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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Assessment of seasonal and environmental variability of key performance traits of Awassi sheep in semiarid conditions

Yarı kurak koşullarda İvesi koyunlarının temel performans özelliklerinin mevsimsel ve çevresel değişkenliğinin değerlendirilmesi

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ABSTRACT

This study was conducted to investigate the effects of certain environmental factors on reproductive and milk traits in ewes, as well as growth performance in lambs, under semi-intensive management of Awassi sheep. The dataset comprised records from a total of 31.372 lambs born to Awassi ewes participating in the National Small Ruminant Breeding Program. Key parameters, including reproductive and milk yield traits in ewes and birth weight (BW), weaning weight (WW), average daily gain (ADG), and Kleiber Ratio (KR) in lambs, were analysed concerning dam age, lamb sex, birth type, and birth month. Statistical analyses were performed using the SPSS software package. At the end of the study, the mean values for BW, WW, ADG, and KR were found to be 4.29 ± 0.01 kg, 19.33 ± 0.01 kg, 250.73 ± 0.08 g, and 27.19 ± 0.01, respectively. The average 210-day milk yield and daily milk production in ewes were calculated as 219.15 ± 0.39 l and 1.22 ± 0.01 l, respectively. The findings demonstrate that environmental factors have significant impacts on reproductive performance and milk yield in Awassi sheep, as well as growth traits in lambs. A comprehensive evaluation of these environmental influences is essential for optimizing production efficiency, enhancing the effectiveness of selection programs, and playing a crucial role in sustainable productivity and resource utilization.

ÖZET

Bu çalışma, yarı-entansif sistemde yetiştirilen İvesi koyunlarında bazı çevresel faktörlerin, analarda döl ve süt verimi, kuzularda ise gelişim özellikleri üzerine etkisini araştırmak amacıyla yürütülmüştür. Çalışmanın verilerini, Ülkesel Halk Elinde Küçükbaş Hayvan Islahı programı kapsamında yer alan İvesi koyunları ve bunlardan doğan toplam 31.372 baş kuzulardan elde edilen değerler oluşturmuştur. Analarda döl ve süt verimi parametreleri, kuzularda ise doğum ve sütten kesim ağırlığı, günlük canlı ağırlık artışı (ADG) ve Kleiber Ratio (KR), gibi temel parametreler; ana yaşı, kuzu cinsiyeti, doğum tipi ve doğum ayı ile ilişkilendirilerek değerlendirilmiştir. Verilerin istatistiki değerlendirmeleri SPSS paket programı ile yapılmıştır. Çalışmanın sonunda ortalama doğum ve sütten kesim ağırlığı, günlük canlı ağırlık artışı ve Kleiber Ratio değeri sırasıyla 4.29 kg, 19.33 kg, 250.73 g ve 27.19 olarak bulunmuştur. Analarda 210 günlük süt verimi 219.15±0.39 l, günlük ortalama süt verimi ise 1.22±0.01 l olarak hesaplanmıştır. Elde edilen bulgular, çevresel faktörlerin İvesi koyunlarında üreme performansı ve süt verimi, kuzularda ise büyüme özellikleri üzerine önemli ve anlamlı etkilerinin olduğunu açıkça ortaya koymaktadır. Çevresel faktörlerin kapsamlı değerlendirilmesi, üretim performansının optimize edilmesini sağlayarak seleksiyon programlarının etkinliğini artıracak ve sürdürülebilir verimlilik ile kaynak kullanımında önemli rol oynayacaktır.

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INTRODUCTION

Natural and fossil resources are among the main factors affecting the development levels of countries. Societies that manage these resources effectively by implementing sound policies and closely following developments have achieved success and gained influence in development. Although oil and minerals come to mind first when it comes to fossil resources, the greatest wealth is arable land. However, when looking at the economic development processes of developed countries, it can easily be seen that the income obtained from agriculture is used as a source of capital in industry and trade.

Small ruminant breeding in Türkiye is generally carried out under extensive conditions, and traditional production methods are still widely practised. Although this situation has been adopted as a suitable production method by breeders, keeping up with developing technology and innovations will ensure sustainability as well as increase the quality and quantity of production.

Türkiye has always been at the top of the list with its natural wealth, soil characteristics, endemic genetic resources and product range compared to many other countries in the world. Sheep breeding, as part of species diversity, has long been a major income source for rural families. Beyond its economic value, it also contributes to food security and provides social companionship.

Awassi sheep are a domestic gene source which is generally bred in the Southeastern Anatolia Region in Türkiye, and which has come to the forefront with its meat, milk and fleece aspects. There are two varieties of fat-tailed Awassi sheep, black and brown, and the black-headed ones are mostly grown in the regions close to the Syrian border, while the brown-headed ones are grown further inland. The breed is very resistant to harsh climatic conditions and diseases and is suitable for extensive breeding (Biçer et al., 2019; Gül & Biçer, 2020).

Environmental and genetic factors such as birth type, gender, temperature, humidity, age, and seasonal variations significantly influence the reproductive traits, growth performance, and milk yields of Awassi sheep. Especially in animal breeding, the determination of these factors used as selection criteria with appropriate and correct methods will ensure that the selection is more objective. Also, Kleiber ratios, the measure of efficiency independent of growth performance, are influenced by both genetic and environmental interactions, with significant variations among different management systems (Kleiber, 1947; Erdoğan et al., 2023; Gül et al., 2024).

It is very difficult to predict the conversion of the feed given to the yield to make an effective feeding in extensive sheep breeding. Optimised environmental and nutritional management can enhance the productivity and efficiency of Awassi sheep farming. Therefore, selection criteria that take into consideration the feed consumed by the animals and their developmental characteristics together have been developed and put into practice (Ghafouri-Kesbi, 2011; Gül et al., 2023).

This study aims to investigate the some environmental factors affecting reproductive performance, growth characteristics, milk yield traits, and KR in Awassi sheep reared in the Fertile Crescent region of Türkiye. In addition, by analysing key parameters such as birth weight, weaning weight, and milk production under varying environmental conditions, this research seeks to provide valuable insights into how nutritional and management factors influence these economically significant traits. Understanding these relationships will contribute to optimising breeding strategies, improving flock productivity, and ensuring sustainable sheep farming in the region. The findings are expected to aid farmers and policymakers in developing adaptive strategies to mitigate environmental stressors and enhance the overall efficiency of Awassi sheep production.

