Insights into Sheep Genetic Improvement Practices Through Crossbreeding in Ethiopia: Achievements, Challenges and Future Prospects

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Abstract

Crossbreeding is one of the genetic improvement methods that enables to utilize between breed genetic variations. It is one of the main sheep genetic improvement strategies practiced for decades in Ethiopia. This review assessed achievements, challenges and future prospects of sheep genetic improvement through crossbreeding in Ethiopia. The crossbreeding scheme involves crossing of exotic breeds with indigenous as well as between indigenous sheep breeds. To improve growth performance of indigenous sheep, a number of exotic sheep breeds were imported from abroad although literature sources about the performance of crossbreeds is available only for Awassi and Dorper sheep crosses. Promising results have been reported in few areas where crossbreeding has been performed effectively. An evidence for this is the realization of up to 10kg yearling live weight superiority of crossbreeds with 50% and above Awassi and Dorper sheep blood levels over the indigenous sheep. As a national genetic improvement strategy, however, crossbreeding achievement in terms of improving productivity of indigenous sheep is generally minimal. Notably, Absence of well-deigned crossbreeding program, miss-match between genotypes and the environment, and resource limitation to maintain and multiply adequate number of exotic sheep and crossbreeds are the major challenges hindering the success of indigenous sheep genetic improvement through crossbreeding. In the future, the use of crossbreeding as a potential strategy for indigenous sheep genetic improvement relies on bringing long lasting solutions to the current problems. In general, implementing well-designed crossbreeding program, particularly between improved exotic sheep and indigenous sheep, should be the primary focus to improve productivity of indigenous sheep. In this way, the contribution of indigenous sheep resources for the smallholder farmers in particular and the country's economic growth in general can be maximized. At the same time, protecting the valuable genetic resources of indigenous sheep should be an integral part of the crossbreeding program.

Keywords: genetic improvement, indigenous sheep of Ethiopia, sheep crossbreeding

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1. INTRODUCTION

Crossbreeding is one of the genetic improvement methods that helps to combine desired parental characteristics into their offspring. Particularly when there is significant genetic variation between breeds for the trait of interest, crossbreeding could result in fast genetic improvement due to the additive and non-additive genetic effects (Schoeman, 2000; Baker and Gray, 2004). The parental breeding values inherited by their offspring correspond to the additive genetic effects while interaction of alleles at the same locus or different loci is related with non-additive genetic components, which is commonly called Heterosis. It is in this way that the crossbreed offspring perform higher than the average performance of their parents. Crossbreeding is also important for new breed formation. Through a review of new breed development efforts in different countries, Shrestha (2005) reported about 443 composite sheep breeds developed by crossbreeding of two and more breeds in 68 countries.

In the tropics where resource is very limited to undergo selective breeding, crossbreeding has been the main sheep genetic improvement strategy although results are largely unsatisfactory (Kosgey *et al*., 2006; Philipsson *et al*., 2011). The situation is very similar in Ethiopia where sheep crossbreeding between indigenous breeds and/or indigenous with improved exotic breeds have been practiced for many years with achievements far below the expectations. The reasons are largely related with lack of implementation strategies. Ethiopian indigenous sheep are generally slow in growth performance with average yearling weight of about 20kg and dressing percentage of below 50% (Gizaw *et al*., 2013; Mekuriaw *et al*., 2013; Tilahun *et al*., 2014; Gulilat *et al*., 2018). The crossbreeding strategy was thought to address such issue. Subsequently, a number of improved exotic sheep were imported from different countries for the purpose of crossbreeding. In addition to exotic sires, local breed rams such as Washera, Bonga and Horro have been widely distributed for interbreeding with other relatively small sized indigenous sheep (Taye *et al*., 2011; Mekuriaw *et al*., 2013; Alayu *et al*., 2014; Lemma *et al*., 2014). In spite of the crossbreeding efforts made for decades, average sheep productivity is still the lowest in the world. Furthermore, the current proportion of crossbreed sheep population is negligible, which is about 0.32% (CSA, 2016).

