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Alternative Village Based-Breeding Schemes for Simien and Gumuz Sheep Breeds in Northwestern Ethiopia

Research Article

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ABSTRACT

The study aimed to design breeding schemes for the improvement of sheep in Northwestern Ethiopia. The alternative breeding schemes were modeled and evaluated using a deterministic approach for genetic and economic efficiency. The input parameters were obtained from a survey of existing flock structures, breeding management, and literature. The predicted genetic response, genetic gain for goal traits, and rate of inbreeding were little different under village-based schemes depending on selection objectives and selection criteria. The highest genetic gains for six month's weight, pre-weaning lamb survival, twining rate, and lambing interval were predicted from village-based schemes with BLUP selection at 5% selection intensity. The highest genetic gain predicted under BLUB at 5% selection intensity for six months weight within and across village breeding schemes were 1.85 kg and 1.87 kg per year respectively. The rate of inbreeding for both schemes increased as the proportion of rams selected decreased from base to 5% selection intensity. The expected genetic gains were higher as it promotes participation of farmers, cooperation of villages, and achieving concentrated lambing which in turn increase selection intensity and genetic progress. This suggested the possibility for sustainable sheep improvement and conservation through village-based schemes.

KEY WORDS genetic gain, inbreeding, sheep, smallholder farmer, traits.

INTRODUCTION

Sheep are the major source of meat for domestic consumption in Ethiopia (Tsegaye *et al.* 2013). Sheep are also important foreign currency earners accounting for 34% of the live animal exports (Solomon *et al.* 2013). However, sheep production in Ethiopia is constrained by feed shortages, diseases, and an absence of a planned breeding program (Solomon *et al.* 2013). Among the various factors, the lack of systematic breeding programs is an important constraint. Sheep genetic improvement programs through crossbreeding and selection have been practiced for decades in Ethiopia to improve the productivity of flocks. However, studies reported that past sheep genetic improvement programs have been failed, as most lacked long-term vision and did not involve farmers in the planning (Gizaw, 2008; Temesgen, 2010). The government-operated central nucleus-based breeding programs are also criticized for being unsuitable for low-input production systems (Kosgey *et al.* 2006; Gizaw *et al.* 2007). This could be due to uncontrolled mating, small flock size, poor infrastructure, inadequate animal performance, and pedigree recording, illiteracy, and ill-functioning public institutions (Wollny *et al.* 2001; Mirkena *et al.* 2012). Sustainable sheep breeding strategies are scarce and often unavailable in developing countries like Ethiopia (Kosgey *et al.* 2004; Gizaw *et al.* 2009; FAO, 2010; Mirkena *et al.* 2012). This implies that an absence of planned, efficient, and sustainable genetic improvement programs for indigenous sheep breeds is one of the causes for losing their competitive advantage (Mirkena *et al*. 2012; Dagnew *et al*. 2017). Strategies for genetic improvement that overcome these constraints need to be considered. In this regard, village-based breeding schemes where genetic improvement is generated within and across village flocks have been suggested (Sölkner *et al*. 1998; Wurzinger *et al*. 2008; Gizaw *et al*. 2009; Haile *et al*. 2011; Mirkena *et al*. 2012).

Haile *et al*. (2011) and Wurzinger *et al*. (2008) showed that village-based schemes could be suitable options for achieving genetic improvement in low-input systems. Gizaw *et al*. (2009) reported that appreciable genetic improvement has been achieved in the Menz sheep and body weights at 3 and 6 months of age increased by 2.29 and 2.46 kg, respectively. Several investigators demonstrated that village-based sheep-breeding programs are a promising start, and serve as a model for breeding programs for sheep breeds in developing countries like Ethiopia (Mirkena *et al*. 2012; Gizaw *et al*. 2013). Conversely, some studies have shown that village-based scheme is targeted for genetic improvement within individual village flocks and do not show how genetic improvement can be implemented at the breed level (Mirkena *et al*. 2012). Thus, alternative schemes that overcome the above-mentioned technical limitations in a village-based breeding program need to be explored. Hence, the present study aimed to evaluate alternative village-based breeding schemes in terms of their biological and economic efficiencies as well as their feasibility to implement under smallholder sheep farming systems.

