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Effect of genotype and environment on the productive and survivability traits of lambs under a community-based management system

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ABSTRACT

The aim of this study was to evaluate the growth and survival of local and Dorper crossbred lambs managed under a community-based management system, using data collected between 2012 and 2021. The fixed effects considered were breed, location, sex, type of birth, parity, season, and year of birth. The results revealed that Dorper crossbred lambs consistently weighed and gained more than local lambs ($p<0.0001$) at all ages and that environmental factors such as location, sex, type of birth, parity, season, and year of birth had considerable influence on most growth traits at all ages. The mean birth weight of local, low-grade, and high-grade Dorper crossbred lambs were 2.12 ± 0.04, 2.94 ± 0.03, and 3.08 ± 0.03 kg, respectively. The corresponding pre-weaning daily gain was 89.12 ± 1.85, 112.16 ± 1.38, and 117.98 ± 1.71 g/day, respectively. The post-weaning body weight gain at 90-180 days for the same groups was 32.6 ± 2.16, 46.85 ± 1.62, and 45.93 ± 1.98 g/day, respectively. Dorper crossbred lambs exhibited a bodyweight advantage of up to 45%, 31%, 34%, and 28% over local lambs at birth, 3, 6, and 12 months of age, respectively. Lambs born in the dry season had the lowest weaning ($p<0.0001$) and six-month ($p = 0.0098$) weight compared to those born in the rainy seasons. Lamb genotype didn't have a significant influence on the survival of lambs at all ages, but most environmental factors influenced survivability. Lambs born to ewes in their 5th parity and above had a mortality risk of 0.51 times higher than those born to ewes in their 1st to 4th parity at the age of 6- months. Year of lambing affected lamb pre-weaning ($\chi 2 = 0.0003$) and post-weaning ($\chi 2 = 0.0001$) survival. Compared to the base year 2021, lambs born in 2017 and 2018 had a higher risk of mortality at 6-month (10.1 and 15.9 times, respectively) than those born in 2021. Season of birth also significantly ($\chi 2 <0.001$) affected lamb survivability, with lambs born in the dry season, having a higher mortality risk at weaning (0.46 times) and yearling (0.66 times). Lambs with a birth weight of 2 kg and below had a 2.3 times higher survival risk at 6-months compared to lambs born with 3 kg and above. In conclusion, Dorper crossbred lambs can be considered to improve lamb growth performance and produce fast-growing lambs. However, the study recommends further research to validate the crossbreeding program (considering the influential production environment, research on supplementation for lambs in the dry-season, adjusting the mating season, and the economic feasibility of crossbreeding are suggested).

1. Introduction

Sheep production is an important agricultural engagement and has made a considerable contribution to smallholder farmers in generating income, and securing livelihoods [1–3]. Studies made by Ref. [4], predicted that small ruminants would provide half of the red meat in sub-Saharan Africa by the year 2025. According to Ref. [5], sheep and goats account for about 90% of the live animal and 92% of skin and hide export value, and 37% of the meat consumed in Ethiopia. Sheep alone contributes 21% of the total ruminant livestock, meat output of the country, with the annual national mutton production estimated to be at 77 thousand metric tons [6]. On the other hand, the demand for sheep and goat meat is increasing, and this triggered the consumption of red meat to increase by 5-6% annually in developing countries [7].

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Most developing countries, including Ethiopia, usually depend on non-specialized multipurpose breeds and follow extensive production systems besides control over breeding animals is often difficult [8]. Existing sheep breeds are adapted to the environmental condition that is characterized by feed scarcity and disease challenges [9,10]. Conversely, the high number of animals, in relation to the dwindling grazing land, climate change and rainfall variability, small landholding size, and decreasing land productivity are existing threats to livestock productivity [11]. Despite all these challenges, studies indicated that local breeds are adaptive but low producers and are not likely to continue sustaining the fast-growing demand for animal-source food that is created everywhere currently [12,13]. Similarly, it is widely recognized that the productivity of sheep in Ethiopia is relatively low. For instance, a yearling local sheep is estimated to yield a carcass weight of only 9-10 kg [12],14, and the average meat production per sheep is estimated to be between 3 and 3.5 kg per year in a given population [6,15].

The low market weight of indigenous sheep breeds affects the desired market weight and [16] has documented this as an important limiting factor on the profitability of sheep in Ethiopia. According to Ref. [12], in the sheep industry, fast-growing and early-maturing sheep are more profitable compared to the slow-growing and late-maturing ones since the main product is mutton. Hence, the productivity of sheep can be improved through crossbreeding with exotic breeds or selection within the local breeds. Crossbreeding is considered as one of the options and it is a potentially attractive breed improvement method due to its quick benefits as the result of breed complementarity and heterosis effects [17–19]. As a result, there has been a significant increase in the transfer of genetic material in recent years [20]. For example, since 1944, a number of exotic sheep breeds have been introduced to Ethiopia with the aim of enhancing the productivity of the local sheep population [2,8,21]. According to the review reports by Ref. [8], the selection of breeds for crossbreeding in the past had primarily prioritized physical appearance over the interests of and preferences of farmers.

On the other hand, the needed infrastructure was limited and the breeding strategy and ram dissemination approaches were not efficiently set and organized. [22], stated that resourceful environments, as well as well-developed infrastructure and markets, have favored such programs. According to multiple authors [23,24], the adoption of livestock technologies in developing countries has been low due to poor resource bases and environmental conditions faced by the farmers. For instance, the proportion of exotic and crossbred sheep population in Ethiopia remains low, 0.41, and 0.08% for hybrid, and exotic, respectively [3] indicating that research and development efforts for sheep crossbreeding in Ethiopia did not deliver the anticipated benefit to smallholder farmers so far. Conversely, governments have generated excessive interest in crossbreeding as a response to the need for higher productivity in order to sustain food security and promote economic development; Owing to this, the introduction of a new specialized meat breed (Dorper) has been made to improve meat production [8,13,25]. According to Ref. [26], the Dorper sheep are known for their fast growth rate, high-quality meat, and adapt to different environmental conditions. Originally bred in South Africa, Dorper sheep have become increasingly popular with farmers around the world due to their ability to thrive in a wide range of production systems. Their docile temperament also makes them easy to handle and manage. Dorper sheep are versatile and productive breed that offers many benefits to farmers looking to improve flock performance and meat production. Since 2006, the Dorper breed has been used as an improver breed in Ethiopia, following breeding and ram dissemination strategies outlined by Ref. [2]. However, there is a lack of comprehensive studies comparing the performance of Dorper crossbreds to local contemporaries raised in the community-based management system. Such strategies are needed to substantiate the benefits of sheep crossbreeding smallholder farmers. By conducting thorough research on the performance of Dorper crossbreds compared to local breeds raised under community-based management systems, farmers and policymakers can gain valuable insights into the potential benefits of crossbreeding programs. This can help inform decision-making and encourage the adoption of improved breeding strategies that could lead to better flock performance and increased productivity for smallholder farmers.