MATERIALS and METHODS

Study location and flock management

This research was conducted in the central and peripheral villages of Gaziantep province, located in the Southwest of Türkiye. Gaziantep province, located on the historical Spice and Silk Road, is in the Southeastern Anatolia Region of Türkiye and has a total of 648.092 head of small ruminant and 6.815.567 acres (da) of land and is located between 36° 28' and 38° 01' east longitudes and 36° 38' and 37° 32' north latitudes. Gaziantep is located at the transition point between a seasonal continental climate. While the southern regions are influenced by the Mediterranean climate, summers are generally hot and dry, and winters are cold and rainy. The province experiences the most precipitation in winter and spring (Table 1).

Table 1. Some climate data of the study regions (Anonymous, 2025)
Çizelge 1. Çalışmanın yürütüldüğü bölgelere ait bazı iklim verileri (Anonim, 2025)

		Araban distircit				
Season	Weather	2019	2020	2021	2022	2023
Winter	Rainfall	66.5	104.3	69.9	62.9	83.9
	Humidity	79.3	73.1	73.5	71.0	69.2
	Temperature	7.4	8.0	8.0	6.2	7.6
Spring	Rainfall	41.8	34.8	11.6	13.8	41.1
	Humidity	55.1	56.1	46.6	48.1	55.0
	Temperature	21.7	20.9	22.5	21.5	20.4
Summer	Rainfall	10.6	1.3	3.8	0.0	0.8
	Humidity	38.7	35.8	34.4	35.6	32.0
	Temperature	29.5	31.3	30.3	29.7	31.3
Autumn	Rainfall	39.4	46.0	8.4	34.9	57.7
	Humidity	62.3	62.7	55.8	65.2	65.2
	Temperature	13.9	14.0	13.5	14.4	14.6
		Nurdağı district				
Winter	Rainfall	156.7	116.6	144.3	110.7	80.2
	Humidity	72.9	68.0	67.6	74.3	65.1
	Temperature	7.6	8.3	9.0	6.8	8.4
Spring	Rainfall	12.3	37.7	3.6	21.1	28.9
	Humidity	55.4	54.2	51.5	46.4	58.8
	Temperature	20.7	20.5	21.8	21.5	20.1
Summer	Rainfall	1.3	0.1	3.3	1.0	0.0
	Humidity	45.4	43.3	45.5	90.3	47.2
	Temperature	27.6	29.6	28.7	28.6	29.4
Autumn	Rainfall	87.8	52.7	57.2	33.0	84.2
	Humidity	58.7	58.4	57.3	66.1	62.9
	Temperature	14.8	14.9	14.5	15.2	15.6

The animals were kept, depending on weather conditions, in closed shelters during cold and rainy periods and in open and/or semi-open shelters during hot periods.

This study's data were sourced from the Awassi sheep and their offspring in the project numbered and named "27IVE2013-02-Genetic Improvement of Awassi Sheep by the Public in Gaziantep Province-II" supported by the General Directorate of Agricultural Research and Policies of the Ministry of Agriculture and Forestry of the Republic of Türkiye within National Sheep and Goat Breeding Project of Türkiye between 2019-2023. According to the project framework, 6300 head of sheep (6000 female, 300 male) are included in the program annually. The study area comprises a total of 40 flocks, with flock sizes ranging between 100 and 300 sheep. In subsequent years, the required breeding stock is sourced from these flocks (Table 3).

Table 2. Some climate data of the study regions (continue), (Anonymous, 2025)

Çizelge 2. Çalışmanın yürütüldüğü bölgelere ait bazı iklim verileri (devam), (Anonim, 2025)

Season	Weather	2019	2020	2021	2022	2023
Şahinbey district						
Winter	Rainfall	141.0	74.9	88.3	85.4	94.9
	Humidity	91.3	57.9	53.4	70.9	65.1
	Temperature	5.5	5.9	7.1	4.5	6.5
Spring	Rainfall	20.0	30.7	4.7	16.1	23.4
	Humidity	50.6	43.0	42.6	46.3	55.3
	Temperature	19.4	18.8	20.2	19.6	18.0
Summer	Rainfall	0.5	0.1	8.3	0.0	0.2
	Humidity	38.9	27.7	38.3	34.4	33.0
	Temperature	26.6	28.5	26.8	28.7	28.3
Autumn	Rainfall	82.6	47.6	34.3	38.5	61.6
	Humidity	50.4	22.1	55.5	64.3	64.4
	Temperature	13.2	13.1	12.3	13.3	13.6
Şehitkamil district						
Winter	Rainfall	137.4	95.2	87.9	81.8	81.9
	Humidity	82.9	76.3	73.0	71.4	75.0
	Temperature	5.1	5.5	6.0	3.4	5.2
Spring	Rainfall	55.8	40.9	4.0	11.5	22.8
	Humidity	58.0	57.6	44.1	49.2	64.8
	Temperature	18.8	18.1	19.7	19.1	17.4
Summer	Rainfall	0.5	1.2	5.9	5.4	0.0
	Humidity	44.8	40.3	38.5	41.6	41.0
	Temperature	26.1	27.7	26.5	26.9	27.6
Autumn	Rainfall	68.4	48.2	33.7	45.5	68.1
	Humidity	67.5	65.8	60.7	71.0	74.6
	Temperature	11.6	11.5	10.9	11.8	12.2
Yavuzeli district						
Winter	Rainfall	111.7	48.5	33.5	35.1	35.1
	Humidity	87.4	79.4	77.5	72.1	66.0
	Temperature	7.5	7.9	7.8	6.3	7.9
Spring	Rainfall	47.9	15.2	2.6	5.5	10.8
	Humidity	58.7	58.5	51.7	49.6	51.3
	Temperature	21.3	20.4	21.9	21.6	20.7
Summer	Rainfall	0.8	0.0	0.2	0.0	0.4
	Humidity	39.2	35.1	37.9	37.2	32.1
	Temperature	29.0	30.5	29.8	30.4	31.4
Autumn	Rainfall	60.9	18.0	10.4	18.0	26.9
	Humidity	68.5	65.9	58.4	65.0	63.8
	Temperature	13.8	13.6	13.1	14.5	14.9

Mating was conducted through free mating between August and September, following a ratio of 1 ram per 20 ewes. Births in the herds occurred in January-March.

