Journal of Anatolian Environmental and Animal Sciences
(*Anadolu Çevre ve Hayvancılık Bilimleri Dergisi*)
DOI: https://doi.org/10.35229/jaes.1362722

JAES
Year: 8, No: 4, 2023 (651-657)
AÇEH
Yıl: 8, Sayı: 4, 2023 (651-657)

ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Effect of Environmental Factors on Preweaning Growth Traits of Morkaraman Lambs

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Geliş/Received: *19.09.2023* ***Kabul/Accepted:*** *16.11.2023* ***Yayın/Puplished:*** *31.12.2023*
How to cite: **Karakuş, F. (2023)**. Effect of Environmental Factors on Preweaning Growth Traits of Morkaraman Lambs. *J. Anatolian Env. and Anim. Sciences*, ***8***(4), 651-657. https://doi.org/10.35229/jaes.1362722
Atıf yapmak için: **Karakuş, F. (2023).** Morkaraman Kuzularının Sütten Kesim Öncesi Büyüme Özellikleri Üzerine Çevresel Faktörlerin Etkisi. *Anadolu Çev. ve Hay. Dergisi*, ***8***(4), 651-657. https://doi.org/10.35229/jaes.1362722

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Abstract: The aim of this study was to analyze the environmental factors impacting preweaning growth traits in Morkaraman herds and to categorize weaning weight using the Gaussian mixture regression model. The mean live weights of lambs at birth, 60th, and 90th day (weaning) were determined to be 3.97 kg, 17.94 kg, and 24.92 kg, respectively. The effect of lambing years on live weights at all ages was quite significant ($p<0.001$). The effect of dam age on birth ($p<0.01$), 60th day ($p<0.001$), and weaning weight ($p<0.001$) was also highly significant. Male lambs were superior to females in terms of birth weight ($p<0.001$), 60th day ($p<0.01$), and weaning weight ($p<0.001$). Birth type was only found to have a significant effect on birth weight ($p<0.001$). Additionally, it was determined that the weaning weights could be categorized according to districts using the Gaussian mixture regression model. As a result, knowing the effects of environmental factors on the growth traits of lambs, which are effective in the emergence of genetic potential, can provide important contributions to the strategies of breeding and management.

Keywords: Morkaraman, lamb, growth traits, environmental factors.

Morkaraman Kuzularının Sütten Kesim Öncesi Büyüme Özellikleri Üzerine Çevresel Faktörlerin Etkisi

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Öz: Bu çalışmanın amacı, Morkaraman sürülerinde sütten kesim öncesi büyüme özelliklerini etkileyen çevresel faktörleri incelemek ve Gauss karışım regresyon modelini kullanarak sütten kesim ağırlığını kategorize etmektir. Kuzuların doğum, 60. ve 90. gün (sütten kesim) ortalama canlı ağırlıkları sırasıyla 3.97 kg, 17.94 kg ve 24.92 kg olarak belirlendi. Kuzulama yılının tüm yaşlardaki canlı ağırlıklar üzerindeki etkisi oldukça önemli bulundu ($p<0.001$). Ana yaşının doğum ($p<0.01$), 60. gün ($p<0.001$) ve sütten kesim ağırlığı ($p<0.001$) üzerindeki etkisi de oldukça önemliydi. Erkek kuzular doğum ağırlığı ($p<0.001$), 60. gün ($p<0.01$) ve sütten kesim ağırlığı ($p<0.001$) bakımından dişilerden daha üstündü. Doğum tipinin yalnızca doğum ağırlığı üzerinde anlamlı bir etkisi bulundu ($p<0.001$). Ayrıca, Gauss karışım regresyon modeli kullanılarak sütten kesim ağırlıklarının ilçelere göre kategorize edilebileceği belirlendi. Sonuç olarak, genetik potansiyelin ortaya çıkmasında etkili olan çevresel faktörlerin kuzuların büyüme özellikleri üzerindeki etkilerinin bilinmesi, ıslah ve yönetim stratejilerine önemli katkılar sağlayabilir.

Anahtar kelimeler: Morkaraman, kuzu, büyüme özellikleri, çevresel faktörler.

INTRODUCTION

Growth traits are a good indicator of the animal's ability to adapt to current environmental conditions. The rapid growth rate is used as a selection criterion as it determines the meat-producing capacity of animals up to the marketing age. Growth traits are greatly influenced by genetic and non-genetic factors (Lalit Malik et al., 2016). Due to its positive genetic correlation with subsequent live

weights, birth weight is important as an early measurable trait. On the other hand, the most crucial economic factor affecting the financial success of industrial sheep flocks is weaning weight (Mellado et al., 2016).

