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Reproductive Performance, Birth Weight and Survival Characteristics in the Conservation-Priority Kaçeli Sheep Genotype

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ABSTRACT

This study was conducted to evaluate the number of lambs born per ewe, birth weight, and lamb survival rate in the Kaçeli sheep genotype, which is conserved as a genetic resource in Western Anatolia. Data were collected from records of 420 ewes and 470 lambs born to them on three farms during the 2024 and 2025 production periods. The overall averages for litter size and birth weight were 1.15 and 2.87 kg, respectively. The effects of year, farm, and month of birth on litter size were found to be statistically insignificant, whereas the effect of ewe age was significant. The highest number of lambs born per ewe was observed in 4–5-year-old ewes. Birth weight was significantly influenced by farm, ewe age, type of birth, and seasonal conditions ($p < 0.05$), while the effects of year and sex on this trait were minimal. The birth weight of single lambs was 21.6% higher than that of twins. The overall survival rate up to the marketing period was 89.36%, with significant differences observed between years. Faceted violin analyses revealed that higher birth weight significantly increased the survival rate, while birth type indirectly influenced this relationship through birth weight. The results indicate that the Kaçeli sheep genotype is genetically stable and resilient to environmental stresses. The genotype's fertility, balanced birth weights, and high survival rate demonstrate sustainable production capacity even under low-input conditions. These findings emphasize that native breeds such as Kaçeli sheep genotype are strategically important not only for their production value but also for preserving genetic diversity, maintaining ecological balance, and enhancing biological resilience against climate change.

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Koruma Öncelikli Kaçeli Koyun Genotipinde Üreme Performansı, Doğum Ağırlığı ve Yaşam Gücü Özellikleri

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Yerel genetik kaynaklar

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ÖZ

Bu çalışma, Batı Anadoluda genetik kaynak olarak korunan Kaçeli koyun genotipinde doğuran koyun başına doğan kuzu sayısı, doğum ağırlığı ve kuzu yaşama gücü performansını değerlendirmek amacıyla yürütülmüştür. Çalışmada, 2024 ve 2025 üretim dönemlerinde üç işletmede bulunan 420 baş koyun ve bunlardan doğan 470 baş kuzuya ait kayıtlardan elde edilen veriler kullanılmıştır. Doğuran koyun başına doğan kuzu sayısı ve doğum ağırlığına ilişkin genel ortalamalar sırasıyla 1.15 ve 2.87 kg olarak elde edilmiştir. Doğuran koyun başına doğan kuzu sayısı üzerine yıl, işletme ve doğum ayı etkileri istatistiksel olarak önemsiz bulunurken, ana yaşının etkisi anlamlı olmuştur. En yüksek doğuran koyun başına doğan kuzu sayısı 4–5 yaşlı koyunlarda gözlenmiştir. Doğum ağırlığı işletme, ana yaşı, doğum tipi ve mevsim koşullarından önemli ölçüde etkilenmiş ($p < 0.05$), buna karşın bu özellike üzerine yıl ve cinsiyet etkileri sınırlı kalmıştır. Tek doğan kuzuların doğum ağırlığı ikizlerden %21.6 daha yüksek bulunmuştur. Pazarlama dönemine kadar genel yaşama gücü %89.36 olup, yıllar arasında anlamlı farklılık göstermiştir. Çoklu yüzey (faceted) violin analizleri, yüksek doğum ağırlığının yaşama olasılığını belirgin biçimde artırdığını, doğum tipinin ise bu ilişkiyi doğum ağırlığı üzerinden dolaylı olarak etkilediğini ortaya koymuştur. Elde edilen sonuçlar, Kaçeli koyun genotipinin genetik olarak istikrarlı ve çevresel streslere karşı dirençli bir yapıya sahip olduğunu göstermektedir. Genotipin döl verimi, dengeli doğum ağırlıkları ve yüksek yaşama gücü, düşük girdi koşullarında bile sürdürülebilir üretim kapasitesine işaret etmektedir. Bu bulgular, Kaçeli gibi yerli genotiplerin yalnızca üretim değeriyle değil, aynı zamanda genetik çeşitliliğin korunması, ekolojik denge ve iklim değişikliğine karşı biyolojik dayanıklılığın sürdürülmesi açısından da stratejik önem taşıdığını vurgulamaktadır.

