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Review

Review of sheep crossbreeding based on exotic sires and among indigenous breeds in the tropics: An Ethiopian perspective

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The objective of this review paper is to examine whether or not sheep crossbreeding is a feasible option to improve indigenous sheep breeds in developing countries using Ethiopian case as example. The paper reviewed and discussed the history of exotic breed introduction, research, and development efforts in crossbreeding and performance of crossbreds under on-station and on-farm management. Earlier, the choice of breed for crossbreeding overlooked interests and preferences of farmers mainly for physical appearance. More recently the introduction of Awassi sheep considered their preference. Performance evaluation results from the on-station and on-farm (mainly based on Awassi pilot crossbreeding villages) showed that crossbreds often outperformed their local contemporaries. Thus comparisons of pure local sheep and crossbreds among those breeds produced in some areas indicated a good outcome of this type of crossbreeding. However, the performance of crossbred sheep varied by location and depended on management and exotic inheritance levels. For most programs, no comprehensive data were available to do on-farm comparisons of herd productivity and cost-benefits or to evaluate the sustainability of the programs. Regardless of location, farmers participating in crossbreeding often showed keen interest in crossbreeding, mainly due to the fast growth, larger body size of crossbreds resulting in higher market prices as compared to their local sheep breeds. Ram multiplication and dissemination from the government farms were found inefficient. The predominant practice of a ubiquitous dissemination and selling of breeding rams to individual farmer dilute the efforts of crossbreeding and prevents generating the benefits expected from crossbreeding programs. Furthermore, indiscriminate crossbreeding without prior analysis of suitability of crossbreds for a given production environment and without clear breeding objectives presents a potential threat to better adapted indigenous breeds. Crossbreeding programs require strong research and development support from public service and non-governmental institutions for sustainable design, optimization, and implementation in clearly defined production environments.

Key words: Awassi, developing countries, Dorper, on-farm performance, smallholder farmer.

INTRODUCTION

Small ruminant production is an important agricultural activity and has a substantial contribution to smallholder farmers in generating income and securing food in developing countries (Kosgey et al., 2006). Tropical developing countries typically rely on non-specialized multipurpose breeds and extensive production systems and control over breeding animals is often poor. Existing breeds are adapted to the existing environmental situation which is characterized by feed scarcity and disease challenge (Baker et al., 2002; Haile et al., 2002; Gizaw et al., 2008a). However, there is a belief that local breeds are less productive and unlikely to continue sustaining the fast growing demand for food that is created by rapid human population growth, urbanization and income growth. Crossbreeding is considered as one of the options and it is a potentially attractive breed improvement method due to its quick benefits as the result of breed complementarity and heterosis effects (Leymaster, 2002; Hayes et al., 2009). FAO (2007) documented that the transfer of genetic material has been increased dramatically in the recent decades. Sheep are among the most widely distributed livestock species. Consequently, based on a review of Shrestha (2005), the widely practiced breed combination resulted in about 443 composite sheep populations worldwide in 68 countries. Some remarkable results have been achieved in well-designed selective and crossbreeding schemes. One example is the improvement of local Awassi using within-breed selection, crossbreeding and gene introgression resulting in a highly productive and prolific genotype in Israel (Gootwine and Pollott, 2000; Pollott and Gootwine, 2004). Another example is the development of Dorper sheep by crossing Dorset Horn rams with fat-rumped Black Head Persian ewes (de Waal and Combrinck, 2000). Such programs have been favored by resourceful environments and well developed infrastructure and markets (Sölkner et al., 1998). However, in developing countries generally, the adoption of livestock technologies has been low due to the environment and poor resource base of farmers (Iñiguez, 2011). The proportion of exotic and crossbred sheep populations in Ethiopia remains low, only 0.2% (CSA, 2013), indicating that research and development efforts of sheep crossbreeding in Ethiopia did not deliver the anticipated benefit to smallholder farmers so far. However, there is still a growing interest of the government and of farmers in sheep crossbreeding. There is no comprehensive study showing the performance of crossbreeding, both biological and economical, to substantiate the argument on the benefit of sheep crossbreeding for smallholder farmers. This paper reviews sheep crossbreeding efforts particularly in Ethiopia and in other African countries with the aim to support decisions related to the future implementation of crossbreeding strategies.