In general, growth from birth to weaning influences post-weaning development and mature or slaughter weight. The high average daily gain before weaning is an indicator of the genetic potential of the developing lamb and the mothering ability of the ewe. However, it is very important to consider the effects of maternal and environmental factors in addition to genetic potential on birth weight and early growth characteristics (Assan, 2020). Many studies have shown the significant effects of non-genetic environmental factors such as lamb's sex, birth type, birth year, birth season, and dam age on the growth of lambs (Maraveni et al., 2018; Ali et al., 2020; Behrem, 2021; Ehsaninia, 2021; Noyan & Ceyhan, 2021; Hagan et al., 2022).

Economically important traits such as live weight gain, egg, milk, and meat production are quantitative and continuously variable traits (Núñez-Torres & Almeida-Secaira, 2022). Quantitative traits show continuous variation due to many small-acting genes and environmental factors that cause individuals of the same genotype to have different phenotypes. For this reason, animals cannot be divided into classes with strict limits in terms of quantitative characteristics (Pollak, 2001; Toghiani, 2012). On the other hand, it has been shown in various studies that animals can be subdivided according to identifiable and stable phenotypes in terms of quantitative traits (Kebede & Gebretsadik, 2010; Yeşilova et al., 2016; Kebede et al., 2019; Garcia-Baccino et al., 2021).

Garcia-Baccino et al. (2021) reported that in practice, there may be situations where the population is a mixture of n different groups that are known to exist physically, and mixture models can be applied when there is a group structure in the data. In mixture modeling, which has been used in many fields in recent years, firstly, the data set is considered heterogeneous, and the heterogeneity is eliminated by dividing the data set into homogeneous subgroups within itself. Compared to cluster and factor analysis, the first advantage of the mixture model calculates the probability that each animal belongs to which subgroup, and the second advantage is to perform a separate regression analysis for each sub-group (Yeşilova et al., 2008; 2016; Kebede et al., 2019; Garcia-Baccino et al., 2021).

Since they have a long history of adaptability and exceptional gene-environment interactions that aid in survival, local sheep breeds are important genetic resources (Arzik et al., 2022). One of Türkiye's most important local fat-tailed sheep breeds, Morkaraman sheep are raised in the Eastern Anatolia Region. Morkaraman with multi-purpose is primarily bred for meat yield. This breed is known for its robust adaptation to various unfavorable environmental conditions (Kopuzlu et al., 2014; Şahin & Kopuzlu, 2022). Although there are studies investigating the environmental factors affecting preweaning growth in Morkaraman lambs, there is no report on the analysis using the mixed model. The purpose of this study was to investigate the environmental factors affecting preweaning growth traits in Morkaraman herds and to classify the weaning weight using the Gaussian mixture regression model.

MATERIAL AND METHOD

Study area and flock management: The experimental procedures were approved by Van Yüzüncü Yıl University Ethical Committee on Animal Experimentation (reference no 2023/07-24). The animal material of this study consisted of Morkaraman sheep raised in enterprises involved in the Morkaraman Breed Sheep Breeding Sub-Project (TAGEM/04MOR2013-01) implemented in Ağrı Province in Eastern Türkiye. The study area is located between 39° 43' 7" N latitude and 43° 3' 3" E longitude. The altitude of the province is 1640 m above sea level, and the annual average rainfall is 521.8 mm.

In the enterprises from which data were obtained in the study, the mating season takes place in September-October, and lamb births occur in February-March. During the breeding period, in addition to pasture, rams, and sheep are given grass straw and crushed barley in the morning and evening. Sheep with lambs are housed separately and fed with the concentrate feed and roughage. During the pasture period starting from April, sheep only benefit from the pasture. The lambs are accustomed to feeding at about two weeks of age and are fed with grower feed and alfalfa hay until they come out to pasture.

Lambs are housed with their mothers until weaning at an average of 90 days of age. During the pasture period, they are kept with their mothers in the evenings and suckled. The lambs are grazed in the pasture between May and July and no additional feeding is done during this period. In late July-September, the lambs are fed with alfalfa hay and crushed barley until they are sold.

Data collection: The newborn lambs were weighed within 12 to 24 h of birth and ear-tagged for identification. Data were recorded for the birth weight and weaning weight at about 90 days of age of 18297 Morkaraman lambs born from 2020 to 2022. Environmental factors affecting the preweaning growth included birth year, age of the dam, gender, and birth type. The 60^{th} and 90^{th} day weights of the lambs were calculated by the linear interpolation method. Weaning weight was corrected for 90 days, which is the mean weaning day of the animals.

