostly it is based on the sheep production system of the country. In most mixed –crop livestock production system, the primary objective for keeping sheep where for income generation, however milk production where the primary objective in agro-pastoral and pastoral production systems of eastern Ethiopia (Nigussie et al., 2013). Milk production from sheep was the primary objective of pastoralists in North-East Ethiopia around Afar (Getachew et al., 2009), while, production and consumption of milk from sheep is not common in mixed crop-livestock system where income generation is considered as the primary objective of keeping sheep (Edea et al., 2012).

Farmers keep large number of sheep along with other farming practice in most densely populated and high human pressured area of the country (Abegaz et al., 2020). Similarly, in Sothern region of Ethiopia sheep reared as primary choice of small-holder farmers with largest number of sheep possession along with other livestock. In southern part of the country, purpose of keeping sheep was depending on the sex of the sheep. The primary purpose of keeping male sheep in Sothern, Ethiopia around Dawuro zone and Konta special woreda where for saving (as an asset) and the primary purpose of keeping female sheep in part of the region where for breeding purpose (Alemayehu, 2011). In general, sheep are used to generate income that is used to purchase cloths, food items, breeding stock, oxen, fertilizer, household supplies and also to pay taxes(Chipman, 2003). furthermore, in Developing countries like Ethiopia, where subsistence agriculture is common, and farmers keep small ruminants for trade and meat consumption in household where gross income is determined by the size of the flock number raised by the owners (Gemeda et al., 2007).

As indicated above the backyard sheep production system lacks reliable definition of breeding objective while,community-based breeding programs(CBBPs) were not only positively influenced the genetic improvement of indigenous sheep's breeds in the county, but also assume to be influence the awareness of small-scale farmers to ward to meet with their traits of interest or selection criteria, so the aim of this study was to dig out the effect of CBBP in terms selecting important traits and to determine farmers' trait preferences among member of CBBPs and traditional sheep farmers along with phenotypically characterization of Abera, Doyogena and Dawuro sheep. Knowing the breeding objective for smallholder farmers in regard to adaptive traits is very important and it should be included in the aim of long term breeding plan of sheep producers since most traits are economically influence in economical gain of farmers.

The breeding objectives and the selection criteria of traits, on which the livestock keepers wish to improve and base of their selection, have to be understood. In this regard, the similarity and dissimilarity of breeding objectives and selection criteria among community members, as well as between neighboring communities, should be assessed. Uniform and consistent views of farmers facilitate the creation of a common understanding and working towards a clear formulation of common objectives.

Material and Methods

Study Area and Breeds

This study was carried out on the on-going Doyogena, Dawuro and Abera sheep CBBPs and surrounding communities in Sothern, South-West and Sidama regions of Ethiopia, respectively.

ICARDA and ILRI in partnership with the Southern Agricultural Research Institute (SARI), Areka Agricultural Research Centre (AARC) adopted CBBP in Doyogena district to improve Doyogena sheep in 2013 and AARC expands the CBBP program in Dawuro sheep since 2018, Hawassa Agricultural Research Center (HARC) also adopted the CBBP on Abera sheep type in six different villages since 2013. A total of six cooperatives, two from each of the Doyogena, Dawuro and Abera sheep CBBP were selected for this study. Non-participating communities having no connection with the CBBP were selected in each site as comparison.

Study Design and Data Collection

A total of 300 owners, 100 from each of the three sites were selected for the interview. In each of the sites, ranking data were collected from 40 flocks (120 ewes) were considered from both participant and non-participant. The collected data structure is demonstrated in Table 1.

Interview and Group Discussion

Farmers from both MCBBP and NMCBBP from 3 locations (Kembata, Dawuro and Sidama) were included in this study. Households were purposely selected with regard to the number of breeding ewe (the selected farmers had 3 and above breeding ewes at least) and active participant in sheep farming were interviewed using structured questionnaire. Three hundred owners of sheep (100 from Doyogena, 100 from Dawuro and 100 from Abera) were interviewed (Table 1)

Table 1 Sampling Structure

Site	Name of Cooperative	Number of Respondent	Number of Animals Sampled
Siddama	Abera Gelede (MCBBP)	60	60
	Abera Gelede (NMCBBP)	40	60
Kembata	HaworaArara(MCBBP)	60	60
	AnchaSedecho(NMCBBP)	40	60
Dauwro	Medehaniyalem(MCBBP)	60	60
	Medehaniyalem (NMCBBP)	40	60
Total		300	360

Note:-MCBBP:-Member of community based breeding program, NMCBBP:-Non-member of community based breeding program.

The structured questionnaire were focused on gather information from the selected households from each MCBBP and NMCBBP. Data on purpose of keeping sheep, ways of purchase and disposal from the farm, breeding practices and selection criteria used for breeding rams and ewes, rank of important traits, disease occurrence and lamb survival rate were investigated. Inclusive list of traits was provided to each owner of sheep and asked to confirm its importance and the direction to improve it. Each sheep owner also asked to rank its breeding ewes based on different breeding traits in ranks (best, average, and poor). The questionnaire were tested before the actual survey to ensure its clarity and accuracy.

Own animal scoring /ranking breeding ewe

Each farmer from MCBBP and NMCBBP asked to rank the first three superior breeding ewes (1^{st}, 2^{nd} and 3^{rd}) within their own flock. The farmers also asked to justify the reason for ranking the animals. Data on body weight (BW), body length (BL), chest girth (CG), height at withers (HW), height at rump (HR), age/dentition, coat color type and pattern, reproductive performance and mothering ability (date of last lambing, parity, lifetime twinning, life time number of lambs born, life time number of lamb weaned, origin of ewe and sire(on farm or external), body condition score (BC). BC score evaluated subjectively 1 to 5 as 1 very thin and 5 very fat.

Pre-weaning lamb survival (PWLS) was calculated for each ewe as proportion of lambs survived to weaning age to total number of lambs born in her lifetime. Twining rate (TR) also calculated for each breeding ewe as proportion number of lambs born to ewe parity. Economic value in terms of amount of money the owner is willing to pay (WTP) if the farmer were to buy the ewe for breeding purpose were recorded for each ewe.

Data Analysis

The R programming language for statistical computing and graphics (R core team 2013) were used in all data analysis. Function in cross table (cross table) in R using"gmodels" packages was used to create cross tabulations for qualitative data. Linear models were used to analyze the records for all traits. Regression in R package (Fox and Weisberg 2011) was used for the GLM (general liner model) analysis and the package lsmean was used for estimation of least square means (Lenth, 2013). Fixed linear model, including the main effects was finally used to elucidate the variation of the sheep traits recorded as follows:

$y_{ijl} = \mu + Rank_i + Breed_j + PL_l + e_{ijl}$

Where: -y_{ijl} is the trait of interest (body weight (kg), body length (cm), heart girth (cm), BCS (1-5), price (price if buying the ewe in ETB), μ is the overall mean for the traits$_j$, $Rank_i$ is the effect of the i^{th} rank of the ewe ($i=1^{st}$, 2^{nd} and 3^{rd}); $Breed_j$ is the effect of j^{th} breed/type group (j = Doyogena, Abera, Dawuro); Participation level $(PL)_l$ is the effect of l^{th} participation level of CBBP (l=MCBBP and NM-CBBP); and e_{ijl} is the random residual effect.

Ranking Reasons

Various reasons given by farmers during own flock ranking were summarized into three groups (body size and appearance, reproduction and mothering ability and body condition) based on their similarity. Body size and appearance included traits related to growth, live weight and lamb and ewe growth rate; reproduction and mothering ability includes reasons related to lambing interval, twining rate and lamb survival, and body condition includes reason related to body fat cover. To calculate the weighted reason (WRi) of each trait (i) to be used for weighting of traits for sheep breed/type and location /site, the following equation, corrected from Bett et al., (2009) were used to calculate the weighted reason (WR_i).

$$WR_i = \sum_{j=1}^{3} r_j X_{ji} / \left(\sum_{i} \sum_{j=1}^{3} r_j X_{ji} \right)$$

Where $\mathbf{X_{ji}}$ is the number of respondents giving reason with order j, j=1,2,3 to traits i, where i=body size and growth, body condition, reproduction and mothering ability, r_j is the weight analogous to reason j. The weight is given by $r_1=3$, $r_2=2$ and $r_3=1$.

Results

Breeding and Production Practices

Source of breeding ewes

Breeding ewes from NMCBBP in all locations were result of natural selection and ingenious knowledge of sheep breeding while; breeding animals from MCBBP were the results of both natural selection and participatory selection of breeding animals. Born in the flock, born in the flock and purchase and purchase breeding ewes were found to be the sources of breeding sheep flock in all locations. Breeding sheep born in the flock were found to be the highest proportion of breeding ewe in both MCBBP (90%) and NMCBBPs (72%). Secondly, the flock of most farmers composed of both breeding ewe from born in the flock and purchased (8.3% in MCBBP) and (15% in NMCBBP) but farmers who keep only purchased breeding ewe were very small proportion (1.7% in MCBBP) and (12.5% in NMCBBP). Practicing participatory breeding program had significant difference on source of breeding ewes ($p<0.05$) while, there was no association ($p>0.05$) between location and source of breeding ewe (Table 2).

Table 2 Frequency of major reasons for the source of breeding ewes in different locations and between Member and non-member of community based sheep breeding.