Productive performance and survivability of lambs can be influenced by various factors, including animal genotype litter size, sex, season and year of birth, parity of birth, production environment, and management differences [12,27–30]. However, there is a lack of comprehensive evaluation of the performance of Dorper crossbred and local genotypes managed under similar on-farm conditions. This limits the availability of adequate and reliable information for future breeding and improvements of sheep in Ethiopia. To address this gap in knowledge, the objective of our study was to examine the effects of genotype and environmental factors on the productive and survivability of Dorper crossbred and local lambs raised under community-based management systems. By conducting a rigorous evaluation of the performance of different genotypes under similar conditions, we can generate valuable information that can inform future breeding and improvement programs.

2. Materials and methods

2.1. Study location

The study was conducted in six different areas of Ethiopia, namely Basona-Worana, Efratana-Gidim, Kewet, Merhabete, Kobo, and Yabello. These locations are situated between 3^0 8' 60.00" and 12^0 14' 60.00" in the North and 37° 18' 03'' and 39° 57' 38.28" in the East (Table 1). The study areas have an altitude range of 1285 to 2827 m.a.s.l and the average annual rainfall varies between 600 and 1062.4 mm. The minimum and maximum temperatures recorded were 6.02 ^{o}c and 33.0 ^{o}c, respectively.

2.2. Study flock and management practices followed

This study utilized indigenous sheep breeds, namely Menz, Afar, Local Merhabete, Tumelie, and Blackhead Somali ewes, whose characteristics have been described by Refs. [10,31,32]. Starting in 2012, volunteer farmers in the study areas were organized into communities to practice crossbreeding programs. The staff of Debre-Birhan, Sirinka, and Yabello Agricultural Research centers provided hands-on training on Dorper crossbreeding. Farmers who had 4-5 indigenous breeding ewes with common grazing and watering points were organized into Dorper breeding groups, and Dorper rams were obtained regularly from the research system. To prevent inbreeding, a Dorper ram is designated to mate with 20-25 breeding ewes, and after a year, a new ram was introduced to the breeding group. The genetic material was not exchanged among the six sites, but within each site. The responsibility of managing the breeding rams was assigned to each member of the breeding group when the ram was within their flock. Natural mating was utilized, and the primary source of feed for the flock was natural grazing material found in the study sites. To ensure optimal nutrition for their breeding rams, farmers provided supplementary feed using the resources available to them.

The flocks of farmers were vaccinated against common sheep diseases in their respective areas and were treated against external and internal parasites following the protocol from the research centers. These treatments were administered at the beginning of the project and then every 3-6 months.

2.3. Traits considered and data collected

Enumerators were recruited from the respective sites and trained by the research staff to carry out community-based Dorper crossbreeding tasks using farmers' flocks. Each animal was assigned a unique plastic ID

Table 1
Description of the study areas.

Description of study sites	Study Sites					
	Basona-Worana	Merhabete	Efratana- Gidim	Kewet	Kobo	Yabello
Global Position						
Altitude (m.a.s.l.)	2827	2225	1448	1285	1470	1707.41
Latitude (North)	9°40'35.97"N	10° 3'25.39"N	10°20'22.50"N	10° 0'0.12"N	12⁰ 14' 60.00''	3⁰ 8'46''- 10⁰ 09' 04''
Longitude (East)	39°31'58.79"E	38°59'34.58"E	39°57'38.28"E	39°53'52.37"E	39⁰ 29' 59.99''	37⁰ 18' 03''- 43⁰ 04' 24''N
Temperature (°C)						
(min)	6.02	12.5	14.67	14.9	19.0	19
(max)	21.03	26.1	28.07	31.46	33.0	24
(Average)	13.5	19.3	21.3	23.19	23.1	21.5
Rainfall (mm)						
(Average)	758	934	1048	1062.4	630	600

at birth or upon joining the flock through purchase or gift. Pedigree information, mortality dates, date of birth, date of weaning, date of 6 months, date of yearling, and respective body weight measurements were collected and recorded in the master breeding herd book prepared for this purpose. The lamb birth weight was taken within 24 h of birth using a salter balance and graduated at 100 g. Body weights at weaning, 6 months, and 12 months were collected and recorded as per the plan. The growth traits that were considered included birth weight (BWT), weaning weight (WWT), 6-month weight (SMWT), and 12-month weight (YWT). Pre-weaning average daily weight gain (PRWADG) from birth to 90 days and post-weaning average daily gain (POWADG) from 90 to 180 and 180-365 days were also calculated from the existing data. The mating and crossbreeding system followed was outlined in Dorper Sheep strategy documents and other relevant materials [2,13, 33].

2.4. Data sets

The study utilized data sets generated between 2012 and 2021, consisting of birth weight measurements of 4066 lambs. The lambs were of different genotypes, with 23.4% being local, 47.8% being Dorper x Local crosses with 12.5-25% Dorper genes (D x L12.5-25%: low-grade), and 28.8% being Dorper x Local crosses with 37.5-43.75% Dorper genes (D x L37.5-43.75%: high-grade). The corresponding growth and survival records at 90, 180, and 365 days were also collected for each lamb and recorded in the data-recording book of individual Dorper crossbreeding groups along with pedigree information.

2.5. Data management and analysis

2.5.1. Growth data

To analyze growth data, we used the General Linear Model (GLM) procedures of the Statistical Analysis System (SAS, 2004 version 14) [34]. GLM procedures help us to assess the variance of fixed effects. Our model took into account a range of factors, including the **location** where the data was collected (Basona-Werana, Efratana-Gidim, Kewet, Merhabete, Kobo, and Yabello), the **breed** of lamb (local, low-grade, high-grade Dorper crossbred), the **sex** of the lamb (male or female), the **season** of birth (dry-season/October to January), long-rainy season/June to September, Short-rainy season/February to May), the **type of birth** (single or twin), the **year of birth** (2012-2021), and the parity of birth (1-5 or more).

Before the analysis, we adjusted growth weights to corresponding 90 (WWT), 180 (SMWT), and 365 (YWT) days, as suggested by Ref. [35].

$$\text{Adjusted weaning weight (kg)} = \frac{90\,(Wt2 - Wt1)}{D} + Wt1$$

$$\text{Average daily BW gains up to weaning (g)} = \frac{(Wt2 - Wt1)}{D}$$

Where W1 = birth weight, W2 = weight at a given age, D = number of days between weighing date and date of birth.

To calculate the adjustment and gain up to 180 and 365 days, as well as the post-weaning gain (from weaning up to yearling), similar patterns were followed. The growth rate for each period was computed as ADGt2-t1= (Wt2-wt1)/(t2-t1), where ADGt2-t1 is the weight gain between the periods t1 and t2, Wt2 is the weight at age t2, Wt1 is the weight at age t1, and t2-t1 represents the age difference.

The statistical model used was as follows:

$$Y_{ijklmno} = \mu + L_i + G_j + Se_k + T_l + Sn_m + Y_n + P_o + e_{ijklmno}$$

where:

$Y_{ijklmno}$: the observation of weight and weight gain at different ages for each animal.

μ : overall mean.

L_i : fixed effects of location (i = 6; Basona-Werana, Efratana-Gidim, Kewet, Merhabete, Kobo, and Yabello).

