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Research Article

Performance Evaluation of Boer × Central Highland Crossbred Bucks and Farmers' Perceptions on Crossbred Goats in Northeastern Ethiopia

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The study aimed to characterize the production system, to evaluate the genetic merit of Boer × Central Highland crossbred bucks, and to solicit the perception of farmers about crossbred goats and crossbreeding program. Data were collected through a personal interview, focus group discussion, field observation, and measurement of the live animal. Besides, data on growth performance were extracted from available performance records at Sirinka sheep and goats breeding station. Data were analyzed using SAS, and the breeding values for bucks were estimated using WOMBAT software. Goats were the second most important animal species, and income generation, home meat consumption, and saving were found to be the main reasons for keeping goats with index values of 0.484, 0.355, and 0.085, respectively. The production system was characterized as a low-input production system. Feed shortage and disease/poor veterinary service were the most important constraints for the goat crossbreeding program. The overall mean estimated breeding values (EBV) for three- and six-month weight of disseminated crossbred bucks were 0.53 and 0.31 kg, respectively. The three-month weight EBV for crossbred goats disseminated in Amhara Sayint and Habru district was lower than their contemporary group. Likewise, the six-month weight EBV for crossbred goats distributed in Amhara Sayint was lower than the contemporary group mean. These results depict the absence of buck selection based on their genetic merit. As per farmers' perception, crossbred goats were superior (odds ratio = 3.94 to 20.9, $P < 0.001$) to indigenous goats in terms of production traits. Besides, the price of the crossbred goat was higher (213 to 372 ETB/head) than indigenous goats with similar management and age. However, poor adaptability and fitness were the major demerits of Boer × Central Highland crossbred goats under a smallholder management system. Therefore, while introducing exotic breeds, it is imperative to give due attention to nutrition and veterinary service.

1. Introduction

Small ruminants play an indispensable role in improving the livelihoods of resource-poor farmers in Ethiopia by providing meat, milk, skin, manure, and short-term cash income [1]. The development plan to intensify goat production in Ethiopia has been and continues to include crossbreeding with exotic breeds as an option to rapidly increase the productivity of animals [2]. Accordingly, various exotic dairy-type goat breeds (Saanen, Toggenburg, and Anglo-Nubian goat) have been introduced to Ethiopia starting from late 1975, and meat-type Boer goat has been introduced to Ethiopia since 2007 [3].

Boer goat breed is known for large frame size, high growth rate, and carcass attributes [4]. Thus, indigenous goat breeds in Ethiopia such as Central Highland, Abergele, and Woyto-Guji goats were crossed with improved Boer goat to improve growth performance and meat production. The crossbreeding program involves the importation of pure Boer bucks, on-station multiplications of 50% F1 crossbred bucks, and dissemination to farmers' flock for crossing with indigenous goats. Different institutions disseminated F1 Boer crossbred bucks to smallholder farmers with the major objective of meat production improvement and farmers' cross-indigenous does with 50% Boer crossbred bucks. Even so, crossing indigenous goats with Boer goat does not significantly improve the productivity of goats under a low-input production system [5].

The phenotypic expression of production traits is influenced by the genetic effect and environmental factors or production inputs. Besides, the acceptance of new breeds by farmers is vital for the success and sustainability of the crossbreeding program. Thus, characterizations of the production inputs, evaluation of the genetic merit of disseminated breeding bucks for the trait of interest and solicit farmers' perception on crossbred goats, and the executed crossbreeding program are immensely important for intervention and to make the right decision on the genetic improvement method to be used. Although the performance of Boer crossbreds was evaluated under semi-intensive management [6,7] and extensive management system [8,9], there is no research on the genetic merit of disseminated crossbred bucks and perception of farmers about Boer × Central Highland crossbred goats so far. On account of this, this study was undertaken to assess the production system, to evaluate the performance of disseminated crossbred bucks, and to solicit the perception of farmers about crossbreds and crossbreeding programs.

2. Materials and Methods

2.1. Study Sites. The study was conducted at three districts, namely Raya Kobo, Habru, and Amhara Sayint. Raya Kobo district is part of the North Wollo Zone. The altitude of Raya Kobo ranges from 900 to 2400 m.a.s.l. The district is located at a geographical coordinate point of 12° 14′ 60.00″ N latitude and 39° 29′ 59.99″ *E* longitude. The maximum and minimum temperature of the study area is 29 and 15°C, respectively [9]. The mean annual rainfall is 630 mm, and the area is characterized by seasonal moisture stress and erratic rainfall.

Habru district is located at 11° 27′ to 11° 55′ N latitude and 39° 33′ to 40° 01′ *E* longitude. It has a total area of 47,210 hectares with an altitude ranging from 1300 to 3800 m.a.s.l. The rainfall distribution is bimodal; the main rainy season occurs between July and September, and the small rainy season (erratic and unpredictable) occurs from the end of February to the end of April [10]. Its mean annual maximum and minimum temperatures are 28.5 and 15°C, respectively. The mean annual rainfall of the district varied from 750 to 1000 mm [11].

