Current status of livestock crossbreeding in Ethiopia: Implications for research and extension

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Abstract

In Ethiopia exotic sheep, cattle, and goat breed importation was initiated in early 1944, the 1950s, and 1975, respectively to improve the productivity of indigenous animals through crossbreeding. However, the per capita consumption of livestock products is still below the standard and cannot supply the ever-increasing human population. Thus, this paper reviews the current status of livestock crossbreeding, causes for failure and discusses how it can be implemented for the future without harming the indigenous animal genetic resources. A cattle crossbreeding has led to higher milk production per animal. A two to fourfold increment in lactation milk yield, 47 to 155 days increment in lactation length and 9 to 32% improvement in yearling weight than indigenous breeds were reported for crossbred cattle. Sheep crossbreeding programs using Awassi sheep breed improved the livelihood of smallholder in the highland areas and they start to produce genetic materials with its limitations. On the other hand, the decline in fitness traits (survival and reproduction) is reported for crossbred cattle and sheep. Both dairy and meat goat crossbreeding programs were not successful under the smallholder management system. Generally, the possible benefits from livestock crossbreeding were not fully exploited. The possible determinants for unsatisfactory achievements and poor sustainability were found to be the absence of a well-established breeding plan, lack of feed resources, poor veterinary services, lack of sustained funding, lack of basic understanding of crossbreeding, poor efficiency of reproductive technologies, access to financial credit and low involvement of smallholders in the implementation of the program. Therefore, careful planning considering the feasibility and sustainability, promoting alternative feed resources, improving veterinary services, enhancing the efficiency of assisted reproductive technologies, sustainable financial support and improving the record-keeping system are all vital for successful and sustainable livestock crossbreeding program.

Keywords: Cattle, crossbreeding, Ethiopia, goat, sheep

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Introduction

Among African countries, Ethiopia has the largest livestock population and has different agro-ecological zones that are suitable for livestock production. There are around 27 cattle breeds (DAGRIS 2007), 9 sheep breeds (Gizaw et al., 2008), 7 goat breeds (Mekuriaw 2016). The total cattle, sheep, and goat population for the country is estimated to be about 60.39 million, 31.30 million, and 32.74 million, respectively (CSA 2018). The livestock sector in Ethiopia contributes 19% of total Gross Domestic Product (GDP), 35% of agricultural GDP (ILRI 2011in Shapiro et al., 2017), 16-19% of the foreign exchange (MoA 2012) and provides a livelihood for 80% of the population (ILRI 2011in Shapiro et al., 2017).

Despite their genetic diversity and huge population, the productivity of indigenous breeds and human population growth is unbalanced. Increasing high density of land use and water resources, poverty, hunger, changing climatic conditions, and pricing of livestock products driven by both domestic and international consumer demand present unprecedented development challenges for developing countries (Freeman et al., 2007). To meet the ever-increasing demand for animal products and thus contribute to economic growth, genetic improvement of indigenous livestock has been proposed as one of the major strategies (Haile et al., 2011). Thus, intensification of livestock production using high productive livestock genotypes has been advocated as a means of improving the livelihoods of farmers. The government plans to increase 93% of milk production in 2020 through crossbreeding, health and feed interventions. Accordingly, cattle crossbreeding in Ethiopia was initiated in the early 1950s (Haile et al., 2011), sheep crossbreeding in 1944 (Getachew et al., 2016) and goat crossbreeding initiated in 1975 (Abegaz and Gizaw 2015). Although crossbreeding programs were initiated early, about 98.24% of cattle and 99.88% of sheep in the country are indigenous breeds (CSA 2018). Moreover, the per capita consumption of livestock products is still below the standard. Henceforth, the article reviews the current of the livestock crossbreeding programs in Ethiopia, the causes of failure and discusses how it can be implemented for the future without harming the indigenous animal genetic resources.

This article was based on an intensive literature review of published and unpublished materials like books, proceedings, working papers, articles, policy brief and other scholarly materials. Besides, the imported milk and milk products data were obtained from the FAOSTAT database. Generally, about 75 publications were utilized for reviewing and documentation of the current status of livestock crossbreeding in Ethiopia.

Livestock productivity and product consumption

Ethiopia had different agro-ecology, wide rangeland, diverse livestock genetic resources, and a huge population. About 14 million households are keeping livestock. Of these, cattle contribute from 31 to 48 % to total household income (FAO 2019). Although there is ample evidence of their adaptation and resistance to most endemic diseases and harsh climatic conditions, the current level of indigenous livestock productivity in Ethiopia is one of the lowest in the world. The average carcass weight of cattle, sheep, and goat was 110 kg, 10 kg and 8 kg, respectively (MoA 2012). The average milk yield per cow per day is about 1.37 liters with a six-month lactation length (CSA 2018). Accordingly, the per capita consumption of meat and milk is 9 kg and 56.2 liters, respectively (FAO, 2019), which is lower compared to other countries and the trend is shown in Figures 1 and 2.

