Article

Not peer-reviewed version

Enhancing Lamb Weight Increase Through Genetic and Environmental Strategies in Arid Environments

Khaled Al-Najjar * , Abdulmounem O. Al Yasin , Mustafa M. Alshdaifat , Moammar Dayoub , Dele Raheem

Posted Date: 5 November 2024

doi: 10.20944/preprints202411.0256.v1

Keywords: Awassi sheep; Growth; Heritability; Breeding Values; Dry Lands

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2024 doi:10.20944/preprints202411.0256.v1

Article

Enhancing Lamb Weight Increase Through Genetic and Environmental Strategies in Arid Environments

Khaled Al-Najjar [1,*], Abdulmounem O. Al yasin [2], Mustafa M. Alshdaifat [3], Moammar Dayoub [4] and Dele Raheem [5]

1 General Commission for Scientific Agricultural Research, GCSAR, P.O. Box 113, Damascus, SYRIA; khnajj2011@yahoo.com
2 Arab Center for the Studies of Arid Zones and Dry Lands, ACSAD, P.O. Box 2440, Damascus, SYRIA; Sams-22@windowslive.com
3 Al-Khanasiri Department for Livestock and Rangelands Research, National Agriculture Research, (NARC), Box 639, Baqa'a 19381, JORDAN; m.shdaifat78@yahoo.com
4 Computing Department, Faculty of Technology, University of Turku, 20014, Turku, FINLAND; moammar.dayoub@utu.fi
5 Global Change, Arctic Centre, University of Lapland, 96101, Rovaniemi, FINLAND; braheem@ulapland.fi
* Correspondence: author khnajj2011@yahoo.com

Simple Summary: Sheep farming is adaptable to diverse climates, with the Awassi breed suited for arid areas but requiring selective breeding and management to enhance productivity. This 2023 study at Al-Fjaj Station in Jordan analyzed the weights of Awassi sheep in a semi-intensive system, using 2,263 records to assess environmental and genetic influences on growth. Key findings include the impact of birth type, sex, ewe age, and parity on lamb weights, with single lambs and males generally heavier. Weight correlations across growth stages are positive, especially from weaning onward. Rams significantly influence weight traits, while maternal effects are stronger early on. Positive genetic correlations among traits suggest that improving one trait can benefit others, and breeding based on genetic values can enhance growth potential. Selecting rams with high breeding values can improve future flock performance, making index selection valuable for sustainable lamb production in arid environments.

Abstract: Sheep farming thrives in diverse climates, with the Awassi breed well-suited for arid environments, though it faces challenges that necessitate selective breeding and innovative management to improve productivity and weight performance. This study, conducted in 2023 at Al-Fjaj Station in Jordan, analyzed the weights of Awassi sheep managed under a semi-intensive system, examining 2,263 records to evaluate the environmental and genetic factors influencing growth and utilizing statistical models to estimate heritability and breeding values. Variance analysis revealed that birth type, lamb sex, parity, and ewe age at lambing significantly influence birth, weaning, 6-month, and annual weights, with single-born lambs generally heavier than twins, males surpassing females, and younger ewes producing lighter lambs at birth that catch up in weight later. Lamb weights are correlated positively across various stages, especially between weaning, six-month, and yearling weights, while the influence of birth weight on later weights is comparatively weaker. Analysis of Variance (Type 3) indicates that rams have the greatest influence on lamb weights at all ages, while ewes primarily affect early weight, and genetic factors play a moderate role in weight variation, with maternal effects being more significant than paternal influences. There are significant positive genetic correlations among lamb weight traits, indicating that improvement in one trait can benefit others, while mean breeding values decrease with age due to increasing environmental influences, suggesting the use of index selection to enhance multiple traits in breeding programs. High correlation coefficients between breeding values and mean weights of Awassi sheep indicate that higher breeding values for specific weight traits are associated with greater actual weights, demonstrating that selection based on breeding values can effectively enhance genetic potential and predict future performance. The genetic performance and growth traits of rams' progeny indicate that selecting rams with higher breeding values can enhance weight gain in future generations, while mean weights serve as performance benchmarks to help breeders improve flock genetics and profitability. In conclusion, this study identifies key factors influencing lamb weights, such as birth type, lamb sex, ewe parity, and ewe age, emphasizing the importance of single lambs and males in achieving higher growth, while suggesting that an index selection approach combining genetic merit with environmental factors is vital for optimizing sustainable lamb production in arid environments.