Introduction

Turkey represents one of the world's most important reservoirs of genetic diversity for small ruminants, harboring numerous indigenous sheep breeds adapted to a wide range of ecological conditions (Zeder, 2008, 2012; Soysal et al., 2020). These breeds have evolved through long-term natural and artificial selection, exhibiting high levels of adaptability, disease resistance, and phenotypic diversity, and have played a critical role in sustaining livestock production systems across diverse environments (Ertuğrul et al., 2009; Yildirir et al., 2023; Aydin et al., 2024; Ata et al., 2025). However, the widespread introduction of highly productive exotic genotypes into industrial production systems has resulted in population decline and genetic erosion in many native breeds, emphasizing the need for sustainable conservation strategies (Bratton, 1988; Taberlet et al., 2008; Taberlet et al., 2011; Yilmaz et al., 2013). Consequently, the conservation of indigenous animal genetic resources through in situ and ex situ programs has become a central component of Turkey's national livestock policy (TAGEM, 2015).

Within this framework, the Kaçeli sheep genotype represents a conserved local genotype uniquely adapted to the coastal ecosystems of Western Anatolia. Despite its limited

population size, the genotype demonstrates high resilience to climatic stressors and maintains productive performance under extensive, low-input production systems. Nevertheless, scientific information on the Kaçeli sheep genotype remains scarce, with existing knowledge largely derived from field observations. In this context, reproductive performance and lamb survival constitute key determinants of the genotype's long-term genetic sustainability.

Fertility, birth weight, and lamb survival are among the most influential traits affecting genetic progress and flock productivity in sheep (Shariati et al., 2018; Nel et al., 2021; Sharif et al., 2022). Fertility directly determines population growth and maternal efficiency, while birth weight reflects prenatal growth conditions and genetic potential. Birth weight is shaped by both genetic background and maternal nutritional status and must be maintained within optimal limits to minimize dystocia and enhance postnatal survival rate (Ridler et al., 2022; Bunter et al., 2023; Besufkad et al., 2024). Numerous studies have demonstrated that low birth weight substantially increases lamb mortality risk, whereas excessively high birth weight is associated with increased incidence of parturition difficulties (Gootwine, 2020; Wallace et al., 2021; Ridler et al., 2022).

Lamb survival is a multifactorial trait that integrates genetic robustness with environmental and managerial conditions (Oyieng et al., 2025; Wilson et al., 2025). It is strongly influenced by birth weight, birth type, sex, dam age, season, and management practices (Nel et al., 2021; Besufkad et al., 2024; Oyieng et al., 2025; Wilson et al., 2025). Lambs born with low birth weight or as multiples are particularly vulnerable due to impaired thermoregulation, reduced immune competence, and insufficient colostrum intake, leading to elevated mortality rates (Morris et al., 2000; Everett-Hincks et al., 2014; McCarthy et al., 2021; Wallace et al., 2021). Therefore, understanding the relationship between birth weight and survival is essential for identifying critical risk factors affecting the sustainability of endangered local breeds.

The Kaçeli sheep genotype, characterized by extended breeding activity and year-round lambing, presents additional challenges in evaluating key performance traits due to pronounced environmental variability. Accordingly, this study aimed to characterize major reproductive and survival-related traits—including litter size, birth weight, and lamb survival—in these genotype maintained under a genetic conservation program. Using multi-center data collected across two production periods, the effects of environmental and physiological factors on these traits were assessed through statistical and graphical analyses. Furthermore, the relationship between birth weight and lamb survival was comparatively evaluated across different birth types, sexes, and production periods.

Materials and Methods

The research was conducted with the permission of the Aydın Adnan Menderes University Animal Experiments Local Ethics Committee dated October 2, 2025, and numbered 64583101/2025/151.

Animal Material

The animal material for the study consisted of 420 Kaçeli sheep genotype and 470 lambs born to them on three farms during the 2024 and 2025 production periods. The ewes' births

were closely monitored, and the lambs were tagged, with detailed birth records maintained. Lamb birth weights were measured using an electronic scale with a capacity of 150 kg and a sensitivity of 50 g. To determine the survival rate, lambs were monitored until the marketing period, which coincided with weaning in the region, and survival data were recorded.

Statistical analysis

The normality of the data distribution was assessed using the SAS statistical software package (SAS, 1999). Descriptive statistics were calculated for the characteristics examined in the study. A Generalized Linear Model approach was employed to determine the effects of systematic environmental factors on characteristics that met the normality assumption. Data related to survival were analyzed using the chi-square (χ^2) test.

Births in ewes occur over a six-month period (Figure 1). Therefore, birth month was included in the statistical models to account for its potential effect on the characteristics studied.