HISTORY OF EXOTIC BREED INTRODUCTION TO ETHIOPIA

The first introduction of exotic sheep breeds into Ethiopia traced back to 1944 when Merino sheep were introduced from Italy by an American aid organization and were maintained at Entoto (located near Addis Ababa) sheep breeding station (DBHBMC, 2007). Romney, Corriedale, Hampshire, and Rambouillet were introduced from Kenya in 1967 and were kept at the government farm Debre Berhan Sheep Breeding and Multiplication Center (DBSBMC) which was established in 1967 and located at Debre Berhan town, in North Shewa administrative zone of the Amhara region. Another state owned farm, Chilalo Agricultural Development Unit (CADU) was also established in the same year in the former province of Arsi. However, the detection of maedi-visna (respiratory viral disease) in the flock of CADU in 1988-1989 prompted closure of the farm (BoA, 2000). In 1980, Awassi sheep were introduced from Israel and kept at DBSBMC and Amed Guya Sheep Breeding and Multiplication Center (AGSBMC). There were also continuous importations of purebred Awassi sheep totaling 45 (ram and ewe lambs). The two government farms have been engaged in multiplication and distribution of crossbred rams to farmers at a subsidized price. Ram dissemination was banned between the years 2001 and 2009 following the confirmed maedi-visna disease in crossbreds and associated sheep flocks (DBHBMC, 2007). In 2011, about 170 pure Awassi sheep were imported from Israel to recommence crossbreeding in the farms.

Dorper sheep were introduced into the Jijiga area (Somali Region) in the late 1980s. On-station performance of crossbred was very good however there was no on-farm evaluation during that time (Awgichew and Gipson, 2009). All sheep were looted from the ranch during the political instability in 1991 (Awgichew and Gipson, 2009).The Ethiopian Sheep and Goat Productivity Improvement Program (ESGPIP), a USAID-funded 5 year project launched in 2006, operated with the

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goal to sustainably increase sheep and goat productivity in Ethiopia and consequently to enhance economic and food security. A total of 120 Dorper sheep (ewes and rams) were imported again from the Republic of South Africa in 2007 (Awgichew and Gipson, 2009). Regional research institutions also showed interest in Dorper sheep and additional ~250 sheep were imported in 2011, aiming to establish new nucleus flocks.

OVERVIEW OF CROSSBREEDING EFFORTS BASED ON EXOTIC AND INDIGENOUS SIRES

Introduction of Romney, Corriedale, Hampshire, and Rambouillet was targeted to cross them with local sheep breeds aiming to supply wool for the Debre Berhan blanket factory established in 1967. From the year 1969 to 1974, a total of 99 crossbred ewe lambs and ram lambs were distributed to farmers. The breeds were performed well in growth performance under station and farmer situation except Romney breed (DBHBMC, 2007); nevertheless, they were not preferred by farmers due to their physical characteristics (face covered with hair, absence of horn in males and thin tail), fatty nature of wool making it difficult to spin wool in the traditional way, and the suspected poor skin quality. Thus, during the monarchy time, crossbreeding was mainly limited to on-station to supply fattened sheep for the king palaces and occasions. Following the downfall of the monarchy (1974), the crossbreeding efforts were directed to produce and disseminate crossbred rams to smallholder farmers. DBSBMC and AMSBMC distributed more than 4000 crossbred rams of different breeds (Awassi, Corriedale, and Hampshire) to smallholder farmers at subsidized prices between the year 1974 and 2001 (DBHBMC, 2007). Hampshire and Corriedale breeds were initially used while these breeds were gradually replaced by Awassi following the introduction of Awassi in 1980. Awassi breed has been well accepted by Ethiopian farmers due to its similar physical appearance to that of local breeds. In the first four years of Awassi ram distribution, individual smallholder farmers were targeted. Later, from 1979 to 1989, the focus was shifted to farmers organized in cooperatives. However, no performance evaluation was performed in the co-operatives, and animals were looted during the government change in 1991. Consequently, the co-operatives were abolished and dismantled (Emana, 2009) so that the focus was again changed to disseminate rams to individual smallholder farmers. The target has been on disseminating rams with 75% Awassi inheritance to farmers for crossbreeding with their local ewes aimed at replacing the local sheep breed through repeated backcrosses (DBSBMC, 2007).

On-station research results on growth, reproductive performance and carcass performances from CADU farm (Osslon and Beyene, 1990) and Sheno (now Debre Berhan) Agricultural Research Center (Demeke et al., 1995) were reported. A survey by DBARC in the year 1997 to evaluate the on-farm performance of crossbred in North Shewa and South Wollo districts of the Amhara Region exposed the total failure of ram dissemination (Gizaw and Getachew, 2009). It was difficult to find either crossbred rams or offspring from disseminated rams in the surveyed areas. Following that an on-farm evaluation of the performance of Awassi × local crossbred sheep under farmers' management was commenced by DBARC in three villages in the highlands of Ethiopia in 1997. Details of the breeding program followed by DBARC are indicated (Gizaw and Getachew, 2009; Getachew et al., 2013). Similarly, the Awassi × Tikur sheep crossbreeding started in two villages of North Wollo by Sirinka Agricultural Research Center in 2007.

