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The Awassi sire can be used to crossbred with low-productive Tikur local ewes to produce export-marketable weight at yearling under farmer's management in the Ethiopian highlands

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Abstract

A community-based sheep cross breeding project was conducted in Ethiopia with exotic Awassi crossbred rams and less productive indigenous Tikur ewes. Fifty-five Awassi crossbred rams having 46, 48, 56 and 65% Awassi blood levels were purchased and distributed to the participating 84 farmers which had 2,884 breeding ewes. The overall least square mean weights for F1 and F2 generation lambs at birth, day 90, 180, 270 and yearling weight were 3.10 ± 0.01, 13.04 ± 0.07, 16.95 ± 0.08, 20.84 ± 0.11 and 24.42 ± 0.14 kg, respectively. Body weight traits were significantly affected by lambing year for birth weight ($P < 0.05$), 180-day(d) weight ($P < 0.05$), 270-d weight ($P < 0.001$) and 360 d (yearling) weight ($P < 0.001$) but no effect ($P > 0.05$) was noted for 90-d weight (weaning weight). Season of lambing had significant effect ($P < 0.01$) only for birth weight. There was a significant difference ($P < 0.001$) among the different villages for birth weight, and for day 90, 180, 270 and 360 body weights. The study showed that crossing Awassi crossbred rams with Tikur ewes can improve birth weight by 71.27%, 90-d weight by 76.78%, 180-d weight by 63.45% and yearling weight by 76.06% under farmer management practices. Results revealed that crossing Awassi crossbred rams with blood level of 56% and above with local Tikur ewes resulted in superior progenies that can fulfill export live weight standard of 25 kg at yearling weight. The future of Awassi-Tikur sheep farming must focus on feed supplementation strategies and on establishing cooperatives for farmers to improve their livelihoods.

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INTRODUCTION

Sheep serve a range of functions, including providing income, meat, skin, manure, coarse wool, risk avoidance during crop failure, and cultural function during festivals[1]. They possess a high adaptive capacity which allows them to survive in different environments ranging from cold mountainous regions to semi-desert or arid zones[2]. There are approximately 31.3 million sheep in Ethiopia, 99.8% of which are indigenous[3], which are divided into 14 traditional sheep populations and nine breeds[4]. There is a low level of productivity despite traditional importance, availability of a large population, and genetic resources[5]. Therefore, increasing current productivity is imperative for supplying meat to the growing population, increasing export earnings, and improving the quality of life for smallhold farmers[6]. Crossing indigenous livestock breeds with exotic or other local breeds can improve genetics quickly because of breed complementarity and heterosis effects[7].

The fat tailed Awassi sheep is a highly productive dairy breed but capable of producing wool and meat[8]. Awassi also possess desirable characteristics such as tolerance to nutritional fluctuations, diseases and parasites, extreme temperatures in addition to high milk yield and growth abilities[9,10]. To improve their productivity, Ethiopian sheep are often crossbred with Awassi sheep imported from Israel. The Debrebrhan Agricultural Research Center has conducted pilot Awassi crossbreeding activities in model villages using Menz and Wollo local sheep and shown that crossbreeding can result in effective results when appropriate designs and monitoring are used[11].

However, adaptability and performance of crossbred animals were significantly influenced by location, management, and exotic blood level[7,12]. Therefore it is better to determine the appropriate exotic blood based on existing management needs in each area and breed[7]. Among Ethiopia's local sheep breeds, the Tikur breed is found in the North Wollo cool highlands; while this breed is the least productive, but it is adapted to survive extremely cold conditions. Accordingly, this study hypothesized that crossbreeding Awassi sires with Tikur dams would improve production performance and help to produce marketable weight at yearlings under farmer management. Therefore, the purpose of the study was to evaluate the growth performance of crossbred Awassi-Tikur lambs at different exotic blood levels under farmer management.

MATERIALS AND METHODS

We conducted the community-based sheep cross breeding in Wadla district at three villages from May 2007 to July 2011. The district is found in North Wollo, Amhara region, Ethiopia.

Farmer selection

Three villages were selected based on their sheep population and production potential through consultation with the district agricultural and rural development office. In each village, interested farmers for the project were selected in collaboration with district agricultural and rural development office. After farmers' selection, agreement was signed between farmers and the Sirinka Agriculture Research center (SARC) to engage farmers until the end of the project. A total of 84 farmers participated in the project and a total of 2884 Tikur ewes were registered, and ear tagged for this project. Awassi crossbred rams were delivered to farmers individually and in groups, per ewe number. A ram was given to each farmer with over 20 local ewes individually, while three to four farmers with five or more ewes were given a ram together.