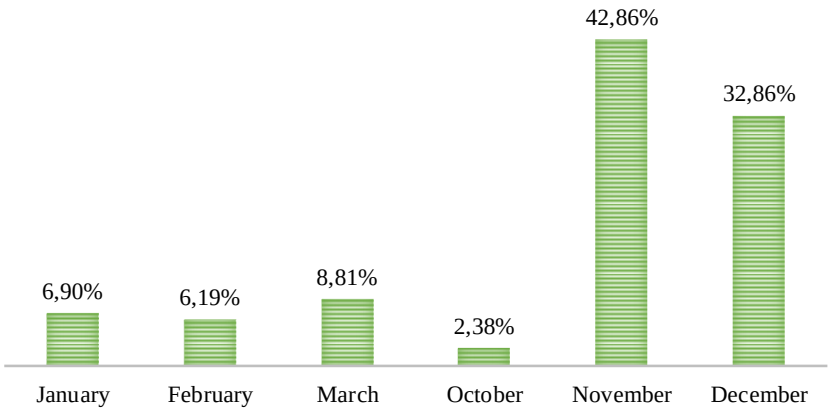

Figure 1. Temporal distribution of births in the Kaçeli ewes
Şekil 1. Kaçeli koyunlarda doğumların zamansal dağılımı

All statistical analyses were conducted using the UNIVARIATE, SIMPLE, GLM, and CATMOD procedures in the SAS software package (1999). Differences among groups were assessed using Duncan's Multiple Range Test as the post hoc multiple comparison procedure. Least Squares Means and their standard errors were calculated based on the statistical models described below.

Statistical models used in the analysis of data related to litter size

$$Y_{ijklm} = \mu + a_i + b_j + c_k + g_l + e_{ijklm}$$

Statistical model used in the analysis of birth weight data

$$Y_{ijklmno} = \mu + a_i + b_j + c_k + d_l + f_m + g_n + e_{ijklmno}$$

In the models;

Y= Observed values for birth type and birth weight
μ= Overall mean of the trait
a_i= Fixed effect of years (i=2024 and 2025)
b_j= Fixed effect of farms (j=*1-3*)
c_k= Fixed effect of dam age (k= *3, 4, 5, 6 and ≥7*)
d_l= Fixed effect of birth type (l= *single and twin*)
f_m= Fixed effect of sex (m=*male, female*)

g_n= Fixed effect of birth months (*n=January, February, March, October, November and December*)
e_{ijklm}= random errors with the assumption of N (0, σ^2).

As a complement to classical statistical analyses, faceted violin plots were employed to examine the distribution structure and variability levels of the data more comprehensively. These visualizations display the distributions of continuous features comparatively across different categorical factors. Probability density distributions were generated using the Kernel Density Estimation (KDE) method, while the median, interquartile range (IQR), and potential outliers were also visualized through box plots embedded within the graphs. By using the faceting method, the data are presented in layers according to different categorical variables, facilitating comparisons between groups.

Additionally, a trend analysis was conducted to examine the temporal relationships among birth month, birth weight, and survival rate. For this purpose, the birth weight variable was categorized into three groups: Low, Medium, and High, with an approximately equal number of observations in each group. This classification was performed using the *qcut* function from the pandas library. Each category was determined based on the data distribution, accounting for data density and outliers, to ensure balanced representation across groups. This approach was implemented to maintain equal representation of each weight category in the survival and other analyses.

The average survival rates for each birth weight category are presented as line plots across the birth months. The uncertainty surrounding these average estimates is represented by 95% confidence intervals, calculated using the non-parametric bootstrap method with B = 1000 resamples. This approach offers a reliable estimate, especially in subgroups with small sample sizes or non-symmetric distributions.

All data processing, analysis, and visualization steps were performed in the Python v3.10 (2021) environment, using the pandas v2.3.0 (2024) library for data organization, along with the seaborn v0.13 (Waskom, 2024) and matplotlib v3.10.3 (Hunter and Matplotlib development team, 2024) libraries.

Results

Descriptive statistics for the data collected during the two production periods (2024 and 2025) covered in this study are presented in Table 1.