Table 3. Flock numbers and distribution by district
Çizelge 3. İlçelere göre sürü sayıları ve dağılımı

Districts	Flock number	Ewe number	Ram number
Araban	4	445	21
Nurdağı	12	1595	78
Şahinbey	9	1975	97
Şehitkamil	4	650	37
Yavuzeli	11	1335	67
Total	40	6000	300

Sheep were taken to the pasture in the morning according to the seasonal conditions and brought back to the farm in the evening. The pastures where the animals graze consist of annual grasses, maquis, shrubs, and wild-type plants. Sheep were fed with an additional ration consisting of wheat straw, barley, bran, and cottonseed cake, ranging from 500 to 750 g/animal/day depending on the season and the condition of the pasture. The sheep's water needs were met through irrigation systems located at different points of the pastures or natural water sources. The lambs were kept with their mothers for the first 5 days. Then lambs were isolated from their mothers and suckled two times per day until 2 months of age in the morning and evening. From the age of 15 days, lambs were fed with a mixture consisting of wheat grit, barley mash, wheat straw, and tree foliage (leafy olive and oak branches). The lambs were weaned at 60 days of age, with this process being carried out gradually

Method

Ewes approaching parturition were moved to separate pens, and the births took place in these designated areas. Upon birth, lambs were immediately assigned temporary ear tags, and the records were kept in the farm's registry. To determine the growth traits of lambs, the birth weight, sex, birth type and weaning weights of the lambs were recorded. Determination of milk yield in sheep began 15 days after birth and was terminated when milk yield dropped below 0.1 l. Milk controls were carried out at 28-day intervals according to the ICAR AT method (Gül, 2008). The reproductive parameters of ewes, such as fecundity, litter size, conception rate, fecundity at weaning, litter size at weaning (60 d) and the survival rate were calculated according to Gül et al. (2024).

Statistical analyses

Statistical analyses of this study were performed with SPSS v23.0 software for Windows. Data were tested for normality with the Kolmogorov-Smirnov and Shapiro-Wilk tests. All values were classified, and the mean and standard error were calculated. Duncan's multiple comparison test was used to statistically compare environmental factors, and the Chi-square (X2) test was used to determine the dependence on these factors. The data were analysed by using the General Linear Model procedure in the SPSS package program and with the following statistical model:

$Y_{ijklm}=\mu+\alpha_i+\beta_j+p_k+\delta_l+£_m+e_{ijklmn}$

In this model,

Y_{ijklmn}, is the data of the 1st animal in the experiment of i^{th} birth year, j^{th} maternal age, k^{th} sex, l^{th} birth type, m^{th} birth month

μ, the mean of the population

αi, the effect of birth year (2019, 2020, 2021, 2022, 2023),

βj, the effect of maternal age (2, 3, 4, 5≥),

pk, the effect of sex (female, male)

δl, the effect of the birth type (single, twin),

£m, the effect of the birth month (Jan, Feb, March),
eijklmn, is the residual term

RESULTS and DISCUSSIONS

Table 4 presents the descriptive statistics for birth weight (BW), weaning weight (WW), average daily gain (ADG) and KR, including the dataset structure used to evaluate the growth performance of Awassi sheep, along with mean values, standard errors, minimum and maximum values, and coefficients of variation.
At the inception of each production season, the project necessitates a population of 6.000 ewes and 300 rams. During the mating season, the rams are released to the flock without restraint, and the information regarding the offspring born is systematically recorded. For this study, a total of 31.372 live-born lambs were recorded at the end of the five years. When the survival rate at weaning is calculated, it can be said that this value is at a high optimum level (99.54%).

Table 4. Descriptive statistics for growth traits of Awassi lambs
Çizelge 4. İvesi kuzularının büyüme özelliklerine ilişkin tanımlayıcı istatistikler

Trait	BW (kg)	WW (kg)	ADG (g)	KR
Number of observations	31.372	31.228	31.228	31.228
Mean	4.29	19.33	250.73	27.19
Standard error	0.01	0.01	0.08	0.01
Minimum	2.40	11.70	120.42	19.04
Maximum	6.12	23.25	323.67	31.02
Coefficient of variation	12.98	4.91	5.79	3.52

* BW, birth weight; WW, weaning weight; ADWG, average daily weight gain; KR, Kleiber Ratio

The descriptive statistics for the growth traits of Awassi lambs provide important insights into the breed's developmental performance and variability. The average birth weight was 4.29 kg, weaning weight 19.33 kg, and average daily gain (ADG) 250.73 g, while the KR averaged 27.19. These estimates, based on a large dataset of 31.372 observations, are highly reliable. The coefficient of variation (CV) for birth weight was relatively high at 12.98%, indicating greater influence from genetic and environmental factors. In contrast, weaning weight (4.91%), ADG (5.79%), and KR (3.52%) showed lower variability, suggesting a more uniform population and consistent management practices. These results are valuable for evaluating growth performance and identifying traits to prioritise in selection programs aimed at improving productivity and efficiency in Awassi sheep (Ali et al., 2020; Ceyhan et al., 2022; Tabbaa et al., 2008).
Table 5 shows the fertility characteristics by year. When we examine this table, the number of ewes giving birth has shown variability over the years. Especially in 2021, the number of ewes giving birth reached the highest level (98.60%), while the lowest level (89.92%) was observed in 2019.

Table 5. Fertility characteristics by the years in Awassi sheep
Çizelge 5. İvesi koyunlarında yıllara göre döl verim özellikleri

Characteristics/Year	**2019**	**2020**	**2021**	**2022**	**2023**	***p* value**	**Chi-sq. value**
Number of ewes for mating	6000	6000	6000	6000	6000	---	---
Number of ewes giving birth	5395	5820	5916	5901	5891	---	---
Number of total born lambs	5998	6437	6414	6216	6309	---	---
Number of total weaned lambs	5998	6408	6389	6157	6277	---	---
Number of single-birth sheep	4792	5206	5418	5586	5473	---	---
Number of twin-birth sheep	603	614	498	315	836	---	---

Table 5 (continued). Fertility characteristics by the years in Awassi sheep
Çizelge 5 (devamı). İvesi koyunlarında yıllara göre döl verim özellikleri

Number of triplet-birth sheep	---	1	---	---	---	---	---
The fertility rate for giving birth (%)	89.92	97.00	98.60	98.35	98.18	0.968	0.552
Infertility rate (%)	10.28	3.00	1.40	1.65	1.82	0.005	14.778
Single lambing rate (%)	79.89	80.88	84.47	89.86	86.75	0.936	0.820
Twin lambing rate (%)	20.11	19.08	15.53	10.14	13.25	0.350	4.436
Survival rate at weaning (60. days)	100.00	99.55	99.63	99.05	99.49	0.999	0.012
Lambing rate per ewe (%)	0.90	0.97	0.99	0.98	0.98	0.999	0.001
Lambing rate per birth (%)	1.11	1.11	1.08	1.05	1.07	0.999	0.001