Amhara Sayint district is located in between 11°15′ to 11°25′ N latitude and 38°40′ to 39°6′ 7″ *E* longitude. The altitude of Amhara Sayint ranges from 500 to 3,700 m.a.s.l. The average annual rainfall is 1165 mm with a maximum of 1649 mm and a minimum of 734 mm. More than 76% of the total rainfall occurs between June and September. Maximum annual temperatures range from 19.1 to 22.8°C, and the minimum annual temperature occurs in November and December with a range of 6.4 to 14.0°C [12].

2.2. Sampling Method and Data Collection. The purposive sampling method was used to select both study areas and respondents. The areas of distribution for Boer × Central Highland crossbred goats were identified first, and a list of participants in the crossbreeding program was taken from the district's office. All participants having at least three Boer crossbred and indigenous Central Highland goats each in their flock were considered for this study purposively. The questionnaire was designed, pretested, and modified before the commencement of the actual administration to check its clarity to respondents. Then, data comprised of the unique characters of crossbreds, adaptability, productivity, management, and production constraints were collected from 46 participants (30 from Raya Kobo, 9 from Habru, and 7 from Amhara Sayint district) using semistructured questionnaires. In addition, a focus group discussion was conducted with eight participants in each Raya Kobo and Habru district and seven participants in Amhara Sayint district to collect additional information and to validate the information obtained about the productivity and adaptability of crossbreds compared to indigenous goat, constraints, and future fate of the crossbreeding program. To assess the perception of farmers, each respondent was asked to give a preference rank on a scale of 1 to 5 (1 = very poor, 2 = poor, 3 = moderate, 4 = good, and 5 = very good) for productive traits, adaptability, and reproductive measures of indigenous and crossbred goats. The market price for both genotypes was estimated by farmers, and the price was estimated based on the year 2018.

The Boer × Central Highland crossbred bucks were disseminated from the research station. Thus, the biological data collected from 2009–2018 at Sirinka Agricultural Research Center shoat breeding station were used to evaluate growth performance and to estimate the breeding value of crossbred bucks. The number of records, number of sires, number of dams, progeny per sire, and progeny per dam were 875, 25, 238, 35, and 4, respectively. A detailed description of biological data was noted in the paper by Tesema et al. [13]. This paper used the term crossbred to refer to the Boer × Central Highland crossbred goat, and the indigenous goat is Central Highland goat.

2.3. Data Analysis. Data were analyzed using PROC GLM procedure of SAS [14] to determine the significance of fixed effects. The breeding values for disseminated bucks were estimated by WOMBAT software fitted animal model [15]. A detailed description of data and the model (fixed and random factors) used for estimation of breeding value was presented by Tesema et al. [13]. The categorical variables were tested for independence using the chi-square test. Indices were calculated for ranked variables in reference to its formula:

$$I = \sum_{n=3}^{3} \frac{RkXnk}{k\sum_{n=1}^{3} RkXnk}, \quad (1)$$

where I is index, R_k is the rank weight associated with criteria k ($R_1 = 3, R_2 = 2, R_3 = 1$), X_{nk} is the proportion of respondents who ranked the k^{th} criteria or preference in the n^{th} rank ($n = 1$ to 3 ranks), and k represents criteria and the purposes of goat production.

Perception data collected using the Likert scale (scores from 1 to 5) were tested for reliability and internal consistency of the scale by Cronbach's alpha (α) test [16] using the Statistical Analysis System [9] according to HOW2-STATS [17]. The formula was presented as follows:

$$\alpha = \frac{kr}{(1 + k - r)r}, \quad (2)$$

where k is number of indicators or number of items and mean interindicator correlation.

The Cronbach's alpha value (α= 0.80) showed that 80% of the variance in the scores was a reliable variance. Then, the ordinal regression with the cumulative logit function was used to quantify the perception of farmers for different attributes of two genotypes because cumulative logit function is appropriate for ordinal-dependent variables with three or more levels [18]. The cumulative logit model was as follows:

$$Logit\,[P(y \leq j, x)] = \log\left[\frac{P(y \leq j)}{P(y > j)}\right] = \alpha_j + \beta x, \quad j = 1, \ldots c - 1, \quad (3)$$

where y is an ordinal response (c categories) and x is an explanatory variable. Spearman's nonparametric correlation coefficient (r) of ranks was used to compare the ranking of traits perceived by farmers. The cumulative probability of an event was calculated as follows:

$$\Pr\left(Y \leq y_j, x\right) = \frac{\exp\left(\alpha_j + \beta x\right)}{1 + \exp\left(\alpha_j + \beta x\right)}, \quad j = 1, \ldots, c, \quad (4)$$

where Pr ($Y \leq$ yj) is the cumulative probability of the event ($Y \leq$ yj); αj are the unknown intercept parameters, satisfying the condition $\alpha 1 \leq \alpha 2 \leq \ldots \alpha k$; and $\beta = (\beta 1, \beta 2, \ldots, \beta k)'$ is a vector of unknown regression coefficients corresponding to x.