Table 1. Descriptive statistics of litter size and birth weight in the Kaçeli sheep genotype
Tablo 1. Kaçeli koyun genotipinde doğumda kuzu sayısı ve doğum ağırlığına ilişkin tanımlayıcı istatistikler

Variable	N	$\bar{X}\pm S_{\bar{X}}$	CV%)	Min	Max
LS	420	1.09±0.284	26.08	1	2
BW (kg)	470	3.34±0.728	21.78	1.55	5.45

LS: litter size, BW: birth weight, CV: coefficient of variation

It is understood that the litter size ranges between 1 and 2, with a relatively high coefficient of variation of 26.08%. Similarly, when examining the distribution of litter size (Figure 2), it is observed that single births occur at a high frequency. In this context, multiple births accounted for only 8.81% of the total 420 lambing observations.

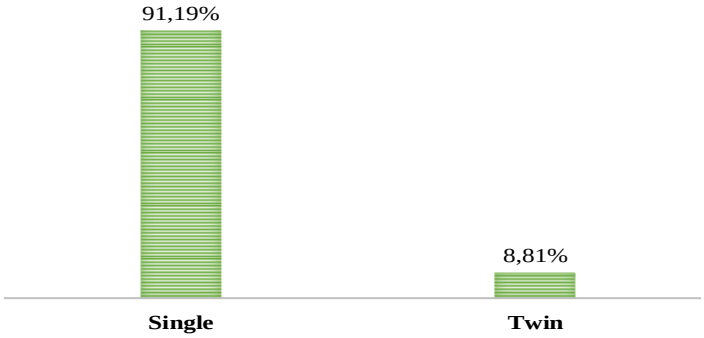

Figure 2. Distribution of litter size in Kaçeli sheep genotype
Şekil 2. Kaçeli koyun genotipinde doğumda kuzu sayısı dağılımı

The least squares means and standard errors for litter size observations, covering three flocks over two production periods in Kaçeli sheep genotype, are summarized in Table 2.

Table 2. Least squares means and standard errors of litter size in the Kaçeli sheep genotype
Tablo 2. Kaçeli koyun genotipinde doğumda kuzu sayısı için en küçük kareler ortalamaları ve standart hataları

Factors	N	LS
Years		p=0.141
2024	193	1.17±0.032
2025	227	1.13±0.035
Farms		p=0.579
Farm 1	19	1.19±0.070
Farm 2	179	1.14±0.028
Farm 3	222	1.12±0.026
Age		p=0.030
3	75	1.13±0.042^{b}
4	65	1.24±0.042^{a}
5	81	1.13±0.043^{b}
6	93	1.14±0.039^{b}
7	106	1.10±0.036^{b}
Birth month		p=0.172
January	29	1.16±0.054
February	26	1.11±0.058
March	37	1.14±0.052
October	10	1.29±0.093
November	180	1.12±0.032
December	138	1.07±0.032
Overall	420	1.15±0.029

LS: litter size, ^{a,b}: different superscript letters within the same column indicate significant differences among groups ($P < 0.05$; Duncan).

When examining the least squares means for litter size in the Kaçeli sheep genotype, it was determined that this trait was not significantly influenced by the factors of year, farm, or month of birth. However, the ewe's age had a statistically significant effect on litter size, indicating that the reproductive performance of Kaçeli sheep genotype varies with age. According to the results, the highest litter size was observed in 4-year-old ewes, with a gradual decline in older age groups. The overall average litter size in the Kaçeli sheep genotype is 1.15, with single births being predominant.

Results on lamb birth weights across all flocks are presented in Table 3.

Table 3. Least squares means and standard errors of birth weight in the Kaçeli lambs
Tablo 3. Kaçeli kuzularda doğum ağırlığına ait en küçük kareler ortalama ve standart hataları

Factors	N	BW (kg)
Years		p=0.212
2024	223	2.83±0.063
2025	247	2.91±0.073
Farms		p=0.000
Farm 1	22	2.07±0.141^{c}
Farm 2	207	3.45±0.059^{a}
Farm 3	241	3.08±0.056^{b}
Age of Dam		p=0.019
3	81	2.69±0.089^{bc}
4	81	2.86±0.081^{c}
5	92	2.95±0.087^{a}
6	105	2.97±0.081^{a}
7	111	2.88±0.078^{ab}
Birth tytpe		p=0.000
Single	393	3.15±0.061
Twin	77	2.59±0.083
Sex		p=0.328
Male	234	2.89±0.066
Female	236	2.84±0.067
Birth month		p=0.000
January	29	2.91±0.117^{b}
February	26	3.03±0.129^{b}
March	41	3.39±0.108^{a}
October	17	2.37±0.159^{c}
November	204	2.69±0.069^{b}
December	153	2.82±0.070^{b}
Overall	470	2.87±0.061

BW: Birth weight, ^{a,b,c}: different superscript letters within the same column indicate significant differences among groups ($P < 0.05$; Duncan).

