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Research Article

Evaluation of the Crossbreeding Scheme and Farmers' Perception of Awassi and Dorper Crossbred Sheep

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The objectives of this study were to characterize the performance of crossbred sheep and crossbreeding scheme and to solicit farmers' opinions about crossbred sheep. A total of 238 respondents were selected from five districts and data were collected through a personal interview, focus group discussion, measurement of animals, and field observation. Continuous type of data were analyzed using different procedures of SAS, while the estimated breeding value (EBV) for distributed rams was estimated by the WOMBAT software fitting animal model. The findings showed that sheep were the most significant species and that they were primarily raised for meat consumption and income generation. The proportions of crossbred sheep were 79.6% in Angot, 61.3% in Dessie zuria, 64.2% in Gazo, 80.6% in Legambo, and 27.5% in the Kobo area. The sheep crossbreeding program was constrained by feed shortage, lack of improved genotype, and diseases. The ongoing sheep crossbreeding program lacks a proper recording scheme, rams were not selected based on genetic merit, not exchanged in time, lack periodic importation of genetically unrelated rams, and lacks fixing the maximum exotic gene level suitable for the production system. The EBVs of Dorper crossbred rams for birth weight and weaning weight were 0.007 kg and 0.273 kg, respectively. Tikur sheep had an earlier age at first lambing (AFL) than Awassi x Tikur sheep. Likewise, the indigenous Wollo sheep had earlier AFL, short lambing interval, and produced a large number of lambs per lifetime than their Awassi crossbreds. Dorper crossbreds were preferred (9.30 - 72.2 times greater and $P < 0.001$) for their growth rate, physical appearance, preference in the market or price, and milk production of ewes compared with indigenous Tumele sheep. The Awassi crossbred sheep were preferred (odds ratio = 12.7– 90.0 and $P < 0.001$) due to their good physical appearance, fast growth rate, wool yield, milk yield, and better preference in the market compared with Tikur and Wollo sheep breeds. The implementation of the crossbreeding program needs some sort of revision, monitoring, and periodic evaluation. Besides, it must be accompanied by improved management to exploit the expected benefits from the crossbreeding program in the low-input production system.

1. Introduction

In Ethiopia's highlands, where agricultural and livestock production are integrated, the sheep enterprise is the most important source of meat, wool, and cash income, as well as social security during bad crop years [1]. Since 1944, when an American aid agency introduced Merino sheep from Italy, many exotic breeds (Romney, Corriedale, Hampshire, Rambouillet, Awassi, and Dorper) have been imported to improve sheep productivity through crossbreeding [2–5]. Currently, only Awassi and Dorper sheep breeds are being utilized in part, and the contribution of other exotic breeds, except for Awassi sheep, is not well-defined or minimal [6].

To increase productivity and thereby attain food security, great interest in crossbreeding of indigenous sheep breeds with Awassi and Dorper sheep has been generated by the government and farmers. Hence, following importation of exotic breeds, different agricultural research institutes, government ranches, and farmers in Chiro area are engaged in evaluation and multiplication of crossbreeds with different exotic blood levels. The resulted in Awassi and Dorper crossbred rams have been distributed to smallholder farmers and private farms by some research centers and livestock agencies in several regional states. Even so, the performance of sheep is still the lowest in the world, and the crossbreeding program is not significantly improving the livelihood of farmers [5]. Besides, if not planned properly, such uncoordinated and scattered dissemination of crossbred rams can lead to genetic resource erosion rather than productivity improvement. Therefore, evaluation of the current status of the sheep crossbreeding program, evaluation of crossbreds in terms of productivity, adaptability, social-economic values generated for the community, and the perception of farmers about the new genotype are immensely important to strengthen the designed breeding scheme or to change to the appropriate breeding system in the future. Hence, the study was conducted to evaluate the performance of the sheep crossbreeding scheme and identify lessons to be learned from the ongoing sheep crossbreeding activities, to characterize the performance of crossbreds under smallholder management system, and to solicit farmers' opinions about crossbred sheep.

2. Materials and Methods

2.1. Description of Study Areas. This study was conducted in five districts of South and North Wollo zones. Gazo (*kebele* 011 and 012), Angot (*kebele* 06 and 07), and Raya Kobo (*kebele* 03 and 06) districts were selected from the North Wollo zone. In addition, Lengambo (*kebele* 025 and 026) and Dessie Zuria districts (*kebele* 035 and 036) were selected from the South Wollo zone. As described above, two *kebeles* from each district were purposefully selected based on sheep population and exposure to crossbreeding. Figure 1 shows a map of the study areas.

Angot district is located at a distance of 50 km from Woldia and 571 km from Addis Ababa. The study area has an altitude range of 3500–4500 m.a.s.l. The mean annual rainfall varies from 1201 to 1800 mm, and the mean minimum and maximum annual temperatures are 15.1 and 27.5°C, respectively. A mixed crop-livestock farming system, involving the production of cereals and different livestock species, is predominantly practiced [7].

The Gazo district is located between 39°12′9″ and 390 45′58″ East and 11° 34′54″ and 11° 58′59″ North. The district is located between 700 and 3200 meters above sea level. Its agroecology is predominantly covering Woina Dega 47.2% followed by Dega 23.3% and Kolla 29.5%. Mixed farming is largely practiced on crop production, followed by livestock rearing which has special importance among wealthier farmers.

Raya Kobo is located at an altitude of 1470 m.a.s.l and the rainfall pattern is bimodal, with two rainfall seasons: *belg* (Feb/Mar–April) and *kiremt* (July–September). The mean annual rainfall amount is about 630 mm, and the temperature varies from 19 to 33°C with a mean annual temperature of 23.1°C.

Legambo district has an area of 1017.35 km^2, and the specific study sites in the Legambo district are situated between 3200 and 3356 m.a.s.l. The area is characterized by Dega agro-ecology, and the community available here is known for animal rearing and barley farming practice.

The altitude of the Dessie Zuria district ranges from 1,800 to 3,500 m.a.s.l and is characterized by a rugged and undulating topography (steep slopes, hills, and plains). About 89% of the population lives in the higher highland ecological zone where sheep rearing is the major mainstay sector for the people in the area other than agriculture [8].