Feed management

Farmers' feeding practices involve natural grazing and crop residues as major feed sources.

Animal management

Fifty-five Awassi crossbred rams having 46%, 48%, 56% and 65% Awassi blood levels were bought and distributed to the selected farmers. The selected villages were Mikael, Geiorgis and Mariam villages. The crossbred rams with 65% Awassi blood level had an average age of six months; the other rams that had 46%, 48% or 56% blood levels had an average age of 12 months. The rams were used to mate local breeding ewes. All the animals and newly born crossbred lambs in the project were identified using individual ear tags. To prevent inbreeding, every cross-bred ram given to a farmer or group of farmers was transferred/exchanged to another farmer or group of farmers after one breeding season.

Before the start of the project, all local rams in each flock were castrated to prevent unwanted mating. The crossbred rams have unrestricted access to the ewes and were kept in the same shed at night. During the daytime, they were grazed on natural pasture. In addition, prior to the start of the project, all the breeding ewes received treatment against common health problems, internal and external parasites. During the project period all the animals received health treatment as needed.

Data collection and statistical analysis

Data on weight at birth, day 90 (weaning), 180, 270 and 360 (yearling) were collected using a 50 kg Salter balance scale. The weight of newborn lambs was taken within 24 hr after birth. Subsequent body weights were recorded after 30-d from the date of birth and were considered as monthly weight of lambs in the analysis.

Data analysis was carried out using data obtained from 128 farmers (we excluded incomplete data from 18 farmers). Exotic blood levels in the lambs were 23.44%, 28%, 32.5%, 44.24% and 48.75%. The traits considered in the analysis were, birth weights of lambs, monthly weights of lambs and average daily body weight gains. The average daily body weight gains of lambs for the period from birth to day 90, day 90 to 180, day 180 to 270 and day 270 to 360 were calculated and analyzed separately for each period and location (villages).

A univariate procedure of SAS was used to check for normality. SAS software was used for normality test and to screen outliers. Analysis of variance and estimation of least square means with their standard errors was conducted using the PROC GLM of SAS (version 9.2; SAS Institute Inc., Cary, NC, USA). The main effects considered in the analysis were location (villages), exotic blood levels, sex, year and season of birth. Least squares means were computed for the main effect and separated statistically by pair-wise *t*-tests (PDIFF option of SAS) when $P \leq 0.05$.

Average daily gains (ADG) were calculated in grams (g) for the following intervals:

ADG 1 = ADG between birth weight and body weight at 90-d
ADG 2 = ADG between body weight at 90 and 180-d
ADG 3 = ADG between body weight at 180 and 270-d
ADG 4 = ADG between body weight at 270 and 360-d

The fixed effects for birth weight, 90, 180, 270 and 360-d weights were:

Lamb year of birth (2007, 2008, 2009, 2010, 2011),
Sex (male and female),
Season (Dry; December to May, and Wet; June to November)
Location Wadla district (Geiorgis, Mikael and Mariam villages)
Awassi blood level (23.44%, 28%, 32.5%, 44.24% and 48.75%)

The following model equation was used for statistical calculations:

$$Y_{ijklm} = \mu + YB_i + L_j + SS_k + S_l + EB_m + (YB*SS)_{ik} + E_{ijklm}$$

Where:

Y_{ijklm} = the weights and ADG of the mth lamb
μ = overall mean
YB_i = Fixed effect of lamb birth year (i = 2007, 2008, 2009, 2010, 2011)
L_j = Fixed effect of location (j = Geiorgis, Mikael and Mariam Villages)
SS_k = Fixed effect of lamb birth season (k = dry, wet)
S_l = Fixed effect of lamb sex (l = male, female)
EB_m = Fixed effect of exotic blood level of Awassi (m = 23.44%, 28.0%, 32.5%, 44.2% and 48.75%)
$(YB*SS)_{ik}$ = Interaction of ith birth year with kth season of birth
E_{ijklm} = residual error