G_j : fixed effects of breed (j = 3; local, low-grade, high-grade Dorper crossbred).

Se_k : fixed effects of lamb sex (k = 2; male, female).

T_l : fixed effects of lamb birth type (l = 2; single, twin).

Sn_m: fixed effect of s lamb birth season (m = 3; dry-season, long-rainy season, and short-rainy season).

Y_n : fixed effect of lamb birth year (n = 10; 2010-2021).

P_o : fixed effect of birth parity (o = 5; 1-5 or more).

$e_{ijklmno}$: effect of random error.

2.5.2. Mortality data

The dependent variable (yi) can assume the value of 1 with a probability of survival pi or the value of 0 with a probability of death 1-pi for observation i; as suggested by Ref. [36], the logit link function was denoted as follows:

$$\text{Log (pi/1-pi)} = \text{logit (pi)} = (\beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 \ldots \beta 8X8)$$

The corresponding model expression with its probability value is:

$$pi = \frac{e^{\beta0+\beta1\ X1+\beta2\ X2+\beta13X3+\beta5\ X5+\ldots\ \beta8\ X8}}{1 + e^{\beta0+\beta1\ X1+\beta2\ X2+\beta13X3+\beta5\ X5+\ldots\ \beta8\ X8}}$$

Where p_i is the probability of lamb survival. Our statistical model examines the survival probabilities of lambs up to 3 months, 6 months, and 12 months of age, with factors including lamb blood level (x1), location (x2), sex (x3), birth type (x4), season of birth (x5), birth parity (x6), birth year (x7), and birth weight category (x8). These factors are represented by regression parameters (β). We compared our model using likelihood ratio and chi-square test statistics.

3. Results and discussion

3.1. Growth performance of lambs

3.1.1. Body weight of lambs

3.1.1.1. Birth weight. The overall least-squares means for birth weight was 2.82 ± 0.04 kg (Table 2). The birth weight for local and different levels of Dorper crossbred (low-grade and high-grade) lambs were 2.21 ± 0.04, 2.94 ± 0.03, and 3.08 ± 0.03, respectively. The birth weight of local lambs obtained in this study is slightly lower than the indigenous sheep breeds; Farta sheep 2.5 kg [37], Washera sheep 2.69 kg [38], Tumelie sheep 2.36 kg [39], Local sheep in the Southern part of Ethiopia 2.37 kg [40], and Menz sheep under a community-based selective breeding program 2.59 kg [41], respectively. The birth weight of Dorper crossbred lambs (low-grade and high-grade), however, was heavier than the birth weight of local sheep.

Breed of lamb was a significant ($p < 0.0001$) source of variation in the birth weight of lambs in which the Dorper crossbred lambs had heavier weight than the local lambs. The low and high-grade Dorper crossbred lambs were 33.0 and 39.4% heavier at birth than the local lambs, respectively. In a similar pattern [42], reported 18.8% birth weight advantage for the Awassi crossbred sheep over the Menz sheep. [39], in their studies noticed higher birth weights for Dorper crossbred lambs than their contemporary locals under on-station management, exhibiting a 37.3% birth weight advantage.

The birth weight of lambs was significantly ($p < 0.0001$) affected by location. Lambs born in Kobo and Merhabete areas had higher birth weights compared to lambs born in Basona-Werena and Efratana-Gidim areas. These differences could be due to differences in climatic factors leading to the differences in rainfall amount and pattern that dictates the feed availability and quality. In agreement with our findings [43], reported the effect of location on the birth of Doyogena sheep.

Male lambs weighed heavier than their contemporary female lambs at birth (2.78 ± 003 vs 2.71 ± 0.03 kg, $p < 0.0001$). Our result is in agreement with the different literature reports [12,39,43]. The superiority observed in males over females could be attributed to the hormonal differences in their endocrinological and physiological functions [44].

The birth type also exerted a significant ($p = 0.0021$) effect on the birth weight of lambs. Lambs born single were heavier than their twin-born contemporaries were (2.79 ± 0.02 vs 2.70 ± 0.04 kg). The results we obtained are in line with the previous reports made by different authors [43,45,46]. The differences in birth weight observed between single and twin-born lambs can be explained by the competition that occurs between fetuses for space within the uterus. As with all mammals, maternal uterine space is limited and can only accommodate a certain number of offspring. Consequently, when the litter size increases, the available space per fetus decreases, leading to a reduction in individual

Table 2
Least squares-means (±SE) for BWT, WWT, SMWT, and YWT (Kg) for Local and Dorper crossbred lambs.