Participation level (Chi square *P* value = 0.007**)**	**Reason**	**Locations (Chi square *P* value** = 0.71**)**			
		Abera	**Doyo gena**	**Dawuro**	**Overall**
MCBBP	Born in the flock	18(90.0)	20(100.0)	16(80.0)	54(90.0)
	Born in the flock and purchased	2(10.0)	0(0)	3(15.0)	5(8.3)
	Purchased	0(0)	0(0)	1(5.0)	1(1.7)
NM-CBBP	Born in the flock	14(70.0)	15(75.0)	14(70.0)	29(72.5)
	Born in the flock and purchased	4(20.0)	2(10.0)	5(25.0)	6(15.0)
	Purchased	2(10.0)	3(15.0)	1(5.0)	5(12.5)

Numbers in parenthesis are percentage for reasons within location: MCBBP = Member of Community based breeding program and NM-CBBP = Non-member of community based breeding program

Breeding ram availability in the flock

There was significant association (p<0.001) between study site and participation level with breeding ram possession. All respondent (100%) from MCBBP in all locations reported that they had breeding ram in the flock while, respondent (45.8%) from NMCBBP reported that they had no breeding ram in the flock and only 4.177 % sheep owners respondents reported that they had at least one breeding ram in the flock. In all site in MCBBP, the most available breeding rams were born in the flock and appeared as the result of participatory selection while breeding rams in NMCBBP resulted from section by farmers based on indigenous knowledge for preference traits (Table 3). The most available breeding rams were born in the flock and appeared as the result of participatory selection while breeding rams in NMCBBP resulted from selection by farmers based on indigenous breeding knowledge.

Table 3 Frequency of breeding ram availability in different locations.

Location/Participation level	Yes	No	Chi square	*P*-Value
Overall	**65(54.17)**	**55(45.83)**	**26.42**	**7.395E-05**
Sidama				
MCBBP	20(100.0)	0(0)		

NMCBBP	2(10.0)	18(90.0)
Kembata		
MCBBP	20(100)	0(0)
NMCBBP	0(0)	20(100.0)
Dawuro		
MCBBP	20(100)	0(0)
NMCBBP	3(15.0)	17(85.0)

Numbers in parentheses are percentage values, MCBBP= Member of Community Based Breeding Program, NMCBBP= Non-Member of Community Based Breeding Program.

Selection Criteria and Breeding Knowledge

Body Size and appearance of the animal, reproduction traits and mothering ability (lambing interval and prolificacy), body condition and morphological characters (mainly coat color and horn) were the main mentioned traits by farmers to select breeding ewes in the flock. Big size with good body condition, tall body frame, coat colors like red and brown (solid or light) and grey were the main criteria to select breeding ewes but, they were mentioned that there were null interest for black coat color in all sites.

Sheep Flock Size and Composition

The mean composition of breeding ram, breeding ewe, ram lamb and ewe lamb were presents in Table 4. The overall mean flock size in the given sites was 6.28 heads, while, the three sites mean flock size were not significantly different ($p<0.05$). The average number of breeding ram were more available in MCBBPs than NMCBBP. Mean of total flock size of sheep in Sidama (Abera), Kembata (Doyogena) and Dawuro were 13.3 heads, 12.3 heads and 11.8 heads, respectively both in MCBBP and NMCBBP. Kembata had larger sheep flock size than Dawuro while, Sidama had larger flock size than both Kembata and Dawuro.

Table 4. Effect of location and participation level of CBBP on sheep flock size and composition

Sheep category	Membership	Sites							
		Sidama (N=100)		Kembata (N=100)		Dawuro (N=100)		Overall (N=300)	
		Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
Breeding Ram	MCBBP	0.70	0.66	0.50	0.60	0.10	0.30	0.31	0.43
Breeding Ewe	MCBBP	3.45	0.76	4.25	1.99	3.70	1.41	3.47	1.02
Ram Lamb	MCBBP	1.95	1.34	0.90	0.70	1.10	1.48	1.08	0.94
Ewe Lamb	MCBBP	1.65	1.04	1.20	0.89	1.30	1.30	1.41	1.00
TFS	MCBBP	7.75	2.59	6.85	1.95	6.20	3.19	6.28	1.98
Breeding Ram	NMCBBP	0.35	0.49	0.20	0.52	0.00	0.00		
Breeding Ewe	NMCBBP	3.40	0.75	2.85	0.49	3.15	0.75		
Ram Lamb	NMCBBP	1.05	0.51	1.10	1.02	0.40	0.60		
Ewe Lamb	NMCBBP	1.00	0.85	1.35	0.88	1.95	1.08		
TFS	NMCBBP	5.80	1.23	5.50	1.60	5.6	1.31		

N = number of respondents, Std. = standard deviation, Ewe and ram lambs represent those with age group between six months and one year while lambs are both male and female groups with age below six months. MCBBP= Member of Community Based Breeding Program and NMCBBP= Non-Member of Community Based Breeding Program, TFS= Total flock size.

Descriptive Statistics

The records in the current study on dentations showed that farmers selected ewes ranging from 1 to 8 years and within an average of 3.2 years of age. Ewes classified by farmers as best had higher mean values for the traits body weight, body length, chest girth, height at wither, body condition score and price than the animals classified as poor quality and the ewes chosen as being average quality in general had the mean values that were in between the best and the poor groups in both MCBBPs and NMCBBPs (Table 5). Dawuro had higher body weight mean value than Abera and Doyogena sheep in both MCBBPs and NMCBBPs.

Effects of Site/ Breed and Membership of CBBP

There were significant effect of rank (best, average and poor), breed/site (Abera, Doyogena, and Dawuro) and participation level, on body weight and all studied traits except height at wither and body condition score in regard to participation level of comunty-based breeding program (Table 6). The rank of breeding ewe based on farmers choice were significant ($p<0.05$) effect on the studded traits and the price of breeding ewes. Farmers' choices of ewes best, average and poor were confirmed by the objective measurements (Table 7). Ewes chosen as best were on average 2.63 g heavier than the average ewes and 5.43 kg heavier than the poor quality ewes significant difference were observed between the best, average and poor ewes. The best ewes were scores the highest BCS then the averages and the poor ewes. Farmers expresses willingness to pay almost double as much for ewes classified as being best compared to the poor quality ewes and up to 17% more for best ewes than for an average ewes. Dawuro ewes were heaver than Abera and Doyogena ewes by 1.4 kg and 2.67 kg, respectively while, Abera and Doyo gena ewes had no significant difference in their body weight. BCS were slightly higher in Abera and Dawuro than Doyo gena ewes.

The price the farmers were willing to pay for the breeding ewe were different across all sites ($p<0.05$). The largest price were recorded for Dawuro ewes (2357 ETB). Dawuro ewes were on average valued at 825.2 ETB and 1082.4 ETB more compared to Abera and Doyo gena ewes, respectively while, Abera ewes were cost more around 257.2 ETB than Doyo gena ewes.

Being member of participatory sheep breed improvement program had significant effect on all studded traits and price except BCS (Table 7). Animals from MCBBP had hiver body weight by 1.92kg than NMCBBPs, also there were significant difference ($P<0.05$) in body length, chest girth and height at wither between animals from MCBBPs and NMCBBPs. Ewes from MCBBP were on average more valued by 159.4 ETB than NMCBBP.

Weighted Reason for Farmers Choices of Breeding Ewes

Farmers from both MCBBPs and NMCBBPs, for best ewes across all sites, the weighted reasons for choice of these animals in the own flock are presented in Figure 1. Both in MCBBP and NMCBBP, body size and appearance of ewes were considered as the most important traits in Abera and Dawuro farmers while, reproduction and mothering ability were weighted more in Doyogena sheep farmers. Weighted reasons for farmers classifying ewes as poor quality ewes in MCBBPs and NMCBBPs across sites are shown in Figure. 2.

In MCBBP, in Abera and Doyogena sheep, reproduction, and mothering ability and in Dawuro sheep, body condition was most often mentioned as the reason for a breeding ewe being selected as poor quality. Similar with MCBBP farmers from NMCBBP also pointed out the trait reproduction and mothering ability and body condition to select ewes as poor quality in Abera and Dawuro sheep but in Doyogena sheep both body size and appearance and reproduction and mothering ability was most often cited as criteria for a ewe being selected as poor quality.

Weight reason by breed and membership of CBBP

Trait preference for each trait group by breed within MCBBP and NMCBBP for best ewes are presented in Table 6. In MCBBP, the best ewes, across breeds (Abera, Doyogena and Dawuro) were most preferred for traits related to body size and appearance and reproduction and mothering ability. While, in NMCBBP, best ewes were pointed out as best ewes because of the traits related to reproduction and mothering ability. Weighted reason in Abera, Doyogena and Dawuro sheep were 0.53 and 017, 0.08 and 0.13 and 0.23 and 0.13, respectively for MCBBP and NMCBBP for body size and appearance traits. Weighted reason in Abera, Doyogena and Dawuro sheep were 0.42 and 0.73, 0.78 and 0.75 and 0.55 and 0.78, respectively for MCBBP and NMCBBP for reproduction and mothering ability traits. Body condition was the last important trait in all breeds in MCBBP and NMCBBP.

Table **5** Overall Mean ($\bar{X}$), standard deviation (s.d.), minimum (Min) and maximum (Max) values for Body Weight (BW), Body Length(BL), Chest Girth (CG), Height at Wither (HW) ,BCS (Body Condition Score), and Price, for the three breed groups Abera, Doyogena and Dawuro sheep from MCBBP and NMCBBP.