Statistical analysis: The effects of some environmental factors on the growth traits of lambs such as birth year, age of the dam, gender, and birth type were

analyzed by the Least Squares Means method in the GLM procedure of the Statistical Analysis System software. Significant differences among means were examined using Duncan's multiple range tests. The statistical model used for the growth traits was:

$$Y_{ijklm} = \mu + a_i + g_j + c_k + d_l + b_m (x_{ijklm} - \bar{x}) + e_{ijklm}$$

Where;

Y_{ijklm} = Birth and weaning weight of the lamb,

μ = overall mean,

a_i = the effect of lambing year (i=2020, 2021, 2022),

g_j = the effect of dam ages (j=1, 2, 3, 4, 5, ≥6)

c_k = the effect of gender (k=1, 2; male, female),

d_l = the effect of birth type (l=1, 2; single, twin),

b_m = linear regression coefficient of birth weight on weaning weight

x_{ijklm} = individual birth weight of the lamb

$\bar{x}$ = mean birth weight

e_{ijklm} = the random residual error.

Information criteria are used to estimate the number of components in a Gaussian mixture model. The two most used information criteria are the Akaike information criteria (AIC) and the Bayesian information criteria (BIC) (Shirinkam et al., 2020). The smallest AIC and BIC criteria were used to determine the number of homogeneous subgroups of the 90th day live weight of the lambs according to the villages where the study was carried out, thus it was determined that 3 homogeneous sub-groups could be formed (Table 1).

Table 1. Model selection criteria for sub-groups.

	Selection Criteria*	
Sub-groups	**BIC**	**AIC**
Model with one sub-group	108973.217	109211.401
Model with two sub-groups	106558.941	106856.183
Model with three sub-groups	**106402.849**	**106449.544**
Model with four sub-groups	107541.028	107613.718

* Lowest BIC and AIC values explain the best model.

It was determined that the AIC and BIC concordance statistics decreased until the three-subgroup model and then increased. Therefore, fit criteria after the 4-subgroup model were not given. Thus, lambs were divided into 3 sub-groups homogeneous within themselves and heterogeneous among themselves, in terms of body weight on the 90th day in 4 different villages.

RESULTS

The least squares mean, standard errors, and multiple comparison test results regarding the effects of some systematic environmental factors on growth from birth to weaning in Morkaraman lambs are given in Table 2. The mean birth weight, 60th day, and weaning weights of Morkaraman lambs were 3.97 kg, 17.94 kg, and 24.92 kg, respectively.

Lambing year: The effect of lambing years on live weights from birth to weaning was highly significant ($p<0.001$). Lambs born in 2022 were significantly heavier at birth than lambs born in 2020 and 2021. However, lambs born in the last lambing year (2022) could not maintain their superiority in terms of birth weight at later ages. Lambs born in 2020 had a significantly higher 60th day and weaning weight than those born in later years ($p<0.001$).

Table 2. Least-squares means (±s.e.) for growth traits of Morkaraman lambs (kg).

Factors		**Birth weight**		**60th day weight**		**Weaning weight**	
		n	**X̄±Sx̄**	**n**	**X̄±Sx̄**	**n**	**X̄±Sx̄**
Overall mean		18297	3.97±0.01	17720	17.94±0.03	17720	24.92±0.04
Lambing year			***		***		***
	2020	6069	3.55±0.03^{c}	5961	19.99±0.07^{a}	5961	28.00±0.10^{a}
	2021	6171	3.60±0.03^{b}	5924	17.31±0.06^{c}	5924	23.98±0.09^{c}
	2022	6057	3.89±0.03^{a}	5835	17.48±0.06^{b}	5835	24.24±0.10^{b}
Dam age			**		***		***
	1	151	3.59±0.06^{a}	148	19.66±0.26^{a}	148	27.51±0.40^{a}
	2	3852	3.72±0.03^{b}	3720	18.01±0.06^{b}	3720	25.02±0.09^{b}
	3	3509	3.68±0.03^{ac}	3412	17.99±0.06^{b}	3412	24.99±0.09^{b}
	4	3114	3.70±0.03^{bc}	2998	17.83±0.06^{c}	2998	24.76±0.09^{c}
	5	2879	3.70±0.03^{bc}	2811	17.98±0.06^{bc}	2811	24.99±0.10^{bc}
	≥6	4792	3.71±0.06^{bc}	4631	18.11±0.05^{b}	4631	25.18±0.08^{b}
Gender			***		**		**
	Male	9051	3.72±0.03^{a}	8764	18.31±0.06^{a}	8764	25.47±0.09^{a}
	Female	9246	3.64±0.03^{b}	8956	18.22±0.06^{b}	8956	25.35±0.09^{b}
Birth type			***				
	Single	15287	4.05±0.01^{a}	14812	18.15±0.05	14812	25.24±0.07
	Twin	3010	3.48±0.02^{b}	2908	18.38±0.08	2908	25.58±0.11
Regression (Lin.)							
	Birth weight		-		0.331±0.037***		-0.003±0.056

a, b, c: Means values with different letters are significant. **: p<0.01, ***: p<0.001

