ESTIMATES OF GENETIC PARAMETERS AND GENETIC TRENDS FOR PRODUCTIVE AND REPRODUCTIVE TRAITS OF DOYOGENA SHEEP IN SOUTHERN ETHIOPIA

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Estimates of Genetic Parameters and Genetic Trends for Productive and Reproductive Traits of Doyogena Sheep in Southern Ethiopia

By

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We, the undersigned, member of the Board of Examiners of the final open defense by **Kebede H/giogis** have read and evaluated his/her thesis entitled **"Estimates of Genetic Parameter and Genetic Trend for Productive and Reproductive Traits of Doyogane Sheep in Southern Ethiopia"** and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree Master of Science in **Animal Breeding and Genetics.**

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DEDICATION

This work is dedicated to my mother w/ro Asegedeche Bekele, my father Ato Habtegiorgis Beshah, my aunt Negat Bekele, my brother Shefera Habtegiorgis, and my cousin Abebe Shiferaw for their great effort in making me successful.

STATEMENT OF AUTHOR

First, I declare that this thesis is my bonafide work and that all sources of material used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal Breeding and Genetics at Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University/College library to be made available to borrowers under rules of the Library.

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BIOGRAPHICAL SKETCH

The author, Mr Kebede Habtegiorgis, was born on August 21, 1990 at Ankober District, North Shewa Zone, Amhara region from his father Ato Habtegiorgis Beshah and his mother W/ro Asegedeche Bekele. He attended his primary education (Grade 1 to 8) in Mehale Wonze primary school from 1998 to 2006 and Secondary education at Ankober secondary school from 2007 to 2008.He also attend his preparatory School at Hailemariam preparatory school. He then joined Debre Birhan University, College of Agriculture and Natural Resources in the department of Animal science and obtained a B.Sc. degree in Animal science in July 27, 2013.Soon after graduation, he was employed by the Seyadeber ena wayu (Deneba) District, Agriculture office and served for 10 months. Then the author was joined the Southern Agricultural Research Institute (SARI) and served as Junior Animal Breeding Researcher for three years. In 2018, he joined the School of Graduate Studies (SGS) of Jimma University to pursue his MSc. study in Animal Breeding and Genetics in the Collage of Agriculture and Veterinary Medicine (JUCAVM) department of animal science.

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ABBREVIATIONS/ACRONYMS

(Co) variance component and parameters

$\sigma^2 p$	Phenotypic Variance
c^2	Maternal Permanent Environmental Variance
h^2	Heritability
h^2_a	Direct Heritability
$h^2 m$	Maternal Heritability
$h^2 t$	Total Heritability
R	Repeatability
r_{am}	Correlation Between Direct Maternal Additive Genetic Effects
r_g	Genetic Correlation
r_p	phenotypic correlation
σ^2_{am}	Maternal-Additive Genetic Variance
σ^2_e	Residual Variance.
σ^2_{pe}	Permanent Environmental Variance Related to Repeated Records of Ewes

Others

AARC	Areka Agricultural Research Centre
6WT	6-Month Weight
ADG	Average Daily Weight Gain
ADG0-3	Average Daily Weight Gain from Birth to Weaning Age
ADG0-6	Average Daily Weight Gain from Birth to 6 Month Age
ADG3-6	Average Daily Weight Gain from Weaning to 6 Month Age
AFL	Age at First Lambing
AIC	Akaike's Information Criterion
ALS	Average Litter Size
ANOVA	Analysis of Variance
ARR	Annual Reproductive Rate
BHS	Black Head Somila
BOKU	University of Natural Sciences and applied Life Sciences
BW	Body Weight
BWT	Birth Weight
CBBP	Community Based Breeding Program
CCPP	Contagious Caprine Pleuropneumonia
CSA	Central Statistics Authority
CV	Coefficient of Variation
DBARC	Debre Birhan Agricultural Research Centre
DBoA	Doyogena Bureau of Agriculture
DDFED	Doyogena District Finance and Economic Development

EBV	Estimated Breeding Value
F	Coefficient of Inbreeding
FGD	Focus Group Discussion
GLM	General Linear Model
ICARDA	International Center for Agricultural Research in The Dry Areas
ID	Animal identification number
Kg	Kilogram
Km	Kilometers
KNMI	Royal Netherlands Meteorological Institute
LI	Lambing Interval
LRT	Log Likelihood Ratio Tests
LS	Litter Size
m.a.s. l	Meters Above Sea Level
Mm	Millimeters
NARS	National Agricultural Research Systems
No	Number
PPR	Paste des petits ruminants
REML	Restricted Maximum Likelihood
SARI	Southern Agricultural Research Institute
SAS	Statistical Analysis System
SE	Standard Error
SNNPR	Southern Nation Nationality People Region
SPSS	Statistical Package for Social Sciences
Sq. Km	Square Kilometers
WOMBAT	Software package for quantitative genetic analysis of continuous data developed by Meyer
WWT	Weaning Weight
χ^2	chi-square

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ABSTRACT

The objective of this study was to estimate the genetic parameters and genetic trends for growth and reproductive traits of Doyogena sheep. Records used in the study were collected over a period of 6 years (2013-2018) from the ongoing Doyogena sheep community-based breeding program (CBBP). Studied traits were birth weight (BWT), 3-month weight (WWT), 6-month weight (6WT), average daily gain from birth to weaning (ADG0-3),average daily gains from weaning to 6-month age(ADG3-6), average daily gain from birth to 6-month age(ADG0-6), litter size(LS), lambing Interval(LI), age at first lambing(AFL) and annul reproductive rate(ARR). (Co) variance components and genetic parameters were estimated using the restricted maximum likelihood (REML). The analyses were carried out using WOMBAT programme. Mixed animal models of univariate and repeatability analyses were applied to estimate genetic parameters. 6 different animal models were fitted by including or excluding maternal additive genetic effects, maternal permanent environmental effect, and covariance between direct-maternal additive genetic effects. A log-likelihood ratio test (LRT) and Akaike's Information Criterion (AIC) were used to select the most appropriate univariate model for each trait. Bivariate and multivariate analysis were applied for correlation estimates. The overall least square mean ± standard errors (LSM±SE) of lamb body weight for BWT, WWT and 6WT were 3.05±0.02 kg; 14.8±2.49 kg and 22±0.22 kg respectively. The overall LSM±SE of ADG0-3, ADG3-6, and ADG0-6 were 130.37±2.27gm, 80.59±3.62gm and 106.18±1.7gm respectively. The least square means for reproductive traits in terms of LI, ARR, LS and AFL were 281.22 ±8.8 days, 2.16 ± 0.06 lamb, 1.75±0.02 lamb and 437.43±31 days respectively. Based on the best fitted models, the direct heritability estimates, for BWT, WWT, 6WT, ADG0-3, ADG3-6 and ADG0-6 were 0.33±0.06, 0.31±0.06, 0.14±0.06, 0.13±0.04, 0.11±0.07, and 0.023±0.05 respectively. Direct heritability estimates for LS, LI and AFL were 0.28±0.12, 0.20±0.51 and 0.001±0.56 respectively. The maternal heritability estimates for BWT and WWT were 0.24±0.12 and 0.6±0.07 respectively. BWT has weak genetic and phenotypic correlation almost all the traits. The estimate of genetic correlations between WWT and 6WT, WWT and ADG0-3, WWT and ADG3-6, WWT and ADG0-6 were 0.52±0.09, 0.95±0.03, -0.23±0.13 and 0.53±0.12 respectively. The genetic correlations between LI with LS was moderate and negative (-0.44±0.9). All growth traits were negatively correlated with LS. Repeatability estimated for LS and LI were 0.61 and 0.26 respectively. Genetic changes over the selection period were 0.00085 kg,0.30 kg,0.151 kg 2.56gm, -0.37gm,0.09 gm, for BWT, WWT, 6WT, ADG0-3, ADG3-6, and ADG0-6, respectively. The genetic changes for LS, LI and AFL over the selection period were 0.002 lambs, -1.69 days and 0.09 days respectively. Genetic progress for most of studied traits has shown promising improvements. Thus, continuation of selection therefore recommended for bringing further improvement in the performance of Doyogena sheep. Estimated direct heritability for growth traits decrease as lamb age increase thus, selection based on earlier body weight will be more efficient. The LS trait suggest that selection based on litter size/number of lambs born per ewe can be effective in improving reproductive performance in Doyogena ewes.

Keywords: Community-Based Breeding Program, Doyogena Sheep, Genetic Parameters, Genetic Trend, Growth and Reproductive Traits, Variance Components

1. INTRODUCTION

1.1. Background and Justification

In Ethiopia, sheep contribute as source of food like meat, milk and non-food products like manure, skins and wool (Adane and Girma, 2008). They also serve as a means of risk mitigation during crop failures, property security, monetary saving and investment, and cultural functions (Tibbo, 2006). Sheep population in Ethiopia stands at 31 million and the numbers have been showing increasing trend over the past years (Leta and Mesele, 2014; CSA, 2017/18). Pertaining to the breeds, about 99.81% are indigenous and 0.12% are crossbreds. The proportion of indigenous sheep reflects their importance for resource poor smallholder farmers.

In southern Ethiopia, sheep production is virtually the major source of income and food security especially in the densely populated areas of the Region, where crop production is hindered by land shortage. According to CSA (2018), the population of sheep in the region is estimated to be 4.64 million. Although the region is endowed with large and diversified sheep genetic resources, their potentials are yet to be fully exploited.

Productivity of sheep can be improved through crossbreeding with exotic breeds or selection with in the local breeds. However, the sustainability of any breeding program largely depends on stakeholder's interest and willingness to work according to planned breeding program (Neef, and Neubert, 2011). Experience has shown that minimal involvement and/or no involvement of farmers' in the design and implementation of any sheep improvement scheme has resulted in the failure of such schemes (Duguma *et al*., 2009; Tibbo *et al*., 2010; Wurzinger *et al*., 2011). Thus, an alternative strategy for sheep improvement has been the community-based breeding program (CBBP) in view of its sustainability (Haile *et al.,* 2014; Lamuno *et al*., 2018). CBBP has been designed to ensure involvement of farmers' (target groups) in all steps of the breeding program (Duguma *et al*., 2009; Mueller *et al*., 2015).

In Ethiopia, CBBP was initiated by the International Center for Agricultural Research in the Dry Areas (ICARDA), the International Livestock Research Institute (ILRI) and the Austrian University of Natural Resources and Life Sciences (BOKU) in collaboration with the National and Regional Agricultural Research Institutes (Duguma, 2010). The program was launched for improvement of Bonga, Menz, Afar and Horro sheep breeds. Later the program was expanded to Atsbi, Doyogena, Abergelle, Konso and few other sites, in different parts of the country with the support of ICARDA, the Federal government and their respective regional governments.

In 2012/13, 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. The Doyogena sheep was previously known by Adilo sheep. The name Adilo, derived from large sheep market place that is situated near Doyogena district (Ashenafi *et al.,* 2013). Doyogena sheep was among the potential breeds of the country with better market preferences in the local market and Addis Ababa (Kocho, 2007). The sheep has attractive morphological features with a great potential for twining and fattening (Taye *et al*., 2016). It is long fat-tailed and short haired. These characters had contributed to the choice of the breed for implementation of selective breeding and conservation program by SARI.

For the implementation of Doyogena sheep CBBP, five kebeles/sites were selected. Accordingly, on-farm data collection of economically important traits focusing on quantitative traits has been recorded, (https://cgspace.cgiar.org/handle/10568/92538).The achievements of Doyogena sheep CBBP, presented in different workshops, attracted the attention of both governmental and non-governmental organizations. However, the data generated under CBBP has not been evaluated to unravel the actual progress of the programme (Haile *et al*., 2019b).

The potential genetic improvement of traits of interest was largely dependent on its heritability value and genetic relationship among the traits of economic importance upon which selection may be applied. Information on heritability is essential for planning efficient breeding programmes, and for prediction of response to selection (Falconer and Mackay, 1996). According to Bekana (2019), evaluation of any designed genetic improvement program is fundamental either to optimize the program if the designed improvement program is progressing towards the set goals or redesign other alternatives if it fails or deviates from the preset goals. Moreover, evaluation of genetic trend gives an indication of genetic direction of the breed as well as the rate of genetic improvement from the time of application of the breeding program (Mallick *et al*., 2016). However, genetic studies of productive and reproductive traits in sheep are scarce due to lack of recorded data (Aguirre *et al*., 2017). In Ethiopia very few genetic parameter estimates have been summarized by Mekuriaw and Haile (2014) based on the earlier studies of Yacob (2008), for Afar and black head somalin (BHS) sheep; Abegaz *et al*. (2002) for Horro sheep; and Gizaw *et al.* (2007) for Menz sheep.

The data generated under Doyogena sheep CBBP for the last six years has not been statistically analyzed and or evaluated to unravel the actual progress achieved in this program. Therefore, the present study has been planned to evaluate this program with following objectives: -

1.2. Objective

1.2.1. General objective

- To evaluate estimated genetic parameters and genetic improvement trends for Doyogena sheep under community-based breeding program.

1.2.2. Specific objectives

- To assess the effect of non-genetic factors influencing growth and reproductive traits
- To estimate inbreeding level, and selection response for growth and reproductive trait.
- To estimate the genetic parameters among growth and reproductive traits.
- To explore the perception of farmer on CBBP
- To generate information for the optimization of the ongoing CBBP

2. LITERATURE REVIEW

2.1. Sheep Breeds of Ethiopia

Phenotypic characterization of Ethiopian sheep breeds had resulted in 14 traditional populations namely; Farta, Menz, Sekota, Simien, Tikur, Wollo, Afar, BHS, Adilo, Arsi-Bale, Horro, Bonga, Gumz, and Washera sheep (Workneh *et al*., 2004). Later, studies that genetically characterized the indigenous Ethiopian sheep population using microsatellite DNA markers grouped the 14 phenotypically characterized breeds into 9 breed groups (Gizaw, 2008). These sheep types are highly adaptable to a broad range of environments (Kocho, 2007). These sheep types are named after their geographic location and/or the ethnic communities keeping them. The sheep types have also been classified in to 6 major groups/breeds, based on their tail type of Short-fat-tailed, Washera, thin-tailed ,long fat tailed,Bonga, and fat-rumped sheep(Gizaw, 2008).

2.2. Community-Based Breeding Programs (CBBPs)

CBBP is a participatory approach where farmers having common interest to conserve and improve their genetic resources jointly engage in a particular scheme. Globally CBBPs have been successfully implemented with promising results in countries of Latin America (Mueller *et al*., 2015), in Africa (Haile *et al*., 2014) and in Asia (Mueller *et al*., 2015). In Ethiopia CBBP were implemented after various fruitless crossbreeding programs (Mueller *et al.*, 2015). Primarily the program was initiated for the genetic improvement of farmer's flocks and conserve indigenous genetic resources (Abegaz, 2014). The CBBP strategies consider the production system holistically and involve the local community at every stage, from planning to operation of the breeding program. CBBP is a single-tiered with no distinction between breeders and producers (Mueller *et al*., 2015). It increases the productivity and profitability of indigenous breeds through interventions access (Haile *et al*., 2019a).

In Ethiopia, CBBP was launched in 2009 in Afar, Bonga, Horro and Menz sheep breeds (Mirkena *et al*., 2012). The selection program was started after detailed studies on the characteristics of the breeds and their production systems (Edea, 2008; Tesfaye, 2008). The program was successful in Menz, Horro and Bonga and still continued under the support of

ICARDA, ILRI and respective regional governments. After promising results reported from the three sites, CBBPs were expanded to Doyogana and Atsbi districts (Getu *et al*., 2015).

The Federal Democratic Republic of Ethiopia (FDRE) livestock master plan (Plan, 2015), envisaged CBBP as the choice of small ruminant's genetic improvement scheme. Accordingly, CBBP was implemented in different parts of the country with the support of governmental and non-governmental organization. The report of Haile *et al.* (2019a) indicated, the ongoing CBBP programs created a direct benefit for 3,200 households in 40 villages of Bonga, Horro, Menz, Doyogena, Abergelle and Konso sites and currently there are 35 formal breeders' cooperatives participating in these breeding programs. In case of Doyogena, there are 5 formal breeders' cooperatives and another two cooperatives were added in 2018. Growth, twining rate and lamb survival were the target trait to be improve in most CBBPs. CBBP has also been out scaled to many countries including Brazil, Bangladesh, Mexico, Peru, Australia, Bolivia, Vietnam, Argentina, New Zealand (Mueller *et al.,* 2015), Burkinafaso, Iran, Malawi, South Africa, Sudan, Tanzania, Uganda and Mongolia (Haile *et al*., 2019a).

2.3. Description of Doyogena Sheep

Doyogena sheep is among the sheep breeds reared in the *Enset*-crop-livestock production system of the SNNPR state, Ethiopia. The sheep is particularly found in Kembata Tembaro zone of the SNNPR. It is characterized and well known by its twining ability (Taye *et al*., 2016). The earlier studies showed that this breed was known by different name. Tibbo (2006) reported sheep population found in Kembata Tambaro zone under Arsi Bale breed and Kocho (2007) named these sheep as Adilo or Kembeta area sheep population. https://www.slideshare.net/ILRI/ethiopia-vct-updatejun2014

In the study of Gizaw *et al*. (2011a) and Deribe *et al. (*2014) Doyogena sheep was named by Wolayta sheep ecotype. Later in 2013, a team of researcher from Areka Agricultural Research Center partnership with ICARDA conducted a value chain analysis of Doyogena sheep (Ashenafi *et al.,* 2013. The report indicated, Doyogena district is the main source of the sheep whereas Adilo is large sheep market place sourced from Doyogena, Alba and Wolitta area.

For the most part, sheep flocks including lambs, ewes and rams from Doyogena market are transported to Adilo market, then purchased by big and small traders. Accordingly, smallholder farmers found in and around Adilo area purchase sheep to fatten or for breeding purpose from Doyogena. For that reason, the sheep is named after the market place (Adilo). In the study of Aberra *et al.* (2013) the morphometric and qualitative traits of the sheep population found in Kembata Tambaro zone was significantly different from the sheep found in Wolayta area. In the report of Zelalem (2018), Doyogena sheep were distributed through Wolayta, Hadiya and Kambata Tambaro zones, called as Adilo sheep some year ago, and currently called Doyogena sheep.

Figure 1. Typical Doyogena ewe with its twin (left) and ram (right)

Morphology of Doyogena sheep is clearly described by Taye *et al*. (2016). The sheep was characterized as being large in size, horned with long fat tail. The mean age at first beeding of Doyogena sheep is 241 and 240 days for female and male sheep, respectively. The same author reported twinning rate of Doyogena sheep to be 1.45±0.45. In the other study, Kocho (2007) reported age at first lambing of this sheep is 378 days for lambing.

Doyogena ewes are prolific with high incidences for multiple births with occasional triplet and quadruplet's (Ayele, 2018). With the introduction of CBBP for Doyogena sheep breed for the last six years, more than 600 breeding rams were produced from Doyogena sheep breeder cooperative and distributed in different agro-ecologies of the region. Survey report indicated that Doyogena rams were more preferred by the farmer for its ability to mate more ewes, for its attractive coat color and for its ability to produce multiple births compared with Bonga and Dorper rams (Kebede, 2017). The breed has attractive morphological features with a great potential for fattening (Taye *et al*., 2016).

2.4. Efficiency of Selection

Effective selection is one of the most important strategies to maximize production in animal breeding. However, the lack of estimates for the genetic parameters necessary to predict genetic gains is commonly cited as an obstacle in the design and implementation of selective breeding programs (Lobo *et al*., 2009). As a result, there are few reports on successful selective breeding programs (Gizaw *et al.*, 2007).

One example of within breed selection program is in Awassi breed. In the review of Galal *et al*. (2008), efforts to genetically improve milk production in Israel and Syria show positive results. In Israel the phenotypic average lactation milk production increased from 297 kg to 500 kg in the 50-years selection, while in Syria a selection program succeeded to increase lactation milk production from 128 kg to 335 kg within 31-years selection. Gholizadeh *et al.* *(*2015), estimated genetic change and annual genetic gain over a 27-year selection program in Baluchi sheep. He reported over the experiment were -0.13 kg, 0.192 kg, 0.082 kg, 0.147 kg and 0.459 kg for BWT, WWT, 6WT, 9-month weight and yearling weight, respectively. Annual genetic gain for BWT, WWT, 6WT, 9 month and yearling weight were 0.00 gm, 7gm, 4gm, 7 gm and 14 gm/year respectively.

Gizaw *et al.* (2014a) reported an increment of change in weight gain of 0.42, 2.29 and 2.46 kg for BWT, WWT and 6WT, respectively for Menz sheep within 8-years selection periods. The same author reported the genetic progresses of village flocks at 4^{th} generation were 0.005kg,0.45 kg and 1.30 kg for BWT, WWT and 6WT respectively over the base generation. There were also increasing trends in the EBV of BWT, WWT, and 6WT (Gizaw *et al.,* 2014b).

Dagnew *et al.* (2018) studied, the genetic gains of four different schemes i.e. a village-based breeding scheme with existing lambing, village-based scheme with improved lambing, central nucleus-based scheme with 5% nucleus size and central nucleus-based scheme with 10%

nucleus size in Gumuz sheep. They found different result of annual genetic gains per year in 6-month weight (kg) across schemes ranged from 0.154 to 0.171 in village-based scheme, and 0.334 to 0.336 in central-based schemes. The same authors reported the annual genetic gain per year in number of lambs born per ewe breed from 0.0017 to 0.0036% in both village-based and central nucleus-based scheme. The genetic gain in the proportion of lambs weaned per ewe was comparable across central nucleus-based scheme but little differed in village-based schemes and ranged from 0.0015 to 0.0016%.

The preliminary phenotypic results from early set up CBBP of Menz, Horro and Bonga were reported by Haile *et al.* (2014). The author attains varied results in consecutive selection years. BWT phenotypic trend of lamb in 2009,2010,2011 were 2.34 kg, 2.29 kg,2.18 kg for Menz sheep breed and 3.59 kg,3.22 kg,3.42kg and 3.43 kg for Bonga sheep breed. Those result are in decreasing and asymmetrical trends. Across the three sites similar trends were reported in WWT and 6WT. The year wise improvement trend, he obtained has had insignificant improvement trend in the first three-year selection period.

In the other study of Haile *et al.* (2018), he, reported, litter size has shown a significant increment across the advancement selection period for Bonga and Horro sheep. The trends of litter size over 8 years selection has been shown in Table 1. litter size shows up increasing pattern from 1.48±0.03 to 1.61±0.016, 1.28±0.033 to 1.46±0.039 for Bonga and Horro sheep respectively.

Table 1. Phenotypic trends of average litter size for Horro and Bonga sheep over 8 year

breed	year	2009	2010	2011	2012	2013	2014	2015	2016	Overall
Horro	LSM	1.28	1.40	1.37	1.36	1.35	1.31	1.37	1.46	1.36
	SE	0.033	0.020	0.020	0.023	0.023	0.024	0.022	0.039	0.010
Bonga	LSM	1.48	1.53	1.48	1.58	1.53	1.54	1.53	1.61	1.53
	SE	0.039	0.026	0.022	0.020	0.018	0.015	0.013	0.016	0.008

Source: (Haile *et al.*, 2018)

Tadel (2014) predicted a genetic gain in a simulated breeding program for Menz sheep. The predicted annual genetic gain in kg for 6WT ranged from 0.213 to 0. 214. The author estimated 6WT is improved from 18.48 to 22.76 in 20 years of selection periods. Similarly, the pre-weaning survival (%) and fertility rate (%) are increased from 93.77±0.41 to 98.88±0.41 and 88.02±0.02 to 89.28±0.02 in 20 years of genetic selection of simulation results. The genetic gain per year in milk yield of Afar sheep breed was in the order of 0.018 to 0.020 kg, while the genetic gain per generation for greasy fleece weight in kg ranged from 0.016 to 0.024 for Menz sheep (Mirkena, 2012).

Under smallholder farmer condition one core problem for genetic improvement of small ruminant breeding is mating with inferior quality breeding rams and breeding bucks. To overcome these limitations established breeder cooperatives produce superior quality breeding ram and breeding buck to disseminate to other smallholder farmers. Until to date, the CBBPs breeder cooperatives disseminate enormous number of superior quality breeding rams and breeding bucks in different agroecology of the country (Shigdaf *et al.,* 2012; Kebede, 2017; Zelalem, 2018).

2.5. Productive performance of Sheep in Ethiopia

The overall productivity of the flock and the economic return from the small ruminants is determined by growth trait. Fast growth performance allows sheep to breed early and contribute more numbers of lifetime lamb crop. Faster rate of growth enables attaining an early marketable weight (Berhanu and Aynalem, 2009). Growth rate of lambs particularly during the early stages of growth, is strongly influenced by breed (genotype) and nursing ability of the ewe. Another factor includes the environment under which the animals are maintained and the availability of adequate feed supply in terms of both quantity and quality (Kassahun, 2000; Mengiste, 2008). Pre-mating weight of dam, ewe Parity, type of birth, sex, season and birth season also contribute for growth performances of small ruminants.

2.5.1. Birth weight (BWT)

Birth weight is the weight, that is registered soon after birth within 24 hours. It is an important component in overall sheep productivity since the subsequent growth of the lamb largely depends on it. BWT is influenced by a number of factors such as parity, year of birth, season, age of dam, type of birth, sex and differences between breeds. BWT is often influenced by the maternal environment provided prenatally (Gardner *et al*., 2007). Birth weight influenced the pre-weaning growth of the young and has a positive relationship with subsequent body weight gain (Gbangboche *et al.,* 2006; Mengistie *et al*., 2010; Momoh *et al*., 2013).

Lambs which are heavier at birth are usually singles or are those produced by ewes with larger body sizes under better management conditions. The indication is that lambs heavier at birth have larger adult weight and higher growth capacity given proper management (Kassahun, 2000; Mengistie *et al*., 2010). Studies indicate, animals heavier at birth will weigh more at weaning time and tend to survive better than lighter animals. Therefore, improving early growth performance correspondingly increases the chance of survival of the lamb afterward, affects feed conversion and grading to achieve maximum returns. In the early setup of CBBPs of Menz, Horro and Bonga sheep breeds, the reported preliminary result for BWT were 2.27±0.043 kg, 3.12±0.129kg, 3.42±0.051kg, respectively (Haile *et al*., 2014). Literature indicated that BWT has weak genetic correlation with adult or market weight and its importance for selection in CBBP is insignificant (Jembere *et al*., 2016). The mean values of BWT reported for Ethiopian breeds of sheep has been summarized in Table 2. Among the sheep breeds, the lowest BWT of 1.98 kg was recorded in Debre Birhan agriculture research Centre (DBARC) cited by Tesfaye (2008) and the highest BWT of 3.6 kg was reported in Bonga sheep (Mestafe, 2015).

2.5.2 Weaning weight (WWT)

Weaning weight is a trait of great economic importance in sheep production since it has influence on growth rate and survival (Mengistie *et al.*, 2010). Different values (the values indicated in Table 2 for WWT were reported by different authors. Pre-weaning and post-weaning growth rate of lambs are as important as the pre-weaning growth performances of lambs. Seasonal variation in growth rate is observed in tropics because feed supply varies remarkably (Kassahun, 2000). The other reason is weaning shock, due to, weaning shock, lower growth rate was observed at post-weaning time (Mengistie *et al.*, 2010). The overall least squares mean of Bonga, Horro and Menz sheep breeds were 14.8±0.226, 11.7±0.548,9.3±0.6 kg (Haile *et al*., 2014). The mean values of WWT reported for different Ethiopian breeds of sheep has been summarized in Table 2.

Table 2. Summary of BWT, WWT and 6WT for Ethiopian sheep breeds

Breed/population	Management	BWT (kg)	WWT (kg)	6WT (kg)	Source
Arsi-bale	On farm	2.89	12.23	-	Getahun, 2008
Arsi-Bale	On farm	2.3	10.4	-	Deribe *et al.* (2014)
Jimma ecotype	On farm	2.89	11.6	-	Belete, 2009
Bonga	On farm	3.6±0.01	15.5±0.0	22.2±0.2	Mestafe, 2015
Bonga	On farm	3.42±0.05	14.8±0.226	21.0±0.708	Haile *et al.* (2014)
Horro	On-station	2.4	9.48	-	Tibbo, 2006
Horro	On farm	3.12±0.13	11.7±0.5	17.3±0.8	Haile *et al. (*2014)
Menz	On farm	2.27±0.04	9.3±0.6	13.7±0.3	Haile *et al.* (2014)
Washera	On farm	2.69	7	12.91	Mengiste *et al.* (2010)
Washera	On farm	2.61	11.	15.6	Shigdafe *et al.* (2013)
Farta	On farm	2.5	10.9	12.37	Shigdafe *et al.* (2013)
Simien	On farm	2.96	11.76	15.78	Surafel *et al.* (2012)
Abera	On farm	2.8	12.3	18.5	Marufa *et al.* (2017)
Afar	on station	2.7	11.5	17.2	Yacob, 2008
BHS	on station	2.6	11.4	23.7	Yacob, 2008
BHS	On farm	2.4-2.7	-	15	Wilson, 2011
Gumuz	On farm	2.79±0.03	12.6±0.24	-	Abegaz, 2007
Gumz	On farm	2.84±0.06	12.04±0.21	15.77±0.28	Yohannes *et al. (*2018)
Rutana	On farm	3.71±0.07	14.40±0.23	18.93±0.29	Yohannes *et al*. (2018)
Sekota	On farm	2.73	11.9	-	Yiheyis *et al*. (2012)

Note: BWT-Birth weight, WWT-Weaning weight, 6WT-six-month weight kg-kilograms

2.6. Reproductive Performance of sheep in Ethiopia

Reproductive performance constitutes a major factor determining the economic efficiency of sheep production (Mukasa *et al.,* 2002). It is an indicator of reproductive efficiency and influences the rate of genetic progress in selection program. Reproductive performances like litter size, age at first lambing and lambing interval are important traits indicating the efficiency of an animals or the breed as a whole. Reproductive performance is influenced by several factors. These include genetic potential of the animal, nutritional status, environmental factors (Mukasa *et al.,* 2002), and health status (Aragaw *et al.*, 2011). Reproductive traits are difficult to measure and are strongly influenced by management (Notter, 2000; Regassa, 2018).

2.6.1. Age at first lambing (AFL)

The age at first lambing (AFL) refers to the age from birth up to the first time the ewe gives birth. Early maturing females are known to have a relatively long and fruitful reproductive life and thus it determines the rate of genetic progress and population turnover rate. Age at first lambing of Ethiopian sheep were summarized by Mourad *et al*. (2015) and that was ranged between 411- 475 days.

In the study of Berhanu and Aynalem, (2009), the mean AFL for ewes under village management conditions, local sheep around Jimma zone was 404±65.40 day. Kocho (2007), reported 381 days of an average age at first lambing for Alaba area sheep in southern Ethiopia. Hailemariam *et al*. (2013) reported an average age at first lambing of 372 days in Gamo Goffa Zone, Southern Ethiopia. According to Edea *et al*. (2012), the average AFL for Bonga and Horro sheep were 447 days and 399 days, respectively. Lakew *et al.* (2014) reported an average age at first lambing of 543 days in eastern Amhara region for local Tumelie sheep. According to Taye *et al. (*2016), the mean AFL of Doyogena sheep was 411days which is similar with Afar sheep (Tesfaye, 2008), lower than Washera sheep (Mengiste *et al.*, 2011), and higher than Adilo sheep (Kocho, 2007). AFL of some indigenous Ethiopian sheep breeds studied under different management conditions is presented in Table 3.

2.6.2 Litter size (LS)

Litter size (LS) is one of the most important reproduction traits, especially in small ruminants with a high economic merit and a noticeable impact on profitability. One of the objectives of CBBP is to maximize genetic progress of litter size. These traits are typically important economic weight traits for sheep producers, depended on ovulation rate and is affected by the number of fertilized oocytes. The higher the ovulation rate, the more oocytes will be available for fertilization (Drouilhet *et al.*, 2013). There is increased litter size with an increase in parity (Berhanu and Aynalem, 2009). Another sources of variation for LS are lambing year, season of lambing (Bermejo, *et al.,* 2010), ewe's level of nutrition and ewe management type. With respect to weight of ewes at mating, Abegaz *et al*. (2002) reported 2.5 percent increment in litter size with each kilogram increase in weight at mating for Horro sheep.

Litter size in tropical sheep breeds varies between 1.08 and 1.75 with the average value of 1.38 (Adane and Girma, 2008). In Ethiopia litter size varied from 1.01 in black head somilia sheep to 1.7 in Arsi-Bale breed. LS of Ethiopian sheep breeds like Afar, Menz and BHS sheep is low which is almost close to one lamb per parturition (Tesfaye,2008, Mirkena, 2010) while paramount litter size were reported from Arsi-Bale, Bonga, Doyogena, Adilo and Horro sheep breeds. LS from Bonga and Horro sheep breeds were 1.40 and 1.36 respectively (Edea, 2008). LS of 1.17 and 1.11 were reported for Gumuz and Washera sheep under village management condition. According to Taye *et al.* (2016), twinning rate obtained from Doyogena sheep is higher than other sheep breeds in the country. Doyogena ewes were preferred for their twining ability and thus, huge number of Doyogena ewes were sold directly from Doyogena market by traders and passed in different market channel (Ashenaf *et al.*, 2013). Some Ethiopian litter size of indigenous sheep has been summarized in Table 3.

2.6.3. Lambing interval (LI)

Lambing interval is the interval between two parturitions and is dependent on the variation in, breed, year of lambing, season, ewe parity, level of nutrition, sex of lamb, type of birth and ewe post-partum body weight (Gbangboche *et al*., 2006; Mengiste, 2008; Mourad *et al.,*2015). According to Mohammadi *et al*. (2011), another factor influencing lambing interval is type of mating and restrictions on breeding. The reproductive efficiency is related to the length of parturition interval; *i.e.* ewe with long LI has lower reproductive efficiency (Deribe, 2009). In literature possibility of three or more parturitions happen from indigenous small ruminants in two years (Getahun, 2008).