The least squares means for birth weight (BW) in lambs indicated that this trait was not significantly affected by year or sex. However, farm, dam age, type of birth, and month of birth

had statistically significant effects. Among the farms, the highest birth weight was recorded at Farm 2 (3.45 kg), while the lowest was at Farm 1 (2.07 kg). The significant influence of maternal age on birth weight ($p < 0.05$) suggests that dam age plays a role in offspring development. Birth weight was lowest in 3-year-old ewes (2.69 kg) and highest in 5- to 6-year-old ewes. Birth type was one of the strongest determinants of birth weight; single-born lambs had a significantly higher average birth weight (3.15 kg) compared to twins (2.59 kg). Although the effect of sex was not statistically significant, male lambs had slightly higher birth weights than females.

The significant effect of birth month ($p < 0.001$) indicates that seasonal conditions influence birth weight. The highest birth weight occurred in March (3.39 kg), while the lowest was in October (2.37 kg).

The chi-square (χ^2) test results for the survival rate of lambs up to weaning age, which also corresponds to the marketing period in the region, are presented in Table 4.

Table 4. Chi-square (χ^2) tests regarding the survival rate of lambs during the marketing period
Tablo 4. Pazarlama dönemi kuzu yaşama gücüne ilişkin ki-kare (χ^2)testleri

Years		N	SR (%)	χ^2
2024	Number of lambs at weaning	214	95.96***	188.453
	Number of live-born lambs	223		
2025	Number of lambs at weaning	206	83.40***	110.223
	Number of live-born lambs	247		
Overall	Number of lambs at weaning	420	89.36***	291.277
	Number of live-born lambs	470		

SR: Survival rate

Chi-square (χ^2) analyses of lamb survival rates in the Kaçeli sheep genotype up to the marketing period revealed significant differences between years. The overall survival rate was calculated as 89.36%, and this value was found to be highly statistically significant ($p < 0.001$). When survival rates were examined by year, it was observed that the lamb survival rate was notably high at 95.96% in 2024; however, this rate declined to 83.40% in 2025.

The effects of fundamental categorical factors such as birth type, sex, and year on the distribution of birth weight were examined in this study. Findings concerning the impact of birth weight and birth type on lamb survival are illustrated in the split violin plot shown in Figure 3.

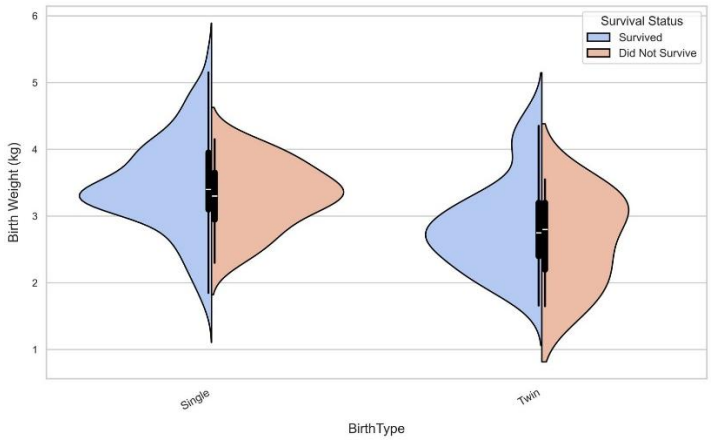

Figure 3. Lamb survival by birth weight and birth type
Şekil 3. Doğum ağırlığı ve doğum tipine göre kuzularda yaşama gücü

When examining the graph illustrating the effects of birth weight and birth type on lamb survival in Kaçeli sheep genotype, it is evident that surviving lambs have higher birth weights than those that died. Birth weights of approximately 3.0 kg and above increase the likelihood of survival, whereas low birth weights are associated with higher mortality rates. Furthermore, the average birth weight of twin lambs is lower than that of single lambs, resulting in reduced survival rates. This outcome is a natural consequence of nutritional and uterine constraints during multiple pregnancies.

Findings on the effects of birth weight and sex on lamb survival are presented in the split violin plot shown in Figure 4.