Dam age: The results of this study indicated that the lowest birth weight was obtained from 1-year-old mothers, while 2-year-old dams had heavier lambs at birth (3.59 kg vs. 3.72 kg, $p<0.01$). At the same time, lambs of 1-year-old dams had a statistically lower birth weight than lambs of 4-, 5-, and 6-years old dams. For birth weight, the difference between the lambs of the 2- and 3-year-old dams was also significant. The effect of dam age on the 60th day ($p<0.001$) and weaning weight ($p<0.001$) was also found to be highly significant. While the lambs of 1-year-old dams had the highest 60th day and weaning weight, the

lowest body weights for both periods were determined in the lambs of 4-year-old dams ($p<0.001$).

Gender: The mean birth weight for male and female lambs was 3.72 kg and 3.64 kg, respectively ($p<0.001$). Male lambs were also heavier than female lambs on the 60th day ($p<0.01$) and weaning ($p<0.01$).

Birth type: A highly significant ($p<0.001$) difference was found between single and twin lambs at birth. Single lambs were 0.57 kg heavier compared with twin lambs. However, since single lambs could not reflect the difference in birth weight, no significant difference was found between single and twin lambs in terms of 60th day and weaning weight.

The linear regression effect of birth weight: The regression coefficient of birth weight on the 60th day weight was found as 0.331. The linear regression effect of birth weight was found to be significant only at day 60. On the other hand, the regression coefficient for weaning weight was estimated as -0.003, which was quite different from day 60.

Distribution of districts according to weaning weight: Table 3 and Figure 1 shows the distribution of 4 districts to sub-groups in terms of weaning weight according to the Gaussian mixture regression model. Weaning weight was determined as 23.868 kg in subgroup 1, 34.850 kg in sub-group 2, and 44.212 kg in sub-group 3. In sub-group 3, which includes the lambs with the highest weaning weight, the highest rate was determined in the Merkez district, and the lowest rate was determined in the Eleşkirt district.

Table 3. Distribution of sub-groups and districts according to weaning weight of lambs.

Sub-groups		Eleşkirt	Hamur	Merkez	Tutak
	Mean	n (%)	n (%)	n (%)	n (%)
1	23.868	3042 (97.13%)	4353 (96.63%)	7769 (86.08%)	1004 (94.99%)
2	34.850	85 (2.71%)	137 (3.04)	1105 (12.24%)	46 (4.35)
3	44.212	5 (0.16%)	15 (%0.33)	152 (1.68%)	7 (0.66%)

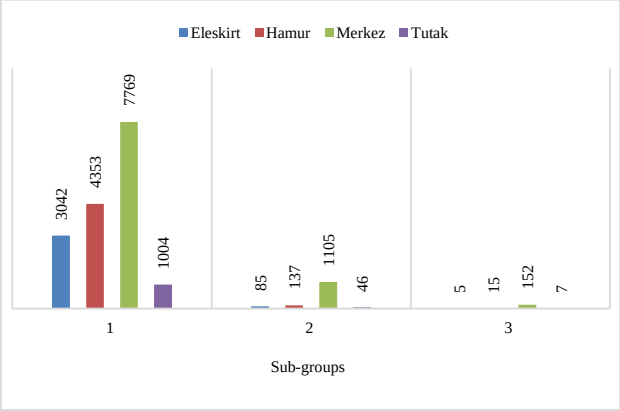

Figure 1. Distribution of districts into sub-groups according to weaning weight of lambs.

DISCUSSION

When compared with the overall mean values of the growth traits given in Table 1, the live weights of Morkaraman lambs at birth, 60th and 90th days were lower than the values reported for Hemsin lambs (Sarı et al., 2014) but higher than the values reported for Savak Akkaraman lambs (Yağcı et al., 2018). Additionally, it was found that compared to some other local sheep breeds, Morkaraman lambs had lower birth weights and higher weaning weights on the 90th days (Şireli et al., 2015; Behrem, 2021; Keçici et al., 2021).