Short lambing interval 199.2 days was reported from Gumuz sheep breed (Abegaz, 2007) while long lambing interval 336 days was reported from BHS sheep (Aden, 2003). Lambing interval for some indigenous sheep breeds is indicated Table 3.

Table 3. Age at first lambing, lambing interval and litter size of some Ethiopian sheep breeds

Breed	Management	AFL (days)	LI (days)	LS	Source
Doyogena	on farm	411.6	328.2	1.45	Taye *et al.* (2016)
Adilo	on farm	438	NA	1.42	Getahun, 2008
Adilo(Alaba)	on farm	372.9	275.7	1.52	Deribe, 2009
Arsi-Bale (Alaba)	on farm	381	234	1.7	Kocho, 2007
Southwest Ethiopia	on farm	389.1	240	1.4	Belete, 2009
Bonga	on farm	447	267.6	1.4	Edea, 2008)
Horro	on farm	399	276.9	1.36	Edea, 2008; Edea *et al.* *(*2012)
Horro	on farm	NA	268.8	1.57	Demissu and Gobena, 2015
BHS	on farm	706.8	313.8	1.04	Fikrte, 2008
BHS	on farm	NA	336	1.01	Aden, 2003
BHA	on farm	720	420	1.06	Wilson, 2011
Menz	on farm	522	261	1.11	Niftalem, 2000; Tesfaye *et al. (*2013)
Menz	on farm	470.1	255	1.08	Tesfaye, 2008
Menz	on farm	NA	270±27	NA	Haile *et al*. (2014)
Washera	on farm	457±4.	303	1.05	Shigdafe *et al. (*2013)
Washera	on farm	465	274.8	1.11	Mengiste, 2008
Wollo	on farm	636	276	NA	Tesfaye *et al*. (2013)
Gumuz	on farm	410.1	199.2	1.17	Abegaz , 2007
Abera sheep	on farm	387	288	1.5	Marufa *et al. (*2017)
Afar sheep	on farm	405.6	270	1.03	Tesfaye, 2008
Rahmani (Egypt)	on farm	501	NA	1.03	Abd-Allah *et al. (*2011)
Djallonke(Benin)	on farm	621	240	1.4	Gbangboche *et al. (*2006)
D'man(Moroco)	on farm	365	222	1.82	Boujenane, 2006
Chiose(Egypt)	on farm	477	NA	1.37	Abd-Allah *et al. (*2011)

Note: NA= not available; LI=lambing interval; AFL=Age at first lambing; LS= litter size

2.6.4. Annual reproductive rate (ARR)

The impact of reproduction on sheep productivity is best estimated by the annual reproductive rate (ARR) which is defined as the number of lambs weaned per ewe of reproductive age per year. According to Berhanu and Aynalem (2009) ARR is significantly affected by year of lambing and birth type. However, they reported that season of birth and parity had no effect on the trait. ARR for some indigenous sheep breeds is given in Table 4.

Table 4. Annual reproductive rate of different Ethiopian sheep breeds

Breed/population	Management	No	ARR (in heads)	Authors
Adilo	On farm	NA	0.89	Kocho, 2007
Local sheep Around jimma Zone	On farm	388	1.82	Berhanu and Aynalem, 2009
Local Tumelie	On station	158	1.49 ± 0.02	Lakew *et al.* (2014)
Washera	On farm	706	1.40±0.04	Shigdafe *et al. (*2013)
Washera	Station	198	1.46± 0.05	Shigdafe *et al. (*2013)
Farta	On farm	NA	1.29 ±0.08	Shigdafe *et al. (*2013)
Abera sheep	On farm	NA	1.9	Marufa *et al. (*2017)

Note: NA= not available; AFL=Annual reproductive rate

2.7. Genetic Parameter Estimates for Growth and Reproductive Traits

The estimates of genetic parameters are helpful in determining the method of selection 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). Effective breeding programs depend on the accuracy of genetic parameter estimates, which include heritability, repeatability and correlation between traits (Wasike, 2006; Ayalew *et al*., 2017).

According to Safary *et al*. (2005), most of the genetic parameters estimated were based on restricted maximum likelihood (REML) and most of the studies on growth in sheep also included models for partitioning of the maternal effect. Among Ethiopian breeds of sheep, genetic studies including models for partitioning of maternal variance were available for a few sheep breeds like Horro (Abegaz, 2002), Afar and BHS sheep (Yacob, 2008) and Menz sheep (Gizaw *et al*., 2014b).

2.7.1. Heritability (h^2)

Heritability is the proportion of the phenotypic variation which is due to additive genetic effects. It is a measure of the degree to which a trait is genetically determined. Obviously, heritability is important among the several factors determining how much genetic improvement can be made in any trait. If individuals are to be selected based on their phenotypic values, success in improvement can be predicted only from the knowledge of correspondence between phenotypic and the breeding values. This degree of correspondence is measured by heritability.

Comparison of heritability estimates for productive and reproductive traits illustrate, lower estimates for female reproductive than productive traits. This was because female reproductive traits were highly influenced by the environment. The reproductive performance of the dam could thus be more improved through manipulation of production environment than selection

2.7.1.1. Growth traits

Genetic parameters for growth traits of lambs influences the development of sheep production (Mohammadi *et al*., 2013). The heritability estimates reported for growth efficiency traits at various age intervals are summarized in Table 5

(I) Birth weight

According to Gowane *et al.* (2010b), maternal effect formed the main part of variation for birth weight trait due to differences in the intrauterine conditions such as capacity and quality of uterine area for growth and development of the fetus. Also, Permanent maternal environmental variance originated from level of feeding at last stage of pregnancy, uterine environment, maternal behavior, and litter size effect on milk yield of the ewe were main effect for BWT traits (Mohammadi *et al*., 2013).

In the review of Safari and Fogarty (2003) the estimate of BWT direct heritability (h^2a) and maternal heritability (h^2m) for tropical sheep breed, is 0.03 ± 0.02, and is 0.13 ± 0.05 respectively. Direct heritability is smaller for BWT, compared to adult weights (Jembere *et al*., 2016). In the study of Yacob (2008), h^2a estimates for BWT for Afar sheep is 0.13 to 0.38 and BHS 0.20 to 0.58). Abegaz (2002) estimate h^2a for Horro sheep is (0.18 - 0.32) and Gizaw *et al*. (2007) estimate of h^2a 0.46 for Menz sheep.

Table 5. Summary of Heritability Estimate for Growth traits

Trait	Country	breed	Model	h^2a	(h^2m)	Author(s)
Birth weight (BWT)	Ethiopia	Afar	univariate	0.13 - 0.38	0.02 - 0.21	Yacob, 2008
		BHS	univariate	0.2 - 0.58	0.06 - 0.46	Yacob, 2008
		Horro	multi-trait	0.18 - 0.32	0.12 - 0.2	Abigaz *et al. (*2002)
		Menz	multi-trait	0.46	NA	Gizaw *et al*. (2007)
Weaning weight (WWT)	Ethiopia	Afar	univariate	0.11 - 0.37	0.12 - 0.21	Yacob, 2008
		BHS	univariate	0.00 - 0.29	0.15 - 0.20	Yacob, 2008
		Menz	multi-trait	0.48	NA	Gizaw *et al*. (2007)
		Horro	multi-trait	0.10 - 0.26	0.19	Abigaz *et al. (*2002)
6-month weight (6WT)	Ethiopia	Afar	univariate	0.14 - 0.32	0.04 - 0.23	Yacob, 2008
		BHS	univariate	0.00 - 0.43	0.12 - 0.2	Yacob, 2008
		Menz	multivariate	0.51	NA	Gizaw *et al*. (2007)
		Horro	multivariate	0.16 - 0.26	0.24	Abigaz *et al. (*2002)
Yearling weight	Ethiopia	Afar	univariate	0.21 - 0.28	0.02 - 0.25	Yacob, 2008
		BHS	univariate	0.12 - 0.25	0.00 - 0.20	Yacob, 2008
		Horro	multivariate	0.23 - 0.31	0.09	Abigaz *et al. (*2002)
		Menz	multivariate	0.56	NA	Gizaw *et al. (*2007)
ADG0-3	Ethiopia	Afar	univariate	0.08-0.30	0.20-0.28	Yacob, 2008
		BHS	univariate	0.00 - 0.19	0.02 - 0.18	Yacob, 2008
		Afar	univariate	0.09	0.00 - 0.09	Yacob, 2008
		BHS	univariate	0.00	0.00 - 0.02	Yacob, 2008
Birth weight (BWT	Egypt	Farafra	univariate	0.25±0.02	0.40±0.01	Mousa *et al*. (2013)
	Zimbabwe	Sabi	univariate	0.27	0.24	Assan *et al*. (2002)
		Sabi	univariate	0.28±0.04	NA	Matika, 2001
	Morocco	Timahdit	univariate	0.18	0.59	El Fadili *et al*. (2000)
6-month weight (6WT)	Egypt	Farafra	univariate	0.21±0.03	0.19±0.01	Mousa *et al*. (2013)
	Kenya	Dorper	univariate	0.28±0.05	0.19±0.04	Kariuki *et al*. (2010)
	Morocco	Timahdit	univariate	0.50	0.24	El Fadili *et al*. (2000)
	Zimbabwe	Sabi	univariate	0.17 ±0.00	NA	Matika., 2001
	Kenya	Dorper	univariate	0.21±0.05	0.21±0.05	Kariuki *et al*. (2010)
Yearling weight	Zimbabwe	Sabi	univariate	0.25±0.01	NA	Matika. (2001)
ADG0-3	Egypt	Rahmani	univariate	0.51±0.05	0.30±0.003	Radwan and Shalaby, 2017
	Tunisia	Barki	GLM(SAS)	0.23±0.08	NA	Chalh *et al. (*2007)
ADG0-6	Egypt	Rahmani	univariate	0.65±0.07	0.15±0.04	Radwan and Shalaby, (2017)
	Kenya	Dorper	univariate	0.12±0.05	NA	Kariuki *et a*l. (2010)
	Egypt	Rahmani	univariate	0.28±0.03	0.05±0.001	Radwan and Shalaby. (2017)

Note: ADG0-3=pre weaning gain, ADG3-6=post weaning gain, BWT, birth weight, ADG0-6, average daily weight gain from birth to weaning, WWT, weaning weight ,6WT,6-month weight, BHS=black head Somalia; NA=not available

(II) Weaning Weight

The estimates of WWT direct heritability (h^2a) for Afar sheep is 0.11 - 0.37, for BHS 0.00 - 0.29(Yacob, 2008) for Horro sheep 0.10 - 0.26 (Abegaz *et al*., 2002) and Menz sheep was 0.48 (Gizaw *et al.*, 2007). A study conducted by Mohammed *et al*. (2013) heritability estimates of WWT ranged between 0.02 to 0.35.

(III) Post-weaning weights

As Safari and Fogarty (2003), summarize various sheep breeds the estimate of 6WT h^2a and maternal heritability (h^2m) for tropical sheep breeds, is 0.04 ± 0.070, and 0.28 ± 0.18 respectively. Post-weaning growth was more heritable than pre-weaning growth, probably because nutrition was not a limiting factor after weaning. The interests in heritability of the different weights are simply in choosing the most adequate weight to use as a selection criterion to improve growth to weaning. More progress in WWT can be made by selection on post-weaning weight than on weaning weight itself, due to the higher h^2a of the post-weaning weight and its high genetic correlation with direct components of WWT (Al-Shorepy, 1995).

2.7.1.2. Reproductive traits

Age at first lambing and lambing interval were strongly influenced by environmental effects (Lobo *et al*., 2009). In the study of Notter (2012), heritability for most of reproductive traits are in range between 0.05 to 0.15 and opportunities for within-breed selection are therefore limited. As documented by Mekuriaw and Haile (2014) litter size has a higher heritability (0.16 -0.19) than the other components traits like fertility (0.10) and survival rate (0.07 - 0.09) for Awassi sheep breeds.

(I) Litter Size

In several studies, a lot of genetic variation for litter size exists between and within breeds. More studies have recommended genetic improvement of this trait than any other sheep reproductive trait. Heritability estimates for litter size for Horro sheep ranges from 0.06 under the repeatability model to 0.17 under the sire model; the direct heritability was 0.11.

According to Abigaz *et al.* (2002, 2005), the heritability of twinning for Horro sheep was estimated to be 0.15 and 0.07 for the direct additive and a repeatability model which is slightly higher than 0.06 to 0.11.The comparison of heritability estimates for productive and reproductive traits showed lower estimates for female reproductive than productive traits because, female reproductive traits were highly influenced by the environment. It could be more improved through manipulation of production environment than selection (Lobo *et al*., 2009). The high heritability estimates for productive traits were due to the high genetic variances attributed to this trait implying possibility of improvement through selection. Maternal effect is a function of maternal variance that arises from the environment (dam effect). However, at weaning when the lamb is separated from the dam, the maternal environment is withdrawn and thus the effects of this environment on variance declines as the lamb grow and become independent.

2.7.1.3. Improvement of reproductive traits

Estimate of heritability under different models have shown that litter size has low heritability (0.063 to 0.167) and the correlation between direct and maternal additive genetic effect is negative (-0.679) for Horro sheep. Thus, genetic improvement for this trait could be difficult. As a result, improving the weight of ewes at mating could make sizable increase in litter size. The result of a study showed that there could be about 2.5% additional lamb for 1 kg increase in flock average weight at mating (Abegaz and Duguma, 2000). Twinning was found to have medium heritability and repeatability, and moderate to high genetic correlation with number of lambs weaned, birth weight, and weaning weight. These suggest that twinning can be used as a selection criterion for improvement in productivity despite increase in lamb mortality with increase in twinning (Abigaz *et al.,* 2002).

2.7.2. Repeatability

Repeatability is the proportion of total phenotypic variance for a trait attributable to permanent differences among individuals. Knowledge of the repeatability of traits is necessary to predict producing abilities of individuals and to predict the change in production that will result from culling the poorer producers from a population (Ozturk, 2001; Abegaz *et al*., 2005; Cilek *et al*., 2009). The proportion of total differences among individuals are attributable to ‘permanent as opposed to temporary effects that is what proportion of an individual’s superiority or inferiority based upon a single measurement of trait is expected to be expressed in future measurements as well.

Repeatability measures the correlation between the repeated measurements of the same individual. It indicates the gain in accuracy that may be expected from the use of the mean multiple measurements instead of single measurement (Kanakaraj, 2001). Like heritabi1ity, repeatability is not a biological constant. It may vary for different traits and for the same trait within a population over time or the same trait measured in different populations (Falconer and Mackay, 1996). Repeatability value is greater than heritability value since repeatability estimates include the permanent maternal environmental variance in addition to the additive genetic variance component (Abegaz and Duguma, 2000).

2.7.2.1. Repeatability for reproductive traits

Abigaz *et al*. (2002) estimated repeatability of 0.16 for twinning for Horro sheep that was higher than repeatability of fertility (0.02) and 0.08 when service sire model was considered as random and fixed effect. The repeatability of fertility value was lower than repeatability estimates of 0.10 to 0.17 from Finn sheep and Rambouillet sheep by linear sire animal models and threshold sire models.

2.8. Correlation Estimates

2.8.1. Genetic correlation (r_g)

Genetic correlation between two traits is the correlation between breeding values for the two traits. It is a measure of the extent to which the same genes, or closely linked genes, cause simultaneous variation in two different traits. The correlation will be positive or negative depending upon whether the preponderance of pleiotropic or linkage effects results in positive or negative associations. It can be zero if none of the same or closely linked genes affect both traits or if positive effects of some loci cancel negative effects of others. The genetic correlations between traits are useful to predict the difference between direct and correlated response to selection (Falconer and Mackay,1996) and determine the optimum selection procedure to genetically improve the productivity.

In Afar and BHS sheep, genetic correlations (r_g) for BWT and WWT, BWT and 6WT, BWT and yearling weight were high and positive; 0.73,0.86,0.74,0.87.0.70, and 0.65 respectively. The reported genetic correlation for Afar and BHS sheep between WWT with 6WT, WWT with yearling weight, 6WT with yearling weight were 0.78,0.99,0.71,0.89,0.95, and 0.65, respectively (Yacob, 2008). According to Abegaz *et al*. (2002), the estimated genetic correlation between BWT with WWT, BWT with 6WT, BWT with yearling weight, WWT with 6WT, WWT with yearling weight, 6WT with yearling weight for Horro sheep were 0.45,0.33,0.30,0.97,0.83,0.87 respectively. The corresponding genetic correlation for Menz sheep were 0.51, 0.52, 0.49, 0.82, 0.69 and 0.81, respectively (Gizaw *et al.,* 2007). This high and positive genetic correlation indicated that selection for one trait improves the other trait in those sheep breeds

2.8.2. Phenotypic correlation (r_p)

Phenotypic correlation (r_p) is the correlation between phenotypic values of two traits. The (r_p) between two quantitative characteristics describes the extent to which individuals above average for one trait are observed to be above, below, or near average for the other trait. In most literature growth trait, genetic correlations were higher than phenotypic correlations. Gizaw *et al*. (2008) estimated the phenotypic correlation of animal live weight with linear size traits ranged from 0.39 for tail length to 0.77 for chest girth. Kariuki *et al*. (2010) reported that, phenotypic correlations ranged from -0.04 to 0.94 for various body weight and daily weight gain traits.

2.9. Research Gap and Hypothesis

As indicated by Haile *et al.* (2019b), Mirkena *et al.* (2012) and Ayele (2018), CBBPs are being implemented in various communities in Ethiopia intended to increase sheep productive and reproductive performances. An essential part of a functional CBBP is evaluating the outputs and its impacts. For effective evaluation of the breeding program, estimating actual change in breeding value for the trait under selection should be done. Estimation of genetic trend is important to test the efficiency of applied CBBP and to provide breeder, researcher and policy maker with information to develop more efficient selection program in the future.

However, studies on genetic effect of CBBPs on productive and reproductive traits in sheep are scarce in Ethiopia.

Doyogena sheep CBBP is established in 2012 in Doyogena district and there is data collected since establishment. The data recorded contain productive, reproductive and health records. Genetic trend estimate for Doyogena sheep under CBBP is unavailable. Few works conducted on characterization of Doyogena sheep and its production system (Taye *et al.*, 2016). Thus, it is important to estimate genetic improvement trend and evaluate the on-going breeding programs. More information specific to genetic parameter estimation and farmer satisfaction on this CBBP should be made available. And these were the basis for the present study

3. MATERIAL AND METHODS

3.1. Description of Study Area

Doyogena sheep CBBP has been undertaken in Doyogena district located in Kembata Tembaro Zone, found at a distance of 258 km to the Southwest of Addis Ababa (national capital) and 171 km from Hawassa (the regional capital). Doyogena district is bordered on the south by Kacha Birra district; on the west and north sides by Hadiya zone and on the east by Angacha district. It is comprised of 14 Kebele (the smallest administrative unit of Ethiopia) and the location of the study district is shown in Figure 2.

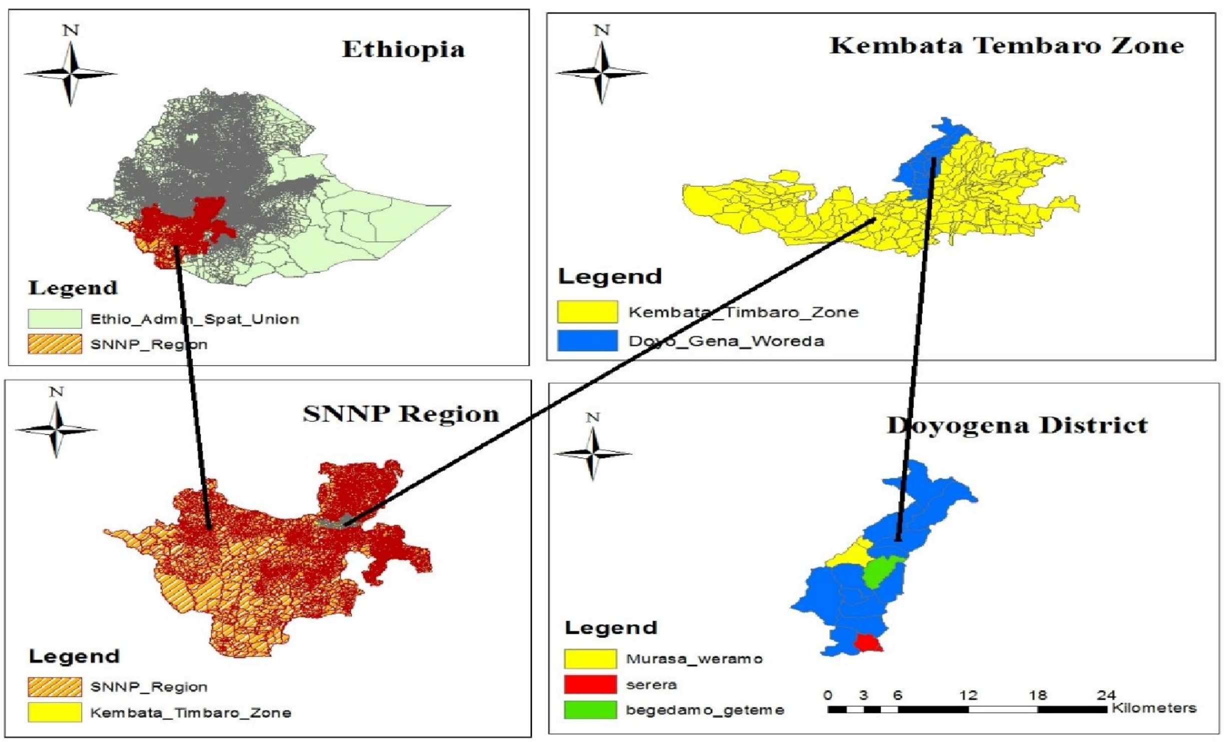


Figure 2. Location of Doyogena district

The basic information of Doyogena district is shown in Table 6. The total area of the District is about 18,089.73 ha, which comprises cultivated land (12,248.6 ha), forest land (3573 ha), grazing land (1110 ha), degraded land (435 ha), swampy land (358.33 ha), potentially cultivable land (202.4 ha) and others (162.4 ha). The total population size of the Doyogena district is about 116,048 of which about 56863 are males and 59185 females. The total household heads are 10171 male 8228 (80.9%) and female 1943 (19.1%) (DDFED, 2018 unpublished). Altitude ranges from 1900 to 2800 meter above sea level (m.a.s.l). The district has highland (70%) and mid land (30%) agroecology.

The maximum, average and minimum land holding per household is 3.5, 0.75 and 0.25ha, respectively and with an average family size of 5 members. The major annual and perennial crops produced in the area include *enset,* potato, wheat, barely, faba bean, sorghum, maize, haricot bean, field pea, and *teff*. The common agricultural practice of the district is mixed crop- livestock production system.In the district main rainy season spans from June to September, small shower falls from February to May and remaining is dry season. The basic information of the district indicated in table 6.

Table 6. Summary of basic information of Doyogena district

Location (latitude and longitude)	7°20' N latitude and 37°50' E longitude
Altitude	1900 to 2800 m.a.s. l
Agro ecology	a. Highland≥2300 m.a.s.l., 70 % of area; b. Midland >500 to <300 m.a.s.l., 30 % of area; and c. Lowland ≤500 m.a.s.l., nil% of area.
Total area	18,089.73 ha i. Cultivated land; 12,248.6 ii. Forest land; 3573 iii. Grazing land; 1110 iv. Degraded land; 435 v. Swampy area; 358.33 vi. Potentially cultivable land; 202.4 and vii. Other land 162.4ha
Species-wise livestock population	a) Cattle; 82271 b) Sheep; 47102 c) Goat; 4501 d) Donkey; 8611 e) Mule;387 f) Horse;2235 g) Honeybee colonies;7692 h) Chickens;9067
Temperature	a) Minimum 12.83°c and b) Maximum 27.76°c
Major crops grown	✓ *Ensete ventricosum,* ✓ Fababean, ✓ Wheat, ✓ Barley, ✓ Field pea ✓ Sorghum, ✓ Maize, ✓ Haricot bean, ✓ *Teff,* and ✓ Horticultural crops
Total human population	116,048 a) Male; 56863 b) Female; 59185

Source: (Ashenaf *et al.*, 2013); (DBoa, 2018)

The district office of livestock and fishery indicated that sheep is the most predominant and important species of livestock, next to cattle. The rainfall pattern from 2010 to

2018(https://climexp.knmi.nl/selectyear.cgi.) has been shown in Figure 3. The district received an average rainfall of 1221 mm between 2013-2017 and smallest total annual rainfall is recorded in 2017 (Figure 3). The minimum, maximum and average temperature of Doyogena district is 12.83°c, 27 °c and 15.30°c, respectively (APPENDIX 11-12)

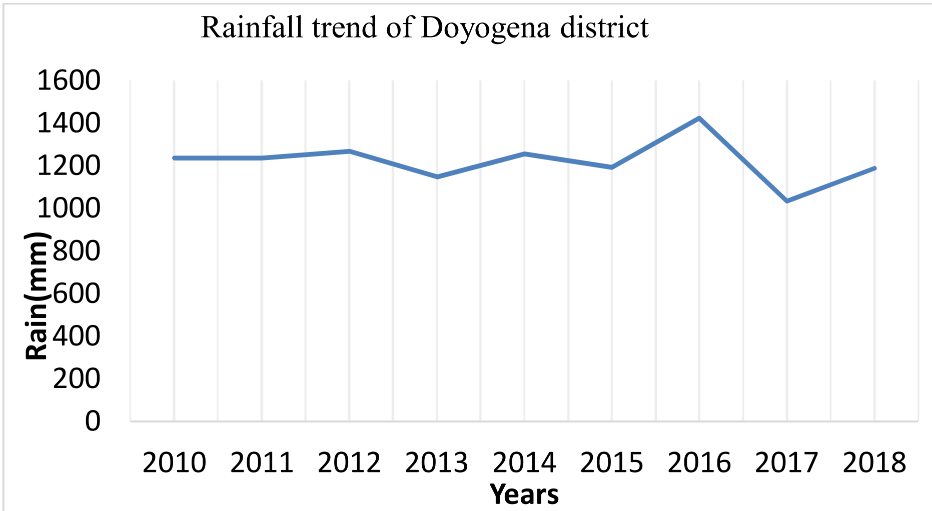


Figure 3. Rainfall pattern of Doyogena district

Source: (https://climexp.knmi.nl/select.cgi?id=someone@somewhere&field=cru4_pre)

3.2. Animal Management

(a) Feeding: Sheep flocks in this study were generally managed by CBBP members. The main feed sources for animals included *Enset* (*E. ventricosum*) products of *Amicho*, corm, crop residue, improved forage/grass, crop aftermath, kitchen leftover, and purchased concentrates. Flocks graze with tethering in the small private land. Feeding in day time and housing at night time is practiced. Often one big house was constructed from bamboo or locally available materials, and shelter for sheep was constructed inside one main house

(b) Veterinary service: Free veterinary service was provided for CBBP participant farmers. Sheep are de-wormed for internal parasite two times a year in January and June. In addition, sheep was given ivermectin for external parasite control, when external parasite infestation is observed (as per the need). Vaccination against blackleg, CCPP and FMD(Orf) has been given once a year while for pasteurellosis, pneumonia and PPR vaccination was given twice a year. Animals were injected with broad spectrum antibiotics (Oxytetracycline L.A.). These operations were usually carried out before and after the rains. Anytime stress was suspected the animals were offered multivitamins (injectable). Moreover, employed health professionals follow up the proper healthiness of animals jointly with participant farmers and data enumerators.

(c) Selection strategy followed: Selection of breeding rams takes place on a programmed date, 2 times per a year. The researcher identifying candidate breeding rams, based on the performance data recorded by the enumerators. Before 2016, selection was done based on the previously quantified selection criteria of overall excellence of animal phenotype (Taye *et al*., 2016). From 2017 onwards, selection was done based on candidate breeding animal estimated breeding value (EBVs). In the first stage, candidate ram's pre-selection and ranking takes place based on WWT. In second stage breeding rams were again ranking based on their 6WT EBVs. Top 10% of the superior breeding rams (1st ranked) were retained for service. 2nd ranked were sold for breeding purpose to other communities. The third ranked were either castrated to be fatted or marketed to prevent un wanted mating (Haile *et al*., 2019b).

Selected best breeding rams serve not more than one year because the rams become big in size and aggressive. Breeding ram holder members sign agreement with the cooperative commitment when they receive the breeding rams. Rams holder handle the breeding rams efficiently. After one-year service, the breeding rams were sold to other area of the region.

3.3. Data Sets

The empirical data and pedigree for the study were obtained from this ongoing CBBP operational in the Doyogena district under Areka Agricultural Research Center (AARC). For implementation of Doyogena sheep CBBP, five cooperatives/sites namely: Ancha Sedecho, Hawora Arara, Serera Bukata, Murasa Wyereramo and Begedamo Getemi were selected. In the cooperative's enumerators were employed to record specified biological data of the sheep flocks owned by members. The research staff of the programme from AARC and other associated institutes carrying regular follow-up of both functionality of the cooperatives and record-keeping practices of the enumerators. Performance data were recorded, as per performance record format prepared by ICARDA. The performance data along with pedigree information is being maintained in Data Recording Book of individual cooperatives.

The data routinely collected by the enumerators were recorded at the time when it happened. At birth, the relevant information about newborn lamb such as owner name, birth date, lamb sex, birth type, lamb birth weight, dam parity, sire ID and dam ID were recorded. Periodically collected data were reported to AARC at least once a month. The data utilized in the present study were (i) productive (growth traits) traits, namely birth weight (BWT), weaning weight (WWT) and 6-month weight (6WT) and (ii) reproductive traits data such as age at first lambing, lambing interval, litter size and annual reproductive rate. The details of the number of observations under each trait are shown in Table 7.

Table 7. Details of number of observations under each trait

S.No.	Name of Trait	Number of observations	Remark
1	Birth weight	2991	
2	Three months weight	2121	
3	6-month weight	1303	
4	Age at first lambing	81	
5	Lambing interval	564	
6	Litter size	2990	Single=1092 (36.5%) Twins =1717 (57.42%) Triplets=161 (5.38%) Quadruplets=20 (0.66%)
7	Annual reproductive rate	564	

The BWT was recorded within 24 hours of lambing; WWT were taken from 85-95 days of age; and 6-month weight was taken between 185-195 days of age. Since both WWT and 6-month weights were recorded on fixed dates, these records were adjusted for fixed age of 90 and 180 days for WWT and 6-month weight, respectively, according to Inyangala *et al*. (1992), as cited by Ayele *et al*. (2015) ;(Sarmiento and Garcia,2007)

Pedigree information reliability and consistency were checked by Pedigree Viewer Software (Kinghorn, 2015). Records with duplicated and bisexuality were removed. Parity was classified as 1, 2, 3, 4, 5, 6 and ≥7 and because of small number of observations all parities above 7 were merged together under parity ≥7. Similarly, birth type was classified as 1, 2, and

≥3 and because of small number of observations; litter size above triplet were included and considered as ≥3. The fixed effect of lambing/birth season was classified in to three classes as main rainy season (June to September) and small shower falls (February to May) and dry season (October, November, December and January). For this study available breeding data from the entire breeder cooperative were compiled by individual lamb ID and were filtered, cross checked for its consistency and informativeness.

3.3.1. Data adjustment

The weaning and 6-month body weights were adjusted at fixed age of 90 and 180 days, respectively, as under:

$$\text{Adjusted weaning weight (kg)} = \frac{90(\text{W2} - \text{W1})}{\text{D}} + \text{W1}$$

$$\text{Adjusted six month weight (kg)} = \frac{180(\text{W3} - \text{W1})}{\text{D}} + \text{W1}$$

Where: W1 = Birth weight;

W2 = Weaning weight on given fixed date;

W3 = 6-month weight on given fixed date

D = Number of days between weighing date and date of birth

The average daily body weight gains from birth to weaning age; weaning to six months of age; and birth to six months of age has been estimated as under:

$$\text{Average daily BW(body weight) gain up to weaning age (gm)} = \frac{\text{AWWt} - \text{BWT}}{90} * 1000$$

$$\text{Average daily BW gain from weaning to 6 month age (gm)} = \frac{\text{A6MWT} - \text{AWWT}}{90} * 1000$$

$$\text{Average daily BW gain from birth to 6 month age (gm)} = \frac{\text{A6MWT} - \text{BWT}}{180} * 1000$$

Where:

BWT=Birth weight,

AWWT=Adjusted weaning weight at 90 days,

A6MWT=Adjusted 6-month weight at 180 days

The annual reproductive rate, which is the number of lambs born per breeding ewes per year, is estimated according to Ibrahim, (1998) as under:

Annual reproductive rate (ARR) $= \frac{LS*365}{LI}$;

Where:

LS = litter size;

LI = Lambing interval;

365= Days of one year

3.4. Farmer's Survey data

To support the genetic trend study, assessment of farmer's perception about the ongoing CBBP also included. The survey was conducted in both participant and non-participant communities. The non- participant farmers were selected from the five breeder cooperatives (Kebeles) and from three neighboring sheep keeping communities (Lemi seticho, Wasera/Eutugae and Gamora Geuwada). The non-participants were initially (first stage) purposely selected based on their (i) experience in sheep rearing as active sheep owners, (ii) proximity with participant farmers, (iii) understanding about sheep breeding and (iv) knowledge about the on-going CBBP in that community. In the second stage both non-participants and participant farmers, as per sample size, were selected randomly. Sample sizes of farmers in the survey were drawn according to Cochran (1977) cited by Kotrlik *et al.* (2001); as:

$$no = \frac{z^2 * p * q}{d^2} \; ; \qquad n1 = \frac{no}{1+\frac{no}{N}};$$

Where:

no=desired sample size;

n_1= finite population correction factors;

N = is total population

Z = standard normal deviation (1.96 for 95% confidence level;

d =is degree of accuracy desired (0.05);

P= 0.11 (proportion of population to be included in sample i.e. 11%) and

q =is 1-P = (0.89);

When the above formula applied;

$$the\ value\ of\ no = \frac{1.96^2 * 0.11 * 0.89}{0.05^2} = 150;$$

The finite population correction factor is used because the total population were <10,000. The detail of which are discussed by Kotrlik *et al*. (2001) and Israel (1992). When the above formula applied, $n1 = \frac{150}{1+\frac{150}{565}}$ =118; (from both group of farmers each118 farmers are sampled). The details of the farmers selected for survey are shown in Table8

Table 8. Details of Farmers selected for survey

Kebeles/Cooperative	Total number of households	Total Number of Participants	number of Participants surveyed	Number of non-participants surveyed
Ancha Sidecho	821	154	24	10
Begedamu geteme	681	66	23	10
Hawora Arara	485	159	24	10
Murasa Weyeramo	664	91	23	10
Serera Bukata	565	95	23	10
Lemi Seticho,	789	Nil	Nil	23
Gemora Gewada	922	Nil	Nil	22
Wasera Eutugae	617	Nil	Nil	23
Total			118	118

The survey was conducted mainly through: (i) individual interviews; (ii) focus group discussion (FGD) and (iii) key informant interviews. A semi-structured questionnaire was prepared and pre-tested before going to actual interview. Afterwards, some changes were made in accordance with respondent's opinion. The questionnaires were administered to the randomly selected households by the researcher of Areka Agricultural Research Center (AARC) and by a team of enumerators. Information through questionnaire from the members were gathered regarding their satisfaction on CBBP, participation and perception on CBBP, trend in improvement, perception on economic importance, perception on breeding ram selection and breeding ram management, awareness development and challenges faced in running the program. Similarly, from non-participant information related to their view about CBBP were considered.