MATERIALS AND METHODS

Description of production system and breeding management

The northern highlands of Amhara region, is among the potential areas in livestock production. Simien sheep are found in the subalpine northern highlands of Simian Mountain in Ethiopia with an altitude of 3000-4000 m above sea level (Melaku, 2012). The breeding tract of Simien sheep extends across five districts in Simien Mountain, namely Janamora, Beyeda, Debark, Dabat, and Wogera districts (Lemma, 2009; Melaku *et al*. 2019). The temperature in the area varies from -2.5 to +18 ˚C and frost is common between October and November. The area is largely depending on sheep farming for their livelihoods. Farmers keep small flocks of sheep under low input and low–output production systems. Northwestern lowland of Amhara region is among the potential areas in livestock production and consequently in the supply of live animals to the Sudan market (Mulugeta *et al*. 2007; Wuletawu *et al*. 2008) and the export market can be exploited after improvement.

The most important sheep breed reared in the study areas is the indigenous Gumuz. In addition, there is also a crossbred sheep between Gumuz and Rutana sheep. The smallholder farmers primarily keep the indigenous Gumuz sheep followed by the crossbreds. As reported by Dagnew *et al*. (2017), Gumuz sheep are kept under low-input and low–output production systems. The major type of herding practiced in both study areas is communal grazing. The common breeding practice is uncontrolled and year-round (Desalegn, 2019). Thus, both selected and unselected rams of the whole village are running with the flocks under the communal village mating system. Some farmers practice selection of rams for breeding based on the animals' appearance and conformation (Abegaz *et al*. 2011: Dagnew *et al*. 2017; Desalegn, 2019). The typical flock sizes were small and selection intensities are low as a selection of rams is carried out within the respective small flocks. Some of the farmers also practice negative selection against good performing animals by either being sold or slaughtered and their number remains small in the flock.

Evaluation of selection schemes

Population structure

In this study, the design and evaluation of selection schemes were illustrated using parameters for the short-fat-tailed and long thin-tailed sheep population in the sheep-cereal and cash crop system in Ethiopia, respectively. A population with discrete generations was simulated based on the existing population structure defined in previous studies (Dagnew *et al*. 2018; Desalegn, 2019; Melaku *et al*. 2019) and was adopted for the current simulation study. In both systems, males are used for breeding once at one year of age and culled as yearlings or castrated for finishing; generations in the male population were considered discrete. In practice, breeding ewes are maintained for more than one year. In our study, we ignored the selection of females. Algorithms to predict the rate of inbreeding in populations under selection are only available for discrete generations (Rutten *et al*. 2002), and therefore, we assumed that only one-year old ewes were used and that no selection was practiced in ewes. A flock of 300 ewes per village was assumed for both within a village and across a village co-operative breeding scheme. The average number of flocks in a village and an average number of breeding ewes in a flock were 15 and 20, respectively. The number of male selection candidates in each mating season was calculated using results of reproductive parameters and flock structures of this study (lambing frequency=1.5 times per year (i.e., three lambing in two years), conception rate=0.833, survival 0-3 months of age=0.80, survival 3-12 months of age=0.92, twinning rate=(1.14 (Simien), 1.33 (Gumuz) and sex-ratio of 50%). The predicted number of selected ram candidates will be 157 and 184 for Simien and Gumuz sheep available for each generation from 300 ewes, respectively. For each generation (year), 300 female candidates were available, whereas the alternative selection scheme for rams was 20%, 10%, and 5% level of proportions. Essential input parameters for running SelAction are presented in Table 1. Some of the parameters required for the designs were generated from the production system, morphological characterization, own flock ranking results of this study, and published report of on-farm monitoring studies (Dagnew *et al.* 2018; Desalegn, 2019; Melaku *et al.* 2019).