3. Results and Discussion

3.1. Household Characteristics. The characteristics of households are shown in Table 1. The age of most of the households in Habru and Raya Kobo district was ranged between 41 and 60 years. However, the age of households in Amhara Sayint was below 40 years. Most (93%) of the respondents in all the study areas were male, and the remaining 7% were female respondents. The proportion of literate goat keepers was lower than the illiterate in Habru. However, most of the households in Raya Kobo and Amhara Sayint were attended primary and secondary school. Education level had significant importance to adopt new technologies and innovations into the communities. The mean family size of visited households (±SD) was 4.00 ± 1.63, 7.44 ± 4.15, and 5.93 ± 1.59 for Amhara Sayint, Habru, and Raya Kobo, respectively. The average landholding per household in Amhara Sayint, Habru, and Raya Kobo district were 1.91 ± 3.97, 1.22 ± 0.49, and 0.77 ± 0.40 ha, respectively. The average landholding per household showed a significant difference ($P < 0.05$) between study areas, and landholding was higher for Amhara Sayint compared to Raya Kobo.

3.2. Flock Size and Purpose of Keeping. The average goat flock size (both indigenous and crossbred goats) per household in this study was 13.8 ± 7.80, 13.1 ± 28.8, and 8.26 ± 5.40 in Raya Kobo, Habru, and Amhara Sayint district, respectively. The mean flock size per household is comparable with the report of FARM-Africa [19] for Central Highland goats and Sheriff et al. [20] but lower than the report of Gatew et al. [21] for indigenous goats in Borana and Somali areas. The variability of flock size may not be surprising as it is affected by land size (feed source), production system, and agroecology. A higher proportion of crossbred goats was found in Raya Kobo (29.2%) followed by Habru (28.9%) and Amhara Sayint (11.9%). Crossbred goats in Amhara Sayint and Habru had lower exotic gene levels (≤12.5%) due to downgrading for many years. The reason for the lower average number of goat possession of visited farmers in Raya Kobo might be explained by the limitation of the grazing/browsing area and higher disease prevalence during the wet season. Accordingly, most of the farmers sold goats at the beginning of the main rainy season and bought them again at the end of the main rainy season.

The relative importance of livestock species and the purpose of goat keeping are presented in Figure 1. Respondents in the study areas have ranked livestock species according to the priority of importance. Cattle, goat, donkey, chicken, sheep, camel, mule, and beehive have been ranked by respondents as 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th}, 6^{th}, 7^{th}, and 8^{th} in order of importance with indexes of 0.399, 0.379, 0.125, and 0.056 and 0.016, 0.012, 0.008, and 0.004, respectively. Income generation, home meat consumption, saving, manure, and skin were found to be the main reasons for keeping goats with index values of 0.484, 0.355, 0.085, 0.048, and 0.028, respectively. The purpose of goat keeping in this study is consistent with previous studies [20,22].

3.3. Management of Goats. Natural pasture/shrubs, crop aftermath, crop residue, established pasture, hay, and concentrate were mentioned as feed sources during the dry season and have been ranked as 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th}, and 6^{th} with an index value of 0.52, 019, 0.12, 0.11, 0.038, and 0.014, respectively. During the wet season, natural pastures/shrubs, established pasture, and concentrate were mentioned as major feed sources with index value of 0.816, 0.163, and 0.02, respectively. This result is partly consistent with the report of Gatew et al. [21]. Likewise, Zergaw et al. [23] noted that natural pasture is the dominant feed source during wet and dry seasons. Nowadays, area closure for soil conservation and expansion of cropland reduces the size of natural pasture. Thus, introducing other forage development options or strategies to farmers would be important to ensure the sustainability of goat production.

Identification of periods of feed shortages is required for effective intervention or to design an alternative coping mechanism. In this study, the main periods of feed shortage

Table 1: Characteristics of households.