To support the individual interview, focus group discussion was held with a group comprising of 6-8 members of experienced elders in each cooperative. Discussions were done by using a prepared check list. The discussion was focused on farmers' perception of the breeding programs, how ram selection is going, rams using, level of ownership of the programs by the communities, challenges faced in running the programs. Besides, key informant interviews had been conducted with district office of marketing and cooperative office, district office of livestock and fishery. Discussions were done mainly to assess their knowledge and linkage with the cooperative. Key informants were asked with a well-prepared check list. The interview also included local administrations and development agents**.**

3.5. Statistical Analysis of performance data

3.5.1 Effects of non-genetic factors

Data used for analysis included birth weight, three-month weight, 6-month weight, age at first lambing, lambing interval, liter size and ARR. Before conducting the main analysis, data were coded and entered into the computer for analysis and preliminary data analysis; like homogeneity test and normality test were employed. Then, data were analyzed using the Generalized Linear Model (GLM) procedures of SAS version 9.2 (SAS, 2009). The non-genetic factors used in the model included year of birth/lambing (2013 to 2018), season (main rainy season, small rainy and dry season), sex (male and female), parity (1, 2, 3, 4, 5, 6 and ≥7), birth type (single, twin, and triplet or above) and site (Ancha, Hawora, Serera, Begedamo and Murasa). The Tukey-Kramer test was used to separate least squares means with more than two levels. Fixed effects which were significant ($p<0.05$) were fitted in to the model to estimate the genetic parameters.

(I) Growth traits and daily weight gain traits

$$Yijklmn = \mu + P_i + S_j + bt_k + yr_l + Se_m + Sx_n + e_{ijklmn}$$

Where:

Yijklmn = growth trait for each animal

μ = overall mean,

p_i = i^{th} parity (i=7; 1, 2, 3, 4, 5, 6, ≥7)

S_j = j^{th} site (j= 5; Ancha, Hawora, Serera, Murasa and Begedamo)

bt_k = k^{th} birth type (k =3; single, twin, triplet and above)

Yr_l = l^{th} year (l=6; 2013 -2018)
se_m = m^{th} season (m=3; main rainy season, Small shower falls, dry season)
Sx_n= n^{th} sex (n = male, female)
eijklmn = random error

(II) Reproductive traits:

(a) Lambing interval, Litter size and ARR:

$Yijklmn=\mu+p_i+Sj+bt_k+yr_l+se_m+Sx_n+eijklm$

Where:

μ = overall mean,
p_i = i^{th} parity (i=7; 1, 2, 3, 4, 5, 6, ≥7)
S_j = j^{th} site (j= 5; Ancha, Hawora, Serera, Murasa and Begedamo)
bt_k = k^{th} birth type (k =3; single, twin, triplet and above)
yr_l = l^{th} year (l-5; 2014 -2018)
se_m = m^{th} season (m=3; main rainy season, Small shower falls, dry season)
Sx_n= n^{th} sex (n = male, female)
eijklmn = random error

Notice: The fixed effect birth type and lamb sex was not used for LS (lamb birth type) and ARR

(b) Age at first lambing:

$Yijkl= \mu + si + bt_j + se_k + y_l + eijkl$

Where:

Yijkl=Age at first lambing
μ = Overall mean
s_i = i^{th} site (i = Ancha, Hawora, Serera, Begedamo and Murasa)
bt_j = j^{th} birth type (j=single, twin)
se_k = k^{th} season (k = main rainy, small shower falls and dry season)
y_l = l^{th} year (l = 2014-2018)
eijkl= random error

3.5.2. Description of pedigree structure

The information of pedigree structure used for genetic parameter analyses is presented in Table 9 and 10. The parent recorded in the pedigree data include rams, dams, rams with its progeny records and dams with its progeny records. In the data set the number of rams were 406, 272, 217, 279, 214, 215, 54, 7 and 10 for BWT, WWT, 6WT, ADG0-3, ADG3-6, ADG0-6, LS, LI, and AFL, respectively. The corresponding number of dams were 1416, 627, 363, 605, 337, 337,142, 19 and 5, respectively.

Table 9. Description of data set for growth traits

No of: -	Growth Traits					
	BWT	WWT	6WT	ADG0-3	ADG3-6	ADG0-6
Records	2990	2121	1303	2098	1287	1293
animal in pedigree	4497	3367	2232	3383	2264	2272
animals without offspring	2675	1903	1172	1881	1163	1267
animals with offspring	1822	899	580	884	551	552
animals with unknown sire	1238	865	571	871	585	584
animals with unknown dam	1465	1191	872	1222	899	903
animals with both parents unknown	992	739	507	749	516	516
animals with records and unknown sire	318	184	122	204	158	158
animals with records and unknown dams	545	510	423	555	472	477
animals with records and both parent unknown	72	58	58	82	89	90
Sires	406	272	217	279	214	215
sires with records & progeny in data	137	108	78	107	76	77
Dams	1416	627	363	605	337	337
dams with records & progeny in data	178	110	58	110	48	49
Animals with paternal grand sire;	1275	919	449	807	390	392
with paternal grand dam	1341	945	329	690	278	280
with maternal grandsire	308	168	70	166	61	62
with maternal grand dam	338	188	55	150	47	48

Note: *BWT=birth weight, WWT=weaning weight, 6WT=six-month weight*
(ADG0-3) average daily gain from birth to weaning age,
(ADG3-6) average daily gain from weaning to 6 months' age,
(ADG0-6) average daily gain from birth to 6 months' age.SD=standard deviation

Table 10. Description of data set for reproductive traits

Item	Reproductive Traits		
	LS	LI	AFL
No. of records	2128	456	81
No. animal in pedigree	2276	504	210
No. of animals without offspring	2004	444	78
No. of animals with offspring	196	26	15
No. of animals with offspring and records	124	12	2
No. of animals with unknown sire	2020	451	67
No. of animals with unknown dam	1961	441	85
No. of animals with both parents unknown	1950	439	64
No. of animals with records and unknown sire	1948	437	54
No. of animals with records and unknown dams	1889	427	72
No. of animals with records and both parent unknown	1878	425	51
No. of sires	54	7	10
No. of dams	142	19	5
No. of dams with records and progeny in data	124	12	5

Note: LS=*litter size, LI=lambing interval, AFL=age at first lambing, No =number*

3.5.3. Genetic parameter estimates

The variance components and resulting genetic parameters were estimated on a model fitting effects of parity, year of birth/year of lambing, season of birth/season of lambing, type of birth, sex, and site(cooperative) as fixed factors and growth, daily weight gain and reproductive traits as response variables. Genetic parameters for performance traits were estimated by WOMBAT software (Meyer, 2012). WOMBAT is a freely available software package for linear mixed model analysis in quantitative genetics with focus on estimation of covariance components and genetic parameters with restricted maximum likelihood (REML), primarily in animal breeding applications.

Based on the first performed analysis of variance using SAS, significant fixed effects were identified to be included in the models. Then the significant fixed effects were fitted in the subsequent models for estimating genetic parameters**.** Mixed univariate and repeatability animal model were fitted to estimate the genetic parameters. Direct additive and maternal additive genetic effects with or without a covariance between them, and maternal permanent environmental effects were tested for all traits in different combinations to yield six models. The six models were as follows:

(Co) variance components **models**

$y = xb + z_1a + e$ ---- ---------------------- (model 1)

$y = xb + z_1a + z_2c + e$ -------------------------(model 2)

$y = xb + z_1a + z_2m + e$ with $cov(a, m) = 0$ --------------- (model 3)

$y = xb + z_{1a}+z_2m + e$, with $cov(a, m) = A\sigma am$ ------------ (model 4)

$y = xb + z_1a + z_2m + z_3c + e$, with $cov(a, m) = 0$ -----------(model 5)

$y = xb + z_1a + z_2m + z_3c + e$; with $cov(a, m) = A\sigma am$ ---------(model 6)

Where:

y = vector of observed traits of animals;

b, a, m, c= Vectors of fixed effects, direct additive genetic effects, maternal additive genetic effects and maternal permanent environmental effects respectively;

X, Z_1, Z_2 and Z_3 = Incidence matrices, respectively relating fixed effects, direct additive genetic effects, maternal additive genetic effects and maternal permanent environmental effects to y;

e=vector of residuals

Generally, the (co)variance structure for studied traits was as follows:

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

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.

$cov(a,m)$; indicate that whether covariance between direct and maternal additive genetic effects was considered. It was assumed that

$$V(a) = A\sigma^2 a;\ V(m) = A\sigma^2 m;\ V(c) = I\sigma^2\ c;\ V(e) = I\sigma^2 e,$$

I	identity matrix
$\sigma^2 a$	direct additive genetic variance
$\sigma^2 m$	maternal additive genetic variance
$\sigma^2 c$	maternal permanent environmental variance
$\sigma^2 e$	residual variance.

All components, with the phenotypic variance ($\sigma^2 p$) being the sum of $\sigma^2 a$, $\sigma^2 m$, σ_{am}, $\sigma^2 c$, and $\sigma^2 e$, were derived at convergence.

Depending on the model, heritability was computed;

Direct heritability as; $h^2 = \frac{\sigma^2 a}{\sigma^2 p}$

Maternal heritability; $m^2 = \frac{\sigma^2 m}{\sigma^2 p}$ and,

the direct-maternal covariance as proportion of phenotypic variance; ($c_{am} = \sigma_{am} / \sigma^2 p$). The maternal environmental variance ratio was estimated by the maternal permanent environmental variance as a proportion of $\sigma^2 c$ ($c^2 = \sigma^2 c / \sigma^2 p$). The genetic correlation between direct and maternal genetic effects (r_{am}) is estimated as a ratio of the estimates of the σ_{am} to the product of the square roots of the estimates of σ^2_a and σ^2_m.

$$r_{am} = \frac{\sigma_{am}}{\sqrt{\sigma a^2 * \sigma m^2}}$$

The details of which are provided by Meyer (2007).

Total heritability ($h^2 t$) was calculated according to the following equation (Willham, 1972).

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

Heritability interpreted on a scale of 0 to 0.1 low or weak,0.1 to 0.3 medium or intermediate and above 0.3 as high heritability (Berhanu, 2000). To determine the most appropriate model, likelihood ratio test (LRT) was used. The AI-REML algorithm was used in the subsequent analysis to check the convergence. Model comparison under log likelihood (logl) was considered to have a significant influence, when its inclusion caused a significant increase in loglikelihood, compared to the model in which it was ignored.

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 (Meyer, 2004). When log likelihoods did not differ significantly (P>0.05), the model that has fewer parameters were selected as the most appropriate model. The detail information is providedd by Wilson *et al*. (2010) in wombat supplementary file 4.

Additionally, 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).

$AIC = -2 \log L + 2k$

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). All models included an additive direct genetic effect and this is the only random factor in Model 1. Model 2 included the maternal permanent environmental effect, fitted as an additional random effect. Model 3 included an additive maternal effect fitted as a second random effect. Model 4 was the same as Model 3, but allowed for a direct maternal covariance $Cov_{(a,m)}$. Model 5 and Model 6 include additive maternal and maternal permanent environmental effects, ignoring and fitting, respectively, direct-maternal covariance.

The genetic trends were estimated by the weighted regression of the average breeding value of the animals on the year of birth or year of lambing. Estimated breeding value (EBVs) in both direct and maternal additive genetic effects from the univariate analysis were linked to original animal ID by R software (R Core team, 2018). Linear regressions of additive EBV, maternal EBV and maternal permanent environment were done on yearly means (birth year /or lambing year). These procedures were carried out with statistical program R and MS-excel pivot chart. Genetic change over the selection period was calculated by subtracting the mean of the estimated breeding values at the beginning of the CBBP from the mean of the EBV at the time of this study 2018 selection year (Gholizadeh *et al.,* 2015)

Repeatability (r) was calculated as:

$$r = \frac{\sigma^2{}_a + \sigma^2{}_{pe}}{\sigma^2{}_p}$$

Where:

$\sigma^2{}_a$ = additive genetic variance,

$\sigma^2 pe$= permanent environmental variance related to repeated records of ewes and

$\sigma^2{}_p$ = phenotypic variance.

Bivariate and multivariate in WOMBAT software (Meyer, 2007; Meyer, 2012) analysis were applied to estimate 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):

The genetic correlation (r_g):

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

phenotypic correlation (r_p):

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

where:

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

$\sigma^2{}_{a1}$ = genetic variance of trait 1, and

$\sigma^2{}_{a2}$ = genetic variance of trait 2.

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

$\sigma^2{}_{a1}$ = phenotypic variance of trait 1, and

$\sigma^2{}_{a2}$ = phenotypic variance of trait 2.

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

3.6. Statistical Analysis of survey data

The survey data were analyzed through descriptive statistics (frequencies, percentages, cross-tabulation and means) to generate summaries and tables for participant and non-participant farmer using SPSS software (SPSS, 2011) version 20. Statistical significance tests were used to see if there was significant variation between members of the breeder cooperatives and non-members as well as within members of the cooperatives. The variables tested were perceptions on CBBP, knowledge on CBBP and improvement difference. Index were calculated to provide rankings of improvement in growth performance, lamb survival, twining rate, lambing interval, age at first lambing, and flock size.

Index = Sum of (6 x number of households ranked first+5x number of households ranked second+ 4 x number of households ranked third+3xnumber of household ranked fourth + 2x number of household ranked fifth+1x number of household ranked sixth) given for an individual reason, criteria or preference divided by the sum of (6x number of household ranked first + 5x number of household ranked second + 4x number of household ranked third + 3x number of household ranked fourth+2x number of household ranked fifth + 1x number of household ranked sixth) for overall improved traits (Kosgey, 2004).

Chi-square test was employed to see associations between participants and non- participant farmers. In addition, Mann Whitney U test was conducted to test for significant differences between participant and non-participant farmer for variables market participation difference and number of animals sold.

4. RESULTS AND DISCUSION

4.1. Effects of Non-Genetic Factors

4.1.1. Growth Traits

The ANOVA showed that the effect of site/cooperative, birth type, birth year and sex were highly significantly affect ($p<0.01$) on BWT, WWT and 6WT, whereas the effect of parity and season were significant effect ($P<0.05$) on BWT and WWT, respectively (APPENDIX 1, 2, 3).The least square means of these traits are presented in Table 11.

(I) Birth weight (BWT)

The overall least square mean of birth weight along with coefficient of variation (CV) is summarized in Table 11. In the present study, the overall least square mean of birth weight was 3.05±0.025 kg with CV of 17.14%.

The least square means (LSM ± SE) of birth weight for cooperatives (Site) were 2.65±0.03, 3.01±0.03, 3.10±0.03, 3.23±0.04 and 3.05±0.04 for Ancha Sedicho, Hawora Arara, Serera Bukata, Murasa Wyeramo and Begedamo Getemi, respectively. The higher birth weight was recorded from Serera Bukata (3.10±0.03 kg) and Murasa Weyeramo (3.23±0.04 kg) whereas the lower BWT was observed in Ancha Sedicho cooperative. The variation in the BWT over cooperatives (Site), observed in present study, may be due to variations in management practice, availability of feed/fodder and efficiency of data enumerators.

The least square means of birth weight for single, twin, and triplet and above were 3.45±0.03, 3.09±0.02, and 2.48±0.04 kgs, respectively. The difference in the LSM between type of births was significant ($P<0.01$). The BWT showed a descending trend among singles, twins and ≥Triplet where in single born were heaviest and ≥Triplet born lambs were lowest. The same results have been reported by Berhanu and Aynalem (2009). The possible reason for these trends may be explained by limited uterine space during pregnancy among twins/ ≥Triplet, singles, nutrition of dam especially during the last trimester of pregnancy. The LSM for BWT of male and female lambs were 3.14±0.03 and 2.88±0.03, respectively, in the present study.

Male were heavier than female lambs and this may be due to the influence of hormones in the two sexes.

The least squares mean (LSM ± SE) of birth weight for the consecutive years were 3.20±0.08, 3.22±0.05, 3.06±0.03, 2.91±0.03, 2.65±0.03, and 3.01±0.03 kg in 2013, 2014, 2015,2016,2017 and 2018, respectively. The pair-wise comparison of BWT means showed that all pair-wise differences were significant except 2013-14, 2013-15, 2013-18 and 2015-18 which were non-significant. The results showed that there was no clear trend for BWT from 2013-18. Except for the year 2018, where it was increased, BWT had exhibited a decreased tend. The year-wise variation in the BWT may be due to variation in the management and environmental conditions including feeding. Another possible reason could be the absence of sufficient number of records in the initial stage of CBBP and poor data quality. However, after, the enumerators gained experience and large number of data collected, the quality of the data collected may be improved. A similar situation was reported from Bonga and Menz site by Haile *et al*. (2014) and Gizaw *et al*. (2014a).

The lowest BWT (2.65±0.03 kg) observed in 2017 may possibly be due to paucity in availability of forage, as there was scanty rainfall during 2017 (Figure 3), and gradual increase in inbreeding coefficient from 2013 to 2017 (Figure 4).The pair-wise comparison of BWT among seven parities showed that all differences among all pairs were non-significant except parity 1-2, 2-4, 2-5, 2-6 and 2-7 parties which were significant.

The BWT of Doyogena sheep 3.05±0.02 Kg was nearly comparable with BWT of 3.12±0.13 Kg of Horro sheep (Haile *et al*., 2014). Mestafe (2015) and Haile *et al*. (2014) reported BWT of 3.6±0.01 and 3.42±0.05 kg for Bonga sheep that is heavier than the present BWT of Doyogena sheep. This might be associated with the breed or environmental difference (Edea, 2008).

Table 11. Least Squares Means (LSM±S.E) for growth traits of Doyogena sheep

Source of Variation	BWT(Kg)		WWT(Kg)		6WT(Kg)	
	N	mean ±SE	N	Mean ±SE	N	LSM ±SE
Overall	2992	3.05±0.025	2121	14.8±2.49	1304	22±0.22
CV%		17.14		16.86		13.25
Parity		*		NS		NS
Parity 1	1422	3.01±0.02[a]	1042	14.11±0.44	668	21.43±0.2
Parity 2	814	2.94±0.03[b]	543	14.08±0.44	316	21.38±0.23
Parity 3	329	3.02±0.03[a]	237	14.33±0.46	137	21.64±0.3
Parity 4	191	3.01±0.04[a]	135	14.17±0.48	89	21.61±0.35
Parity 5	95	2.97±0.06[a]	73	14.32±0.52	43	22.03±0.49
Parity 6	53	3.04±0.07[a]	41	14.38±0.58	25	22.61±0.63
Parity ≥7	87	3.08±0.06[a]	51	13.80±0.56	26	22.67±0.63
Cooperative		**		**		**
Ancha Sedicho	918	2.65±0.03[d]	566	12.18±0.44[d]	301	22.78±0.25[a]
Hawora Arara	896	3.01±0.03[c]	648	13.85±0.45[c]	397	20.43±0.26[c]
Serera Bukata	512	3.10±0.03[b]	389	15.76±0.45[a]	250	22.79±0.29[a]
Murasa Weyeramo	354	3.23±0.04[a]	290	15.06±0.46[b]	218	21.69±0.30[b]
Begedamo Getemi	311	3.05±0.04[bc]	229	14.00±0.47[c]	138	21.85±0.34[b]
Birth type		**		**		**
Single	1093	3.45±0.03[a]	846	15.25±0.44[a]	529	22.84±0.23[a]
Twin	1718	3.09±0.02[b]	1170	14.47±0.44[b]	712	22.65±0.21[a]
≥Triplet	180	2.48±0.04[c]	106	12.78±0.49[c]	63	20.23±0.42[b]
Sex		**		**		**
Male	1773	3.14±0.03	1345	14.84±0.44	921	23.22±0.22
Female	1218	2.88±0.03	777	13.50±0.44	383	20.59±0.25
Season		NS		*		NS
Main rainy season	1107	3.0±0.03	752	13.95±0.45[b]	439	21.65±0.26
Small shower rain fails	900	3.0±0.03	704	14.44±0.45[a]	470	22.18±0.25
Dry season	984	2.9±0.03	666	14.12±0.44[b]	395	21.89±0.26
Birth year		**		**		**
2013	50	3.20±0.08[ab]		NA		NA
2014	154	3.22±0.05[a]	68	14.57±0.34[b]	34	19.60±0.58[d]
2015	636	3.06±0.03[b]	486	15.66±0.16[a]	301	23.84±0.26[a]
2016	711	2.91±0.03[c]	556	14.60±0.15[b]	353	22.05±0.25[bc]
2017	739	2.65±0.03[d]	605	13.32±0.14[c]	443	21.60±0.22[c]
2018	701	3.01±0.03[b]	406	14.07±0.16[b]	173	22.44±0.31[b]

*Note: 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; 6WT-six-month weight; kg-kilograms; NA-data not available;** highly significant (p<0.01), *significant (p<0.05) and; NS -non-significant (p>0.05)*

(II) Weaning weight (WWT)

In the present study, the overall least square mean of WWT was 14.8±2.49 with CV of 16.86%. The effect of parity was non-significant (Table11).

The least mean squares (LSM ± SE) of WWT for the five sites were 12.18±0.44, 13.85±0.45, 15.76±0.45, 15.06±0.46, 14.00±0.47 for Ancha Sedicho, Hawora Arara, Serera Bukata, Murasa Wyeramo and Begedamo Getemi, respectively. The pair-wise comparison of the means showed that WWT differences among all pairs of cooperatives (Site) were significant except Hawora Arara and Begedamo Getemi cooperatives (Site), which was non-significant. The WWT of Serera Bukata (15.76±0.45) was highest whereas it was lowest (12.18±0.44kgs) in Begedamo Getemi cooperative.

Single born lambs (15.25±0.44 kg) were heavier than twin (14.47±0.44 kg) and ≥Triplet (12.78±0.49). This effect may be attributed to lesser availability of uterine space (horns) among multiple births affecting prenatal nutrition/ development and also competition for dams' milk during pre-weaning period. Similar results were document by several authors (Mengistie *et al.*, 2009; Shigidafe *et al.*, 2013).

Male lambs were significantly heavier than female lambs. The differences in birth weights observed between the sexes might be due to difference in hormones and physiological functions between the two sexes. Tibbo (2006) and Mengistie *et al*. (2009) have documented similar results. The WWT was lowest in main rainy season (13.95±0.45), intermediate in dry season (14.12±0.44) and highest in small shower rainfall (13.95±0.45) indicating that small shower rainfall possibly provided optimum conditions for development of Lambs. The differences in WWT of Small shower rain fail differed significantly from main rainy season and dry season. The effect of season is associated with difference in feed and disease situation (Berhanu and Aynalem, 2009).

The WWT among possible pairs of year of birth were significant except between 2014-16 and 2014-18 years which were non-significant. The possible reasons for year-wise variation in the WWT may be due to variation in the management and environmental conditions including feeding. Results obtained in the current study was nearly comparable with the report of

Yohannes *et al*. (2018); 14.40±0.23 kg for Rutana sheep in traditional management system and Haile *et al*. (2014); 14.8±0.22kg) for Bonga sheep in CBBP management system. However higher result of WWT (15.5±0.0 kg) was reported by Mestafe (2015) for the Bonga sheep breed.

(III) Six-month weight (6WT)

The overall least square mean of 6WT was 22±0.22 kg with 13.25% of CV. The effect of cooperatives (Site), birth type, sex and year of birth on 6WT (Table 11) were highly significant (P<0.01) whereas the effect of parity and season were non-significant.

The least mean squares (LSM ± SE) of 6WT for the cooperatives (Site) were 22.78±0.25, 20.43±0.26, 22.79±0.29, 21.69±0.30 and 21.85±0.34 kg for Ancha Sedicho, Hawora Arara, Serera Bukata, Murasa Wyeramo and Begedamo Getemi, respectively. The 6WT was highest (22.79±0.29) in Serera Bukata whereas lowest 6WT (20.43±0.26) was observed in Hawora Arara cooperative.

The least square means of 6WT for single, twin and ≥Triplet lambs were 22.84±0.23, 22.65±0.21, 20.23±0.42 kg, respectively. The single lambs showed highest 6WT followed by twins and ≥Triplet lambs. This trend was possibly a carryover effect of BWT and WWT where in single born lambs had highest respective weights. The 6WT in males were higher than females (23.22±0.22 VS 20.59±0. 25 kg, respectively). The present result is agreed with previous studies in other breeds by several authors (Duguma *et al*., 2002; Zelalem, 2018; Yohannes *et al*., 2018).

Year of birth was a significant source of variation for 6WT and all pairwise differences were significant except 2016-17, 2016-18 and 2017-18, which were non-significant. Perusal of 6WT across year of birth showed that highest 6WT was recorded in 2015 and lowest 6WT was in 2014. The 6WT for other years (2016, 2017 and 2018) was intermediate between these two years indicating that 6WT failed to show any appreciable increase over years. This could be associated with the lack of accurate ram selection, inadequate follow-up, gaps in enumerator's data recording skill. The other reason could be the difference of year-to-year variation in the availability of feed and other environmental conditions.

The 6WT (22±0.22 kg) of Doyogena sheep was comparable with 6WT of Bonga sheep (22.2±0.21 kg; Mestafe (2015) and (21.0±0.708; Haile *et al*. (2014) under CBBP and higher than 6WT of Menz and Horro sheep breeds under CBBP (Haile *et al*., 2014). However, under on station management system heavier than the present result 23.7 kg of 6WT was reported for BHS (Yacob, 2008).

4.1.2. Daily Weight Gain Traits

The ANOVA of effect of parity, cooperatives (Site), birth types, year of birth and season on average daily weight gains was presented in APPENDIX 4, 5, 6 and least square means of these traits are presented in Table 12.

(I) Daily weight gains from birth to weaning age (ADG0-3)

The overall ADG (in grams) from birth to weaning age was 130.37±2.27gm/day and CV was 22.72%. The effect of cooperatives (Site), birth type, year and sex on daily weight gain from birth to weaning were highly significant ($P<0.01$) whereas the effect of parity and season were non-significant (Table12).

The least mean squares (LSM ± SE) of ADG0-3 of the cooperatives (Site) were 113.3±2.3, 127.5±2.4, 146.5±2.7, and 136.7±2.87 and 128±2.95 gm/day for Ancha Sedicho, Hawora Arara, Serera Bukata, Murasa Wyeramo, Begedamo Getemi, respectively. The differences among cooperatives (Site) were significant among all pairs except Begedamu- Hawora pair which was non-significant. The cooperatives failed to show any trend in the ADG0-3. The least square means of ADG0-3 for single, twin and ≥Triplets were 135.3±2.33, 132.2±2.17and 123.6±3.5 gm/day, respectively. The ADG0-3 means of singles /twins differed significantly from ≥Triplet lambs. The average daily weight gains of ≥Triplet born lambs were lower than Single and twin type of births.

Males lambs had higher average ADG0-3 than females (133.2±2.34 vs 127.5±2.3 gm/day), respectively. The LSM of ADG0-3 across years showed that all pair-wise comparisons of means were significant except 2013-15, 2013-16, 2013-18, 2014-16, 2014-18, 2015-16, 2015-18, 2016-18 and 2017-18 pairs which were non-significant. Tibbo (2006); Mengiste *et al*.

(2010), Surafel *et al.* (2012), and Shigdafe *et al*. (2013) reported lower ADG0-3 in traditional management system compared with the current result. This difference might be attributed to both the genetics (as Doyogena sheep is a large in size and also the better management as practiced by member farmers who are economically dependent (to a large extent) on the sheep sale.

The current result was comparable with the report of Mestafe (2015) who reported 129.1±1.16 gm/day gain from birth to weaning for Bonga sheep under CBBP but higher than the values reported by Haile *et al*. (2014) he, reported 80±0.007 and 90±0.006 gm/day for preliminary result of Menz and Horro sheep.

(II) Daily weight gain from weaning to 6 months age (ADG3-6)

The overall ADG (in grams) from 3 months (weaning) to 6-month age was 80.59±3.62 gm /day and CV was 41.6% (Table 11). The effect of cooperatives (Site), birth type and sex on daily gain from weaning to six-month age were highly significant (P<0.01) whereas the effect of parity, season and year of birth were non-significant. The effect of parity was in line with the report of Yebrah, (2008) where the effect of parity on post weaning gain was not statistically significant (P>0.05) for Afar and BHS sheep on station management condition.

The least mean squares (LSM±SE) of ADG3-6 of the cooperatives (Site) were 107.7±3.74 (Highest), 67.84±3.97 (Lowest), 75.48±4.29,70.58±4.44 and 81.37±4.8gm/day for Ancha Sedicho, Hawora Arara, Serera Bukata, Murasa Wyeramo, Begedamo Getemi, respectively. Perusal of results showed that all possible comparison of cooperatives (Site) for ADG3-6 were significantly different from each other except Hawora- Murasa, Serera- Murasa and Serera- Begedamu cooperatives which were non-significant.

The least square means of ADG3-6 for twin births was highest (86.09±3.4 gm/day) than singles (79.04±3.69 gm/day) and ≥Triplet (76.64±5.78 gm/day; Lowest) in the present study. The highest ADG3-6 in twins, observed in present study, was contrary to the trends shown in both, BWT and WWT, (Table 11) where in singles had highest and ≥Triplet lowest weights in present study. The possible reason may be that postnatal competition was eliminated after weaning and thus twins expressed their potential in ADG3-6. The current result was higher than the previous reports on other Ethiopian sheep breeds (Duguma *et al*., 2002; Tibbo, 2006). Male lambs had higher average ADG3-6 than females (133.2±2.34 vs 127.5±2.3 gm/day, respectively). The result was higher than the report of Tibbo (2006); Mengistie *et al.* (2009) and Shigdafe *et al*. (2013). The current result was higher than the report of Mestafe (2015) who reported daily weight gain of 69.3gm/day for Bonga sheep under CBBP.

(III) Daily weight gains from birth to six months (ADG0-6)

The overall ADG (in grams) from birth to 6-month age was 106.18±1.7 gm /day and CV was 16.34%. The effect of cooperatives (Site), birth type, year and sex on daily weight gain from birth to six-month age (Table12) were highly significant (P<0.01) whereas the effect of parity and season were non-significant (Table12).The present finding of non-significant effect of parity on ADG0-6 months was in agreement with the report of Yacob (2008) where the effect of parity in daily weight gain was not statistically significant (P>0.05) for Afar and BHS sheep on station management condition. The least squares mean (LSM±SE) of ADG0-6 of the cooperatives (Site) were 112.8±1.8 (Highest), 98.45±1.9 (Lowest), 110.4±2, 103.6±2.1 and 105.7±2.3gm/day for Ancha Sedicho, Hawora Arara, Serera Bukata, Murasa Weyeramo, Begedamo Getemi, respectively. The pair-wise comparison of LSM showed that all pairs differed significantly except Ancha Sedicho - Serera Bukata and Murasa Wyeramo - Begedamo Getemi

The least square means of ADG0-6 for twin births was highest (109±1.6 gm/day) than singles (107.9±1.7 gm/day) and ≥Triplet (101.6±2.8gm/day; Lowest) in the present study. The highest ADG0-6 in twins, observed in present study, was contrary to the trends shown in both, BWT and WWT, (Table 11) wherein singles had highest and ≥Triplet lowest weights in present study. The possible reason may be that postnatal competition was eliminated after weaning and thus twins expressed their potential in ADG0-6 and this trend was consistent with ADG3-6. The LSM of singles and twins showed significant difference with ≥Triplet lambs in ADG0-6 trait. The male lambs had higher average (ADG0-6,) than females (110±1.8vs 102.4±1.88 gm/day, respectively). The LSM of ADG0-6 was highest (114.4±1.5 gm/day) in 2015 whereas it was lowest (99.75±7.55 gm/day) in 2013.