On the other hand, the demand for livestock products (meat and milk) in Ethiopia is enhancing due to population growth, urbanization, increasing incomes and changes in diets. Thus, in addition to improving the local production, because of gaps between demand and supply of livestock products, Ethiopia has been importing milk and milk products such as skimmed milk, whole fresh milk, whole dried milk, whole milk evaporated, yogurt, cheese and butter by spending a million USD dollars (13,301,057 UD$ in 2011, 15,728,676US$ in 2012, and 11,002,015 US$ in 2013) (Zijlstra et al., 2015). Imported milk and milk products were increased linearly across the years (Figure 3). According to Shapiro et al. (2017), if there is no any intervention in the improvement of the productivity of livestock, there will be 53% for all meat (1.332 million tons) and 24% for cow milk (1987 million liters) deficit in 2028 due to rapid population growth and rising per capita income. To bridge the deficit, the introduction of genetics through AI integrated with estrus synchronization, improving the feeding health service considered as the best option by the government.

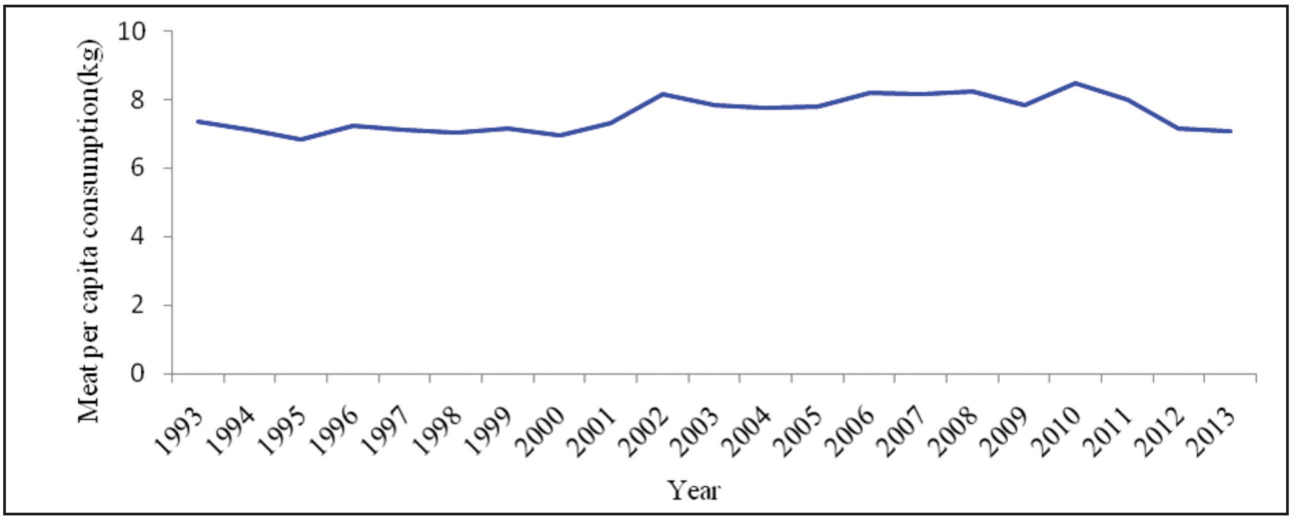

Figure 1. Meat consumption trend in Ethiopia (Source, FAOSTAT, various years).