Despite its lack of effectiveness at the national level, sheep crossbreeding based on both exotic and indigenous sires have been continuing for different indigenous sheep breeds. Thus, critically assessing the current sheep crossbreeding practices, achievements and associated challenges including the benefits provided for the smallholders could be useful to generate information as inputs for policy makers and other concerned bodies for designing effective and sustainable crossbreeding program in the future. As such, this review aimed at assessing sheep crossbreeding practices for a wider insight into the achievements, challenges and future prospects in Ethiopia.

2. OVERVIEW OF SHEEP CROSSBREEDING PRACTICES IN ETHIOPIA

In Ethiopia, importation of exotic sheep breeds started as early as 1944 when Merino rams brought from Italy by humanitarian organization (Markos, 2006). Later on, multiple exotic breeds such as Corriedale, Hampshire, Romney Marsh, Blue De Maine and Rambouillet have been imported from different countries (Markos, 2006). Awassi from Israel and Dorper from South Africa are the recently introduced exotic sheep breeds in Ethiopia (Gizaw et al., 2013). Following importation, evaluation and multiplication of crossbreeds with different exotic blood level have been carried out in different agricultural research institutes and government ranches. Then, high-grade crossbreed rams have been distributed in different parts of the country for crossbreeding with the indigenous sheep. Among the introduced exotic breeds, however, information about the performance of crossbreeds is available only for Awassi and Dorper sheep. The occurrence of disease outbreak and lack of well-designed ram distribution strategies are reported to be the principal factors that contributed for the anonymity of other exotic breeds (Gizaw et al., 2013).

Average growth performance of indigenous sheep is very low compared with Dorper and Awassi exotic sheep in their native areas. As shown in Table 1, Dorper sheep in South Africa is more than three times heavier than Ethiopian Menz and Farta indigenous sheep breeds at about similar age group. Similarly, a six month old improved Awassi sheep in Turkey weighs higher than a yearling Ethiopian Bonga indigenous sheep. Given such facts, the major target of implementing crossbreeding between imported exotic breeds and indigenous sheep was improving growth performances of indigenous sheep (Gizaw et al., 2013). The fact that indigenous sheep are the result of natural selection and geographical isolation, they are assumed to retain genes playing vital roles for environmental adaptation. Thus, crossing of indigenous sheep with improved exotic sheep make sense biologically to exploit the advantage of breed complementary. Subsequently, smallholders engaged in sheep rearing could earn better income by selling crossbreed lambs with fast growth performance at a better price thereby empowers the efforts made to create food self-sufficiency. Currently, crossbreeding is continuing although achievements are unattractive due to different challenges.

Table 1. Yearling weight of some indigenous sheep compared to exotic breeds

Breeds*	Average yearling weight (kg +SE)	Sources
Menz	20.07± 0.48	Lemma et al., 2014
Afar	26.6±0.14	Yibrah, 2008
Farta	20.08±0.73	Mekuriaw et al., 2013
Wello	21.6±1.00	Amare et al., 2018
Gumz	23.05 ±0.645	Solomon, 2007
Horro	19.7 ±0.63	Kassahun, 2000
Washera	24.70±1.13	Mekuriaw et al., 2013
Bonga	28.69 ± 0.48	Zewdu, 2008
Blackhead Somali	25.7	Bireda et al., 2016
Dorper (South Africa)	64.4 ±1.1	Snyman and Olivier, 2002
Dorper (Romania)	55±0.89	Gavojdian et al., 2013
Dorper (Ethiopia)	34.43 ±0.79	Abebe et al., 2015
Awassi (Turkey)	37 (in 6 month)	Dikmen et al., 2007

*All except Dorper and Awassi sheep are indigenous to Ethiopia

3. ACHIEVEMENTS OF SHEEP CROSSBREEDING IN ETHIOPIA

Achievements in sheep crossbreeding can be assessed from two perspectives. The first one is the level of genetic improvement for the traits of interest on indigenous sheep while the second is related with the contribution of genetic improvement following crossbreeding to livelihood development of the smallholder farmers.