Factors	BWT (kg)		WWT (kg)		SMWT (kg)		YWT (kg)	
	N	*LSM±SE*	N	LSM±SE	N	LSM±SE	N	LSM±SE
Overall	*4066*	*2.82 ± 0.08*	3116	12.97 ± 0.19	2625	16.63 ± 0.26	1169	24.04 ± 0.62
CV (%)	4066	18.42	3116	16.62	2625	15.90	1169	15.13
Lamb Genotype		*p<0.0001*		*p<0.0001*		*p<0.0001*		*p<0.0001*
Local	952	2.21 ± 0.04^{c}	730	10.57 ± 0.17^{c}	589	13.30 ± 0.23^{c}	156	20.42 ± 0.54^{c}
Low-grade crossbred	1941	2.94 ± 0.03^{b}	1490	13.22 ± 0.13^{b}	1303	17.30 ± 0.17^{b}	798	25.07 ± 0.45^{b}
High-grade crossbred	1173	3.08 ± 0.03^{a}	896	13.83 ± 0.16^{a}	732	17.79 ± 0.21^{a}	215	26.03 ± 0.48^{a}
Location		*p<0.0001*		*p<0.0001*		*p<0.0001*		*p<0.0001*
Basona-Werana	1812	2.55 ± 0.03^{d}	1454	12.77 ± 0.13^{b}	1241	16.16 ± 0.18^{b}	341	24.89 ± 0.49^{a}
Efratan-Gidim	230	2.58 ± 0.05^{d}	77	13.55 ± 0.28^{a}	63	16.52 ± 0.38^{ab}	20	24.71 ± 0.95^{ab}
Kewet	711	2.80 ± 0.03^{bc}	453	12.73 ± 0.16^{b}	325	17.27 ± 0.23^{a}	105	24.96 ± 0.56^{ab}
Kobo	467	2.93 ± 0.04^{a}	379	12.47 ± 0.17^{b}	332	15.65 ± 0.22^{b}	146	22.08 ± 0.52^{c}
Merhabete	475	2.85 ± 0.04^{ab}	410	13.06 ± 0.18^{ab}	337	16.37 ± 0.25^{b}	234	22.21 ± 0.57^{c}
Yabello	371	2.73 ± 0.04^{c}	343	10.65 ± 0.19^{c}	326	14.80 ± 0.25^{c}	323	24.19 ± 0.51^{ab}
Lamb Sex		*p<0.0001*		*p=0.0001*		*p<0.0001*		*p<0.0001*
Male	2027	2.78 ± 0.03	1514	12.69 ± 0.14	1257	16.41 ± 0.19	491	24.42 ± 0.45
Female	2039	2.71 ± 0.03	1602	12.39 ± 0.14	1367	15.85 ± 0.19	678	23.26 ± 0.45
Birth Type		*p=0.0021*		*p=0.0002*		*p=0.0257*		*p=0.9073*
Single	3711	2.79 ± 0.02	2862	12.81 ± 0.12	2412	16.35 ± 0.16	1088	23.87 ± 0.57
Twin	355	2.70 ± 0.04	254	12.27 ± 0.18	212	15.91 ± 0.24	81	23.82 ± 0.39
Parity of birth		*p<0.0001*		*p=0.0001*		*p=0.0023*		*p<0.0001*
1st	2558	2.65 ± 0.03^{b}	1968	12.13 ± 0.12^{b}	1698	15.80 ± 0.16^{c}	781	22.57 ± 0.38^{b}
2nd	921	2.71 ± 0.03^{b}	708	12.48 ± 0.14^{a}	586	16.13 ± 0.19^{bc}	268	23.54 ± 0.43^{a}
3rd	353	2.77 ± 0.04^{a}	275	12.65 ± 0.17^{a}	212	16.53 ± 0.24^{ab}	78	24.66 ± 0.56^{a}
4th	143	2.83 ± 0.05^{a}	100	12.72 ± 0.24^{a}	83	16.23 ± 0.33^{bc}	29	25.19 ± 0.77^{a}
5th & above	91	2.74 ± 0.06^{ab}	65	12.72 ± 0.29^{a}	45	15.95 ± 0.42^{bc}	13	23.24 ± 1.07^{b}
Birth Season		*p=0.0441*		*p=0.0001*		*p<0.0001*		*p=0.9544*
Dry season	1621	2.74 ± 0.03^{ab}	1249	12.25 ± 0.14^{b}	1041	15.79 ± 0.19^{b}	487	23.85 ± 0.45
Long- rainy	1330	2.77 ± 0.03^{a}	1012	12.74 ± 0.16^{a}	847	16.23 ± 0.21^{a}	294	23.88 ± 0.48
Short-rainy	1115	2.72 ± 0.03^{b}	855	12.63 ± 0.15^{a}	736	16.37 ± 0.20^{a}	388	23.79 ± 0.47
Birth year		*p<0.0001*		*p=0.0001*		*p<0.0001*		*p<0.0001*
2012	28	2.56 ± 0.11^{c}	26	12.27 ± 0.46^{c}	25	15.36 ± 0.58^{bc}	24	24.25 ± 0.90^{abc}
2013	166	2.57 ± 0.05^{c}	152	12.33 ± 0.23^{c}	137	16.19 ± 0.31^{bc}	95	24.51 ± 0.60^{ab}
2014	438	2.91 ± 0.04^{a}	287	12.97 ± 0.18^{ab}	262	17.15 ± 0.24^{ab}	208	25.57 ± 0.46^{a}
2015	703	2.87 ± 0.03^{ab}	491	13.30 ± 0.15^{ab}	433	16.93 ± 0.20^{ab}	202	25.49 ± 0.44^{ab}
2016	1077	2.90 ± 0.03^{ab}	878	13.33 ± 0.12^{ab}	770	16.70 ± 0.17^{ab}	253	24.57 ± 0.42^{ab}
2017	979	2.80 ± 0.03^{b}	788	12.20 ± 0.12^{c}	556	15.43 ± 0.17^{c}	134	22.03 ± 0.47^{d}
2018	248	2.74 ± 0.04^{bc}	109	12.49 ± 0.23^{c}	43	16.29 ± 0.42^{abc}	3	23.13 ± 2.16^{bc}
2019	41	2.82 ± 0.09^{ab}	19	12.05 ± 0.50^{c}	29	16.15 ± 0.53^{bc}	24	23.11 ± 0.88^{bc}
2020	274	2.65 ± 0.05^{c}	254	11.99 ± 0.20^{d}	259	15.35 ± 0.27^{c}	195	22.80 ± 0.58^{c}
2021	112	2.59 ± 0.06^{c}	112	12.46 ± 0.26^{c}	110	15.71 ± 0.33^{c}	31	22.95 ± 0.86^{bc}

The mean values with different superscripts (^{a,b}) across columns are significantly different (p<0.05), LSM-Least squares-means, SE-Standard error, BWT-birth weight, WWT-weaning weight (in kilogram), N- number.

birth weights [47].

The birth parity of the ewe also influenced the birth weight ($p < 0.0001$) of the lambs. The birth weight of lambs showed an increasing trend as parity advanced and started to decline after the 4th parity and this could be attributed to the potential of milk production by the ewe as age and parity advances. [48], indicated that milk production increases with parity and older ewes are larger and are better milk producers. Similar reports were produced by previous studies [13,45]. However, other authors [49] on the other hand reported no significant effect of parity on the birth weight of Dorper crossbred lambs up to 5th parity.

The season of lambing had a significant effect on birth weight ($p = 0.0441$). Lambs born in the long rainy season had a higher birth weight than those born in the short rain. The effects induced by variability in rainfall that could lead to variability in the quality and quantity of forage that indirectly affect the condition of the dam could explain the influence of season on lamb birth weight. Our result is in agreement with previous reports by Refs. [46,49,50].

The birth year was a significant ($p < 0.0001$) source of variation for the birth weights. Lambs born in the years 2014-2016 and 2019 had heavier birth weights and whereas lambs born in the years 2012, 2013, 2020 and 2021 had lighter birth weights. Similar observations were made by several authors on the influence of the year of birth on lamb birth weight [39,42,43]. An explanation for this could be that the difference in birth weight in different years might be associated with the amount and quality of forage available for pregnant ewes.

3.1.1.2. Body weights at 3, 6, and 12 months of age. The overall WWT, SMWT, and YMWT for the lambs were 12.97 ± 0.19, 16.63 ± 0.26, and 24.04 ± 0.62 kg, respectively (Table 2). The WWT, SMWT, and YWT of local lambs were 10.57 ± 0.17, 13.3 ± 0.23, and 20.42 ± 0.54 kg, respectively (Fig. 1), and are comparable with Horro sheep [12], Farta sheep [37], while higher in WWT and SMWT than Tumelie sheep [39]. The least-squares means and standard errors for WWT, SMWT, and YWT of Dorper crossbred lambs were (13.22 ± 0.13, 17.30 ± 0.17, 25.07 ± 0.45 kg, for the low grades) and (13.83 ± 0.16, 17.79 ± 0.21 and 26.03 ± 0.48 kg, for the high grade), respectively (Fig. 1). The influence of breed was significant ($p < 0.0001$) on the body weight of lambs at all ages. The Dorper crossbred lambs, were heavier than their local contemporaries were at all ages. Dorper crossbred lambs weighed up to 30.8, 33.8, and 27.5% weight than local lambs at 3, 6, and 12 months of age indicating the superiority of Dorper crossbred lambs under the farmers' management system [50]. reported a similar observation for the local x Awassi crossbred sheep in the cool highlands of Ethiopia. [39], in their studies reported comparable results of WWT, SMWT, and YWT for Dorper x Tumelie crossbred lambs managed under semi-intensive management.