RESULTS AND DISCUSSION

Growth performance

The overall least square means body weight of Awassi crossbred lambs at birth weight, day 90, 180, 270 and yearling weights were 3.10 ± 0.01, 13.04 ± 0.07, 16.95 ± 0.08, 20.84 ± 0.11 and 24.42 ± 0.14 kg, respectively, as shown in Table 1. Meanwhile the overall mean growth performance of local Tikur sheep in this study were 1.81 ± 0.06, 7.58 ± 0.19, 10.37 ± 0.23 and 13.87 ± 0.30 kg for birth weight, day 90, 180 and 360, respectively (Table 2). As compared to local Tikur sheep, crossing Awassi crossbred rams with Tikur ewes increased the weights of the yearlings by 71.27%, 76.78%, 63.45%, and 76.06% at birth, 90 d, 180 d, and 180-d, respectively. In comparison with Hassen et al.[13] study, our crossbred lambs

Table 1. Body weight (LSM ± SE) of Awassi-Tikur crossbred sheep based on location and year of birth.

Variable	n	BW ± SE	S	n	BWT 90 ± SE	n	BWT180 ± SE	n	BWT270 ± SE	n	BWT360 ± SE
Overall	2,069	3.10 ± 0.01		785	13.04 ± 0.07	809	16.95 ± 0.08	692	20.84 ± 0.11	642	24.42 ± 0.14
Year of birth		*			ns		*		***		***
2007	203	3.09 ± 0.05^{b}		4	12.84 ± 1.14	7	17.62 ± 0.96^{ab}	6	19.63 ± 1.27^{b}	31	21.18 ± 0.81^{c}
2008	610	3.17 ± 0.04^{ab}		148	12.81 ± 0.28	184	16.92 ± 0.34^{ab}	176	20.09 ± 0.47^{b}	162	24.70 ± 0.57^{b}
2009	814	3.21 ± 0.04^{a}		467	12.58 ± 0.30	498	16.53 ± 0.31^{b}	431	20.17 ± 0.45^{b}	392	25.24 ± 0.52^{b}
2010	367	3.15 ± 0.04^{ab}		98	12.54 ± 0.30	84	17.43 ± 0.41^{a}	48	23.28 ± 0.62^{a}	40	31.82 ± 0.85^{a}
2011	75	3.08 ± 0.07^{b}		68	12.47 ± 0.31	36	16.88 ± 0.69^{ab}	31	22.98 ± 0.99^{a}	17	28.91 ± 1.47^{a}
Villages		***			***		***		***		***
Mariam	254	3.18 ± 0.05^{b}		72	11.13 ± 0.44^{c}	79	15.38 ± 0.49^{c}	75	19.39 ± 0.65^{c}	68	23.86 ± 0.71^{c}
Mikael	602	3.35 ± 0.04^{a}		138	13.53 ± 0.33^{b}	163	18.24 ± 0.37^{b}	146	22.54 ± 0.51^{b}	148	28.29 ± 0.52^{b}
Geiorgis	654	2.79 ± 0.04^{c}		155	14.89 ± 0.35^{a}	187	21.28 ± 0.39^{a}	186	27.28 ± 0.53^{a}	177	33.27 ± 0.57^{a}

$^{a,\ b,c,d}$ Means bearing different superscript in a column differ significantly (P < 0.05). * P < 0.05, ** P < 0.01, *** P < 0.001, LSM = least square mean, BW = birth weight, BWT90 = body weight at 90 d, BWT180 = body weight at 180 d, BWT270 = body weight at 270 d, BWT360 = body weight at 360 d and SE = standard error.

Table 2. Body weight (LSM ± SE) of local Tikur sheep in Wadla district.

Variable	n	BW ± SE	n	BWT90 ± SE	n	BWT180 ± SE	n	BWT360 ± SE
Overall		ns		ns		ns		ns
	50	1.81 ± 0.06	48	7.58 ± 0.19	44	10.37 ± 0.23	11	13.87 ± 0.30
Sex		ns		ns		ns		ns
Female	29	1.87 ± 0.08	27	7.75 ± 0.26	23	10.29 ± 0.32	5	13.92 ± 0.45
Male	21	1.72 ± 0.09	21	7.35 ± 0.29	21	10.46 ± 0.33	6	13.83 ± 0.41
CV		23.22		17.62		14.61		7.19