3.1. Achievements in growth performance traits

So far, growth performances of some of the crossbreed sheep have been evaluated both under improved and traditional management practices (Gizaw and Getachew, 2009; Mekuriaw et al., 2013; Lakew et al., 2014; Tilahun et al., 2014; Lemma et al., 2014; Teklebrhan et al., 2016). Improved management refers to the

husbandry practice implemented in research farms with better health care and feed provision while the traditional management is the low-input system practiced at smallholder level. To compare growth performances of crossbreeds with pure indigenous sheep, weight at birth, 3 months (weaning age) and 12 months (yearling age) are presented in Table 2.

Awassi exotic sheep have been largely crossed with Menz, Wello and Tikur indigenous sheep. Based on the information in Table 2, regardless of Awassi's sheep blood level, crossbreeds have higher body weight at different growth periods compared to the local indigenous sheep. For example, under improved management practice, the indigenous Menz sheep have birth and weaning weight of about 1.96 and 7.82kg, respectively while its 50% Awassi crossbreeds weighed about 2.53kg at birth and 16.84kg at weaning age under similar rearing system. Interestingly, introgression of as little as less than a quarter of Awassi's sheep blood level into indigenous sheep through crossbreeding have resulted in a reasonable amount of body weight improvement (Table 2). Furthermore, when the amount of Awassi sheep blood level increases, crossbreeds perform much better than indigenous local sheep even under farmers' management practices (Figure 1). Based on the results depicted in Figure 1, crossbreeds with 50% and above Awassi's sheep genotypes have shown the highest weights recorded from birth to yearling ages than indigenous sheep and low grade Awassi genotypes. For example, an average of 10kg live weight difference observed between high grade Awassi crossbreeds and indigenous sheep at yearling age.
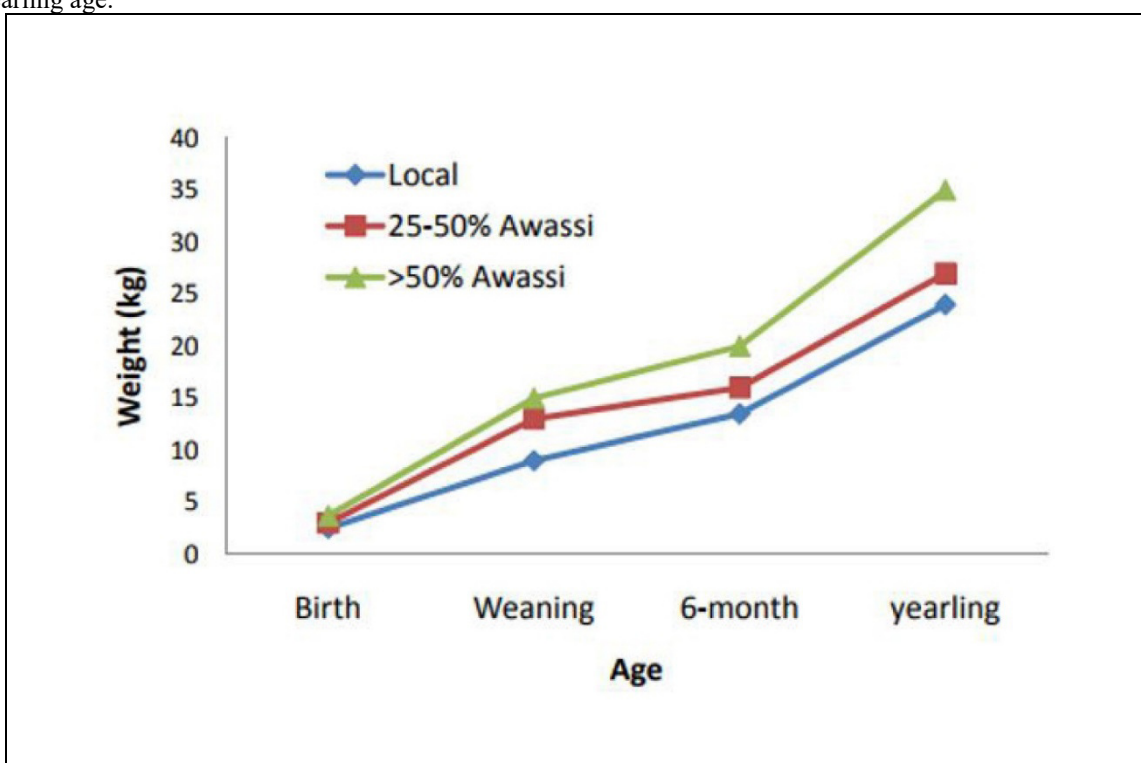