			MCBBP				**NMCBBP**			
Trait	**Breed**	**Rank**	$\bar{X}$	**s.d.**	**Min**	**Max**	$\bar{X}$	**s.d.**	**Min**	**Max**
BW(kg)	Abera	Best	31.5	3.7	26	39	29.9	4.2	22	36
		Average	29.5	3.07	25	38	27.5	3.6	21	34
		Poor	26.6	2.45	24	39	24.2	1.9	21	28
BL(cm)	Abera	Best	68.2	5.11	60	79	66	3.37	60	76
		Average	66.4	4.08	60	74	65	3.9	58	76
		Poor	64.4	3.84	58	70	63	3.3	60	72
CG(cm)	Abera	Best	75.8	6.16	64	87	74.6	8.4	55	87
		Average	74.25	6.15	60	85	73.1	7.9	55	82
		Poor	71.1	5.73	61	80	71.1	6.9	56	81
HW(cm)	Abera	Best	62.05	4.08	56	70	59.2	2.8	55	64
		Average	61.65	3.9	56	69	60.2	2.6	55	67
		Poor	60.05	3.23	52	65	59.2	3.49	55	67
BCS(1-5)	Abera	Best	3.67	0.49	3	4.5	3.5	0.49	3	4
		Average	3	0.43	2.5	4	3.0	0.38	3	4

		Poor	2.5	0.32	2	3	2.6	0.38	3	3
Price(ETB)	Abera	Best	1740	264.6	1300	2200	1757.5	284.4	1200	2200
		Average	1500	235.65	1200	2000	1552.5	264.3	1100	2000
		Poor	1302.5	173.56	1100	1600	1342.5	219.6	900	1800
BW(kg)	Doyogena	Best	31.28	3.86	23	37	29.7	4.4	19	36
		Average	29.61	3.43	25	36	24.6	3.3	19	30
		Poor	26.96	3.59	20	31	19.95	2.3	17	25
BL(cm)	Doyogena	Best	73.67	5.66	61	81	71.6	6.9	60	84
		Average	73.5	12.48	26	81	67.35	7.22	50	80
		Poor	72.93	14.61	26	81	58.3	12.1	50	71
CG(cm)	Doyogena	Best	77.94	5.43	67	90	65.4	8.3	50	82
		Average	75.22	5.84	67	93	63	5.8	53	75
		Poor	70.64	5.69	62	80	55.5	5.6	45	66
HW(cm)	Doyogena	Best	65.33	3.12	60	70	64.7	6.9	54	76
		Average	64.5	3.13	60	72	63	6.5	50	73
		Poor	62.5	3.39	57	68	58.5	6.34	50	71
BCS(1-5)	Doyogena	Best	3.3	0.64	2	4	2.8	0.57	2	4
		Average	3.25	0.6	3	4	2.3	0.49	2	3
		Poor	2.75	0.64	3	4	1.7	0.34	2	3
Price(ETB)	Doyogena	Best	1777.7	434.61	1100	3000	1340	289.1	900	2000
		Average	1566.6	398.52	1000	2800	1308	191.7	700	1500
		Poor	1271.4	205.42	800	1600	778.5	195.0	600	1500
BW(kg)	Dawuro	Best	32.65	6.03	24	47	31.1	3.94	25	37
		Average	29.3	6.14	21	46	30	3.16	25	35
		Poor	27.4	4.51	19	37	29.3	3.14	22	36
BL(cm)	Dawuro	Best	66.05	4.62	58	74	64.7	4.39	58	72
		Average	62.9	4.63	56	72	66.7	5.82	56	76
		Poor	62.5	4.52	55	70	64.9	4.3	58	72
CG(cm)	Dawuro	Best	80.25	5.27	71	94	80.5	3.51	74	86
		Average	77.35	5.77	70	92	76.3	6.2	61	83
		Poor	75.65	5.86	63	84	78.1	4.4	70	87
HW(cm)	Dawuro	Best	67.2	4.88	58	76	64.5	3.5	58	71
		Average	63.3	4.36	56	74	63.7	3.5	58	69

		Poor	63	3.77	54	70	64.3	4.1	58	71
BCS(1-5)	Dawuro	Best	3.75	0.63	3	5	3.6	0.5	3	4
		Average	2.85	0.58	2	4	3.2	0.8	2	4
		Poor	1.95	0.68	1	3	2.9	0.75	2	4
Price(ETB)	Dawuro	Best	2760	838.8	1500	4500	2785	944.38	1500	4500
		Average	2281	649.7	1400	4200	2195	647.64	1400	3500
		Poor	2105	511.4	1500	3800	2020	599.6	1000	3000

ETB=Ethiopian Birr; 1USD=41.013 ETB; MCBBP=Member of Community Based Sheep Breeding Program ; NMCBBP= Non- Member of Community Based Sheep Breed Program.

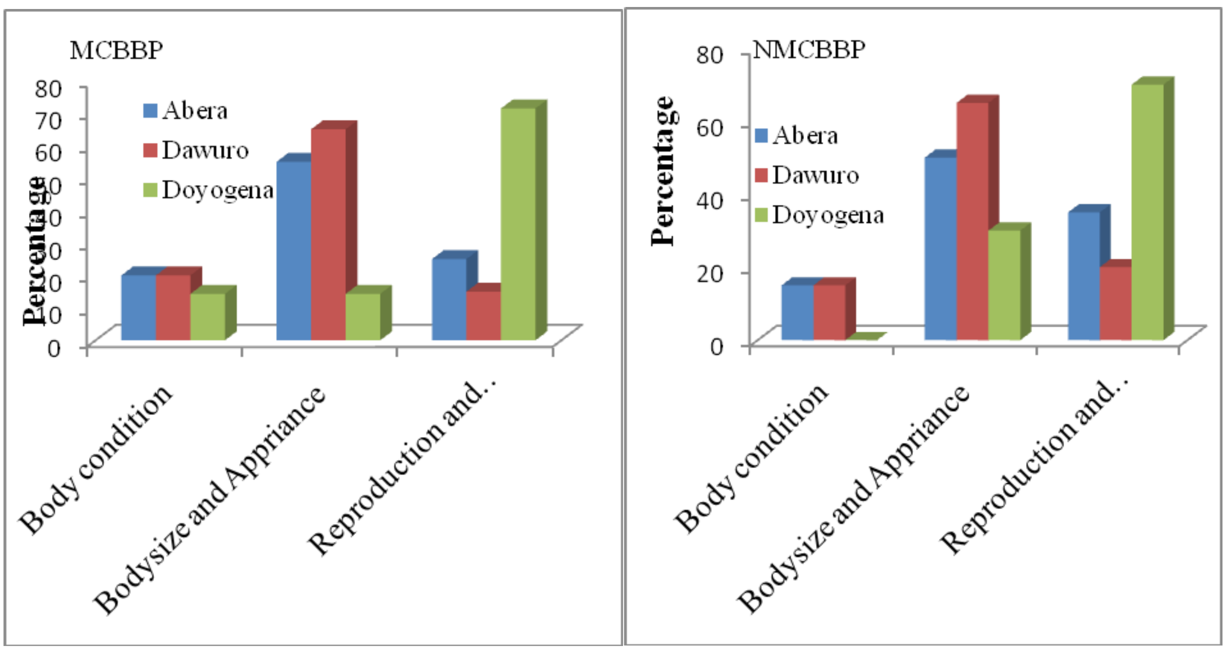

Figure 1. Weighted reasons for farmers from MCBBP classifying ewes as Best quality across sites and members and non-members of community based breeding: relative importance of trait preferences for each breed group in percent

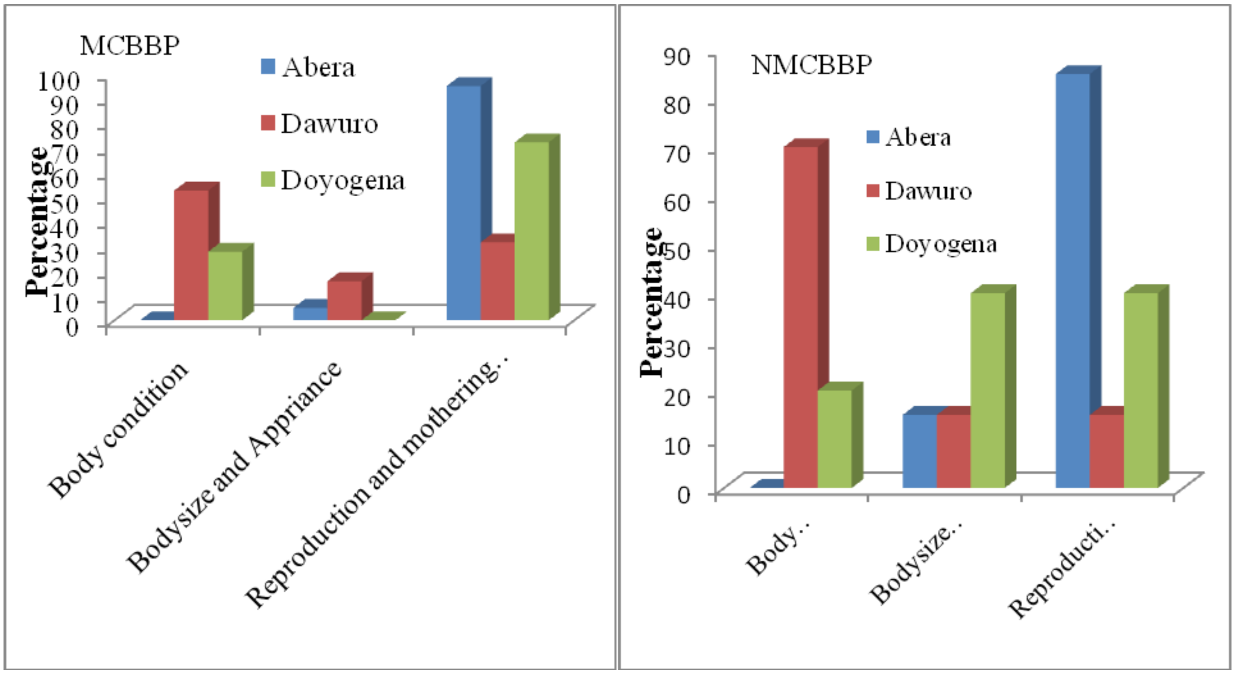

Figure 2. Weighted reasons for farmers classifying ewes as Poor quality across sites and members and non-members of community based breeding: relative importance of trait groups identified as inferior for each breed group in percent.

Table 6. Level of significance for effects of various factors in the model for the traits Body Weight, Body Length, Chest Girth, Height at Wither, BSC and Price

Factors	BW	BL	CG	HW	BSC	Price
MCBBP/NMCBBP	p<0.001	P=0.012	p<0.001	P=0.075	P=0.064	P=0.011
Breed	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
Rank	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001

BW = Body Weight, BL = Body Length, CG = Chest Girth, HW= Height at Wither, BCS = Body Condition Score, MCBBP = member of community based breeding program, NMCBBP = non-member comunity based breeding program.