The ESGPIP project was implemented in collaboration with local universities and research centers at 2 nucleuses and 10 Breeding, Evaluation and Distribution (BED) sites, established in different parts of the country since 2007. Their nucleus sites were used to multiply the imported purebred Dorper sheep and provide a continuous supply of pure Dorper sheep to the BED sites, private commercial or cooperative farms and to those individuals who wished to establish their own pure breed producing farms. At BED sites, purebred sires were crossed with indigenous dams to obtain F1 sires for dissemination to farmers. The funding of ESGPIP terminated in 2011 and the activities were handed over to local universities and research centers for further implementation of the crossbreeding program.

Crossbreeding among indigenous breeds has also been practiced at DBARC as an alternative to the use of exotic genotypes for crossbreeding. Indigenous Washera rams were distributed in the highlands of North Shewa, South Wollo, North Wollo, and Gondar areas (ANRS-BoARD, 2004). In 2005, a village-based Farta × Washera sheep crossbreeding program has been started (Mekuriaw et al., 2013) with the aim to increase productivity of medium sized indigenous Farta (Gizaw et al., 2008a) by crossing or introducing male and females of indigenous Washera sheep.

GROWTH PERFORMANCE

On-station performance

Several studies from the on-station evaluation of growth performance of crossbreds using exotic (Awassi and Dorper) sires in different areas of Ethiopia confirmed that the crossbreds are superior to their local counterparts (Demeke et al., 1995; Olsson and Beyene, 1990; Tibbo, 2006; Tsegay et al., 2013; Lakew et al., 2014; Tilahun et al., 2014). The study by Olsson and Beyene (1990) at

CADU showed that birth weight, weaning weight, and annual greasy wool weights improved with increased levels of exotic blood. Evaluation of the effect of 3 genotypes (local Menz, 50% Awassi 50% Menz and 75% Awassi 25% Menz) and 2 levels of feed supplementation (supplemented and non-supplemented) and 2 treatments against internal parasite (treated and non-treated) on the overall productivity of sheep was carried out at DBARC for 10 months (Tibbo et al., 2005). At the beginning of the experiment (yearling age), the 75% Awassi × Menz were superior in live body weight than the indigenous Menz sheep (23.5 vs. 16.6 kg). At the end of the 10 months experimental period, also crossbreds performed better in live body weight, carcass weight, and fleece yield and had higher marginal profit. However, overall marginal profit including skin price showed that the indigenous Menz sheep were more profitable than the crossbreds due to the higher skin price compared to the crossbreds at that time. However, the authors explained that crossbreds already reached market weight of Menz sheep at the beginning of this experiment indicating that keeping those crossbred sheep for longer time can be costly compared to local genotypes. Indigenous Menz sheep and 50% Awassi showed better resistance against parasites compared to 75% Awassi.

A 90 days experiment aiming to compare growth and carcass traits of Hararghea Highland (HH) and Black Head Ogaden (BHO) sheep and their crosses with Dorper (D) sheep with two feeding types (hay *ad libitum* + 150 g day^{-1} concentrate feed and hay *ad libitum* + 300 g day^{-1} concentrate feed) at the age of about 7 months was carried out at Haramaya University (Tsegay et al., 2013). The result revealed that Dorper sired crossbred lambs produced from HH ewes had better growth performance compared to the Dorper sired crossbred lambs produced from BHO ewes. This might be an indication that HH ewes are more suitable for crossing with Dorper for crossbred lamb production than the BO ewes. Crossbreds of Dorper with both BHO and HH showed comparable average daily gains of 69.4 and 63.9 g day^{-1}, respectively, in the 90 days feeding trial. Average daily gains in the 90 days trial for Pure BHO and HH were 40.7 and 39.2 g day^{-1}, respectively, significantly lower than crossbreds. The two locals were not different from each other. Another study at DBARC showed Dorper crossbred lambs produced from improved Menz ewes were better at birth and weaning weight (3.15 and 15.35 kg) than crossbred lambs produced from unimproved Menz (2.87 and 13.86 kg) (Goshme et al., 2014). Weaning, six months and yearling weights of 50% Dorper crossbreds were much higher with values of 14.95, 20.43, and 31.37 kg, respectively compared to the corresponding values for local breed in North Wollo lowland areas of Ethiopia with values of 8.53, 11.92, and 22.38 kg, respectively (Lakew et al., 2014). Feedlot performance of 25 and 50% Dorper crossbred was also superior to the local sheep breeds (Tilahun et al., 2014). Growth performance of Menz sheep and their crosses with either indigenous Bonga or Washera sheep were studied at DBARC (Lemma et al., 2014a). The result revealed that Bonga × Menz showed better growth performance compared to pure Menz and Washera × Menz, whereas the latter two genotypes were not different from each other.