WWT, SMWT, and YWT of lambs were significantly ($p < 0.0001$) affected by location. Heavier lambs were weaned at Efratana-Gidim and Merhabete and lambs with lighter weight were weaned at Yabello, whereas lambs born at Kewet and Efratana-Gidim had higher SMW and those born at Yabello had lower SMW. Compared to lambs born in Kobo and Merhabete areas, lambs with heavier YWT were born in Basona-Werana, Efratana-Gidim, Kewet, and Yabello areas. Such differences could be due to differences in climatic factors leading to the differences in rainfall amount and pattern that dictates the feed availability and quality and the management difference employed in the different locations. In agreement with our findings [43], reported the effect of location on the weaning weight of Doyogena sheep.

The sex of the lamb was a significant source of variation for body weight at 3, 6, and 12 months of age. Male lambs had higher weights at all ages than their female counterparts. Our findings are in line with the results reported by different authors [13,51,52] who explained that the effect of sex starts at three to five months of age. This superiority observed in males over females could be attributed to the hormonal differences in their endocrinological and physiological functions [44].

Types of birth exerted significant effects on lambs' weight at weaning ($p = 0.0002$) and six months of age ($p = 0.0257$) but its influence was not observed at yearling ($p = 0.9073$). Similarly, single-born lambs were heavier at weaning and at six months but had similar yearling weights to twins. The results we obtained are in line with the previous reports made by other authors [37,46,53]. According to Ref. [54], the superiority of single-born lambs continues up to weaning and declines thereafter, and thus twin born lambs had comparable body weight then after whereby such differences could be explained by the carryover effect of the heavier weight of single-born lambs at birth [55] and the fact that single born lambs are the sole users of their dam milk until weaning age [12].

Birth parity of the ewe also significantly affected the WWT ($p = 0.0001$), SMWT ($p = 0.0023$), and YWT ($p < 0.0001$) of the lambs (Table 2). The WWT, SMWT, and YWT of lambs showed an increasing trend as parity advanced and started to decline after the 4th parity and this could be attributed to the potential of milk production by the ewe as age and parity advances [48]. indicated that milk production increases with parity and older ewes are larger and are better milk producers. Similar reports were produced by previous studies [13,45]. However,

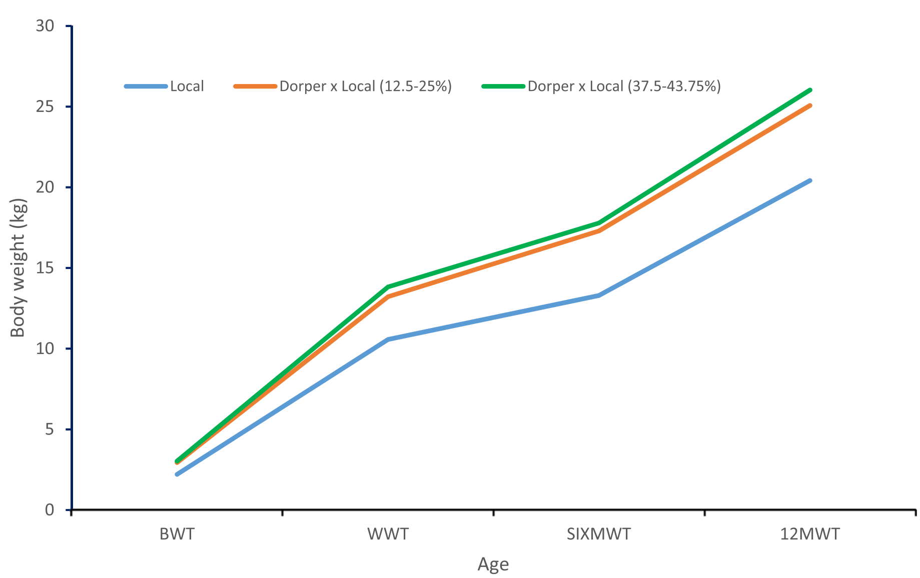

Fig. 1. Growth performance of Local and Dorper x Local crossbred lambs.

reported no significant effect of parity on the birth weight of Dorper crossbred lambs up to 5th parity.

The season of lambing had a significant effect on body weight at weaning and six months of age. Lambs born in the long and short-rainy seasons were heavier than those born in the dry season (12.63, 12.74 vs 12.25 kg, $p = 0.0001$, for weaning), and (16.23, 16.37 vs 15.79 kg, $p = 0.0001$, for six months), respectively. The important influence of season on lamb weaning and six months weight was reported by several authors, accordingly, our result is in agreement with previous reports by Refs. [13,46]. According to Ref. [50], weaning weight is known to vary with rainfall, quality, quantity of forage, and availability of milk production by the dam. Therefore, the difference in weight at 3 and 6 months could be due to the variability of feedstuffs among the different seasons. The study also revealed that there was no significant effect ($p = 0.9544$) of the season on lambs' yearling weight. Our result is contrary to the report of [39] who reported that Tumelie and Dorper crossbred lambs born during the dry season were heavier at the yearling than those born in the rainy season under the semi-intensive management system whereby ewes were supplemented with concentrate during the dry season.

Birth year contributed to the variability in the WWT, SMWT, and YWT of the lambs. Lambs with heavier WWT and SMWT were born in the years 2014-2016 whereas lambs with lighter weight at weaning were born in the year 2020. The YWT of lambs also varied across the years of birth and heavier lambs were born in the years between 2012 and 2016. Coherent with these the results, several authors also reported the significant effects of the year on lamb weight at different ages [42,43,46]. The possible reason for such differences in the body weight of lambs could be associated with the differences in climatic factors that could be the sources of variability in the quality of and quantity of feed access across years for the ewes as well as for the lambs.

3.1.2. Pre and post-weaning growth rate of lambs

Pre-weaning growth rate of lambs.

The overall average daily gain of local and Dorper crossbred lambs was 112.51 ± 2.10 g/day. Pre-weaning growth rate was significantly affected by lamb genotype, location, season, and year of birth ($p < 0.0001$), lamb sex ($p = 0.0009$), birth type ($p = 0.0017$), parity ($p = 0.0090$), respectively. A report by Ref. [39] revealed a slightly higher overall growth rate estimate for Tumelie and Dorper crossbred lambs managed under a semi-intensive management system.

The pre-weaning average daily body weight gain (PRWADG) of lambs was significantly influenced by lamb genotype ($p < 0.0001$). From birth to 90 days, local lambs had a PRWADG of 89.12 ± 1.85, while low and high-grade Dorper crossbred lambs had a PRWADG of 112.16 ± 1.38, and 117.98 ± 1.71 g/day, respectively. Dorper crossbred lambs grew faster than local lambs, with low and high-grade crossbreds showing weight gain advantages of 25.9 and 32.4%, respectively, indicating the positive effect of the Dorper gene on local sheep growth performance.