Table 7. Ranking of breeding objective traits for breeding ewe as farmers preferences in different locations among member and non-member of community based sheep breeding programs

Breed and Trait group	MCBBP Reasons[a] 1	2	3	Sum	WRs[b]	NCBBP Reasons[a] 1	2	3	Sum	WRs[b]
Abera										
Body size and Appearance	15	17	0	32	0.53(1)	4	3	3	10	0.17(2)
Reproduction and mothering ability	5	1	19	25	0.42(2)	15	16	13	44	0.73(1)
Body condition	0	2	1	3	0.05(3)	1	1	4	6	0.1(3)
Doyogena										
Body size and Appearance	1	4	0	5	0.08(3)	6	2	0	8	0.13(2)
Reproduction and mothering ability	20	14	13	47	0.78(1)	14	16	15	45	0.75(1)
Body condition	0	3	5	8	0.13(2)	0	2	5	7	0.12(3)
Dawuro										
Body size and Appearance	4	6	4	14	0.23(2)	8	0	0	8	0.13(2)
Reproduction and mothering ability	15	12	6	33	0.55(1)	12	20	15	47	0.78(1)
Body condition	1	2	10	13	0.22(3)	0	0	5	5	0.08(3)

[a] Reasons 1–3, where the most important reason was weighted by 3, etc. [b] Weighted reasons as proportion of the total sum of reasons by breed and membership of community based sheep breeding:- MCBBP =member community based breeding program and NMCBBP=non-member of community based breeding program, WRs= Weighted reasons.

Table 8. Relative importance (accumulated weighted) reason for trait categories as assessed by farmers for best ewes by breed and membership of community based breeding program

Trait	MCBBP Abera	Doyogena	Dawuro	NMCBBP Abera	Doyogena	Dawuro
Body size and Appearance	0.53	0.08	0.23	0.17	0.13	0.13

Reproduction and mothering ability	0.42	0.78	0.55	0.73	0.75	0.78
Body condition	0.05	0.43	0.22	0.10	0.12	0.08

MCBBP =Member Community Based Breeding Program and NMCBBP=Non-member of Community Based Breeding Program.

Discussion

Breeding and production practices

Even if the available sheep flocks in all sites are results of long lasting natural selection, practicing participatory breeding program had significant difference on source of breeding ewes as famers maintain breeding animals for long breeding season than NMCBBP. Similar findings were stated by Abebe et al., (2020) sheep in the northwest highlands of Ethiopia and Dawuro and Konta sheep of southern region of Ethiopia (Alemayehu et at., 2015) also confirmed that born in the flock and purchased sheep were the main source of their flock.

Genetically improved animals are very important to transform traditional and subsistent production system in to economically attractive and market-oriented enterprise (Gizaw et al., 2010). While, as indicated in the in current result, sheep production challenge were more related to the lack of improved breeding ram in the flock, it is more common in NMCBBP than MCBBP.

As indicted by different scholars, the main sheep production objective is income generation (Alemayehu et al., 2015; Dossa et al., 2015; Haile et al., 2015; Abebe et al., 2020). Similarly in this study, early put on the market of male sheep as immediate income source resulted from lack of awareness is the critical problem and leads shortage of mating rams in NMCBBP while, MCBBP were maintain their breeding ram until selection and the selected breeding rams serve in the community until two years. Shortage of breeding ram in the sheep flock also reported in different production system of the country. For instance:- majority of respondents confirmed that the absence of breeding ram in the flock in mixed-crop production system (72%) and in Agro-pastoral sheep production system(58%) in central and eastern part of Ethiopia (Gebregziahear et al., 2019), also having only one breeding ram (48.3% in Tocha and 60% in Marka) in Dawuro zone and having no breeding ram(63.3%) in Konta special worda in mixed crop production system of Southern Ethiopia also reported (Alemayehu, 2011).

Selection criteria and breeding knowledge

Breeding sheep selection criteria mentioned by farmers from both MCBBP and NMCBBP in this study in general agreement with other studies in small holder farmers in different sheep farming areas (Arandas et al., 2017; Alemayehu, 2011; Melak et al., 2021) while, this study is not in line with the report of Haile et al., (2015) who reported that in Tahtay Maychew (Basonawera) district farmers do not include body size and appearance as primary criterion for selecting breeding ewes. Rather, they selected twining ability as first ranked and farmers from Inhamunsregion, Ceará, Brazil, selected and give priority for adaptation and disease resistance traits than size and appearance traits (de Aguiar et al., 2020). Lack of farmers preference for black coat color sheep might be associated with belief (taboo), low market demand and socio-cultural practices. Similar with the current result, culling or rejection to select sheep because of black coat color also reported by different scholars (Alemayehu, 2011; Edea et al., 2012; Nigussie et al., 2013; Tiesnamurti et al., 2021; Hamadou et al., 2019).

Sheep fock size and composition

Total mean of flock size in all sites, in current result (6.28) were similar with the report of Nigussie et al., (2015) as average sheep flock size were around 6.42 in mixed-crop livestock production system in Eastern, Ethiopia while, lower than the report of Amare et al., (2018) for Wollo high land sheep (22.6) and report of Sub-alpine sheep (20.1) as indicated by Gizaw, (2008). The present study reveal that the average flock size per smallholder famers from both MCBBP and NMCBBP is generally small. As indicated by different scholars, average sheep flock size per household is small and varied across production systems in the country. For example, Alemayehu et al., (2015) reported that 11.35 in Tocha, 9.72 in Mareka and 10.75 in Konta in mixed-crop production stem of Sothern region; Edea et al., 2012 also reported sheep flock size of 8.20 to 11.3 in Horro and Adiyo kaka districts of crop livestock mixed production system while Nigussie et al., 2015 reported higher average sheep flock size (97 in pastoral and 72 in agro-pastoral sheep production). Getachew, (2008) also reported an average flock size of 31.45 in Menz mixed crop-livestock production and 23 in Afar pastoral production system.

Descriptive statistics

Being superior in morphometric traits in sheep, worth higher value in sheep farmers to categorize them as best breeding animals. Similar with current result, ewes classified, as best had higher mean value for the studied traits in indigenous sheep in the northwest highlands of Ethiopia (Abebe et al., 2020) and Red Maasai and Dorper sheep in Kenya (Zonabend et al., 2016).Variable body weight and different attributes in different rank groups of ewes from different experiment also reported in different (Afar, Bonga, Horro and Menz) sheep breed of Ethiopia (Mirkena, 2010; Duguma et al., 2011) and indigenous sheep in the northwest highlands of Ethiopia (Abebe et al., 2020).

Similar with the current result, participatory sheep breed improvement programs revealed that there were significant body weight traits improvement and registered better performance of sheep in many part of the county and elsewhere (Getachew et al., 2010; Gutu et al., 2015; Muller et al., 2019; Areb et al., 2020; Habtegiorgis et al., 2020; Haile et al., 2020; Kassie et al., 2021) and in west African Djallonké sheep breed (Yapi-Gnaoré et al., 2001) and in Inhamuns region, Ceará, Brazil,(de Aguiar et al., 2020; Wurzinger et al) and sheep from Morada Nova (Arandas et al., 2017).

Weighted reason for farmers choices of breeding ewes

Similar with the current result, body size and appearance were reported as the first criteria of farmers to select in breeding ewes (Mirkena, 2010; Alemayehu, 2011; Nigussie et al., 2013; Koning et al., 2016; Abegz et al., 2020). Doyogena sheep were known with its prolificacy (Jimma, 2021 and Habtegiorgis, 2019) this key trait for sheep production may resulted the of farmers section on the trait for reproduction and mothering ability (Figure 1) but different with the current result farmers around Doyogena select breeding ewes based on their body size and appearance (Taye et al., 2016).

Similar with the current result, in red Maasi ewe, small body size and slow growth and poor body condition and in Dorper sheep poor reproduction and mothering ability were often cited as a reason for the ewe being classified as a poor quality (König et al., 2016).

Weight reason by breed and membership of community based breeding

Similar with the current result, body size and growth traits also reported as first criteria to select breeding ewes as best in different breeds (Farta, Lay Gayint and Sekela sheep) in western Amhara region of Ethiopia (Adimasu et al., 2019) and in indigenous sheep in the northwest highlands of Ethiopia (Abebe et al., 2020). Unlike with the current result, comparative analysis of preference rankings of individual traits of female sheep used as selection criteria across the three West African cities of Kano (Nigeria), Bobo Dioulasso (Burkina Faso) and Sikasso (Mali) indicates good apparent health status of ewes were used to select ewes as best and the big body size come in second place (Dossa et al., 2015).but, sheep in Red Maasai from Amboseli site farmers assed body size and growth and reproduction and mothering ability traits as criteria to select breeding ewes as "best" (Koning et al., 2016).

Conclusion

Results confirmed that participatory approaches including questionnaire, group discussion and flock ranking seem useful tool in understanding the production situation and identifying key traits of interest among MCBBPs and NMCBBPs. Significant ($p<0.05$) variation were observed on rank, breed and participation level of community based breeding program on body weight and all studied traits including price of ewe except height at wither and body condition score in regard to participation level. Growth traits like those that body size and appearance were more picked by MCBBP while, traits of reproduction and mothering ability were more focused by NMCBBP. Size and appearance traits and mothering ability (lamb growth and survival), in varied level were identified as major traits to be improved in all sites and MCBBP and NMCBBP. Breeding ram were scares in NMCBBPs while MCBBPs were significantly loaded in breeding ram in the flock. Breeding animals form CBBPs had more price in the market than unimproved from NMCBBP.