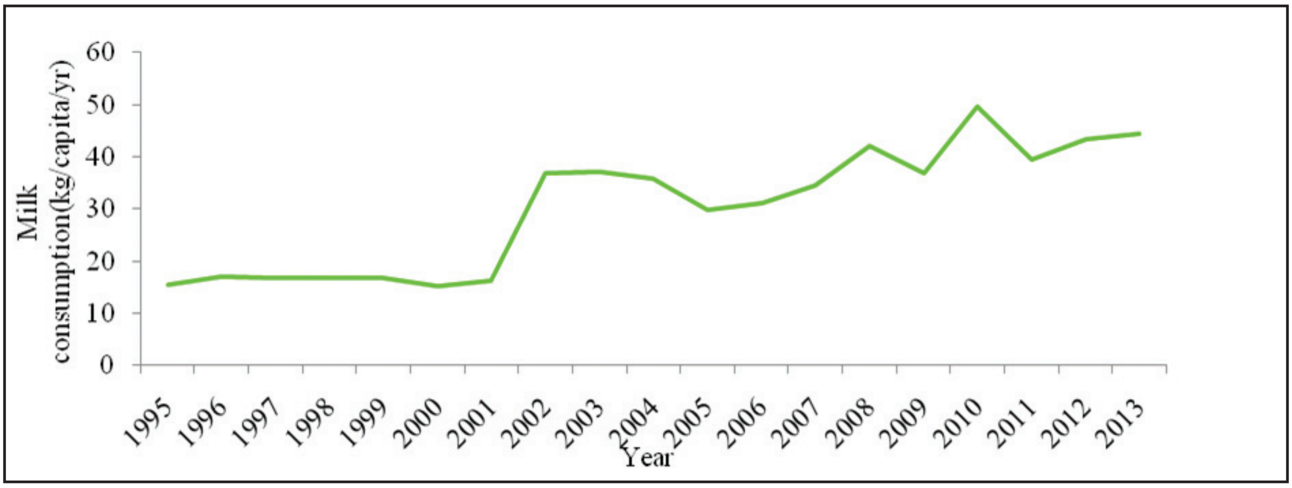

Figure 2. Per capita milk consumption trends in Ethiopia (source: FAOSTAT, various years).

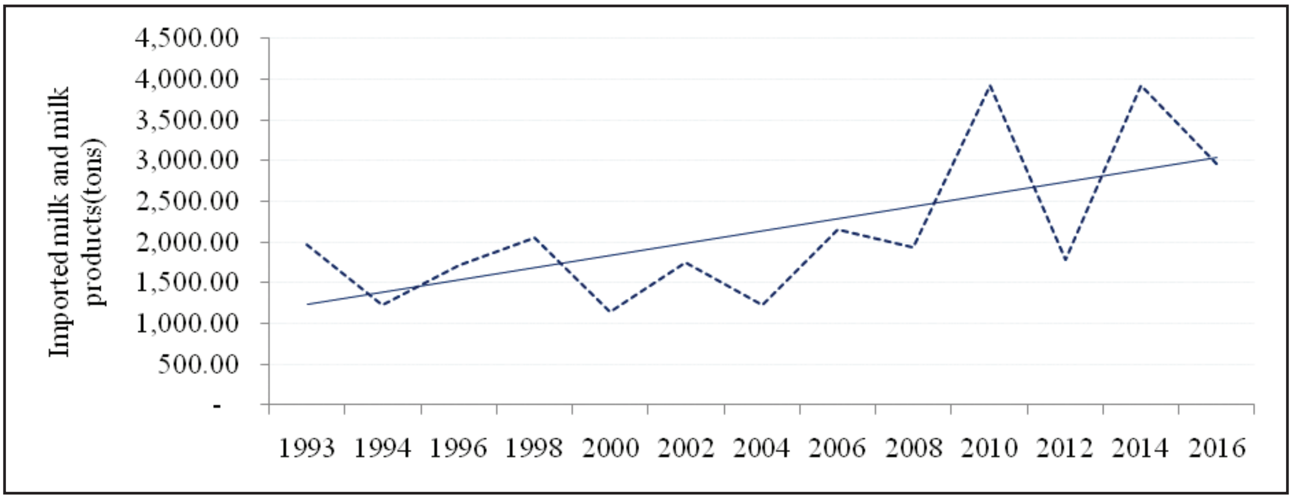

Figure 3. Imported milk and milk products in Ethiopia (Source: combined from FAOSTAT database).

Current status of livestock crossbreeding in Ethiopia

Cattle crossbreeding

With the aim of improving milk production and growth performance, the crossing of indigenous cattle breeds with different exotic breeds was conducted since the 1950s. Bulls and semen of Holstein Friesian, Jersey, Simmental, Angus, Brahman, Hereford, Charolais, and Santa Gertrudis were imported to Ethiopia in different years. Most of these exotic breeds were not found currently, only Holstein Friesian and Jersey breeds are being utilized partially.