The pre-weaning average daily weight gain performance of the local sheep lambs was comparable to that of Menz sheep [12], Washera, and Farta sheep under the station, and on-farm conditions [37], and higher than Tumelie sheep [39]. The PRWADG of Dorper crossbred lambs in the current study was higher than that reported for Awassi x local crossbred lambs (101 g/day) under on-farm conditions [50], and Dorper x Afar 50% (73.19 g/day and Dorper x Menz 50% (106.24 g/day) reported by Ref. [45] under on-station management conditions. However, the study by Ref. [39] reported a higher PRWADG (129.97 g/day) for Dorper x Tumelie crossbred lambs managed under a semi-intensive system. The difference in PRWADG could be due to differences in management practices, feed availability, and genetic potential of the animals. Overall, the results suggest that incorporating the Dorper gene into local sheep breeds can significantly improve their pre-weaning growth performance.

Interestingly, location was also found to have a significant effect ($p < 0.0001$) on PRWADG, with higher values recorded at Basona-Werana, Merhabete, and Efratana-Gidim areas compared to Yabello, where the least PRWADG was recorded. This result may be attributed to differences in climatic factors such as rainfall amount and pattern, which in turn affect feed availability and quality. Consistent with our findings, a study by Ref. [43] reported the impact of location on the PRWADG of Doyogena sheep. Therefore, it is essential to consider these factors when evaluating lamb growth performance and designing effective breeding and management strategies.

The results of the study revealed that the sex of the lamb had a significant impact on the PRWADG of lambs. Male lambs had a significantly higher PRWADG compared to their female counterparts during the first 90 days of life (107.80 ± 1.54 vs 105.04 ± 1.54 g/day, $p = 0.0009$). This finding is consistent with previous studies which have reported a significant effect of sex on lamb growth [46,51,52]. In contrast, other studies, such as [45,50,54] have reported that sex did not influence the growth rate during the pre-weaning period. The observed difference in PRWADG between male and female lambs could be attributed to the hormonal differences in their endocrinological and physiological functions [44]. Male lambs have higher levels of growth hormones and androgens, which are known to stimulate muscle growth and increase feed efficiency. However, further research is needed to elucidate the underlying mechanisms behind the observed sex-based differences in PRWADG.

The study found that single-born lams had significantly better body weight gain up to 90 days of age compared to lambs born in multiple births, with a p-value of 0.0017. This finding is consistent with previous studies by Refs. [36,43,50]. One possible explanation for this result is that milk produced by ewes bearing and rearing multiple lambs may not be sufficient to nourish all of their offspring, whereas single-born lambs have exclusive access to their dam's milk. This is supported by research by Ref. [13], who found that single-born lambs grew better during the pre-weaning period. The study also found that the parity of the ewe had an impact on the PRWADG of the lambs, with a p-value of 0.0090. The PRWADG increased especially as the parity of the ewe advanced. This may be due to the increased milk production potential of older ewes, as suggested by Ref. [48] and supported by other studies such as those by Refs. [45,53].

The study found that the season of birth had a significant effect ($p < 0.0001$) on lambs' pre-weaning growth rate. Lambs born during the long-rainy and short-rainy seasons had higher PRWADG compared to those born during the dry season (108.59 and 107.2 g/day vs 103.47 g/day, respectively). These findings are consistent with previous research by Refs. [45],50, who reported similar results for local and crossbred lambs. However, contrary to our results [39] found higher average daily body weight gain in lambs born during the dry season but managed under a semi-intensive management system. The possible reason for the observed differences in growth rates between seasons could be the varying availability of feed resources, which is generally higher during the rainy seasons. Furthermore, lambing year was also found to be a significant source of variation ($p < 0.0001$) for PRWADG of lambs. The study observed that lambs born in 2015 and 2016 had a higher growth rate compared to those in 2019, 2020, and 2017 (113.64 ± 1.61 g/day), and 2016 (114.11 ± 1.35 g/day vs 98.89 ± 5.39 g/day, 100.99 ± 2.19 g/day, 102.62 ± 1.33 g/day, respectively). These findings are consistent with several studies that have reported the influence of lambing year on pre-weaning body weight gain, including [43,49]. The variation in growth rates observed among the different years could be attributed to the variability in feed resource availability, which is often dictated by weather conditions. Overall, the results of this study suggest the need for strategic management practices that consider seasonal variations in feed resources and optimize lambing timing for improved growth rates.

3.1.2.1. Post-weaning growth rate of lambs. The overall average daily body weight gain for the lambs from 90 to 180 and 180 to 365 days were

40.60 and 40.44 g/day (Table 3). Lambs typically experience a weaning shock when they are transitioned from a diet of highly nutritious milk and some grazing to sole grazing, which often results in a lower growth rates during the post-weaning period compared to their growth rate prior to weaning [39,45].

Our study revealed a significant difference in post-weaning growth rates among lamb breeds ($p < 0.0001$). The low-grade and high-grade Dorper crossbred lambs exhibited higher growth rates (46.85 ± 1.62 and 45.93 ± 1.98 g/day, respectively) than the local breed lambs (32.60 ± 2.16 g/day) between 90 and 180 days of age, and this pattern persisted at 180 to 365 days of age. Our findings were comparable to but slightly higher than, those of a study on Dorper x Tumelie lambs raised under an extensive management system, which reported an average gain of 44.1 ± 1.46 g/day at similar age [49]. These results suggest that the crossbreeding program involving low- and high-grade Dorper breeds could improve the post-weaning growth rate of lambs.

Our study identified significant environmental factors that influenced the growth rate of lambs between 90 and 180 days, including location, birth year ($p < 0.0001$), lamb sex ($p = 0.0010$), and birth season ($p = 0.0098$). Lambs born during the short rainy season (43.82 ± 1.87 g/day) showed higher growth rates than those born in the dry season (40.22 ± 1.77 g/day), while lambs born in the long rainy season (41.34 ± 1.94 g/day) had comparable growth rates. Additionally, lambs born in 2014 (48 g/day) had faster growth rates than those born in 2017 (37 g/day), 2012 (38 g/day), and 2021 (39 g/day) between 90 and 180 days of age, and this trend continued at a later age. These differences could be attributed to variations in management practices and differences in agro-ecological factors and climatic conditions such as rainfall. Our findings highlight the importance of considering these environmental factors when developing strategies to enhance lamb growth rates. Concurrent with these results, similar birth season and year effects were reported by Refs. [39,50].

Interestingly, we found that birth type and parity did not significantly affect the daily body weight gain of lambs between 90 and 180 days of age ($p = 0.9096$, and $p = 0.7404$, respectively), but the birth type had a significant influence ($p = 0.0069$) on lamb growth rates during the 180-365 day growth period. In contrast, birth parity and birth season had no significant effect ($p = 0.1268$ and $p = 0.8416$, respectively) on lamb growth rates as they advanced in age between 180 and 365 days. These results are consistent with the findings reported by Ref. [49] who also observed no significant effects of birth parity on lamb growth performances at post-wearing ages (90-180 and 180-365 days, respectively). These findings suggest that birth type should be considered as a potential factor affecting lamb growth rates and further studies are warranted to better understand the underlying mechanisms.

Table 3
Least-squares means and standard errors of post-weaning growth performance of Local and Dorper x Local crossbred lambs.