Variables	Amhara Sayint N (%)	Habru N (%)	Raya Kobo N (%)	χ^2-value	P value
Age (years)					
<30	4 (57.1)	0 (0.00)	1 (3.30)		
30–40	2 (28.6)	1 (11.1)	5 (16.7)	23.8	0.001
41–50	0 (0.000	1 (11.1)	10 (33.3)		
51–60	1 (14.3)	7 (77.8)	14 (46.7)		
Sex					
Female	1 (14.3)	0 (0.00)	2 (6.70)	1.32	0.517
Male	6 (85.7)	9 (100)	28 (93.3)		
Education					
Illiterate	1 (14.3)	5 (55.6)	8 (26.7)		
Read and write	0 (0.00)	1 (11.1)	2 (6.70)		
Adult education	0 (0.00)	0 (0.00)	2 (6.70)	7.49	0.485
Primary school	6 (85.7)	3 (33.3)	16 (53.3)		
Secondary school	0 (0.00)	0 (0.00)	2 (6.70)		
Family size	4.00 ± 1.63^{b}	7.44 ± 4.15^{a}	5.93 ± 1.59^{b}	—	0.031
Landholding (ha)	1.91 ± 3.97^{a}	1.22 ± 0.49^{ab}	0.77 ± 0.40^{b}	—	0.046

Least squares means with different superscripts within the same column and class are statistically different. χ^2= chi-square value.

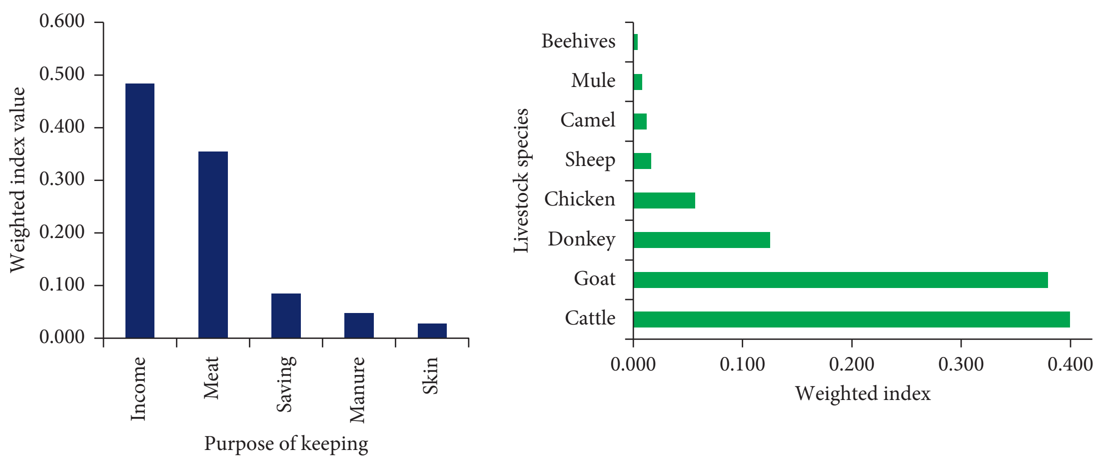

Figure 1: Purpose of goat keeping (left) and relative importance of livestock species (right).

cover were from June to October in the visited areas of Raya Kobo and from January to June in the visited areas of both Habru and Amhara Sayint. During these dearth periods, most (77.3%) of the respondents in all study areas do not supplement their goats while 22.7% of goat keepers supplemented goats with homemade grain, commercial concentrates, green leaves, and salt. In addition, goat keepers in both Raya Kobo and Habru districts supplemented their goats with perennial forage tree leaves through the cut-and-carry system. Likewise, Gatew et al. [21] noted that farmers in Bati area provide green leaves and pod from perennial plants, crop residues collected, and standing hay to cope with a feed shortage. This study demonstrated that the majority (68.3%) of the respondents do not give special management for crossbred goats, and only 31.7% of the respondents supplemented crossbred goats with green leaves through the cut-and-carry system, homemade grain, and commercial concentrate during dearth period, although it was inconsistent.

Pasteurellosis, mange mites, anthrax, and sheep and goat pox were the probable diseases in the study areas with index values of 0.264, 0.167, 0.167, and 0.150, respectively. Although there are veterinary services in all areas, farmers in Raya Kobo and Habru complained about the poor service and low efficiency of veterinary service provided by the government. Due to this, they lost a number of crossbred and indigenous goats each year. Moreover, the remaining crossbreds could not able to express their full genetic potential if there is an unfavorable environment.

Appropriate housing is vital for protecting animals from climatic stress, providing protection against losses by predators, making management easier, and saving labor. The present study revealed that almost all interviewed respondents housing goats separated from other livestock species and kids also separated from their dams during the night for up to one month. This result is in line with the report of Zergaw et al. [23]. In all areas, all of the respondents reported roofed goat shelter in both dry and wet seasons.

Nevertheless, the form of houses differed between households; 84.1% of the respondents use separated houses, and the remaining 13.6% and 2.3% shelter their goats inside the family house and adjacent to the family house, respectively.