Figure 1. Growth rate of local sheep and their crosses with Awassi exotic sheep under village management conditions in Ethiopia (Source: Gizaw and Getachew, 2009)

In addition to Awassi with indigenous sheep crossbreeding, the South African Dorper sheep have been crossed with different Ethiopian indigenous sheep breeds. As shown in Table 2, crossbreeds with 50% Dorper genotype are superior at birth, weaning and yearling ages as compared to indigenous Menz and Wello sheep that have been used as dam sources for crossbreeding. Characteristically, Dorper sheep are hairy type of breed that are suitable for medium to lowland agroecology but are also known to have wide ecological adaptation which can be evidenced by the superiority of Dorper crossbreeds when crossbred with Menz indigenous sheep reared in cool highland areas. Given the fast growth rate and wide adaptation potential of Dorper sheep (Snyman and Olivier, 2002), implementing well designed crossbreeding between Dorper and Ethiopian indigenous sheep could play decisive roles in improving the productivity of the latter.

Table 2. Growth performance of crossbreeds compared to pure indigenous sheep with standard error (SE)

Genotypes*+	Management	Birth weight (kg $\pm$ SE)	Weaning weight (kg $\pm$ SE)	yearling weight (kg $\pm$ SE)	Sources
37.5%Awassi X Menz	Traditional	3.35	10.47	15.28 (6 month)	Hasan et al., 2002
Pure Menz sheep	Improved	1.96+0.03	7.82±0.16	20.07±0.48	Lemma et al., 2014
Awassi X Menz	Improved	2.53	16.84	-	Hasan et al., 2004
75% Awassi X Menz	Improved	3.32	18.89	-	Hasan et al., 2004
23.44%% Awassi X Tikur sheep	Traditional	3.10±0.10	12.01±0.32	24.16±0.54	Tilahun et al., 2016
32.5% Awassi X Tikur sheep	Traditional	3.08±0.03	12.56±0.25	25.65±0.45	Tilahun et al., 2016
Dorper X Wello sheep	Improved	3.24±0.04	14.95±0.21	31.37±0.38	Lakew et al., 2014
Pure Wello sheep	Traditional	1.90+0.04	10.70±0.60	21.60 ±1.00	Amare et al., 2018
Dorper X Bonga sheep	Improved	2.62±0.19	13.90±.85	20.97±2.6 (6 month)	H/Giorgis et al. 2017
Dorper X Blackhead Somali	Improved	3.10±0.10	15.10±0.30	-	Teklebrhan et al., 2014
Dorper X Menz	Improved	2.77±0.04	13.34±0.25	31.33±0.56	Abebe et al., 2015
Pure Washera sheep	Traditional	2.61+0.00	12.78 ±0.45	24.70±1.13	Mekuriaw et al., 2013
WasheraX Farta	Traditional	2.59+0.02	11.17±0.49	22.50±1.56	Mekuriaw et al., 2013
Pure Farta sheep	Traditional	2.50+0.01	9.94±0.74	20.08±0.73	Mekuriaw et al., 2013
Washera X Menz	Improved	2.02+0.03	8.01±0.16	19.93±0.49	Lemma et al., 2014
Bonga X Menz	Improved	2.05+0.03	8.30±0.16	21.73±0.53	Lemma et al., 2014
75%Washera X Menz	Improved	2.33+0.04	9.10±0.25	17.20±0.82	Lemma et al., 2014
75%Bonga X Menz	Improved	2.46+0.05	10.80±0.27	20.40±0.78	Lemma et al., 2014

*All except Dorper and Awassi sheep are indigenous to Ethiopia.
[+]Crossbreed's genotype is 50% unless the genotype is given. E.g. Dorper X Wello sheep genotype means crossbreeds with 50% Dorper & 50%Wello sheep while 37.5% Awassi X Menz genotype means crossbreeds with 37.5% Awassi & 62.5%Menz sheep blood level.

