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On-station comparative analysis of reproductive and survival performance between Red Maasai, Dorper, and Merino sheep breeds

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ABSTRACT

The reproductive performance of ewes and the survivability of lambs to weaning have a critical economic impact on sheep farming worldwide. Further, knowledge of major mortality causes allows an opportunity for improved flock management to evade financial losses. The maximum likelihood estimates for generalised linear mixed models and chi-square test methods were used to examine 971 mating records, 839 and 763 lambs born and weaned (singles or twins) from the Naivasha Sheep and Goats station in Kenya for the years 2011 to 2020 consisting of Dorper, Red Maasai (**RedM**), and Merino breeds. The RedM ($P < 0.05$) outperformed Dorper and Merino in weaning rate, whereas reproductive performance between the three breeds was not significantly different ($P > 0.05$) in litter size and multiple lambings per ewe lambing. On the one hand, Dorper significantly ($P < 0.05$) outperformed the other two breeds only in weaning weight per lamb born. In addition, among all the major causes of death, pneumonia appeared to be the one to which Dorper breeds were most susceptible (chi-square test, $P < 0.05$). According to the findings of this study, neither the Dorper nor the Merino sheep breeds were reproductively superior to the RedM in an extensive semi-arid production environment. In addition, Dorper's susceptibility to the leading causes of mortality, particularly pneumonia and sheep pox, were relatively high compared to other breeds and could be a precursor to massive economic losses for Dorper sheep producers. In contrast to the indigenous RedM breed, imported sheep breeds appeared to be more susceptible to major mortality-related under an extensive production system. Therefore, regardless of weaning weight, RedM breed production appears to be a more viable investment for small-scale farmers, particularly in semi-arid regions.

Implications

Studies have suggested that the Red Maasai sheep are heat tolerant and resistant to *Haemonchus* nematodes. However, farmers haphazardly cross-breed them with non-native breeds, particularly Dorper and Merino, to improve native breeds' reproduction capabilities, putting Red Maasai's landrace genes at risk of erosion. According to the findings of this study, the Red Maasai's reproductive performance under comparable production conditions was not significantly inferior to the other two breeds. However, the Red Maasai's susceptibility to mortality-causing agents was significantly lower than the Dorper breed. Within-breed selection would reduce production costs while also ensuring breed conservation *in situ*.

Introduction

In sheep breeding, the reproductive efficiency of individual ewes and/or the flock and lambs' survival are compound characteristics that influence economic performance. Increasing the number of lambs weaned per ewe exposed to the ram or served is an overall goal of the sheep breeder. Low survival rates from lambing to weaning result in reduced ewe productivity and may significantly hinder the attainment of optimal reproductive efficiencies (Nel et al., 2021). The sheep breeders' profit can be optimised by increasing multiple births per ewe joined or lambing. Still, low lamb survival can neutralise the economic benefits of multiple

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births (Slee et al., 1991). Therefore, breeding strategies should aim to improve not only reproductive efficiency (Rosati et al., 2002) and fecundity but also the survival of lambs.

The Red Maasai (**RedM**), a native sheep breed of Kenya that has adapted to the local environmental conditions, has low reproductive efficiency. Farmers cross-breed RedM with exotic breeds, especially Dorper and Merino, in an effort to improve their growth and reproductive performance. Dorper sheep, which originated from South Africa (Budai et al., 2013), were imported into Kenya in the 1970s for research and multiplication (Zonabend König et al., 2016), while Merino sheep were imported from Australia and maintained in the semi-arid region of the country for wool production purposes (Preston and Allonby, 1979). Both breeds are believed to outperform the RedM in terms of growth and reproductive traits, but they do not adapt well to the harsh environmental conditions. Studies have shown that cross-bred generations had poor survivability in harsh environments (Zonabend König et al., 2016).

The haphazard cross-breeding threatened the existence of the pure RedM breed. As a result, conservation efforts for this breed were started at Government-owned farms, including Naivasha Sheep and Goats Station.

This study compared the on-station reproductive and survival performance of the indigenous Red Maasai sheep breed (RedM) to the pure Dorper and Merino, non-indigenous breeds, under an extensive management system.

Material and methods

Source of data, flock management and environmental information

The data for this study were obtained from performance records kept at the Ol'Magogo sheep and goats station in Naivasha, 100 kilometers west of Nairobi. The station is located at latitude −0.551494 and longitude 36.413791, of elevation of 1 830 and 2 330 meters above sea level (m a.s.l.), on volcanic, alkaline, and sodic deep soils. The seasonality of herbage availability throughout the year was caused by the seasonal rainfall, which averages 680 mm per year with mean daily minimum and maximum temperatures of 8 °C and 23 °C, respectively. The dominant vegetation type is natural star grass (*Cynodon plectostachyus*) with scattered tall acacia trees (*Acacia xanthophyloea*).