While the fertility rate was 89.92% in the first year of the evaluation (2019), this value increased to 98.60% in 2021, owing to the scientific contributions of the breeders regarding herd management (P<0.05). Furthermore, the twinning rate exhibited a decline from 20.11% to 10.14%. The decline can be attributed to the suboptimal conditions of the pastures, which have been adversely affected by the prevailing drought conditions experienced throughout the province. No significant difference was observed in terms of survival rate. Despite a decline in lamb yield per lamb born, an increase in lamb yield per ewe was observed. The fertility characteristics of Awassi sheep exhibited consistently high and stable reproductive performance, reflecting the effectiveness of management and breeding strategies within the studied population. The fertility rate of ewes giving birth increased from 89.92% in 2019 to over 98% in subsequent years; although this increase was not statistically significant, it indicates a positive trend in reproductive success. More notably, the infertility rate significantly declined from 10.28% in 2019 to approximately 1.82% in 2023 (P<0.05), underscoring substantial improvements in reproductive health management, potentially attributable to enhanced nutrition or optimised environmental conditions. In terms of lambing type, the proportion of single births rose markedly, peaking at 89.86% in 2022, while twin births decreased to their lowest recorded level of 10.14% during the same year. Although these shifts were not statistically significant, they may reflect underlying genetic or management factors influencing prolificacy. Importantly, lamb survival rates until weaning remained exceptionally high, consistently above 99% highlighting the success of neonatal care and flock management practices throughout the period. Despite a stable annual number of 6.000 mated ewes, lambing rates per ewe and birth showed minimal variation, demonstrating sustained reproductive efficiency. Collectively, these findings emphasise significant advancements in fertility and reproductive health alongside consistently high lamb survival, which are critical for improving productivity and ensuring the sustainability of Awassi sheep production systems. (Keskin et al., 2005; Gül & Erdoğan, 2021; Gül & Oflaz, 2021).

Table 6. Developmental characteristics of the lambs by the years (mean ± se)
Çizelge 6. Kuzuların yıllara göre gelişim özellikleri (ortalama ± standart hata)

Year	**n**	**BW**	**n**	**WW**	**ADG**	**KR**
2019	5997	4.14 ± 0.01^{a}	5997	19.10 ± 0.01^{a}	249.23 ± 0.14^{a}	27.28 ± 0.01^{c}
2020	6437	4.26 ± 0.01^{b}	6408	19.22 ± 0.01^{b}	249.34 ± 0.17^{a}	27.16 ± 0.01^{b}
2021	6413	4.28 ± 0.01^{b}	6389	19.43 ± 0.01^{c}	252.50 ± 0.17^{b}	27.29 ± 0.01^{c}
2022	6216	4.38 ± 0.01^{c}	6157	19.46 ± 0.01^{d}	251.32 ± 0.21^{c}	27.11 ± 0.01^{a}
2023	6309	4.37 ± 0.01^{c}	6277	19.44 ± 0.01^{bc}	251.20 ± 0.22^{b}	27.12 ± 0.01^{a}
P		0.000		0.000	0.000	0.000
Overall	31372	4.29±0.01	31228	19.33±0.01	250.73±0.08	27.19±0.01

BW, birth weight; WW, weaning weight; ADG, average daily gain; KR, Kleiber Ratio

Descriptive statistics of the developmental characteristics of the lambs are presented in Table 6. The analysis of growth traits of Awassi lambs between 2019 and 2023 reveals a consistent improvement in performance metrics, reflecting the interplay of genetic selection, maternal effects, and environmental management.

The analysis of growth traits of Awassi lambs between 2019 and 2023 reveals generally a consistent improvement in performance metrics, reflecting the interplay of genetic selection, maternal effects, and environmental management. Birth weight (BW) exhibited significant interannual variation ($P < 0.001$), with the lowest value observed in 2019 (4.14±0.01 kg) and the highest in 2022 (4.38±0.01 kg). These findings underscore the physiological importance of optimal maternal nutrition and placental efficiency, which directly influence foetal growth trajectories during gestation (Amati et al., 2014; Lecorguillé et al, 2021). Enhanced feeding protocols and reproductive management likely contributed to this upward trend (Gül & Keskin, 2010; Talafha & Ababneh, 2011; Gül et al., 2020).

Weaning weight (WW) followed a similar pattern, increasing from 19.10±0.01 kg in 2019 to 19.46±0.01 kg in 2022 ($P < 0.001$). This indicates improved postnatal growth conditions and possibly enhanced milk production during lactation. The average daily gain (ADG) reached its peak in 2021 at 252.50±0.17 g, suggesting a particularly favourable balance of nutrition, health status, and management during that year. Interestingly, the KR, a metric that integrates growth efficiency relative to metabolic size, also peaked in 2021 (27.29±0.01), supporting the assertion that this year yielded the most metabolically efficient growth performance (Koster et al., 1994; Supakorn and Pralomkarn, 2012; Gül & Ekici, 2020; Mahala et al., 2020). Conversely, numerically declines in KR were noted in 2022 and 2023 (27.11±0.01 and 27.12±0.01, respectively), despite continued high weaning weights. This might indicate that although lambs grew heavier, their growth efficiency relative to metabolic size was slightly diminished, possibly due to higher maintenance energy costs or shifts in feed composition. KR remains a robust indicator for selecting animals with superior feed efficiency, as it captures both size and weight gain independently of environmental bias (Kenyon et al., 2014). Overall, these results reflect the success of integrated breeding, nutritional, and health strategies applied over time. However, they also emphasise the importance of ongoing monitoring and adaptive management to sustain and enhance lamb performance across varying ecological and operational contexts (Table 1).

The effects of maternal age, gender, birth month and birth type on the growth performance of lambs were examined according to LSM and are given in Table 7. In this study, the relationship between ewe age and lamb growth performance was evaluated from both statistical and physiological perspectives.