3.4. Major Constraints to Goat Crossbreeding. Identification of the major bottlenecks to goat crossbreeding is paramount to ameliorating the productivity of goats and thereby the livelihood of farmers. Feed shortage, a high prevalence of disease and parasites, lack of capital, and poor adaptability of the crossbreds were mentioned by the goat keepers as the most limiting factor for goat crossbreeding (Figure 2). This result is supported by Leroy et al. [24] who noted that the opportunities to express the genetic potential (*i.e.* feed resource and veterinary service) and access to credit are the major determinants of crossbreeding programs in developing countries. The previous studies elsewhere in Ethiopia [25–27] also noted feed shortage and diseases as the major constraints for goat production. Thus, due intervention should be given to these factors while introducing the exotic genotypes to achieve the goal of the crossbreeding program.

3.5. Breeding Value of Disseminated Bucks. The integration of selection with crossbreeding program could enhance genetic progress. To do so, estimation of genetic parameters including breeding value is the prerequisite. The live weight and estimated breeding value (EBV) of disseminated bucks ($n = 73$) and their contemporary group are shown in Table 2. The least-squares mean for three- and six-month weight of Boer × Central Highland goats were 11.8 ± 0.40 and 15.2 ± 0.37 kg, respectively. The three-month weight of Boer × Central Highland crossbred goats was lower than the report of Zhang et al. [28] and Menezes et al. [29] for Boer goat. Likewise, higher three-month and six-month weight than the current study were noted by Al-Saef [30] for Aradi goat, Damascus goat, and their crossbreds. The variation of performance among breeds could be attributed to the genetic potential of the breed, nutrition, and overall management variability.

The overall mean estimated breeding values for three- and six-month weight of disseminated bucks were 0.53 and 0.31 kg, respectively. The EBV of selected bucks must be higher than the mean EBV of their contemporary group to be effective in the genetic improvement program aiming productivity improvement. However, the three-month weight EBV for Boer × Central Highland crossbred goats disseminated in Amhara Sayint and Habru district was found to be lower than the average EBV of their contemporary group. Likewise, the six-month weight EBV for Boer × Central Highland crossbreds distributed in Amhara Sayint was lower than the contemporary group means. The three- and six-month weight EBV for bucks disseminated in Raya Kobo were found to be better than bucks disseminated in the other areas. The selection of bucks and dams based on EBV for the traits of interest could enhance the genetic progress.

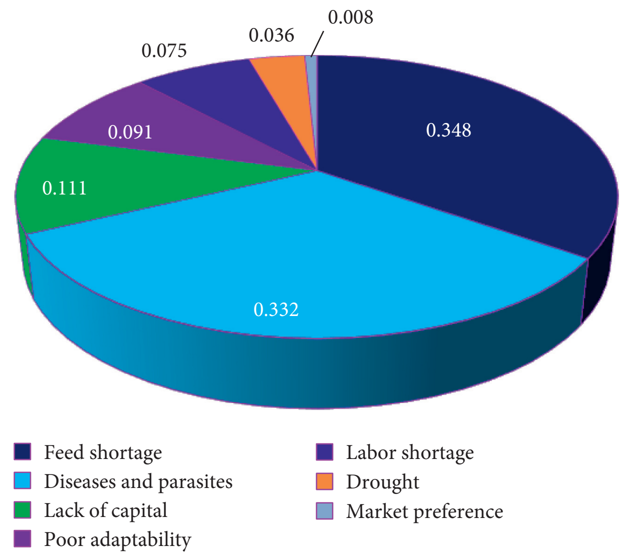

Figure 2: Major constraints to goat crossbreeding (the pie chart is based on weighted index).

3.6. Perceptions of Farmers on Crossbred Goats

3.6.1. Reproductive Performance of Crossbred Bucks. The reproductive performance of a flock is strongly influenced by the male, and the fertility of individual males has a greater influence on flock performance than does the fertility of individual females [31]. The odds of the libido of Boer × Central Highland crossbred bucks were 0.26 times lower ($P < 0.01$) than the indigenous Central Highland bucks (Table 3). Besides, crossbred bucks mate lower (odds ratio = 0.49, 95% CI = 0.20–0.81, $P < 0.05$) number of does per day compared to indigenous bucks. During focus group discussion, almost all of the respondents in all study areas mentioned that crossbred bucks cannot challenge indigenous bucks during mating, i.e. crossbreds are not aggressive and cannot mate if they are kept with indigenous bucks. This depicts the superiority of the indigenous goats in terms of sexual desire and mating efficiency compared with crossbred goats. The lower libido for crossbred bucks could be explained by a lack of appropriate management (preconditioning, good nutrition, and appropriate shelter) before and during mating. Besides, according to Maurya et al. [32], the male sexual behavioural pattern, seminal attributes, the process of spermatogenesis, and the ability of sperm to fertilize the ovum were affected by heat and nutritional stress. In addition, Mekashsa [33] reported that supplementation of indigenous Ogaden bucks significantly improves their testicular size, sperm production, and sperm motility. However, farmers would allocate statistically similar scores for both genotypes in terms of the number of mount/ejaculation and frequency of service/doe.