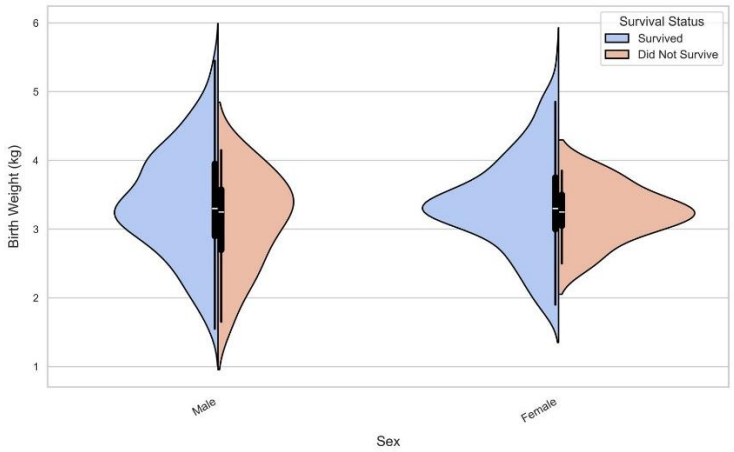

Figure 4. Lamb survival by birth weight and sex
Şekil 4. Doğum ağırlığı ve cinsiyete göre kuzu yaşama gücü

As examined in the study on the effects of birth weight and sex on lamb survival in Kaçeli sheep genotype, it was found that the average birth weight of surviving lambs was higher than that of deceased lambs in both sexes, as shown in Figure 3. This indicates that low birth weight negatively affects survival rates. Male lambs generally had slightly higher birth weights but exhibited a similar survival rate distribution to female lambs. These results suggest that sex is not a direct determinant of survival rate but may have an indirect effect through birth weight.

Results on the effects of birth weight and production periods on lamb survival rates are presented in the split violin plot shown in Figure 5.

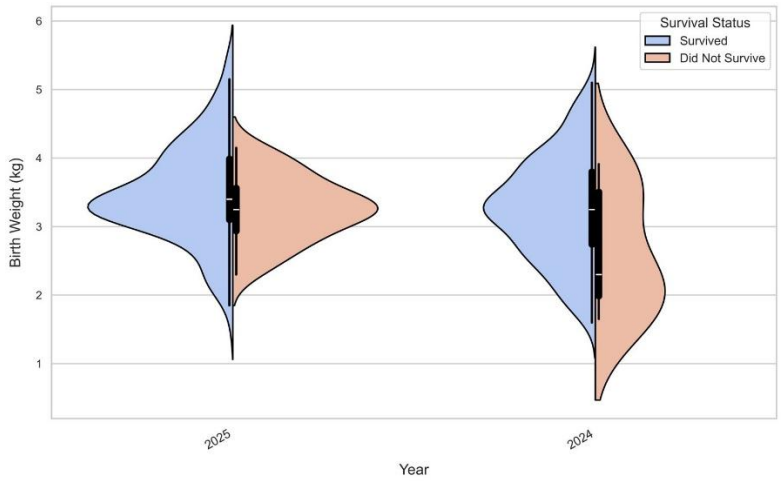

Figure 5. Lamb survival by birth weight and production period
Şekil 5. Doğum ağırlığı ve üretim dönemine göre kuzu yaşama gücü

Figure 5 illustrates the relationship between birth weight and the production periods (2024 and 2025) in Kaçeli sheep genotype, as well as the effects of these variables on lamb survival. The data show that the average birth weights of lambs that survived in both production periods were significantly higher than those of lambs that died. Additionally, lambs born in 2025 generally exhibited a slightly higher birth weight distribution. This difference may be attributed to variations in environmental conditions, nutritional levels, or management practices between the two years. Nevertheless, a consistent trend was observed in both years: lambs with low birth weights experienced higher mortality rates.

Results on lamb survival rates by birth month, categorized by birth weight, are presented in Figure 6.