The indigenous RedM, Dorper, and Merino were managed separately on the farm, and no breeds received any special management practices. The ewes and their lambs were grazed on an extensively managed pasture during the day (average of 8 hours) and enclosed at night. Lambs were left to run with their mothers until weaning (90–120 days) after lambing. Individual selection for breeding was based on typical resemblance to the pure breed (true to type body morphological characteristics). Besides, BW at tupping was also considered during selection, as individual ewes weighing below 25 kg were not exposed to the rams. Two mating seasons were practised, considering the rainfall patterns. Ewes were joined with the rams in October–November and April–May to lamb in August–September and February–March, respectively. Mating close relatives was avoided. Ewes of all age categories were randomly presented in each single ram mating group, with age at first mating being 12–18 months. The ratio of ram to ewes was 1:30, a paint on the rams was used to determine the mated ewes and the ram responsible. Except for mineral-licking blocks, the flocks were grazed on natural pasture with no feed supplementation. Water was provided ad libitum. Biosecurity and prophylactic disease management measures were carried out with periodic drenching, vaccinations, and other management practices performed uniformly on all breeds. Reproductive and growth performance recordings were also performed by trained personnel at the station. Qualified veterinary personnel carefully assessed any arising deaths within the flock through postmortem and reported the causes of death.

Description of data

Pooled annual data on reproductive and survival traits between 2011 and 2020 of the RedM, Dorper, and Merino sheep breeds in Ol'magogo Sheep and Goats Station, Naivasha, Kenya, were used in this study. Reproductive records obtained on the flock include:- number of ewes joined with the ram, number of ewes lambing either live and/or dead lambs, number of lambs born alive or dead, number of lambs weaned, number of lambs born twins or more, average weaning weight, preweaning mortality, and general causes of mortality in the farm. A total of 971 records on ewes from different breeds were obtained, comprising 359, 215, and 396, for Dorper, Merino, and RedM, respectively. Table 1 presents the breed mean of reproductive indices per year.

The reproductive indices/fertility indices in Table 1 were calculated as follows:

Number of ewes lambing per ewes joined, fertility rate = Number of ewes lambing/number of ewes joined with the ram.
Number of lambs born per ewe lambing, litter size = Total number of lambs born/number of ewes lambing.
Number of lambs weaned per lamb born, Weaning rate = Number of lambs weaned/number of lambs born.
Multiple lambings per ewe lambing = Number of lambs born twins or more/number of ewes lambing.
Weaning weight per lamb born = Total weaning weight of lambs weaned/number of lambs born.

Statistical analysis

Four models involving linear models, linear mixed models, generalised linear models (glm) (Nelder and Wedderburn, 1972), and generalised linear mixed models (Hedeker, 2005) were tested for each variable. The model with the lowest Akaike Information Criterion (**AIC**) value (Chakrabarti and Ghosh, 2011) was the most preferred. However, not all models that exhibited the lowest AIC value were used since further model inspection depicted a violation of model assumptions, particularly the independent distribution of residuals. In such cases, second-best fit models were inspected and used if they met all the assumptions.

The tested models include the following.

Model 1; $y = B_0 + B_iX_i + e$.
Model 2; $y = B_0 + B_iX_i + u + e$.
Model 3; $g(\mu_i) = B_0 + B_ix_i + e$.
Model 4; $g(\mu_i) = B_0 + B_ix_i + u + e$.

where

y = Response variable representing the reproductive trait.
X_i = A vector of fixed effects influencing y.
B_0 = Intercept of the model.
B_i = Breed (Dorper, RedM, and Merino).
u = Random effect variance (year).
e = Residual variance.
g = Glm *Gamma* family that links the mean of the trait (μ).

Model 4 was considered the best fit after meeting all the assumptions. Therefore, using the *glmer* function of the LME4 package (Bates et al., 2007) in R software (Team. 2019), the maximum likelihood estimation method for the generalised linear mixed

Table 1
Annual rates of the examined reproductive features for Dorper, Red Maasai, and Merino sheep breeds.