Table 12. Least squares mean (LSM±S.E) for daily weight gain traits

Source of Variation	ADG0-3(g) N	ADG0-3(g) mean ±SE	ADG3-6(g) N	ADG3-6(g) mean ±SE	ADG0-6 (g) N	ADG0-6 (g) mean ±SE
Overall	2099	130.37±2.27	1280	80.59±3.62	1294	106.18±1.7
CV%		22.72		41.6		16.34
Parity		NS		NS		NS
Parity 1	1017	131.0±2.2	640	79.11±3.58	644	104.9±1.7
Parity 2	553	131.1±2.4	325	79.5±3.7	329	106.1±1.8
Parity 3	236	130.1±2.7	132	81.37±4.4	136	105.3±2.17
Parity 4	135	132.4±3.2	87	75.86±5.06	89	105.9±2.44
Parity 5	68	130.6±4.1	45	83.41±6.43	45	108.9±3.12
Parity 6	40	129.3±5.1	24	75.07±8.2	24	100.6±4
Parity ≥7	50	128.1±4.6	27	89.84±7.8	27	111.5±3.79
Cooperative		**		**		**
Ancha	567	113.3±2.3^{d}	310	107.7±3.74^{a}	310	112.8±1.8^{a}
Hawora	648	127.5±2.4^{c}	386	67.84±3.97^{b}	390	98.45±1.9^{b}
Serera	376	146.5±2.7^{a}	240	75.48±4.29^{c}	245	110.4±2^{a}
Murasa	281	136.7±2.87^{b}	212	70.58±4.44^{bc}	214	103.6±2.1^{c}
Begedamu	227	128±2.95^{c}	132	81.37±4.8^{c}	135	105.7±2.3^{c}
Birth type		*		*		*
Single	829	135.3±2.33^{a}	522	79.04±3.69^{b}	524	107.9±1.7^{a}
Twin	1164	132.2±2.17^{a}	698	86.09±3.4^{a}	710	109.0±1.6^{a}
≥Triplet	106	123.6±3.5^{b}	60	76.64±5.78^{b}	60	101.6±2.8^{b}
Sex		**		**		**
Male	1298	133.2±2.34	844	84.48±3.72	843	110.0±1.8
Female	801	127.5±2.3	454	76.7±3.87	451	102.4±1.88
Season		NS		NS		NS
Main rainy season	759	128.5±2.47	449	82.54±3.98	454	106.4±1.93
Small shower falls	677	131.5±2.48	433	79.17±3.9	439	105.7±1.92
Dry season	663	131.1±2.4	398	80.07±3.8	401	106.5±1.87
Birth year		**		**		**
2013	9	140.5±10.03^{a}	6	65.82±15.5^{bc}	6	99.75±7.55^{bc}
2014	72	128.6±3.94^{bc}	38	65.43±6.7^{c}	38	99.83±3.2^{bc}
2015	477	138.4±1.94^{a}	306	85.57±3.1^{b}	306	114.4±1.5^{a}
2016	538	128.6±1.8^{ab}	339	84.48±3^{ab}	347	107.0±1.45^{b}
2017	591	120.9±1.7^{c}	403	89.75±2.7^{a}	407	105.7±1.32^{bc}
2018	412	125.3±1.9^{ab}	188	92.51±3.5^{a}	190	110.4±1.7^{abc}

*Note: Mean values with different superscripts across columns are significantly different (P<0.05); LSM-Least Square Means; SE-Standard Error; N number of observations; ** highly significant (p<0.01), *significant (p<0.05) and NS -non-significant (p>0.05; ADG0- daily weight gain from birth to weaning, ADG 3-6-daily weight gain from weaning to 6-month age and ADG0-6-daily weight gain from birth to 6-month age. Ns=non-significant.*

The pair-wise comparison of LSM showed non-significant differences among 2013-14, 2013-16. 2013-17, 2013-18, 2014-16, 2014-17, 2014-18, 2015-18, 2016-17, 2016-18 and 2017-18 pairs whereas all other pairs were significant.

4.1.3. Reproductive Traits

The ANOVA of effect of non-genetic factors on reproductive traits (LS, LI, and ARR) was presented in APPENDIX 7,8,9 and least square means of these traits are presented in Table 13 and 14.

(I) Litter size (LS)

The influence of Parity of ewes, cooperatives (Site), and year of birth on litter size was highly significant ($p<0.01$) and birth season was significant at $p<0.05$ (Table 13). The overall least square means of liter size obtained was 1.75±0.02 litter/head/ewe and CV 34.5%. The present results indicated that liter size increased as parity advanced from 1 to ≥7. The pair-wise means of LS among parities were significant except parities 2-3, 2-4, 3-4 and 5-6 pairs. The increase in the litter size with advancing parity may be due to the fact that ewes attain physiological maturity with advanced age (Mengiste *et al.*, 2010).

The Litter size was highest (1.80±0.03) in Begedamu cooperative whereas it was lowest (1.68±0.03) in Serera cooperative. The pair-wise comparison of LS showed that all pair-wise means differed significantly except Ancha- Hawora, Ancha- Begedamu and Serera- Murasa pairs which were non-significant. The LS failed to show any uniform trend in the LS over the years. The LSM of LS were significantly different among different pairs of years except 2013-14, 2013-15,2013-16,2014-15,2014-16, and 2015-16 pairs which were non-significant. The results of LS in the three seasons of lambing showed that higher LS was observed in wet season (1.78±0.03) followed by 1.76±0.02 in dry season and lower (1.70±0.03) in small shower falls seasons. The differences in LS were significant between main rainy season - dry season and small shower falls - dry season in the present study. The possible reason for high LS in wet season may be due to availability of ample amount of forage. and ewes are fleshed well in small shower fail season. The present finding was in agreement with the report of Aragaw (2011) and Taye *et al*. (2016).

Table 13. Litter size, lambing interval LSM±SE (days)and annual reproductive rate (ARR)

Source of Variation	Litter size		Lambing interval (days)		ARR	
	N	LSM ±SE	N	mean ±SE	N	mean ±SE
Overall	2167	1.75±0.02	564	281.22±8.8	564	2.16±0.06
CV%		34.5		26.3		41.74.12
Dam parity		**		**		**
Parity 1	1146	1.37±0.02[c]	159	325.99±9.3[a]	159	1.86±0.07[b]
Parity 2	511	1.70±0.02[b]	161	269.5±9.2[b]	161	2.20±0.07[a]
Parity 3	229	1.72±0.04[b]	117	286.6±10.33[b]	117	2.19±0.09[a]
Parity 4	120	1.71±0.05[b]	55	282.37±12.57[bc]	55	2.29±0.12[a]
Parity 5	64	1.75±0.06[ab]	35	255.45±15.01[c]	35	2.32±0.16[a]
Parity 6	36	1.92±0.09[ab]	11	276.00±24[bc]	11	1.84±0.0.28[b]
Parity≥7	61	2.01±0.07[a]	26	272.48±17.33[bc]	26	2.28±0.18[a]
Site		**		NS		NS
Ancha	665	1.78±0.02[a]	197	285.15±8.6	197	2.23±0.058
Hawora	631	1.78±0.03[a]	134	267.84±10.6	134	2.25±0.072
Serera	401	1.68±0.03[b]	121	278.65±11.05	121	2.09±0.075
Murasa	262	1.69±0.04[b]	70	279.06±12.85	70	2.10±0.08
Begedamu	208	1.80±0.04[a]	42	295.41±14.67	42	2.14±0.09
Lamb birth type	-	-	-	NS	-	-
Single	-	-	219	279.29±8.4	-	-
Twin	-	-	316	287.10±7.8	-	-
≥triplet	-	-	37	277±16.74	-	-
Lambing year	-	**		NS		NS
2013	32	1.71±0.09[ab]	-	-		-
2014	111	1.67±0.1[ab]	32	290±16.2	32	2.22±0.11
2015	469	1.72±0.03[ab]	123	303±9.4	123	2.00±0.06
2016	511	1.73±0.03[ab]	127	283±9.4	127	2.1±0.06
2017	537	1.64±0.02[b]	150	279±9.0	150	2.19±0.06
2018	507	1.75±0.02[a]	123	286±9.5	123	2.29±0.06
Lambing season		*		NS		NS
Main rainy season	1101	1.78±0.03[a]	222	279.9±9.8	222	2.23±0.06
Small shower falls	894	1.70±0.03[b]	165	276.6±10.5	165	2.05±0.07
Dry season	965	1.76±0.03[ab]	177	287.09±9.8	177	2.22±0.06
Lamb sex	-	-		NS		NS
Male	-	-	325	274.8±9.04	325	2.18±0.07
Female	-	-	239	287.65±9.8	239	2.14±0.08

*Note: Note: Mean values with different superscripts across columns are significantly different (P<0.05); LSM-Least Square Means; SE-Standard Error; N number of observation; NA- data not available;** highly significant (p<0.01),* significant (p<0.05) and NS -non-significant (p>0.05) , ARR=Annual reproductive rate*

The current result of litter size was higher than several previous authors reported by Kocho (2007); Getahun (2008); Deribe (2009) and Taye *et al.* (2016) but slightly higher than the current estimate was reported 1.82 litter/head/ewe for Moroccan D'man sheep breed by Boujenane (2006).

(II) Lambing interval (LI) and annual reproductive rate (ARR)

The effect of parity was highly significant (P<0.01) on both LI and ARR. However, effect of cooperatives (Site), year of birth, season of birth and sex of lamb were non-significant on both LI and ARR. The overall least squares mean for LI and ARR, in the present study, is 281.22±8.8 days and 2.16±0.06, respectively, and their corresponding CV was 26.3 and 41.7%, respectively.

The pair-wise comparison showed that all pair-wise comparisons were significant except parity 1-2, 3-4, 3-6, 3-7, 4-5, 4-6, 4-7, 5-6, 5-6 and 6-7 parities which were non-significant. This result was in agreement with the report of Mengiste (2008) and Regassa (2018) who stated that, as parity increases the lambing interval decreased. In the present study, the longest (325.99±9.3 days) and the shortest (255.45±15 days) LI observed were in the first parity and fifth parity ewes, respectively. The shorter lambing interval, recorded in parity five in the current study was agreed with report of Berhanu and Aynalem (2009). The longest LI in first parity ewes, observed in present study, may possibly be due to the fact that reproductive organs of ewe may not be fully developed at this stage.

The present results of LI in Doyogena sheep was comparable with lambing interval of the 276, 275.7, 288, days reported for Horro sheep, Adilo (Alaba) sheep and Abera sheep respectively, reported by Edea *et al*. (2012); Deribe (2009) and Marufa *et al*. (2017).However, Abegaz (2007) reported that Gumz sheep had an average lambing interval of 199.2 days which was the shortest lambing interval compared with other breeds of sheep in the country. The present finding was within the range of 270–360 days reported LI for tropical sheep (Gatenby, 2002). Similarly, the present estimates of ARR (2.16±0.06) were higher than the report of 1.49 ± 0.02 for Washera sheep (Lakew *et al.,* 2014);1.29 ±0.08 for Farta sheep

(Shigdaf *et al*., 2013) and 1.82 ± 0.44 for local sheep around Jimma Zone (Berhanu and Aynalem, 2009).

The reproductive performance in terms of ARR, from the data showed that lower ARR (1.86±0.07) and highest ARR as ewes' parity advanced. This seems to be logical as LS was lowest in first parity ewes and thereafter showed improvement in subsequent parities, which is reflected in lower and higher ARR in first and subsequent parity ewes. The effect of parity on ARR was also reported by Berhanu and Aynalem (2009), who reported that ewes in their early parity showed a smaller ARR than ewes in the middle parities. Particularly in parity 5 ewes had in average higher ARR value than the remaining parity. The possible reason may be that ewes in their middle parity may attain their physiological maturity, which contributed to have shorter LI and higher ARR.

(III) Age at first lambing (AFL)

The ANOVA of effect of non-genetic factors (Parity, cooperatives/site, birth type, season of birth and year of birth) on AFL was presented in (Appendix 9) and least square means of AFL are presented in Table 14. The overall mean of AFL was 437.43±31days (14.58 months) with 18.01% of CV in the present study.

The present duration of AFL (437.43 days or 14.58 months) in Doyogena sheep was almost comparable with the earlier report of Getahun (2008) who reported 438 days of AFL under village management conditions in Alaba but was slightly longer than the report of Taye *et al.* (2016) who stated that AFL of Doyogen sheep was 411.6 days. Compared with other Ethiopian sheep breeds, the present finding was shorter than AFL of 470 days for Menz sheep (Tesfaye *et al.,* 2013); 447 days in Bonga sheep (Edea, 2008); 465 days in Washera sheep(Mengiste, 2008) and 636 days in Wollo sheep(Tesfaye *et al.,* 2013).However, the present finding of AFL in Doyogena sheep is slightly longer than 381,408,399 and 387 days for Arsi-Bale sheep, Jimma Zone ecotype, Horro sheep and Abera sheep, respectively reported by Kocho (2007); Berhanu and Aynalem(2009); Edea(2012); and Marufa *et al*. (2017) respectively.

Table 14. Age at first lambing LSM±SE (days)

Source of Variation	Age at first lambing(days)	
	N	mean ±SE
Overall	80	437.43±31
CV%		18.01
Site		NS
Ancha Sedicho	23	481±34
Hawora Arara	31	432±30
Serera Bukata	12	447±39.28
Murasa Wyeramo	9	413±40
Begedamo Getemi	5	412±48
Birth type		NS
Single born ewe	47	431±35
Twin born ewe	31	400±59
Ewe birth season		0.8845
Main rainy season	30	430±34
Small shower falls	26	440±30
Dry season	24	441±37
Ewe year of birth		NS
2014	7	407.9±43
2015	36	433±29
2016	30	470.5±32.6
2017	5	437±46.4

*Note: LSM-Least Square Means; SE-Standard Error; N number of observations; ** highly significant (p<0.01), *significant (p<0.05) and NS -non-significant (p>0.05)*

4.2. Inbreeding

The average coefficient of inbreeding trends (% per year) is illustrated in Figure 4. Coefficient of inbreeding (F) shows increasing trend within the 6-year selection period. The coefficient of inbreeding was assumed to be zero until the year 2014, afterwards it increased with the selection years. At the time of study (2018), coefficient of inbreeding was 0.30% with average annual inbreeding trend 0.0823%. The proportions of inbred animals in the population were 37. Amongst the inbred animals 18.4% of inbreeding were found. Inbreeding was peak in 2017, after which there was a somewhat fall in percentage. The most likely reason for this inbreeding increment could be selection of superior breeding rams without seeing their detail pedigree. It is; however, there might be take measurement taken in 2018 and the F trend slightly decreased. Studies have shown that, inbreeding levels, higher than 10% could lead to inbreeding depression.

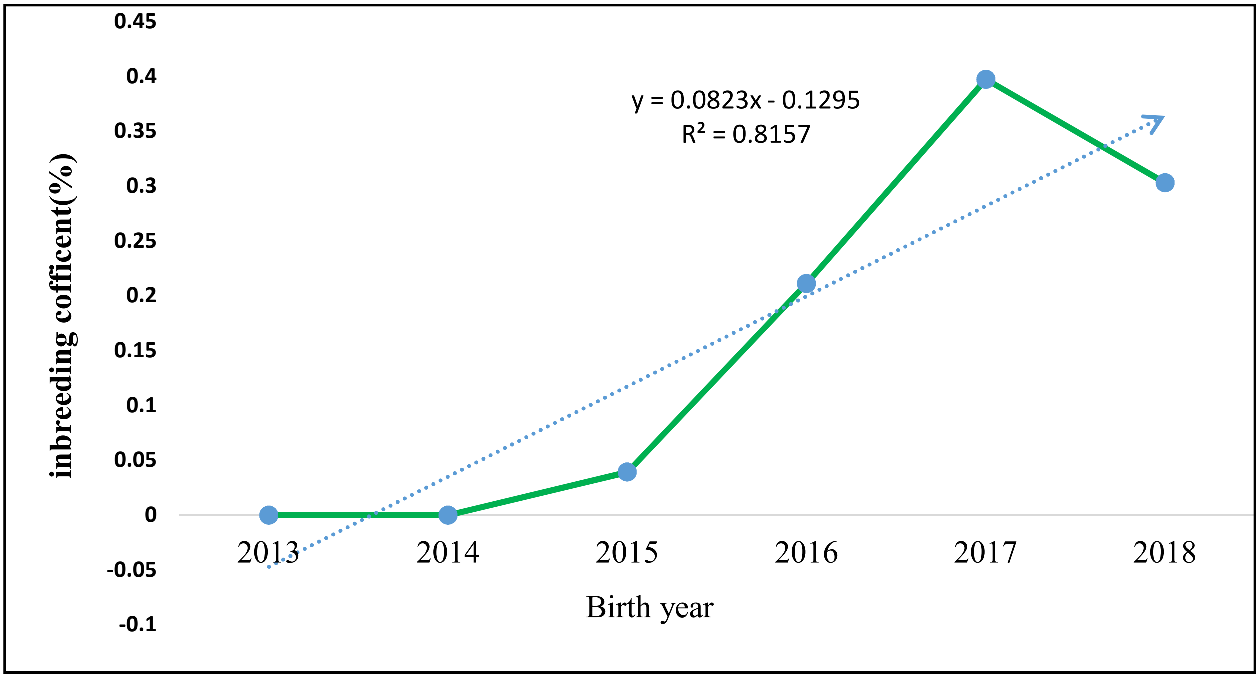


Figure 4. Annual mean of inbreeding

The inbreeding coefficients (F) obtained for Doyogena sheep considerably in acceptable percentage, however, F is in an increasing trend, and thus consideration should be given during allocation of breeding rams. Negussie *et al.* (2002) reported, inbreeding coefficient of 0.78% with annual trend 0.07% for Horro sheep on the station management system. In the study of Gizaw *et al*. (2013), inbreeding coefficient for Menz sheep was 1.7% with 0.17% increment per generation. When inbreeding was on the rise in the populations and in general, inbreeding leads to reduction in additive genetic variance and heritability (Falconer and Mackay, 1996). The traits declined with increase in inbreeding and caution should be taken in during selection. Annual inbreeding trends for the 5-breeder cooperative have been illustrated in APPENDIX 23.

4.3. Model comparison from univariate analysis

Log L and AIC value of all the different models on the traits considered are presented in Table 15 and 16. The most suitable models are marked in bold font .The univariate analysis of 6 different models for BWT, WWT, 6WT, ADG0-3, ADG3-6, ADG0-6, LS, LI, and AFL showed that the changes in estimates of (co)variance components tended to be different. The full model (Model 6) for BWT had the highest logL value. The result in Table 15 showed that allowing for direct and maternal additive genetic covariance (Model 4) for WWT significantly increase log L when compared with other models. It can be shown that allowing for direct and maternal additive genetic covariance (Model 4) for WWT significantly increase logL when compared with other models. The most appropriate models for average daily weight gain and litter size traits showed that maternal permanent environmental influences were important for those raits. The most appropriate model for AFL and LI is model 1.

Table 15. Log L Values from Univariate Analyses for each Trait (Best model in bold Font)

Model	model 1	model 2	model 3	model 4	model 5	Model 6
BWT	499.44	548.56	546.44	552.51	551.04	**562.50**
WWT	-2975.77	-2964.902	-2969.47	**-2918.72**	-2926.40	-2985.26
6WT	-2096.33	**-2074.64**	-2074.33	-2074.33	-2069.45	-2074.12
ADG0-3	-8110.37	**-8095.67**	-8093.89	-8095.81	-8095.67	-8094.73
ADG3-6	-5288.45	**-5286.38**	-5287.07	-5287.05	-5286.38	-5286.344
ADG0-6	-4369.38	**-4355.17**	-4361.28	-4360.49	-4358.82	-4358.762
LS	238.471	**243.345**	244.286	245.643	244.286	245.643
LI	**-2721.333**	-2721.333	-2721.334	-2721.320	-2721.333	-2721.334
AFL	**-452.207**	-450.336	-452.209	-450.544	-450.185	-449.884

Note: $P<0.05$ was used to identify the best model, BWT=birth weight, WWT=weaning weight, 6WT = six- month Weight, ADG0-3 = average daily gain from birth to weaning age, ADG3-6=average daily gain from weaning to 6 months' age, ADG0-6=average daily gain from birth to 6, months' age, LI) =Lambing interval, LS=litter size, AFL= age at first lambing.

Table 16. AIC values from univariate analyses for each trait (best model in bold Font)

Model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
BWT	**501.43**	551.56	549.44	556.51	555.04	567.50
WWT	-2973.77	-2961.90	-2966.47	-2914.72	-2922.40	**-2980.26**
6WT	**-2094.33**	-2071.64	-2067.63	-2070.33	-2065.45	-2069.12
ADG0-3	**-8108.37**	-8092.67	-8090.89	-8091.81	-8091.67	-8089.73
ADG3-6	**-5286.45**	-5283.38	-5284.07	-5283.05	-5282.38	-5281.34
ADG0-6	**-4367.38**	-4352.17	-4358.28	-4356.49	-4354.82	-4353.76
Litter size	**309.93**	310.93	314.30	319.60	315.30	320.60
LI	**-2719.33**	-2718.33	-2718.33	-2717.32	-2717.33	-2716.33
AFL	**-450.21**	-447.34	-449.21	-446.54	-446.19	-444.88

Note: LI=Lambing interval, AFL= age at first lambing

4.4. Variance component and genetic parameter estimates for growth traits

The results of estimated variance and covariance components of direct heritability, maternal heritability, maternal permanent environmental variance and correlation of direct genetic with maternal genetic in different models are presented in Table 17. Based on the log likelihood ratio test, the most suitable model for BWT, WWT and 6WT were model 6, model 4 and model 2 as it is bold font in Table 17.

The variance component due to direct genetic effect for BWT was 0.09 with relative variance due to maternal genetic effects of 0.08. Variance due to permanent maternal environmental effects that is an effect of the dam (possibly due to uterine capacity, feeding level at late gestation, and maternal behavior of the ewe), were 0.06 and 3.01 of the total variances for BWT and 6WT, respectively. The estimate of variance component for WWT due to direct genetic effects was 2 with relatively higher variance of maternal genetic component of 3.85. This result showed that the role of maternal genetic effect in BWT and WWT was the most important source of variation next to unknown environmental effects (which is almost the greatest source of variations) in creating phenotypic variations.

Based on the appropriate models, the estimates of direct heritability (h^2a) for BWT, WWT, and 6WT were 0.33±0.06, 0.31±0.06, and 0.14±0.06, respectively. Except the moderate heritability estimates for 6WT, which reflect less variation among lambs at 6-month age, the estimates of direct heritability for BWT and WWT fall within the range of values reported in the high heritability value. The results showed that from an early age to a 6-month age, the proportion of genetic effects on variation is decreased as the proportion of environmental effects increased. This indicate, that the effects of unknown environmental effects also direct effects on growth traits as the lamb aged from birth (0.12), WWT (2.72) and 6WT (5.11) continuously increased.

The present estimate of direct heritability for BWT (0.33±0.06) was; found in the range reported by Yacob (2008) of a direct heritability estimated for Afar sheep (0.1-0.38) and BHS sheep (0.2-0.58) using univariate analysis. A very high estimated h^2a of (0.46) from the multi-trait animal model was estimated for Menz sheep by Gizaw *et al*. (2007), while Abegaz *et al.*

(2002) estimated h^2a of 0.20±0.05 for Horro sheep using same model and reported lower estimate than the current estimate for Doyogena sheep. The current result was higher than the estimate of Assan *et al*. (2002) for Sabi sheep (0.28), El Fadili *et al*. (2000) for Moroccoian Timahdit sheep (0.18) and Gizaw *et al.* (2014b) for Menz sheep (0.019±0.036) using multi-trait individual animal model analysis.

The estimate of h^2a for WWT (0.31±0.06) was also found in the estimated range reported by Yacob (2008) for Afar sheep (0.11 - 0.37) and BHS sheep (0.00 - 0.29) but lower than the estimated for Menz sheep (0.46) by Gizaw *et al*. (2007).The estimate by Abegaz *et al.* (2002) for Horro sheep (0.16±0.05) and Gizaw *et al.* (2014b) for Menz sheep (0.194) was lower than the present estimates.

The estimate of direct heritability(h^2a) for 6WT (0.14±0.06) was found in the range of direct heritability estimated for Afar sheep (0.11-0.37) and BHS (0-0.29), while, the report of Gizaw *et al.* (2014b) for Menz sheep 0.46 was much higher than the present estimate. Abigaz *et al.* (2002) estimated 0.18±0.05 of direct heritability for Horro sheep that was lower than the current estimate. From the genetic point of view, higher direct heritability estimates for BWT and WWT indicates that high variation within the breed and will be a greater opportunity for selection response during genetic improvement through selection for these traits. Moreover, WWT will be the best criterion for selection to increase pre weaning growth rate because selection on the basis of BWT which has the highest heritability could cause dystocia. However, the confounding effect of direct genetic and maternal genetic effect need to be consideration. For more accurate estimation of genetic effects on 6WT traits, controlling the environmental advert effects could decrease its effect to this trait.

The permanent maternal environmental effect (c^2) for BWT was moderate in this study (0.20±0.09). This indicates the importance of maternal environment and care at the birth of lambs. The current estimates were similar to the findings of Gowane *et al*. (2010a) in Bharat Merino sheep (0.19 ± 0.02) and Singh *et al*. (2016) with Marwari sheep breed(0.19 ± 0.031). For the 6WT trait, the maternal environmental effect is more important than maternal genetic effects. A similar finding was reported by Meyer (1992) in Herefords cattle and Venkataramanan (2013) for Nilagiri and Sandyno Indian sheep breeds. The result suggested that, even if maternal effects tend to diminish with age, some adult traits will nevertheless contain this source of variation (Robison, 1981).

The current finding of BWT and WWT indicated that maternal heritability(h^2m) is important variance components and the estimates were 0.24±0.12 and 0.60±0.07 respectively. compared with other study, the BWT maternal heritability estimate was ranged in the estimate for BHS sheep (0.06-0.46) estimated by Yacob (2008).

Abegaz (2002); Assan *et al*. (2002) and Yacob (2008) estimated h^2m of 0.12±0.2, 0.24, and 0.02-0.21 for Horro sheep, Sabi sheep, and Afar sheep respectively and these all value are lower than the present estimate. However, higher estimated value of h^2m were reported for Moroccoian Timahdit sheep (0.59) by ElFadili *et al.* (2000) and Farafra sheep (0.40±0.001) by Mousa *et al*. (2013). The present estimate of maternal heritability (0.6±0.07) for WWT was higher than the above-mentioned sheep breeds estimated maternal heritability.

High and negative additive-maternal genetic correlation estimates were observed (Table 17) for BWT (-0.61±0.15) and WWT (-0.81±0.11) traits. Similar results were summarized by Safari and Fogarty (2003) for a wide range of sheep breeds. The correlation estimates between direct additive and maternal genetic effect (r_{am}) for both the traits become negative means improvement in one will result in reduction of another. The result might be due to the structure of the data set used in the analysis i.e. the number of generations the animals were measured both directly and as dams were limited caused lack of large pedigree.

It is essential to have a high proportion of dams and dams of dams with records (Safari *et al.,* 2007). However, the data set for the present study were collected over only a period of 6 years, it could be lacking the optimum pedigree structure for accurate and reliable estimates of direct-maternal covariance components. Maniatis and Pollott (2003) reported similar reason for the estimation of correlation between direct and maternal genetic effects that dependent on pedigree relationships. Meyer (1992); Radwan and Shalaby (2017) estimated similar r_{am} of -0.59 and -0.78 for Hereford cattle and Rahmani Lambs respectively. Similarly, Singh *et al*. (2016) estimated similar results for Marwari sheep and he recommended, the inclusion of sire

× year interaction in the model could lead to a reduction in the negative correlation estimate between the animal effects. The present analysis, however did not include this interaction.

The estimates of total heritability (h^2t) for BWT, WWT and 6WT were 0.21, 0.12, and 0.14, respectively. The estimate of total heritability (h^2t) of for the mentioned traits were in the moderate range and decrease in value as the lamb advance in age. The high estimates in early body weights may be due to the fact that lambs receive better management at an early age. In the studied community farmers have the tremendous practical knowledge on sheep keeping and their earlier knowledge coupled with scientific rearing (CBBP) results in faster improvement in lamb body weight. Since the area has been practically limited grazing land to rear a greater number of sheep, many numbers of farmers are more focusing on lamb's quality with better management in the early age of lamb to be sold after weaning age. This might result the lambs raised in a better nutritional environment. This could result the lambs expressing their genetic potential at early age. Edriss *et al*. (2002), reported similar results and reasons for Iranian Bakhtiari sheep breed.

Compared with other study Abegaz (2002) reported for Horro sheep a direct heritability of 0.20±0.05, 0.16±0.05 and 0.18±0.05 for BWT, WWT, and 6WT respectively. The total heritability estimates reported by the author were 0.14, 0.12 and 0.21 for Horro sheep for BWT, WWT and 6WT, respectively shown little increment across lamb age, which is slightly in contrast with the present results.

Generally genetic parameter for growth traits in this study indicated that, maternal genetic effects on BWT and WWT of Doyogena lambs need to be considered during selection programme, also the direct-maternal genetic covariance was important for BWT trait. The result indicated that, maternal effects were important for weights until about 6 months of age.

Table 17. Estimates of (co) variance components and genetic parameters for growth traits

Models	Model 1	Model 2	Model 3	Model 4	Model 5	**model 6**
Birth weights						
$\sigma^2{}_a$	0.14	0.07	0.069	0.095	0.073	**0.09**
$\sigma^2{}_c$	-	0.08	-	-	0.071	**0.06**
$\sigma^2{}_m$	-	-	0.08	0.137	0.015	**0.08**
σ_{am}	-	-	-	-0.06	-	**-0.05**
$\sigma^2{}_e$	0.13	0.12	0.12	0.11	0.12	**0.12**
$\sigma^2{}_p$	0.28	0.28	0.28	0.28	0.28	**0.28**
$h^2a \pm S.E$	0.51±0.04	0.26±0.04	0.24±0.04	0.33±0.0	0.25±0.05	**0.33±0.06**
$c^2 \pm S.E$	-	0.3±0.02	-	-	0.25±0.08	**0.20±0.09**
$h^2m \pm S.E$	-	-	0.30±0.02	0.48±0.0	0.05±0.08	**0.24±0.12**
$r_{am} \pm SE$	-	-	-	-0.53±0.1	-	**-0.61±0.15**
h^2t	0.51	0.26	0.39	0.25	0.28	**0.21**
Weaning weight						
$\sigma^2{}_a$	2.29	2.26	1.1034	**2**	1.10	2.00
$\sigma^2{}_c$	-	0.86	-	**-**	1.00	0.79
$\sigma^2{}_m$	-	-	2.03	**3.85**	1.02	3.05
σ_{am}	-	-	-	**-2.1**	-	-2.2
$\sigma^2{}_e$	3.99	3.22	3.24	**2.72**	3.25	2.75
$\sigma^2{}_p$	6.29	6.33	6.38	**6.35**	6.38	6.35
$h^2a \pm S.E$	0.36±0.05	0.35±0.05	0.17±0.04	**0.31±0.06**	0.17±0.04	0.31±0.06
$c^2 \pm S.E$	-	0.14±0.02	-	**-**	0.16±0.03	0.22±0.08
$h^2m \pm S.E$	-	-	0.32±0.03	**0.60±0.07**	0.16±0.0	0.39±0.01
$r_{am} \pm SE$	-	-	-	**-0.81±0.11**	-	-0.99
h^2t	0.36	0.35	0.33	**0.12**	0.25	0.04
6-month weight						
$\sigma^2{}_a$	3.6	**1.30**	1.16	1.93	1.28	1.82
$\sigma^2{}_c$	-	**3.01**	-	-	2.77	4.9
$\sigma^2{}_m$	-	**-**	3.003	4.20	0.25	2.44
σ_{am}	-	**-**	-	-1.50	-	-1.14
$\sigma^2{}_e$	5.85	**5.11**	5.28	4.88	5.12	4.89
$\sigma^2{}_p$	9.5078	**9.44**	9.44	9.44	9.43	9.43
$h^2a \pm S.E$	0.38±0.06	**0.13±0.06**	0.12±0.06	0.20±0.083	0.14±0.06	0.19±0.08
$c^2 \pm S.E$	-	**0.32±0.04**	-	-	0.29±0.20	0.14±0.22
$h^2m \pm S.E$	-	**-**	0.31±0.04	0.44±0.11	0.02±0.20	0.25±0.29
$r_{am} \pm SE$	-	**-**	-	-0.55±0.26	-	-0.54±0.38
h^2t	0.38	**0.14**	0.28	0.19	0.15	0.14

Note: σ^2a = direct additive genetic variance; σ^2c= maternal permanent environmental variance; σ^2m= maternal additive genetic variance; σ_{am}= additive and maternal additive genetic covariance, σ^2e=residual variance, σ^2p=phenotypic variance, h^2a=direct heritability c^2=ratio maternal permanent environmental variance to phenotypic variance, h^2m= maternal heritability; r_{am}= correlation between direct maternal additive genetic effects, h^2t=total heritability and SE = standard error

4.5. Variance Component and Genetic Parameter Estimates for Daily Weight Gain Traits

The results of estimated variance and covariance components of direct heritability, maternal heritability, ratio of maternal permanent environmental variance on total variance and correlation of additive-maternal genetic with different models are presented in Table 18. The log L result show that, covariance between direct and maternal genetic and maternal genetic effect for ADG0-3, ADG3-6 and ADG0-6 were found to have statistically non-significant ($P>0.05$).Based on the log likelihood ration test value(LRT),the best fitted selected model was model 2 which constitutes direct additive genetic effect and permanent maternal environmental effect. Therefore, the main effect caused variation in average daily weight gain among lambs is the effect of animal's own genes of direct additive genetic effect and permanent maternal environmental effect.

Based on the best fitted model, the estimate of direct heritability (h^2a) for ADG0-3, ADG3-6 and ADG0-6 were 0.12±0.04, 0.11±0.07 and 0.02±0.05 respectively. Compared with the other models, the estimate indicated that, the inclusion of maternal permanent environmental effects in the analyses can improve the models for daily weights gain traits. The fractions of maternal permanent environmental variance highly reflected for all considered average daily weight gain traits. The estimate indicates variance due to permanent maternal environmental effects (c^2) for ADG0-3(0.21±0.03) and ADG0-6(0.26±0.04) have been found significantly higher than later age daily weight gain traits of ADG3-6 (0.09±0.04). It decreases with increasing lamb age. This could be due to the influences of feeding level at later age of the lambs and the maternal behavior of the dam especially for pre weaning growth traits in the lambs. The value of maternal permanent environmental variance in model (2) for this trait is not significantly different from other models' values.