Given the difficulties of importing, multiplying and maintaining exotic sheep due to resource limitation, between indigenous sheep crossbreeding has been tried. For instance, crossbreeding between Washera X Menz, Washera X Farta and Bong X Menz sheep have been performed (Mekuriaw et al., 2013; Lemma et al., 2014). Crossbreeding between indigenous breeds has a number of advantageous when compared with crossbreeding of indigenous sheep with exotic breeds. For example, it does not require importations of exotic breeds, maintaining of pure exotic breeds, continuous multiplication and distribution of cross breeds. Furthermore, not only most indigenous sheep are found geographical in close proximity but also the farming communities share a number of sociocultural characteristics that make crossbreeding between indigenous sheep as an ideal strategy in principle to improve sheep productivity.

However, performance variation between indigenous sheep is small, thus performances of crossbreeds are not better than parents. Performance of crossbreeds obtained from two indigenous sheep breeds is displayed in Table 2, showing that crossbreeding between indigenous sheep with the current performance level of the local sheep is not logical. A better option could be applying selective breeding for indigenous sheep genetic improvement for certain generations and trying crossbreeding later. Studies conducted so far have shown that indigenous sheep have high within population genetic diversity than the between population showing their potential for improvement through selective breeding instead of crossbreeding (Gizaw et al., 2007; Helen, 2015).

3.2. Contribution to smallholders' livelihood development

So far, no adequate impact assessments have been made to disentangle the contribution of sheep crossbreeding for livelihood development of smallholder farmers in Ethiopia. However, Tefera et al. (2014) evaluated diffusion rate and financial gain of Awassi X Menz sheep crossbreeding in model villages and reported that the composition of crossbreeds in the sampled flock is nearly equal with that of the indigenous sheep. These authors argued that the number of crossbreeds and local indigenous sheep would not be balanced in the flock of a farmer unless s/he credited the importance of crossbreeding. The same authors also mentioned that farmers fetch better price for crossbreeds over the locals and were able to accumulate reasonable amount of asset by selling

crossbreed lambs. It has been reported that breeder farmers have been created to produce genetic material with high grade Awassi crossbreeds that can be supplied to other areas (Gizaw and Getachew, 2009). Such practices, however, are concentrated in few villages where farmers carryout crossbreeding with better understanding through continuous support from government institutes.

Scholars have been arguing that despite the long period practices of sheep crossbreeding in the country, its impact on the livelihood of smallholders is generally insignificant. Explicitly, the existing facts about Ethiopian indigenous sheep current productivity could not reflect the existence of crossbreeding based genetic improvement efforts made for more than half a century. For example, population size of crossbreed sheep is below 1% of the total sheep resources of the country (CSA), 2016). Furthermore, national average productivity of indigenous sheep is still very low and well below commercial market requirements (CSA, 2016). Considering such facts, the contribution of sheep crossbreeding on livelihood development of smallholder farmers who have been involving in sheep rearing is nowhere near what has been anticipated except the success stories in a very limited villages involving small number of farmers. There are, however, a number of challenges that are assumed to contribute to the vain achievements of sheep crossbreeding in Ethiopia.

4. CHALLENGES OF SHEEP CROSSBREEDING PRACTICES IN ETHIOPIA

One of the major obstacles hindering effectiveness of crossbreeding strategy in Ethiopia is the absence of clear crossbreeding program supported by policy and implementation strategies. As a result, specialized exotic breeds imported with high cost or sometimes through foreign aids have been crossed with indigenous breeds indiscriminately. Often for long period, crossbreed rams with high grade exotic blood level have been distributed to smallholder farmers as a campaign without establishing recording system in the production environment (Gizaw *et al*., 2013). Subsequently, most of the imported exotic breeds became anonymous over time. At present, information or literatures about the performance of crossbreeds is available only for Awassi and Dorper sheep where the latter imported lately.

