Genetic trends in growth and reproductive Performance of indigenous sheep breeds managed under community-based breeding programs in the highlands of Ethiopia

By CBBP team

Introduction

In developed countries and in high input animal production systems, animal breeding has been traditionally supported by the state and implemented by large national breeding programs. Data recording, channeling of the recorded data towards a data processing centre, estimation of 'breeding values' with complex statistical methods and central decisions about the use of male breeding animals are ingredients of such breeding programs.

In developing countries, the required supportive infrastructure is largely unavailable, so attempts to replicate 'developed-country' approaches have met with little success. As an alternative, centralized breeding schemes, entirely managed and controlled by governments – with minimal, if any, participation by farmers – were developed and implemented in many developing countries through a nucleus breeding unit limited to a central station. These centralized schemes were usually run by a governmental organization attempting to undertake all or part of the complex processes and breeding strategy roles (i.e. data recording, genetic evaluation, selection, delivery of genetic change, and feedback to farmers).

Although well intended, these centralized schemes failed to sustainably provide the desired genetic improvements (continuous provision of a sufficient number and quality of improved males to smallholders) and also failed to engage the participation of the end-users in the process.

Another widely-followed alternative is importing improved commercial breeds in the form of live animals, semen, or embryos. These are crossbred with the indigenous and 'less productive' breeds to upgrade them, but in most cases, it is done without sufficient pretesting of the appropriateness (suitability and adaptability) of the breeds and their resulting crosses to local production systems or conditions. Where indiscriminate crossbreeding with the local populations has been practiced, genetic erosion of the adapted indigenous populations and breeds has occurred.

A new approach is therefore required. One such approach is a community-based breeding Programs (CBBP). Programs that adopt this strategy take into account the farmers' needs, views, decisions, and active participation, from inception through to implementation, and their success is based upon proper consideration of farmers' breeding objectives, infrastructure, participation, and ownership (Mueller 1991; Sölkner et al. 1998; Haile et al., 2011; Wurzinger et al. 2011; Mueller et al., 2015).

Cognizant of this, the International Center for Agricultural Research in the Dry Areas (ICARDA), the

International Livestock Research Institute (ILRI), and the University of Natural Resources and Life Sciences (BOKU), in partnership with the Ethiopian National Agricultural Research System, designed and implemented CBBPs in Ethiopia. CBBPs have also been implemented in Mexico and Agrentina with goats, with Llamas in Bolivia, Uganda and Malawi (goats). However, performance of the programs (both biological and economic) have not been documented. Recently, socio-economic performances of sheep CBBPs of Ethiopia were reported (Gutu et al., 2015). Here, we report the biological performance of the sheep from three CBBs namely, Bonga, Horro and Menz from Ethiopia with the following objectives.

- Evaluate the growth and reproduction performance of Ethiopian sheep breeds kept under CBBPs;
- Study the effects of non-genetic factors on performance of sheep breeds in Ethiopia; and
- Evaluate the genetic progress in community-based breeding programs (CBBPs).

Background to the CBBPs

Since 2009, Ethiopian community-based sheep breeding programs are being implemented in three locations with three breeds (Bonga, Horro and Menz) involving more than 8000 sheep. There are six communities in the three locations. Each community has on average 60 households.

The goal of the project is to improve the productivity and income of these small-scale resource-poor sheep producers by providing access to improved animals that respond to improved feeding and management, facilitating the targeting of specific market opportunities. There is a governmental rural organization associated with each of the project sites. Local enumerators were recruited for each community to help the research system in animal identification and recording. Indigenous knowledge of the community is considered at each phase of the project. For example, the community decides how rams are managed and how they are shared and used. The core in this project is to get community members working together in ram selection, management and use.

Two stages of selection are applied: initial screening when first sales of young rams occur (4– 6 months) and final selection for admission to breeding at 12 months of age. Selection at the first stage is based on lambs 6 months weight and twining rate. Additional yearling weight and conformation were considered in the final selection. All young rams are collected at one central place in each community on an agreed screening date. Selection is then carried out based on the data analyzed.