2.2. Sampling and Sample Size. A cross-sectional study involved the purposive selection of study sites and a random selection of respondents was conducted. Before the major data collection, a quick informal field survey and consultation with the district agricultural office experts were conducted to determine the distribution of the targeted breed in each research region. Based on the outcome of the rapid informal field survey and discussion, five districts (Gazo, Angot, Dessie zuria, Legambo, and Kobo) were purposively selected from South and North Wollo zones based on the distribution of targeted sheep breeds. Two *kebeles* were selected purposively from each selected district based on the distribution of targeted breeds and on their experience in sheep crossbreeding and sheep population. The respondents for the Awassi crossbreeding program were selected randomly from households that participated in the sheep-crossbreeding program. However, the households for the Dorper crossbreeding program were selected purposively due to a limited number of participants in Dorper crossbreeding program. The sample size was determined as per the formula given by Arsham [9] for survey studies:

$$N = \frac{0.25}{\mathrm{SE}^2}, \quad (1)$$

Where N is the sample size and SE is the population's standard error. As a result, 238 smallholder farmers were chosen using the random sample approach, with a standard error of 3.24% and a 95% confidence interval.

2.3. Data Collection. Data were collected through a personal interview, focus group discussion, measurement of morphological traits, and field observation. A single-visit multiple-subject formal survey technique was used to interview the household heads using a semi-structured questionnaire. A formal survey was conducted after pretesting and making required changes to the questionnaire. To know the perception, each house hold was asked to give a preference rank on five scales (very poor, poor, moderate, good, and very good) for productive traits and adaptability of indigenous and crossbred sheep. In order to confirm the data obtained from the individual interviews, focus groups were convened. The group had eight persons knowledgeable about the crossbreeding and crossbred sheep in their respective localities. Physical conformation, mating ability, and testicle condition of disseminated rams were ranked as poor, fair, and good by researchers. For Dorper crossbred rams disseminated from the Sirinka sheep breeding station, data collected for nine years were used to estimate their breeding value. However, it was impossible to obtain data

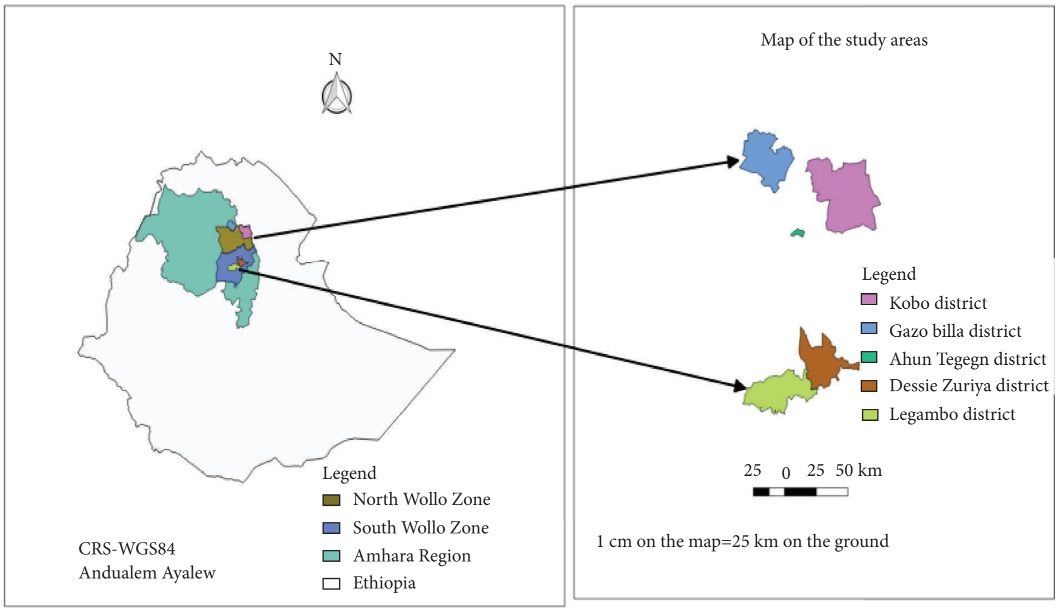

Figure 1: The map of the study areas (Angot = Ahun Tegegn).

for estimating the breeding value of Awassi crossbred sheep.

2.4. Data Analysis. Continuous types of data were analyzed using the general linear model procedure of SAS [10]. The WOMBAT software fitted animal model was used to determine the breeding values. The estimation of breeding value was based on all animals in the flock. Detailed description of data, pedigree information, and fixed effects considered and included for breeding value estimation was shown in Tesema et al. [11]. The chi-square test was used to determine if the categorical variables were independent. The perception of farmers regarding traits of two genotypes was quantified using ordinal regression with the cumulative logit function as it is suitable for ordinal dependent variables with three or more levels [12]. The cumulative logit model was as follows:

$$\text{Logit}[P(y \leq j, x)] = \log\left[\frac{P(y \leq j)}{P(y > j)}\right] = \alpha_j + \beta x,\ j = 1, \ldots .c - 1, \quad (2)$$

Where x is an explanatory variable, y is an ordinal response (c categories), α_j is the unknown intercept parameters, and β is a vector of unknown regression coefficients corresponding to x.

For ranking variables, indices were constructed using the following formula: Index = Σ [3* rank 1 + 2*rank 2 + 1*rank 3] given for particular qualitative variables divided by Σ [3* rank 1 + 2*rank 2 + 1*rank 3] for all qualitative variables considered.

3. Results and Discussion

3.1. Characteristics of the Households. Most of the interviewed households in the study area had male heads (Table 1). The age of the majority (76.0%) of the respondents was less than 50 years, which is the active age group. The adoption of new technologies is highly associated with the educational background. In this study, the educational status of respondents was 20.3, 19.0, 48.5, 8.40, and 1.70% for illiterate, read and write (religious or adult education), primary, secondary, and above secondary school, respectively. Education level was significantly associated ($\chi^2 = 43.9$ and $P = 0.028$) with study sites, and the number of illiterate in Raya Kobo was higher than in other areas. The mean family size was varied across study areas ($P = 0.002$), and a relatively higher family size was observed for Gazo, Kobo, and Legambo areas. The average landholding in Gazo was significantly higher than in other areas. This value is comparative with the report of Kenfo et al. [1].