The lambing year was one of the main factors affecting growth traits from birth to weaning in Morkaraman lambs. There were statistically highly significant differences ($p<0.001$) among the lambing years in all growth periods. Lambs born in the first lambing year of this study (2020) weighed 4.02 and 3.76 kg more at weaning than lambs born in the following years (2021 and 2022), respectively ($p<0.001$). Many studies revealed the effect of year on live weights at different ages of lambs (Akhtar et al., 2012; Keçici et al., 2021; Sharif et al., 2022; Tesema et al., 2022; Balasundaram et al., 2023). According to reports, the effect of lambing year on live weight at various ages is caused by variations in climate, nutrition, management, and hygiene from year to year, which mostly have an impact on lambs directly or indirectly through their dams (Baneh & Hafezian, 2009; Abbas et al., 2010). On the other hand, Shibab et al. [32] reported that there was no significant effect of year on birth and weaning weight in local and Turkish Awassi sheep.

The significant variations in growth traits of lambs born from dams between the ages of 1 to ≥6 were observed in the current study. The lambs with the lowest birth weight were obtained from the 1-year-old dams, while the 2, 4, 5 and ≥6 years old dams produced the lambs with the highest birth weight ($p<0.01$). Consistent with the study findings, Sharif et al. (2022) reported that, unlike younger ewes, mature and older ewes spend most of their energy on fetal development, resulting in larger lambs at birth. The statistically significant effect of dam age on preweaning growth continued and lambs from 1-year-old dams performed much better at day 60 ($p<0.001$) and weaning ($p<0.001$) compared to lambs from older dams. Kelman et al. (2022) stated that factors such as maternal ability, milk production, and colostrum composition may be responsible for the effect of young dams on lamb weight. Contrary to the study findings, the growth

performance of Rahmani and Chios lambs (Abbas et al., 2010), Awassi lambs (Özbeyaz et al., 2018), and different meat type lambs (Kader Esen & Elmacı, 2021) were not affected by dam age.

Morkaraman male lambs were superior to females in terms of birth weight, 60th day, and weaning weight. The mean differences between the genders were found to be statistically significant ($p<0.001$ and $p<0.01$), although not much. In many studies on different sheep breeds, the effect of gender, as one of the macro-environmental factors, on birth and body weight at various ages was found to be significant (Abbas et al., 2010; Selvi & Üstüner, 2021; Bozgüllü & Macit, 2022; Sharif et al., 2022). The body composition and muscular development of male and female lambs varies, and male lambs tend to deposit most of their muscle mass in the chest area, which may explain the differences between the genders (Málková et al., 2020). On the other hand, Kuchtik & Dobes (2006) concluded that the effect of gender on body weight was not significant at birth, 30th and 70th days.

In this study, single-born lambs were heavier than twin-born lambs at birth ($p<0.001$). The birth weight difference (0.57 kg) between single and twin Morkaraman lambs was found to be lower than values reported for different sheep breeds (Alarslan & Aygün, 2019; Olfaz et al., 2019; Noyan & Ceyhan, 2021; Sharif et al., 2022). On the other hand, the effect of birth type on weight at the 60th day and weaning was insignificant. No differences were also reported for Hemsin (Sarı et al., 2014) and Awassi (Hızlı & Yazgan, 2021) lambs in the same growth periods. Contrary to study findings, in the Irish sheep breed population, single-born lambs were determined to have the heaviest birth, preweaning, and weaning weights ($p<0.001$) compared to multiple births (McGovern et al., 2020).

In the regression analysis performed in the study, there was a highly significant relationship between birth weight and day 60 ($p<0.001$), but no significant effect of birth weight on weaning weight was found. These two variables were negatively (-0.003) correlated. Contrary to this study, linear regression of birth weight on weaning weight was found to be 2.58 ($p<0.01$) in Kıvırcık lambs (Cemal et al., 2005) and 0.19 ($p<0.01$) in Awassi sheep (Şahin, 2022).

According to the Gauss mixture regression model (Table 3), the district with the highest number of lambs with a weaning weight below the overall mean (23.868 kg, sub-group 1) was Eleskirt with 97.13%, while it was in Merkez district the least with 86.08%. Merkez district also had the highest rate in sub-groups 2 and 3 (12.24% and 1.68%, respectively), which included lambs with above-average weaning weight. The higher rate of lambs with higher weaning weight in the Merkez district compared to the other three districts may have resulted from better selection planning, feeding and management practices as well as better environmental conditions in sheep in this district. With Gaussian mixture regression model used in this study, it was shown that Anatolian buffaloes can be divided into three subgroups according to their lactation milk yield. The effects of lactation period, dam age, and villages on lactation milk yield were found to be statistically significant in sub-group 1 with the highest average lactation milk yield ($p<0.01$).