A breeding ram selection committee composed of about 3–5 members elected by the community are involved in the selection. If for example 15 rams were to be selected from 100 candidates, say 20 would be preselected based on their breeding value and the culling of the last five and the ranking of the selected rams would be made by the committee. The committee checks at the conformation, colour, horn type, tail type and other criteria in decision making.

Description of the sites and breeds

As indicated earlier, the community-based breeding programs were set up in three locations (Bonga, Horro and Menz) representing different production systems and agro-ecology. The numbers of households (HH) and mean flock size (SD) in the different locations when the program started is presented in Table 1.

Bonga is located in southwest Ethiopia about 460 km from Addis Ababa, with altitudes ranging from 1,000 to 3,400 meters. The temperature in the area can be as high as 24 ºC and can also reach the lowest value of 12 ºC. For the Bonga breed, the tail is wide and long. Both male and female are polled; the ear is long, the hair is short and smooth. The breed is judged as good for traits like growth rate, meat quality, fattening potential, twining rate and temperament (Edea et al., 2009). The prominent farming system is a mixed crop-livestock production.

Horro is located in the western Ethiopian mid-highland region (i.e. 1,600 to 2,800 m altitude) about 310 km from Addis Ababa. Horro is believed to be closer to the epicenter of the Horro sheep breed origin. Horro sheep is a fat-tailed hair-type sheep with bigger growth potential compared with other indigenous breeds in Ethiopia. Farming in the Horro area is dominated by mixed crop-livestock system (Edea et al., 2009).

Menz is located in the Ethiopian highlands at about 280 km north-east of Addis Ababa, with an altitude range of 2,700 to 3,300 m.a.s.l. The Menz area is considered as the epicenter of distribution of the Menz breed. The Menz breed is one of the few coarse woolly fat-tailed sheep types, adapted to the high altitude precipitous terrain with scarcity of feed and where production of crop is limited due to extreme low temperature and drought in the cool highlands. This is a hardy small breed, which controls the level of internal parasite infection and is productive under low input production circumstances of the degraded ecosystems (Getachew et al., 2010).

Table 1. Number of households (HH) and mean flock size (SD) when CBBPs were initiated in the different locations

Location	Community	№ of HH	Average flock size (SD)	Range
Bonga	Boqa	63	9.4 (4.98)	4 – 23
	Shuta	64	7.5 (3.85)	4 – 21
	Mean		8.5 (4.53)	4 – 23
Horro	Kitlo	59	18.4 (14.24)	3 – 72
	Lakku-Iggu	63	16.5 (10.01)	4 – 50
	Mean		17.4 (12.23)	3 –72
Menz	Mehal-Meda	64	22.7 (12.95)	4 – 64
	Molale	58	16.5 (9.67)	4 – 41
	Mean		19.8 (11.87)	4 – 64

Data recorded and analysis

We developed data recording formats and hired enumerators to collect data from each household. Data Analyzed included Birth weight, six months weight and litter size.

Least squares analysis was carried out to study performance of sheep and examine fixed effects (SAS, 2002). The fixed effects fitted were: year of birth (8 classes: 2009-2016), lambing season, grouped into three classes, based on the pattern of annual rainfall distribution in the area (November-February: dry period; June to October: wet season; March to May: short rain); sex (two classes: Male and Female) and litter size (three classes: single, twin, triple). A fixed effect model was fitted. The Tukey–Kramer test was used to separate least squares means with more than two levels.

The Average Information Restricted Maximum Likelihood method (AI-REML) of WOMBAT (Meyer, 2007), fitting univariate animal model was used to estimate breeding values. WOMBAT assesses whether an analysis has converged, based on the following criteria: 1) a change in log L of $< 5\times10^{-4}$, 2) a change in parameters of $< 10^{-8}$ and 3) a gradient vector norm $<10^{-3}$.

Analysis Model:

$$Y = X\beta + Za + e$$

Where Y is a (Nx1) vector of observations; β, the vector of fixed effects of birth type, birth year, sex of animal, related to incidence matrix X; a, the vector of direct genetic effects, related to incidence matrix Z; and e, the vector of random residuals.