LSM = least square means, ns = non-significant at P < 0.05, BW = birth weight, BWT90 = body weight at 90 d, BWT180 = body weight at 180 d, BWT270 = body weight at 270 d, BWT360 = body weight at 360 d and SE = standard error.

advantage over local Tikur sheep at birth weight was higher (71.27%) than theirs which reported 8.3% improvement. The heterosis effect may have caused the difference between the two studies because the local breeds used were different. However, the crossbred lamb performance in the present study was lower than those reported by Shaker et al.[14]. These authors reported live birth and weaning weights of 4.37 ± 0.16 kg and 17.84 ± 0.68 kg in crossbred F1 Awassi × Charollais crossbred lambs, 3.85 ± 0.16 kg and 18.94 ± 0.69 kg in crossbred F1 Awassi × Romanov crossbred lambs, and 3.58 ± 0.24 kg and 13.13 ± 1.08 kg in Awassi lambs, respectively. One possible explanation for the observed differences is the breed of dams and their management systems.

The 90-day weight Awassi-Tikur crossbred lambs (13.04 kg) was higher in our study than that reported by Lemma et al.[15] for Awassi crossbred sires (AL) mating with local ewes (LL). Nonetheless, our lamb weight at 180 d is lower than that reported for (AL × LL, 17.26 kg) by the same author. The reason may be related to the availability of feed due to location differences since feed sources are entirely dependent on grazing and farmer management after weaning. Moreover, the 90 and 180-d weight in our study (13.04 and 16.95 kg) were much higher than 10.47 and 15.28 kg reported by Hassen et al.[16] for Awassi crossbred lambs, respectively.

Overall average daily gains of Awassi-Tikur crossbred lambs in this study were 102.44 ± 0.76, 37.56 ± 0.60, and 36.94 ± 0.68 g/day, respectively at 90-d, between 90 and 180-d, and between 270 and 360 -d (Table 3). According to Ameha et al.[17], the weight of yearlings obtained from crossing Awassi and Tikur sheep is within the range of weight approved for export from Ethiopia: 15–30 kg (depending on the importing country's requirements).

Location

At birth and on days 90, 180, 270 and 360, body weights were significantly different among villages (P < 0.001), as shown in Table 1. Geiorgis village lambs were heavier than those born in the other villages on all traits. The presence of large and productive communal grazing lands at Geiorgis village may contribute to improved growth performance. Across Geiorgis, Mikael, and Mariam villages, the weights of Awassi crossbred lambs at yearling were 33.27 ± 0.57 kg, 28.29 ± 0.52 kg and 23.86 ± 1.15 kg, respectively. Even if they are similar breeds, we observed drastic differences in performance across locations due to feed availability and farmer management. This result showed that their performance was different across locations based on management. Similarly, Getachew et al.[18] reported a difference in survival and productivity under farmers' management. Despite the location difference, the overall results showed that crossbreeding Awassi-Tikur crossbred rams improved body weight and help to reached marketable weight earlier than local Tikur breed in the Ethiopian highlands, as shown in Tables 1 and 2.

Lambing year and season of birth

Lambing year had significant effect on body weight and average daily gain of Awassi crossbred lambs as shown in Tables 1 and 3. Except for 90-d body weight, all other variables were affected (P < 0.05) by lambing year (Table 1). At birth, Awassi crossbred lambs born in 2009 (3.21 kg) were heavier (P < 0.05) than those born in 2007 (3.09 kg) or 2011 (3.08 kg). As compared with 2008 (94.50 g/d), pre-weaning average daily gain was significantly higher (P < 0.001) in 2011 (103.09 g/day) and 2010 (105.56 g/d) (Table 3). Moreover, average daily gain at other weight periods also were better in 2010 and 2011 compared to other years. Even though the data was not

Table 3. Average daily gain (g/d) of Awassi-Tikur crossbred sheep based on year of birth, location, and season.