3.2. Characteristics of the Production System

3.2.1. Relative Importance of Sheep and Purpose of Keeping Sheep. The relative importance and purpose of keeping sheep were shown in Figure 2 and Table 2, respectively. Sheep were identified as a highly important species by respondents in the study areas. In order of significance, sheep, cattle, chicken, goat, horse, donkey, camel, mule, and beehive were listed as being first, second, third, fourth, fifth, sixth, seventh, eighth, and ninth, with indices of 0.427, 0.339, 0.079, 0.049, 0.045, 0.033, 0.014, 0.011, and 0.004,

Table 1: Household characteristics ($n = 238$).

Variables	Angot	Dessie zuria	Gazo	Kobo	Legambo	χ^2-value	P value
Age (year)							
30	14.6	22.5	14.7	5.88	12.2	29.3	0.156
31–40	37.5	30.0	18.0	32.3	32.6		
41–50	33.3	32.5	29.5	29.4	34.7		
51–60	8.33	15.0	18.0	11.7	10.2		
>60	6.25	0.00	19.6	20.6	10.2		
Education level							
Illiterate	21.6	2.44	26.2	37.1	14.0	43.9	0.028
Read and write (religious or adult education)	13.7	12.2	26.2	17.1	26.0		
Primary (1–8)	49.0	63.4	40.9	37.1	52.0		
Secondary (9–12)	11.7	19.5	4.92	5.71	6.00		
Above secondary	3.92	0.00	1.64	2.86	0.00		
Sex							
Female	9.80	4.88	4.92	8.57	4.00	7.11	0.525
Male	90.2	95.1	95.1	91.4	96.0		
Family size	5.02 ± 0.18^b	5.22 ± 0.34^b	6.18 ± 0.26^a	6.03 ± 0.38^a	6.22 ± 0.25^a	—	0.002
Land holding (ha)	1.05 ± 0.11^b	1.29 ± 0.10^b	2.20 ± 0.17^a	1.25 ± 0.15^b	1.40 ± 0.09^b	—	0.001

Least square means with different superscripts within the same column and class are statistically different.

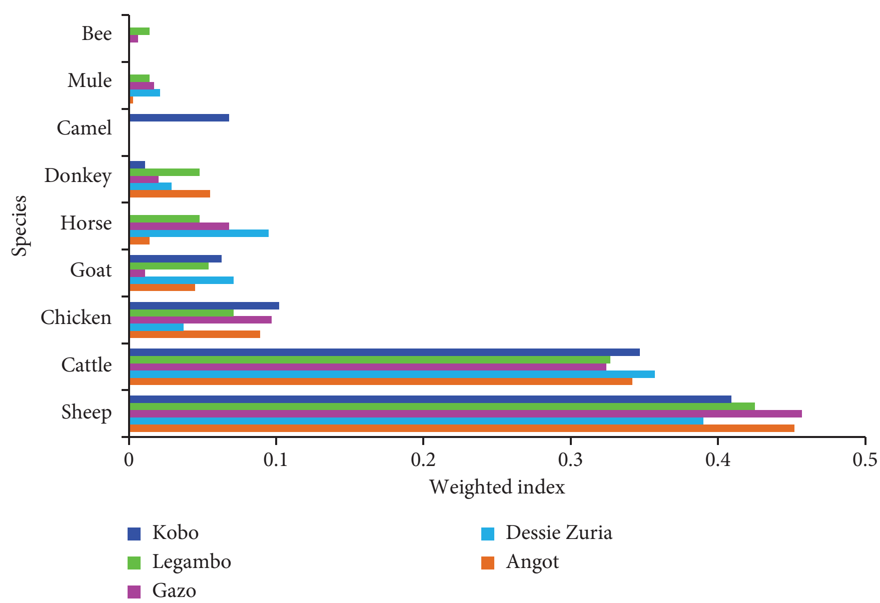

Figure 2: Rank of livestock species based on perceived importance by households.

Table 2: The purpose of sheep keeping (a weighted index).

Trait	Angot	Dessie zuria	Gazo	Legambo	Kobo	Overall
Income generation	0.488	0.472	0.489	0.483	0.518	0.490
Meat consumption	0.278	0.214	0.292	0.211	0.327	0.264
Saving	0.141	0.153	0.134	0.188	0.111	0.145
Manure	0.052	0.113	0.041	0.077	0.045	0.066
Skin	0.041	0.004	0.041	0.000	0.000	0.017
Wealth status	0.000	0.032	0.000	0.013	0.000	0.009
Wool	0.000	0.012	0.000	0.023	0.000	0.007
Milk	0.000	0.000	0.000	0.003	0.000	0.001
Blood	0.000	0.000	0.003	0.000	0.000	0.001

respectively. This indicates that sheep are the most important livestock species in study areas. Likewise, Getachew [13] noted that the role of sheep is more pronounced in the extreme highland areas where crop production, as well as larger animal production, is challenging due to environmental difficulties.

The main motivation of farmers keeping sheep was to generate income by selling live animals (0.490), for home meat consumption (0.264), for saving (0.145), and to use the manure as a fertilizer for crop (0.066). A similar result has been reported by several scholars [14, 15].

3.2.2. Flock Size and Genotype Composition. The average flock size and genotype composition in the study areas are presented in Figure 3. The average flock size in Angot, Dessie zuria, Gazo, Kobo, and Legambo were 15.2 ± 8.71, 11.0 ± 4.81, 21.5 ± 10.1, 11.4 ± 5.22, and 19.1 ± 11.3, respectively. The average number of crossbred sheep was higher than indigenous sheep in all study areas except Kobo. The proportions of crossbred sheep in the visited farmers were 79.6% in Angot, 61.3% in Dessie zuria, 64.2% in Gazo, 80.6% in Legambo, and 27.5% in the Kobo area. The proportion of crossbred sheep in all study areas except for Kobo is higher than the proportion of crossbred sheep in Angolelana Tera (63.6%), Menz Gera (42.1%), and Legambo (64.0%) districts reported by Teferra et al. [16]. Farmers in Legambo (Chiro) and Gazo areas produced crossbred rams and sold them to their neighboring villages at a better price. Indeed, farmers' participation and engagement in ram multiplication would play a great role in the success and sustainability of the crossbreeding program. Even so, total substitution of indigenous breed by high-grade crossbreds may reduce the fitness traits of animals which are vital in tropics, and dissemination of crossbreds in a wide range of locations may influence the indigenous sheep genetic resource.