The genetic trend was estimated by the weighted regression of the average genetic value of the animals on the year of birth.

Results and Discussion

Genetic trends in growth performance

Birth weight: The birth weight of lambs has not improved over the years in Menz (Table 2 and Figure 1). In Horro, there is even a slight decrease (Figure 2). Given that we have not selected for birth weight in the community flock we did not expect change. However, through correlated responses there could be an effect. This was not observed in all three breeds. The lack of significant improvement in birth weight is particularly advantageous because selection for this trait beyond a particular level may be associated with dystocia and loss of productivity. Thus, care should be taken when undertaking selection in birth weight. Indeed, many studies have shown that genetic correlation between birth weight and later weights is weak and this has advantages because selection for each trait could be effected independently of the other and therefore selection for say, weaning weight or gain would not increase birth weight.

Six month's weight: For the three sites, six months weight, the major selection trait in our community-based breeding programs, increased over the years (Table 2; Figures 3, 4, 5). In Menz the average increase was 0.14 ± 0.006 kg per year, followed by average increase of 0.26± 0.058 kg per year in Bonga and 0.31 ± 0.060 kg for Horro. This is quite substantial in an on farm situation. The increases were particularly significant in larger framed breeds (Horro and Bonga) compared to Menz sheep, which is relatively small.

Table 2. Estimated breeding values over years for birth and six months weight in Bonga, Horro and Menz CBBPs

	Molale 6 month weight	Molale birth weight	Gitlo 6 month weight	Gitlo birth weight	Bonga 6 month weight
Overall	0.14±0.006	0.0019±0.000034	0.31±0.060	-0.045±0.0012	0.26±0.058
2009	0.07±0.017	0.0019±0.000108		-0.076±0.0043	-0.07±0.266
2010	0.08±0.013	0.0022±0.000081	-0.03±0.143	-0.054±0.0026	0.18±0.189
2011	0.11±0.014	0.0018±0.000085	0.06±0.095	-0.040±0.0025	0.22±0.158
2012	0.13±0.015	0.0019±0.000090	0.24±0.082	-0.046±0.0027	0.24±0.139
2013	0.20±0.016	0.0014±0.000095	0.36±0.086	-0.032±0.0028	0.35±0.112
2014	0.25±0.014	0.0013±0.000088	0.28±0.079	-0.029±0.0029	0.46±0.082
2015	0.14±0.027	0.0025±0.000094	0.52±0.097	-0.036±0.0028	0.32±0.065
2016			0.78±0.339	-0.045±0.0050	0.38±0.209