Variable	n	ADG1 ± SE	n	ADG2 ± SE	n	ADG 3 ± SE	n	ADG 4 ± SE
Overall		***		***		***		***
	542	102.44 ± 0.76	675	37.56 ± 0.60	613	34.95 ± 0.67	523	36.94 ± 0.68
Year of birth		**		***		***		***
2007	3	91.30 ± 11.22^{abc}	4	56.88 ± 9.49^{ab}	5	34.40 ± 8.19^{b}	3	24.05 ± 9.90^{bc}
2008	75	94.50 ± 3.31^{c}	140	45.55 ± 2.68^{b}	160	31.37 ± 3.21^{b}	136	36.89 ± 2.95^{c}
2009	311	100.18 ± 2.67^{b}	437	46.02 ± 2.42^{b}	393	33.11 ± 3.10^{b}	353	42.07 ± 2.69^{b}
2010	93	105.56 ± 3.09^{a}	60	56.22 ± 3.25^{a}	28	50.97 ± 4.46^{a}	17	60.16 ± 5.11^{a}
2011	60	103.09 ± 3.28^{ab}	34	33.39 ± 4.83^{c}	27	60.14 ± 5.89^{a}	14	50.21 ± 6.86^{abc}
Villages		***		***		***		***
Mariam	71	85.98 ± 4.48^{c}	72	49.85 ± 3.77^{b}	73	42.78 ± 4.07^{b}	64	44.92 ± 3.82^{c}
Mikael	117	107.98 ± 3.46^{b}	130	56.56 ± 2.94^{a}	123	44.60 ± 3.36^{b}	92	52.95 ± 3.17^{b}
Giorgis	121	119.08 ± 3.69^{a}	130	59.26 ± 6.10^{a}	123	62.46 ± 3.47^{a}	92	60.28 ± 3.33^{a}
Season		ns		ns		ns		ns
Dry	294	99.28 ± 3.61	459	44.06 ± 2.92	439	42.51 ± 3.51	385	39.31 ± 3.40
Wet	248	98.57 ± 4.46	216	51.17 ± 4.08	174	41.49 ± 4.30	138	46.04 ± 4.73

$^{a, b,c,d}$ Means bearing different superscript in a column differ significantly (P < 0.05). * P < 0.05, ** P < 0.01, *** P < 0.001, ADG 1 = ADG between (birth weight) and (body weight at 90 d), ADG 2 = ADG between (body weight at 90 d) and (body weight at 180 d), ADG 3 = ADG between (body weight at 180 d) and (body weight at 270 d), ADG 4 = ADG between (body weight at 270 d) and (body weight at 360 d) and SE = standard error.

recorded, the drought situation in 2009 could have caused a feed shortage in the study area, resulting in a decrease in Awassi-Tikur cross lamb growth rate. Contrary to this, in 2010 and 2011, there was sufficient precipitation and F2-generations were born with high exotic blood levels, contributing to greater growth rates in crossbred lambs. In most cases, body weight differences between years can be attributed to variation in precipitation and its effect on pastures, forages, and other feeds, which can either directly affect lambs or indirectly through dams by affecting milk production of ewes. Similarly, Albial et al.[19], Shaker et al.[20] and Lemma et al.[15] reported the effect of lambing year on the growth rate of sheep breeds.

At birth weight, lambs born in the dry season were significantly heavier than lambs born in the wet season (P < 0.01) (Table 4). Lambing seasons difference in body weight and gain have been attributed to variation in rain precipitation and its impact on pastures, forage, and feed availability. Consistent with our results, Albial et al.[19] reported higher birth weight during the dry season. The differences in birth weight between these seasons are potentially explained by moderate weather conditions and green forages available during pregnancy and lambs' growth stages. In contrast to our study, lambs born during the rainy season were heavier at birth and weaning and grew faster than lambs born during the light rainfall or the dry season[13,18].

Furthermore, there were significant interactions between year and season for birth weight, 180-d weight, 270-d weight, and yearling weight (P < 0.05), as shown in Table 5. As a result of varying rainfall patterns across years, the seasons effect was not constant during the study period.

Lamb sex

All traits were non-significant (P > 0.05) for Lamb's sex (Table 4). However, most studies showed significant differences between sex and males having higher weight and gain than females[21−23].

Exotic blood level

Body weight was significantly affected by Awassi blood levels on days 90, 270, and 360 (P < 0.001), as well as on day 180 (P < 0.05) (Table 4). Despite this, blood levels did not affect birth weight (P > 0.05). Further, Hassen et al.[16] reported that birth and weaning weights were significantly increased by Awassi blood levels up to 75%.

Table 4. Body weight (LSM ± SE) of Awassi-Tikur crossbred sheep based on season, sex and exotic blood level.