On-farm performance

The first report from an on-farm trial in Ethiopia was by Hassen et al. (2002) who compared 37.5% Awassi crossbreds and local breeds at one of the crossbreeding villages called Serity. Live weights were recorded at birth and then monthly until 210 days. In all the measurements, crossbreds performed better than local breed except for weight on 90 days where both crossbred and local were not significantly different. Results from another village (Chiro) showed that growth of lambs to yearling age increased as the Awassi level increased under farmer's management. Yearling weight of local Wollo, 25 to 50% Awassi and above 50% Awassi was about 22, 26, and 35 kg, respectively (Gizaw and Getachew, 2009). Based on the combined analysis from the three villages (Serity, Negasi-Amba, and Chiro), 37.5% Awassi was recommended for small holder farmers (Gizaw et al., 2014). However, the authors suggested further study in this regard since the data size for high grade crosses is comparatively small.

In 2005, a village-based Farta × Washera sheep crossbreeding program has been started by Andassa Livestock Research Center in Lay Gaint and Farta districts of South Gondar (Mekuriaw et al., 2013) aiming to increase productivity of medium sized Farta (Gizaw et al., 2008a) by crossing or introducing male and female Washera sheep. Improvement program on indigenous Farta sheep using indigenous Washera breed indicated that growth performance of crossbred was better than the pure Farta sheep (Mekuriaw et al., 2013).

REPRODUCTIVE PERFORMANCE AND LAMB SURVIVAL

On-station performance

Mating of related individuals was unavoidable due to small flock size, leading to inbreeding depression. The inbreeding rates per generation derived from the number of breeding males and females were 6.1% at Debre Berhan and 32.5% at Amed Guya (BoA and ARARI, 2001). Based on the data at DBSBMC collected from 25 Awassi rams and 92 different matings between the year 2009 and 2013, number of ewes lambed per ewe mating

was on average 37% with a range of 10 to 77.5%.

Demeke et al. (1995) carried out a study at Sheno Agricultural Research Center to evaluate the effect of breeds (pure Menz, Menz × Corriedale and Menz × Awassi) and feed supplement (grazing and grazing + 300 g concentrate supplement day^{-1}) on reproductive performances. The authors reported that age at first lambing and the proportion of ewes lambed was not influenced by genotype and supplementary feeding, whereas body weight at conception was influenced by both factors and the interaction of the two. Crossbreds respond more to supplementary feed than pure Menz breed. Awassi × Menz and Corriedale × Menz crossbred lambs were heavier at birth compared to pure Menz lambs. The overall effect of supplementation was not significant on lamb birth weight. However, breed by feeding analysis showed lambs from supplemented pure Menz and Awassi crosses ewes were heavier at birth than their counterpart lambs born from the non-supplemented ewes. Olsson and Beyene (1990) reported a comparable performance of crossbreds in litter weight and lamb survival whereas in total weaning weight of lambs per ewe lambed were increased with increasing level of exotic genes up to 50%.

On-farm performance

Age at first lambing, lambing interval, ewe post-partum weight, number of lambs born ewe^{-1} year^{-1}, and number of lambs weaned per ewe^{-1} year^{-1} and lamb survival of local and their crosses with Awassi and Corriedale based on the data from the three villages, Serity (Chacha), Negasi-Amba (Menz) and Chiro (Wollo) were studied (Getachew et al., 2013, 2015). A total of 71 farmers and more than 6000 lambing records were used for the analysis. Crossbred ewes had exotic level of 25 to ~50%. The results revealed that crossbreds showed inferior performance for age at first lambing, lambing interval, and number of lambs born ewe^{-1} year^{-1} than local breeds in all locations. However, crossbred and local ewes were similar in number of lambs weaned per ewe per year. Lambing interval of local ewes ranged from 227.1 days in Wollo to 260 days in Menz and of Awassi cross ewes ranged from 249.7 in Wollo to 329.4 days in Menz. Corriedale crosses found only in Wollo site showed comparable reproductive performance with local ewes under farmer management. Crossbreeding increased ewe postpartum weight by 21.5% in Wollo, which was higher compared to 16.4% in Menz and 9.5% in Chacha. Though vary by location crossbred, lambs had better pre-weaning survival than local lamb (Getachew et al., 2015).