Breeding goal and selection criteria

The Simien and Gumuz sheep farmers breeding goal traits required for the design were generated from previous studies (Melaku, 2012; Dagnew *et al*. 2017; Desalegn, 2019). The breeding-objective traits identified and included six-month weight (SWT), post-weaning gain, pre-weaning lamb survival (PWS), litter size (LTS), and lambing interval. Bio-economic models were constructed on a Microsoft Excel spreadsheet to derive economic values of traits, considering both tangible and intangible benefits of rearing Simien and Gumuz sheep (Desalegn, 2019). The Simien and Gumz sheep relative economic weight were used for the current simulation study. The relative economic weights for breeding objective traits are presented in Table 2.

Selection of villages and alternative designs of breeding schemes

Multi-stage stratified sampling was employed to select villages purposively based on sheep breed distribution, sheep population, and accessibility. Six villages were selected from the two-study district. The villages with the highest concentration of pure Simien and Gumz sheep in each district were selected to introduce the breeding program. The selection was based on the previous flock inventory results taken from each village, secondary data from the district agriculture and rural development office, focus group discussions held with key informants, village leaders, researchers, and livestock experts in the area. The criteria employed were high Simien and Gumuz sheep possession, presence of communal grazing land in the villages, accessibility, and willingness of the community in the village to participate in the breeding strategy. Those villages were selected because of the existence of relative Simien and Gumuz sheep. In this study, two main schemes were proposed for evaluating optimal breeding programs: these were within-village and across-village schemes (scheme 1-2) which are being implemented by the Amhara agricultural research institute (ARARI) and Gondar Agricultural Research Center (GARC). The two alternative schemes were simulated using SelAction computer program (Rutten *et al.* 2002). In the within-village schemes, evaluation and selection of replacement animals were carried out across individual flocks (flocks owned by individual farmers) within the village. Under the across-village schemes, selection was across neighboring villages, with all the flocks in the villages participating in the scheme considered as one large population. For each scheme, four different proportions of rams were selected. A constant number of ewes per village (300) were assumed for all schemes. Under across-village schemes, an exchange of rams among cooperating villages was assumed.

The scheme involves cooperation among farmers within a village. The whole village sheep population is involved in selection. The villagers select breeding rams from across all the flocks in the village taken as one big breeding flock and use the selected ram communally. We evaluated across-village selection schemes in which the number of cooperating villages within one scheme ranged from two to six. Each across-village selection scheme was evaluated for the four proportions of selection of rams. The proportion of breeding rams selected corresponds to the current flock structure (ram:ewe mating ratio, 1:12) and the proportion of rams (P) selected were, P=5%, P=10%, and P=20%, respectively. Within-village-based schemes were compared under mass selection (own information sources) and BLUP (includes information from relatives).

Genetic and phenotypic parameters

The phenotypic standard deviations, and the traits' heritabilities, genetic and phenotypic correlations are presented in Table 3. Since the genetic parameters are lacking for the Simien and Gumuz sheep breed, the parameters estimated for Menz sheep are used (Gizaw et *al*. 2004b).

Prediction of genetic gains and rate of inbreeding

Genetic gains and rate of inbreeding were predicted using deterministic simulation methods using the SelAction program (Rutten *et al.* 2002). In this study, flock populations were considered discrete to allow for the prediction of inbreeding rates because of the limitation in the SelAction program for overlapping generations. Selection response was predicted for the Bulmer equilibrium situation (Rutten *et al*. 2002). Responses were estimated for breeding-objective traits. Aggregate responses (R_H) were approximated as the proportion of the total economic response (TER) and the genetic standard deviation of aggregate genotype (s_H) i.e., (TER/s_H).