Variable	n	BW ± SE	n	BWT90 ± SE	n	BWT180 ± SE	n	BWT270 ± SE	n	BWT360 ± SE
Season		**		ns		ns		ns		ns
Dry	1,209	3.19 ± 0.04^{a}	497	12.99 ± 0.32	533	16.90 ± 0.39	489	21.55 ± 0.54	466	26.71 ± 0.51
Wet	860	3.09 ± 0.09^{b}	288	12.30 ± 0.46	276	17.25 ± 0.45	203	20.91 ± 0.65	176	26.03 ± 0.74
Sex		ns		ns		ns		ns		ns
Female	1,021	3.15 ± 0.05	410	12.75 ± 0.34	437	17.20 ± 0.39	377	20.90 ± 0.56	350	26.22 ± 0.54
Male	1,048	3.13 ± 0.06	375	12.55 ± 0.41	372	16.95 ± 0.48	315	21.56 ± 0.70	292	26.51 ± 0.80
Awassi Blood		ns		***		*		***		***
23.44%	548	3.10 ± 0.03	105	12.01 ± 0.32^{bc}	123	16.05 ± 0.35^{b}	116	19.67 ± 0.47^{c}	119	24.16 ± 0.54^{c}
28.00%	69	3.05 ± 0.06	23	11.26 ± 0.48^{c}	24	17.05 ± 0.56^{ab}	23	22.62 ± 0.72^{a}	20	25.99 ± 0.92^{b}
32.50%	1,414	3.08 ± 0.02	638	12.56 ± 0.25^{b}	644	17.26 ± 0.27^{a}	540	21.74 ± 0.37^{ab}	494	25.65 ± 0.45^{b}
44.24%	21	3.08 ± 0.11	9	12.96 ± 0.75^{ab}	9	17.78 ± 0.93^{ab}	5	19.13 ± 1.40^{bc}	--	---
48.75%	17	3.39 ± 0.12	10	14.46 ± 0.72^{a}	9	17.23 ± 0.89^{ab}	8	22.99 ± 1.28^{a}	9	29.68 ± 1.55^{a}
CV		15.86		14.68		13.97		13.92		14.32

$^{a, b,c}$ Means bearing different superscript in a column differ significantly (P < 0.05). * P < 0.05, ** P < 0.01, *** P < 0.001, LSM = least square mean, BW = birth weight, BWT90 = body weight at 90 d, BWT180 = body weight at 180 d, BWT270 = body weight at 270 d, BWT360 = body weight at 360 d and SE = standard error.

Table 5. Two-way table for the interaction between year of birth and season of birth of Awassi-Tikur crossbred sheep.

Year of birth	Birth season	n	BW ± SE	n	BWT90 ± SE	n	BWT180 ± SE	n	BWT270 ± SE	n	BWT360 ± SE
			**		ns		***		*		ns
2007	Dry	116	3.18 ± 0.06^{b}	3	13.51 ± 1.15	3	15.96 ± 1.41^{ab}	3	19.32 ± 1.75^{bcd}	16	22.07 ± 1.03
2007	Wet	87	3.01 ± 0.06^{c}	1	12.16 ± 1.95	4	19.27 ± 1.23^{a}	3	19.94 ± 1.74^{bcd}	15	20.27 ± 1.03
2008	Dry	383	3.16 ± 0.05^{b}	99	12.64 ± 0.30	111	16.37 ± 0.37^{b}	108	19.67 ± 0.51^{d}	110	24.05 ± 0.58
2008	Wet	227	3.18 ± 0.05^{b}	49	12.99 ± 0.36	73	17.47 ± 0.40^{ab}	68	20.50 ± 0.55^{cd}	52	25.35 ± 0.70
2009	Dry	447	3.29 ± 0.04^{a}	296	12.83 ± 0.25	326	16.68 ± 0.32^{b}	318	19.83 ± 0.45^{d}	293	25.08 ± 0.52
2009	Wet	367	3.14 ± 0.04^{b}	171	12.33 ± 0.28	172	16.39 ± 0.35^{b}	113	20.50 ± 0.52^{c}	99	26.41 ± 0.60
2010	Dry	218	3.15 ± 0.05^{b}	56	12.81 ± 0.34	61	17.77 ± 0.41^{ab}	32	24.24 ± 0.66^{a}	32	31.91 ± 0.77
2010	Wet	149	3.15 ± 0.05^{b}	42	12.28 ± 0.38	23	17.08 ± 0.58^{b}	16	22.32 ± 0.85^{b}	8	31.73 ± 1.35
2011	Dry	45	3.17 ± 0.08^{abc}	43	13.20 ± 0.36	32	17.73 ± 0.50^{ab}	28	24.67 ± 0.68^{a}	15	30.44 ± 1.06
2011	Wet	30	2.98 ± 0.10^{c}	25	11.75 ± 0.45	4	16.03 ± 1.24^{b}	3	21.30 ± 1.77^{abcd}	2	27.39 ± 2.60
CV			16.45		14.94		13.72		13.83		14.32