SKIN, WOOL AND MILK

Indigenous sheep breeds, particularly those from the Ethiopian highlands, are reputed to have one of the best quality skins for leather products having fine natural qualities of clarity, thickness, flexibility, strength, and compact texture (Mahmud, 1999). It is hypothesized that crossing exotic genotypes with indigenous breeds for improving growth might negatively affect important leather characteristics. Skins from Awassi × Menz crossbred sheep are either sold at lower prices or are rejected completely. Tibbo et al. (2005) found that the market price of skin of the indigenous, Menz, sheep was 3 to 4 times higher than 50 and 75% Awassi. However, skin quality studies (considering percent elongation, tensile strength, size of skin) confirmed that there is no evidence supporting the suspected inferiority of skins from crossbreds up to 50% inheritance of exotic Awassi and Dorper (Getachew et al., 2011; Teklebrhan et al., 2012). Tibbo et al. (2005) reported crossbreeding increased fleece yield of Menz sheep by 147% when upgraded to 50% Awassi-Menz and 218% when upgraded to 75% Awassi–Menz levels.

In one of the crossbreeding villages (Chiro), farmers showed interest to use sheep milk while it is unusual to consume sheep milk in other highland areas. Based on informal interviews with farmers and measurements of milk yield (few observations), in a good season, a ewe can produce in the range of 0.5 to 1 L of milk per day. Further investigation is required to see the possibility of using Awassi crossbreds for milk production.

FARMERS' PERCEPTION ON BREED IMPROVEMENT

Farmers in Ethiopia showed keen interest to adopt and implement breeding programs when they found them working and benefitting them. However, depending on their level of experience and capacity, farmers might support either crossbreeding or pure breeding. Farmers are interested in adoption of sheep crossbreeding due to the fast growth of crossbreds compared to their local sheep breeds in the Awassi × Menz and Farta x Washera crossbreeding attempts in the highlands of the Amhara region (Taye et al., 2011; Teferra et al., 2014). A workshop and field visit of the community based Menz sheep breeding program in the highlands was held with higher officials and different stakeholders engaged in livestock breeding on January 15, 2014. The program has been implemented by DBARC in collaboration with ILRI-ICARDA-BOKU and detailed (Haile et al., 2011). The aim of the workshop was to strengthen the idea of delineating Menz area for pure breeding based on the indigenous Menz breed as the poor feed resource base of the area could not support larger exotic genotypes. Farmers clearly explained that they are benefiting from the community based pure breeding program. Farmers also explained that a previous introduction of larger breeds in the area showed adaptation problems.

Considering the interest of farmers and the performance of sheep in the field the team agreed to support the idea of farmers of strengthening the ongoing community based pure breeding program in such areas.

BENEFITS AND ADOPTION OF SHEEP CROSSBREEDING

A survey based economic evaluation of Awassi x Menz and Awassi x Wollo crossbred sheep was performed and the extent of diffusion of Awassi crosses from three crossbreeding villages in Angolelana Tera, Menz Gera and Legambo districts were studied (Teferra et al., 2014). A total of 208 farmers, 71 starters (got initial breeding ram from research center), 63 co-farmers (start crossbreeding by buying crossbreds from the starters) and 74 non-users (they do not have crossbred sheep in their flocks) were considered in this study. Low input small holder farmers participating in the pilot village crossbreeding program were able to improve their income and livelihood. Similarly, the farm Africa goat development project in Kenya showed that the exotic Toggenburg goat performed well under low input farmers conditions and improved the income of smallholder farmers in Kenya and Tanzania (Peacock et al., 2011). In all locations, crossbreds were superior in market price compared to their corresponding locals at similar age and under similar management. For example the price (in Ethiopian Birr) of crossbred vs. local ram lambs was 319 vs. 171, 362 vs. 177, and 497 vs. 180 in Angolelana Tera, Menz Gera and Legambo, respectively (Teferra et al., 2014). In one of the Awassi crossbreeding villages, farmers started to produce genetic material and they are serving as sources of breeding rams. The positive impact of crossbreeding on their livelihood was mentioned by almost all farmers in the three locations. Increased proportion of crossbreds over time showed the acceptance of crossbreeding (Gizaw et al., 2014; Teferra et al., 2014). Proportion of crossbred sheep in the project participant farmers flocks in Angolelana Tera, Menz Gera, and Legambo districts was 63.6, 42.1, and 64%, respectively. The proportion of crossbreds in flocks of co-farmers was also comparable, with proportions of 47.8, 35.6%, and 54.7 % in respective villages.