3.6.2. Productive Performance of Crossbred Goats. Goat keepers' perception of productive and traits of Central Highland and Boer × Central Highland crossbred goats is presented in Table 4. Boer crossbred goats are 9.16 times

Table 2: Estimated breeding values (LSM±SE) of disseminated bucks.

Source of variation	N	Three-month weight			Six-month weight		
		Weight (kg)	IEBV (kg)	GEBV (kg)	Weight (kg)	IEBV (kg)	GEBV (kg)
Overall mean	73	11.8 ± 0.40	0.53 ± 0.11	0.27 ± 0.03	15.2 ± 0.37	0.31 ± 0.10	−0.02 ± 0.01
Amhara sayint	10	9.37 ± 0.40	0.29 ± 0.14	0.51 ± 0.00	13.2 ± 0.42	−0.07 ± 0.11	−0.003 ± 0.0
Habru	11	11.8 ± 1.29	0.18 ± 0.21	0.25 ± 0.10	15.6 ± 1.14	0.33 ± 0.31	0.02 ± 0.02
Raya Kobo	52	12.1 ± 0.46	0.65 ± 0.14	0.24 ± 0.04	15.5 ± 0.43	0.37 ± 0.12	−0.03 ± 0.01

IEBV, mean estimated breeding value of disseminated goat; GEBV, mean estimated breeding value of contemporary group.

Table 3: Odds ratio estimate for reproductive traits of crossbred and indigenous bucks.

Trait	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
FSD	Indigenous	3.30	6.70	36.7	33.3	20.0	1.00
	Crossbred	3.20	9.70	32.3	35.5	19.4	0.98 (0.39–2.44)^{ns}
Libido	Indigenous	2.60	2.60	10.5	44.7	39.5	1.00
	Crossbred	0.00	5.30	55.3	15.8	23.7	0.26 (0.11–0.62)**
NME	Indigenous	0.00	8.60	28.6	42.9	20.0	1.00
	Crossbred	0.00	5.70	28.6	37.1	28.6	1.33 (0.56–3.14)^{ns}
NSD	Indigenous	0.00	6.30	21.9	43.8	28.1	1.00
	Crossbred	0.00	18.2	36.4	18.2	27.3	0.49 (0.20–0.81)*

VP, very poor; P, poor; M, moderate; G, good; VG, very good; OR, odds ratio; CI, confidence interval. FSD, frequency of service/doe; NME, number of mount/ejaculation; NSD, number of services/day. Ns, $P > 0.05$; **, $P < 0.05$; **, $P < 0.01$.

Table 4: Odds ratio estimates of the productive attributes (crossbred vs indigenous goats).

Attributes	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Physical appearance	Indigenous	—	10.9	30.4	26.1	32.6	1.00
	Crossbred	—	—	21.7	32.6	45.7	9.16 (3.82 to 21.9)***
Growth rate	Indigenous	3.20	9.70	41.9	16.1	29.0	1.00
	Crossbred	—	—	—	42.2	57.8	20.9 (6.42 to 39.6)***
Meat yield	Indigenous	—	3.10	34.4	37.5	25.0	1.00
	Crossbred	—	—	16.7	40.0	43.3	3.94 (1.47 to 10.6)**
Milk yield	Indigenous	2.90	—	11.8	50.0	35.3	1.00
	Crossbred	—	—	8.9	28.9	62.2	6.99 (2.47 to 19.8)***
Market preference	Indigenous	2.50	5.00	55.0	27.5	10.0	1.00
	Crossbred	—	—	7.50	50.0	42.5	12.5 (4.53 to 34.8)***

VP, very poor; P, poor; M, moderate; G, good; VG, very good; OR, odds ratio; CI, confidence interval. Ns, $P > 0.05$; ***, $P < 0.001$; **, $P < 0.01$.

($P < 0.001$) more likely to be preferred by farmers than the indigenous goat for their better physical appearance. The odds of a higher growth rate of the crossbred goat were 146% higher than the odds for indigenous goats. Farmers are more likely to allocate a higher score to crossbred goats compared with the indigenous goats (odds ratio = 6.99; $P < 0.001$) for their greater milk yield. For Boer crossbreds, the odds of being preferable in the market are 12.5 times as higher as the odds for the indigenous goats. In Ethiopia, the superiority of crossbred goats and sheep in terms of productive traits with a slight reduction in reproductive traits was reported elsewhere [34–37].

Farmers said that the meat from Boer × Central Highland crossbred goats is lean and thus more preferable in the highland and semiurban areas, whereas, in lowland rural areas, meat from indigenous goats is preferable to crossbreds due to its higher fat content and fine test. They said that indigenous goats are selective feeders, i.e. browsing medicinal plants selectively and focusing on browsing than crossbred goats. This feeding behavior of indigenous goats may have resulted in good meat quality. Generally, in terms of physical appearance, growth rate, meat yield, milk yield, and market preference, crossbred goats were preferable to indigenous goats. This implies the superiority of crossbred goats for productive traits and the suitability of crossbreeding with Boer goat to ameliorate the productivity traits of goats.