Another challenge is that exotic breeds have been developed in different environment than that of the Ethiopia condition. Although crossbreeding is expected to combine the genes responsible for better growth from exotic breeds and adaptation merits from the indigenous sheep, the existing low-input production system of the country significantly undermined expression of the genotypic potentials. This has been typical phenomena in Ethiopia where crossbreed sheep failed to express their potentials due to miss-match between genotypes and the environment especially when the genetic material of exotic breeds has been increased. Furthermore, the non-genetic components, such as feed and health aspects, were not integrated in the crossbreeding practice while using highly productive exotic sheep. In such scenario, addressing larger areas of the country for wider scale sheep genetic improvement through crossbreeding could be difficult.

A Further headache is that exotic sire based crossbreeding requires frequent importations and maintaining of pure exotic breeds, and continuous multiplication and distribution of cross breeds (Gizaw and Getachew, 2009; Gizaw *et al*., 2013). This could be a huge burden for resource poor country like Ethiopia. As an option to exotic sire based crossbreeding, between indigenous sheep crossbreeding have been tried (Taye *et al*., 2011; Mekuriaw *et al*., 2013; Lemma *et al*., 2014). However, such scheme has faced two challenges. First, performance difference among indigenous sheep breed for economically important traits such as growth is quite small, thus genetic improvement following crossbreeding has not been attractive. Second, none of the indigenous sheep breeds has been developed for a specific purpose instead evolved through natural selection and largely merited for adaptation to low-input production environments. Thus, genes controlling economically important traits may not adequately be expressed as a result crossbreeding exerts little effect on quantitative traits.

In general, ineffectiveness of sheep crossbreeding in Ethiopia is known to be associated with multilateral factors that encompass technical, financial and institutional issues. Such issues have to be clearly sorted out and adequately addressed in the genetic improvement program in the future. If planned well and implemented accordingly, the exotic sire based crossbreeding strategy has the potential to improve indigenous sheep productivity adequately and thereby maximize their contribution for livelihood development of the community in particular and the country's economic growth in the broader context.

5. FUTURE PROSPECTS OF SHEEP CROSSBREEDING IN ETHIOPIA

Ethiopia has huge sheep genetic resources numbering at about 30.7 million heads of which 99.72% are indigenous type (CSA, 2016). Average productivity of sheep, however, is one of the lowest in the world. Despite the poor productivity of indigenous sheep, they are known to provide diverse functions such as income and food sources for the smallholder farmers in the country. The fact that food insecurity and poverty are chronic problems particularly at smallholder level, improving productivity of indigenous sheep could be a good pathway to bring long-lasting solutions for such nagging challenges. Although attempts have been made to improve genetic performances of indigenous sheep through crossbreeding, achievements are far below the expectations due to the summed up effects of multiple factors. Thus, learning adequate lesson from past failure is crucial to

plan effective crossbreeding strategy for sustainable genetic improvement in Ethiopian indigenous sheep.

5.1. Exotic sheep breed based crossbreeding

Exotic sheep in this article is to refer to those improved through selective breeding for economically important traits in their native area and imported to Ethiopia for crossbreeding with indigenous sheep. Typical examples are the Israeli's Awassi and South African hairy Dorper sheep that are already imported and used for crossbreeding purpose in Ethiopia. The Ethiopian indigenous sheep are not subjected to systematic selection for a particular trait instead developed through natural selection to survive and reproduce in low-input and stressful production environment. Way of combining the good adaptive potential of indigenous sheep with the high productive capacity of improved breed is through crossbreeding. Biologically, it can be considered as the optimal way to make productivity of indigenous sheep better off.