Table 1 Input parameter for modelling for alternative breeding schemes for Simien and Gumuz sheep

Parameters	Simien	Gumuz
Population parameters		
Population size (ewes)	300	300
Number of proven males/years	157	184
Proportion of rams selected	0.20, 0.10, 0.05	0.20, 0.10, 0.05
Biological parameters		
Breeding ewes in use (years)	5	5
Breeding rams in use (years)	2 or 3	2 or 3
Mean age of rams at birth of first offspring	1.5	1.2
Mean age of ewes at birth of first offspring	1.3	1.1
Lambing rate	0.85	0.85
Mean time period b/n subsequent lambing (years)	0.71	0.71
Mean number of lambs per litter (litter size)	1.13	1.5
Number of lambing/ewe/year	1.14	1.33
Lamb survival to six month (%)	0.85	0.85
Cost parameter		
Animal identification/ewe/year ($)	1.03	1.64
Drug/ewe/year ($)	1.03	1.64
Enumerator salary ($)	1.18	1.18
Stationary materials for recording ($)	0.34	0.34
Interest rate return (%)	0.03	0.05
Interest rate cost (%)	0.08	0.08
Investment period/year	15	15

Table 2 Economic weights (EW) of traits of Gumuz and Simien sheep

Breeding goal traits	Gumuz	Simien
	Economic weight ($)	Economic weight ($)
Six-month weight	2.35	1.31
Post-weaning gain (average daily gain 3-6 month)	0.56	1.38
Litter size/twining rate	1.56	0.82
Pre weaning lamb survival (0-3 months)	4.66	3.33
Lambing interval	0.34	0.26

Table 3 Phenotypic standard deviations (σ_p), heritabilities along with diagonal, genetic (above diagonal), and phenotypic (below diagonal) correlations used in simulated selection in Menz sheep

Traits	Variance	SWT	LTS	PWS
SWT	4.64	0.29	0.09	0.10
LTS	0.012	0.09	0.13	- 0.02
PWS	0.013	0.10	0.00	0.07

SWT: six-month weight; LTS: litter size and PWS: pre-weaning survival (Solomon and Joshi, 2004).

RESULTS AND DISCUSSION

The genetic gains (ΔG) in the breeding objective traits, the aggregate response (R_H) and rate of inbreeding (ΔF) per generation for within-village based scheme are presented in Table 4. These parameters varied depending on the P (5%, 10%, and 20%) and the selection criteria (mass and BLUP). The result showed that the within village-based scheme resulted in faster genetic progress under BLUP selection than mass selection. Under mass selection, the genetic gains for six-month weight, pre-weaning lamb survival, twining rate, and lambing interval derived from P (P=5%, 10% and 20%) were relatively higher than the corresponding gains obtained under base selection. With the mass selection, genetic gains were approximately zero for post-weaning gain and twinning rates under base selection.

The highest genetic gain was obtained under highest proportion of ram selection intensity (P=5%). These gains were reduced as the proportion of ram increased from 5% to 20%. And lambing interval and pre-weaning lamb survival had the highest genetic gain while six month weight and twining rate the lowest. Under mass selection, aggregate responses increased from 0.112 to 0.205 as the proportion of rams selected decreased. The rate of inbreeding also increased from 0.00139 to 0.00160, with an increase in P from 5% to 20%. Relatively larger genetic gains for breeding-objective traits were predicted under BLUP selection, but similar in pattern to those predicted under mass selection. The genetic gains for six month weight, pre-weaning lamb survival, and lambing interval were larger than the corresponding gains obtained under mass selection.

The highest genetic gain of 1.85 kg per year for six month's weight was predicted for BLUP selection (P=5%). Aggregate genetic responses increased from 0.211 to 0.406 under BLUP selection as the proportion of rams selected decreased from base selection to selection at 5% (P=5%). The rate of inbreeding increased from 0.00105 under base selection to 0.00156 under 5% selection (Table 4).