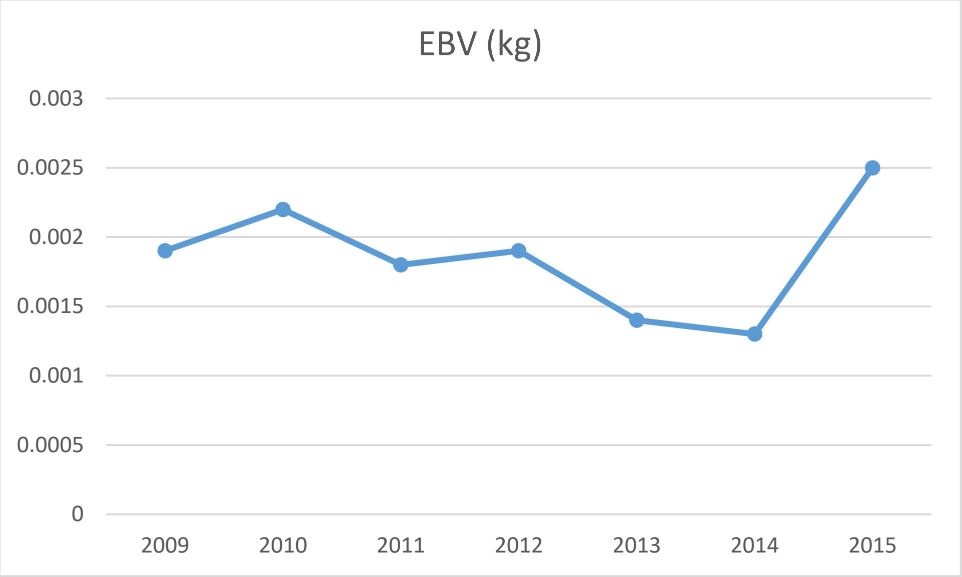

Figure 1. Molale birth weight

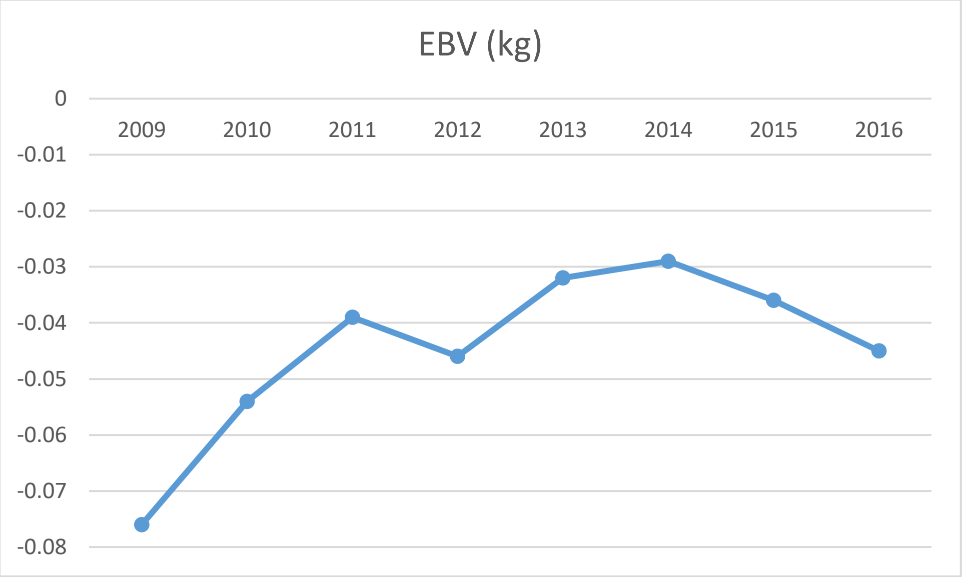

Figure 2. Horro birth weight

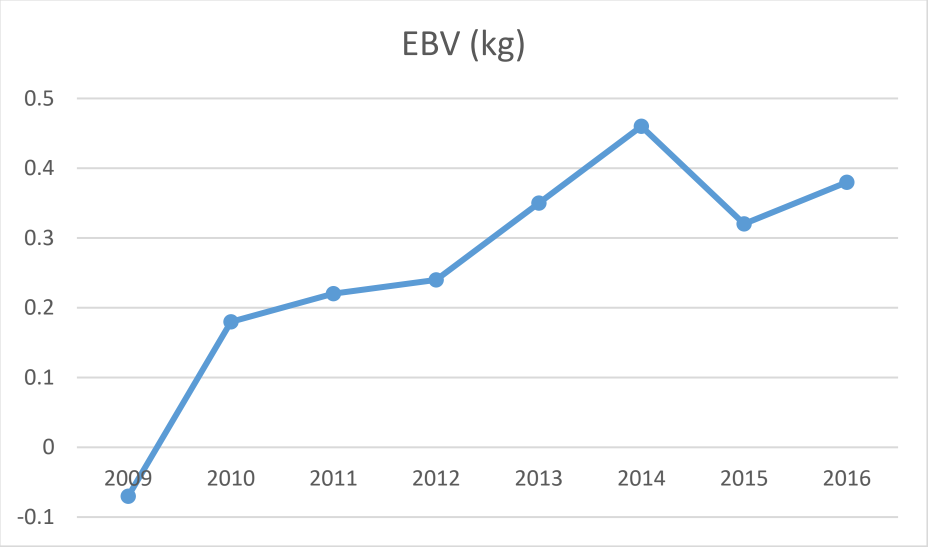

Figure 3. Bonga six months weight

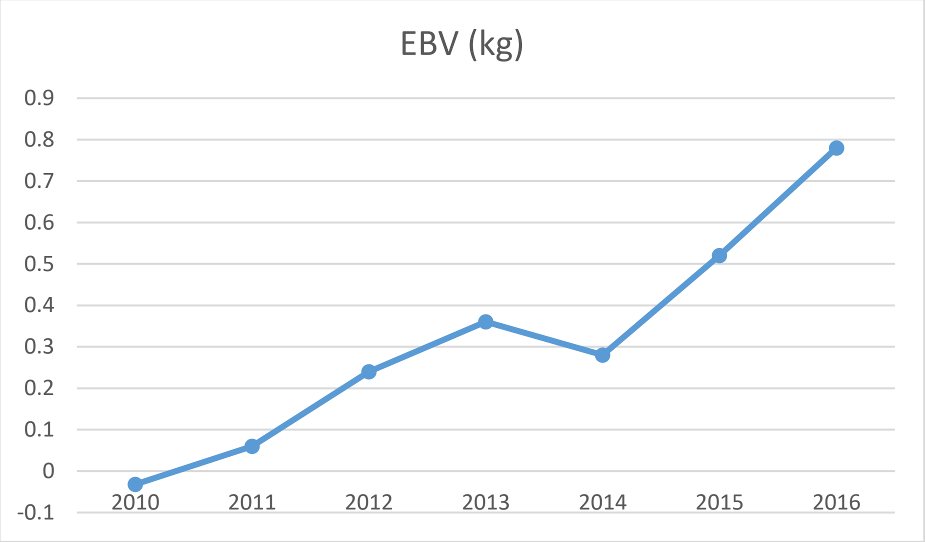

Figure 4. Gitlo six months weight

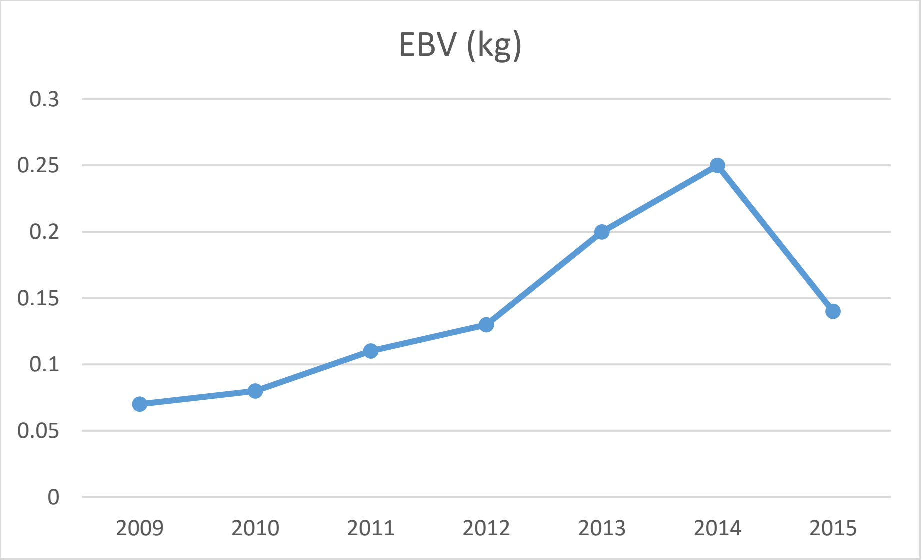

Figure 5. Molale six months weight

Litter size

Least squares means (and standard errors) for litter size for the Bonga and Horro flock is presented in Table 3. Litter size of lambs born increased ($p<0.01$) over the years in both Bonga and Horro. The increase was 12% (from 1.28 to 1.46) in Horro and 8% (from 1.48 to 1.61) in Bonga. Twinning rate is one of the selection traits in both sites and the increase in litter size over years is expected. Where resources, particularly feed and water, permit selection for litter size, it can make substantial impact in sheep production. Phenotypically we have the evidence that Bonga and Horro sheep are prolific. We are now looking at genes/ genomic regions responsible for prolificacy in these breeds.