Numerous scholars evaluated the performance of crossbred cattle although most of the reports do not include the performance of indigenous under the same management. The F1 Holstein Friesian x Barka produces above threefold (1644 kg more milk) and milked for 47 more days than pure Barka (Tadesse and Dessie 2003). According to Haile et al. (2009), the F1 Holstein Friesian x Boran exhibited a fourfold increase over the Boran breed in terms of lactation milk and daily milk yield; they were also milked for 97 more days than Boran cattle. Likewise, the F1 Holstein Friesian x Zebu crossbreds produced more milk (1423 kg/lactation) than the pure Zebu and milked an additional 75 days than pure Zebu cattle (Kiwuwa et al., 1983). The F1 Holstein Friesian x Arsi produced more milk (1168 kg/ lactation) than the indigenous Arsi and Zebu and crossbreds milked additional 84 days than pure Arsi cattle. Whereas the Jersey x Arsi produce (905 kg/lactation) more milk than pure Arsi cattle and lactation length also increased by 62 days (Kiwuwa et al., 1983). Besides milk production, the positive impact of crossing indigenous breeds with Jersey and Holstein Friesian cattle on reproductive traits (age at first calving and calving interval) was reported by numerous scholars (Beyene 1992; Negussie et al., 1998; Demeke et al., 2004; Haile et al., 2006; Roschinsky et al., 2015). However, reproductive performances, milk yield, growth performance, and survival of calves from *inter se mating* of F1 temperate-Zebu crosses are rather poor (Beyene 1992). This is due to recombination losses in second or later generations. Thus, using F1 crossbreds would be better in terms of fitness and productivity as they had better additive and non-additive gene contributions.

Under the smallholder management system, about 2123±65.6 liter/lactation with 325 days lactation length was reported for Holstein Friesian crossbreds and 403±90 liter /lactation with 204.3 days lactation length was noted for indigenous cattle under similar management (Kumar et al., 2014). Similarly, about 2430±154 kg milk yield per 313 days lactation length for Holstein Friesian x Guraghe Highland (GH) and 2364±85 kg milk yield per 270 lactation lengths for Jersey x GH was reported by Ayalew et al. (2018). Moreover, the age at first calving and calving interval was reduced by 1.6 and 1.1 years, respectively through crossbreeding according to Roschinsky et al. (2015). These results depict that crossbreeding exploits additive and non-additive allele gene effects leading to improvements in production and reproduction performance. If integrated with alternative feed sources and improved health services, crossbreds able to express their genetic potential and thereby improve the livelihood of smallholder farmers.

An evaluation was conducted at Alemaya College of Agriculture from 1961 to 1967 comprised of Borana cows with a bull of Angus, Brahman, Hereford, Charolais, and Santa Gertrudis. This result exhibited that crossbred calves were 19.6% heavier at birth and 23.6% heavier at weaning than Boran Zebu calves. Among crossbreds, Angus and Charolais calves were the lightest and heaviest respectively (Wagner et al., 1969). According to Demeke et al. (2003), crossing with Holstein Friesian increased the yearling weight of Boran, Barka, and Horo cattle breed by 21.2% (27 kg), 25% (31.7 kg) and 20.4% (25.2 kg), respectively. Crossing with Simmental cattle breed improved the yearling weight of Boran, Barka, and Horo cattle by 20.1% (26 kg), 19.2% (24.1 kg) and 20% (24.6 kg), respectively (Demeke et al., 2003). The F1 Jersey x Boran, Jersey x Barka and Jersey x Horo cattle were higher by 13.6% (17.6 kg), 13.8% (17.2 kg) and 9.2 % (11.3 kg) than pure Boran, Barka, and Horo cattle breed, respectively (Demeke et al., 2003). Likewise, Haile et al. (2010) reported that crossing with Holstein Friesian increased the yearling weight of Boran cattle by 32% (35.7 kg). Besides, the F1 Jersey x Horo calves were heavier by 15 kg (Abera et al., 2013) and by 18 kg (Hundie et al., 2013) than pure Horo cattle. Based on these results, the yearling weight advantage of Jersey crossbreds is lower than Holstein Friesian and Simmental crosses.

Cattle crossbreeding were initiated early in the 1950s. Since 1981, government organization NAIC (National Artificial Insemination Centre) distributed fresh semen from genetically superior bulls to different areas of the country and private companies such as WWS (World Wide Sires) from 2005-2008 and since 2009 ALPPIS (Addis Livestock Production and Productivity Improvement Service) are the leading AI service-provider in Ethiopia. Besides, many ranches and research centers are producing crossbred cattle, evaluating the performance and distributing to farmers. Among these; Holetta, Debre Zeit, Adaberga, Metekel ranch, Andasa and Adami Tulu research centers are the major sources. However, about 98.24% of cattle in the country are indigenous breeds (CSA 2018) and 97% of the milk is produced by indigenous cattle and the remaining 3% produced from crossbred and pure exotic cattle (Zijlstra et al., 2015). Most of the crossbred cattle are mainly found within the urban and peri-urban farming systems and within the commercial farms in the milk sheds (Zijlstra et al., 2015). Moreover, there is no significant change in the per capita consumption of milk. These signify the lower efficiency of the cattle crossbreeding program. This lower efficiency could be associated with poor efficiency of AI service, lack of infrastructure, extension service and financial support. Thus, boosting private service providers, private farms, financial and technical support for ranches and fully participating farmers can be a good opportunity for bridging the existing gap between the demand and supply of livestock products and to improve the livelihood of farmers. Meanwhile, it is vital to delineate the crossbreeding areas to reduce its impact on indigenous animal genetic resources.