3.6.3. Adaptability of Crossbred Goats. The perception of farmers about the adaptability of Boer × Central Highland crossbred goats relative to the indigenous Central Highland goats is shown in Table 5. In low-to-medium input production systems, fitness traits such as survival and reproduction rate will often be the key determinants of overall economic value. Thus, giving more credit for adaptability is imperative due to the prevailing stresses arising from high temperature, parasites and disease, and poor nutrition. In

Table 5: Odds ratio estimates of the adaptability attributes (crossbred vs indigenous goats).

Attributes	Genotype	VP (%)	P (%)	M (%)	G (%)	VG (%)	OR (95% CI)
Feed requirement	Indigenous	2.40	17.1	36.6	19.5	24.4	1.00
	Crossbred	—	4.70	2.30	20.9	72.1	34.7 (14.1 to 55.7)***
Diseases resistance	Indigenous	—	—	18.4	63.2	18.4	1.00
	Crossbred	13.6	45.5	27.3	9.10	4.50	0.05 (0.02 to 0.13)***
Kid survival	Indigenous	2.30	4.7	60.5	32.6	0.00	1.00
	Crossbred	—	34.2	39.5	21.1	5.30	0.08 (0.03 to 0.23)***
Drought tolerance	Indigenous	—	4.50	18.2	52.3	25.0	1.00
	Crossbred	2.30	34.1	50.0	9.10	4.50	0.02 (0.01 to 0.08)***
Cold tolerance	Indigenous	—	—	5.00	25.0	70.0	1.00
	Crossbred	5.10	23.1	30.8	17.9	23.1	0.58 (0.26 to 1.30)^{ns}
Heat tolerance	Indigenous	—	10.3	33.3	38.5	17.9	1.00
	Crossbred	6.70	20.0	46.7	20.0	6.70	0.04 (0.01 to 0.10)***
Walking ability	Indigenous	—	—	11.4	47.7	40.9	1.00
	Crossbred	—	22.5	52.5	22.5	2.50	0.02 (0.00 to 0.06)***

VP, very poor; P, poor; M, moderate; G, good; VG, very good; OR, odds ratio; CI, confidence interval. Ns, $P > 0.05$; ***, $P < 0.001$; **, $P < 0.01$.

this study, for Boer × Central Highland crossbred goats, the odds of being disease-resistant were 0.05 times as lower ($P < 0.001$) as the odds for an indigenous goat being disease-resistant. Likewise, the odds of survival of crossbred kids were 0.08 times lower ($P < 0.001$) than indigenous kids. Once the crossbreds are affected by diseases, it is difficult to treat them and they need high medical costs. Most of the disseminated crossbred bucks were not served for more than one or two years. Even though both genotypes focus on grazing and browsing, crossbred goats spend more time in grazing and the reverse is true for indigenous goats. This grazing behavior of crossbreds might be the possible reason for the susceptibility of diseases and internal parasites.

Other adaptability traits such as drought tolerance, heat resistance, cold resistance, and walking ability of crossbred goats were lowest than the indigenous goats (Table 5). These results are partly agreed with Nigussie [35] who noted that crossbred goats had lower longevity, higher mortality rate, and lower number of births per lifetime than indigenous goats. These all confirm poor adaptability and recovery of crossbreds compared with the indigenous goats; thus, long-term economic and social capital could be substantially reduced due to lower adaptability of exotic goats if the indigenous breeds are fully substituted by crossbreds in the existing infrastructure and production system.

The Spearman's nonparametric rank correlations among the most important traits are shown in Table 6. The correlations of production traits and feed requirement with adaptation traits were found to be negative. This might be the reason why the productive Boer crossbreds were not successful (not adaptable) under the smallholder management system. However, market preferences were positively associated with productivity traits and negatively related to adaptability traits. This could be explained by the marketing structure where goats are sold on a size and live weight basis, and therefore, a heavier and larger goat is expected to fetch a higher market price. This type of preference could be a great threat to adaptive indigenous goats.

3.7. Market/Slaughtering Age and Willingness to Pay. The average market/slaughtering age was 5.12 ± 1.42 and 7.66 ± 2.60 months for Boer × Central Highland crossbred and Central Highland goats, respectively. The market/slaughtering age for Boer crossbreds is earlier than those other indigenous goats such as Abergelle goat (8.98 ± 2.01 to 9.03 ± 2.16 months) and Central Highland goat (6.25 ± 1.88 months) reported by Alemu [38] and also earlier compared with Borena (8.71 months) and short-eared Somali goat (8.48 months) reported by Gatew [26]. Besides, the price of the Boer × Central Highland crossbred goat was higher (by 213 to 372 ETB/head) than Central Highland goats with similar management and age (Table 7). This indicates that farmers are willing to pay more for Boer crossbred goats than Central Highland goats.