GENERAL DISCUSSION

Choice of breed

In developing countries, acceptance of new breeds by farmers is influenced not only by their productive performances but also by non-production traits like beauty and appearance of the animal (Ndumu et al., 2008) and cultural values (Leroy et al., 2015). Traits like coat color, tail type, horn and ear size of sheep can also have significant influence on price in the predominant live animal marketing (Tadesse, 2009). At the beginning, exotic breed introduction targeted wool and meat production that overlooked the preference of farmers for appearance of sheep. Ignoring farmer preference led to low acceptance and resulted in low up-take rates. Introduction of Awassi sheep from Israel considered the preferred physical appearance. This breed is developed for milk and used as a triple purpose for meat, milk and wool (Pollott and Gootwine, 2004; Galal et al., 2008; Gürsoy, 2011). The improved Israeli Awassi is characterized by producing the highest amount of milk, having highest fertility and twinning rate, and heaviest body weight among all Awassi populations (Galal et al., 2008). Promoting a new market for sheep milk in the future in the Ethiopian highlands where traditionally this product is not consumed would be an extra advantage. However, at present looking for meat line Awassi (if any), or selection for meat traits among the crossbred population would be more beneficial due to the expected potential risk of mastitis and other udder problems when using high producing dairy Awassi for crossbreeding in areas where no sheep milking is done.

Breeding ram multiplication and dissemination

Efficient multiplication and dissemination of appropriate genotypes is one of the core elements in a breed improvement program. Until now introduction and maintaining of exotic breeds, as well as multiplication and dissemination of crossbreds are mainly mandated to government farms. Managing animals in government farms characterized by high level of lamb mortality (Getachew et al., 2015) suffered from inbreeding due to small numbers of exotic animals and diseases (e.g. maedi-visna) associated with confinement. In addition, low fertility with natural mating in the farms, lack of infrastructure and logistics (e.g. shortage of mating pens) restricted efficiency of improved ram multiplication. Fertility level observed for Awassi breed in Ethiopia are lower than the fertility of Awassi in the Middle Eastern countries ranging between 60 to 95% (Gursoy et al., 1995; Galal et al., 2008). Ahuya et al. (2005) reported the previous government approach based on multiplication and dissemination of exotic bucks from government farms failed to bring anticipated change. Learning from a previous non-successful Ethiopian dairy goat project (Ayalew et al., 2003), the German Development Cooperation (GIZ) and FARM Africa initiated a community approach which was led by farmers and became more successful in significantly improving the livelihoods of resource poor families in Kenya (Peacock et al., 2011). As mentioned earlier community based breeding ram production has starred in one of the

crossbreeding village. It seems more feasible in reducing higher level of mortality associated with confinement and budget limitation under on-station management. However, comparative advantages of ram multiplication at farmers' management need to be assessed. Its sustainability depends on the technical and infrastructural support from government and other institutions.

Efficiency of breeding ram dissemination to the targeted production unit also found unsatisfactory. An informal survey in 1997 in South Wollo and North Shewa to evaluate the on-farm performance of crossbreds exposed that there were no any apparently crossbred sheep found even though a significant number of rams were disseminated to farmers (Tibbo, 2006; Gizaw and Getachew, 2009). Disseminated crossbred rams were castrated, found in farmers having no or few breeding ewes, or sold after castration (Gizaw and Getachew, 2009). Thus the predominant practice of selling crossbred rams to individual farmers does not seem suitable for smallholder situation. Firstly, farmers tempted to sell crossbred rams for their short term need and keeping and managing such a big animal might be difficult for a farmer. Secondly, rams were underutilized due to small flock size. Furthermore, ram dissemination was not focused to specific areas and the effort of crossbreeding was diluted. Instead of selling rams to single farmers, devising schemes involving communal use of breeding rams which have been successfully implemented in the community based sheep breeding programs (Gizaw and Getachew, 2009; Haile et al., 2011; Gizaw et al., 2014) should be considered. Insufficient knowledge of farmers and unreliable external support were also mentioned as limitations leading to low adoption rates of crossbreeding.