Selection of compatible exotic gene level is vital for a successful crossbreeding program. Milk production, reproduction performance, and milk composition traits were all in favor of the 50% exotic cross (IAR 1982; Haile et al., 2011; Philipsson et al., 2011). Hence, the introduction of exotic genes at a 50% level could be considered best for highland mixed farming and smallholder dairy farming systems. On the other hand, higher exotic inheritance levels could be suitable for intensive production systems. Thus, the dissemination of crossbreds must be conducted as per this principle to effective in dairy cattle crossbreeding programs. Moreover, selecting suitable breeds based on the production systems is the major determinant for the success of the crossbreeding program. For example, the Jersey breed has been suggested as one suitable breed for low-input smallholder conditions (Haile et al., 2011) because of having a smaller body size, better reproductive performance, a fair amount of milk with higher milk fat content, and some heat tolerance. Holstein Friesian will remain the choice in intensive and semi-intensive production systems.

Sheep crossbreeding

Crossbreeding using exotic breeds

In Ethiopia, different exotic breeds were imported since 1944 when Merino sheep were introduced from Italy by an American aid organization (Getachew et al., 2016; Alemayehu et al., 2018). Romney, Corriedale, Hampshire, and Rambouillet were introduced from Kenya in 1967. Recently, Awassi were introduced from Israel in 1980 and Dorper sheep from South Africa in 1980s to Jijiga and in 2007 by Ethiopian Sheep and Goat Productivity Improvement Program (Awgichew and Gipson 2009). Therefore, Ethiopia exercises sheep crossbreeding programs for about 74 years due to believe in the low productivity of indigenous sheep breeds. However, except Awassi sheep, the contribution of other exotic breeds was not well-defined (we can say no significant contribution at all).

Crossing indigenous sheep with Dorper sheep showed a considerable improvement in growth rate and the resulted in crossbreed lambs could attain the minimum requirement for the export market (25-30 kg) at yearling age. According to Lakew et al. (2014) and Abebe et al. (2016), the crossing of local sheep with Dorper sheep exhibited a significant improvement of growth performance (Table 1). Besides, Dorper x Hararghe Highland sheep had significantly higher empty body weight, hot carcass weight and cold carcass weight compared with Hararghe Highland and Blackhead Ogaden sheep. However, Dorper x Blackhead Ogaden sheep was not significantly different from pure Blackhead Ogaden (Tsegay et al., 2013). Indeed, the expected improvement from any crossbreeding program depends on the initial performance variation between two parental breeds. According to Tilahun et al. (2014), hot carcass weight for local, 25% and 50% Dorper x local sheep was 10.3, 16.6, and 15.3 kg, respectively. Besides, according to farmer's perception in the study of Habtegiorgis and Jimma (2017), Dorper sheep have better growth performance i.e. they grow fast under the best management system than local sheep. However, its coat color and susceptibility to diseases were considered as the weakness of Dorper sheep. In addition to research results, considering farmersí preferences is vital for a sustainable and successful crossbreeding program. Thus, the fitness of Dorper crossbred sheep should be evaluated under smallholder management before further dissemination to farmers.

Crossing indigenous of indigenous Tikur, Wollo, and Menz sheep with Awassi sheep was conducted for many years in the highland areas of Ethiopia. Gizaw and Getachew (2009) reported that the yearling weight of Wollo sheep, their crossbreds with 25% to 50% Awassi blood level and above 50% Awassi blood level were 22, 26, and 35 kg, respectively. According to Amare et al. (2018), the yearling weight of F1 Awassi x Wollo sheep was higher by 40.7% (8.8 kg) and F1 Washera x Wollo was greater by 39.8% (8.6 kg) than the indigenous Wollo sheep under the smallholder management system. Likewise, the six-month weight of Wollo, F1 Awassi x Wollo and Washera x Wollo crossbred sheep were 15.7, 22.7 and 19.5 kg, respectively which is higher than most of the indigenous breeds. Similarly, Abebe et al. (2016) reported that the weaning weight of Awassi x Menz sheep with 25-50% and 75% Awassi blood level was higher than pure Menz sheep by 30.2%(2.58 kg) and 44.6 %(3.83 kg), respectively. These results indicated that crossing with Awassi is considerably ameliorating the growth performance of sheep.