CONCLUSION

As a result of the study, it was determined that the preweaning growth traits of Morkaraman lambs were affected by environmental factors. Since the income of the breeder depends on the sale of non-breeding lambs weaned in the enterprises where the study is carried out, birth weight and weaning weight or preweaning live weight gain is important as a measure of growth traits. Lambing year, dam age and gender had statistically significant ($p<0.01$, $p<0.001$) effects on birth weight, 60th day, and weaning weight, whereas birth type only influenced birth weight. In addition, as another result of the study, it was seen that the Gaussian mixture regression model could be used in categorizing the weaning weights according to the districts.

Environmental factors, which have been identified as the main sources of variation in the growth traits of lambs, play an important role in the expression of genetic potential (Rahimi et al., 2014). Knowing the environmental factors affecting birth and weaning weights will also contribute to breeding and management strategies.

ACKNOWLEDGEMENTS

The data used in this study were obtained within the scope of Morkaraman breed sheep breeding sub-project. I would like to thank the Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Agricultural Research and Policies for their support in the project.

REFERENCES

Abbas, S.F., Abd Allah, M., Allam, F.M. & Aboul-Ella, A.A. (2010). Growth performance of Rahmani and Chios lambs weaned at different ages. *Australian Journal of Basic and Applied Sciences*, ***4***(7), 1583-1589.

Akhtar, M., Javed, K., Abdullah, M., Ahmad, N. & Elzo, M.A. (2012). Environmental factors affecting preweaning growth traits of Buchi sheep in Pakistan. *The Journal of Animal & Plant Sciences*, ***22***(3), 529-536.

Alarslan, E. & Aygün, T. (2019). Determination of growth and some morphological traits of Kıvırcık lambs in Yalova. *Journal of Animal Production*, ***60***(1), 39-50. DOI: 10.29185/hayuretim.556669

Ali, A., Javed, K., Zahoor, I. & Anjum, K.M. (2020). Analysis of non-genetic and genetic influences underlying the growth of Kajli lambs. *South African Journal of Animal Science*, ***50***(4), 613-625. DOI: 10.4314/sajas.v50i4.13

Arzik, Y., Kizilaslan, M., White, S.N., Piel, L.M.W. & Cinar, M.U. (2022). Estimates of genomic heritability and genome-wide association studies for blood parameters in Akkaraman sheep. *Scientific Reports*, ***12***, 18477. DOI: 10.1038/s41598-022-22966-8

Assan, N. (2020). Effect of genetic and non-genetic factors on growth traits in goats and sheep production. *Scientific Journal of Zoology*, ***9***(1), 106-122. DOI: 10.14196/sjz.v9i1.539

Balasundaram, B., Thiruvenkadan, A.K., Murali, N., Muralidharan, J., Cauveri, D. & Peters, S.O. (2023). Genetic parameters of growth traits and quantitative genetic metrics for selection and conservation of Mecheri sheep of Tamil Nadu. *Animals*, ***13***, 454. DOI: 10.3390/ani13030454

Baneh, H. & Hafezian, S.H. (2009). Effects of environmental factors on growth traits in Ghezel sheep. *African Journal of Biotechnology*, ***8***(12), 2903-2907.

Behrem, S. (2021). Effects of environmental factors growth traits of Akkaraman sheep in Çankırı province. *Livestock Studies*, ***61***(1), 22-27.

Bozgüllü, Ö. & Macit, M. (2022). Morkaraman ırkı kuzuların mer'ada performans özelliklerinin belirlenmesi. *Palandöken Journal of Animal Science, Technology and Economics*, ***1***(1), 24-32.

Cemal, İ., Karaca, O. & Altın, T. (2005). Live weights of Kıvırcık ewes and lambs in some periods under extensive management conditions. *Turkish Journal of Veterinary & Animal Sciences*, ***29***, 1329-1335.

Ehsaninia, J. (2021). Estimates of (co)variance components and genetic parameters for pre-weaning body weight traits and Kleiber ratio in Sangsari sheep breed. *Italian Journal of Animal Science*, ***20***(1), 918-927. DOI: 10.1080/1828051X.2021.1908860

Garcia-Baccino, C.A., Marie-Etancelin, C., Tortereau, F., Marcon, D., Weisbecker, J.L. & Legarra, A. (2021). Detection of unrecorded environmental challenges in high-frequency recorded traits, and genetic determinism of resilience to challenge, with an application on feed intake in lambs. *Genetics Selection Evolution*, ***53***(4), 1-14. DOI: 10.1186/s12711-020-00595-x

Hagan, B.A., Salifu, S., Asumah, C., Yeboah, E.D. & Boa-Amponsem, K. (2022). Effects of genetic and non-genetic factors on body weight, pre-weaning growth, birth type and pre-weaning survivability of lambsin a sheep nucleus station. *Livestock Research for Rural Development*, ***34***(4), 1-12.