Recommendation

Up-scaling CBBPs to every neighboring distract and dissemination of improved breeding ram in organizing different mating groups and arrange ram sharing system would help to increase ram accessibility as well as help in speed up genetic progress by allowing use of few top ranked rams from CBBPs. Training of the traditional sheep framers about maintaining breeding ram until recommended breeding years(at list for two breeding years),reforming selection criteria breeding objective which are practical in genetic improvement, mating system, ram sharing and controlling the effect of inbreeding is recommended.

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Conflict of interest

The authors declare that they have no conflicting interests

References

Abebe, AS., Alemayehu, K., Johansson., AM., Gizaw, S., 2020. Breeding practices and trait preferences of smallholder farmers for indigenous sheep in the northwest highlands of Ethiopia:

Inputs to design a breeding program. PLoS ONE 15(5): e0233040. https://doi.org/10.1371/journal. pone.0233040.

Abegaz, S., Alayu, K., Tsehay, S., Kolech, T., Abitew, Y., Abebe, B., 2020. Participatory identification of breeding objective traits and optimizing community based breeding program for simien sheep in the highlands of North Gondar.

Adimasu, E., Almayehu, K., Getachew.,T., 2019.Breedingobjective, breedingpractices and selectioncriteria of indigenoussheep in western amhara, Ethiopia. international journal of sustainableagriculturalresearch, conscientia beam, volume. 6(4), pages 172-182.

Alemayehu, A., 2011. Phenotypic characterization of indigenous sheep types of Dawuro zone and Konta special woreda of SNNPR, Ethiopia. An M Sc Thesis presented to the School of Graduate Studies of Haramaya University, Dire Dawa, Ethiopia.

Alemayehu, A., Mekasha, Y., Abegaz, S and Jimma, A., 2015. Description of sheep production system, husbandry practices and assessment of major constraint in Dawuro Zone and Konta Special Wereda of South Region of Ethiopia. Global Journals Inc (USA). file:///C:/Users/user/Downloads/1619-1-1600-1-10-20151006%20(1).pdf.

Amare, T., Goshu, G., Tamir, B., 2018. Flock composition, breeding strategies and farmers' traits of interest evaluation of Wollo highland sheep and their F_1 crosses. Journal Animal Science Technology 60,14. https://janimscitechnol.biomedcentral.com/track/pdf/10.1186/s40781-018-0173-9.pdf.

Arandas, JKG., Alves, ÂGC., Facó O., Belchior, EB., Shiotsuki, L., de Arruda Leite, PMB., Ribeiro, MN.,2017. Do traditional sheep breeders perform conscious selection? An example from a participatory breeding program of Morada Nova sheep. Tropical Animal Health Preproduction. doi: 10.1007/s11250-017-1350-4. Epub 2017 Jul 30. PMID: 28756554.

Assan, N., Makuza, S., Mhlanga, F. and Mabuku, O., 2002. Genetic evaluation and selection response of birth weight and weaning weight in indigenous Sabi sheep. Asian-Australasian journal of animal sciences. Volume: 15(12),Pages:1690-1694.

Chipman, J., 2003. Observations on the potential of Dangila sheep for improved food security around Quairit and Adet, West Gojjam, Northwestern Ethiopia. A field study. Hosted by International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia.

De Aguiar, A.L., da Silva, R.R., Alves, S.M., 2020. Breeding objectives and selection criteria of a participatory community-based breeding programme of goats and sheep. Tropical Animal Health Production **52,** 1933–1943. Available at https://doi.org/10.1007/s11250-020-02209-6.

Dossa, L.H., Sangaré, M., Buerkert., 2015. Production objectives and breeding practices of urban goat and sheep keepers in West Africa: regional analysis and implications for the development of supportive breeding programs. SpringerPlus**4,** 28. Available at:-https://springerplus.springeropen.com/track/pdf/10.1186/s40064-015-1075-7.pdf.

Duguma, G., Mirkena, T., Haile, A., Okeyo, AM., Tibbo, M., Rischkowsky, B., Sölkner, J., Wurzinger, M., 2011. Identification of smallholder farmers and pastoralists' preferences for sheep breeding traits: choice model approach. Animal. 1984-92. doi: 10.1017/S1751731111001029. PMID: 22440475.

Duguma, G., Tadesse,T., Kumsa,T., Abegaz,S., 2007. Evaluation of the impact of plane of nutrition on growth and carcass traits of Horro lambs castrated at different ages. pp. 13-22. Proceeding of the 15th Annual Conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, October 4-6, 2007.

Edea, Z., Haile, A., Tibbo, M., Sharma, AK., Sölkner, J., Wurzinger, M., 2012. Sheep production systems and breeding practices of smallholders in Western and South-Western Ethiopia: Implications for designing community-based breeding strategies. Livestock Research for Rural Development. Volume 24, Article #117.http://www.lrrd.org/lrrd24/7/edea24117.htm.

Gebregziabhear, E., Urge, M., Animut, G., Ketema, M., 2019. Characterization of sheep production practices in mixed crop livestock and agro-pastoral systems of Central and Eastern Ethiopia. East African Journal of Veterinary and Animal Sciences. https://haramayajournals.org/index.php/EAJVAS/article/view/914/450.

Getachew, T., 2008. Characterization of Menz and Afar indigenous sheep breeds of smallholders and pastoralists for designing community-based breeding strategies in Ethiopia. MSc thesis in Agriculture (Animal Genetics And Breeding). Haramaya, Ethiopia: Haramaya University.

Getachew, T., Haile, A., Tibbo, M., Sharma, A.K., Kifle, A., Terefe, E., Wurzinger, M., Sölkner, J., 2009. Morphological characters and body weight of Menz and Afar sheep within their production system. Ethiopian Journal of Animal Production 9(1): 99–115.

Getachew, T., Haile, A., Tibbo, M., Sharma, A.K., Sölkner, J., Wurzinger, M., 2010. Herd Management and Breeding Practices of Sheep Owners in a Mixed Crop-Livestock and a Pastoral System of Ethiopia. African Journal of Agricultural Research, 5, 685-691.

Gizaw, S., Komen, H., van Arendonk, J.A.M., 2010. Participatory definition of breeding objectives and selection indexes for sheep breeding in traditional systems, Livestock Science, Volume 128, Issues 1–3, Pages 67-74, ISSN 1871-1413, https://doi.org/10.1016/j.livsci.2009.10.016.

Gizaw, S., Tegegne, A., Gebremedhin, B., Hoekstra, D., 2010. Sheep and goat production and marketing systems in Ethiopia: Characteristics and strategies for improvement. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 23. ILRI (International Livestock Research Institute), Nairobi, Kenya. 58 pp.

Gutu, Z., Haile, A., Rischkowsky, B., Mulema, A., Kinati, W., Kassie, G., 2015. Evaluation of community-based sheep breeding programs in Ethiopia. Addis Ababa: ICARDA.

Habtegiorgis, K., Haile, A., Ahmed, M., Getachew, T., 2020. Estimates of Genetic Parameters and Genetic Trends for Growth Traits of Doyogena Sheep in Southern Ethiopia. http://www.jabg.org/article/?num=JABG_20-002.

Köhler-Rollefson, I., 2000. Management of Animal Genetic Diversity at Community Level. GTZ, Eschborn, Germany. http://hdl.handle.net/10568/3679.

Haile, A., Getachew, T., Merkena, T., Duguma, G., Gizaw, S.,Wurzinger, M., Soelkner, J., Mwai, O., Desse, T., Abebe, A., Abate, Z., Jemebere, T.,Rekik, M., Lobo,R., Mwacharo, J., Terfa, Z., Kassie, G., Mueller, G.,Rischkowsky, B., 2020. Community-based sheep breeding programs generated substantial genetic gains and socioeconomic benefits. Animal, Volume 14, Issue 7, Pages 1362-1370, ISSN 1751-7311. https://doi.org/10.1017/S1751731120000269.

Haile, D., Gizaw, S., Kebede, K., 2015. Selection criteria and breeding practice of sheep in mixed crop livestock farming system of North Shoa, Ethiopia, Journal of Biology, Agriculture, and Healthcare. https://core.ac.uk/download/pdf/234661801.pdf.

Hamadou, I., Moula, N., Siddo, S., Issa, M., Marichatou, H., Leroy, P., Antoine-Moussiaux N., 2019. Valuing breeders' preferences in the conservation of the Koundoum sheep in Niger by multi-attribute analysis. Archives Animal Breeding. https://aab.copernicus.org/articles/62/537/2019/aab-62-537-2019.pdf.

Kassie, G.T., Asnake, W., Haile, A., Getachew, T., Gizaw, S., Rischkowsky, B., 2021. Welfare impact of community-based veterinary and breeding services on small ruminant keepers. Frontiers in Veterinary Science. https://doi.org/10.3389/fvets.2021.610610.

Kosgey, I.S. and Okeyo, A.M., 2007. Genetic Improvement of Small Ruminants in Low-Input, Smallholder Production Systems: Technical and Infrastructural Issues. Small Ruminant Research, 70, 76-88. http://dx.doi.org/10.1016/j.smallrumres.2007.01.007.

Kosgey, I.S., Baker, R.L., Udod, J., van Arendon., 2006. Successes and failures of small ruminant breeding programmes in the tropics: a review. Small Ruminant Research; 61(1): 13-28. DOI**:** https://doi.org/10.1016/j.smallrumres.2005.01.003.

Kosgy, I.S., 2004. Breeding objective and breeding strategy for small ruminant in tropics. PhD, thesis. Animal Breeding and Genetics Group, Wegeningen University. https://edepot.wur.nl/121527.

Legesse, G., Abebe, G., Siegmund-Schultze, M., Valle Zarate, A., 2008. Small ruminant production in two mixed-farming systems of Southern Ethiopia: status and prospects for improvement. Experimental Agriculture, 44(3), 399-412. doi:10.1017/S0014479708006376

Melak, A., Hailu, A., Assefa, A., Aseged, T., Sinkie, S., Tsion, S., 2021. Characterization of the production system and breeding practices of sheep producers in TahtayMaychew District, Northern Ethiopia. International Journal Tropical Dry lands 5: 5-11.https://smujo.id/td/article/view/7960/4821.