Factors	PRWADG (g/day)		POWADG (g/day)			
	0-90 days		90-180 days		180-365 days	
	N	LSM±SE	N	LSM±SE	N	LSM±SE
Overall mean	3116	112.51 ± 2.10	2579	40.60 ± 1.73	1137	41.80 ± 2.22
CV (%)	3116	20.28	2579	38.59	1137	43.87
Lamb Genotype		*p<0.0001*		*p<0.0001*		*p=0.0005*
Local	730	89.12 ± 1.85^{c}	586	32.60 ± 2.16^{b}	153	$37.80 + 2.69^{c}$
Low-grade crossbred	1490	112.16 ± 1.38^{b}	1270	46.85 ± 1.62^{a}	795	$41.88 + 2.26^{b}$
High-grade crossbred	896	117.98 ± 1.71^{a}	723	45.93 ± 1.98^{a}	189	$46.32 + 2.52^{a}$
Location		*p<0.0001*		*p<0.0001*		*p<0.0001*
Basona-Werana	1454	113.36 ± 1.45^{a}	1212	36.75 ± 1.71^{b}	309	46.52 ± 2.49^{b}
Efratan-Gidim	77	111.15 ± 3.02^{ab}	63	44.75 ± 3.48^{ab}	20	37.88 ± 4.71^{c}
Kewet	453	108.54 ± 1.79^{b}	325	49.98 ± 2.12^{a}	105	38.35 ± 2.83^{bc}
Kobo	379	105.01 ± 1.83^{b}	316	35.46 ± 2.11^{b}	146	37.76 ± 2.61^{c}
Merhabete	410	113.04 ± 1.98^{a}	337	36.79 ± 2.30^{b}	234	37.00 ± 2.88^{c}
Yabello	343	87.42 ± 2.02^{c}	326	46.99 ± 2.29^{a}	323	54.49 ± 2.59^{a}
Lamb Sex		*p=0.0009*		*p=0.0010*		*p=0.0245*
Male	1514	107.80 ± 1.54	1236	43.36 ± 1.80	479	43.23 ± 2.31
Female	1602	105.04 ± 1.54	1343	40.23 ± 1.80	658	40.77 ± 2.28
Birth Type		*p=0.0017*		*p=0.9096*		*p=0.0069*
Single	2862	108.82 ± 1.32	2372	41.90 ± 1.55	1063	45.01 ± 2.01
Twin	254	104.02 ± 1.96	207	41.69 ± 2.27	74	38.99 ± 2.88
Parity of birth		*p=0.0089*		*p=0.7404*		*p=0.1268*
1st	1968	103.21 ± 1.33^{b}	1668	42.27 ± 154	755	39.13 ± 1.92
2nd	708	106.04 ± 1.54^{a}	583	41.90 ± 1.76	265	39.59 ± 2.16
3rd	275	106.68 ± 1.89^{a}	206	44.04 ± 2.23	76	44.80 ± 2.81
4th	100	106.68 ± 2.64^{a}	80	41.38 ± 3.04	29	43.13 ± 3.79
5th & above	65	109.47 ± 3.10^{a}	42	39.39 ± 3.97	12	43.35 ± 5.47
Birth Season		*p<0.0001*		*p=0.0098*		*p=0.8416*
Dry season	1249	103.47 ± 1.54^{b}	1011	$40.22 + 1.77^{b}$	470	41.74 ± 2.29
Long rainy	1012	108.59 ± 1.66^{a}	843	$41.34 + 1.94^{ab}$	292	42.49 ± 2.42
Short-rainy	855	107.20 ± 1.60^{a}	725	$43.82 + 1.87^{a}$	375	41.77 ± 2.38
Birth year		*p<0.0001*		*p<0.0001*		*p=0.0003*
2012	26	105.12 ± 4.93^{bc}	25	38.26 ± 5.31^{b}	24	45.49 ± 4.45^{ab}
2013	152	106.29 ± 2.48^{bc}	137	44.99 ± 2.81^{ab}	95	44.96 ± 2.97^{ab}
2014	287	109.14 ± 1.91^{b}	262	48.78 ± 2.19^{a}	208	48.04 ± 2.32^{a}
2015	491	113.67 ± 1.61^{ab}	431	42.60 ± 1.88^{b}	202	43.87 ± 2.22^{ab}
2016	878	114.11 ± 1.35^{ab}	763	39.42 ± 1.60^{b}	253	40.27 ± 2.08^{b}
2017	788	102.62 ± 1.33^{c}	551	37.31 ± 1.60^{b}	134	34.36 ± 2.34^{c}
2018	109	106.47 ± 2.43^{bc}	41	45.00 ± 3.94^{ab}	3	36.52 ± 10.58^{bc}
2019	19	98.89 ± 5.39^{c}	17	41.20 ± 5.98^{b}	14	41.86 ± 5.39^{b}
2020	254	100.99 ± 2.19^{c}	241	40.46 ± 2.49^{b}	173	43.65 ± 2.96^{ab}
2021	112	106.88 ± 2.77^{bc}	111	39.42 ± 3.05^{b}	31	40.99 ± 4.25^{b}

The mean values with different superscripts (^{a,b}) across columns are significantly different ($p<0.05$), LSM-Least-squares means, SE-Standard error, PRWADG-pre-weaning average daily gain (in gram), POWADG-post-weaning average daily gain (in gram), N- number.

3.2. Survival of lambs

The mean survival rate of lambs up to 3, 6, and 12 months of age was 93.7%, 87.4%, and 80.1%, respectively, in this study. At the same time point, the survival rate for local, low-grade, and high-grade Dorper crossbred lambs was similar (93.7%, 86.8% 76.6% (for local), 93.4%, 88.0%, 81.8% (for low-grade), and 94.2%, 87.0% 80.0% (for high-grade), respectively. These results are higher than those reported by Ref. [56] for Dorper x Tumelie crossbred lambs under semi-intensive on-station management. However, the pre-weaning survival is comparable with the report of [57] for Dorper x indigenous sheep breeds under semi-intensive management [58]. reported a higher pre-weaning survival (97.1%) for Dorper crossbred lambs, which was higher than our results. On the other hand, the survival rate obtained for the crossbred under the current study is higher than reported by Ref. [45] for Awassi x Menz 25-50% crossbred, which was 80.69% at the age of 3 months under semi-intensive management. These results suggest that Dorper x local crossbreed lambs managed under a community-based management system have higher survival potential.

The mortality risk for lambs born to ewes in their 5th and above parity is 1.562 times higher than lambs born to ewes in their 1st to 4th parity, at 6 months of age (Table 4). Our findings are consistent with those of [59], who reported that ewe age did not significantly affect lamb survival at weaning and yearling age. However [60], found that primiparous ewes had higher colostrum immunoglobin G concentration than multiparous ewes.

The year of lambing significantly affected lamb's pre-weaning survival rates, with lambs born between 2012 and 2020 having a higher risk than those born in 2021 ($\chi2 = 0.0003$; OR = 0.001). Higher mortality rates were observed at 6 and 12 months in 2014, 2016-2018, and 2020 while all lambs born in 2021 survived until waning and over 96% survived at 6 and 12 months of age. These results are consistent with previous studies [24,59], which also documented variability in lamb survival rates across years.