[a, b,c,d] Means bearing different superscript in a column differ significantly (P < 0.05). * P < 0.05, ** P < 0.01, *** P < 0.001, LSM = least square mean, BW = birth weight, BWT90 = body weight at 90 d of age, BWT180 = body weight at 180 d of age, BWT270 = body weight at 270 d of age, BWT360 = body weight at 360 d of age and SE = standard error.

Table 6. Average daily gain (g/d) of Awassi-Tikur crossbred sheep based on sex, and Awassi blood level.

Variable	n	ADG1 ± SE	n	ADG2 ± SE	n	ADG 3 ± SE	n	ADG 4 ± SE
Sex		ns		ns		ns		ns
Female	284	97.79 ± 3.89	358	49.41 ± 3.11	329	41.43 ± 3.49	279	39.18 ± 3.59
Male	258	100.07 ± 4.18	317	45.82 ± 3.56	284	42.57 ± 4.84	244	46.18 ± 4.18
Awassi blood		ns		***		***		*
23.44%	97	95.80 ± 3.20	103	38.26 ± 2.95^{c}	112	39.84 ± 2.98^{c}	97	37.79 ± 3.41^{b}
28.00%	21	91.31 ± 4.64	22	61.01 ± 4.21^{a}	19	57.94 ± 4.55^{a}	15	34.34 ± 5.11^{b}
32.50%	411	98.99 ± 2.55	534	48.02 ± 2.33^{b}	471	46.86 ± 2.42^{b}	405	42.22 ± 2.98^{ab}
44.24%	9	109.59 ± 7.03	9	57.06 ± 6.36^{ab}	5	25.06 ± 8.14^{c}		
48.75%	4	98.94 ± 9.27	7	33.71 ± 6.53^{c}	6	40.29 ± 9.84^{abc}	6	56.35 ± 7.73^{a}
CV		17.18		41.78		47.48		41.91

[a, b,c,d] Means bearing different superscript in a row differ significantly (P < 0.05). * P < 0.05, ** P < 0.01, *** P < 0.001, ADG 1 = ADG between (birth weight) and (body weight at 90 d), ADG 2 = ADG between (body weight at 90 d) and (body weight at 180 d, ADG 3 = ADG between (body weight at 180 d) and (body weight at 270 d), ADG 4 = ADG between (body weight at 270 d) and (body weight at 360 d) and SE = standard error.

The average daily gain of crossbred Awassi-Tikur among exotic blood levels did not show significant effects until weaning (90 days). However, the differences were significant (P < 0.001) after weaning (Table 6). We found that all the Awassi exotic blood levels in our study met Ethiopian marketable standards for export marketing between 15–30 kg. However, a higher standard of weight above 25 kg was achieved at yearling when Awassi sires with 56%–65% exotic blood levels were used to produce lambs with blood levels greater than 28% Awassi-Tikur lamb.

CONCLUSIONS

In the highlands of North Wollo zone, where sheep production is the mainstay of the economy, Awassi crossbred rams crossed with Tikur ewes proved to be able to adapt well to cold weather, leading to an increase in birth weights, 90, 180, and 360-d weights by 71.27%, 76.78%, 63.45%, and 76.06%, respectively. The results of this research showed that cross-breeding Awassi crossbred rams with blood levels of 56% and above can produce superior progeny that can produce yearling weight that meet the export live weight standard of 25 kg. Therefore, this study showed crossbred lambs can perform well under traditional conditions and can be used as a reliable approach/technology in the highlands of North Wollo and other similar agro-ecological regions to improve the livelihood of farmers. It would be helpful to scale up this approach and introduce it in various highland regions. To improve farmers' livelihoods and secure sustainable production, future research should examine different feed supplementation strategies to achieve export marketable weight at an earlier age.

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Conflict of interest

The authors declare that they have no conflict of interest.

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