Keywords: awassi sheep; growth; heritability; breeding values; dry lands

1. Introduction

Sheep farming thrives across a range of climates and geographical conditions, from humid highlands to arid landscapes, and is practiced successfully in both developed and developing nations. Arid regions, however, present specific health risks for sheep and goats, with both the dry and wet seasons bringing unique challenges to livestock well-being [1]. One notable breed well-suited to these conditions is the Awassi sheep, recognized for its distinctive fat tail and native to the Middle East spanning Jordan, Syria, Iraq, the West Bank, Egypt, Lebanon, and Turkey. This breed is herded traditionally across pastures in harsh environments, displaying a high level of adaptability. Their resilience has enabled successful introduction to other parts of the world, including Europe, Australia, New Zealand, and China, where they continue to perform well.

In the Middle East, boosting productivity in sheep farming begins with selecting ewes for high milk yield early in lactation [2]. Focusing on prime-aged ewes (3–7 years) and providing specialized nutrition can lead to faster-growing, healthier lambs [3]. Although environmental factors influence production, choosing superior rams and carefully selecting females can amplify yields even further [4]. Adding to this, enhanced prenatal nutrition and attentive care for newborn lambs can help unlock the full potential of each flock, creating a more robust and productive herd [5].

The Awassi breed is perfectly suited for arid environments, making it an economically valuable asset. However, it does face challenges, including limited prolificacy. Thanks to selective breeding programs, significant strides have been made in enhancing both milk production and body weight [6–8]. In Jordan, the productivity of Awassi sheep plays a crucial role in providing quality meat and milk. Yet, various factors, such as arid climate, water scarcity, limited pasture, high feed costs, economic pressures, disease management issues, and a lack of technological resources, can impact their performance [9]. By adopting innovative herd management practices and focusing on genetic improvements, the full potential of this remarkable breed can be unlocked.

This study examines the factors that affect weight in Awassi sheep at key developmental stages: birth, weaning, six months, and one year. The research analyzes environmental factors such as birth type, sex, and parity, as well as genetic factors, to identify the primary determinants of weight. Additionally, the study evaluates the potential for genetic improvement by estimating genetic parameters like heritability and breeding values. By ranking rams based on their genetic merit, the research aims to improve breeding strategies and enhance the overall weight performance of Awassi sheep.

2. Materials and Methods

2.1. the location

This study was conducted in 2023 at Al-Fjaj Station, part of the Al-Khanasri Center under the Animal Wealth and Range Research Department of the National Center for Agricultural Research in Jordan. Located 200 kilometers north of Amman in the northern part of the Mafraq Governorate, the station houses a herd of Awassi sheep in semi-open pens and operates under a semi-intensive management system. This center provides a suitable environment for examining the effects of environmental factors and genetic parameters on the weights of Awassi sheep (Figure 1).

 doi:10.20944/preprints202411.0256.v1

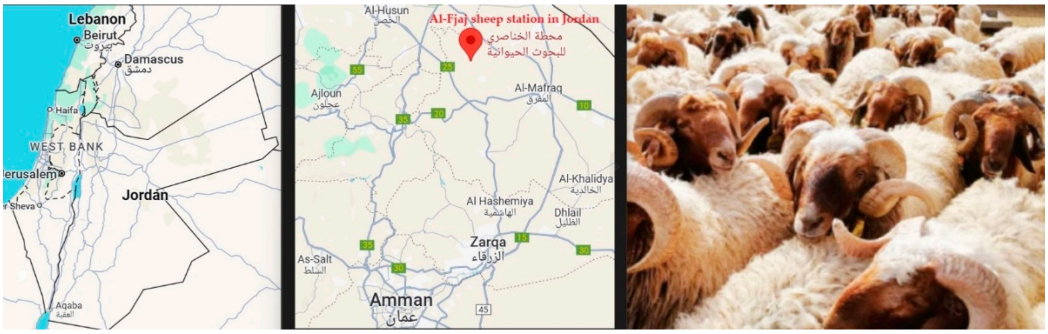

Figure 1. Map of Jordan showing the locations of Awassi sheep flocks in Mafraq Governorate, with the coordinates of the area (32.3045°N, 36.3173°E).