Table 7. Developmental characteristics of lambs in Awassi sheep by the age of the mother, birth month, sex, and birth type (mean ± se)

Çizelge 7. İvesi koyunlarında kuzuların ana yaşı, doğum ayı, cinsiyet ve doğum tipine göre gelişim özellikleri (ortalama ± standart hata)

Age	**n**	**BW (kg)**	**n**	**WW (kg)**	**ADG (g)**	**KR**
2	9240	4.29±0.01^{ab}	9192	19.35±0.01^{b}	251.03±0.15^{b}	27.20±0.01
3	6713	4.28±0.01^{a}	6669	19.32±0.01^{ab}	250.79±0.18^{ab}	27.21±0.01
4	5760	4.30±0.01^{b}	5738	19.35±0.01^{b}	250.75±0.19^{ab}	27.18±0.01
5 and over	9659	4.28±0.01^{a}	9629	19.31±0.01^{a}	250.39±0.15^{a}	27.18±0.01
P		0.042		0.005	0.026	0.127
Birth month						
Jan	16515	4.29±0.01	16124	19.32±0.01^{b}	250.64±0.11^{b}	27.19±0.01^{b}
Feb	14794	4.29±0.01	15045	19.34±0.01^{b}	250.85±0.12^{b}	27.20±0.01^{b}
March	63	4.31±0.06	59	19.10±0.14^{a}	246.21±1.92^{a}	26.96±0.10^{a}
P		0.860		0.027	0.021	0.031
Sex						
Male	17096	4.33±0.01	17020	19.45±0.01	251.92±0.11	27.20±0.01

Table 7 (continued). Developmental characteristics of lambs in Awassi sheep by the age of the mother, birth month, sex, and birth type (mean ± se)

Çizelge 7 (devamı). İvesi koyunlarında kuzuların ana yaşı, doğum ayı, cinsiyet ve doğum tipine göre gelişim özellikleri (ortalama ± standart hata)

Female	14276	4.23±0.01	14276	19.19±0.01	249.30±0.12	27.18±0.01
P		0.000		0.000	0.000	0.174
Birth type						
Single	26475	4.32±0.01^{b}	26343	19.37±0.01^{b}	250.90±0.09	27.17±0.01^{a}
Twin	4894	4.11±0.01^{b}	4882	19.10±0.01^{ab}	249.79±0.21	27.34±0.01^{a}
Triplet	3	2.90±0.06^{a}	3	18.27±0.42^{a}	256.28±6.97	28.99±0.30^{b}
P		0.000		0.000	0.100	0.000
Overall		4.28±0.01		19.33±0.01	250.73±0.08	27.19±0.01

BW, birth weight; WW, weaning weight; ADG, average daily gain; KR, Kleiber Ratio

Ewe age significantly influenced birth weight (BW), weaning weight (WW), and average daily gain (ADG), while no significant effect was observed on the KR. Lambs born to 4-year-old ewes exhibited the highest mean birth weight (4.30±0.01 kg) and weaning weight (19.35±0.01 kg) compared to other age groups, suggesting that ewes at this age have optimal placental development during gestation and higher milk production during lactation. Lambs from younger ewes (2 years old) showed the greatest average daily gain (251.03±0.15 g), possibly due to more active maternal behaviours and enhanced nursing motivation. Conversely, lambs from ewes aged 5 years and older demonstrated relatively lower performance parameters (BW: 4.28±0.01 kg, WW: 19.31±0.01 kg), likely reflecting physiological declines in uterine efficiency and lactation capacity associated with ageing. This finding aligns with the physiological maturity and optimal reproductive capacity of ewes in their prime age (Rosales-Nieto et al., 2013; Ceyhan et al., 2022).

Mukasa-Mugerwa et al., 1991; Notter, 2000 reported optimal growth performance in sheep aged 3–4 years. Rosales-Nieto et al. (2013) indicated that ewes at their reproductive peak provide more effective in-utero nutrition and superior postnatal care through enhanced milk production. Younger ewes may possess immature reproductive systems and lower milk yield, while ageing ewes might suffer from declining physiological efficiency, both conditions negatively impacting lamb growth.

The month of birth significantly affected growth traits, with lambs born in January and February achieving higher weaning weights and ADG compared to those born in March. While birth month did not significantly affect birth weight, significant differences were observed in WW, ADG, and KR ($P<0.05$). Lambs born in January and February showed higher WW (19.32±0.01 kg and 19.34±0.01 kg) and ADG (250.64±0.11 g and 250.85±0.12 g) compared to those born in March, which had the lowest WW (19.10±0.14 kg) and ADG (246.21±1.92 g). Similarly, KR values were significantly higher for lambs born in January and February (27.19±0.01 kg and 27.20±0.01 kg) compared to March-born lambs (26.96±0.10 kg), indicating better growth efficiency in the earlier birth months. These results suggest that seasonal factors associated with birth month, such as variations in ambient temperature, body condition, feed availability, and photoperiod may influence postnatal growth and metabolic efficiency. Previous studies have similarly reported seasonal effects on lamb growth performance, emphasising the importance of management practices tailored to optimise birth timing for improved productivity (Rawlins et al., 2007; Smith et al., 2018; Behrem, 2024; Kızılaslan et al., 2024). Optimal forage quality and cooler temperatures in winter and early spring enhance maternal nutrition and lactation performance, whereas lambs born in March may face diminished pasture quality and increased environmental stressors, resulting in slower growth rates.

The growth performance of lambs was evaluated based on sex, revealing significant differences in BW, WW, and ADG between males and females ($P < 0.001$). Male lambs exhibited higher mean BW (4.33±0.01 kg), WW (19.45±0.01 kg), and ADG (251.92±0.11 g) compared to females, which had mean values of 4.23±0.01 kg,

19.19±0.01 kg, and 249.30±0.12 g, respectively. However, no significant difference was observed in the KR between sexes, indicating similar growth efficiency despite differences in absolute growth parameters. Male lambs consistently outperformed females in birth weight, weaning weight, and daily gain, consistent with known physiological differences among mammals. Androgens such as testosterone promote greater muscle development, bone growth, and metabolic activity in males (Clarke et al., 2012; Rizk et al., 2023). These hormonal effects drive higher growth rates, feed efficiency, and muscle accretion. The absence of significant differences in the KR suggests that while males achieve greater absolute growth, their growth efficiency relative to metabolic size is comparable to that of females. These findings support the genetic predisposition of males towards greater growth potential while suggesting that growth efficiency is comparable between sexes. Similar results have been reported in the literature, where sex significantly influences growth traits but has a limited impact on efficiency indices (Şireli et al., 2015; Ceyhan et al., 2022).