Mirkena, T., 2010. Identifying breeding objectives of smallholders/pastoralists and optimizing community-based breeding programs for adapted sheep breeds in Ethiopia. PhD thesis. Wien, Austria: University of Natural Resources and Life Sciences, Vienna. https://hdl.handle.net/10568/72828 .

Muller, J., Haile, A., Getachew, T., Rekik, M., Rischkowsky, B. 2019. Genetic progress and economic benefit of community-based breeding programs for sheep out- and up scaling options in Ethiopia. Small Ruminant Research, 177, pp. 124-132.

Nigussie, H., Mekasha, Y., Kebede, K., Abegaz, S., Kumar, S., 2013. Production objectives, breeding practices and selection criteria of indigenous sheep in eastern Ethiopia.

Nigussie, H., Mekasha, Y., Kebede, K., Abegaz, S., Pal, SK., 2015 Indigenous sheep production system in eastern Ethiopia: Implications for genetic improvement and sustainable use. American Scientific Research Journal for Engineering, Technology, and Sciences, 136–152.

Taye, M., Yilma, M., Mengistu, S., Abiso, T., Bassa, Z., Wolde, S., Haile, A., 2016. Characterization of production system and breeding practices of sheep producers in Doyogena district, Southern Ethiopia. African Journal of Agricultural Research, 11(52), 5192–5201. https://doi.org/10.5897/ajar2016.11825.

Tiesnamurti, B., Anwar., Destomo, A., Febresiana, A., 2021. Coat cover characteristics of sheep in North Sumatera, Indonesia. IOP Conference Series: Earth and Environmental Science. Available at https://iopscience.iop.org/article/10.1088/1755-1315/788/1/012009/pdf.

Yapi-Gnaoré, C.V., Dagnogo, B., Oya, B.A., 2001. Community-based livestock improvement and conservation: experiences from open-nucleus breeding programmes in West Africa. http://www.fao.org/3/y3970e/y3970e09.htm#TopOfPage.

Zonabend König, E., Mirkena, T., Strandberg, E.,Audho, J., Ojango, J., Malmfors, B., Okeyo, A.., Philipsson, J., 2016. Participatory definition of breeding objectives for sheep breeds under pastoral system in the case of Red Maasai and Dorper sheep in Kenya. Tropical Animal Health Preproduction 48**,** 9–20 (2016). https://doi.org/10.1007/s11250-015-0911-7.

Paper III

Optimizing Abera sheep community based breeding program for mating ratio and increases breeding candidates (Ready for submission for publication in Animal-the international journal of animal biosciences)

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Abstract

A simulation study was conducted to optimize selection based on growth traits of village-based sheep breeding scheme of community-based breeding program (CBBP) of Abera sheep type of Ethiopia. Six-month weight (SMWT, kg) were identified as selection criteria trait, 9 breeding alternatives or schemes were simulated and evaluated for Abera Bongodo breeder village. Alternatives were set by availing available candidates and male to female ratios on current practices of 50 candidates available at selection time and 1 male to 9 female ratios. The schemes were as follows: scheme (1) 50 candidates with 1 male: 9 female sex ratio (current practice), *scheme (2) 100 candidates with 1 male: 9 female sex ratio, scheme (3) 150 candidates with 1 male: 9 female sex ratio, scheme (4) 50 candidates with 1 male: 18 female sex ratio, scheme (5) 100 candidates with 1 male: 18 female sex ratio, scheme (6) 150 candidates with 1 male: 18 female sex ratio, scheme (7) 50 candidates with 1 male: 27 female sex ratio, scheme (8) 100 candidates with 1 male: 27 female sex ratio and scheme (9) 150 candidates with 1 male: 27 female sex ratio. The annual genetic gain(AGG) for six-month weight(SMWT) ranges 0.06 to 0.16 kg, annual monetary genetic gain(AMGG) ranges $ 0.27 to 0.64 and discounted profit per ewe ranges $-0.04 to 1.87. Scheme 9 (150 candidates at selection time and 1:27 male to female ratio) is recommended over all other schemes. Breeder cooperatives, researchers and enumerators shall work in harmony to maximize available candidates and re-arranging mating groups.*

Keywords: *Annual genetic gain, breeding scheme, six-month weight, simulation, discounted profit, sheep.*

Introduction

Ethiopia can be considered a center of livestock diversity and a route of sheep migration from Asia to Africa and the country has known for its largest livestock population in Africa and accounted around 40 million head of sheep (CSA, 2020). Livestock production contributed about 17 percent of the gross domestic product (GDP) of Ethiopia and 39 percent of agricultural GDP in 2013(Shapiro et al., 2017). Livestock management is often ineffective in Ethiopia, with low and defective returns that leave many livestock-producing households in poverty (Rettbeg et al., 2017) however, over the past decade, community based breeding programs(CBBPs) have been promoted as viable approach to improving smallholder livelihood trough systematic livestock breeding and technically feasible result in measurable genetic gains in performance traits and impact in the livelihood of farmers(Mueller et al 2015; Haile et al., 2020; Wurzinger et al., 2021). The approach was structured to prevail positive economic impact on livelihood of small-scale sheep farmers along with measurable genetic gain with participation of low input smallholder production system and farmers interest, observations, and decisions, encouraging active farmer participation from the program design through its end implementation (Mueller et al., 2015; Haile et al., 2018).

The overall aim of any breeding program is to improve one or more traits of economic importance in a population through genetic techniques (Werf, 2006). Strategy involving optimum breeding structure that considers both genetic and economic merits with exploitation of production trait should be adopted in breeding programs (Getachew et al., 2022).

Community-based sheep breeding programs (CBBPs) were started in three locations with three sheep breeds (Bonga, Horro and Menz) involving more than 8000 sheep in 2009 (Haile et al., 2014). Following the successful implementation of these CBBPs, many more breeding programs has been initiated and being implemented by different institutions in Ethiopia and other African and Asian countries. Hawassa Agricultural Research Center (HARC) adopted the CBBP on Abera sheep type in six different villages since 2013.

In one of the villages of Abera sheep CBBP, a genetic progress of 0.04 kg and 0.05 kg per year was observed for six months and weaning weight, respectively (Part I of this paper). This is rather low compared to Menz, Bonga and Horro sheep CBBPs (Haile et al., 2020), this low genetic improvement may be due to the presentation of un-optimum candidate number during selection period of the year and small mating ratio.but,with the given biological parameters 200 breeding females can produce about 150 candidates per year. However, about 50 candidates were presented in a year in the current breeding system. The mating ratio of 9 females per 1 ram is also too low compared to the recommended values (Getachew et al., 2022). Therefore, the current simulation hypothesize that optimization to increase number of proven lambs for selection and to increase number of breeding female might increase the genetic progress and profitability of the breeding program.

As a result, re-planning of Abera sheep CBBP is very much important as breeding plans should be dynamic and must be optimized to ensure that the desired levels of improvement are achieved. In other words, breeding programs need active and dynamic approach that can help to put optimal selection outcome, tactical decisions, and strategic plan. Therefore, the overall objective of the current study was to optimize the CBBPs of Abera sheep community–based breeding program to increase the genetic progress and profitability of the breeding program. Then, this study was designed to optimize Abera sheep CBBPs by evaluating the genetic gains and economical profits of different breeding plan alternatives tested by varying number of candidate breeding rams and male to female sex ratio.

Materials and Methods

Target breed and breeding management

Abera Bongodo village was selected for the simulation study among the six Abera sheep community-based breeding programs. Abera Bongodo located in Hula woreda of Sidama region located on geographic coordinates of 38º 38’-38º 51’ E longitude and 6º 36’-6º 54’ N latitude with altitude ranging from 1200 to 2900 meters above sea level. Average annual maximum and minimum temperature of 28 ºC and 19 ºC respectively, with 1200-1700 mm ranges of total rainfall. Mixed crop-livestock production system is agricultural practice of the district.

Input parameters for modeling schemes

Biological, population, genetic parameters, and economic parameters were obtained from the data on the ongoing Abera sheep CBBP and agricultural research and extension office records (Table 1). To represent the current system, 22.22 breeding rams and 200 breeding ewes were considered in the simulated CBBP. About 150.11 proven rams were produced with an estimated conception rate of 90 percent, a twinning rate of 1.26 lambs per ewe per lambing, a lambing interval of 0.61 year, and a sex ratio of 0.5, an estimated 85 percent of lambs survived to selection age and 5 percent of candidate rams were culled for physical appearances. Out of 150.11 rams proven, culling 5 percent for inferior performance, gives 52.83 breeding rams for the base population. The base size of 475.52 breeding ewes was then determined by the availability of rams for the base and the male to female ratio of 1:9.

The inputs presented in the current model are for the basic scheme (lifetime service of breeding ram, level for number of breeding ewe and mating ratio). Fixed costs (salaries for enumerators, supplies, and communication costs). The breeding program was planned for 10 years as to fit with planning period of agricultural development plans in Ethiopia. The economic value of trait of breeding objective indicate the increase in revenue related to one unit increment of the goal trait. Economic value were calculated number of expressions of the trait during one year per breeding ewe multiplied by marginal profit (Muller et al., 2021). Marginal profit also calculated as the difference between the total revenues and total costs per ewe per year. The current market price and cost of the traits of inputs in December 2021 were used to calculate revenue and cost.

The economic value calculation assumed that, when the trait is increased by one-unit, other traits remain constant (FAO, 2015).

All costs related for community-based breed program for Abera sheep CBBPs divided by six CBBPs were considered and for Abera Bongodo village total $670.66 fixed costs (salaries for enumerator($340.63), capacity building, and training costs ($84.5) communication costs ($33.33) and cost for motorcycle for the organizer of data collection.($212.2) were considered. Fixed cost per breeding ewe per village $3.35 as calculated as Total fixed costs ($670.66)/Total number of breeding ewe in Abera Bongodo CBBP. Variable cost for animal treatment ($150), animal identification cost ($60) and breeding ram cost in traditional system ($100) were considered for 200 breeding ewe per year in CBBP which is equal to variable cost of $1.55 per ewe per year.