The aggregate genetic responses, genetic gains for breeding objective traits and level of inbreeding are presented in Table 5. When compared with the within-village based scheme, aggregate genetic responses and genetic gains for breeding objective traits were larger under across village-based schemes. Under mass selection, the larger genetic gains for six months weight, pre-weaning lamb survival and lambing interval were predicted under 5% selection intensity with a subsequent reduction in the latter. Comparison of these genetic gains to those derived under BLUP selection showed a larger variation in the traits of six months weight, pre-weaning lamb survival and lambing interval. However, the genetic gains for post-weaning gain were relatively lower under both mass and BLUP selection criteria. Under BLUP selection, genetic gains for twining rate with 5% selection intensity were relatively higher than those predicted under mass selection. The higher aggregate genetic response was also predicted under BLUP selection across village-based schemes. The rates of inbreeding in the present study were lower than the recommended acceptable levels. The rate of inbreeding for mass selection increased from 0.00111 to 0.00135 as the proportion of rams selected decreased from base to 5% selection intensity. Correspondingly, the rate of inbreeding for BLUP selection increased from 0.00097 to 0.00133.

Village-based breeding program is suitable option for achieving genetic improvement within individual villages but the uncontrolled gene flow between flocks in a village and the relatively small flock sizes could limit the efficiency of this program. Thus, alternative schemes that can achieve higher genetic responses while maintaining an acceptable level of inbreeding could be considered as optimal breeding schemes. In this study, the within-village and across-village based breeding schemes were designed and evaluated for optimal response levels and inbreeding rates. Four selection objectives were defined and considered based on mass and BLUP selection criteria. Previous studies also suggested that the breeding structure in developing regions can be best described as a one-tier structure since farmers areboth breeders and producers (Gizaw *et al.* 2009; Bett *et al.* 2012; Dagnew *et al.* 2018).

In this study, aggregate genetic response and genetic gain across village-based scheme result in faster genetic progress than within village-based scheme. The most optimal scheme was found to be across-village selection with the highest intensity of selection (P=5%). For instance, the genetic gain for six months weight under BLUP selection in across-village-based scheme with the highest proportion of rams selected (P=0.05) was higher compared to a within-village-based scheme. The genetic gain of six months weight predicted in this study is comparable to the predicted genetic gain of six months weight of western lowland and Abergelle goats (Abegaz *et al.* 2014). Galukande *et al.* (2013) also reported that applying higher selection intensity would result in higher genetic gains. The present study also indicates genetic progress in post-weaning gain and pre-weaning lamb survival was low and comparable among village-based schemes. The genetic gain for lamb survival in the current study was comparable to the genetic gain of lamb survival for the Ethiopian Afar sheep breed (Mirkena *et al.* 2012). The low genetic gain in reproductive traits is attributed to their low heritability and genetic correlations with growth traits (Safari *et al.* 2005; Mirkena *et al.* 2012; Gizaw *et al.* 2014a; Gizaw *et al.* 2014b) in the breeding objective.

Aggregate genetic responses and genetic gains were larger under BLUP selection compared to the mass selection, but the rate of inbreeding also increased. In addition, very low genetic gains of twining rate under mass selection were predicted from all alternatives ranging from 0.000 % to 0.0014% compared to BLUP selection. This agrees with the findings of Gizaw *et al.* (2009). Under mass selection, evaluation within-village breeding schemes indicates that the highest genetic gain could be attained within the highest intensity of selection (P=5%). This implies that the genetic gain is more affected by selection intensity. The importance of selection intensity has also emphasized in previous studies (Quinton and Smith, 1995; Gizaw *et al.* 2009; Bett *et al.* 2012).

By increasing selection intensity into the current breeding practices, aggregate genetic response and genetic gains from both village-based schemes were relatively higher than those from base-selection. A study in the Ethiopian highlands (Gizaw *et al.* 2016) also reported that higher proportions of ram selection could have implications in genetic improvement and flock productivity. As expected, aggregate genetic responses and genetic gains were larger under BLUP selection compared to the mass selection, but implementing such kind of genetic evaluation requires pedigree recorded data which is not applicable in the smallholder production system.