The influence of birth type on lamb growth performance was evaluated, revealing significant differences in BW, WW, and KR among groups ($P < 0.01$), while ADG did not differ significantly. Single-born lambs had the highest BW (4.32±0.01 kg) and WW (19.37±0.01 kg), followed by twins with lower BW (4.11±0.01 kg) and WW (19.10±0.01 kg). Triplet lambs exhibited the lowest BW (2.90±0.06 kg) and WW (18.27±0.42 kg), although their ADG (256.28±6.97 g) was relatively high but with greater variability. Notably, triplet lambs had the highest KR (28.99±0.30 g), significantly greater than single and twin lambs (27.17±0.01 g and 27.34±0.01 g, respectively), indicating increased growth efficiency relative to metabolic weight despite lower absolute weights. These findings suggest that litter size strongly influences growth performance, with single showing superior growth in absolute terms, while higher-order multiples may compensate through improved feed conversion efficiency. Similar patterns have been documented in sheep and other livestock species, where increased litter size often reduces individual birth weight but may be associated with enhanced relative growth efficiency (Gül et al., 2020; Xiao et al., 2025). Birth type had a pronounced effect on growth traits. Single lambs were significantly heavier at birth and weaning than twins and triplets, consistent with the intrauterine competition hypothesis whereby multiple foetuses compete for limited uterine resources (Ali et al., 2020).

The physiological basis for these findings relates to maternal nutrient intake, placental efficiency, hormonal regulation, and postnatal environmental conditions. Optimal maternal age corresponds to peak reproductive organ function and efficient nutrient partitioning to the foetus and neonate. Seasonal effects reflect changes in ewe nutrition and thermoregulatory demands. Sex differences arise from endocrine-mediated growth pathways, while birth type reflects resource allocation during gestation and lactation. From a practical standpoint, these insights emphasise the importance of selecting ewes in their prime reproductive years, aligning lambing seasons with periods of optimal forage availability, tailoring nutritional management according to lamb sex, and providing targeted care for multiple births to improve survival and growth. Such strategies can enhance the productivity and sustainability of Awassi sheep populations (Dunlap et al., 2021; Lecorguillé et al., 2021; Xiao et al., 2025).

Milk yields of Awassi sheep calculated according to 210 days, according to dam age and years, are given in Table 8. While dam age was found to significantly influence milk yield overall ($P<0.01$), it had no significant effect either numerically or statistically on the milk yield of ewes that lambed in 2020.

Based on the year-by-year evaluation of each age group individually, it can be concluded that there was a significant increase in milk yield in the final year of the study ($P<0.01$). When we consider the daily milk yield amounts in ewes, the age of the mother has an effect. The analysis of lactation milk yield and average daily milk (ADM) in Awassi sheep across different ages and years revealed significant variation, underscoring the combined effects of physiological maturity and environmental conditions. A clear trend was observed wherein milk yield increased with ewe age up to the fourth year (from 215.44±0.69 l in 2-year-olds to 221.80±0.91 l in 4-year-olds; $P<0.001$), followed by a slight decline in the 5+ age group (221.22±0.72 l). This pattern aligns with physiological expectations: younger

ewes, particularly at age 2, are often still allocating energy toward somatic growth and are less hormonally primed for maximal lactation (Lerias et al., 2014; Perez-Hernandez et al., 2023).

Table 8. Effect of parity and year on lactation and average daily milk yield in Awassi sheep (mean ± se)
Çizelge 8. İvesi koyunlarında doğum sırası ve yılın, laktasyon ve günlük ortalama süt verimi üzerindeki etkisi (ortalama ± standart hata)

Milk yield (l)						
Years	2	3	4	5+	P	Overall
n	1659	784	1615	946	0.000	5004
2019	191.79±1.18^{aA}	200.84±1.58^{bA}	205.36±1.73^{cA}	204.08±1.33b^{cA}		199.74±0.72
n	1788	1611	1193	607	0.768	5332
2020	215.03±1.31^{B}	216.31±1.49^{B}	217.36±2.34^{B}	215.22±1.36^{B}		215.67±0.75
n	1453	1982	1193	2162	0.104	5739
2021	223.83±1.57^{C}	226.86±1.91^{C}	228.55±1.81^{C}	222.74±1.88^{C}		225.10±0.90
n	1130	1380	1193	2162	0.039	5865
2022	221.04±2.16^{aC}	222.86±1.90^{abC}	226.24±2.12^{abC}	227.84±1.57^{bD}		225.05±0.95
n	1301	1989	1121	1379	0.000	5790
2023	223.98±1.50^{aC}	223.40±1.93^{aC}	226.59±2.05^{aC}	236.24±1.75^{bE}		227.27±0.89
P	0.000	0.000	0.000	0.000		
n	7331	7746	6435	6218	0.000	27730
Overall	215.44±0.69^{a}	219.42±0.82^{b}	221.80±0.91^{c}	221.22±0.72^{bc}		219.15±0.39
			ADM (l)			
2019	1.07±0.01^{aA}	1.12±0.01^{bA}	1.14±0.01^{cA}	1.13±0.01^{bcA}	0.000	1.11±0.01
2020	1.19±0.01^{B}	1.20±0.01^{B}	1.21±0.01^{B}	1.20±0.01^{B}	0.877	1.20±0.01
2021	1.24±0.01^{C}	1.26±0.01^{C}	1.27±0.01^{C}	1.24±0.01^{C}	0.112	1.25±0.01
2022	1.23±0.01^{aC}	1.24±0.01^{abC}	1.26±0.01^{abC}	1.27±0.01^{BD}	0.041	1.25±0.01
2023	1.24±0.01^{aC}	1.24±0.01^{aC}	1.26±0.01^{aC}	1.31±0.01^{bE}	0.000	1.26±0.01
P	0.000	0.000	0.000	0.000		
Overall	1.20±0.01^{a}	1.22±0.01^{b}	1.23±0.01^{c}	1.23±0.01^{bc}	0.000	1.22±0.01

ADM, Average Daily Milk; Lowercase letters are used to denote the values in the row, while uppercase letters are used to denote the statistical comparison of the values in the column.

By the third and fourth years, the mammary gland reaches full functional development, maximising alveolar tissue and milk secretory capacity. The marginal decline in older ewes (5+ years) may reflect age-related involution of mammary tissue or decreased endocrine responsiveness. Annual fluctuations in milk yield were also pronounced. Ewes in 2019 exhibited the lowest yield (199.74±0.72 l), while the highest values (227.27±0.89 l) were recorded in 2023. These trends paralleled those observed in ADM, which increased from 1.11±0.01 l in 2019 to 1.26±0.01 l in 2023 ($P<0.001$). Such variations likely reflect differences in climatic conditions, forage quality, and management practices across years. Heat stress, for example, is known to suppress prolactin levels and reduce milk synthesis (Salama et al., 2003), while improved feeding and housing in later years may have enhanced both quantity and persistency of milk production. Interestingly, ADM followed a similar age-related pattern as total milk yield, with significant increases from 1.20±0.01 l at age 2 to 1.23±0.01 l at age 4 ($P<0.001$). Notably, in 2023, older ewes (5+) had the highest ADM (1.31±0.01 l), suggesting that under optimal conditions, even older animals can maintain efficient lactation. These results highlight the importance of synchronising genetic potential with optimal environmental conditions to maximise milk yield in Awassi sheep. They also emphasise the physiological adaptability of this breed under varying management regimes.