Table 1. Biological and economic parameters

Parameters		Mating ratio 1:9	Mating ratio 1:18	Mating ratio 1:27
No of breeding females	150	200	200	200
Six month weight (kg)	20.75	20.75		
Lambing interval	0.61	0.61	0.61	0.61
Conception rate	0.9	0.9	0.9	0.9
Twining rate	1.25	1.26	1.26	1.26
Lambs born per ewe per year	1.84	1.86	1.86	1.86
Lam born - all sex	276.64	371	371	371
Male born	138.32	185	185	185
Female per ram	9.00	9	18	27
Ram needed	16.67	22	11	7
Cull physical appearances	0.95	0.95	0.95	0.95
Lambs survival to selection age (%)	0.85	0.85	0.85	0.85
Available candidate	117.57	158	158	185
Proven	111.69	150	150	150
Candidate shown at selection		50, 100, 150	50, 100, 150	50, 100, 150
Surplus breeding ram no	39.18	27, 77, 127	38, 89, 139	97, 192,

selection				142
			700, 1602,	1826,
		250, 700,	2502	2502,
Targeted base	352.62	1150		3850
Cost parameters				
Fixed cost per breeding ewe, US$	3.35	3.35		
Variable cost in the CBBP per ewe, US$	1.55	1.55		
Price of 1 kg SMW, US$	2.64	2.64		
Price of 1 lamb US$	54.78	54.78		

Simulation of the breeding program

Abera sheep breeding program was simulated using ZPLAN+ software (Täubert et al., 2010). The breeding objective was to get improved genetic gain of the growth traits considering six-month weight. The simulation of ZPALN+ is based on nine breeding alternatives aimed to increase the genetic gain and profit of growth trait. The genetic gain for single trait, annual genetic gain of breeding objective, cost, and profit from CBBP were used to test options to the current system.

Result

Genetic gain, mating ratio and candidate number for breeding objective trait

The annual genetic gain (AGG) achievements per generation for six-month weight (SMWT) in Abera Bongodo CBBP with nine different mating ratio and candidate alternatives are presented in Figure 2. Six months weight (kg), the major selection criterion in this study. Small AGG registered in alternative 1 with 50 candidates breeding ram with 1 male to 9 females mating ratio. The highest AGG per ewe for SMWT is 0.16 kg with 150 candidate and 1:27 male to female ratio as indicated in alternative 9 then if we consider alterative 6 and 8 the AGG for SMWT registered around 0.15 kg. While, there would be around 91 g difference in AGG between alternative with highest gain (alternative 9) and alternative with the lowest gain (alternative 1). in general, in the current simulation the AGG was high at alternative 9 which is considered with 150 candidate of breeding ram with 1 to 27 male to female sex ratio.

Monetary genetic gain and economic benefit

The monetary genetic gain (MGG), discounted return (DR), discounted profit (DP) and selection proportion (SP) from nine alternative breeding schemes for current simulation are presented in Table 3. Evaluation of the breeding program of Abera Bongodo breeder village, over the investment period, revealed that from use of 1:9 male to female sex ratio (alternative 1) generate minimum MGG of US$ 0.27 and from use of 150 candidates breeding ram with 27 female to one breeding ram sex ratio (alternative 9) generated maximum MGG of US$ 0.64. Evaluation of the breeding program, based on DP per ewe over the investment period, resulted the use of 150 candidate breeding ram with 1 to 27 sex ratio generate $1.87 DP per ewe over 10 years.

Nevertheless, currently practiced breeding alterative with 1 breeding ram for 9 breeding ewe (alternative 1) registered rebuff DP.

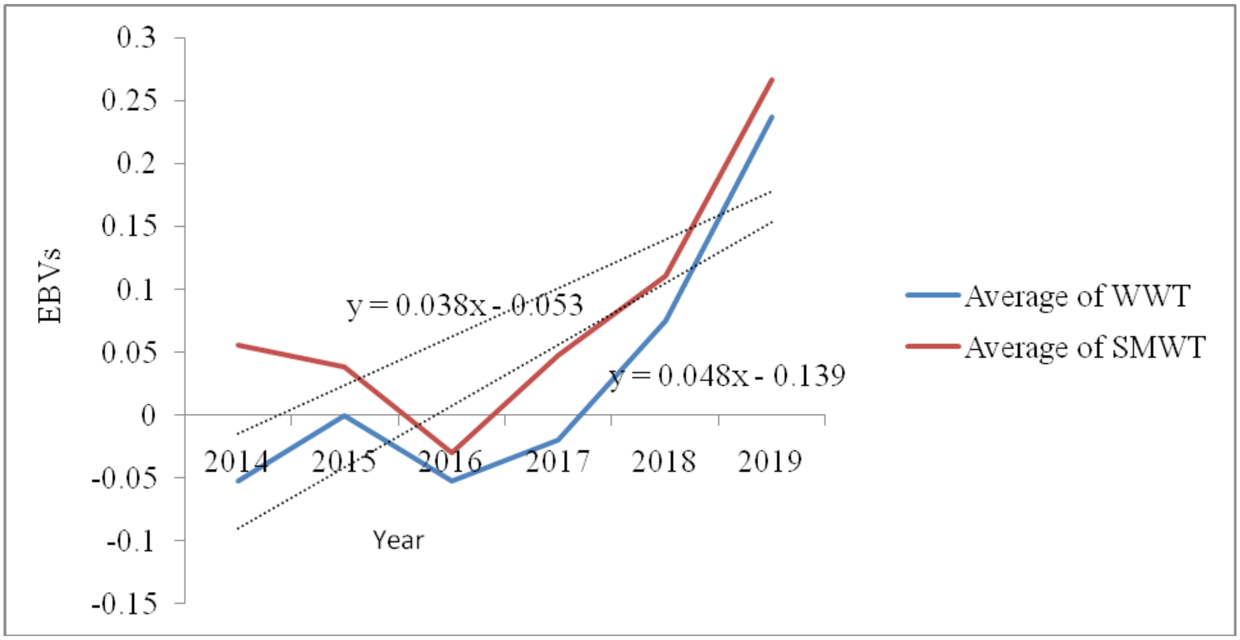

Figure 1. Genetic progress per year of SMWT and WWT Abera Bongodo village.

Table 3. Genetic progress for different alternatives (with fixed cost of 1.9 per ewe and variable cost of 1.03 US$)

	Alternatives								
Parameter	1	2	3	4	5	6	7	8	9
Accuracy (%)	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Selection proportion (%)	0.44	0.22	0.15	0.22	0.11	0.07	0.14	0.07	0.05
Monetary genetic gain(US$)	0.27	0.41	0.48	0.41	0.52	0.58	0.48	0.58	0.64
Discounted return(US$)	1.44	2.16	2.51	2.16	2.74	3.01	2.56	3.07	3.35
Discounted profit(US$)	-0.04	0.68	1.03	0.68	1.26	1.56	1.06	1.59	1.89

Alternatives (1= 50 candidates with 9:1 female to male sex ratio, 2= 100 candidates with 9:1 female to male sex ratio, 3= 150 candidates with 9:1 female to male sex ratio, 4= 50 candidates with 18:1 female to male sex ratio, 5= 100 candidates with 18:1 female to male sex ratio, 6= 150 candidates with 18:1 female to male sex ratio, 7= 50 candidates with 27:1 female to male sex ratio, 8=100 candidates with 27:1 female to male sex ratio and 9= 150 candidates with 27:1 female to male sex ratio).

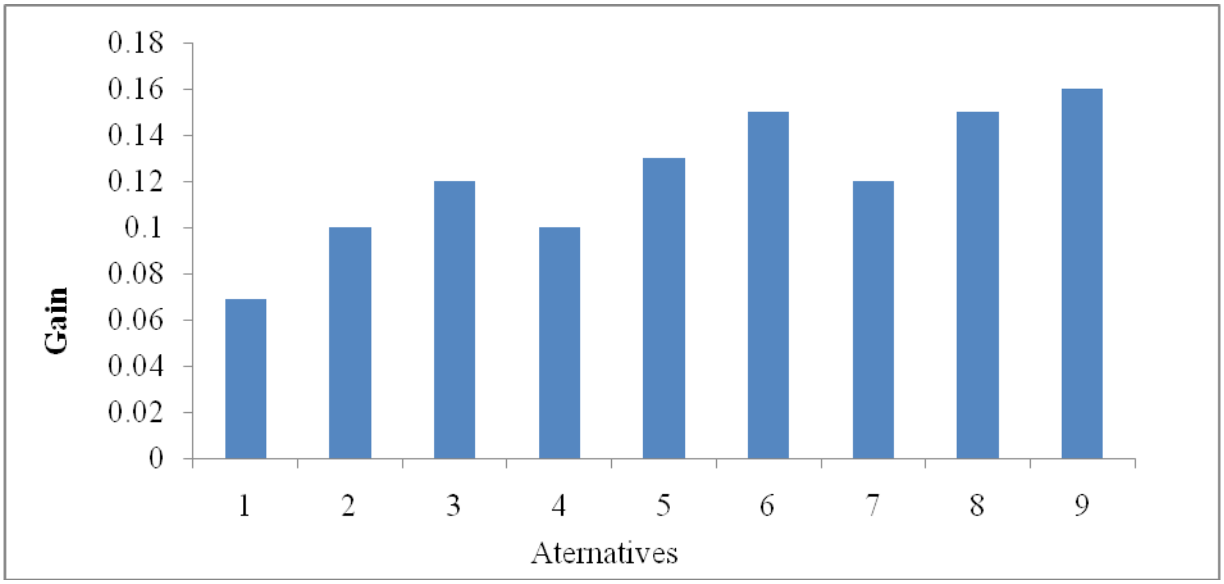

Figure 2. Genetic progress(gain per year) for different alternatives (1: 50 candidates 9:1, 2: 100 candidates 9:1, 3: 150 candidates 9:1, 4: 50 candidates 18:1, 5: 100 candidates 18:1,6: 150 candidates 18:1,7: 50 candidates 27:1,8: 100 candidates 27:1 and 9: 150 candidates 27:1).