3.2.3. Management and Breeding Practice. Natural pasture, own-established pasture, and hay were the dominant feed sources during the wet season with a weighted index value of 0.518, 0.186, and 0.89, respectively, whereas natural pasture, crop residues, and hay were the major feed resources during the dry season with an index value of 0.290, 0.272, and 0.119, respectively. However, most (99.2%) of the respondents were reported to have feed shortages, especially during January to May in the highland areas (Angot, Dessie zuria, Gazo, and Legambo) and April to June in the lowland area (Raya Kobo). During these dearth periods, most of the farmers (83.3–96.6%) who participated in the Awassi crossbreeding program gave special care (supplement feed) for disseminated crossbred rams, whereas the majority of respondents (60.6%) did not give special management for Dorper crossbred rams. Roughage, concentrate, and mineral/salt were the most important supplements with index values of 0.55, 0.29, and 0.15, respectively. Flour byproducts (40.4%) followed by homemade grain (36.0%) were the major concentrate feed types supplemented for sheep in the study areas. About 89% of farmers had access to veterinary services within a distance of less than five kilometers.

Pasture mating was the dominant method of mating followed by hand mating and controlled mating (Table 3). Most farmers shared crossbred rams with their neighbors to enhance the productivity of indigenous sheep through crossbreeding. Awassi and Dorper rams were disseminated to farmers by different stakeholders in the highland and lowland areas, respectively. Most of the disseminated Awassi crossbred rams (59.3%) were given a mating service. However, in areas where Dorper crossbreeding was conducted, the majority (57.1%) of disseminated rams died. Selling and castrating breeding rams were also common practice in most study areas. The overall mean service length for crossbred rams was 2.57 ± 0.07 years. The service length in Kobo and Angot was relatively shorter ($P = 0.0035$) than in other areas. This depicts that there is a high probability of ram mate with his daughters, and this could result in inbreeding. Thus, the service length of ram in the flock should not be greater than one year to reduce the inbreeding effect. The blood level of disseminated crossbred Dorper rams was 50%. A relatively high number of rams with a high Awassi gene level (65–88%) were disseminated to farmers in the highland areas. This is because Awassi crossbreeding was initiated earlier, and if there is an ample feed resource, the performance of Awassi crossbreds is improved with their gene level and fetches a better market price. Thus, there was a practice of upgrading Awassi level to high-grade crossbreds.

3.3. Constraints to Sheep Crossbreeding. Feed shortage, lack of improved genotype, and diseases were the major constraints challenging the sheep crossbreeding program in the highland areas (Angot, Dessi Zuria, Gazo, and Legambo). However, in the lowland area where Dorper crossbreeding was conducted, diseases or poor veterinary service were the major bottleneck followed by feed shortage and genotype (Table 4). Feed resources, veterinary services, access to credit, and availability of the improved genotype are all important factors for the effective implementation and sustainability of crossbreeding programs, according to a number of scholars [17–19]. Thus, due attention should be given to these factors while introducing the improved genotype. If not, crossbred animals are not able to express their full genetic potential and the anticipated change would not be brought. For instance, the production of improved forage using different development strategies including irrigation, improvement of pastureland, and improved utilization of available feed resources can be a way to tackle the feed shortage challenge.

Farmers understand the principle of crossing and the advantage of Awassi crossbreds. However, ranches and research centers are being challenged by disease outbreak and cannot sustainably supply crossbred rams to farmers. To alleviate the problem of ram shortage, they purchase rams with a high exotic gene level (≥75% Awassi level) from farmers in and out of their village. However, the recording system of farmers was not improved, and thus, the incorrect blood level of rams and inbreeding are threats to purchase breeding rams from farmers. Thus, breeding ram producers must be technically and financially supported by experts and the government, respectively. In addition, developing a composite breed would be the other option to alleviate ram shortage, ensure the sustainability of the crossbreeding program, and improve the livelihood of farmers if there is infrastructureto do so.

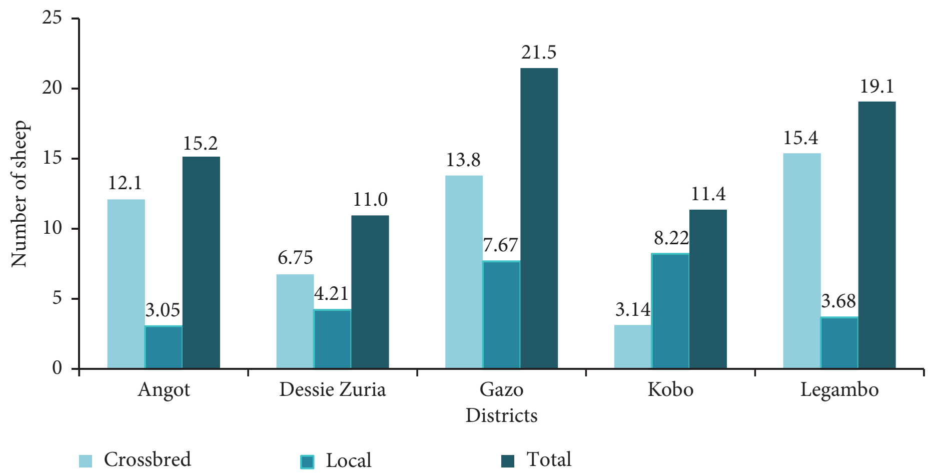

Figure 3: Sheep population by genotype.

Table 3: Sheep breeding practice in the study areas.

Parameters	Angot N (%)	Dessie zuria N (%)	Gazo N (%)	Kobo N (%)	Legambo N (%)	χ^2-value	P value
Mating method							
Controlled	3 (5.90)	18 (43.9)	3 (4.90)	1 (2.90)	31 (62.0)		
Uncontrolled hand mating	7 (13.7)	4 (9.80)	7 (11.5)	9 (25.7)	6 (12.0)	91.7	<0.0001
Uncontrolled natural mating	41 (80.4)	19 (46.3)	51 (83.6)	25 (71.4)	13 (26.0)		
Having crossbred ram							
Yes	9 (17.6)	8 (19.5)	17 (27.9)	30 (85.7)	12 (24.0)	56.2	<0.0001
No	42 (82.4)	33 (80.5)	44 (72.1)	5 (14.3)	38 (76.0)		
Ram status							
Serving	34 (66.6)	26 (63.4)	35 (57.4)	11 (31.4)	25 (50.0)		
Died	5 (9.80)	5 (12.2)	8 (13.1)	20 (57.1)	10 (20.0)	67.7	<0.0001
Castrated	7 (13.7)	5 (12.2)	10 (16.4)	4 (11.4)	6 (12.0)		
Sold	5 (9.80)	6 (14.6)	8 (13.1)	0 (0.00)	9 (18.0)		
Ram share with neighbours							
Yes	45 (88.2)	37 (90.2)	47 (77.0)	27 (77.1)	35 (70.0)	12.1	0.148
No	6 (11.8)	4 (9.80)	14 (33.0)	8 (22.9)	15 (30.0)		
Ram service length (year)	2.37 ± 0.11^{c}	2.62 ± 0.14^{ab}	2.85 ± 0.14^{a}	2.01 ± 0.19^{c}	2.73 ± 0.15^{ab}	—	0.0035

Least square means with different superscripts within the same column and class are statistically different.