Overall, these findings are consistent with previous studies in Awassi and other dairy breeds, indicating that both intrinsic (age, physiological stage) and extrinsic (year, environment) factors substantially influence milk production

traits (Gürsu & Aygün, 2014; Ceyhan et al., 2022; Aksoy et al., 2023). The interaction between genetic maturity and management strategies must be optimised to sustain high production across lactations. The increase in milk yield with age in ewes is closely linked to the physiological maturation of the mammary gland and more effective hormonal regulation. Repeated pregnancies and lactations enhance alveolar development, while hormones like estrogen, progesterone, prolactin, and oxytocin work synergistically to improve milk synthesis. Moreover, improved endocrine control and greater adaptation to environmental stressors help realise the animal's genetic milk production potential (Hue-Beauvais et al., 2021; Perez-Hernandez et al., 2023; Webster et al., 2024).

In conclusion, this study provides a comprehensive evaluation of the impact of environmental factors on key performance traits, including reproductive efficiency, growth dynamics, and milk yield, in Awassi ewes reared in the Fertile Crescent region of Türkiye. The findings of the present study demonstrated that both seasonal variability and environmental factors played a significant role in the manifestation of phenotypic traits. Growth traits in lambs and milk yield in dams were influenced by environmental fluctuations. This situation underscores the necessity for the development of environment-specific adaptation strategies. The data obtained are valuable for optimising breeding programmes, improving management practices and ensuring the sustainability of Awassi sheep breeding in semi-arid and ecologically sensitive areas. In the future, the integration of genomic tools and long-term climate data may contribute to a deeper understanding of genotype-environment interactions in this valuable breed.

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STATEMENT OF CONFLICT OF INTEREST

The author(s) declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

AUTHOR'S CONTRIBUTIONS

The authors of the manuscript declare that they have contributed equally to the study.

STATEMENT OF ETHICS CONSENT

This article does not involve any research with human or animal subjects; therefore, ethical approval is not required.

REFERENCES

Aksoy, Y., Şekeroğlu, A., Duman, M., & Çoban, Ö.B. (2023). A study on the determination of some reproductive traits of ewes and the growth performance of lambs Akkaraman raised under farm conditions in the province of Niğde. *Turkish Journal of Agriculture - Food Science and Technology, 11* (6), 1168-1175. https://doi.org/10.24925/turjaf.v11i6.1168-1175.5991

Ali, W., Ceyhan, A., Ali, M., & Dilawar, S. (2020). The merits of Awassi sheep in terms of milk production and major factors affecting the reproductive traits. *Journal of Agriculture, Food, Environment and Animal Sciences, 1* (1), 50-69.

Amati, F., Hassounah, S., & Swaka, A. (2014). The impact of Mediterranean dietary patterns during pregnancy on maternal and offspring. *Nutrients, 11* (5), 1098. https://doi.org/10.3390/nu11051098

Anonymous. (2025). *T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, Meteoroloji Genel Müdürlüğü.*

Behrem, S. (2024). Unveiling the pre-weaning growth performance and some reproductive characteristics of Akkaraman and Central Anatolian Merino sheep. *Veterinary Medicine and Science, 11*, e70221. https://doi.org/10.1002/vms3.70221

Biçer, O., Keskin, M., Gül, S., Gündüz, Z., Oflaz, N.Z., & Behrem, S. (2019). Comparison of yield characteristics of brown and black headed Awassi sheep. *Mustafa Kemal University Journal of Agricultural Sciences, 24* (1), 58-61.

Ceyhan, A., Avcı, M., Tanrıkulu, M.M., Yılmaz, B., & Ul Hassan, M. (2022). The effect of different management systems on milk yield and milk quality in Awassi sheep. *Archives Animal Breeding, 65*, 407-416. https://doi.org/10.5194/aab-65-407-2022

Clarke, S.D., Clarke, I.J., Rao, A., Cowley, M.A., & Henry, B.A. (2012). Sex differences in the metabolic effects of testosterone in sheep. *Endocrinology, 153* (1), 123-131. https://doi.org/10.1210/en.2011-1634

Dunlap, K.A., Brown, J.D., Keith, A.B., & Satterfield, M.C. (2015). Factors controlling nutrient availability to the developing fetus in ruminants. *Journal of Animal Science and Biotechnology, 6* (1), 16. https://doi.org/10.1186/s40104-015-0012-5

Erdoğan, İ.E., Karaman, R., Hızlı, H., & Gül, S. (2023). Reproductive performance and kid growth in Hair goats raised under farmer conditions in Adana Province of Türkiye. *Mustafa Kemal University Journal of Agricultural Sciences, 28* (2), 446-453. https://doi.org/10.37908/mkutbd.1283298

Ghafouri-Kesbi, F., Abbasi, M.A., Afraz, F., Babaei, M., Baneh, H., & Abdollahi Arpanahi, R. (2011). Genetic analysis of growth rate and Kleiber ratio in Zandi sheep. *Tropical Animal Health and Production, 43* (6), 1153-1159. https://doi.org/10.1007/s11250-011-9816-2

Gül, S. (2008). *Farklı Keçi Genotiplerinin Doğu Akdeniz Bölgesi Koşullarındaki Performanslarının Karşılaştırılması* (Doktora tezi). Mustafa Kemal Üniversitesi Fen Bilimleri Enstitüsü, Antakya-Hatay.

Gül, S., & Biçer, O. (2020). Fattening performance of Awassi sheep and evaluation of carcasses according to EAAP method. *Mustafa Kemal University Journal of Agricultural Sciences, 25* (1), 20-26. https://doi.org/10.37908/mkutbd.606873

Gül, S., & Ekici, H. (2020). Effect of weaning age on lamb growth performance and milk production in Awassi sheep. *Journal of Animal Science and Products, 3* (2), 95-103.