The rates of inbreeding in the present study were lower than the recommended acceptable levels. Maximizing genetic response while restricting the rate of inbreeding will change the alternative selection schemes compared to maximizing genetic gains alone (Van Arendonk and Bijma, 2003).

Table 4 Predicted aggregate response, genetic gains in breeding objective traits, and level of inbreeding (ΔF) per generation under different within village cooperative selection schemes

Item	Ram selection intensity	Aggregate genetic response	Goal traits					ΔF
			SMW	PWG	PWLS	LS	LI	
Mass selection	Base- scheme	0.112	0.45	0.000	0.106	0.000	1.855	0.00116
	20% scheme	0.168	0.67	0.000	0.160	0.001	2.791	0.00139
	10% scheme	0.187	0.75	0.001	0.178	0.014	3.104	0.00149
	5% scheme	0.205	0.82	0.001	0.194	0.014	3.391	0.00160
BLUP selection	Base-scheme	0.211	0.96	0.000	0.104	0.001	0.288	0.00105
	20% scheme	0.331	1.51	0.000	0.163	0.001	0.451	0.00131
	10% scheme	0.370	1.68	0.000	0.182	0.002	0.182	0.00143
	5% scheme	0.406	1.85	0.000	0.200	0.002	0.553	0.00156

SMW: six month live weight; PWG: post-weaning gain (3-6 month); LS: litter size; PWLS: pre-weaning lamb survival (0-3 month); LI: lambing interval and ΔF: rate of inbreeding.

Table 5 Predicted aggregate response, genetic gains in breeding objective traits, and level of inbreeding (ΔF) per generation under different across village cooperative selection schemes

Item	Ram selection intensity	Aggregate genetic response	Goal traits					ΔF
			SMW	PWG	PWLS	LS	LI	
Mass selection	Base-scheme	0.106	0.48	0.001	0.092	0.000	1.562	0.00111
	20% scheme	0.160	0.72	0.001	0.141	0.011	2.387	0.00121
	10% scheme	0.178	0.80	0.001	0.157	0.012	2.662	0.00128
	5% scheme	0.194	0.87	0.001	0.172	0.014	2.914	0.00135
BLUP selection	Base-scheme	0.204	0.97	0.000	0.083	0.041	0.221	0.00097
	20% scheme	0.320	1.52	0.000	0.131	0.065	0.131	0.00116
	10% scheme	0.359	1.71	0.000	0.117	0.073	0.395	0.00124
	5% scheme	0.394	1.87	0.000	0.162	0.080	0.434	0.00133

SMW: six month live weight; PWG: post-weaning gain (3-6 month); LS: litter size; PWLS: pre-weaning lamb survival (0-3 month); LI: lambing interval and ΔF: rate of inbreeding.

Therefore, a participatory across village-based breeding scheme under mass selection would be optimal and reasonable for implementation in the smallholder conditions. Because there is no need for pedigree recording, and the program is owned and managed by the communities. Gizaw *et al.* (2009) and Abegaz *et al.* (2014) also indicated that lack of ownership is main factor contributing to the failure of the introduced breeding program in developing countries like Ethiopia.

CONCLUSION

The BLUP method offers the best-predicted aggregate response and genetic gains for breeding objective traits compared with those obtained by mass selection. However, mass selection can be also used as a basis for evaluation and reducing the costs of pedigree recording. A within-village based breeding scheme could be effective under mass selection in achieving larger genetic gains, but the rate of inbreeding is relatively higher. On the other hand, across-village breeding scheme under mass selection results in a reasonable genetic gain and a low rate of inbreeding that is below acceptable levels. These imply that across-village breeding scheme would be optimal for implementation in the smallholder sheep production systems. However, the scheme requires cooperating group of farmers across two or more villages. Running such a one tire breeding structure may be sustainable for smallholder produces in developing countries like Ethiopia.

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