The location of the study sites also influenced lamb survival rates ($\chi2 = 0.0001$-0.0015, OR = 1.071 at weaning, 0.583-1.354 at 6 months, and 0.645 at yearling age) compared to the base year 2021. This could be due to differences in the production environment, including variations in climatic factors. Season of birth too was another significant factor affecting lamb survivability, with lambs born in the dry season having a higher mortality risk at weaning and yearling ($\chi2<0001$, OR = 1.526 - 2.186, respectively). These findings are consistent with the observations of [24,61] that the season of lambing influences lamb mortality risk, with dry-season births having a higher risk. Finally, our results also indicate that lambs born weighing 2 kg or less have higher mortality at yearling age ($\chi2 = 0.0090$, OR = 0.442; CI = 0.262 - 0.745) compared to the lambs born weighing over 3 kg. This finding is consistent with [62] who reported similar observations for Harnali sheep, highlighting the importance of good birth weight for lamb survival.

4. Conclusion

This study showed that the genetic group had a substantial impact on lambs of all ages in terms of body weight and growth rates. Lambs from Dorper crossbreeds outperformed local lambs (which were heavier and larger in size), grew more quickly, and maintained good body condition up to yearling age. The body weight and growth rate of lambs were considerably influenced by environmental factors such as location, lamb

Table 4
Lambs' survivability using logistic regression with various predictor variables at 3, 6 & 12 months of age.

Effect	Survival to 3 months		Survival to 6 months		Survival to 12 months	
	OR	95% CI	OR	95% CI	OR	95% CI
Lamb genotype	$\chi^2 = 0.3389$		$\chi^2 = 0.2543$		$\chi^2 = 0.6860$	
Low-grade crossbred	0.830	0.768 - 1.893	1.018	0.695 - 1.390	0.935	0.804 - 1.424
High-grade crossbred	1.113	0.572 - 1.414	1.256	0.574 - 1.103	1.044	0.733 - 1.252
Location	$\chi^2 = 0.0009$		$\chi^2 = \mathbf{0.0001}$		$\chi^2 = 0.0015$	
Basso vs Yabello	0.324***	1.566 – 6.065	0.738*	0.762 – 2.407	0.934	0.6669 - 1.714
Efrata vs Yabello	0.635	0.741 - 3.347	1.259	0.428 - 1.477	0.801	0.723 - 2.154
Kewet vs Yabello	0.884	0.704 - 2.001	1.717***	0.353 - 0.962	1.550***	0.428 - 0.972
Kobo vs Yabello	0.826	0.653–2.243	0.875	0.655 - 1.992	1.079	0.587 - 1.464
Merabete vs Yabello	0.698	0.735 - 2.790	0.671**	0.829 - 2.679	1.014	0.614 - 1.587
Lamb sex	$\chi^2 = 0.2794$		$\chi^2 = 0.8724$		$\chi^2 = 0.0853$	
Male vs Female	1.153	0.668 - 1.124	1.016	0.812 - 1.193	1.151	0.740 - 1.020
Birth type	$\chi^2 = 0.0424$		$\chi^2 = 0.1628$		$\chi^2 = 0.0764$	
Single vs Twin	0.640*	1.016 - 2.402	0.791	0.910 - 1.757	0.781	0.974 - 1.682
Ewe parity	$\chi^2 = 0.5831$		$\chi^2 = 0.0299$		$\chi^2 = 0.2393$	
Parity 1 vs Parity5	0.732	0.650 - 2.869	0.505*	1.186 - 3.309	0.695	0.890 - 2.327
Parity 2 vs Parity5	0.855	0.553 - 2.476	0.631	0.941 - 2.671	0.785	0.781 - 2.076
Parity 3 vs Parity5	1.009	0.452 - 2.173	0.715	0.803 - 2.438	0.899	0.662 - 1.868
Parity 4 vs Parity5	0.725	0.546 - 3.490	0.572	0.910 - 3.353	0.687	0.796 - 2.663
Birth season	$\chi^2<0001$		$\chi^2 = 0.1985$		$\chi^2<0001$	
Short rain vs Dry season	0.458***	1.524 – 3.134	0.824	0.951 - 1.548	0.655***	1.244 - 1.872
Long rain vs Dry season	0.682	1.087 – 1.980	0.843	0.943 - 1.492	0.753	1.098 - 1.605
Birth year	$\chi^2 = 0.0003$		$\chi^2<\mathbf{0.0001}$		$\chi^2<\mathbf{0.0001}$	
2012 vs 2021	0.001***	0.001-999.999	3.661	0.034 - 2.193	3.922	0.059 - 1.012
2013 vs 2021	0.001***	0.001-999.999	3.442	0.062 - 1.359	3.779	0.094 - 0.746
2014 vs 2021	0.001***	0.001-999.999	2.215*	0.102 - 2.005	2.299***	0.163 - 1.166
2015 vs 2021	0.001***	0.001-999.999	4.560	0.052 - 0.932	3.247	0.120 - 0.788
2016 vs 2021	0.001***	0.001-999.999	6.300***	0.038 - 0.660	4.244	0.093 - 0.598
2017 vs 2021	0.001***	0.001-999.999	10.082***	0.024 - 0.405	7.480***	0.053 - 0.338
2018 vs 2021	0.001***	0.001-999.999	15.861***	0.015 - 0.269	12.808***	0.030 - 0.203
2019 vs 2021	0.001***	0.001-999.999	4.973	0.035 - 1.149	2.530	0.107 - 1.459
2020 vs 2021	0.001***	0.001-999.999	1.683**	0.124 – 2.847	3.601	0.106 - 0.723
BWT-Category	$\chi^2 = 0.0618$		$\chi^2 = 0.2802$		$\chi^2 = 0.0090$	
Light vs Heavy	2.633	0.167 - 0.862	1.576	0.343 - 1.175	2.264**	0.262 - 0.745
Medium vs Heavy	1.533	0.392 - 1.085	1.170	0.582 - 1.257	1.562	0.458 - 0.893
Birth weight	$\chi^2 = \mathbf{0.2294}$		$\chi^2 = \mathbf{0.7331}$		$\chi^2 = \mathbf{0.2663}$	
Birth weight	1.280	0.522 - 1.169	1.057	0.685 - 1.305	1.165	0.654 - 1.125

OR, odd ratio; CI, confidence interval, Lamb birth weight category;<=2 kg = Light, >2 = 3 = medium, >3 kg = Heavy.

sex, birth year, birth parity, season, and year of birth up to six months of age, whereas the birth type and season had no significant impact at yearling age. Location, lamb sex, birth type, parity, season, and year of birth all had a major impact on the lamb's pre-weaning growth rate. However, birth type and birth parity have no discernible impact on post-weaning body weight gain at the age of 90–180 days. Surprisingly, it was also observed that mortality at yearling age was higher among lambs born weighing 2 kg or less compared to those born with 3 kg and above. It is recommended to take into account and make adjustments for important environmental parameters while taking into consideration the Dorper crossbreed lambs' larger body weight and faster growth rate. It is suggested that further research be done on marketing and feeding (supplementation) during crucial seasons.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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