Gül, S., & Erdoğan, İ. (2021). A model for oestrus synchronisation and superovulation in Awassi sheep breeding. *Mustafa Kemal University Journal of Agricultural Sciences, 26* (1), 528-536. https://doi.org/10.37908/mkutbd.762115

Gül, S., & Keskin, M. (2010). Reproductive characteristics of Awassi ewes under Cornell Alternate Month Accelerated Lambing system. *Italian Journal of Animal Science, 9* (49), 255-259.

Gül, S., & Oflaz, N.Z. (2021). Comparison of some morphological and physiological characteristics of Awassi sheep grown in Gaziantep and Kilis provinces. *Journal of Tekirdag Agricultural Faculty, 18* (1), 146-156. https://doi.org/10.33462/jotaf.747072

Gül, S., Arzık, Y., Kızılaslan, M., Behrem, S., & Keskin, M. (2023). Heritability and environmental influence on pre-weaning traits in Kilis goats. *Tropical Animal Health and Production, 55*, 85. https://doi.org/10.1007/s11250-023-03509-3

Gül, S., Keskin, M., Biçer, O., Gündüz, Z., & Behrem, S. (2020). Effects of different lambing season on some reproductive characteristics of ewes and growth performance of lambs in Awassi sheep. *Livestock Studies, 60* (1), 32-36. https://doi.org/10.46897/lahaed.779729

Gül, S., Keskin, M., Kaya, Ş., & Dikme, M. (2024). Investigation of some environmental factors on reproductive characteristics, milk traits and Kleiber ratios of Kilis goats reared in the fertile crescent of Türkiye. *Livestock Studies, 64* (1), 24-31.

Gürsu, G., & Aygün, T. (2014). Some characteristics of milk yield in Awassi ewes maintained at village conditions. *Journal of Advanced Agricultural Technologies, 1* (1), 19-23.

Hue-Beauvais, C., Faulconnier, Y., Charlier, M., & Leroux, C. (2021). Nutritional regulation of mammary gland development and milk synthesis in animal models and dairy species. *Genes, 12*, 523. https://doi.org/10.3390/genes12040523

Kenyon, P.R., Thompson, A.N., & Morris, S.T. (2014). Breeding ewe lambs successfully to improve lifetime performance. *Small Ruminant Research, 118*, 2-15. https://doi.org/10.1016/j.smallrumres.2013.12.022

Keskin, M., Biçer, O., Gül, S., & Sarı, A. (2005). A study on improving of lamb yield by three lambing in two years in Awassi sheep. *Lalahan Hayvancılık Araştırma Enstitüsü Dergisi, 45* (1), 33-39.

Kızılaslan, M., Arzık, Y., & Behrem, S. (2024). Exploring the economically important growth traits and environmental influences on Akkaraman lambs in Ankara. *Livestock Studies, 64* (1), 17-23. https://doi.org/10.46897/livestockstudies.1509590

Kleiber, M. (1947). Body size and metabolic rate. *Physiological Reviews, 27*, 511-541.

Koster, E., van der Westhuizen, J., & Erasmus, G.J. (1994). Heritability estimates for different Kleiber ratios obtained from growth performance data in a Hereford herd. *South African Journal of Animal Science, 24* (2), 71-72.

Lecorguillé, M., Teo, S., & Phillips, C.M. (2021). Maternal dietary quality and dietary inflammation associations with offspring growth, placental development, and DNA methylation. *Nutrients, 13*, 3130. https://doi.org/10.3390/nu13093130

Leras, R.J., Hernandez-Castellano, L.E., Suarez-Trujillo, A., Castro, N., Pourlis, A., & Almeida, A.M. (2014). The mammary gland in small ruminants: Major morphological and functional events underlying milk production – a review. *Journal of Dairy Research, 81*, 304-318. https://doi.org/10.1017/S0022029914000235

Mahala, S., Saini, S., Kumar, A., Sharma, R.C., & Gowane, G.R. (2020). Genetic trends for the growth rates and Kleiber ratio in Avikalin sheep. *Small Ruminant Research, 189*, 106143. https://doi.org/10.1016/j.smallrumres.2020.106143

Perez-Hernandez, G., Hanling, H.H., Schramm, H.H., Lengi, A.J., & Corl, B.A. (2023). Milk production and anatomical udder capacity changes of udder halves subjected to increased milking frequency at two stages of lactation. *Journal of Dairy Science, 106*, 9855-9867. https://doi.org/10.3168/jds.2023-23704

Rawlings, N.C., & Bartlewski, P.M. (2007). Clinical reproductive physiology of the ewe. In R. S. Youngquist & W.R. Threlfall (Eds.), *Current therapy in large animal theriogenology* (2nd ed., pp. 642-648). Saunders Elsevier.

Rizk, J., Sahu, R., & Duteil, D. (2023). An overview on androgen-mediated actions in skeletal muscle and adipose tissue. *Steroids, 199*, 109306. https://doi.org/10.1016/j.steroids.2023.109306

Rosales Nieto, C.A., Ferguson, M.B., Macleay, C.A., Briegel, J.R., Wood, D.A., Martin, G.B., & Thompson, A.N. (2013). Ewe lambs with higher breeding values for growth achieve higher reproductive performance when mated at age 8 months. *Theriogenology, 80* (5), 427-435. https://doi.org/10.1016/j.theriogenology.2013.05.004

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.

Smith, J.A., & Jones, R.B. (2018). Adaptation and resilience in sheep breeds: An overview. *Journal of Animal Science, 96* (4), 1123-1134.

Supakorn, C., & Pralomkarn, W. (2012). Genetic parameter estimates for weaning weight and Kleiber ratio in goats. *Songklanakarin Journal of Science and Technology, 34* (2), 165-172.

Tabbaa, M.J., Alnimer, M.A., Shboul, M., & Titi, H.H. (2008). Reproductive characteristics of Awassi ewes mated artificially or naturally to Jordanian or Syrian Awassi rams. *Animal Reproduction, 5* (1), 23-29.

Talafha, A.Q., & Ababneh, M.M. (2011). Awassi sheep reproduction and milk production: Review. *Tropical Animal Health and Production, 43* (7), 1319-1326. https://doi.org/10.1007/s11250-011-9858-5

Webster, H.H., Lengi, A.J., & Corl, B.A. (2024). Mammary epithelial cell exfoliation increases as milk yield declines, lactation progresses, and parity increases. *JDS Communications, 5*, 707-712. https://doi.org/10.3168/jdsc.2023-0534

Xiao, S., Liu, W., Zhang, S., & Schroyen, M. (2025). The role of maternal dietary protein on livestock development, production and health. *Animal Reproduction Science, 276*, 107835. https://doi.org/10.1016/j.anireprosci.2025.107835