Hızlı, H. & Yazgan, E. (2021). Comparison of the growth curve models on live weights in terms of different environmental factors in Awassi lambs. *Iranian Journal of Applied Animal Science*, ***11***(3), 577-586.

Kader Esen, V. & Elmacı, C. (2021). The estimation of live weight from body measurements in different meat-type lambs. *Journal of Agricultural Sciences*, ***27***(4), 469-475.

Kebede, K. & Gebretsadik, G. (2010). Statistical modelling of growth performance data on sheep using mixed linear models. *Livestock Research for Rural Development*, ***22***(4).

Kuchtik, K., Tilahun, M., Abebe, G. & Goetsch, A. (2019). Analysis of growth performance data in sheep using linear mixed model. *World Journal of Agriculture and Soil Science*, ***2***(4),1-5. DOI: 10.33552/WJASS.2019.02.000541

Kecici, P.D., Öztürk, N., Coskun, R. & Ekiz, B. (2021). Effects of certain environmental factors on growth performances of Kivircik lambs. *Journal of Research in Veterinary Medicine*, ***40***(2), 106-115. DOI: 10.30782/jrvm.980628

Kelman, K.R., Alston-Knox, C., Pethick, D.W. & Gardner, G.E. (2022). Sire breed, litter size, and environment ınfluence genetic potential for lamb growth when using sire breeding values. *Animals*, ***12***, 501. DOI: 10.3390/ani12040501

Kopuzlu, S., Sezgin, E., Yuksel, S., Ozluturk, A., Biberoglu, Ö., Esenbuga, N., Bilgin, Ö.C., Bayram, M. & Keskin, M. (2014). Phenotypic and genetic parameters for growth characteristics of Morkaraman sheep. *Journal of Applied Animal Research*, ***42***(1), 97-102. DOI: 10.1080/09712119.2013.822808

Kuchtik, J. & Dobes, I. (2006). Effect of some factors on growth of lambs from crossing between the Improved Wallachian and East Friesian. *Czech Journal of Animal Science*, ***51***(2), 54-60.

Lalit Malik, Z.S., Dalal, D.S., Dahiya, S.P., Patil, C.S. & Dahiya, R. (2016). Genetic analysis of growth traits in Harnali sheep. *Veterinary World*, ***9***(2), 128-132. DOI: 10.14202/vetworld.2016.128-132

Málková, A., Ptáček, M., Stádník, L. & Ducháček, J. (2020). Factors determining survivability traits of Charollais, Kent lambs, and their crossbreds during rearing. *Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis*, ***68***(3), 539-549. DOI: 10.11118/actaun202068030539

Maraveni, M., Vatankhah, M. & Eydivandi, S. (2018). Phenotypic and genetic analysis of lori-bakhtiari lamb's weight at different ages for autosomal and sex-linked genetic effects. *Iranian Journal of Applied Animal Science*, ***8***(1), 67-75.

McGovern, F.M., McHugh, N., Fitzmaurice, S., Pabiou, T., McDermott, K., Wall, E. & Fetherstone, N. (2020). Phenotypic factors associated with lamb live weight and carcass composition measurements in an Irish multi-breed sheep

population. *Translational Animal Science*, ***4***, 1-9. DOI: 10.1093/tas/txaa206

Mellado, J., Marín, V., Reyes-Carrillo, J.L., Mellado, M., Gaytán, L. & De Santiago, M.D.L.A. (2016). Effects of non-genetic factors on pre-weaning growth traits in Dorper sheep managed intensively in Central Mexico. *Ecosistemas y Recursos Agropecuarios*, ***3***(8), 229-235.

Noyan, M. & Ceyhan, A. (2021). Yarı entansif koşullarda yetiştirilen Akkaraman ırkı kuzuların büyüme performansı. *Journal of Agriculture, Food, Environment and Animal Sciences*, ***2***(2), 147-162.

Núñez-Torres, O.P. & Almeida-Secaira, R.I. (2022). Genética cuantitativa: principios de la crianza enla producción pecuaria. *Journal of the Selva Andina Animal Science*, ***9***(1), 23-36.