The estimate for ADG0-3 and ADG0-6 were comparable with the estimate observed by Kariuki *et al*. (2010) for Kenyan Dorper sheep breed (0.12±0.05). The result is also found in the range reported by Yacob (2008) for Afar and BHS sheep and lower than the report of Radwan and Shalaby (2017) and Matika (2001) for Rahmani and Sabi sheep respectively.

Table 18. Co-variance components and genetic parameter estimates for daily weight gain traits

Models	Model 1	**Model 2**	Model 3	Model 4	Model 5	Model 6
Average daily gain from birth to weaning (ADG0-3)						
σ^2_a	230.49	**114.2**	115.16	152.39	114.2	144.1
σ^2_c	-	**179**	-	-	179	198.89
σ^2_m	-	**-**	179.71	297.48	0.007	83.796
σ_{am}	-	**-**	-	-131.57	-	-109.88
σ^2_e	648.09	**587**	590.35	565.52	587	570.03
σ^2_p	878	**880**	885.22	883.82	880.4	880.03
$h^2a \pm S.E$	0.26±0.05	**0.12±0.04**	0.13±0.04	0.17±0.05	0.13±0.04	0.16±0.05
$c^2 \pm S.E$	-	**0.21±0.03**	-	-	0.20±0.12	0.22±0.13
$h^2m \pm S.E$	-	**-**	0.20±0.03	0.31±0.08	0.±0.125	0.09±0.16
$r_{am} \pm SE$	-	**-**	-	-0.6±0.2	-	-0.84±0.5
h^2t	0.26	**0.13**	0.23	0.11	0.12	0.05
Average daily gain from weaning to 6 months (ADG3-6)						
σ^2_a	75.688	**163.72**	162.99	177.9	163.68	182.4
σ^2_c	-	**86.654**	-	-	137.3	155.82
σ^2_m	-	**-**	116.7	147.02	0.01	5.03
σ_{am}	-	**-**	-	-34	-	-30
σ^2_e	255.84	**237.46**	1147	1137	1127	1115.4
σ^2_p	331.53	**1428**	1427	1427	1428	1428.5
$h^2a \pm S.E$	0.22±0.07	**0.11±0.07**	0.11±0.07	0.13±0.08	0.11±0.07	0.13±0.08
$c^2 \pm S.E$	-	**0.09±0.04**	-	-	0.09±0.17	0.10±0.19
$h^2m \pm S.E$	-	**-**	0.08±0.048	0.10±0.11	0.00±0.17	0.004±0.2
$r_{am} \pm SE$	-	**-**	-	-0.21±0.8	-	-0.99±0.00
h^2t	0.23	**0.11**	0.15	0.14	0.11	0.10
Average daily weight gain from birth to 6 months (ADG0-6)						
σ^2_a	75.6880	**7.6410**	6.1339	24.8220	6.8702	13.1730
σ^2_c	-	**86.6540**	-	-	85.7540	87.0010
σ^2_m	-	**-**	77.9750	132.430	0.0010	4.5529
σ_{am}	-	**-**	-	-57.3320	-	-7.7418
σ^2_e	255.84	**237.4600**	247.2400	232.000	239.0000	235.2000
σ^2_p	331.530	**331.7600**	331.3500	331.920	331.6300	332.1900
$h^2a \pm S.E$	0.2±0.07	**0.02±0.05**	0.02±0.05	0.07±0.07	0.02±0.06	0.04±0.07
$c^2 \pm S.E$	-	**0.26±0.04**	-	-	0.25±0.1	0.26±0.23
$h^2m \pm S.E$	-	**-**	0.23±0.04	0.39±0.12	0±0.193	0.014±0.3
$r_{am} \pm SE$	-	**-**	-	-0.99±0.5	-	-1.0000
h^2t	0.23	**0.023**	0.14	0.015	0.02	0.011

Note: σ^2a = direct additive genetic variance; σ^2c= maternal permanent environmental variance; σ^2m= maternal additive genetic variance; σ_{am}= additive and maternal additive genetic covariance, σ^2e = residual variance, σ^2p=phenotypic variance, h^2a=direct heritability c^2a=ratio maternal permanent environmental variance to phenotypic variance, h^2m= maternal heritability; r_{am}= correlation between direct maternal additive genetic effects, h^2t=total heritability and SE = standard error

The estimate of direct heritability for ADG3-6 were comparable with the report of Yacob (2008) that was 0.00 and 0.09 for Afar and BHS sheep under on station management condition.

0.12, 0.11 and 0.023 respectively were, estimates of total heritability (h^2t) values for ADG0-3, ADG3-6 and ADG0-6 that is in similar range to the direct heritability estimates. The estimates are in moderate range with the exception of ADG0-6. Total heritability estimates of ADG0-3 and ADG0-6 is comparable with the finding of Abegaz (2002) for Horro sheep, which is 0.13±0.04 and 0.04±0.03 respectively.

4.6. Variance component and genetic Parameter estimates for reproductive traits

(I) Litter size

The results of the univariate analysis of litter size under the six different models are presented in table 19. Direct additive and maternal permanent environmental variation including was important variance component for litter size.

Under the best fitted model, the direct additive variance accounted 0.08% of the total variance. The estimate of variance due to permanent maternal environmental effects that is an effect of the dam (possibly due to uterine capacity and feeding level at late gestation was 0.092% of the total variances.

In the present study the estimate of direct heritability and total heritability for litter size were 0.28±0.12 and 0.29, respectively. The direct heritability estimate indicated that, genetic improvement through direct selection for this trait would be high for Doyogena sheep. Compared with other study, the current heritability estimate for litter size was higher. Abegaz, *et al*. (2002) reported h^2a of twinning estimated from a direct additive and repeatability models were 0.15 and 0.07 respectively for Horro sheep. Matika (2003) and Mohammadi *et al.* (2012) reported estimated heritability of 0.26 for Sabi and 0.14 for Zandi sheep by fitting threshold model. Khan *et al*. (2017) estimated litter size hertability of 0.25 for Rambouillet Sheep in India using Paternal half sib correlation method. The h^2 values reported were lower than the current finding. The reason could be due to the data used in the analysis, since; more than 63% of the data were multiple birth record. In terms of lamb record, single lambs represented 36.5% of the data set, 57.42% were twins and the remaining were from litters of triple or more than triplet. The total heritability 0.29 does not mean that a trait is 29% caused by genetic factors; it means that 29% of the variability in this trait between the ewe is due to genetic differences among ewes. The point with this estimation is, the lowest heritability had the lowest variation in estimated heritability and those with the highest heritability had the highest variation. Therefore, current estimate of heritability shown for litter size has highest heritability range and thus, genetic improvement through selection for this trait would be high.

The estimate of maternal permanent environmental variance (c^2) was 0.31±0.01. The results indicated that, the inclusion of maternal permanent environmental effects in the analyses can improve the models for litter size trait. The reflection of variance due to maternal permanent environmental effect indicates improving the environment could improve the reproductive performance of Doyogena ewe.

Table 19. Co (variance) components and genetic parameter estimates for litter size

Parameter	Models of Estimation					
	1	**2**	**3**	**4**	**5**	**6**
$\sigma^2{}_a$	0.09	**0.08**	0.070	0.084	0.037	0.084
$\sigma^2{}_c$	-	**0.092**	-	-	0.090	0.090
$\sigma^2{}_m$	-	**-**	0.012	0.044	0.037	0.044
σ_{am}	-	**-**	-	-0.035	-	-0.035
$\sigma^2{}_e$	0.19	**0.108**	0.20	0.155	0.110	0.009
$\sigma^2{}_p$	0.28	**0.28**	0.28	0.24	0.28	0.24
$h^2a \pm S.E$	0.32±0.12	**0.28±0.12**	0.13±0.15	0.33±0.2	0.13±0.15	0.33±0.20
$c^2 \pm S.E$	-	**0.31±0.01**	-	-	0.33±0.007	0.38±0.02
$h^2m \pm S.E$	-	**-**	0.13±0.1	0.18±0.1	0.13±0.10	0.24±0.08
$r_{am} \pm SE$	-	**-**	-	-0.58±0.23	-	-0.58±0.23
h^2t	0.32	**0.29**	0.27	0.30	0.20	0.30

Note: σ^2a = direct additive genetic variance; σ^2c= maternal permanent environmental variance; σ^2m= maternal additive genetic variance; σ_{am}= additive and maternal additive genetic covariance, σ^2e=residual variance, σ^2p=phenotypic variance, h^2a=direct heritability c^2a=ratio of maternal permanent environmental variance to phenotypic variance, h^2m= maternal heritability; r_{am}= correlation between direct maternal additive genetic effects, h^2t=total heritability and SE = standard error

(II) Lambing interval

The results of the univariate analysis of lambing interval under the six different models are presented in Table 20. The model 1 was the best fitted model for lambing interval (Table 15) and this indicated that additive genetic component ($\sigma^2{}_a$) was most important variance component for lambing interval. Under the best fitted model, the estimate of direct heritability ($h^2a \pm S.E$) and total heritability (h^2t) for LI were 0.20±0.5 and 0.20 respectively. Lobo *et al.* (2009) and Abdoli *et al*. (2019) estimated a direct heritability of 0.06 and 0.02 for LI for Brazilian multibreed meat sheep and Iranian Lori-Bakhtiari sheep. The h^2 values reported were lower than current estimate.

Table 20. Co (variance) components and genetic parameter estimates for lambing interval

Parameter	Models of Estimation					
	1	2	3	4	5	6
$\sigma^2{}_a$	**1248.3**	1218.7	1277.5	1379	1256.2	1319
$\sigma^2{}_c$	**-**	37.64	-	-	173.38	2675
$\sigma^2{}_m$	**-**	-	0.86	6.11	0.73	1.6
σ_{am}	**-**	-	-	-72	-	-1.4
$\sigma^2{}_e$	**4882.7**	4874.7	4856	4746	4704	2140
$\sigma^2{}_p$	**6131**	6131	6134	6060	6134.3	6134
$h^2a \pm S.E$	**0.20±0.5**	0.19±0.51	0.20±0.55	0.22±0.05	0.20±0.05	0.21±0.56
$c^2 \pm S.E$	**-**	0.06±0.001	-	-	0.03±0.002	0.43±0.56
$h^2m \pm S.E$	**-**	-	0.001±0.4	0.001±0.1	0.0±0.4	0.0±0.8
$r_{am} \pm SE$	**-**	-	-	-0.78±0.0	-	-0.03±00
h^2t	**0.20**	0.20	0.20	0.21	0.20	0.21

Foot note same as for Table 19

(III) Age at first lambing

The results of the univariate analysis of age at first lambing under the six different models are presented in Table 21. The model 1 was the best fitted model for age at first lambing and this indicated that additive genetic component ($\sigma^2{}_a$) was most important source of variation for age at first lambing similar to lambing interval.

Under best fitted model the direct heritability ($h^2a \pm S.E$) and total heritability h^2 estimate for AFL was 0.001±0.32 and 0.007, respectively. Since AFL was strongly influenced by environmental effects, low heritability estimate was obtained. The low estimates of heritability observed here for AFL did not mean that there was no possibility for genetic improvement, but rather that the expected genetic gain was low, if selection for these traits was also low (Lobo *et al*., 2009). Selection based on AFL performance may result in slow genetic improvement. Therefore, selection for ewe for AFL trait of ewes should be based on female relatives of ewes or on correlated traits which have high and positive genetic correlation with ewe AFL. Lobo *et al.* (2009) and Abdoli *et al*. (2019) estimated 0.04 and 0.07 of AFL heritability for Brazilian multibreed meat sheep and Lori-Bakhtiari sheep breed respectively. The h^2 values reported were higher than the current finding.

Table 21.Co (variance) components and genetic parameter estimates for age at first lambing

Parameter	**Models of Estimation**					
	1	**2**	**3**	**4**	**5**	**6**
$\sigma^2{}_a$	**9.60**	0.78	6.14	3562	1724.9	2061.6
$\sigma^2{}_c$	**-**	12183	-	-	12129	11208
$\sigma^2{}_m$	**-**	-	156.39	18129	1.09	2831
σ_{am}	**-**	-	-	-8036	-	-2414
$\sigma^2{}_e$	**13572**	1541.5	13420	0.028	0.9	0.002
$\sigma^2{}_p$	**135582**	13726	13582	13655	13896	13376
$h^2a \pm S.E$	**0.001±0.32**	0.11±0.45	0±0.00	0.16±0.76	0.12±0.56	0.15±0.7
$c^2 \pm S.E$	**-**	0.83±0.005	-	-	0.87±0.156	0.81±0.47
$h^2m \pm S.E$	**-**	-	0.012±0.7	-	0.014±0.17	0.20±0.33
$r_{am} \pm SE$	**-**	-	-	-99±0.02	-	-0.98
h^2t	**0.0007**	0.0001	0.006	0.04	0.12	0.008

Foot note same as for Table 19

Table 22. Summary of Estimates of (Co) variance components and Genetic parameters from Univariate Analyses Under the 'Best' Models

Trait	Model fitted	$\sigma^2{}_p$	r_{am}	$h^2a \pm S.E$	$c^2 \pm S.E$	$r_{am} \pm SE$	$h^2m \pm SE$	h^2t
BWT	Model 6	0.0284	-0.049	0.33±0.06	0.20±0.09	-0.61±0.15	0.24±0.12	0.21
WWT	Model 4	6.35	-2.1	0.31±0.05	-	-0.81±0.11	0.6±0.07	0.12
6WT	Model 2	9.4	-	0.14±0.06	0.32±0.04	-	-	0.14
ADG0-3	Model 2	880	-	0.13±0.04	0.20±0.03	-	-	0.12
ADG3-6	Model 2	163.72	-	0.11±0.07	0.09±0.04	-	-	0.11
ADG0-6	Model 2	331.76	-	0.023±0.05	0.261±0.04	-	-	0.023
LS	Model 2	0.28	-	0.28±0.12	0.31±0.01	-	-	0.29
LI	Model 1	6131	-	0.20±0.5	-	-	-	0.20
AFL	Model 1	13582.	-	0.001±0.5	-	-	-	0.001

Note: *BWT=birth weight, WWT=weaning weight, 6WT=six-month weight, (ADG0-3) average daily gain from birth to weaning age, (ADG3-6) =average daily gain from weaning to 6 months age (ADG0-6) =average daily gain from birth to 6 months' age, LS=litter size, LI=lambing interval, AFL=age at first lambing, σ^2p=phenotypic variance, r_{am}= correlation between direct-maternal- additive genetic effects, h^2a=direct heritability, c^2= ratio of maternal permanent environmental variance to phenotypic variance, σ^2am= maternal additive genetic variance, h^2m= maternal heritability, h^2t= total heritability and SE = standard error.*

4.7. Correlations Estimates

4.7.1. Correlation estimates between growth traits

The genetic and phenotypic correlation between growth traits (BWT, WWT, 6WT, ADG0-3, ADG3-6 and ADG0-6), using a multivariate analysis, is presented in Table 23.

(I) Genetic correlations

The estimate of genetic correlations of WWT and 6WT, WWT and ADG0-3, WWT and ADG3-6, WWT and ADG0-6 was 0.52 ± 0.09, 0.95 ± 0.03, -0.23 ± 0.13 and 0.53 ± 0.12, respectively. The correlation coefficients for 6WT and ADG0-3, 6WT and ADG3-6, ADG0-6 was 0.52 ± 0.09, 0.95 ± 0.03, -0.23 ± 0.13 and 0.53 ± 0.12, respectively. The present study indicated that BWT had weak genetic correlation with the studied body weights and daily weight gain traits. The weak association of BWT with other traits could be due to the fact that BWT is affected by both prenatal and postnatal maternal environments compared to WWT and 6WT traits. The current result implies, selection of BWT could not bring positive response to selection on the other traits.

The genetic associations (Correlation) between WWT and other traits, in the present study, were moderate to high except BWT and ADG3-6 months which were low. Similarly, 6WT had moderate to strong correlation with other traits and had highest genetic correlation coefficient of 0.97 ± 0.07 with ADG0-6 months. The genetic correlation of ADG0-3 with ADG3-6 was negative (-0.35 ± 0.14) but was positive and of medium magnitude with ADG0-6 months (0.43 ± 0.13). However, genetic correlation of ADG3-6 and ADG0-6 months was positive and near to strong (0.66 ± 0.09). The negative correlation (-0.35±0.14) between ADG0-3 and ADG3-6 indicating, lambs that grew faster in the preweaning period, grew more slowly during post-weaning period and vice versa. Mohammadi *et al*. (2015) reported similar finding with the present study in Lori sheep breed.

Among growth traits, WWT and 6WT are the most economically important and easily measured traits. Both of these traits (WWT and 6WT) were considered as most appropriate selection criteria in CBBP (Jembere *et al*., 2016). A moderate and positive genetic correlation was observed between WWT and 6WT (0.52±0.09). The positive genetic correlations between the two traits indicate that the gens that are responsible for increasing WWT result in increasing of 6WT traits. It could be used as selection criteria for improvement in body weights traits. The positive / moderate genetic correlation that post-weaning body weights and body weight gains may be under the influence of same set of genes (Pleiotropy). This is also borne out by high genetic correlation of ADG3-6 and ADG0-6 months. Both of these traits (WWT and 6WT) were considered as most appropriate selection criteria in CBBP (Jembere *et al*., 2016). These genetic correlations were similar to those reported by Safari *et al*. (2007) and Abegaz (2002) estimated, for Australian Merino and Horro sheep respectively.

Table 23. Estimates of genetic (below diagonal) and phenotypic (above diagonal) correlations between growth traits in multi trait analysis

Trait	BWT	WWT	6WT	ADG0-3	ADG3-6	ADG0-6
BWT	-	0.23 ±0.02	0.17 ±0.02	-0.01 ±0.23	0.005 ±0.02	-0.01 ±0.02
WWT	0.21 ±0.07	-	0.35 ±0.02	0.65 ±0.01	-0.30 ±0.02	0.22 ±0.02
6WT	0.21 ±0.09	0.52 ±0.09	-	0.19 ±0.02	0.54 ±0.02	0.74 ±0.01
ADG0-3	-0.003 ±0.09	0.95 ±0.03	0.37 ±0.12	-	-0.46 ±0.02	0.33 ±0.02
ADG3-6	0.06 ±0.12	-0.23 ±0.13	0.70 ±0.09	-0.35 ±0.14	-	0.67 ±0.01
ADG0-6	0.06 ±0.1	0.53 ±0.12	0.97 ±0.04	0.43 ±0.13	0.66 ±0.09	-

Note=*(BWT)birth weight, (WWT)=weaning weight, (6WT) =six-month weight (ADG0-3) average daily gain from birth to weaning age, (ADG3-6) average daily gain from weaning to 6 months' age, (ADG0-6) average daily gain from birth to 6 months' age*

(II) Phenotypic correlations

The phenotypic correlations were generally similar or slightly smaller in magnitude than the corresponding genetic correlations (Table 23). The BWT was correlated with WWT, 6WT, ADG0-3, ADG3-6 and ADG0-6 by magnitude of 0.23 ± 0.02, 0.17 ± 0.02, -0.01 ± 0.23, 0.005 ± 0.02, -0.01 ± 0.02, respectively. The phenotypic correlation among growth traits varied from low to higher. Most of the estimates for phenotypic correlations were positive. However, the phenotypic correlation of BWT with ADG0-3 and of ADG3-6 with WWT and BWT with ADG0-6 showed negative values. Abegaz *et al.* (2002) found negative phenotypic association between ADG0–3 with ADG3-6 (-0.11) for Horro sheep agreed with this estimation. The phenotypic correlations among other body weights and daily gain were positive and low to higher. High estimates greater than 0.7 were observed for ADG0-6 with 6WT.

4.7.2. Correlation between litter size and growth traits

Genetic and phenotypic correlations between litter size and growth traits are shown in Table 24. The correlations were all negative ranging from -0.50±0.04 to -0.11±0.02. Litter size and birth weight had the high negative genetic correlation (-0.50±0.04) while the lowest was recorded for 6WT and litter size. The negative correlations were expected since large litter size had been shown to have negative effect on body weights of lambs. Safari *et al*. (2007) reported positive but week genetic correlation between growth and litter size traits for various sheep breeds. Similarly, Matika (2001), reported a genetic correlation between litter size and WWT for Sabi sheep was 0.07.

The estimates of phenotypic correlations between lamb body weight at different ages and reproductive traits in this study were almost similar degree with their genetic correlation. The phenotypic correlations between litter size and growth traits also ranged from -0.42±0.01 (litter size and birth weight) to -0.11±0.02 (litter size and 6WT). In the literature both negative and positive genetic correlation between litter size and growth traits had been reported (Fogarty, 1995; Bromley *et al*., 2001; Safari *et al*., 2005). According to Gootwine (2005) and Bloomfield *et al*. (2003), variability among estimates depends on environment, and, suggested, increased litter size should be a priority when environmental conditions was prevailed. In general, the negative correlation between growth traits with litter size indicates, litter size, could not be considered as selection criteria to indirectly improve growth traits.

Table 24. Estimates of genetic (below diagonal) and phenotypic (above diagonal) correlations between growth and reproductive traits at different ages in multi trait analysis

Trait	BWT	WWT	6WT	Litter size
BWT	-	0.24 ±0.02	0.19 ±0.02	-0.42 ±0.01
WWT	0.23 ±0.07	-	0.36 ±0.02	-0.21 ±0.02
6WT	0.22 ±0.09	0.58 ±0.09	-	-0.11 ±0.02
Litter size	-0.50 ±0.04	-0.24 ±0.07	-0.18 ±0.08	-

Note*: BWT=birth weight, WWT=weaning weight, 6WT=six-month weight*

4.7.3. Correlation estimates between reproductive traits.

The bivariate analysis of genetic correlation between reproductive traits of litter size and lambing interval is given in Table 25.A negative estimate of genetic correlation of -0.44±0.9 was obtained between LI and LS. However, the genetic correlation between AFL and LS were strong and negative (-0.98±0.32). The estimate of genetic correlations was similar to the other estimates reviewed by Safari *et al*. (2005). The phenotypic correlations were generally smaller than the corresponding genetic correlations. phenotypic correlation between AFL and LS were low and negative (-0.13±0.11). Khan (2017) also reported comparable genetic correlation of -0.00±0.02 and -0.006±0.02 for LS with AFL and LS with LI in Rambouillet Sheep respectively.

Table 25. Estimates of genetic (below diagonal) and phenotypic (above diagonal) correlations between reproductive traits in bivariate analysis

Trait	Lambing interval	Litter size
Lambing interval	-	0.018±0.04
Litter size	-0.44±0.9	-

4.8. Repeatability Estimates

Repeatability was estimated for two traits, namely lambing interval and litter size, and is presented in Table 26. These are the traits usually considered to have a high enough maternal component to be analyzed as traits of the dam. The repeatability of litter size was 0.61 whereas it was 0.26 for lambing interval in the present study. Both repeatability results are higher than the corresponding heritability estimates. This is in agreement with the theory that repeatability sets the upper limit to heritability estimates. In Ethiopia, Abegaz *et al*. (2002) estimated litter size repeatability for Horro sheep was 0.12 under repeatability model and it is lower than the current finding. Similarly, the result of repeatability estimates for Zandi sheep (0.25); Mehraban sheep(0.4) and Lori-Bakhtiari sheep (0.28) by Mohammadi *et al*. (2012); Yavarifard *et al*. (2015) and by Vatankhah and Talebi (2008) respectively were lower than the estimate in the current study.

As a result of the high repeatability, maternal influence can be regarded as an important source of variation for the two reproductive traits. Results indicated that the current performance of Doyogena sheep in terms of litter size and lambing interval will perform for the future. Therefore, the accuracy of selection for these traits using reputable trait of record can be high as repeatability evaluates the correlation between performance records of the ewe.

Table 26. Repeatability estimate for lambing interval and litter size

Traits	σ^2_a	σ^2_{pe}	σ^2_e	σ^2_p	$h^2a \pm S.E$	$pe^2 \pm S.E$	r
Litter size	0.08	0.092	0.108	0.28	0.28±0.12	0.31±0.01	0.61
lambing interval	1228	290.20	4484.6	6103.2	0.21±0.53	0.048±0.003	0.26

Note: *σ^2a = direct additive genetic variance; σ^2pe = maternal permanent environmental variance; σ^2e = residual variance, σ^2p=phenotypic variance, h^2a = direct heritability; σ^2pe = maternal permanent environmental variance r=repeatability and S.E = standard error*

Repeatability estimates for the two-trait shown a good picture of the ongoing CBBP; therefore, obtaining more records may lead to achieving a higher accuracy, as the prediction accuracy is a function of the repeatability estimate and the number of records. Moreover, the results indicated that litter size with high repeatability performance will be repeated in future lambing and this could be used as criteria for breeding ewe selection.

4.9. Performance Traits Phenotypic Trends

(I) Growth traits

The year-wise growth traits phenotypic trends exhibited increment in 6WT (0.23 kg/year), whereas BWT and WWT show decreasing trend by -0.0058 kg/year, and -0.0379 kg/year respectively. Year wise decreasing in BWT and WWT could be due to the fact that the negative effect of improvement in twining over the selection period. Another possible reason could be the influence of environment and data quality.

An overall phenotypic improvement was observed in 6WT traits over the selection period, however, the improvement in year wise is not consistent. Between 2014 to 2015 there was consistent linear upward progress, after attaining the peak performance in 2015, decline was observed in 2016 and 2017.The differences could be attributed to the variation in rainfall and ambient temperature during the course of selection year. Similar result was reported by Haile *et al*. (2014) and Gizaw *et al*. (2014a) for analysis result of Bonga, Horro and Menz CBBP. The body weight change were 0.19 kg, 0.84 kg and 2.32 kg for BWT, WWT and 6WT respectively per 6-year selection. Gizaw *et al*. (2014a) reported body weight change of 0.004, 0.11 and -0.12 kg for BWT, WWT and 6WT respectively for Menz sheep and that was lower than the current result.

(II) Daily weight gain traits

The average daily gain traits phenotypic trends gm/year) exhibited increment value by 0.499 and 0.209 for ADG0-3 and ADG0-6 traits while for ADG3-6 in are in decreasing trend by -0. 92. This could be due to the fact that the negative effect of environment and weaning shock. The overall phenotypic change 2.4 gm, -6.15 gm and 3.66 gm were obtained for ADG0-3, ADG3-6 and ADG0-6.

(III) Reproductive traits

Annual phenotypic trend for LS, LI and AFL were, respectively, 0.017 lamb/year, -4.18 days/year and 2.18 days/year. Improvement in reproductive traits were observed with slow progress. The observed phenotypic changes were 0.1 lambs, -6.5 days and -6.9 days per selection period.

4.10. Breeding value and Genetic Trends

4.10.1. Growth traits breeding value and genetic trends

(I) Birth weight (BWT)

The model used to obtain the EBVs were the best fitted model as per Table 15. The genetic trend (direct and maternal genetic trends) over the selection period (2013-18) is presented in Figure 5. Both direct and maternal additive genetic trends for BWT in this study fluctuated over the years.

The direct additive genetic trend for BWT showed relatively decreasing trend (-0.0026 kg/year and insignificant ($p>0.05$) while, the maternal genetic trends showed increased trend (0.0023kg/year)**.** The estimate of direct and maternal genetic gain is 0.00085 kg and -0.004 kg respectively. When compared to other study, Gizaw *et al*. (2014) reported higher and positive genetic change in BWT for Menz sheep. The author reported genetic progress of 0.005 kg at 4th generation. Gholizadeh *et al.* (2015) reported almost no genetic gain for Baluchi sheep which is almost similar with current finding. Since, direct genetic gain for the traits showed slightly negative trend, demonstrate that these traits should not be take into consideration in the selection process by breeder cooperatives.

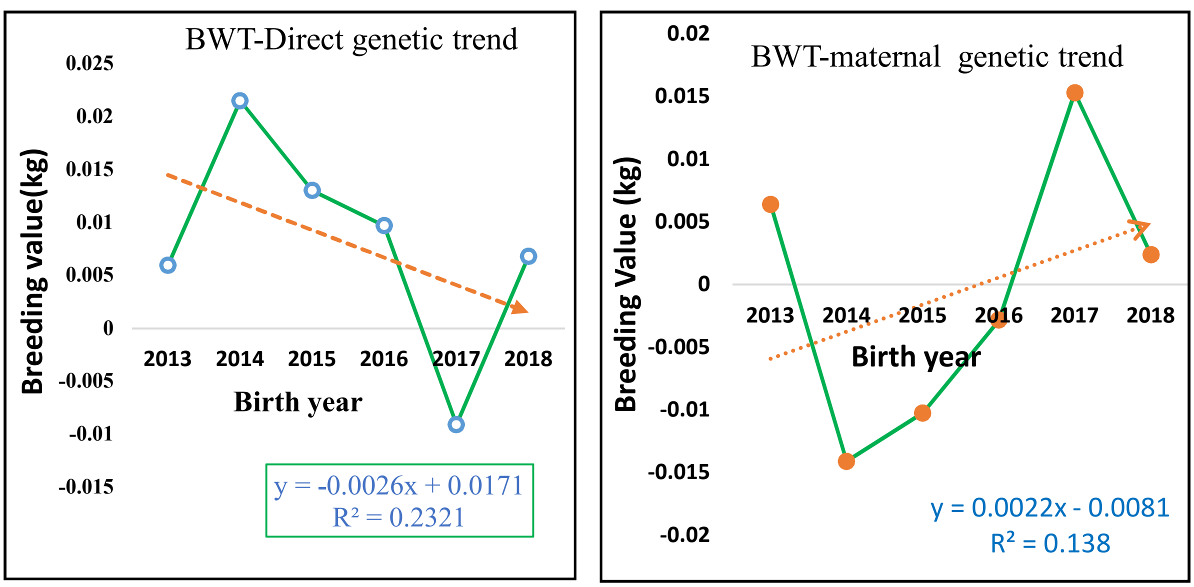


Figure 5. Additive and Maternal Genetic Trend

(II) Weaning weight (WWT)

The models used to obtain the EBV were the best fitted model as per Table 15. Figure-6 shows the value of direct genetic and maternal genetic trend over selection period. The direct genetic and maternal genetic trend for WWT, over the selection period (2013-18) is presented in Figure 6. Perusal of results showed that both direct and maternal additive genetic trends had irregular trend and there has been significant ($p<0.05$) genetic improvement for direct genetic with 0.3 kg in a period of 6-years selection (0.048 kg/year).

During the period from 2015 to 2017 the direct additive genetic trend decreased but after this, the direct genetic trend increased in values. Contrary to this, the maternal genetic trend has decreased from 2014 to 2015, increased from 2015 to 2017 but again decreased thereafter. The decreasing direct additive genetic trend during 2015 to 2017 may be ascribed to sale of superior breeding rams to areas outside the areas covered by CBBP and inbreeding. This could result for minor decline in growth performance of the flock.

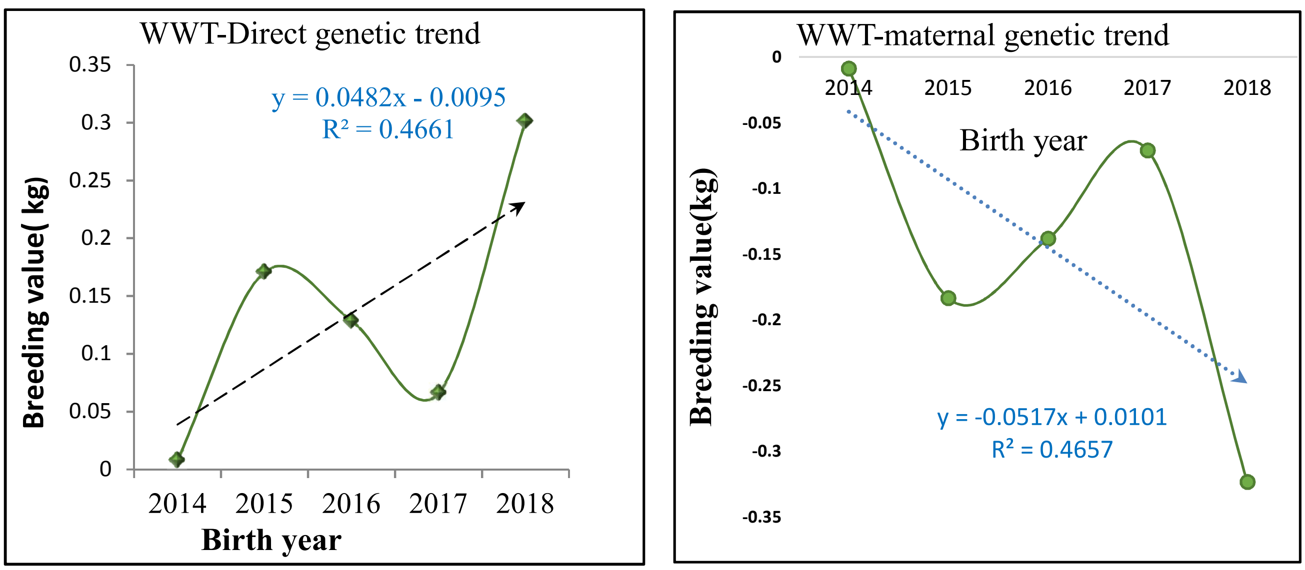


Figure 6. Direct Genetic and Maternal Genetic Trend

The maternal genetic trend (maternal random effect) had a decreasing trend -0.23 kg per 6-year selection and -0. 051 kg per year. The genetic gain 0.048 kg/year was higher than the report for Arman sheep 0.007 kg/year (Mostafa *et al*., 2011) and lower than the report of Mokhtari. (2010) for Kermani sheep (0.125 kg/year). Gizaw *et al*. (2014b) reported 0.45 kg of genetic gain at 4th generation of Menz sheep which is higher than the current result of direct genetic gain (0.3 kg). The difference might be due to difference in year of selection, since only 6-year selection data were considered in the present study.