Table 3. Horro and Bonga CBBP least squares means (± SE) for litter size over the years

	Gitlo	Bonga
Overall	1.36±0.010	1.53±0.008
Year	**	**
2009	1.28±0.033	1.48±0.039
2010	1.40±0.020	1.53±0.026
2011	1.37±0.020	1.48±0.022
2012	1.36±0.023	1.58±0.020
2013	1.35±0.023	1.53±0.018
2014	1.31±0.024	1.54±0.015
2015	1.37±0.022	1.53±0.013
2016	1.46±0.039	1.61±0.016

Effects of non-genetic factors

The effects of non-genetic factors (sex, birth season and birth type) on growth performance of sheep flock in Menz, Bonga and Horro sites are presented in Table 4.

Sex: Weight differences for the different sexes were all significant ($p<0.01$) except for six months weight in Menz. For both Bonga and Horro, males were heavier than females at birth and six months of age. Whereas, in Menz females were slightly heavier than males at birth but this difference was lost ($p>0.05$) at six months. Many reports (for example Tibbo, 2006; Saghi et al., 2007) in literature concur with our observations that favor male sheep which could obviously be related to inherent physiological variations.

Birth type: This had significant ($p<0.01$) effect on weights (both birth and six months weight) of sheep in Bonga and Horro. Single born sheep had heavier weights at all ages than twins and triples. Sheep in Menz give birth to singles in most cases and this trait was not considered for Menz sheep.

Season of birth: This is a significant source of variation for both birth and six months weight of sheep. In Bonga and Horro, weight in the long rainy season are inferior to those of dry and short rainy season. Lambs born in the dry season had better weights than those born in the wet season (p<0.01). This is indeed unexpected as more feed is expected to be available in the rainy seasons. Indeed for birth weight, better feeding in the wet seasons might have resulted in bigger lambs at birth in the dry season.

Table 4. Least squares means (± SE) for effects of birth season, lamb sex and birth type on birth weight and six months weight in Bonga, Horro and Menz sheep

Effect and level	BWT, Gitlo	SWT, Gitlo	BWT, Bonga	SWT, Bonga	BWT, Molale	SWT, Molale
N	3552	1253	6757	2246	3219	2443
Overall	2.88±0.057	16.9±0.41	3.47±0.023	22.7±0.13	2.72±0.01	16.9±0.41
CV%	25	20	19	16	24	17
Birth season	**	**	**	**	**	**
Long rain	2.75±0.059^{a}	16.6±0.42a	3.45±0.025a	22.5±0.14a	2.82±0.02	13.7±0.08
Dry	2.91±0.062^{b}	16.8±0.47ab	3.45±0.026a	23.0±0.18b	2.73±0.02	13.6±0.08
Short rain	2.98±0.061^{c}	17.3±0.43b	3.52±0.028b	22.6±0.20b	2.61±0.03	12.6±0.12
Sex	**	**	**	**	**	NS
1	2.80±0.059	16.7±0.42	3.38±0.025	21.4±0.15	2.81±0.02	16.7±0.42
2	2.96±0.058	17.1±0.42	3.57±0.025	24.0±0.15	2.64±0.02	17.1±0.42
Birth type	**	**	**	**		
1	3.20±0.018^{a}	16.8±0.20^{a}	3.95±0.014^{a}	24.4±0.11^{a}		
2	2.96±0.023^{b}	16.1±0.23^{b}	3.42±0.014^{b}	21.8±0.13^{b}		
3	2.48±0.168^{c}	17.8±1.13^{ab}	3.05±0.065^{c}	19.5±0.67^{c}		

Conclusions

Community-based breeding programs in the three study sites are technically feasible, economically rewarding (Gutu et al., 2015) and result in substantial genetic gain in biological traits. Therefore, where centralized breeding programs do not work because of various reasons, we strongly recommend to implement such an approach particularly in low-input systems like those of the Ethiopian highlands.

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