Year	Breeds	Fertility rate	Litter size	Weaning rate	Multiple lambing rate	Weaning weight/lambs born (kg)
2011	Dorper	1.057	1.057	0.757	0.114	25.000
	RedM	1.043	1.114	0.878	0.227	19.000
	Merino	0.857	1.000	0.833	0.000	21.000
2012	Dorper	1.000	1.000	0.833	0.000	23.000
	RedM	0.982	1.058	0.891	0.115	19.300
	Merino	0.762	1.000	0.750	0.000	19.000
2013	Dorper	0.938	1.000	0.767	0.000	21.000
	RedM	0.881	1.057	0.865	0.114	18.000
	Merino	0.800	1.000	0.900	0.000	18.000
2014	Dorper	0.861	1.033	0.806	0.067	22.000
	RedM	1.000	1.098	0.844	0.195	17.000
	Merino	0.650	1.000	0.615	0.000	21.000
2015	Dorper	1.000	1.118	0.816	0.235	22.200
	RedM	0.875	1.000	1.000	0.000	17.100
	Merino	1.037	1.167	0.786	0.333	17.800
2016	Dorper	1.048	1.100	0.864	0.200	21.500
	RedM	0.731	1.000	1.000	0.000	18.100
	Merino	0.840	1.000	0.857	0.000	17.900
2017	Dorper	1.046	1.079	0.765	0.159	24.600
	RedM	0.906	1.043	0.896	0.087	22.800
	Merino	0.773	1.214	0.824	0.429	20.200
2018	Dorper	1.000	1.061	0.914	0.121	17.900
	RedM	0.667	1.000	1.000	0.000	15.000
	Merino	0.667	1.000	0.900	0.000	18.000
2019	Dorper	1.056	1.118	0.816	0.235	22.200
	RedM	0.826	1.000	0.974	0.000	17.100
	Merino	0.593	1.000	1.375	0.000	17.800
2020	Dorper	1.000	1.000	1.000	0.000	18.000
	RedM	0.800	1.000	1.000	0.000	17.000
	Merino	0.615	1.000	0.750	0.000	16.600

Abbreviations: RedM = Red Maasai.

model (Hedeker, 2005) was used to establish the performance differences between the breeds. Each response variable (reproductive index) was modelled separately against the explanatory variable (breed). The response variables tested were fertility rate, litter size, weaning rate, multiple lambings, and weaning weight per lamb born.

The posthoc Tukey test to determine performance difference between breeds was done using the estimate marginal means (emmeans) package (Lenth et al., 2019).

Using the dplyr package (Mailund, 2019), causes of mortality cases occurring less than one year after birth were analysed. Visualisation was carried out using the lessR package (Gerbing, 2022). The chi-square test was used to examine the proportionate differences between causes, breeds, months, and sexes (Tallarida and Murray, 1987).

Results

The reproductive performance between breeds

The least-square means of the reproductive trait/index per breed investigated in this study are presented in Table 2. The RedM breed significantly (P = 0.001) outperformed both Dorper and Merino in weaning rate, whereas Dorper significantly (P < 0.001) outperformed other sheep breeds in Weaning weight per lamb born. Dorper and RedM significantly outperformed the Merino breed in fertility rate (P < 0.001). However, there was no significant difference between the three breeds in liter size (P = 0.989) and multiple lambings (P = 0.575).

Causes of death on the farm

Pneumonia was the main cause of mortality on the farm, representing 38% (chi-square test; P = 0.008) of all the mortality cases on the farm, while accidents were the least common cause of mortality (P = 0.008; Fig. 1). Pneumonia disease-related mortalities also occurred across all the months except February, when no mortality was registered. Sheep pox-related deaths were highly reported (chi-square test; P = 0.000) in May (Fig. 2). Dorper sheep were the most vulnerable to pneumonia, while Merino sheep were the least affected (chi-square test P = 0.001; Fig. 3). In terms of a general loss of individual sheep population, Dorper had the deaths (78%), while Merino's deaths only accounted for 1% of the total deaths (chi-square test; P = 0.003). However, there was no difference in death occurrence between the sexes (chi-square test P-value P = 0. 314), whereas most lamb deaths occurred in October, May, and August.

Table 2
The Least square means and RSD of Dorper, Red Maasai, and Merino performance per reproductive index.

Traits\Breeds	Dorper	Red Maasai	Merino	RSD	*p*. value
Fertility rate	1.008[a]	0.871[ab]	0.754[b]	0.112	< 0.001
Litter size	1.060	1.040	1.040	0.050	0.989
Weaning rate	0.882[a]	0.967[b]	0.828[a]	0.122	0.001
Multiple lambing	1.110	1.080	1.070	0.095	0.575
Weaning weight per lamb born	21.800[a]	18.100[bc]	18.900[c]	0.065	< 0.001

Least square means without a common subscript differ significantly (P < 0.05).