Table 4: Constraints for sheep crossbreeding ranked by respondents (a weighted index value).

Constraints	Angot	Dessie zuria	Gazo	Legambo	Kobo	Overall
Feed shortage	0.368	0.395	0.243	0.404	0.241	0.330
Lack of improved genotype	0.225	0.210	0.229	0.153	0.166	0.197
Diseases/poor vet service	0.091	0.086	0.189	0.115	0.326	0.161
Drought occurrence	0.119	0.142	0.166	0.167	0.128	0.144
Capital	0.081	0.094	0.103	0.080	0.032	0.078
Labor	0.091	0.052	0.037	0.017	0.080	0.056
Market access	0.000	0.013	0.000	0.063	0.000	0.015
Adaptability	0.021	0.000	0.031	0.000	0.016	0.014
Water shortage	0.004	0.009	0.003	0.000	0.011	0.005

3.4. Breeding Soundness and Breeding Value of Disseminated Rams. A ram should have traits that will increase the production potential of the flock in which ram is used, as well as the ability to successfully mate and pass on these traits. Most disseminated crossbred rams had better physical conformation a broad muzzle, straight back, thick chest, and deep hindquarters), testicle condition (testicles and penis were firm, free from injury, normal, and adequate in size), and mating ability (libido) (Figure 4). The average body condition score of disseminated rams was 3.4 which is

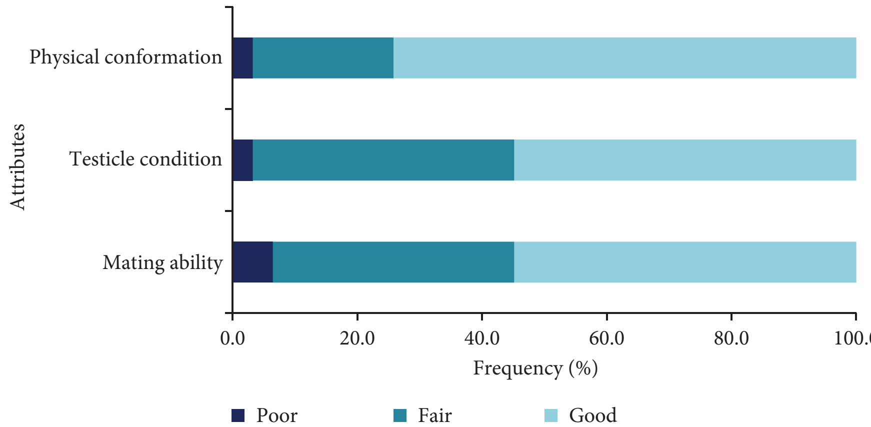

Figure 4: Breeding soundness of disseminated rams.

a good condition for mating, and the live weight varied from 28 to 56 kg with an overall mean of 46.8 kg.

The estimated breeding value of disseminated rams and ewes is presented in Table 5. The birth weight and weaning weight of disseminated Dorper crossbred sheep were 3.32 ± 0.05 and 15.3 ± 0.33 kg, respectively. Disseminated crossbred Dorper rams and ewes had a positive breeding value, and the expected progeny difference or the genetic merit of an animal's progeny for birth weight and weaning weight of disseminated crossbreds were 0.0035 and 0.1365 kg, respectively, compared to a ram and ewe with an EBV of 0. However, the breeding value of crossbreds varied across locations, and a lower EBV was noted for crossbreds disseminated in Raya Kobo. This indicates that the progeny of these rams and ewes on an average have lower genetic capacity for weaning weight. This unfavorable breeding value might be attributed to a low intensity of selection. Thus, to be effective in a genetic improvement program, animals with a positive EBV (depending on the type of trait) must be selected for growth traits as the aim of the crossing is to improve growth and meat production.

3.5. Reproductive Performance of Different Sheep Genotypes. Successful and profitable sheep farming depends on good reproductive performance. Reproductive performances of sheep as per respondent response are presented in Table 6. The overall least square mean age at first service for male (MAFS), age at first service for female (FAFS), age at first lambing (AFL), number of lambs born per lifetime (NLPL), and lambing interval (LI) were 9.33 ± 0.14 months, 10.0 ± 0.14 months, 15.3 ± 0.16 months, 10.2 ± 0.15 lambs, and 8.51 ± 0.11 months, respectively. The AFL of all genotypes is longer than the report of Nigussie et al. [20], and LI is comparable with the same authors. The overall mean liter size was 1.17, and there was no significant difference among genotypes.

AFL is a good indicator of early sexual maturity and lifetime productivity of ewes. According to Wilson [21], the AFL of traditionally managed sheep was ranged from 15 to 18 months and the results for all genotypes in this study are found within the range. The NLPL is a very important trait to improve sheep productivity and profitability, and it is also an indicator of adaptability. In this study, Tikur sheep had earlier AFS and AFL than their crossbreds with Awassi. Likewise, the indigenous Wollo sheep had earlier AFL, large NLPL, and short LI than their Awassi crossbreds. A similar observation has been made by Getachew et al. [22] and Lemma et al. [23]. Under a moderate level of production inputs, LI of 8 months (245 days) in indigenous sheep can be achieved, facilitating three lambings in two years. However, Awassi x Wollo sheep had an extended LI compared with other genotypes. The ability of crossbred ewes to nurse their lambs to weaning age can compensate for their longer AFL and LI [13, 22]. Even so, reducing the age at first lambing and lambing interval are the most important ways of increasing the off-take rate, and this may help in meeting the growing demand for animal source protein (meat). If there is an organized structure and support, synthetic breed development could be one option to use the reproduction superiority of indigenous ewes. The reproductive performance of Dorper and their crossbreds was statistically similar ($P > 0.05$).