(III) 6-month weight (6WT)

The model used to obtain estimated breeding value is the best fitted model as per Table 15. Direct genetic trend and permanent maternal environment trend over the selection period (2013-18) is presented in Figure 7. The estimated annual direct genetic trend (0.036 kg/year) was positive and highly significant (p<0.01). The fit of the regression shows 73.4% coefficient of determination with the regressed value. The estimate of direct genetic change (0.151 kg) for 6WT provides a good picture of the selection program with respect to 6WT.Because the existing method of selection practiced was based on 6WT trait. The present estimate of direct genetic trend was in concurrent with the study of Mokhtari and Rashidi (2010) for Kermani sheep and Mohammadi *et al*. (2011) for Zandi sheep (0.021 kg/year).

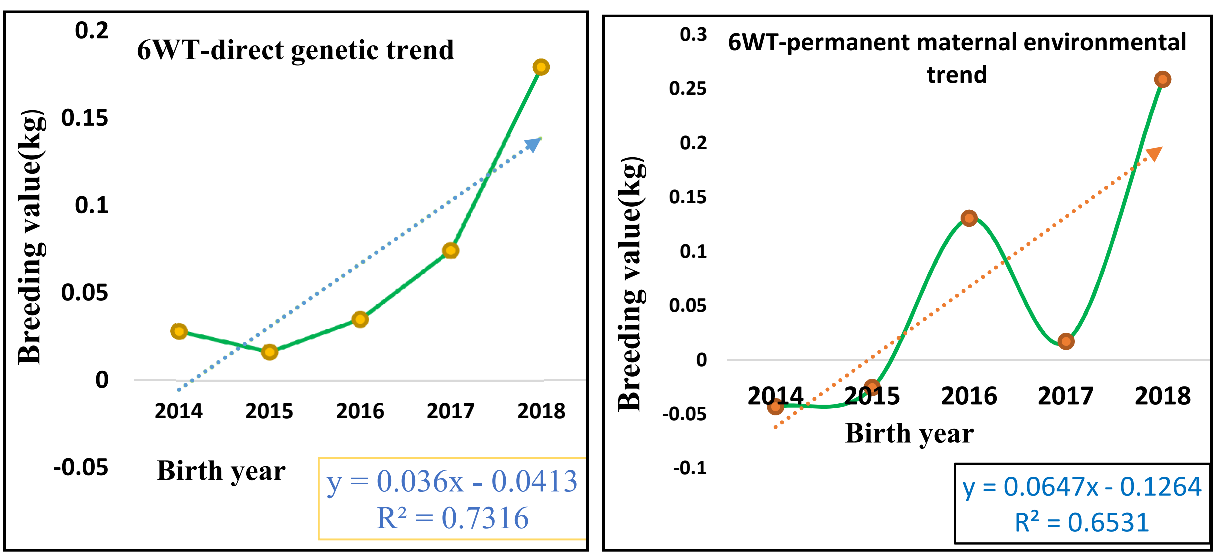


Figure 7. Direct genetic and permanent environmental trend

Higher estimate was reported by Shaat (2004) in Rahmani sheep (0.135 kg/year) and Arora *et al*. (2010) in Malpura sheep (0.061 kg/year). The present estimate is lower than the report of Gizaw *et al*. (2014b) in Menz sheep 1.3 kg of genetic gain at 4^{th} generation.

The permanent maternal environmental variance trend for 6WT (Figure 7) showed that it increased from 2014 to 2016, then decreased in 2017 and again increased from 2017 onwards. Permanent maternal environmental trend for 6WT increased (0.064 kg/year) as the fit of the regression 65.31% coefficient of determination with the regressed value.

Table 27. Genetic change over the 6 years selection based on estimated breeding values (EBVs) for BWT, WWT and 6WT

Trait	Direct (kg)	Maternal (kg)	p-value	R^2
BWT	0.00085	-0.00401	0.09	0.23
WWT	0.30	-0.23	0.014	0.46
6WT	0.151	-	0.0002	0.73

(IV) Growth traits Genetic Trend Evaluation across Cooperatives

Genetic trend evaluation for each breeder cooperative gives an indication of the breeder cooperative performance in the genetic improvement, since application of CBBP. In the present case WWT and 6WT were considered. The year-wise genetic trends across cooperative exhibited significant differences in improvement. Positive direct genetic trends in WWT and 6WT traits were observed in Ancha, Hawora, Murasa and Begedamu breeder cooperative. However, WWT in Begedamu and 6WT trait in Serera breeder cooperative show negative trend detail information of WWT and 6WT genetic trend for each cooperative has been illustrated below.

(a) Ancha Sedicho breeder cooperative

The value of direct genetic trend for this breeder cooperative is represented in Figure 8 and Table 28. During the period of 5-years, direct genetic trend for WWT and 6WT increased by 0.0302 and 0.143 kg/year. Perusal of Figure 8 showed that direct genetic trend increased from 2014 to 2015, then decreased from 2015 to 2017 followed by steep increase in WWT whereas in 6WT it decreased from 2014 to 2015, increased up to 2016, again decreased up to 2017 followed by steep increase thereafter. The direct genetic change for WWT and 6WT was 0.19 and 0.68 kg per, respectively, for five-year selection (Table 28).

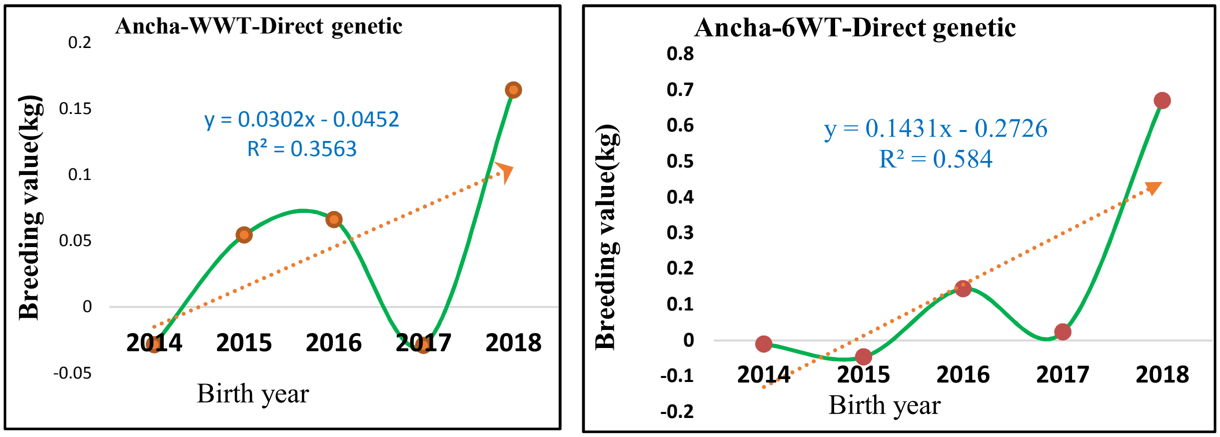


Figure 8. Direct genetic trend for Ancha Sedicho breeder cooperative

Table 28. Growth trait genetic gain for each breeder cooperative

Trait	Ancha	Hawora	Serera	Murasa	Begedamo
WWT	0.19(6)	0.54(2)	0.0023(4)	0.033(2)	-0.0001(2)
6WT	0.68(2)	0.146(2)	-0.00015(2)	0.071(1)	0.18(1)

Figure in the parenthesis are best fit model

(b) Hawora Arara breeder cooperative

The value of direct genetic trend for this breeder cooperative is represented in Figure 9 and Table 28. The genetic trend for WWT and 6WT was 0.129 and 0.054 kg/year, respectively. Perusal of Figure 9 showed that direct genetic trend showed gradual increase from 2014 to 2016 followed by steep increase thereafter for WWT whereas it increased from 2014 to 2017 but then declined for 6WT. The direct genetic change for WWT was 0. 54 kg while for 6WT it was 0.146 kg over a five-year selection period (Table 28).

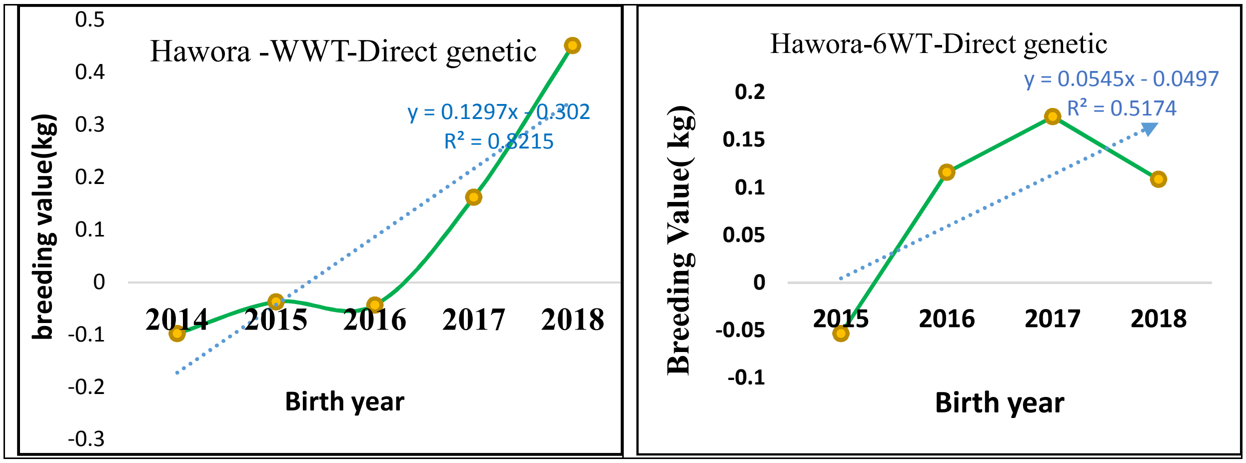


Figure 9. Direct Genetic trend for Hawora Arara cooperative

(c) Serera Bukata breeder cooperatives

The value of direct genetic trend for this breeder cooperative is represented in Figure 10 and Table 28. Based on the selected model, the estimates of genetic progress for WWT was positive, showed increasing trend from 2014 to 2015, decreasing trend from 2015 to 2016 followed by increasing trend thereafter. However, genetic trend of 6WT increased from 2015 to 2017 but then it decreased thereafter. In this cooperative he genetic change, based on EBVs, was positive for WWT (0.0023 kg/ year) but negative for 6WT (−0. 00014 kg/ year) over the five-year selection period (Table 28).

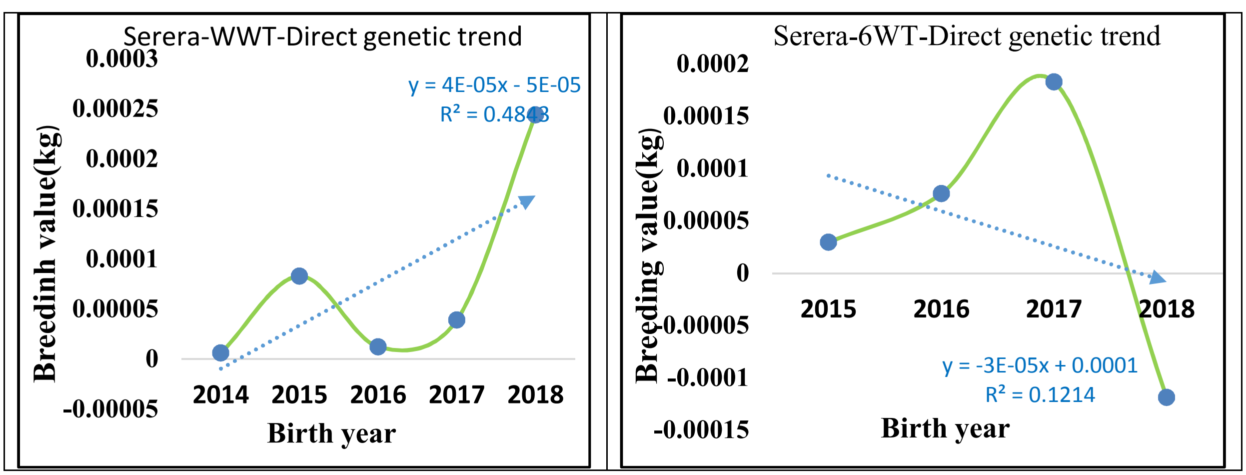


Figure 10. Direct genetic trend for Serera Bukata breeder cooperatives

(d) Murasa Weyeramo breeder cooperative

The value of direct genetic trend for this breeder cooperative is represented in Figure 11 and Table 28. Based on the selected model, the estimates of genetic progress for WWT was positive, showed increasing trend from 2014 to 2016, decreasing trend from 2016 to 2017 followed by increasing trend thereafter. However, genetic trend of 6WT decreased from 2015 to 2017 but then it increased thereafter. In this cooperative genetic the change, based on EBVs, was positive for WWT (0.033 kg/ year) and 6WT (0.071 kg/year) over the five-year selection period (Table28).

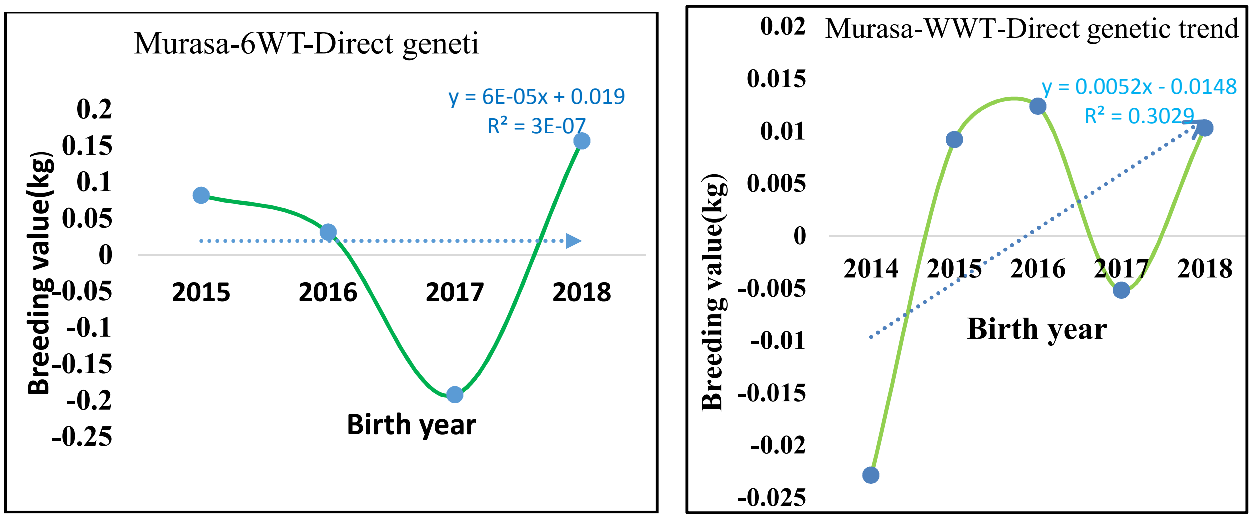


Figure 11. Direct genetic trend for Murasa Weyeramo breeder cooperative

(e) Begedamu Getemi breeder cooperative:

The value of direct genetic trend for this breeder cooperative is represented in Figure 12 and Table 28. Based on the selected model, the estimates of genetic progress for WWT showed increasing trend from 2015 to 2016 followed by sharp decreasing trend from 2016 to 2018. However, genetic trend of 6WT decreased from 2015 to 2017 but then it increased thereafter. In this cooperative genetic the change, based on EBVs, was negative for WWT (-0.000103 kg / year) but positive for 6WT (0.18 kg/year) over the five-year selection period (Table 28).

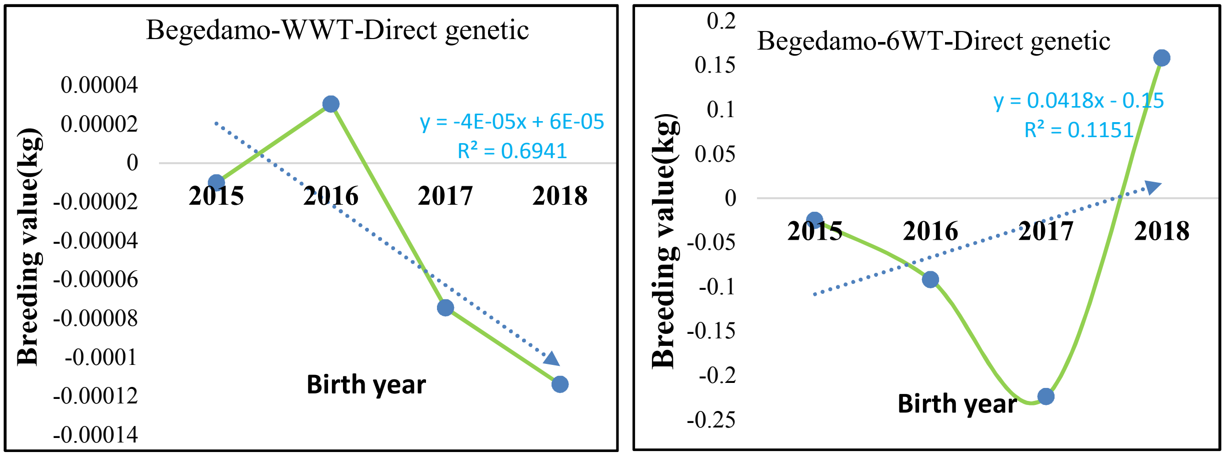


Figure 12. Direct genetic trend for Begedamu Getemi breeder cooperative

For the cooperative having negative trend (Begedamu and Serera) require intensive follow-up by the researcher, capacitate the data enumerators and members to use the allocated breeding rams properly, change the enumerators to another cooperative, culled/or marketed all third ranked animals, and prevent unwanted mated from rams purchased by farmers from market for fattening purpose is required.

4.10.2. Daily body weight gain trait breeding value and genetic trend

The estimates of genetic trend (gm/ year) for daily weight gain traits, ADG0-3, ADG3-6, and ADG0-6, are shown in the figures 13, 14,15 respectively and Table 29

(I) ADG0-3 months

The models used to obtain the EBV values were the best fitted models as per Table 15. The estimate of direct genetic trend (gm/year) for daily weight gain traits, are shown in the Figures 13. The positive genetic improvement indicated the breeding program has been relatively effective in respect to this trait. ADG0-3 was increased by 2.56 gm with 6- year period by 0.46 gm/year. There is also positive improvement in environmental variance for ADG0-3(Figure 13 and Table 29)

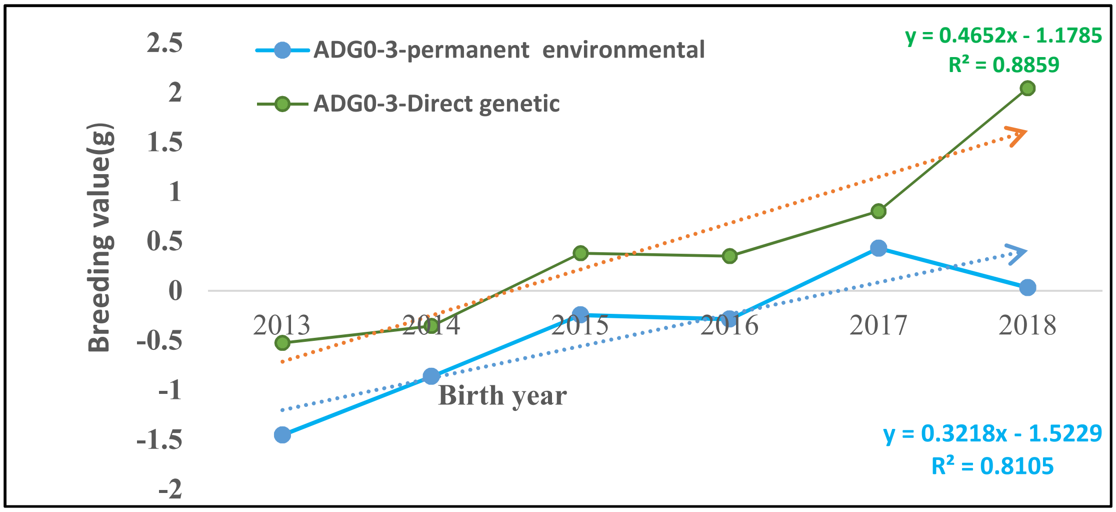


Figure 13. Genetic progress of ADG0-3

(II) ADG3-6

The models used to obtain the EBV values were the best fitted models as per Table 15. The direct genetic trend and permanent maternal environment trend for ADG3-6 over the selection period (2013-18) is presented in Figure 14. Perusal of Figure 14 showed that direct genetic trend increased from 2013-2014, decreased in 2015, remained constant from 2015 to 2017 but thereafter it fell sharply downwards. The direct genetic trend was negative (-0.135 gm per year) within the period of 6-year selection.

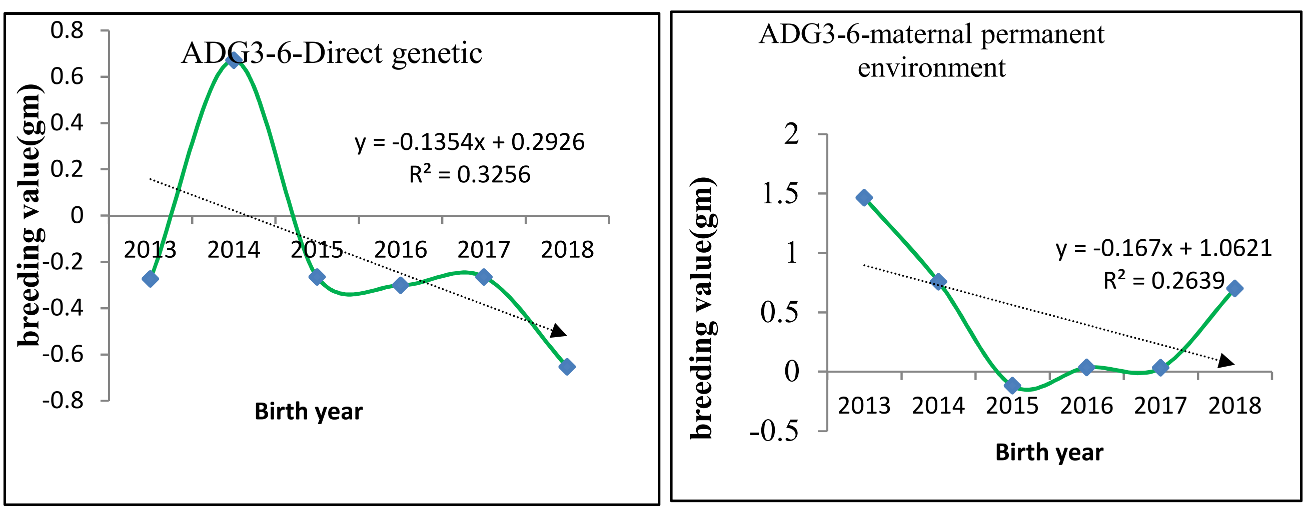
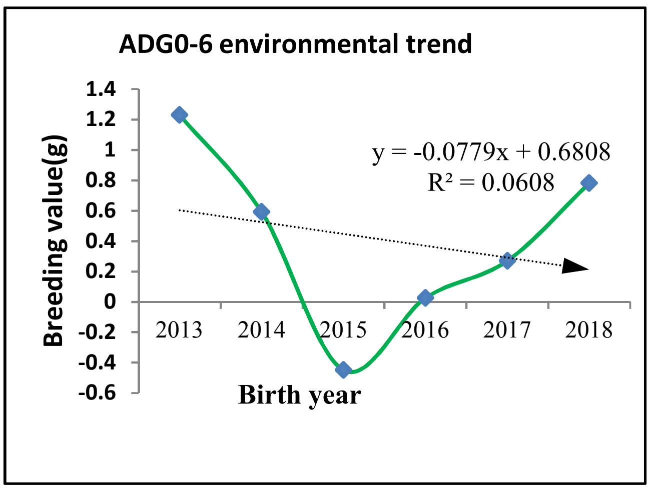


Figure 14.Direct genetic and maternal genetic trend for ADG3-6

As perceived since, the beginning of study period, descendant direct genetic trends. ADG3-6 decreased by -0.37 gm with 6-year period (Figure 14). The maternal permanent environmental trend (Figure 14) decreased from 2013 to 2015, remained static (Constant) from 2015 to 2017 and then increased thereafter**.**

(III) ADG0-6

The models used to obtain the EBV values were the best fitted models as per Table 15. The direct genetic trend and permanent maternal environment trend genetic for ADG0-6 months Over the selection period (2013-18) is presented in Figure 15. Perusal of figure 15 showed that direct genetic trend increased from 2013-2014, decreased from 2014 to 2016 but thereafter it increased consistently. The direct genetic trend (0.014 gm per year) increased within the period of 6-year selection. As perceived since, the beginning of study period,



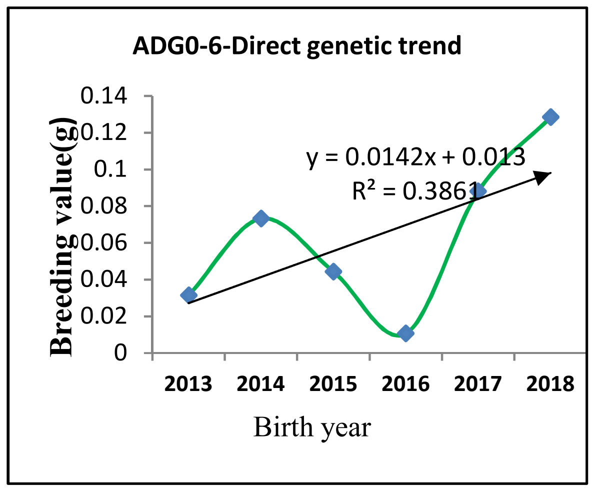


Figure 15. Direct genetic and maternal genetic trends for Average daily weight gain from birth to 6-month age

ascendant direct genetic trends. ADG0-6 is increased by 0.09 gm with 6-year period by (Figure 15). The maternal permanent environmental trend (Figure 15) decreased from 2013 to 2015, but increased from 2015 onwards.

Table 29. Daily weight gain traits direct genetic change

Trait	Direct genetic (g)	Maternal environment(g)
ADG0-3	2.56	1.48
ADG3-6	-0.37	-0.7
ADG0-6	0.09	-0.6

4.10.3. Reproductive traits breeding value and genetic trend

(I) Litter size

The models used to obtain the EBV values were the best fitted models as per Table 15. The direct genetic change and maternal permanent environmental trends for litter size over the selection period (2013-18) is presented in Figure 16-17 and Table 30.

The direct genetic trend for litter size was decreased trend (Figure 16) from 2013 to 2016 thereafter steady increase whereas maternal permanent environmental trend showed a decreasing trend over selection period (Figure 17). LS direct genetic trend was non-significant ($p>0.05$). The estimated additive genetic value was positive (0.002) and maternal environmental variance estimated trend was negative trend values of -0.005 (Table 30). The genetic progress of LS show improvement across selection year and could be taken into consideration in the process of selection.

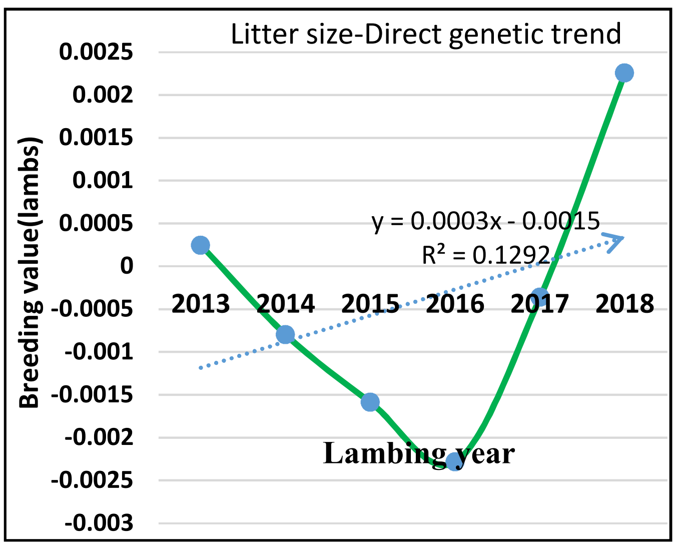


Figure 16. Direct genetic trend

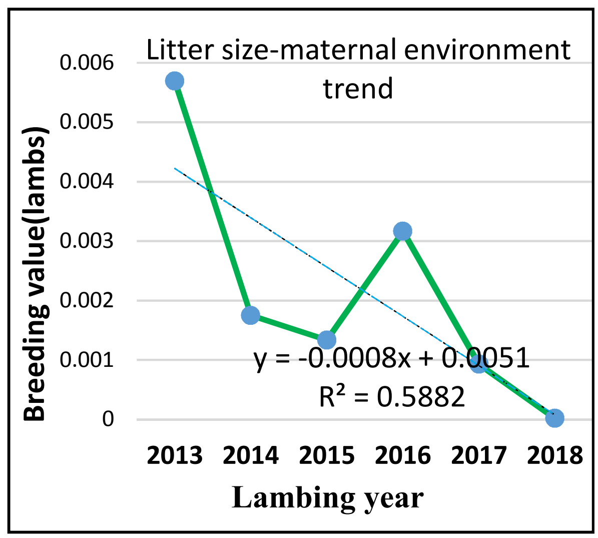


Figure 17. Permanent maternal environmental trend

(I) Lambing Interval

The direct additive genetic trend showed an increasing trend from 2014 to 2015 followed by decreasing trend from 2015 to 2017, and then increased from 2017 onwards. Annual genetic trend of LI show (Figure 18) a decreasing trend (-0.826 days/year) and -1.6981 over 6-year selection. Genetic gains of the reproductive traits considered in the present study are presented in Table 30.

(III) Age at First Lambing

The models used to obtain the EBVs values were the best fitted models as per Table 15. The direct genetic change (Trend) for AFL over the selection period (2014-18) is presented in Figure 19. The direct additive genetic decreased from 2014 to 2015, then increased from 2015 to 2017 and again showed decreasing trend from 2017 onwards (0.0274 days /year). The direct additive genetic gain (Table 30) was positive (0.09 days).

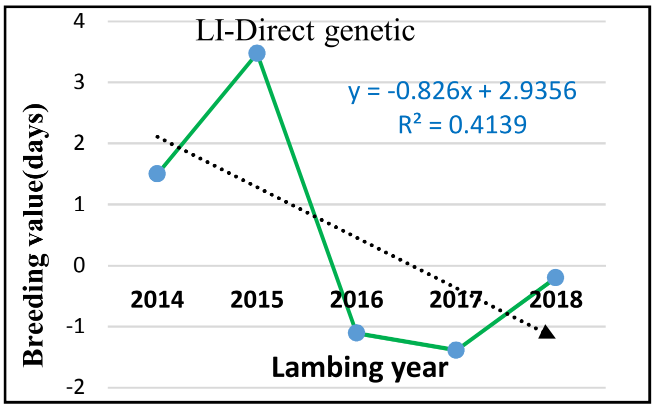


Figure 18. AFL Direct genetic trend

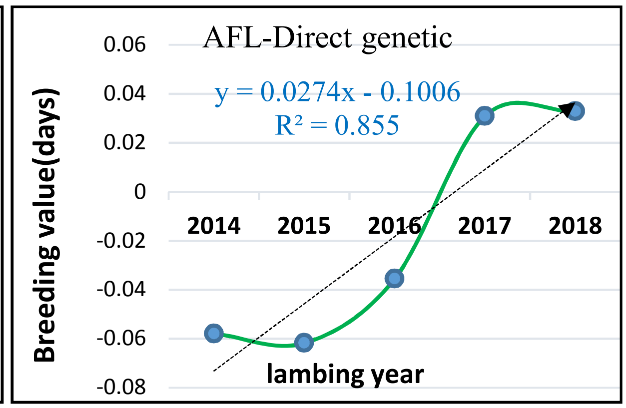


Figure 19. LI Direct genetic tre**nd**

Table 30. Genetic change over the 6 years in Reproductive Traits

Trait	Direct genetic change	Maternal permanent environmental change
Litter size	0.002	-0.005
Lambing interval	-1.6981	-
Age at first lambing	0.09	-

4.10.3.1. Genetic Trends of Litter Size across Cooperatives

The value of the five-breeder cooperatives genetic trend is represented in figure 20 and table 31. Except Murasa Weramu breeder cooperative the other four breeder cooperatives show positive genetic trend in litter size. Perusal of figure 20, Ancha Sidecho cooperative showed that direct genetic trend increased from 2015 to 2017, then no change from 2017 to 2018. The direct genetic change was 0.0013 lamb/year and 0.0038lamb per five-year selection period

(Table 31). The value of direct genetic trend for Hawora Arara cooperative showed that direct genetic trend increased from 2014 to 2015, then decreased from 2015 to 2017 followed by an increase thereafter. The direct genetic change and maternal change for litter size in this cooperative was 0.003 lamb/year and 0.029 lambs per five-year selection (Table 31).

The value of direct genetic trend for Serera Bukata breeder cooperative showed that direct genetic trend increased from 2015 to 2017 and thereafter it decreased. The direct genetic gain was 0.0005 lamb /year and 0.0011107 in four-year selection (Table 31). Similarly, in Begedamo Getami breeder cooperative figure 20 and table 31 showed that direct genetic trend decreased from 2015 to 2017 and thereafter it steep increased from 2017 onwards. The direct genetic change was 0.005 lamb/ year 0.021 within four-year selection (Table 31).

The value of litter size direct genetic trend for Murasa Weramo breeder cooperative is in negative trend. Perusal of figure 20 and table 31 for cooperative showed that direct genetic trend decreased from 2015 to 2017 and thereafter it increased from 2017 to onwards. Direct genetic and maternal genetic change were negative (-0.042 lambs/year) and -0.22 in the five-year selection period (Table 31).