However, the indigenous sheep breeds showed better reproductive performance (lambing interval, age at first lambing, and the number of lambs born per ewe per year) than Awassi crossbred sheep (Getachew et al., 2013). Menz ewes demonstrated better fertility (31%) more, lambing rate (30%) and advantage in weaning rate (16%) over the Dorper ewes (Abebe et al., 2016). Similarly, farmers reported that Awassi x Wollo sheep had high feed requirement, susceptible to diseases and low reproductive ability (age at first lambing and lambing interval) as compared with indigenous Wollo sheep (Tesema et al., 2018). Reproductive merit is considered as an indicator of fitness and adaptability capacity of the animals in a particular environmental condition. Thus, there should be due intervention (research and management intervention) to enhance the reproductive performance of crossbreds besides growth performance. If not, improving only growth performance reduces the productivity and profitability of sheep production.

The positive impact of crossbreeding on the livelihood of farmers due to better growth rate and the superior market price of Awassi crossbreds compared with local sheep at the same age and under the same management was noted by Tefera et al. (2014). As a result, farmers started to produce genetic material and they are serving as sources of breeding rams for other areas. Currently, a large number of Awassi rams are being distributed to farmers from various private and government ranches. Among these, Amed Guya sheep breeding ranch, Guguftu sheep ranch, Debre Birhan sheep breeding ranch, Debre Birhan Research Center, farmers in Talet and Angolela Tera districts are the major sources of Awassi crossbred rams. On the other hand, a few numbers of research centers (Debre Birhan, Sirinka, Werer and Areka research center) are engaged in the evaluation and distribution of crossbred Dorper sheep to farmers. However, the sustainability of sheep

Table 1. Comparative advantages of Dorper and Awassi crossbreds

Breed	BWT	WWT	SMWT	YWT	Management	References
BHO	2.5	11.3	-	23.1	On-station	Yibrah (2008)
D x BHO	3.0	15.1*	-	-	On-station	Teklebrhan et al. (2014)
Tumele	2.36	8.53	11.92	22.38	On-station	Lakew et al. (2014)
D x Tumele	3.24	14.95	20.43	31.37	On-station	Lakew et al. (2014)
Menz	2.09	9.10	-	17.3	On-station	Markos (2006)
D x Menz	2.77	12.34	17.25	31.33	On- station	Abebe et al. (2016)
Afar	2.7	11.5		26.6	On-station	Yibrah (2008)
D x Afar	2.57	9.45	13.18	24.96	On- station	Abebe et al. (2016)
A x Tikur	3.10	13.04	16.95	24.42	On-farm	Tilahun et al. (2014)
Wollo	1.9	10.8	15.7	21.6	On-farm	Amare et al. (2018)
A x Wollo	2.08	12.9	20.4	-	On-farm	Tesema et al. (2018)
A X Wollo	2.4	13.8	22.7	30.4	On-farm	Amare et al. (2018)
W x Wollo	2.2	14.2	19.5	30.2	On-farm	Amare et al. (2018)

BHO: Black head ogaden; D: Dorper; A: Awassi; W: Washera; BWT: birth weight; WWT: weaning weight; SMWT: six month weight; YWT: yearling weight

crossbreeding programs is being challenged by disease susceptibility of pure exotic and their crossbreds. Maedi-visna disease in Awassi crossbreds and Orf like undefined diseases in Dorper crossbreds are the major diseases common in crossbreds.

Crossing among indigenous sheep breeds

Crossbreeding was also conducted between indigenous sheep breeds. The yearling weight of Menz x Bonga sheep with 75% Bonga blood level was 22% (3.7 kg) heavier than Menz sheep under on-station management (Lemma et al., 2014). However, the growth performance of Menz sheep was similar to Washera x Menz and Bonga x Menz with a 50% blood level (Lemma et al., 2014). Through crossing of Farta sheep with Washera ram; the weaning weight, six-month weight, and yearling weight were improved by 12.3%, 17.6% and 12%, respectively (Mekuriaw et al., 2013). Besides, crossbred sheep were more preferred by the farmers for their overall merits of both adaptation and productivity. Likewise, the six-months and yearling weight of Wollo x Washera was higher by 24.2% and 39.8% than pure Wollo, respectively (Amare et al., 2018). Based on these results, crossbreeding among indigenous breeds seems good and could be considered as an option. Moreover, the breeding programs would be sustainable as there is no adaptation problem and require less input cost relative to exotic breeds.