Discussion

Compared to other CBBPs villages in Ethiopia, flock size of Abera sheep is small and in Abera Bongodo breeder village mean flock size were small about 5.00 ± 1.10 sheep per household (Digesa, 2021) and one improved breeding ram was given to 5 households for mating with male to female ratio of 1:9. Researchers select potential candidates based on their performance and final approval is done by the committee from the community looking for the size, physical condition and morphological characters. Usually farmers anticipate the type lambs can pass the selection process and may not bring some of the lambs when they perceived they are not good enough physically compared to others. This biases the selection process in that good-looking animals because of better feeding and older age may not be genetically superior and the vice versa. With the given biological parameters, 200 breeding females can produce about 150 candidates per year. However, about 50 candidates were presented in a year. The mating ratio of 9 females per 1 ram is also too low compared to the recommended values(Getachew et al., 2022).Small AGG of 0.04 kg and 0.05 kg per year was observed in Abera Bongodo village for SMWT and WWT respectively (Figure 1). This AGG is low when we compared with other indigenous breeds like Bonga, Horro and Menz sheep CBBPs (Gizaw et al., 2014, Haile et al., 2020).

Sale of lambs before selection age reported as main problem in Menz and Bonga CBBPs and developed a strategy targeting earlier age (Haile et al., 2021). However, this is not the case in Abera sheep selective breeding program. Farmers are willing to retain their animals until selection moment (Digesa, 2021). While, there might be many reasons for less number of candidates available during selection event, regarding only few best animals have been approved as breeding animal to be used in the community. Selected lamb procured by the community with premium price.

Nine breeding alternatives focused on number of candidate breeding ram and male to female ratio were simulated. optimization process involves identifying the best breeding scheme by improving the male to female ratio and increasing the number candidate breeding ram for breeding, and designing a feasible sheep breeding program that fits Abera sheep CBBP. The optimal criteria were selected based on the genetic gain per time unit, and the total discounted return and profit over the 10 year investment period. Substantial discounted profit was attained at each step of the optimization. Finally, the optimum size of the base ewe population was also determined using a simulation study.

In the current study, important increase in discounted profit per ewe ($1.87) which was achieved by increasing the number of female per breeding ram from 9:1 to 27:1(Table 3) were achieved and this finding agrees with the research of Getachew et al., 2022, who indicated the use of one breeding male for 25 female substantially increase the discounted profit per doe around 88.5% in Borna goat and higher selection intensity contributed in increment of discounted profit in Areb and Oromo goat populations in Ethiopia(Sheriff et al., 2022).

Conclusion

Different breeding scenarios were evaluated to optimize the breeding structure of Abera sheep community based breeding program of Ethiopia, with consideration of six-month weight as breeding objective trait. Shifting the current male to female ratio 1:9 to 1:27 with increased number of candidate breeding ram for selection lead to maximize the genetic progress and profitability of the breeding program than the former breeding scenario. To enable factual genetic improvement program, considering improved management like health and feeds are crucial. The recommended breeding alterative in the current study will be practical with the consideration of the integration of different institutions to facilitate and ensure in data collection, the estimation of breeding values, candidate selection, mating arrangements, veterinary support, feed supply, and follow-up.

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Conflict of Interest

The authors declare that they have no competing interests.

References

CSA., 2020. Agricultural Sample Survey 2019/20 [2012 E.C]. Volume II report on livestock and livestock characteristics (private peasant holdings). Central Statistical Agency (CSA): Addis Ababa, Ethiopia.

Digessa, S., 2021. Evaluation of Abera sheep community-based breeding programs in Dara and Hula districts, Sidama regional state, Ethiopia. MSc Thesis, Haramaya University, Ethiopia, pp: 35-37.

FAO, 2015. The second report on the state of world´s animal gentic resources for food and agriculture. Rome. https://www.fao.org/3/i4787e/i4787e.pdf.

Getachew, T., Rischkowsky, B., Rekik, M., Mueller, J., Tessema, T., Solomon, D., Haile, A., 2022.Optimizing breeding structures and related management in community-based goat breeding programs in the Borana pastoral system of Ethiopia. Livestock Science, Volume 256, ISSN 1871-141, https://doi.org/10.1016/j.livsci.2021.104819.

Gizaw, S., Getachew, T., Haile, A., Rischkowsky, B.,Sölkner, J., Tibbo, M., 2013. Optimization of selection for growth in Menz Sheep while minimizing inbreeding depression in fitness traits. Genetics Selection Evolution 45**,** 20 https://doi.org/10.1186/1297-9686-45-20.

Haile, A., Desse, T and Rischkowsky, B., 2014. Performance of indigenous sheep breeds managed under community based breeding programs in the highlands of Ethiopia.

Haile, A., Getachew, T., Merkena, T., Duguma, G., Gizaw, S.,Wurzinger, M., Soelkner, J., Mwai, O., Desse, T., Abebe, A., Abate, Z., Jemebere, T.,Rekik, M., Lobo, R., . Mwacharo, J.,Terfa ,Z., Kassie, G., Mueller, G and Rischkowsky, B., 2020. Community-based sheep breeding programs generated substantial genetic gains and socioeconomic benefits. Animal, Volume 14, Issue 7, Pages 1362-1370, ISSN 1751-7311. https://doi.org/10.1017/S1751731120000269.

Haile, A., Gizaw, S., Getachew, T., Rischkowsky, B., 2018. Challenges in small ruminant breeding programs and resulting investment priorities in Ethiopia. Proceedings of the World Congress on Genetics Applied to Livestock Production, 11:475.

Hazel, L. N., 1943. The genetic basis for constructing selection indexes. Genetics. Volume 28, No 6, 476-490. https://www.genetics.org/content/genetics/28/6/476.full.pdf.

Julius van der Werf, 2006. Optimizing design of breeding programs. Animal breeding summer course. https://jvanderw.une.edu.au/BPDesignJW.pdf.

Melesse, A., Banerjee, S., Lakew, A., Mersha, F., Hailemariam, F., Tsegaye, S., and Makebo,T., .2013. Morphological Characterization of Indigenous Sheep in Southern Regional State, Ethiopia. Animal GeneticResources/Ressources Génétiques Animales/RecursosGenéticos Animales, 52, 39-50. doi:10.1017/S2078633612000513.

Mueller, J., Rischkowsky, B., Haile, A., Philipsson, J., Mwai, O., Besbes, B., Valle Zárate A., Tibbo, M., Mirkena, T., Duguma, G., Sölkner, J., Wurzinger, M., 2015. Community-based livestock breeding programmes: Essentials and examples. Journal of Animal Breeding Genetics. April; 132(2):155-68. doi:10.1111/jbg.12136. PMID: 25823840.

Muller, J.P., Getachew, T., Rekik, M., Rischkowskr, B., Abate, Z., Wondimu, B., Haile, A., 2021. Converting multi-trait breeding objectives into operative selection indexes to insure genetic gains in low-input sheep and goat breeding programs. Animal 15,100198. https://doi.org/10.1016/j.animal.2021.100198.

Muller, JP., Haile, A., Getachew, T., Rekik, M., Rischkowsky, B., 2019. Genetic progress and economic benefit of community-based breeding programs for sheep out- and up scaling options in Ethiopia. Small Ruminant Research, 177, pp. 124-132.

Rettberg, S., Gabriele, B., Margitta, M., and Anja, S., 2017. Ethiopia's Arid and Semi-Arid Lowlands: Towards Inclusive and Sustainable Rural Transformation. Berlin: Centre for Rural Development (SLE). https://edoc.hu-berlin.de/bitstream/handle/18452/18671/03.pdf.

Shapiro, B. I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G. and Mechale, H., 2017. Ethiopia livestock sector analysis. ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Sheriff, O., Wondimagegn, K., Haile, A., Getachew, T., Wacharo, J., 2022. Genetic and economic evaluation of alternative breeding schemes for two indigenous goat populations of Ethiopia. Journal of Applied Animal Research, 50(1):80-85:DOI:10.1080/09712119.2021.2023549.

Täubert, H., Reinhardt, F., Simianer, H., 2010. ZPLAN+, a new software to evaluate and optimize animal breeding programs. Proc. 9th World Congr. Genet. Appl. to Livest. Prod. 1–6.

Wurzinger, M., Gutiérrez, GA., Sölkner, J and Probst, L., 2021. Community-Based Livestock Breeding: Coordinated Action or Relational Process? Front. Vet. Sci. 8:613505. doi: 10.3389/fvets.2021.613505.

12. BIOGRAPHICAL SKETCH

The author of this dissertation, Amelmal Alemayehu, was born on November 10, 1985 in Jimma town from her father Ato Alemayehu Abera and her mother W/o Tayech Aserese. She attended her elementary education in Mendera and Jiren elementary School, Jimma, and her secondary school in Jimma high school, currently called Jimma preparatory and vocational training school. She joined Haramaya University in 2004 and graduated with BSc degree in animal science in 2006 and also joined Haramaya University again in 2008 and graduated in 2011 with MSc degree in animal breeding and genetics.

After completion of her undergraduate study, she worked as expert of forage production in Loma woreda agricultural office, Dauwro zone. Later on she moved to Areka Research Center and Hawassa Research Center, South Agricultural Research Institute (SARI) and served as researcher on animal breeding until the date of starting PhD study.

In 2015, she joined the School of Graduate Studies (SGS) of Hawassa University/Collage of Agriculture to pursue her PhD study in Animal Breeding and Genetics in the Department of Animal and Range Sciences.