Table 31.Estimates of genetic change for litter size across breeder cooperative

Change	Ancha Sidecho	Hawora Arara	Serera Bukata	Murasa Weramo	Begedamu Getemi
Direct genetic	0.003869	0.029	0.0011107	-0.22	0.021
Maternal genetic	-	0.04	-	-0.042	0.0003037
Model	2	3	1	4	3

The positive genetic trend in the four-breeder cooperative reflected that, participant farmers appropriately use the assigned breeding rams to serve breeding ewe, convenience of better flock management, effective follow up by data enumerators, better veterinary accessibility and closely followed up by researcher. The difference of litter size direct genetic trend among breeder cooperatives could be due to the fact that, the difference of flock management among cooperative and skill difference among data enumerators. The negative trend of litter size in Murasa Weramo breeder cooperative could be related to poor follow by data enumerators.

Litter size across breeder cooperative

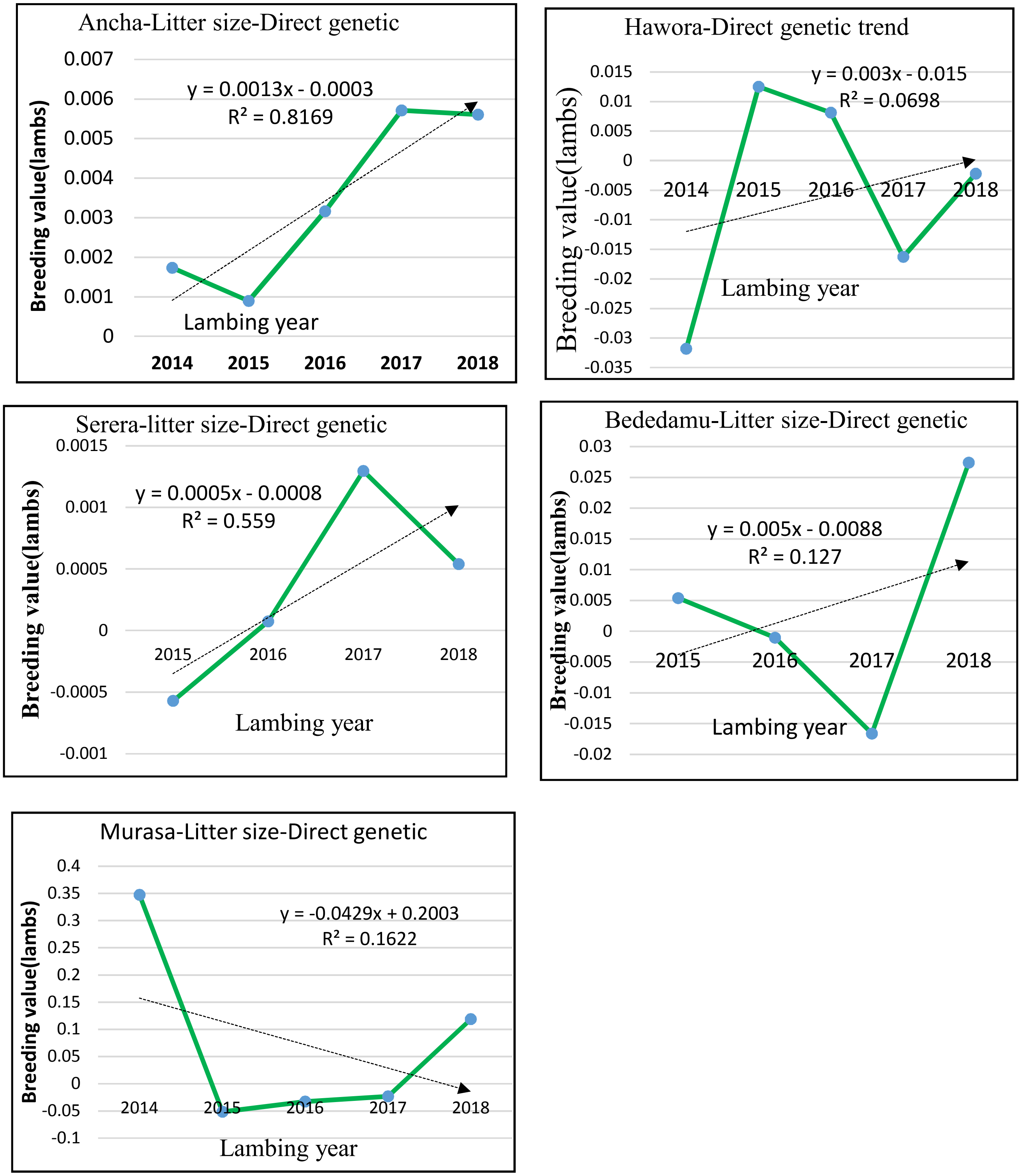


Figure 18.Litter size genetic trends for the 5-breeder cooperative

Table 32 shows an example of superior breeding rams and breeding ewes within the 6-year selection period. Those breeding rams and breeding ewes were filtered based on their 6WT and litter size traits EBVs. Conservation of this superior breeding rams and breeding ewes should be done in the communities. In this case, the table shows the possibility of maternal line selection together with paternal line selection as a next direction.

Table 32.Average estimated breeding value for Superior breeding ewe and rams

Breeding ewes				Breeding rams			
Site	Ewe ID	EBVS	Accuracy of EBVs (%)	Site	Ram ID	EBVS	Accuracy of EBVs (%)
Ancha	21736317	0.58	0.59	Ancha	21736317	7.27	0.76
Ancha	21738617	0.56	0.66	Ancha	21738617	6.75	0.76
Ancha	21875614	0.53	0.55	Hawora	21875614	6.42	0.74
Ancha	21736717	0.52	0.55	Ancha	21736717	6.17	0.74
Ancha	218503	0.52	0.55	Hawora	218503	5.74	0.74
Begedamu	218479	0.52	0.55	Hawora	218479	4.94	0.75
Hawora	21735417	0.51	0.55	Ancha	21735417	4.86	0.74
Hawora	221416	0.51	0.55	Begedamu	221416	4.48	0.73
Hawora	21852517	0.51	0.55	Hawora	21852517	4.45	0.74
Hawora	218506	0.51	0.55	Hawora	218506	4.30	0.72
Hawora	21915616	0.50	0.55	Murasa	21915616	4.21	0.74
Hawora	218637	0.50	0.66	Hawora	218637	4.16	0.73
Hawora	2215916	0.50	0.66	Begedamu	2215916	4.16	0.76
Hawora	21831416	0.50	0.55	Hawora	21831416	3.75	0.87
Serera	21831516	0.50	0.55	Hawora	21831516	3.71	0.77
Serera	22018415	0.49	0.55	Serera	22018415	3.69	0.71

4.11. Results from the Survey

4.11.1. Participation of community in CBBP

The implication of community participation in CBBP is clearly explained by Haile *et al.* (2019b). He pointed out that, when farmers participate in whole process of flock improvement program, the breeding program become successful and farmer's adoption is very high. In the study of Haile *et al.* (2014) and Gutu *et al.* (2015), CBBP were successful and the farmer's participation is still high in the country.

In this regard, Doyogena CBBP was started with 148 males and 24 females house hold in two cooperatives. Subsequently, another three cooperatives started the program. Since the formation of cooperatives, farmers of the community were continuously joining CBBP. Achievements of participating farmers have attracted other farmers and members are an increasing trend. Currently, more than 614 (Table 33) households directly participate in this breeding program. Since the initiation of CBBP in the district, there was no report of dropouts from all the cooperatives unlike the reported dropouts from CBBP membership in Horro, Menz (Gutu *et al.,* 2015) and Atsbi Wenberta sites (Regassa, 2018)

Table 33. Community participation in the CBBP

Cooperatives	Members at the beginning of CBBP		Dropouts report		New Entry		Current number of members		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
Ancha	53	7	NA	NA	85	11	138	18	156
Hawora	28	14	NA	NA	113	25	141	39	180
Serera	35	6	NA	NA	55	18	90	24	114
Begedamo	14	2	NA	NA	43	8	56	10	66
Murasa	22	3	NA	NA	59	14	81	17	98
Total							506	108	614

Note: NA=not available

4.11.2. Farmers Perception on CBBP

About the 99.1% of participant farmers revealed that CBBP is acceptable and workable in the community. In addition, the FGD result displayed that farmers were satisfied by introduction of CBBP in their respective areas due to for the improvement of their sheep. During the survey and FGD, non-member farmers were asked about their interest to join or to form new cooperative. The result indicated that about 94.8% of non-member farmers showed interest to join the breeder cooperative or to establishes new cooperative. We did not find noticeable challenge that can hinder non-participant farmers to become a member of breeder cooperative or to establish new cooperative except some farmers raise economic problem to pay membership share. This indicated that these farmers were ready to establish the breeder cooperative in future and thus more work need to be done from district office of marketing and cooperative, district office of agriculture and AARC. Farmers know the importance of best breeding ram's selection (Table 34). Higher proportion of farmers agree on the requirement of selection for sheep genetic improvement. Additionally, FGD and key informant support farmer response.

Table 34. Percentage of participants and non-participant farmers by their agreement on sheep genetic improvement through selection

Agreement on selection of best breeding rams for sheep breed improvement	Percentage	
	participants	Non-participants
Strongly agree	48.2	47.8
Agree	49.1	45.5
Not sure	2.6	5.4
Disagree	0	1.3

4.11.3. Farmer perception on inbreeding

The farmers' perception about inbreeding problem was captured through questionnaire and FGD. The results revealed that the majority of the farmer are familiar with inbreeding. There is significant knowledge difference between the member and non-member farmers. About, 99.2% of Participant farmers were well aware about inbreeding with its effect and solution. Due to continuous follow-up and training, they could capture better knowledge about effect of inbreeding and measurement taken to reduce it. On the other hand, about 85% of non-participant farmers were also aware of inbreeding, however, they did not take any measure to solve the problem as they believe inbreeding is not a major problem for animal productivity. In the breeder cooperatives breeding rams had been assigning out of its location and service allowed for only one year. At the time of breeding ram's allocation researcher, data collector and cooperative committee take care to avoid mating between relatives.

4.11.4. Farmer perception on improved performance traits

The improvement in the Doyogena sheep productivity after launching of the CBBP, based on participant farmers' ranking, is presented in Table 35.The results showed that there was improvement, after the start of the CBBP, in growth, survival of lambs, twining rate, lambing interval, AFL and flock size of Doyogena sheep and these traits were ranked as I, II, II, IV, V and VI, respectively, by the farmers. The growth performance in terms of body size and lamb survival of sheep were ranked as I and II in improvement in this breed respectively. The importance of growth and lamb survival traits, observed in the present study, was in agreement with results of reported by Mirkena *et al.* (2012).

Table 35. Participant Farmers' Ranking on Improvement in Breed Productivity through CBBP

Parameters	N	Index	Rank
Growth performance	120	0.26	1
Lamb survival	109	0.22	2
Twining rate	111	0.2	3
Lambing interval	95	0.12	4
Age at first lambing	68	0.11	5
Flock size	86	0.09	6

4.11.5. Farmers' Perception on Income from Sales of Sheep

The mean annual income comparison from sale of different categories of sheep by participants and non-participants respondents is presented in Table 36. The difference in average annual income from sale of sheep between the two groups of farmers (Participants and Non-participants) sold was statistically significant. The total average income was 3004.49 Ethiopian Birr/head by participant farmers whereas it was 1822.45 Ethiopian Birr by non-participants. This showed that the more average income was realized by participant farmers compared to another group. This finding of present study was in line with earlier reports of Gizaw *et al*. (2013) and Gutu *et al.* (2015).

Table 36. Mean income from Sale of sheep by Farmers

owner group	No of animals	Animal age group	Average price	Mann Whitney U test p-value
participant	107	Adult ram	3207(630)	0.000
	2	Adult ewe	1525(106)	
	3	young female (post weaning to one year)	923(254)	
	6	young male (post weaning to one year)	930(309)	
	118	Total	3004(878.4)	
non-participant	57	Adult ram	2222.6(986)	
	14	Adult ewe	1931(1009)	
	26	Young female (post weaning to one year)	1168(522.4)	
	21	Young male (post weaning to one year)	1474(741)	
	118	Total	1822.4(963)	

Note: Figures in parenthesis represent standard deviation; Mean incomes are in Ethiopian Birr.

4.11.6. Number of sheep sold

The number of head of sheep sold by participant and non-participant farmers is presented in Table 37. The difference in the number of sheep sold by these two group of farmers is statistically significant. A participant farmer sold 4 head of sheep per year while non-participants sold 2 head of sheep per year. This variation could be again explained by an increase in the flock size and performance difference between flock of participant and non-participant farmers. The discussion with participant farmers revealed that number of sales of sheep per year improved after CBBP intervention

Table 37. Numbers of sheep sold in one year by CBBP members and non-members

Sheep flock size	N	Median	p-value (Mann WhitneyU test)
CBBP Participant	118	4	0.000
CBBP Non participant	118	2	
Total	236	3	

4.11.7. Challenges for CBBP intervention

The major challenges related to CBBP are presented in Table 38. The overall result showed that, lack of transparency and management, financial related problem, Problem related with breeding ram selection and management and lack of training and facility were ranked as first, second, third and fourth constraints.

Lack of transparency and management existed in all cooperatives. It is related with weak linkage with the district office of cooperative, poor commitment of selected committee for regular meeting and weak leadership. Among the challenges lack of timely audit is one critical problem in all cooperatives. Auditing was not done for the three cooperatives so far. Discussion with District marketing and cooperative officers revealed that, improper file management is one major reason to delay their auditing. In the same connection lack of finical skill in committee had been raised during the FGD discussion. This caused difficulty to audit timely. The reason might be, poor educational background of financial committee. Similar problem and reason were reported by Gutu *et al.* (2015).

The challenge of young and fast-growing lambs being sold for cash needs is reported during the survey. This caused keeping the best rams in the CBBP difficult. Lack of training and awareness was reported from newly joined members. In this regard awareness creation needs to be done about the program. Another problem reported from two cooperatives were animal handling facility with shed. Large sheep holding tin roofed yard were built for three cooperatives by ICARDA.

Table 38.Major challenges of CBBP interventions

Challenges	1st	2nd	3rd	4th	Index	Rank
Lack of transparency and management	33	17	8	11	0.36	1
Financial related problem	29	15	9	2	0.31	2
Problem related with breeding ram selection and management	11	7	10	25	0.19	3
Lack of training and facility	7	10	4	2	0.11	4

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Promising results of selection were observed from the ongoing selection of Doyogena sheep CBBP. As compared to other local breeds of the country, Doyogena sheep is better in most of the productive and reproductive performance. The effect of non-genetic factors like birth site/cooperatives, birth year/lambing year, sex, ewe parity, and birth type had a significance influence on the growth and reproductive performance traits of Doyogena sheep. This suggested that considering those fixed effect during genetic parameter estimation is required.

Co) variance components and genetic parameter estimates, based on different models showed that including or excluding various maternal components of variance resulted significant effects in the analysis. The most complete model (model 6) including non-zero direct maternal genetic covariance was most appropriate models for BWT. For WWT, the suggested model was model 4, with direct genetic and maternal genetic as random effects (including non-zero direct maternal genetic correlation). For 6WT, daily weight gain and litter size traits genetic parameter estimation, direct additive genetic effect and maternal permanent environmental effect should be considered (model 2). Model 1 was the most appropriate model for estimate of genetic parameter for age at first lambing and lambing interval.

The different estimates of heritability obtained from the different models suggest that model choice is an important aspect for obtaining reliable parameter estimates to be used in genetic parameter estimation. The moderate to high estimated heritability for the growth traits suggested that the scope for further improvement of these traits. The genetic trend for showed there was negative genetic trends observed for BWT trait. For WWT and 6WT lambs are genetically improved across birth years.so selection has been successful across selection years. The genetic trend slope indicates the occurrences of selection limit and inbreeding has been surprising and limiting the expression of genetic improvement. The genetic gain for productive traits indicated better weight gain after six-year selection. Generally, the greater the superiority of the individuals selected for breeding purposes and the higher the heritability of the trait, the more progress will be made in selection.

Coefficient of inbreeding showed increasing trend across selection years. BWT had weak genetic correlation with most of growth and reproductive traits. The moderate genetic correlation estimated between WWT and 6WT suggested scope of early selection of animals at weaning instead of present practice of selection at 6 months of age. The estimates of genetic gain for 6WT trait was the greatest among the body weight traits.

The perception of member farmers revealed that CBBP is acceptable and workable in the community. The comparison of member farmers and non-member farmers result indicted that the non-member farmer show interest to join the breeder cooperative or to establishes new cooperative. There is also significant knowledge difference in inbreeding, price obtained from sheep sale and number of animals sold, between the member and non-member farmers. The participation of farmers in CBBP is in increasing trend since establishment.

Based on the result, it can be concluded that:

- 6WT could be considered as selection criteria and which could be effective for enhancing growth and reproductive trait
- Higher genetic variability for the growth and daily weight gaits traits were observed in the early growth of lambs.
- Direct heritability estimates for growth traits decrease as lamb age increase and the highest estimate was found in BWT.
- In order to avoid bias in estimation of genetic parameters, inclusion of maternal effect is important.
- The selection for LS will be more efficient, due to its higher genetic variance, however, it may have a negative effect on growth performance

5.2. Recommendations

Based on the results of present study it is recommended as under:

i. Estimate of genetic progress indicated that, there was satisfactory genetic improvement in most of studied traits due to selective breeding under CBBP in Doyogena breed. Thus, improvement of this breed under CBBP needs to be continued and/or strengthened;

ii. Due to the importance of maternal effect, maternal line selection needed to be initiated
iii. All possible steps be initiated to reduce inbreeding levels to minimum. These may include designing a mating plan where-under breeding rams are rotated among the cooperatives ensuring that mating among close relatives is avoided.
iv. Lower genetic variation for AFL indicated that the additive genetic variation in this trait is very low, thus improvement of management interventions (Ewe reproduction) should be paid greater attention. Besides the genetic parameters of AFL be investigated on large data;
v. The phenotypic and genetic estimates for litter size was higher. Thus, studies on the gene controlling this trait in Doyogena sheep could be made;
vi. The existence of correlations between WWT and 6WT allows an advantage of selection in earlier age. It could also permit culling un-productive lambs in the earlier age
vii. To sustain CBBP, linkage between district office of marketing and cooperative, district office of livestock and fishery should be improved.
viii. Awareness/ training to newly joined members concerning CBBP principle along with other aspects of improvement in feeding, managements needs to be organized on sustainable basis.
ix. The committees of cooperatives be made functional, strengthened and made more transparent;
x. Farmer perception should be changed toward the chief objective of breeding program. Improving capital of each cooperative and easy access to credit services will enable the members to retain young and fast-growing lambs till selection age and their sale will be prevented; and
xi. Optimization of the ongoing CBBP using the generated data during the current study.

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7. APPENDIX

Appendix 1. Analysis of variance (ANOVA) for BWT

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ewe Parity	6	3.6156468	0.6026078	2.20	0.0402
Site/cooperative	4	110.2069559	27.5517390	100.61	<.0001
birth type/litter size	2	162.0585273	81.0292636	295.91	<.0001
Birth year	5	85.3866866	17.0773373	62.36	<.0001
Birth Season	2	0.6552348	0.3276174	1.20	0.3024
Sex	1	44.1094997	44.1094997	161.08	<.0001
Error	2970	813.290405	0.273835		

Appendix 2. Analysis of variance (ANOVA) for weaning weight

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ewe parity	6	22.661239	3.776873	0.61	0.7261
Site/cooperative	4	3139.389108	784.847277	125.83	<.0001
birth type	2	645.610936	322.805468	51.75	<.0001
Birth year	5	1491.955285	298.391057	47.84	<.0001
Birth season	2	86.463551	43.231775	6.93	0.0010
Sex	1	846.434031	846.434031	135.70	<.0001
Error	2101	13104.99272	6.23750		

Appendix 3. Analysis of variance (ANOVA) for 6-month weight

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ewe parity	6	83.558667	13.926445	1.49	0.1767
Site/cooperative	4	1249.953801	312.488450	33.52	<.0001
birth type/litter size	2	369.020855	184.510428	19.79	<.0001
Birth year	4	1149.675517	287.418879	30.83	<.0001
Birth season	2	54.640471	27.320236	2.93	0.0537
Lamb Sex	1	1768.472729	1768.472729	189.68	<.0001
Error	1284	11971.14961	9.32333		

Appendix 4. Analysis of variance (ANOVA) for ADG0-3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ewe Parity	6	941.9667	156.9944	0.18	0.9822
Site/cooperative	4	251730.0342	62932.5086	72.41	<.0001
birth type/litter size	2	13134.4800	6567.2400	7.56	0.0005
Birth year	5	82122.7779	16424.5556	18.90	<.0001
Birth season	2	3680.5004	1840.2502	2.12	0.1206
Lamb Sex	1	15401.9126	15401.9126	17.72	<.0001
Error	2078	1806068.110	869.138		

Appendix 5. Analysis of variance (ANOVA) for ADG3-6

	DF	Type III SS	Mean Square	F Value	Pr > F
Ewe Parity	6	5615.8332	935.9722	0.67	0.6701
Site/cooperative	4	294827.4715	73706.8679	53.14	<.0001
birth type/litter size	2	15591.3942	7795.6971	5.62	0.0037
Birth year	5	29230.8371	5846.1674	4.21	0.0008
Birth season	2	2482.3843	1241.1921	0.89	0.4089
Lamb Sex	1	16443.8601	16443.8601	11.85	0.0006
Error	1259	1746371.191	1387.110		

Appendix 6. Analysis of variance (ANOVA) for ADG0-6

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ewe parity	6	2275.66627	379.27771	1.16	0.3260
Site/cooperative	4	40508.74712	10127.18678	30.94	<.0001
birth type/litter size	2	3081.88533	1540.94267	4.71	0.0092
Birth year	5	18000.87639	3600.17528	11.00	<.0001
Birth season	2	152.54791	76.27396	0.23	0.7922
Lamb Sex	1	15699.32146	15699.32146	47.96	<.0001
Error	1273	416676.2954	327.3184		

Appendix 7. Analysis of variance (ANOVA) for litter size

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ewe parity	6	81.50410275	13.58401712	48.00	<.0001
Site/cooperative	4	4.64511216	1.16127804	4.10	0.0026
Lambing season	2	2.42491390	1.21245695	4.28	0.0139
Lambing year	5	6.55333820	1.31066764	4.63	0.0003
Error	2149	608.2224810	0.2830258		

Appendix 8. Analysis of variance (ANOVA) for lambing interval

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Ewe parity	6	320432.4127	53405.4021	8.83	<.0001
Site/cooperative	4	33124.8810	8281.2203	1.37	0.2431
Birth type/litter size	2	8783.9049	4391.9524	0.73	0.4840
lambing year	5	57356.0300	11471.2060	1.90	0.0930
Lambing season	2	9033.1502	4516.5751	0.75	0.4742
Lamb Sex	1	21846.3031	21846.3031	3.61	0.0578
Error	543	3282346.411	6044.837		

Appendix 9. Analysis of variance (ANOVA) for age at first lambing

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Site/cooperative	4	40086.29749	10021.57437	1.59	0.1858
Birth type/litter size	2	22840.17472	11420.08736	1.82	0.1703
Lambing Season	2	1545.52647	772.76324	0.12	0.8845
Lambing year	3	32278.80730	10759.60243	1.71	0.1728
Error	67	420983.8269	6283.3407		

Appendix 10. Analysis of variance (ANOVA) for ARR

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Parity	6	23.81573129	3.96928855	4.75	<.0001
Site/cooperative	4	2.44706056	0.61176514	0.73	0.5707
lambing year	4	5.21708125	1.30427031	1.56	0.1837
Lambing season	2	3.33172966	1.66586483	1.99	0.1374
Sex	1	0.24097404	0.24097404	0.29	0.5916
Error	546	456.6079437	0.8362783		

Appendix 11. Average annual rainfall distribution of Doyogena district

Year	Annual rain fall (mm
2010	1236.90
2011	1236.60
2012	1268.40
2013	1148.60
2014	1257.10
2015	1193.50
2016	1424.80
2017	1035.00
2018	1189.80
Average	1221.19

Appendix 12. Average temperature of Doyogena district

Year	Min(°c)	Max(°c)	Tmax -Tmin
2010	12.83	27.60	14.77
2011	12.48	27.78	15.29
2012	12.05	27.66	15.61
2013	12.50	27.84	15.34
2014	12.28	27.73	15.45
2015	12.63	28.30	15.67
2016	12.92	27.81	14.89
2017	12.41	27.71	15.30
2018	12.02	27.43	15.42
Average	12.83	27.76	15.30

Survey part
Appendix 13. A survey questionnaire for participant farmers

A. Some general information

1. Questionnaire code----------name of the respondents------------------date-------------
2. Cooperative ------------------- role in the cooperative -------------------------------
3. How long have you have been a member of this cooperative? (yrs) ________years.
4. Do you have a sheep before CBBI setup? 1. Yes 2. No
5. How many sheep flock do you have before CBBP?
6. Compare flock size before and after CBBP program

no	Category of Sheep	Before CBBP	After CBBP
1	Total flock size		
2	Adult Rams (≥ 1-year age)		
3	Adult Ewes (≥ 1-year age)		
4	Young Male (Post weaning to < 1-year age)		
5	young Female (Post weaning to < 1-year age)		
6	Male Lambs (Birth to weaning)		
7	Female Lambs (Birth to weaning)		
8	Castrate		

B. Improvement progress

1.How do you see trend of flock size since CBB established?

1. Do you want to expand flock sizes and production in the future? 1. Yes 2. No If yes please list and rank it.

S/N	Reasons	Rank
1		
2		
3		
4		

2. Have you seen improvement in the flock size, age at first lambing, lambing interval, growth performance, lamb survival and twining rate after breeding program? Please compare each other and rank according to its improvement?

Parameter	Showed improvement	no change	Decreased	Rank
Flock size				
Lamb survival				
Age at first lambing				
Lambing interval				
Growth performance				
Twining rate				

3. Is there any complain in the effectiveness of the CBBP? 1. Yes 2. No, if you say yes what are the reason? ____

C. perception on importance, breeding ram management and inbreeding

1. Do you think income gained from sale of sheep is increased after the introduction of CBBP?
   1. Yes Improved 2. No change 3. Decreased
2. Do you think CBBP member sheep is superior to non-member sheep? 1, yes 2, No
3. Are you thoroughly aware the principle of CBBP program? Have you got skill (knowledge) with this program? please kindly list the skill you develop___________________________

   ____
4. Do you think CBBP approach is crucial to improve sheep breed? 1.Yes 2. No 3.not sure

If you say Q (4) Is it workable and widely acceptable in this community? 1. Yes 2. No 3.not sure. If you say yes, why__________________________if no why____________________________?,

5. If I say best breeding ram selection is key for Doyogena sheep breed improvement? What is your agreement? 1. Strongly agree 2. Agree 3. Not sure 4. Disagree 5. Strongly disagree

6. Are you aware of inbreeding? A. Yes B. No. if you say yes. Have you seen so far in your flock or else? What are the signs of inbreeding?
   I. ____
   II. ____
7. How record keeping is going on?
8. How breeding ram selection is going on?
9. Do you have a chance to hold a breeding ram so far? 1, yes, 2, no. if yes, for how many rounds you keep breeding ram_________ how long you keep the breeding ram? __________years.
10. Are you interested to keep the breeding ram in the future? 1, interested, 2 not happy if you currently keep breeding ram please tell me it's ID ____Are you satisfied with this price share of the ram?
    1. Yes 2. No
11. For how long you used the current rams ____and for how long you wanted to use selected rams for breeding? (1) below one year (2) 1-2 year (3) 2-3 years (4) 3 years (5) More than three years
12. How many people have been used the rams _______number of ewes allocated? ______
13. Are the assigned rams enough/under-utilized/overused in the group? 1, yes enough 2, not enough. If not, enough what is the reason____
14. Is there any time of the year when you don't have access to the breeding rams? 1. Yes 2. No
    If you say yes, what is the reason____
15. What is the fate of unselected/or rank 3 rams? ___________________________________
16. Where you sell your sheep? ____
17. Do you think number of sheep sold from your sheep stock price is increased over the last 6 years? 1. Yes 2. No 3. Not sure
18. If you sold sheep for the last one year, kindly fill the following Table. (starting from early to recent)

s/n	Number of animals sold	Sheep category or age group	Dd/mm/yy	Sex of the animal	Where you sold?	Weight if measured	Price
Initial							
Mid							
Recent							

19. Would you continue to be a member of the breeding cooperative if technical and financial support stops? 1. Yes 2. No

D. perception on support and training

1. Have you got training on selection of best rams for breeding and support? 1. Yes 2. No
2. Who gave the training/support? ____
3. If yes, what are those supports? 1. training/advises 2. Material/inputs 3. Live sheep
4. What type of training was imparted? ____
5. What was frequency of these trainings? ____
6. What was the benefit of these trainings? ____
7. Do you have still needed a training____
8. If yes to Q 7, what type of skill is needed? ______________________________________

9. Comment on training____

E. Constraints

1. What are major constraints that hinder effectiveness of this program? Please list and Rank it.

s/n	Major constraints	Rank
1		
2		
3		

4. Any comment on the effectiveness of CBBP____
____

Appendix 14. A survey questionnaire for non-participant's farmers

A. General information

1.Questionnaire code--------------------name of the respondents-----------------date-------------

2. Do you have a sheep? 1. Yes 2. No

B. trend of sheep flock

Trend	Tick
Increasing	
Decreasing	
Stable	

If you tick one of the trends, what are the reasons for that trend?

1. In Case flock size is stable, do you want to expand flock sizes and production in the future? 1. Yes 2. No If yes, please list and rank it.

S/N	Reasons	Rank
1		
2		
3		

2.Which category of sheep is owned by you and what was its source.

s/n	Category of Sheep	Number	State your source
1	Total flock size		
2	Adult Rams (≥ 1-year age)		
3	Adult Ewes (≥ 1-year age)		
4	Young Male (Post weaning to < 1-year age)		
5	young Female (Post weaning to < 1-year age)		
6	Male Lambs (Birth to weaning)		
7	Female Lambs (Birth to weaning)		
8	Castrate		

Are you aware of sheep breeding cooperatives in this district? 1. Yes 2. No if yes, how did you hear about? From what body's ____

2. Do you think sheep flocks of the cooperative members are superior to their counterpart kept by other farmers? 1. Yes superior 2. No difference 3. Inferior
3. Where you sell your sheep? ____
4. Do you think number of sheep sold from your sheep stock price is increased over the last 6 years? 1. Yes 2. No 3. Not sure

5. If you sold sheep for the last one year kindly fill the following table. (starting from early to recent)

s/n	Number of animals sold	Sheep category or age group	Dd/mm/yy	Sex of the animal	Where you sold	Weight if measured	Price
Initial							
mid							
Recent							

6. Do you think improving local sheep breed through best ram selection would bring significant change in sheep productivity and performance? 1. Yes 2. No; If you say yes, state your agreement
   1. Strongly agree 2. Agree 3. Not sure 4. Disagree 5. Strongly disagree
7. Do you know inbreeding 1? Yes 2. No if yes what is its effect --
   ----
8. Would you take your ewes to the best selected ram in your neighbor for mating? 1. Yes 2. No
9. Is there a difference in sale price of breeding animals from CBBP and non-member?
   1. Yes 2. No 3. Not sure
10. Do you think CBBP approach is crucial to improve sheep breed? 1, Yes 2, No 3, not sure
11. If you say yes Q (10), Is it workable and acceptable in this community? 1. Yes, 2. No 3.not sure.
12. If you say yes Q (11) why not join the breeding cooperative? or why not establish new cooperative? ____
13. If you say Q (12) no; Have you seen a problem in the cooperative and what are the key reasons that result delay in non-member farmer to join the cooperative?

please list those issues.

Reason | rank

i. ____ _____
ii. ____ ______
iii. ____ _____

14. If you are given a chance to join the breeding cooperative, would you be willing to pay the cooperative requirement? 1. Yes 2. No 3. Not sure

D. support

1. Have you received training and support on sheep husbandry and management?1. Yes 2.No. If yes, by whom? 1. Research Centre 2. District extension 3. ICARDA 4. NGO (other)
2. What are those supports? 1. training/advises 2. Material/inputs 3. Live sheep
3. What type of training was imparted? ____
4. What was the frequency of these trainings? ______________________________________
5. Who imparted these trainings? ____
7.What was the benefit of these trainings? ____

Appendix 15. Checklist prepared for FGD

1. What are the benefits you gain from CBBP?
2. Is CBBP is acceptable by the community?
3. How about your linkage with, AARC, district livestock and fishery and district office of cooperative and promotion?
4. Condition and frequency of follow-up. What is their support
5. Problem identified, solved need remedy in the future
6. How audit, financial management, market linkage going on?
7. How record keeping is going on?
8. How breeding ram selection going on?
9. How many breeding rams your cooperative sell?
10. How many rounds you select? Your income?
11. Current number of active rams usually selected and included in best rams for breeding service and number of ewes usually served (from how many rams, how much ewes would they serve in the community? Is there ram shortage if so, what is the reason?
12. Currently for how long time the selected would rams serve? Is there an idea to extend or shorten ram service period? Are you satisfied with two third price sharing?
13. Had any of rams selected (and bought) by the committee has been found to be unacceptable by cooperative members? Or any complain?
14. Are you satisfied with the price for best breeding rams sell to other area?

Perception on benefit and improvement progress

1. Have you observed improvement in CBBP participants by changes flock size in growth performance, twining rate, age at first lambing, lambing interval, lamb survival and total flock size through the CBB Program?

Improved trait	Rank
Lamb survival	
Growth performance	
Twining rate	
Age at first lambing	
Lambing interval	
Flock size	

2. How the community perceived the role of breeding ram before establishment of this cooperative and CBBP- inbreeding, negatives selection ...etc?
3. Compare performance of sheep flock before and after the sheep breeding cooperative mothering ability (lamb survival to coat color, libido).
4. Do you think the selected rams from improved breed would fetch higher premium compared to the other local breeds?
5. Is there the price difference between with member and non-member?
6. How is the attitude of (nonmember) neighboring communities towards this cooperative?