3.8. Farmers' Interest for Crossbreeding Program. The success and sustainability of the genetic improvement program are determined by the interest and active participation of participants. Most (80%) of the visited farmers in the Raya Kobo district showed a keen interest in crossbreeding. However, maintaining the Boer × Central Highland crossbred goats during the main rainy season was challenging due to feed shortage, disease prevalence, and parasite infestation. Thus, the crossbreeding activity in this area should be complemented with an improved production environment, value addition, and improved market system. Based on the interview result, 57.1% of the respondents in Amhara Sayint district showed an interest in crossbreeding, but they decided to keep indigenous Central Highland goats after intense focus group discussion. Likewise, 77.8% of the respondents in the Habru district do not want to continue with crossbreeding due to the poor adaptability of the crossbred goats. Therefore, community-based within-breed selection could be conducted in these areas with the active participation of farmers to improve the productivity of indigenous goats.

Table 6: Spearman's rank correlation among important traits.

	PA	GR	MY	HT	WA	DT	DR	KSR	MP	FR
PA										
GR	0.55^{***}									
MY	0.38^{**}	0.49^{***}								
HT	-0.26^{*}	-0.55^{***}	-0.16^{ns}							
WA	-0.30^{**}	-0.54^{***}	-0.32^{*}	0.69^{***}						
DT	-0.25^{ns}	-0.50^{***}	-0.19^{ns}	0.74^{***}	0.72^{***}					
DR	-0.24^{*}	-0.46^{***}	-0.10^{ns}	0.59^{***}	0.57^{***}	0.67^{***}				
KSR	-0.22^{ns}	-0.44^{***}	-0.11^{ns}	0.62^{***}	0.59^{***}	0.55^{***}	0.70^{***}			
MP	0.46^{***}	0.54^{***}	0.24 ns	-0.23^{*}	-0.45^{***}	-0.19^{ns}	-0.15^{ns}	-0.19^{ns}		
FR	0.44^{***}	0.62^{***}	0.31^{*}	-0.46^{***}	-0.49^{***}	-0.40^{***}	-0.38^{**}	-0.34^{**}	0.55^{***}	

PA, physical appearance; GR, growth rate; MY, milk yield; HT, heat tolerance; WA, walking ability; DT, drought tolerance; DR, disease-resistant; KSR, kid survival rate; MP, market preference; FR, feed requirement. ***, <0.001; **, <0.01; ***, <0.05; ns = nonsignificant.

Table 7: Estimated price for indigenous and crossbred goats.

Age category	Estimated price (ETB) (mean ± SD)		*P* value
	Central Highland goat	Boer × Central Highland goat	
3–6 month	717.8 ± 161.2	930.7 ± 124.9	<0.0001
7–9 month	891.0 ± 171.0	1262.5 ± 195.6	<0.0001
10–12 month	1303.3 ± 275.7	1656.6 ± 274.4	<0.0001
>12 month	1525.0 ± 288.1	1897.5 ± 443.8	<0.0001

ETB, Ethiopian birr; SD, standard deviation.

4. Conclusions

Based on the level of production inputs, the production system was classified as a low-input system. Most of the Boer × Central Highland crossbred bucks disseminated to farmers' flock were not selected based on their breeding value. As per farmers' perception, the productivity of Boer × Central Highland goats was superior to Central Highland goats. However, the adaptability, fitness, and libido of crossbred goats under a smallholder management system were not good. Feed shortage and poor veterinary service were the most important factors that influence the crossbreeding program. Therefore, while introducing exotic breeds, it is imperative to give due attention to nutrition and veterinary service. Besides, bucks with high genetic merit should be disseminated to farmers' flock to exploit both additive and non-additive genetic effect. If there is no intervention in these regards, crossbreeding only could not ameliorate goat productivity and community-based within-breed selection would be the apposite option for low-input production system.

Abbreviations

IEBV: Mean estimated breeding value of disseminated goat
GEBV: Mean estimated breeding value of contemporary group
EBV: Estimated breeding value
FSD: Frequency of service/doe
NME: Number of mount/ ejaculation
NSD: Number of services/day
VP: Very poor
P: Poor
M: Moderate
G: Good
VG: Very good
OR: Odds ratio
CI: Confidence interval
PA: Physical appearance
GR: Growth rate
MY: Milk yield
HT: Heat tolerance
WA: Walking ability
DT: Drought tolerance
DR: Disease-resistant
KSR: Kid survival rate
MP: Market preference
FR: Feed requirement
ETB: Ethiopian birr
SD: Standard deviation.

Data Availability

Data available on request due to privacy/ethical restrictions.

Ethical Approval

Not applicable.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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