3.6. Market Age and Price of Crossbred Sheep. The market age and price of sheep breeds as per farmers estimation are summarized in Table 7. The overall mean age for selling sheep was 6.71 ± 0.09 months. The selling age of crossbreds was earlier by 2.2 to 3.5 months compared with indigenous sheep breeds. Besides, the market price of Awassi crossbreds was higher ($P < 0.001$), i.e. near to one fold of the price of indigenous sheep breeds. In line with this result, high selling price of Awassi crossbreds compared to local sheep was noted by Teferra et al. [16] and Tiruneh et al. [24]. Likewise, the price advantage of Dorper crossbreds was ranged between 420 and 640ETB compared with indigenous sheep under similar management and age.

Table 5: The estimated breeding value of distributed crossbred Dorper rams and ewes.

Sources of variation	N	BWT	BWT-EBV	WWT	WWT-EBV
Overall mean	112	3.32 ± 0.05	0.007 ± 0.001	15.3 ± 0.33	0.273 ± 0.07
Sex		ns	ns	ns	*
F	25	3.35 ± 0.10	−0.014 ± 0.03	14.6 ± 0.52	0.514 ± 0.09
M	87	3.32 ± 0.06	0.013 ± 0.02	15.5 ± 0.40	0.208 ± 0.08
Location		ns	ns	*	*
Gubalafto	20	3.21 ± 0.11	−0.003 ± 0.04	17.6 ± 0.80^{a}	0.652 ± 0.16^{a}
Research center	7	3.48 ± 0.14	0.035 ± 0.05	15.7 ± 0.82^{ab}	0.599 ± 0.15^{a}
Sendafa	27	3.31 ± 0.10	−0.027 ± 0.03	14.4 ± 0.51^{b}	0.459 ± 0.09^{ab}
Habru	12	3.26 ± 0.20	−0.041 ± 0.05	15.0 ± 1.19^{ab}	0.284 ± 0.18^{ab}
Kalu	5	3.36 ± 0.12	0.024 ± 0.03	15.7 ± 0.95^{ab}	0.397 ± 0.27^{ab}
Raya Kobo	41	3.36 ± 0.09	0.043 ± 0.03	14.8 ± 0.61^{ab}	-0.108 ± 0.11^{b}

BWT: birth weight; WWT: weaning weight; EBV: estimated breeding value; Ns, $P > 005$; *, $P < 0.05$. Least square means with different superscripts within the same column and class are statistically different.

Table 6: Reproductive performance of local and crossbred sheep (LSM ± SE).

Source of variation	N	MAFS (month)	FAFS (month)	AFL (month)	NLPL (lamb)	LI (month)
Overall	238	9.33 ± 0.14	10.0 ± 0.14	15.3 ± 0.16	10.2 ± 0.15	8.51 ± 0.11
Genotype		***	***	***	***	**
Tikur	112	8.42 ± 0.27^{b}	9.09 ± 0.26^{b}	14.1 ± 0.24^{c}	9.40 ± 4.30^{bc}	8.35 ± 0.25^{b}
Awassi x Tikur	112	10.4 ± 0.26^{a}	11.2 ± 0.29^{a}	16.3 ± 0.32^{ab}	10.5 ± 0.33^{ab}	7.97 ± 0.22^{b}
Awassi x Wollo	91	9.76 ± 0.36^{a}	11.0 ± 0.38^{a}	16.8 ± 0.44^{a}	10.1 ± 0.29^{bc}	9.82 ± 0.29^{a}
Wollo	91	10.4 ± 0.34^{a}	10.4 ± 0.30^{a}	15.5 ± 0.32^{b}	11.6 ± 0.35^{a}	8.01 ± 0.20^{b}
Dorper x Tumele	35	6.95 ± 0.32^{c}	8.00 ± 0.39^{b}	13.0 ± 0.32^{c}	8.88 ± 0.54^{c}	8.37 ± 0.31^{b}
Tumele	35	7.12 ± 0.33^{c}	8.20 ± 0.39^{b}	13.1 ± 0.36^{c}	9.71 ± 0.34^{bc}	8.73 ± 0.31^{b}

N = number of respondents, MAFS = male age at first service, FAFS = female age at first service, AFL = age at first lambing, NLPL = number of lambs born/life time, LI = lambing interval; **, $P < 0.01$; ***, $P < 0.001$. Least square means with different superscripts within the same column and class are statistically different.

Table 7: Marketing age and market price based on farmers' estimation.

Sources of variation	Marketing age (month)	Price (ETB)			
		3–6 month	7–9 month	10–12 month	>12 month
Overall	6.71 ± 0.09	1309.5 ± 21.9	1708.9 ± 21.7	2099.5 ± 33.1	2730.0 ± 43.0
Genotype	***	***	***	***	***
Tikur	8.91 ± 0.20^{a}	737.9 ± 24.7^{e}	946.5 ± 23.8^{f}	1176.3 ± 28.7^{f}	1651.1 ± 45.0^{e}
Awassi x Tikur	5.38 ± 0.13^{c}	1216.0 ± 28.2^{c}	1615.2 ± 36.2^{d}	2070.3 ± 49.6^{d}	2689.4 ± 70.7^{c}
Wollo	7.82 ± 0.18^{b}	1016.6 ± 23.0^{d}	1392.4 ± 32.2^{e}	1760.9 ± 39.6^{e}	2278.9 ± 44.2^{d}
Awassi x Wollo	4.82 ± 0.15^{c}	2144.1 ± 43.4^{a}	2756.9 ± 50.8^{a}	3372.1 ± 62.3^{a}	4298.3 ± 85.6^{a}
Tumele	7.55 ± 0.22^{b}	1244.6 ± 45.7^{c}	1780.3 ± 60.6^{c}	2244.6 ± 73.4^{c}	2670.3 ± 92.8^{c}
Dorper *x* Tumele	5.32 ± 0.21^{c}	1664.9 ± 54.2^{b}	2223.5 ± 76.2^{b}	2717.0 ± 99.9^{b}	3310.5 ± 124^{b}
Sex	ns	***	***	***	***
Female	6.82 ± 0.13	1242.9 ± 29.8	1603.9 ± 36.5	1949.9 ± 43.6	2428.0 ± 51.9
Male	6.60 ± 0.13	1376.3 ± 31.8	1814.3 ± 39.9	2249.0 ± 48.9	3030.7 ± 65.4

Ns, $P > 0.05$; ***, $P < 0.001$. Least square means with different superscripts within the same column and class are statistically different. NB: The price for Tikur and Awassi x Tikur sheep was estimated in 2019, and the price for other genotypes was estimated in 2020.