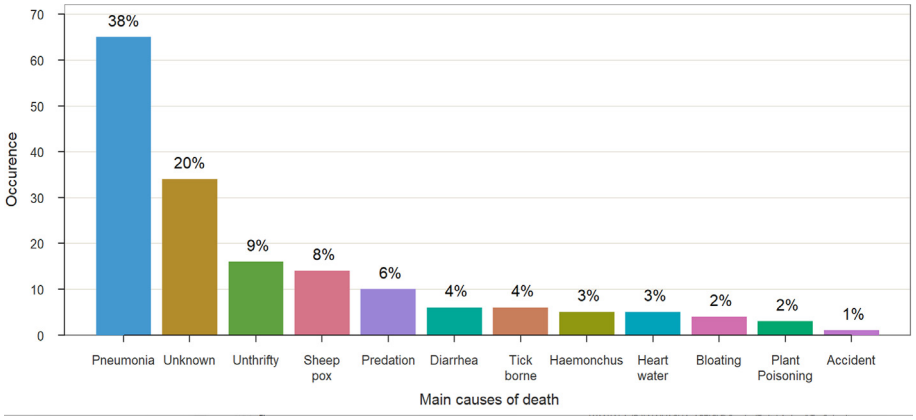

Fig. 1. General occurrence of mortality causes for all sheep breeds.

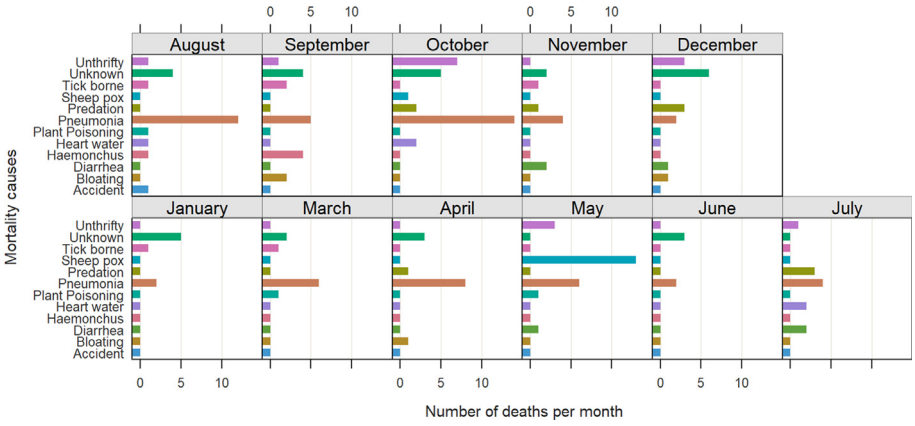

Fig. 2. Mortality cases and their causes per month for all sheep breeds.

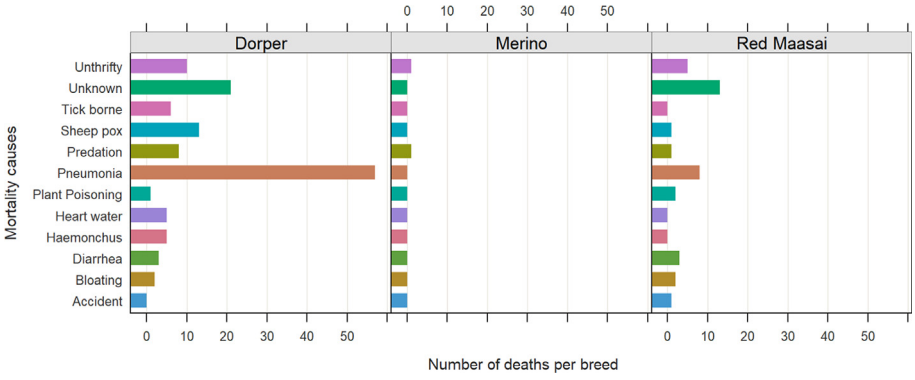

Fig. 3. Dorper, Red Maasai, and Merino's susceptibility to major mortality causes.

Discussion

The reproductive performance between breeds

To the best of our knowledge, this study is the first to compare the reproductive and survival performance of the RedM with that of the Dorper and Merino sheep breeds kept under the same management environment.