Olfaz, M., Tırınk, C. & Önder, H. (2019). Use of CART and CHAID algorithms in Karayaka sheep breeding. *Kafkas Universitesi Veteriner Fakultesi Dergisi*, ***25***(1), 105-110. Doi: 10.9775/kvfd.2018.20388

Özbeyaz, C., Bilgiç, Ö.F., Kocakaya, A. & Ünal, N. (2018). Eskişehir'de yetiştirici koşullarındaki İvesi koyunlarında bazı özelliklerin incelenmesi. *Lalahan Hayvancılık Araştırma. Enstitüsü Dergisi*, ***58***(1), 1-6.

Pollak, E. (2001). Quantitative trait, In: Brenner, S. & Miller, J.H. (Ed), *Encyclopedia of Genetics*, 1597-1598p, Academic Press, Elsevier Science Inc., USA.

Rahimi, S.M., Rafat, S.A. & Jafari, S. (2014). Effects of environmental factors on growth traits in Makuie sheep. *Biotechnology in Animal Husbandry*, ***30***(2), 185-192.

Sarı, M., Önk, K., Aksoy, A.R., Tilki, M. & Adıgüzel Işık, S. (2014). Hemşin kuzularında büyüme ve bazı vücut ölçülerinin belirlenmesi. *Lalahan Hayvancılık Araştırma Enstitüsü Dergisi*, ***54***, 15-20.

Selvi, T.N. & Üstüner, H. (2021). Some fertility traits and growth characteristics of Kivircik sheep breed in the extensive farm conditions. *Journal of Research in Veterinary Meicine*, ***40***(2), 116-119. DOI: 10.30782/jrvm.995392

Sharif, N., Ali, A., Dawood, M., Khan, M.I.-u.-R. & Do, D.N. (2022). Environmental effects and genetic parameters for growth traits of Lohi sheep. *Animals*, ***12***, 3590. DOI: 10.3390/ani12243590

Shibab, O.H., Abdullah, D.S. & Abdulrahman, E.G. (2022). Factors affecting in some productive traits for local and Turkish Awassi sheep. *Tikrit Journal for Agricultural Sciences*, ***22***(3), 70-77. DOI: 10.25130/tjas.22.3.8

Shirinkam, S., Alaeddini, A. & Gross, E. (2020). Identifying the number of components in gaussian mixture models using numerical algebraic geometry. *Journal of Algebra and Its Applications*, ***19***(11). DOI: 10.1142/s0219498820502047

Şireli, H.D., Vural, M.E., Karataş, A., Akça, N., Koncagül, S. & Tekel, N. (2015). Birth and weaning weights of Awassi lambs raised in the GAP International Agricultural Research and Training Center. *Ankara Üniversitesi Veteriner Fakültesi Dergisi*, ***62***, 139-145.

Şahin, M.S. & Kopuzlu, S. (2022). Determination of some growth traits in Morkaraman lambs. *Journal of Animal Science and Products (JASP)*, ***5***(1), 24-39. DOI: 10.51970/jasp.1090998

Şahin, Ö. (2022). Evaluation of some factors on birth and weaning weights in Awassi sheep by using GLM and CART analysis. *Tropical Animal Health and Production*, ***54***, 400.

Tesema, Z., Deribe, B., Lakew, M., Getachew, T., Tilahun, M., Belayneh, N., Kefale, A., Shibesh, M., Zegeye, A., Yizengaw, L., Alebachew, G.W., Tiruneh, S., Kiros, S., Asfaw, M. & Bishaw, M. (2022). Genetic and non-genetic parameter estimates for growth traits and Kleiber ratios in Dorper × indigenous sheep, *Animal*, ***16***, 100533. DOI: 10.1016/j.animal.2022.100533

Toghiani, S. (2012). Quantitative genetic application in the selection process for livestock production, In: Javed, K. (Ed), *Livestock production, 2nd ed.*, 1-32p, IntechOpen.

Yağcı, S., Baş, S. & Tatlıyer, A. (2018). Şavak Akkaraman kuzuların yetiştirici koşullarında büyüme ve yaşama gücü özellikleri. *Lalahan Hayvancılık Araştırma Enstitüsü Dergisi*, ***58***(2), 81-88.

Yesilova, A., Okut, H. & Kaki, B. (2008). Kategorik veriler için karışımlı poisson ve karışımlı lojistik regresyon yöntemlerin teorik özelliklerinin incelenmesi. *YYÜ Fen Bilimleri Enstitüsü Dergisi*, ***13***(1), 19-23.

Yesilova, A., Yilmaz, A., Ser, G. & Kaki, B. (2016). Modeling with Gaussian mixture regression for lactation milk yield in Anatolian buffaloes. *Indian Journal of Animal Research*, ***50***(6), 989-994. DOI: 10.18805/ijar.v0iOF.4545