3.7. Farmers' Perception on Productivity and Adaptability of Awassi and Dorper Crossbred Sheep. Farmers' preferences, breed productivity, and adaptability are critical factors in the crossbreeding program. The perceptions of farmers on productive and adaptability traits are shown in Table 8. When compared with indigenous sheep breeds, farmers preferred Dorper crossbreds for their growth rate (72.2 times greater and $P < 0.001$), physical appearance (68.7 times greater and $P < 0.001$), preference in the market (9.30 times greater and $P < 0.001$), and milk production of ewes (15.8 times greater and $P < 0.001$). Likewise, Lakew et al. [25] and Habtegiorgis and Jimma [26]noted that farmers had a keen interest to keep Dorper crossbreds due to their fast growth rate, high market demand, and price compared to local sheep. However, Dorper crossbreds were not preferred by farmers (0.01 times compared with indigenous sheep breed and $P < 0.001$) for their resistance to diseases, drought tolerance, heat tolerance, and long-

Table 8: Perception of farmers (n= 238) on productivity traits.

Trait	Breed	Awassi crossbreeding						Dorper crossbreeding					
		VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
PA	Indigenous	8.37	43.8	45.3	1.97	0.49	1.00	2.86	5.71	82.9	8.57	0.00	1.00
	Crossbred	0.00	0.00	6.40	27.1	66.5	82.3^{***}	0.00	0.00	8.57	25.7	65.7	68.7^{***}
GR	Indigenous	4.57	49.2	43.1	2.03	1.02	1.00	0.00	14.3	80.0	5.71	0.00	1.00
	Crossbred	0.00	0.51	3.06	17.3	79.1	90.0^{***}	0.00	0.00	8.57	31.4	60.0	72.2^{***}
MQ	Indigenous	1.13	3.39	13.0	30.5	52.0	1.00	0.00	6.06	57.6	18.2	18.2	1.00
	Crossbred	0.00	14.6	51.7	26.9	6.74	0.10^{***}	0.00	6.06	30.3	24.2	39.4	2.69^{*}
WY	Indigenous	4.21	27.4	51.6	12.6	4.21	1.00	—	—	—	—	—	—
	Crossbred	2.65	6.35	11.6	42.3	37.0	12.7^{***}	—	—	—	—	—	—
MY	Indigenous	3.77	39.6	43.4	8.81	4.40	1.00	0.00	0.00	86.4	13.6	0.00	1.00
	Crossbred	0.63	6.25	3.13	38.7	51.2	32.8^{***}	5.26	0.00	21.0	26.3	47.4	15.8^{***}
MP	Indigenous	1.60	41.0	45.7	10.6	1.06	1.00	0.00	0.00	58.1	29.0	12.9	1.00
	Crossbred	0.53	1.60	1.60	10.1	86.2	89.1^{***}	0.00	0.00	12.9	29.0	58.1	9.30^{***}
CT	Indigenous	0.51	1.54	12.8	28.2	56.9	1.00	—	—	—	—	—	—
	Crossbred	3.61	22.7	40.2	26.	6.70	0.07^{***}	—	—	—	—	—	—
DR	Indigenous	0.52	3.13	12.0	22.4	61.9	1.00	0.00	0.00	2.86	28.6	68.6	1.00
	Crossbred	6.81	35.1	46.6	8.90	2.62	0.03^{ns}	2.86	57.1	37.1	2.86	0.00	0.01^{***}
DRT	Indigenous	0.50	1.01	8.54	19.1	70.8	1.00	0.00	0.00	11.7	26.5	61.8	1.00
	Crossbred	7.5	41.7	41.2	7.54	2.01	0.01^{ns}	2.94	26.5	61.8	8.82	0.00	0.01^{***}
FR	Indigenous	1.06	24.5	53.7	11.2	9.57	1.00	0.00	5.71	68.6	20.0	5.71	1.00
	Crossbred	2.69	12.4	3.76	13.4	67.7	10.5^{***}	0.00	0.00	14.3	28.6	57.1	18.9^{***}
HT	Indigenous	—	—	—	—	—	—	0.00	0.00	17.1	22.9	60.0	1.00
	Crossbred	—	—	—	—	—	—	0.00	23.5	70.6	5.88	0.00	0.01^{***}
WA	Indigenous	0.00	1.59	10.0	22.2	66.1	1.00	0.00	0.00	11.4	34.3	54.3	1.00
	Crossbred	2.12	29.6	46.0	19.0	3.17	0.03^{ns}	0.00	14.3	82.9	2.86	0.00	0.01^{***}
LS	Indigenous	0.58	11.6	37.8	27.9	22.1	1.00	0.00	0.00	20.0	48.6	31.4	1.00
	Crossbred	0.58	11.7	36.3	37.4	14.0	0.90^{ns}	0.00	22.9	45.7	22.9	8.57	0.12^{ns}

VP, very poor, P, poor; M, moderate; VG, very good; OR, odds ratio; CI, confidence interval. PA, physical appearance; GR, growth rate; MQ, meat quality; WY, wool yield; MY, milk yield; MP, market preference; CT, cold tolerance; DR, diseases resistance; DRT, drought tolerance; FR, feed requirement; HT, heat tolerance; WA, walking ability; LS, lamb survival, Ns, $P > 0.05$; $^{*}P < 0.05$; $^{***}P < 0.001$; 1.00, reference

distance walking ability. Besides, crossbreds had a high feed requirement compared with indigenous sheep breeds. This result is in agreement with the reports of Lakew et al. [25] and Habtegiorgis and Jimma [26]. Improving productivity alone may lead to poor fitness, particularly under tropical conditions, and it is therefore necessary to balance production and adaptation ability. Therefore, due intervention in terms of efficient veterinary service and forage development is required while introducing the crossbreds to smallholder farmers.