Goat crossbreeding program

Dairy goat

Saanen, Anglo-Nubian, and Toggenburg goats are some of the important breeds that have been introduced in Ethiopia since 1975 (Abegaz and Gizaw 2015) to improve the milk production potential of indigenous goats through crossbreeding. The performance evaluation result indicates that Sannen x Afar does with 25% blood level produce 29% more milk than purebred Afar does (24 kg vs 31 kg with 12-week lactation) without any reduction in other productivity and reproductive traits under the same management (Awigchew et al., 1989). Galal et al. (1982) reported that milk yield increased by 50% in Saanen crossbred but the crossbreds were less adaptive to the areas than local breeds or Adal. Similarly, the average milk yield of indigenous highland goats from three month lactation was 19 kg. This was improved to 52 kg in 50% Saanen crossbred does, with a slight reduction in reproductive rates and a minor improvement in the growth potential of crossbreds (Tsegahun et al., 2000). This depicts that increasing the exotic gene-level under a low-input production system would be worthless.

Anglo-Nubian x Hararghe Highland and Anglo-Nubian x Somali were used for milk production by smallholders in central, southeastern, eastern, and southern parts of the country and crossbreds showed increments in milk yield. Under the smallholder management system, Anglo-Nubian x Hararghe Highland goats had higher daily milk yield (0.56 vs 0.38 litters), lactation length (4.2 vs 3.07 months), lifetime milk yield and births per year than local goats. With these features, about 91.6% of the interviewed farmers had exhibited more interest in crossbred goats than indigenous goats (Nigussie 2010). However, crossbred goats had lower longevity, a lower number of births per lifetime, and a higher mortality rate than local goats (Nigussie 2010). In general, the dairy goat crossbreeding programs under smallholder management was not successful because of the incompatibility of the genotype with the existing low-input production systems and due to poor adaptability of crossbreds (Ayalew et al., 2003; Kosgey et al., 2006). Due to these, the resulted in benefit from the dairy goat crossbreeding program was found to be negligible.

Meat goat

Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP) imported Boer goat in 2007 from South Africa and crossed with indigenous goats such as Central Highland, Abergele and Woyit-Guji goats in order to improve their productivity through crossbreeding. The six-month weight for Boer x indigenous goat ranges between 13.54±0.20 kg for Boer x Central Highland (Deribe et al., 2015) and 18.95±0.23 kg for Boer x Abergele (Belay et al., 2014) under on-station management (Table 2). The yearling weight of crossbred Boer goat was varied from 19.53±0.38 kg for Boer x Central Highland (Deribe et al., 2015) to 27.8±0.53 kg for Boer x Abergelle goat (Belay et al., 2014). According to FAO (2010), the crossbreds should perform at least 30% better than purebred animals to consider crossbreeding as an option. As per this principle, only the growth performance of Boer x Abegelle goat seems to be better than purebred (Abergelle goats) and crossing other indigenous goats with Boer does not significantly improve the growth performance under an extensive management system. As a result, crossbreeding using Boer goat is becoming to neglecting.

This is not meant that the Boer goat breed had poor genetic potential. The feedlot performances of indigenous and Boer crossbreds were evaluated under the same (semi-intensive to intensive) management. For example; according to Tesema et al. (2018), the hot carcass weight for Central Highland and their crossbred with Boer goat was 10.7±0.52 kg and 14.0±0.91 kg

(30% higher), respectively. Similarly, Mohammed et al. (2012) reported a 9.23 kg carcass weight for Boer x Arsi Bale goat and 6.23 kg for pure Arsi Bale goat. The carcass weight of Central Highland, Boer x Central Highland goat with 25% and 50% Boer blood level was 9.0 kg, 10.9 kg, and 12.8 kg, respectively (Tilahun et al., 2014). These results showed the superiority of Boer crossbreds over indigenous goats under a medium to a high-input production system. However, under a low level of management, the performance of the Boer crossbreds was not superior to indigenous Ethiopian goat breeds (Mohammed et al., 2012; Tesema et al., 2018). From these results, we can conclude that Boer goat is suitable for semi-intensive and intensive production systems. However, almost all smallholder farmers in Ethiopia managed their goats extensively which is characterized by poor feed quality and poor veterinary services. Thus, the expected benefit from goat crossbreeding using Boer goat in Ethiopia will not be obtained, if the existing management is not improved.