Performance of crossbreds

Better growth performance and lamb survival of Awassi and Dorper crossbreds (Gizaw and Getachew, 2009; Tsegay et al., 2013; Tilahun et al., 2014). In the range of inferior to comparable reproductive performances were reported for crossbred ewes (Getachew et al., 2013; Lemma et al., 2014b). The inferiority of Awassi crossbred ewes in age at first lambing and lambing interval are mostly more than compensated by the relative larger size of ewes resulted in better ability of crossbred ewes to raise their lambs to weaning age (Olsson and Beyene, 1990; Tibbo, 2006; Getachew et al., 2013, 2015). The observed performance levels found in this review seem lower than the potential of the breed in its breeding tract (Rihawi et al., 2010; Üsünter 2013). These low performances for both local and crossbred sheep in Ethiopia suggest that output can be increased by improving environmental conditions. Local breeds may sometimes be unprofitable as they have limited genetic capacity to respond to an improved management. The local Awassi managed by Bedouin farmers in the southern dry region of Israel also remain unprofitable and economic assessment showed that traditional extensive sheep farming in low input system based on the local Awassi breed was not positively contributing to family income and nutrition however still regarded as cultural benefit (Valle Zárate et al., 2009). The introduction of improved Awassi (Afec-Awassi) was successful and made these flocks profitable (Gootwine et al., 2009). Similarly, the introduction of different ram breeds in extensive semi-arid regions of Argentina improved carcass yield and conformation with varying performance among sires (Álvarez et al., 2010).

Genotype by environment interaction

Crossbreeds have been benefiting Ethiopian small holder farmers due to their fast growth. Higher price of Awassi crossbreds (about double) compared to locals under farmer management is a clear indication of benefit. Similarly in Kenya, crossbreeding between Dorper and Red Maasai sheep has been used by a majority of farmers in Kajiado district and are playing important role for the livelihood of the people (Liljestrand, 2012). However, presence of genotype by environment interaction on performances of sheep has been well documented in Ethiopia (Demeke et al., 1995; Getachew et al., 2013; Getachew et al., 2015), Kenya (Baker et al., 2002; Zonabend et al., 2014) as well as cattle in tropical countries (Galukande et al., 2013). For example, in Kenya, in the poor environment both local and crossbreds had about the same body weight whereas in the other site (better environment and market oriented farmers) Dorper and crossbreds had superior weight (Zonabend et al., 2014). Those variable research results on the performance of crossbreeding based on location, genotype and management suggested that the importance of differential recommendations for different locations and careful delineation of crossbreeding area.

Safeguarding indigenous genetic resources

Erosion of the diversity of domestic animals due to natural cause and human activity is considered as one of the serious concerns to sustain the production levels and addressing the change in demand of future market (Shrestha and Fahmy, 2005). Due to the massive introduction and multiplication of Awassi and Dorper sheep, large number of crossbred rams might be expected to be disseminated to farmers in wider areas of the country. This might have great potential to contribute to improve productivity of smallholder sheep if planned and utilized appropriately. On the other hand, they present a threat if they are able to dilute the adaptive

indigenous genetic resources. Red Maasai sheep in Kenya, which is well known for its maternal traits, disease and drought tolerance are currently at high risk due to the massive introgression of Dorper genes (Muigai et al., 2009) and currently requires breeding program to conserve the breed (Zonabend et al., 2014). Thus, delineating crossbreeding areas and controlling breed introduction should be considered as critical steps to reduce risk of genetic dilution due to indiscriminate crossbreeding. Crossbreeding might focus on sheep populations along the roads, near towns and cities, near market places and buffer zones between two geographically separated areas as those populations are mixed and non-descript. Conservation priorities set for Ethiopian sheep breed considering genetic and non-genetic factors (Gizaw et al., 2008b) need to be consulted for the decision. Crossbreeding among selected indigenous breeds might also be helpful to reduce the effect of genetic dilution expected from indiscriminate crossbreeding by use of relatively higher genetic distant of the exotic breeds.

Choosing appropriate crossbreeding program

Sustainability of crossbreeding program highly depends on the choice of appropriate breeding scheme (Leroy et al., 2015). Once crossbreeding areas are delineated, alternative breeding programs should be evaluated and selected based on their genetic progress, inbreeding level, cost and feasibility under smallholder situation. In addition, access and continuous supply of breeding stock plays crucial role in choosing breeding strategy (Leroy et al., 2015). Combining different merits of the indigenous breeds would also be helpful to develop more productive ewe line which would help to increase productivity in terminal crossbreeding using specialized meat sire breeds. Gizaw et al. (2014) also suggested terminal crossbreeding as an alternative to upgrading as the later takes long time and seem complex under farmers' situation. This would allow to exploit the benefit of all possible heterosis effects while conserving the indigenous breeds (Scholtz and Theunissen, 2010). However, it requires setting up straight breeding programs for the local and exotic breeds to supply the parent populations. The feasibility of terminal crossbreeding might hampered by low levels of organization in small holder environments so that the performance of the exotic sires for terminal crossbreeding as well as its feasibility under small holder situation has to be evaluated before implementation.