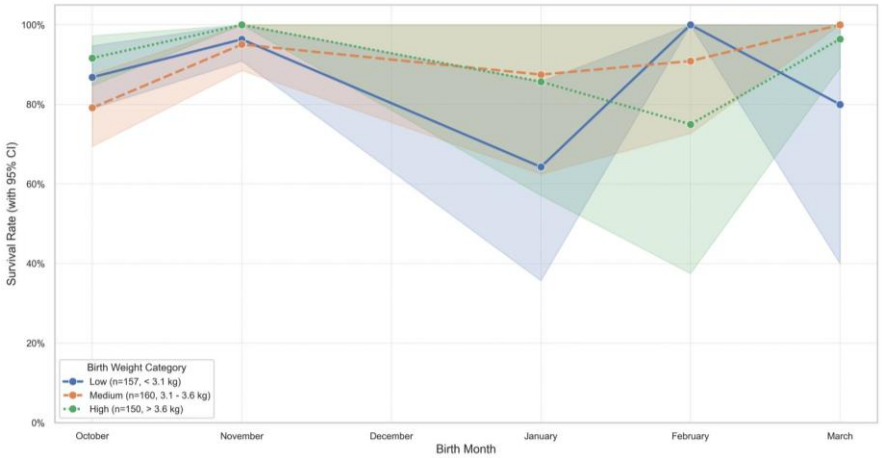

Figure 6. Trend in lamb survival rates by birth month according to birth weight groups
Şekil 6. Doğum ağırlığı gruplarına göre doğum aylarındaki kuzu yaşama gücüne ilişkin trend

The figure illustrates the trends in monthly survival rates of lambs categorized by birth weight (Low: <3.1 kg; Medium: 3.1–3.6 kg; High: >3.6 kg) during their birth months. Overall, survival rates fluctuated depending on the birth month, with significant differences observed between weight groups. Lambs with high birth weight generally exhibited the highest survival rates, remaining above 90% in most periods, except for a slight decline in January. In contrast, low birth weight lambs showed more variable and lower survival rates, with a marked decline particularly in January. The medium birth weight group displayed a more balanced survival trend compared to the other groups. The increase in survival rates in November and February–March suggests that factors such as environmental conditions, feeding status, or disease prevalence may have influenced lamb survival. Additionally, the widening of confidence intervals in some months may be attributed to differences in sample size or variability in the data.

Discussion and Conclusion

The findings suggest that environmental conditions and management practices in the conserved Kaçeli sheep populations have remained relatively consistent across years and farms, indicating that variations in litter size performance are likely attributable primarily to genetic or individual factors. Furthermore, the lack of significant differences in litter size based on birth month suggests that the genotype can maintain similar fertility levels under varying seasonal conditions and possesses a degree of adaptability to environmental stressors. Similarly, studies in the literature indicate that birth month generally has a limited effect on litter size variation, implying that litter size is influenced more by genetic and physiological factors (Assan, 2020; Pettigrew et al., 2021).

Findings regarding sheep age are consistent with the general pattern of fertility increasing at younger ages and declining at older ages due to physiological fatigue, decreased ovulation rates, or deterioration of uterine health. Similar trends have been reported in various native sheep breeds, with the 4–5-year age range identified as the period of optimal fertility (Kenyon et al., 2014; Aktas et al., 2015; Vlahek et al., 2023; El Amiri and Rahim, 2024).

The litter size values observed in Kaçeli sheep genotype are consistent with those reported for some Turkish native sheep breeds (Yakan et al., 2012; Boran and Torun, 2018; Savaş et al., 2020) but lower than values reported in other studies (Karaca et al., 2019; Karaca et al., 2021; Tüfekci, 2023). The findings regarding litter size suggest that the animals studied exhibited sustainable reproductive success rather than high rates of multiple births under conservation conditions. Previous research on this topic (Kristensen et al., 2015; Gicquel et al., 2020) has emphasized that, in protected populations, breeding programs should prioritize genetic diversity and consider the potential negative effects of excessive selection, rather than focusing on increasing multiple births. In this context, the primary objective in preserving the Kaçeli sheep genotype as a genetic resource should be the conservation of genetic diversity.

The difference in birth weight between years was found to be statistically insignificant. However, studies reporting similar findings (Dafur and Mbap, 2021; Haslin et al., 2021) contrast with other research indicating that the year effect significantly impacts the trait under consideration (Vlahek et al., 2021; Heinzen et al., 2023; Liu et al., 2024). In this context, the findings suggest that environmental conditions and care-feeding practices were maintained at a

consistent level throughout the study period. This result implies that interannual variation in the protected Kaçeli sheep genotype has a limited effect on birth weight and that the population may exhibit a degree of phenotypic stability in response to environmental fluctuations.

The fact that the farm effect was found to be statistically significant at a high level indicates that differences in management conditions, selection, and feeding practices play a decisive role in birth weight. Indeed, most of the literature supports these findings (Arrebola et al., 2009; Kelman et al., 2022; Sahin, 2022; Aksoy et al., 2023). It is believed that this difference may arise from variations in husbandry and feeding practices between farms. This result highlights that early growth characteristics, such as birth weight, are highly sensitive to environmental factors and emphasizes the importance of farm management in breeding.