The Awassi crossbred sheep were preferred (odds ratio = 82.3–90.0 and $P < 0.001$) due to their good physical appearance, fast growth rate, and better preference in the market compared with indigenous sheep breed. The higher live weight and the fast growth rate of Awassi crossbreds compared to indigenous sheep under the smallholder management system were noted elsewhere [16, 27, 28]. Even so, Awassi crossbred sheep were not appreciated for their meat quality (odds ratio = 0.10 and $P < 0.001$), cold tolerance (odds ratio = 0.07 and $P < 0.001$), and feed requirement compared to indigenous breed. Thus, utilization and conservations of indigenous breeds may be valuable to cope with climate change as indigenous breeds are able to use marginal land and crop residues for maintenance and production. Although Awassi is developed for milk, the breed is also used for meat and wool production [29]. In this study, the Awassi crossbreds were more preferred (odds ratio = 32.8 and $P < 0.001$) by farmers in terms of milk production and 12.7 times greater ($P < 0.001$) in terms of wool production compared to indigenous sheep. The consumption of sheep milk is generally considered cultural taboo and unpopular among smallholder farmers. Besides, farmers did not benefit from wool due to the absence of a market and market linkage. Thus, awareness creation about the nutritional value of sheep milk, production of quality wool, and market linkage is immensely important to efficiently utilize the potential of Awassi crossbred sheep.

3.8. Shortfall and Achievements of the Ongoing Sheep Crossbreeding Program. In this study, the implementation of the crossbreeding program, the outputs at the animal and household level, and farmers' perception of the crossbreeding program and crossbreds were assessed directly or indirectly. The implementation lacks a proper recording scheme, rams were not selected based on genetic merit, rams were not exchanged in time, lack periodic importation of genetically unrelated rams, and lacks of fixing the maximum exotic gene level suitable for the production system. Farmers selected crossbred rams based on morphological traits such as physical appearance, coat color, ear length, and leg hair length. In addition, crossbred rams were distributed to farmers by different institutions as part of a campaign, but there was no periodical exchange or substitution of rams and no follow-up and feedback on the status of rams. As a result, the average ram service length of crossbred rams was 2.57 ± 0.07 years, which may result in inbreeding in the flock. Up to 50% Awassi level was recommended for the low-input production system by Getachew [13]. However, farmers were rearing high-grade crossbreds up to 87.5% Awassi level, and the production inputs (feed and health aspects) for high-grade were similar to those for low-grade crossbreds and local sheep. Consequently, genes controlling trait of interest may not be adequately expressed, and the probability of survival or adaptation is reduced when exotic blood level increases.

With the above limitations, improvement in the performance of flock, a well-functioning farmers' breeding association governed by their by-laws, production of crossbred rams for neighboring villages, income improvement, and recording of biological data of the sheep owned by members of the cooperatives are the major achievements that have been made, particularly in Legambo (Chiro) and Gazo (Talet). The crossbred rams produced by farmers were bought and distributed to different areas of the North Wollo, South Wollo, and North Shoa zones by the Bureau of Agriculture and Universities. For instance, Awassi crossbred sheep were distributed in 16 districts of South Wollo and seven districts of the North Wollo zone. Although ram producer farmers are benefited from the sale of crossbred rams with better price, such type of indiscriminate dissemination of crossbreds could dilute the indigenous sheep genetic resources, and thus, the crossbreeding modalities need some sort of revision and should be implemented in areas vulnerable to breed admixture (e.g. urban, peri-urban, and road side areas). In addition, designing and implementation of the within-breed genetic improvement program for undiluted indigenous sheep population/breeds in the marginal areas could ensure the sustainability and improve the productivity of indigenous sheep. In line with the current result, the improvement of household income due to rearing of Awassi crossbred sheep was reported by Teferra et al. [16] and Tiruneh et al. [24]. As a result, all visited farmers (100%) in the highland were interested in Awassi crossbreds and wanted to continue the crossbreeding program. Likewise, most of the visited farmers (80%) in the Raya Kobo district showed keen interest in sheep crossbreeding. However, about 20% of the respondents in Raya Kobo do not want to continue with the Dorper crossing due to poor disease resistance and adaptability.

4. Conclusions

The implementation of the crossbreeding scheme lacks a proper recording scheme, selection based on genetic merit, sire rotation, periodic importation of unrelated rams, and fixing the maximum exotic gene level suitable for the production system. With these limitations, sheep crossbreeding using Awassi had a significant influence on the income of visited farmers. The better physical appearance, growth rate, and income due to high price than indigenous sheep are the main reasons for rearing crossbreds. However, Awassi x Wollo crossbreds had poor reproductive performance than indigenous Wollo sheep. Feed shortage, lack of the improved genotype, and poor veterinary service were the major constraints for sheep crossbreeding. The failure to provide these required inputs to the crossbred sheep could result in a significant loss in productivity and may affect the welfare of animals. Thus, crossbreds must be accompanied by improved management to exploit the expected benefits from crossbreeding in the low-input production system. The implementation of the crossbreeding program needs revision, technical support, monitoring, and periodic evaluation to increase the efficiency and ensure the sustainability of the crossbreeding program. Further research should be conducted to improve the reproductive performance of Awassi crossbred sheep.

Abbreviations

BWT: Birth weight
WWT: Weaning weight
EBV: Estimated breeding value
LSM: Least square mean
MAFS: Male age at first service
FAFS: Female age at first service
AFL: Age at first lambing
NLPL: Number of lambs born/life time
LI: Lambing interval
PA: Physical appearance
GR: Growth rate
MQ: Meat quality
WY: Wool yield
MY: Milk yield
MP: Market preference
CT: Cold tolerance
DR: Diseases resistance
DRT: Drought tolerance
FR: Feed requirement
HT: Heat tolerance
WA: Walking ability
LS: Lamb survival
N: Number of observation
OR: Odds ratio
VP: Very poor
P: Poor
M: Moderate
VG: Very good
CI: Confidence interval.

Data Availability

The data supporting the findings of the current study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

Zeleke Tesema was involved in conception of the work, analysis of data, and interpretation of the result and write-up. Alemu Kefale, Belay Deribe, Getasew Esayas, Demlie Chanie, Getachew Worku Alebachew, Solomon Tiruneh, and Mekonnen Shibeshi were involved in conceptualization, data curation, methodology, writing, and revision of the manuscript.

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