Following selection of the genetic improvement strategy, the next step is devising ways of implementation based on interests of the target beneficiaries and communities. Implementing genetic improvement program requires clear understanding of both the genetic and non-genetic components beyond the theoretical consideration, which are key determinants for the success of any breeding program (Baker and Gray, 2004; Kosgey *et al.*, 2008). One of the issues that detracts the success of exotic sheep based crossbreeding that has been conducted for long time in Ethiopia is the inability of crossbreed lambs to express their full potential under traditional management system. In other words, the existing husbandry practices do not support highly productive sheep implying improvement on the management condition should be performed with similar magnitude like that of the genetic component. Thus, matching the crossbreeds' genotype with the production environment is fundamental to achieve goals through exotic sheep based crossbreeding.

5.2. Setting clear crossbreeding goal

Crossbreeding can be used to develop synthetic breed, substitute less performing breed with superior breeds over time or upgrade to a certain level of the genetic make-up of the favored parent into the crossbreed offspring (Baker and Gray, 2004; Shrestha, 2005; Philipsson *et al.*, 2011). However, achieving such targets could require different procedure implying that the goal of crossbreeding should be clearly defined. From Ethiopian indigenous sheep perspectives, upgrading of crossbreeds to appropriate exotic blood level seems promising. Introgression of exotic blood level ranging from half to a three-quarter is reported to be effective for Ethiopian indigenous sheep in terms of improving growth performance (Gizaw and Getachew, 2009; Lemma *et al.*, 2014, Teklebrhan *et al.*, 2014; H/Giorgis *et al.*, 2017). Thus, designing systems that enable to use the appropriate crossbreed genotypes at wider scale will have paramount importance in achieving the target goal.

Synthetic breed formation could also be reasonably applicable in Ethiopian condition though no previous attempt has been made. Globally, a number of synthetic sheep breeds haven developed through crossbreeding method. The best examples for synthetic breed formation through crossbreeding are the development of Dorper in South Africa (Cloetea *et al.*, 2000) and Assaf sheep in Israel (Pollitt and Gootwine, 2004). Dorper is a hardy, early maturing and fast grower South African composite breed developed from a cross between the Black-headed Persian and the Dorset Horn sheep. The Assaf dairy sheep, on the other hand, have been originated from a cross involving improved Awassi and East Friesian sheep breeds. Considering such achievements, new breed formation from a cross between the preferred exotic sheep and selected Ethiopian indigenous sheep could be realistic. In this regard, establishing crossbreed sheep breeders cooperative at smallholder level could be a good entry point for synthetic breed formation. Furthermore, synthetic breed formation could eliminate the constraints associated with maintaining of pure exotic breeds.

5.3. Prevent crossbreeding from becoming a threat for genetic resource

Crossbreeding has to be implemented to wider scale to address large smallholder farmers who own indigenous sheep. However, due consideration should be given to prevent valuable genes of indigenous sheep from becoming victims of extinctions by genes from exotic breed. In this regard, establishing indigenous sheep genetic resource conservation program is needed. Conservation of all indigenous sheep breeds may not be feasible under the current situation in Ethiopia, for instance, due to resource limitation. Thus, breed prioritization for conservation and delineating crossbreeding areas should be integral parts of the crossbreeding based genetic improvement program. In general, genetic improvement should not be at the expense of the genetic resource of indigenous sheep of the country.

6. CONCLUSIONS

To improve growth performance of Ethiopian indigenous sheep, crossbreeding between exotic and indigenous as well as between indigenous sheep breeds have been practiced for longer period. From the crossbreeding attempts made so far, promising achievements have been reported in few areas where crossbreeding has been performed effectively. A typical example is the realization of up to 10kg yearling live weight superiority of high grade

Awassi crossbreeds over the indigenous sheep. As a national genetic improvement strategy, however, achievements of crossbreeding in terms of improving productivity of indigenous sheep are generally minimal. Technical and financial resource limitations and poor institutional setup of the livestock sector are the core problems that constrained the success of sheep crossbreeding in the country. In the future, the use of crossbreeding as a potential tool for indigenous sheep genetic improvement lies in bringing long lasting solutions to the current problems. In general, implementing well-designed crossbreeding program, particularly between improved exotic sheep and indigenous sheep, should be the primary focus to improve productivity of indigenous sheep. In this way, the contribution of indigenous sheep resources for the smallholder farmers in particular and the country's economic growth in general can be maximized.

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