Improving efficiency of reproduction

Recent attempt of estrus synchronization and artificial insemination (AI) in station and farmers sheep flocks in Ethiopia provides an opportunity for rapid multiplication of crossbred population. Efficiency of the government farm (DBSBMC) is too low due to poor fertility of the natural mating of Awassi rams to Menz ewes and shortage of mating pens. Estrus synchronization and AI would help to increase the number of crossbred lambs and help in adjusting lambing time to a better season. Furthermore, the use of pure Awassi semen in the farmers flock shortens the upgrading time and reduces complexity associated with upgrading. The success and limitations of the use of AI and other reproductive technologies in tropical countries has been discussed in detail (Galukande et al., 2013).

Farmer participation, institutions, and other operational issues

Adoption of crossbreeding technologies and increased crossbreed population in farmers flock (Taye et al., 2011; Teferra et al., 2014) and continuous introduction of exotic breeds are indicators of the interest of the government to relay on crossbreeding. Gizaw et al. (2013) reported in a review that a total of 26 sheep research projects have been supported by the National Institute of Agricultural Research and in the field of breeding, nutrition, health and marketing and 10 of them were focusing on Dorper (n=9) and Awassi (n=1) crossbreeding. However, there is no national sheep breeding strategy to lead and control the breeding programs (Gizaw et al., 2013) except attempts to develop sheep breeding guidelines in the regional states to some extent. Recent establishment of Livestock and Fishery Minister at national level showed that the focus for livestock development has been increased. Long-term commitment of national government, conducive policies, good development plan, and organized effort of institutions are crucial for success and sustainability of livestock development (Haile et al., 2011; Rege et al., 2011; Wurzinger et al., 2011). However, poor integration among institutions, lack of knowledge about livestock improvement at each level and absence of breeding programs are drawbacks for the success of breeding programs (Sölkner et al., 1998; Kosgey et al., 2006; Gizaw et al., 2013). Crossbreeding programs should be devised at national level considering the agro ecological potential of the areas, level of the community, level of farmers' participation and sociological factors (Sölkner et al., 1998; Philipsson et al., 2011; Peacock et al., 2011; Wurzinger et al., 2011; Leroy et al., 2015).

CONCLUSION

This review paper revealed that growth and reproductive

performances of crossbreds greatly vary and are influenced by many factors like management, location, dam breed used for crossing, and breed composition levels. Both under station and farmers management, Awassi based crossbred lambs outperformed their local (Menz and Wollo) contemporaries in some of the North Shewa and Wollo highland areas of the Amhara region, Ethiopia. Dorper crossbreds performed well under station management; however, its wider dissemination should be based on their performance under farmer's management. More complete analyses considering the total inputs and outputs of flocks in the smallholder systems of Ethiopia are required to draw firm conclusions for particular scenarios. Unfortunately such data are not available for most crossbreeding programs in Ethiopia. Gebre et al. (2014) have employed dynamical systems analysis to find whether genetic improvement of body size is profitable in a community based pure breeding system of the Menz area. The authors concluded from the simulations that genetically bigger animals are more profitable under constant management and fattening of young rams is also more profitable compared to the current state. It is likely that results will be similar for fast growing crossbred animals compared to the unimproved Menz sheep if prolificacy and fertility of the crossbreds are not worse compared to purebred Menz. Delineating crossbreeding areas considering breed preference of farmers, climatic conditions and potential for feed, market and health service development should be prerequisite to start crossbreeding.

Efficient and easy crossbreeding systems which maximize ram multiplication in the breeding units and efficient ram dissemination to the production units should also be devised. The appropriate proportion of indigenous and exotic breeds considering the existing management needs to be determined for different areas. Long-term strategies to achieve and maintain the optimal genotypes need to be devised. Experience of implementing community based sheep breeding either based on pure breeding or crossbreeding reveals that the success of any breeding program mainly depends on the full farmers' participation, continuous commitment and integrated effort of institutions. Continuous research and development interventions are crucial to develop and optimize crossbreeding scheme, replicate and scale up the models, establish pedigree and performance recording, determine appropriate level of admixture, and devise appropriate management for each areas. Optimizing the breeding programs considering new products (like milk and wool) created from crossbreeding might be helpful to increase the overall benefit but should be considered in relation to potential market demand.

Conflict of interests

The authors have not declared any conflict of interests.

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