Commonly, farmers hold the opinion that it is only profitable to breed native sheep breeds when they are crossed with exotic species. The belief that native sheep breeds are reproductively inferior to exotic breeds has led to unobjective cross-breeding between the RedM and the exotic breeds. However, in this study, the RedM significantly outperformed Dorper and Merino in the weaning rate. On the other hand, Dorper only outperformed the RedM in weaning weight per lamb born, whereas Merino did not outperform the RedM in any investigated reproductive indices. Given their superior genetic makeup and good mothering ability (Gavojdian et al., 2015; Kosgey et al., 2008; Oyieng et al., 2022), the performance of Dorper in weaning weight per a lamb born was anticipated. Additionally, it has been claimed that Dorper is less choosy when grazing (Budai et al., 2013; Gavojdian et al., 2013), giving them a chance to sufficiently meet their daily nutritional needs. The comparative performance between the RedM and both

exotic sheep breeds in fertility rate, litter size, and multiple lambing suggested that the reproductive performance of Dorper and Merino could have been affected by environmental conditions since both breeds are well known for their superior reproductive performance (Cognie, 1990; Cloete et al., 2000; Gavojdian et al., 2015). Notably, the RedM sheep outperformed the two exotic breeds in terms of weaning rate, suggesting that, when produced under a similar extensive production system, the RedM's adaptability may influence their reproductive competitiveness among the exotic breeds. The results observed in this study are comparable to other studies, e.g., the Dorper breed (Cloete et al., 2000; Schoeman, 2000). The present Merino performance results, however, are lower than those found in studies on the Hungarian Merino (Nagy et al., 1999), the Anatolian Merino (Huisman et al., 2008), and the Namibian False Upper Karoo Merino (Snyman and Herselman, 2005). In comparison to other native breeds, RedM's reproductive performance was higher than the Ethiopian Menze and Horro breeds (Mukasa-Mugerwa et al., 2002) and lower than the indigenous sheep of Bangladesh (Pervage et al., 2009). These results suggest that the RedM was not inferior reproductively to the two exotic breeds. To improve the conservation strategies of the RedM, their genetic characterisation, e.g. (Kusza et al., 2009, 2010, 2011, and 2015), should be done.

Causes of mortality on the farm

The most common cause of mortality was pneumonia (Fig. 1), and November was the deadliest month overall (Fig. 2). The Dorper breed appeared to be the most susceptible to pneumonia (Fig. 3). Many of the previous research work also reported pneumonia as a major economic ramification in the sheep industry, e.g. (Alley et al.,1999; Gilmour et al., 1979; Peeler & Wanyangu, 1998). Pneumonia was most common in the station since the station is located in a dusty area most of the year. The farm recorded no deaths in February across the study period. Further investigations are needed to explain these results scientifically. In terms of vulnerability by gender, this study reported no significant difference between the sexes of the lambs. The farm also reported a few endoparasite and ectoparasite-related deaths, although most cases were reported in Dorper sheep. Sheep pox was more frequent in May. This coincides with a high and long rainfall period in the region. Mortality cases seemed to be spread equally between male and female lambs, suggesting neither sex was more susceptible. The present results suggest that raising pure Dorper in such environments would yield massive economic losses without proper management and veterinary care.

Conclusions

Contrary to popular belief, this study has demonstrated that RedM's reproductive performance was not inferior to exotic breeds in terms of the fertility rate, liter size, weaning rate as well as multiple lambings when raised in an extensive production system. The vulnerability of Dorper to foetal and parasite-related diseases, particularly pneumonia, tick-borne sheep pox, and *Haemonchus*, might expose the farmers to a significant financial loss despite their superior performance in weaning weight per lamb born. Producers must raise their operating expenditures by enhancing the flock's veterinary care in order to reduce mortality. For most farmers with inadequate access to resources, especially pastoralists, this may not be sustainable. Additionally, Merino exhibited comparatively poor performance under similar environmental conditions, indicating that the production of Merino by a small-scale farmer was not sustainable. As a result, we draw the conclusion that, without respect to weaning weight per lamb born, the RedM breed's production appears a more viable investment for small-scale farmers, particularly under the extensive production system in Kenya.

Ethics approval

Not applicable.

Data and model availability

None of the data were deposited in an official repository. The data that support this study are available from the authors upon request.

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Conceptualisation, **G.W., N.K.** and **Sz.K.**; writing-original draft preparation, **G.W.**; statistical analysis, **G.W.**; writing – reviewing and editing, **P.K.A., N.K.,** and **P.S.**; supervision, **Sz. K.**, all authors have read and agreed to the published version of the manuscript.

Declaration of Interest

None.

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