Perception on Support and Challenges

1. How communities in this area (including members) perceived the breeding cooperative?
2. Have you received training, if yes on what aspect by whom, how many times? Knowledge gained to members?
3. Would you have to be always supported by the researchers to select the best rams?
4. Comments on the breeding scheme.
5. Please list the most important challenge you encounter. Which are solved and which ones need further work

Appendix 16. Checklist prepared for key informant

1. How your offices support the ongoing CBBP in this district?
2. How about your linkage with cooperative?
3. Your support? By whom
4. Frequency and content of communication with the cooperative.
5. Do you know thoroughly the principle of CBBP?
6. How about your linkage with AARC and SARI? Is there sharing of responsibility? If you say yes, what was your responsibility?
7. Have you given training for the cooperative?
8. If Q no 8 yes, who give the training, in what issue you focus?
9. Frequency of training?
10. Have you given a support for the cooperative? If yes
11. What type of support?
12. Have you seen weakness in cooperative during your follow-up?
13. Strength of cooperative during inspection.
14. Skill gap of cooperative member and committee
15. What is the remedy to solve?
16. Current number of the cooperative (Male/Female). how about changes over years.
17. Reason for new members joining the cooperative? Total drop___outs__male__female ___
18. How would set the price best rams and profit share after the ram sold?
19. How would set the margin of ram after it sold?
20. In what ways has the CBBP contributed towards the district level cooperative development interventions?
21. Has this sheep breeding scheme been part of innovations (experiences) visited by farmers from other district or experts from (other) offices of agriculture?
22. What contributions do you think the breeding scheme has made in improving farmers' livelihood (thoughts, perceptions and attitudes)?
23. Challenges encountered for these programs. Does it vary between cooperatives?
24. Comments on the breeding scheme.

i. ______________________________

ii. ______________________________

iii. ______________________________

iv. ______________________________

Appendix 17. Least Squares Means (LSM±S.E) for growth traits Ancha breeder cooperative

Ancha Sedicho								
Source of Variation	BWT(Kg)		WWT(Kg)		6WT(Kg)		Litter size(lamb)	
	N	mean ±SE	N	Mean ±SE	N	LSM ±SE	N	LSM ±SE
Overall	918	2.7±0.02	566	12.64±0.2	301	22.9±0.4	641	1.71±0.03
CV%		14.7		17.95		14.7	35.22	
Parity		**		NS		NS		**
Parity 1	419	2.6±0.02	276	12.7±0.2	156	22.0±0.55	328	1.42±0.03^{b}
Parity 2	233	2.5±0.03	122	12.6±0.2	56	22.6±0.6	133	1.76±0.04^{a}
Parity 3	97	2.6±0.04	65	13.02±0.3	36	22.3±0.7	69	1.73±0.06^{a}
Parity 4	64	2.6±0.05	41	12.38±0.48	23	22.3±0.7	41	1.58±0.08^{ab}
Parity 5	35	2.6±0.07	22	12.5±0.5	12	22.2±0.09	22	1.64±0.11^{ab}
Parity 6	19	2.9±0.09	13	12.48±0.6	9	23.6±1.24	12	1.95±0.15^{a}
Parity ≥7	51	2.68±0.06^{a}	27	12.8±0.4	9	25.6±1.25	36	1.94±0.09^{a}
Birth type		**		**		NS	-	-
Single	308	3.08±0.03^{a}	223	13.54±0.2^{a}	129	23.2±0.4	-	-
Twin	539	2.75±0.02^{b}	310	12.4±0.18b	153	23.5±0.4	-	-
≥Triplet	71	2.26±0.05c	33	12±0.4^{c}	19	22±0.9b	-	-
Sex		**		**		**		-
Male	539	2.86±0.02	365	13.4±0.21	230	24.5±0.4	-	-
Female	379	2.53±0.03	201	11.8±0.24	71	21.3±0.5	-	-
Season		NS		**		NS		NS
Main rain	317	2.73±0.03a	198	12.8±0.24^{b}	90	22.9±0.5	224	1.71±0.03
Small rain	272	2.7±0.03a	192	12.9±0.24^{a}	113	23.5±0.5	200	1.66±0.03
Dry	329	2.67±0.03^{a}	176	12.1±0.25^{b}	98	22.4±0.54	217	1.77±0.03
Birth year		**		**		**		**
2013	49	2.93±0.06^{ab}		-		-	-	-
2014	127	2.83±0.04^{a}	62	12.78±0.3^{b}	28	19.9±0.8^{d}	128	1.66±0.05^{ab}
2015	194	2.86±0.03^{b}	140	14.5±0.26^{a}	70	24.4±0.5^{a}	189	1.70±0.04^{ab}
2016	177	2.58±0.03^{c}	124	12.2±0.28^{b}	73	23.9±0.1^{bc}	176	1.74±0.04^{ab}
2017	191	2.36±0.03^{d}	143	11±0.25^{c}	91	23.3±0.5^{c}	191	1.56±0.04^{b}
2018	180	2.61±0.03^{b}	97	12.6±0.29^{b}	39	23.1±0.7^{b}	181	1.81±0.04^{a}

Appendix 18. Least Squares Means (LSM±S.E) for growth traits Hawora breeder cooperative

Hawora Arara								
Source of Variation	BWT(Kg)		WWT(Kg)		6WT(Kg)		Litter size(lamb)	
	N	mean ±SE	N	Mean ±SE	N	LSM ±SE	N	LSM ±SE
Overall	896	3.09±0.04	648	14.04±0.2	397	21.71±0.4	631	1.74±0.05
CV%		19.12		17.95		14.4		31.09
Parity		NS		NS		NS		**
Parity 1	434	3.04±0.04^{b}	317	13.95±0.2	200	21.01±0.3	347	1.32±0.02^{c}
Parity 2	258	2.95±0.04^{b}	179	13.84±0.2	103	20.85±0.4	155	1.68±0.04^{b}
Parity 3	101	3.06±0.06^{b}	76	13.58±0.3	44	20.83±0.56	67	1.68±0.06^{b}
Parity 4	52	3.15±0.08^{ab}	37	14.01±0.4	25	21.57±0.6	31	1.87±0.09^{ab}
Parity 5	20	2.94±0.13^{b}	14	14.99±0.6	10	22.39±0.9	12	1.71±0.15^{ab}
Parity 6	16	3.05±0.15^{ab}	13	14.76±0.6	6	23.04±1.2	9	1.92±0.18^{a}
Parity ≥7	15	3.41±0.15^{a}	12	13.13±0.4	9	22.29±1.05	10	1.92±0.17^{ab}
Birth type		**		**		**	-	-

Single	317	3.57±0.05[a]	247	15.18±0.3[a]	126	22.6±0.47[a]	-	-
Twin	513	3.2±0.04[b]	357	14.4±0.2[b]	156	22.21±0.4[a]	-	-
≥Triplet	66	2.48±0.08[c]	44	12.53±0.4[c]	115	20.24±0.6[b]	-	-
Sex		**		**		**	-	-
Male	499	3.2±0.05	382	14.73±0.3	264	23.14±0.4	-	-
Female	397	2.9±0.05	266	13.3±0.3	133	20.28±0.5	-	-
Season		*		**		NS		NS
Main rainy	354	3.01±0.05[b]	221	13.7±0.3[b]	126	21.55±0.47	249	1.73±0.03
Small rain	290	3.09±0.05[b]	241	14.45±0.3[a]	156	21.48±0.4	214	1.68±0.03
Dry season	252	3.16±0.06[a]	186	13.9±0.3[b]	115	22.1±0.54	168	1.73±0.04
Birth year		**		**		**		*
2014	218	3.78±0.12[a]	4	13±1.13[b]	4	23.01±1.5[d]	24	1.52±0.12[c]
2015	209	3.0±0.05[b]	159	14.6±0.2[a]	86	22.95±0.4[a]	217	1.86±0.04[a]
2016	216	2.8±0.05[c]	162	14.2±0.2[b]	113	20.59±0.3[bc]	209	1.82±0.04[a]
2017	228	2.5±0.05[d]	187	13.5±0.22[c]	149	20.39±0.3[c]	207	1.72±0.04[ab]
2018	25	3.3±0.05[b]	136	14.3±0.2[b]	45	21.61±0.5[b]	226	1.76±0.04[ab]

Appendix 19. Least Squares Means (LSM±S.E) for growth traits Serera breeder cooperative

	Serera Buketa							
Source of Variation	BWT(Kg)		WWT(Kg)		6WT(Kg)		Litter size(lamb)	
	N	mean ±SE	N	Mean ±SE	N	LSM ±SE	N	LSM ±SE
Overall	512	3.04±0.05	389	15.86±0.41	250	22.68±0.6	401	1.78±0.03
CV%		12.74		14.47		12.01		27.45
Parity		NS		NS		NS		**
Parity 1	235	3.01±0.06	188	15.76±0.4	127	22.3±0.69	203	1.28±0.03[c]
Parity 2	140	3.03±0.06	102	15.77±0.4	57	22.5±0.7	93	1.57±0.04[b]
Parity 3	59	3.04±0.07	41	16.53±0.52	24	22.38±0.9	47	1.69±0.06[b]
Parity 4	37	3.0±0.08	26	15.7±0.6	21	22.6±0.9	25	1.66±0.08[b]
Parity 5	19	3.0±0.1	17	15.41±0.7	10	23.75±1.14	16	1.8±0.09[b]
Parity 6	9	2.99±0.14	7	17.35±0.9	5	22.87±1.4	8	1.79±0.16[b]
Parity ≥7	13	3.22±0.11[a]	8	14.53±0.8	6	22.19±1.2	12	2.39±0.15[a]
Birth type		**		**		NS	-	-
Single	317	3.5±0.04[a]	179	16.86±0.3[a]	115	24.17±0.38[a]	-	-
Twin	513	3.04±0.03[b]	205	16.36±0.24[b]	132	23.99±0.4[a]	-	-
≥Triplet	66	2.57±0.15[c]	5	14.37±1.01[c]	3	19.87±1.8[b]	-	-
Sex		**		**		**	-	-
Male	305	3.15±0.05	254	16.49±0.41	170	23.9±0.65	-	-
Female	207	2.94±0.06	135	15.24±0.45	80	21.45±0.72	-	-
Season		**		**		**		**
Main rain	223	3.15±0.06[a]	165	15.11±0.43[b]	104	21.68±0.73[b]	172	1.83±0.03[a]
Small rain	281	3.03±0.06[b]	116	16.45±0.46[a]	88	23.16±0.71[a]	114	1.64±0.04[b]
Dry	8	2.95±0.06[b]	108	16.04±0.45[b]	58	23.19±0.71[a]	115	1.76±0.04[ab]
Birth year		**		*		**		*
2015	81	3.32±0.07[a]	72	16.01±0.2[ab]	52	24.09±0.7[a]	79	1.88±0.06[a]
2016	131	3.07±0.06[b]	109	16.45±0.4[ab]	61	21.97±0.7[b]	129	1.72±0.04[ab]
2017	153	2.81±0.06[d]	121	15.75±0.4[b]	96	22.26±0.65	151	1.67±0.04[b]
2018	147	2.97±0.06[c]	87	15.25±0.46[b]	41	22.39±0.83[b]	147	1.69±0.04[ab]

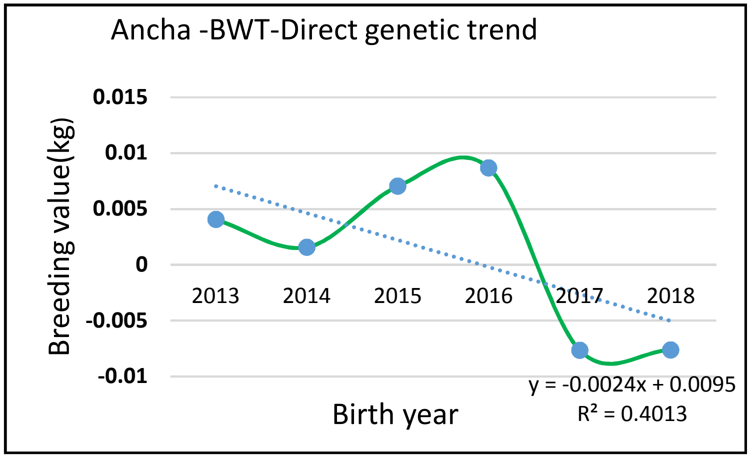
Appendix 20. Least Squares Means (LSM±S.E) for growth traits Murasa breeder cooperative

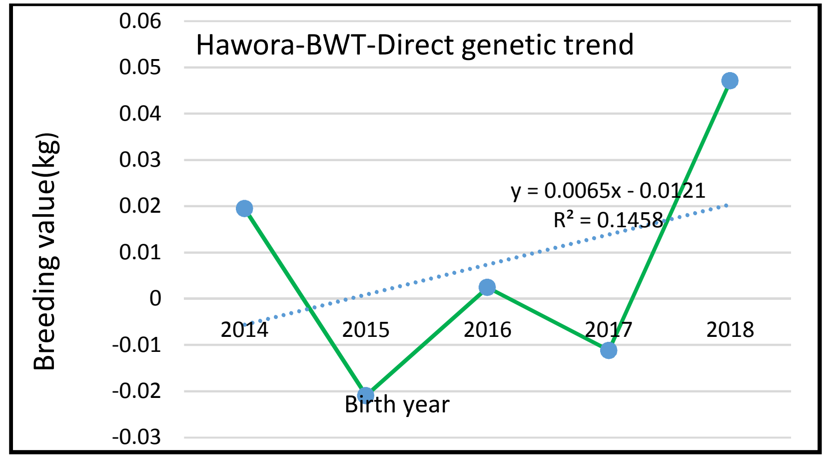
Murasa weyeramo								
Source of Variation	BWT(Kg)		WWT(Kg)		6WT(Kg)		Litter size	
	N	mean ±SE	N	Mean ±SE	N	LSM ±SE	N	LSM ±SE
Overall	354	2.87±0.1	290	14.92±0.42	218	21.68±0.6	262	1.40±0.08
CV%		13.05		10.56		10.2		27.98
Parity		NS		NS		NS		**
Parity 1	183	3.03±0.09	153	15.02±0.3	119	22.4±0.69	29	1.24±0.07[b]
Parity 2	100	3.03±0.09	79	14.94±0.3	61	22.3±0.7	11	1.37±0.08[a]
Parity 3	37	2.97±0.12	28	15.05±0.4	18	22.8±0.9	8	1.28±0.1[ab]
Parity 4	17	2.99±0.08	14	14.92±0.5	9	21.7±0.9	4	1.36±0.14[a]
Parity 5	11	2.87±0.15	11	14.5±0.6	7	22±1.14	2	1.46±0.15[a]
Birth type		**		**		*		-
Single	143	3.37±0.09[a]	119	15.97±0.3[a]	94	22.6±0.6[a]		-
Twin	203	2.9±0.08[b]	165	15.53±0.24[b]	118	22.5±0.5[a]		-
≥Triplet	8	2.24±0.18[c]	6	13.27±0.7[c]	6	19.8±1.15[b]		-
Sex		**		**		**		
Male	246	2.95±0.1	203	15.43±0.41	162	22.6±0.6		
Female	108	2.78±0.1	87	14.42±0.45	56	20.7±0.6		
Season		*		*		**		NS
Main rain	130	2.95±0.1[a]	102	14.71±0.4[b]	73	21.4±0.73	129	1.69±0.04
Small rain	116	2.78±0.11[c]	102	14.73±0.46[b]	81	22.04±0.7	115	1.75±0.05
Dry	108	2.87±0.1[ab]	86	15.33±0.42[a]	64	21.5±0.6	107	1.63±0.05
Birth year		**		**		**		NS
2015	71	2.97±0.1[b]	63	19.23±0.4[a]	56	23.05±0.7[a]	71	1.64±0.36
2016	100	3.06±0.08[a]	78	14.8±0.38[b]	56	19.8±0.6[c]	98	1.54±0.05
2017	97	2.7±0.08[b]	93	13.61±0.36[c]	68	20.3±0.5[bc]	97	1.54±0.05
2018	84	2.9±0.08[b]	54	13.06±0.39[c]	36	21.6±0.6[b]	83	1.73±0.06

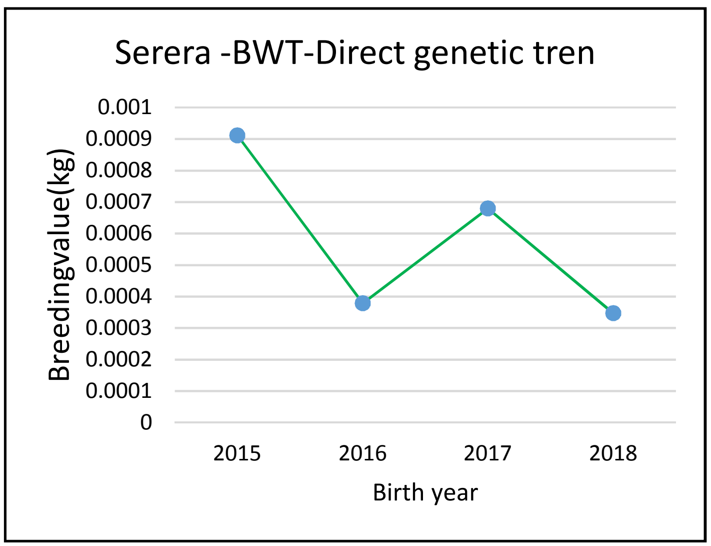
Appendix 21. Least Squares Means (LSM±S.E) for growth traits Begedamu breeder cooperative

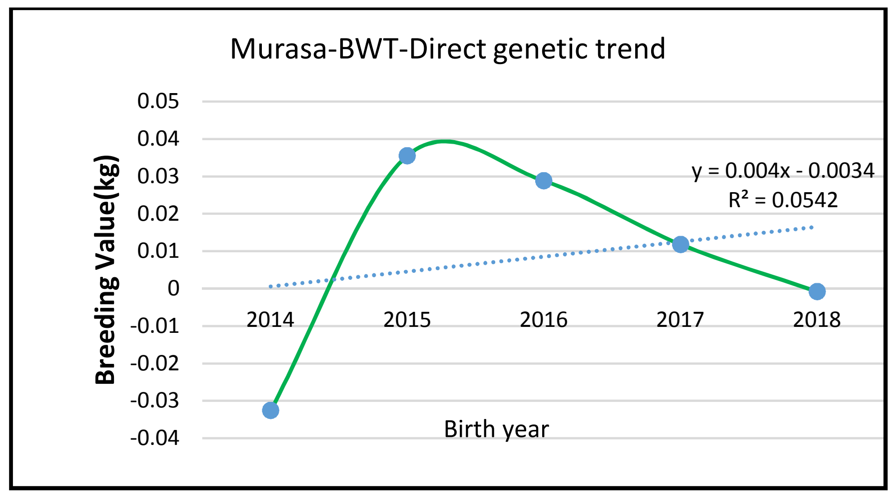
Source of Variation	BWT(Kg)		WWT(Kg)		6WT(Kg)		Litter size(lamb)	
	N	mean ±SE	N	Mean ±SE	N	LSM ±SE	N	LSM ±SE
Overall	311	2.9±0.07	229	13.45±0.46	138	20.8±0.5	208	1.86±0.08
CV%		19.48		20.5		10.2		34.9
Parity		NS		NS		NS		**
Parity 1	151	3.00±0.06	153	13.62±0.3	119	21.9±0.5	114	1.35±0.05[b]
Parity 2	84	2.9±0.07	79	13.7±0.4	61	21.8±0.6	55	1.90±0.07[a]
Parity 3	34	3.06±0.1	28	13.7±0.6	18	21.4±0.8	34	1.75±0.13[a]
Parity 4	20	2.92±0.13	19	14.2±1	NA	NA	20	1.85±0.15[a]
Birth type		**		**		*	-	-
Single	102	3.26±0.08[a]	119	14.59±0.34[a]	94	22.2±0.6[a]	-	-
Twin	182	2.98±0.07[b]	165	14.59±0.4[a]	118	21.6±0.5[a]	-	-
≥Triplet	27	2.5±0.12[c]	6	11.16±0.7[b]	6	18.5±1.0[b]	-	-
Sex		NS		**		**		
Male	184	2.98±0.07	203	13.9±0.41	162	21.8±0.6	184	
Female	127	2.85±0.08	87	12.9±0.45	56	19.8±0.6	126	
Season		*		*		NS		NS
Main rain	84	2.9±0.09[ab]	102	12.7±0.4	73	19.7±0.5[b]	64	1.91±0.06
Small rain	79	3.06±0.09[a]	102	13.7±0.5	81	20±0.7[ab]	53	1.88±0.07
Dry	148	2.79±0.08[b]	86	13.84±0.4	64	22±0.6[a]	91	1.79±0.05
Birth year		**		**		**		NS
2015	73	2.91±0.09[a]	63	13.8±0.5[a]	56	22.3±0.6[a]	51	1.84±0.07
2016	94	3.11±0.08[a]	78	14.7±0.4[a]	56	22.4±0.6[a]	62	1.83±0.07
2017	82	3.01±0.11[a]	93	11.52±0.6[b]	68	17.3±0.8[b]	51	1.86±0.07
2018	62	2.63±0.09[b]	54	13.07±0.6[a]	36	21.1±0.6[a]	44	1.91±0.08

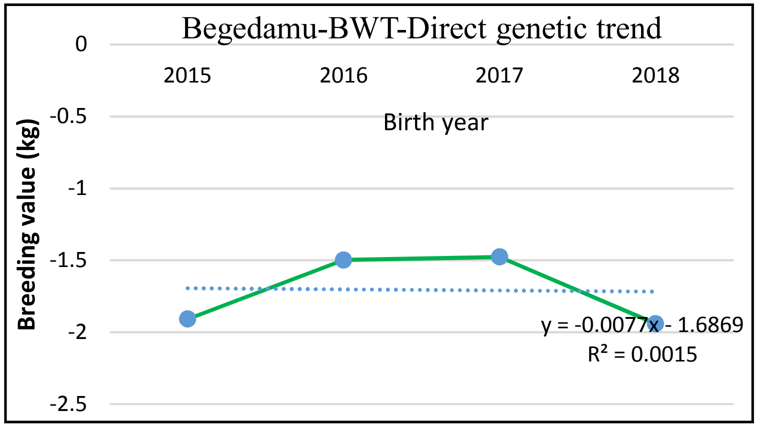
Appendix 22. Genetic progress of some important traits



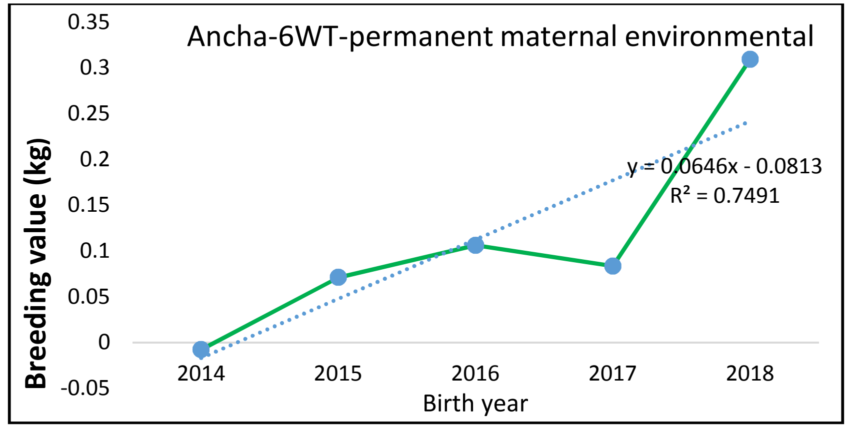




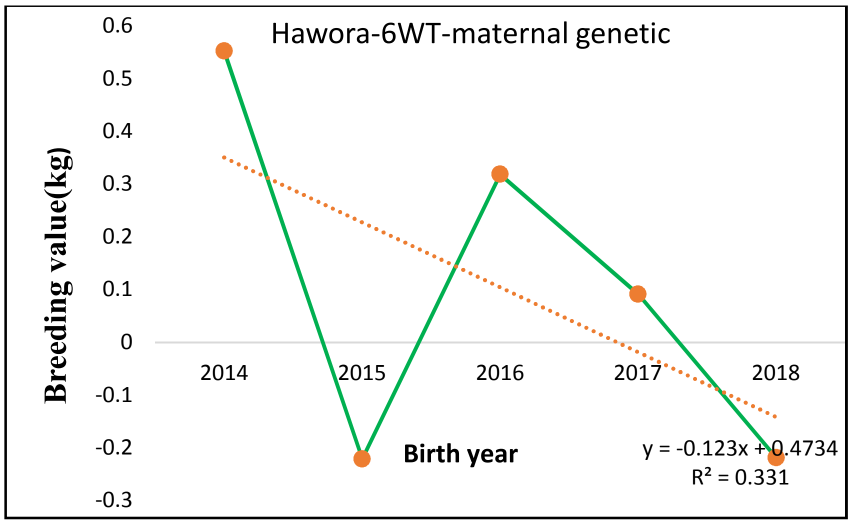




Begedamu-BWT-Direct genetic trend
0
-0.5
-1
-1.5
-2
-2.5
2015
2016
2017
2018
Birth year
Breeding value (kg)
y = -0.0077x - 1.6869
R² = 0.0015

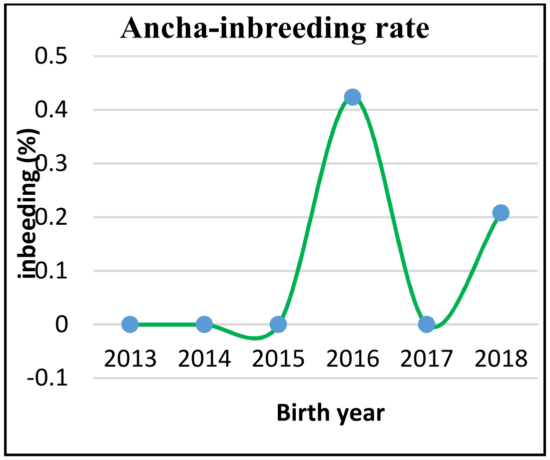


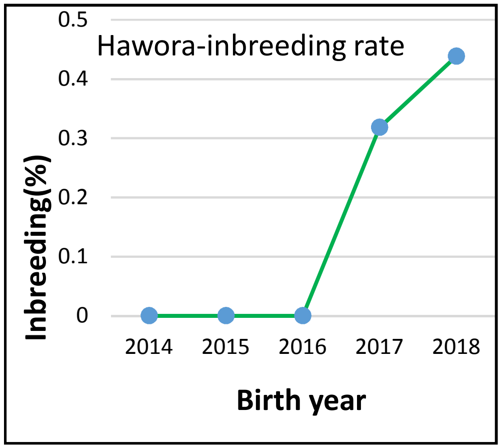
Ancha-6WT-permanent maternal environmental
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
2014
2015
2016
2017
2018
Birth year
Breeding value (kg)
y = 0.0646x - 0.0813
R² = 0.7491

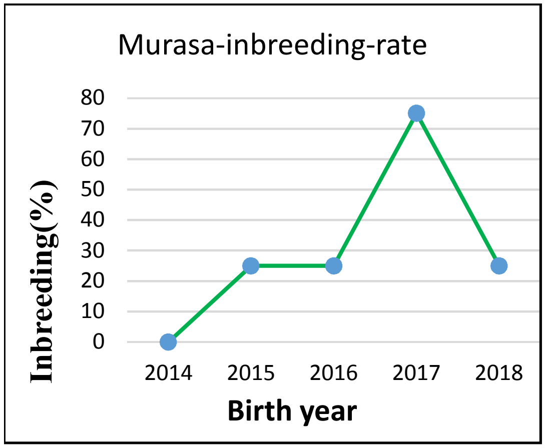


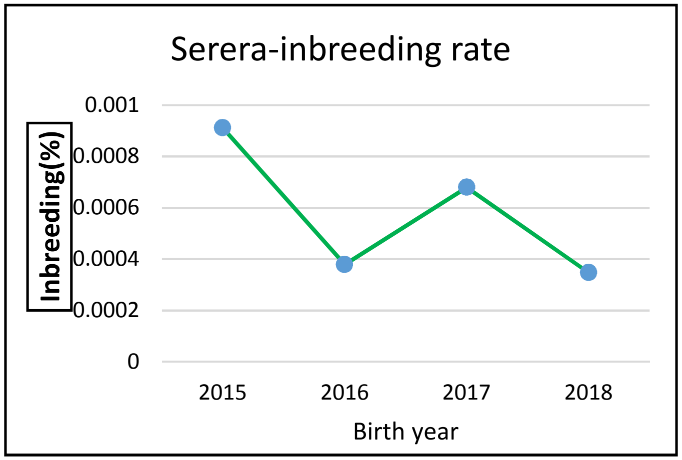
Hawora-6WT-maternal genetic
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
2014
2015
2016
2017
2018
Birth year
Breeding value(kg)
y = -0.123x + 0.4734
R² = 0.331

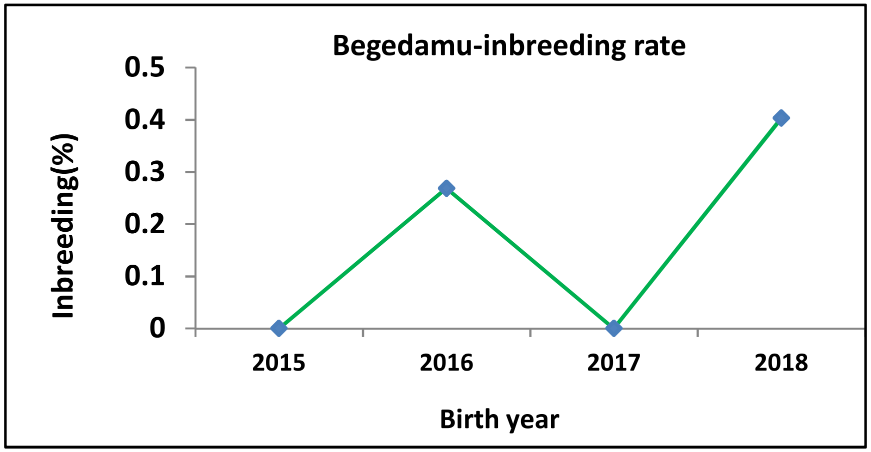
Appendix 23. Level of inbreeding among breeder cooperatives











LamId	SireID	DamId	farmer	site	Btype	Birth_Date	month	date	year	season	Sex	BWT	Parity
21794615	21738813	21794515	Zeleke Abule	Ancha	1	1/13/2015	1	13	2015	1	2	3.5	5
21794815	21721713	21794715	Tigabu Asefa	Ancha	2	1/15/2015	1	15	2015	1	1	3.5	4
21794915	21721713	21794715	Tigabu Asefa	Ancha	2	1/15/2015	1	15	2015	1	2	3	2
21795115	21721713	21795015	Tigabu Asefa	Ancha	2	1/17/2015	1	17	2015	1	1	3	1
21795215	21721713	21795015	Tigabu Asefa	Ancha	2	1/17/2015	1	17	2015	1	1	2.5	5
21795315	21714612	21730012	Desalgn Woler	Ancha	2	1/9/2015	1	9	2015	1	1	2.5	5
21795415	21714612	21730012	Desalgn Woler	Ancha	2	1/9/2015	1	9	2015	1	1	2	4
21795515	2172613	21785014	Tefery Shameb	Ancha	1	1/22/2015	1	22	2015	1	1	3.5	1
21795615	21738013	21769314	Demise Desta	Ancha	1	1/23/2015	1	23	2015	1	2	3	3
21795715	21738813	0	Adise Mathew	Ancha	2	2/6/2015	2	6	2015	2	2	3	4
21795815	21738813	0	Adise Mathew	Ancha	2	2/6/2015	2	6	2015	2	2	3	8
21795814	21738812	21730312	Lema Wanore	Ancha	3	1/19/2015	1	19	2015	1	1	2	6
21795915	21738812	21730312	Lema Wanore	Ancha	3	1/19/2015	1	19	2015	1	2	3	3
21796015	21738812	21730312	Lema Wanore	Ancha	3	1/19/2015	1	19	2015	1	2	2.5	4
21796215	2172613	21796113	Terefe Amede	Ancha	2	1/24/2015	1	24	2015	1	2	3	7
21796315	2172613	21796113	Terefe Amede	Ancha	2	1/24/2015	1	24	2015	1	2	2.5	5
2.2E+07	218716	21846217	Abeko Hanano	Hawora	2	9/3/2017	9	3	2017		2	2	5
218539	21819816	2186915	Abeko Hanano	Hawora	2	12/14/2017	12	14	2017		1	3.6	5
218540	21819816	2186915	Abeko Hanano	Hawora	2	12/14/2017	12	14	2017		2	3.4	5
21798415	21721713	21797113	Haile Hankore	Ancha	2	2/8/2015	2	8	2015	2	1	3.5	3
21798515	21721713	21797113	Haile Hankore	Ancha	2	2/8/2015	2	8	2015	2	2	3	5
21798615	2173613	21797513	Belachew Lons	Ancha	2	2/11/2015	2	11	2015	2	1	3	3
21798715	2173613	21797513	Belachew Lons	Ancha	2	2/11/2015	2	11	2015	2	1	2.5	3
218803	21819716	21816916	Abeko Hanano	Hawora	2	7/17/2018	7	17	2018		2	3.8	4
218804	21819716	21816916	Abeko Hanano	Hawora	2	7/17/2018	7	17	2018		2	3.6	4
21799015	21721713	21715212	Bachore Legato	Ancha	2	2/25/2015	2	25	2015	2	2	3	3
21799115	2177113	21733412	Tafese Alito	Ancha	2	2/30/2015	2	30	2015	2	2	3.5	2

Appendix 24. Sample picture of Doyogena sheep, data recording format and tin roof partitioned house

Appendix 25. Sample picture of major activities in the ongoing CBBP