Significant statistical differences in birth weight based on birth type can be attributed to a reduction in the amount of nutrients available per offspring in multiple births, resulting from variations in nutrient sharing within the uterus and placental development. Indeed, studies conducted on other breeds have demonstrated that birth type affects birth weight (Gardner et al., 2007; Roca Fraga et al., 2018; Demirel, 2024).

Although most of the literature on the subject (McHugh et al., 2017; Koyuncu et al., 2018; Yağcı et al., 2018; Washaya et al., 2023) reports that gender has a significant effect on birth weight, some studies (Demirel, 2024; As et al., 2025) have found this discrete factor to be insignificant. In the present study, the difference observed between genders was not statistically significant. This discrepancy with the literature is thought to arise from factors such as sample size, type of birth, maternal age, nutritional status, breed, and environmental conditions. The differences in birth weight according to birth month reflect the impact of variations in feed quality and environmental temperature during the prenatal period on fetal development. It is believed that the increased feeding level during the final stage of pregnancy in winter months, along with enhanced metabolic efficiency due to cooler conditions, supports this finding. Similar results have been reported in the literature (Heinzen et al., 2023; Demirel, 2024; Gabr et al., 2025).

The survival rates observed in this study indicate that the Kaçeli sheep genotype demonstrates a high level of survival under conservation conditions and possesses a strong capacity to adapt to environmental and management factors. The statistically significant χ^2 tests for both years ($P < 0.001$) suggest that the observed differences were not due to chance, reflecting significant changes in environmental or management factors affecting survival rates between years. The decline in survival rate observed in 2025 may be attributed to environmental factors such as adverse conditions during the birth period or pre-weaning care, climatic stress, nutritional deficiencies, or an increased incidence of disease. Such annual fluctuations are highly sensitive to management practices, particularly in small populations under conservation. Overall, the survival rate exceeding 89% supports the genetic resilience and adaptive potential of the Kaçeli sheep genotype. This rate aligns with the average lamb survival rates reported in several sheep breeds (Flinn et al., 2020; Ridler et al., 2022; Heinzen et al., 2023; Anwar et al., 2024). Therefore, the survival rates obtained for the Kaçeli sheep genotype can be considered highly satisfactory.

Faceted violin plots revealed that birth weight is a primary factor influencing survival in lambs. The effect of birth type on this relationship was found to be indirect, largely mediated through birth weight rather than direct. However, gender differences did not produce a

statistically significant impact on survival. These findings emphasize that prenatal care and feeding strategies in native sheep breeds are critically important for survival rates, while physiological variations such as sex play a limited role. Furthermore, it was concluded that inter-annual environmental variability had only a minor effect on this relationship, maintaining a relatively stable pattern of survival rate across different production periods. These results are consistent with previous studies (Aslaminejad et al., 2011; Gaur et al., 2022; Besufkad et al., 2024; Kuru and Ölmez, 2024).

When examining the trend in lamb survival rates by birth month across different birth weight groups, it is evident that birth weight has a significant and decisive impact on lamb survival. The findings reveal that survival rate increases markedly with higher birth weights, and lambs with greater birth weights exhibit superior survival rates during the postnatal period. Similar results have been reported in previous studies on this topic (Hatcher et al., 2009; Everett-Hincks et al., 2014).

This study of the Kaçeli sheep genotype provides a broader perspective on the sustainability of local genetic resources and the future of animal husbandry, extending beyond traditional production-focused evaluations. The findings indicate that the genetic stability of Kaçeli sheep under environmental variability reflects the evolutionary adaptation of native breeds developed through long-term harmony with natural ecosystems. These results emphasize the need to reassess ecological balance and adaptive capacity—often underestimated in intensive production systems—through the lens of indigenous genetic resources.

The significance of the Kaçeli sheep genotype extends beyond its productive traits to its crucial role in preserving genetic diversity. Its consistent reproductive performance, resilient birth weight, and high survival rate indicate that biological resilience results from natural selection processes that require minimal human intervention. These characteristics make native breeds strategic biological safeguards against the increasing challenges posed by climate change, resource limitations, and sustainability pressures in livestock production.

Accordingly, the Kaçeli sheep genotype should be regarded not merely as a regional genetic resource but as a biological model that can inform more sustainable, ethical, and ecologically grounded livestock policies. Conserving this genotype, therefore, represents both the protection of genetic diversity and the preservation of long-standing environmental adaptations and culturally embedded production systems. Ultimately, these findings call for a shift in livestock production paradigms toward genetic sustainability in harmony with natural systems, recognizing native breeds as key components of resilient agricultural futures.

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