2.2. The sheep care

Sheep were managed semi-intensively, grazing 4-3 hours daily. Pregnant ewes received 0.5 kg alfalfa hay and 1.5-1.8 kg concentrate. Lambs were weaned at 14 kg after a suckling program. Mature ewes grazed on pastures and received 250-500 g/head supplements. In winter, they received 0.5-1.0 kg/head mixed feed. Lambs were weighed at birth, weaning, 6 months, and annually.

During dry periods, ewes were fed forage legumes and cereals, while grazing on crop residues and shrubs at other times. In winter, they received concentrates, hay, and straw. Pregnant ewes were provided with a special concentrate mix including barley, wheat bran, soybean meal, and limestone, along with vitamins, salt, and minerals. The study tracked lamb weights at birth, weaning, 6 months, and annually, with both lambs and their mothers following a controlled lactation program and receiving supplementary feed to ensure optimal growth.

2.3. Data analyses

The dataset comprised 2,263 records of weights from Awassi sheep, including 111 rams, 1,714 ewes, and 1,908 lambs, offering a detailed view of growth and management patterns within this specific environment. Statistical analyses were conducted using the SAS program [10], applying the General Linear Model (GLM).

The fixed model was applied as follows.

$$Y_{ijkl} = \mu + BT_i + S_j + P_k + B(X_{ijkl} - \bar{X}) + e_{ijkl} \quad (1)$$

Where, Y_{ijk} = Birth weight, weaning weight, weight at 6 months, and annual weight of ijkl[th] observations. μ= overall mean. BT_i = Birth type (1= Single, 2= Twins). S_J = Sex of calf (1= Male, and 2= Female). P_k = Parity (1= First … 8= Eighth). B = linear partial regression coefficient of the birth weight, weaning weight, weight at 6 months, and annual weight of ijkl[th] observations on the ewe's age at lambing. X_{ijkl}= the k[th] ewe's age at lambing, $\bar{X}$ = the grand mean of the ewe's age at lambing. e_{ijkl} = random error term associated with the Y_{ijkl} observations with zero mean and variance $I\sigma^2 e$. Duncan's multiple-range test [11] was used to notice differences between means.

Partial correlation coefficients were estimated from the SSCP errors matrix with their corresponding probability values denoted by (Prob.>|r|) according to model (1).
Heritability values for weights were computed using the paternal half-sib method (Method = TYPE 3) according to [12]. The mixed model applied in this analysis was as follows.

$$Y_{ijkl} = \mu + BT_i + S_j + P_k + B(X_{ijkl} - \bar{X}) + R_{ijkl} + e_{ijkl} \quad (2)$$

Where, Y_{ijkl} = Birth weight, weaning weight, weight at 6 months, and annual weight of ijkl[th] observations. R_{ijkl} = Ram (i = 1, 2… 111). The prior model displays the remaining symbols and e_{ijkl}= Effect of environmental and genetic deviation related to individuals in a group of ram. Therefore, the equations are following:

$$h^2 = 4\,t \quad , \qquad t = \frac{V_S}{V_S + V_W} \quad , \qquad k = \frac{1}{s-1}\left\{N - \frac{\sum N_I^2}{N}\right\} \quad , \quad (3)$$

$$SE(h^2) = 4\sqrt{\frac{2(1-t)^2(1+(k-1)t)^2}{k(k-1)(s-1)}}$$

Where, $h^2 =$ heritability value, $V_S =$ Variance component of ram, $V_W =$ Variance component of an individual, t and k are the constant, $SE(h^2) =$ Standard error of heritability, $N =$ Total number of progeny, $N_i =$ Number of progeny per ram, and $S =$ Number of rams.

$$EBV = \frac{N_i h^2}{4 + (N_i - 1)h^2}\,(P_{prog.} - P_{pop.}) \quad (4)$$

Estimated breeding values (EBV) were computed with [13].