Major constraints for pervious crossbreeding attempts

In the case of Ethiopia, the advantages of cross-breeding were not fully exploited due to different technical and non-technical constraints. According to several scholars (Philipsson et al., 2011; Rege et al., 2011; Leroy et al., 2015), the opportunities to express the genetic potential (feed resource and veterinary services), access to credit, and access to improved stock are the key factors for successful implementation of crossbreeding program. To sustainably utilize the advantages of cross-breeding, there should be a formal organization that supports these factors. Besides, lack of technical knowledge at all levels or lack of basic understanding of crossbreeding (Roschinsky et al., 2015), poor efficiency of reproductive technologies, lack of sustained funding, incompatibility with the breeding objective of the farming system, low involvement of smallholders in the implementation of the programs (Kosgey et al., 2006), lack of monitoring and genetic evaluation (Effa et al., 2011; Philipsson et al., 2011) and a lack of livestock-keeper

Table 2. Growth performance of Ethiopian indigenous goats and their crossbreds with Boer

Breed	BWT	WWT	SMWT	YWT	Management	References
Abergele	1.91±0.04	6.84±0.19	9.13±0.31	14.15±1.20	Extensive	Deribe (2008)
Abergele	2.28±0.02	7.40±0.09	9.48±0.15	-	Extensive	Birhanie et al.(2018)
Boer x Abergele	2.9±0.09	15.3±0.38	18.95±0.23	27.8±0.53	Semi-intensive	Belay et al.(2014)
Bati	2.70±0.05	10.44±0.18	15.57±0.19	-	Extensive	Gatew (2014)
Central Highland	2.01±0.03	9.02±0.18	13.82±0.39	20.61±0.74	Extensive	Deribe and Taye (2013)
Central Highland	2.29±0.03	10.7±0.30	17.7±0.50	-	Extensive	Alemu (2015)
Central Highland	2.68±0.04	9.42±0.19	15.73±0.54	-	Extensive	Zergaw et al.(2016)
Boer x Central Highland	2.6±0.02	9.63±0.15	13.54±0.20	19.53±0.38	Semi- intensive	Deribe et al. (2015); Tesema et al. (2017)
Woyito Guji	2.03±0.04	9.04±0.18	11.49±0.47	-	Extensive	Zergaw et al.(2016)
Boer x WG	2.89±0.38	10.39±1.86	13.90±2.19	19.05±3.51	Extensive	Girma et al. (2016)

WG: Woyito Guji goat

participation in activities such as animal identification and performance recording (Philipsson et al., 2011; FAO 2015) are the other determinants for successful implementation of crossbreeding program.

Modality of successful crossbreeding program

To consider crossbreeding as an option: First, assessment of the production system and document the nature and stability of nutrition and management resources at all times to sustain production above current levels. Likewise, the breeding goal/ trait should be determined. Once the trait of interest is known, it is important to collect information on estimates of genetic and phenotypic parameters, heterosis, breed performance and fitness for the breed(s) under consideration (FAO 2010; Philipsson et al., 2011). Second, the candidate and the base breed should be evaluated under similar management and the performance of crossbred should be greater by 20-30% than the indigenous base breeds (Gibson and Cundi 2000; FAO 2010). Third, suitable crossbreeding scheme should be selected. Selection of suitable crossbreeding scheme depends on the merit and availability of the breed, heterosis for economically important traits, the expected breed complementarity, replacement herd/flock, easy of application, the availability of pure breed sires with accurately expected progeny differences (http://users.tamuk.edu/kfsdl00/Chapter19-33335-bw), breeding goal and production system, and conservation of the adapted local breed. Fourth, there should be well designed operation plan for the implementation of the program. The appropriate breed and exotic gene level must be determined based on the production system and there should be record keeping system. Moreover, the areas of crossbreeding must be delineated to reduce genetic dilution. Fifth, the genetic gain and economic return should be evaluated periodically and the dissemination of the genotype must be carefully planned and implemented successfully.

Implications and recommendations

Crossbreeding is vital to combine the productivity and adaptable merits of exotic and indigenous livestock breeds, respectively. If implemented properly, it is the ideal strategy to bridge the existing gap between demand and supply of livestock products and thereby improve the nutritional status of the human. However, in the case of Ethiopia, most of the crossbreeding program has lacked a well-organized implementation plan and sustainability, lacked a clear vision of where to bring an impact and not integrated with improved animal management. Accordingly, possible benefits from livestock crossbreeding have not been fully exploited due to such problems and other technical and non-technical constraints. Therefore, careful planning considering the feasibility and sustainability, promoting alternative feed resources, improving veterinary services, enhancing the efficiency of assisted reproductive technologies, sustainable financial support and improving the record-keeping system in addition to institutional and policy associated issues are all vital for successful and sustainable livestock crossbreeding program. Besides, indiscriminate crossbreeding which threatening local genetic resources must be avoided and a conservation-based crossbreeding strategy in the delineated area/production system has to be adopted.

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