Where, $EBV =$ breeding value, $N_i =$ Number of progeny per ram, $h =$ Root of heritability value, $P_{prog.} =$ Average trait of progeny, and $P_{pop.} =$ Average birth weight of the population. The previous models show the remaining symbols.

3. Results

The variance analysis for birth weight, weaning weight, 6-month weight, and annual weights (Model 1) demonstrates that birth type, lamb sex, parity, and ewe age at lambing are significant factors influencing these weight traits. Birth type and parity had the most pronounced effects across all stages of weights. Lamb sex was found to significantly affect birth, weaning, and annual weights, though it had no notable impact on 6-month weight. Additionally, ewe age played a particularly important role in determining wean-ing and 6-month weights.

Table 1 indicates that single-born lambs maintain a higher weight than twin-born lambs throughout their lives, with males generally surpassing females in weight. Lambs born to younger ewes are typically lighter at birth but catch up by reaching comparable annual weights. Interestingly, lambs from ewes with a higher number of offspring show higher birth weights but tend to be lighter at weaning. Weight variation is most pronounced at the weaning and six-month stages. All regression coefficients for lamb weights relative to ewe age at lambing are positive, though the influence of ewe age is especially evident at weaning and six months.

Table 1. Least-square means of birth weight, weaning weight, weight at 6 months and annual weight traits (Model 1).

Traits / Factors		Birth Weight	Weaning Weight	Weight at 6 Months	Annual Weight
Overall mean		3.83±0.17	16.34±0.93	30.15±1.84	64.75±2.66
Birth Type	**Single**	4.75±0.03a	18.30±0.20a	34.86±0.41a	60.79±0.59a
	twins	4.08±0.04b	16.57±0.24b	32.86±0.48b	58.46±0.69b
Lamb Sex	**Male**	4.51±0.04a	17.85±0.22a	34.06±0.44a	60.09±0.62a
	Female	4.31±0.04b	17.03±0.21b	33.67±0.43a	59.16±0.63b
Parity	**1st**	4.20±0.05b	18.19±0.26b	35.55±0.52b	56.63±0.75c
	2nd	4.32±0.04ab	17.21±0.22b	34.52±0.44c	57.17±0.64c
	3rd	4.49±0.04a	17.92±0.22b	35.34±0.43b	59.00±0.62c
	4th	4.62±0.05a	16.98±0.29b	33.49±0.58bc	58.27±0.84c
	5th	4.49±0.07ab	16.88±0.39b	32.01±0.78bc	58.28±1.12c
	6th	4.47±0.09ab	16.94±0.49b	29.11±0.97bc	58.25±1.41c
	7th	4.51±0.13ab	16.76±0.69b	36.56±1.36a	62.93±1.97b
	8th	4.20±0.12b	18.63±0.66a	37.30±1.31a	66.45±1.89a

If two means share at least one identical letter, it indicates no significant difference between them. The regression coefficients of lamb weights on ewe age at lambing are as follows: birth weight = 0.023 ± 0.015, weaning weight = 0.263 ± 0.123, 6-month weight = 1.532 ± 0.243 and annual weight = 0.351 ± 0.020. The coefficients of variation for each weight stage are birth weight = 16.38%, weaning weight = 21.59%, 6-month weight = 21.71%, and annual weight = 18.98%.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2024 doi:10.20944/preprints202411.0256.v1

Table 2 highlights the correlations between lamb weights at various stages of age, revealing that lambs heavier at one stage are likely to remain heavier at subsequent stages. The data shows particularly strong correlations between weaning, six-month, and year-ling weights, indicating that lambs with higher weights at these weights tend to maintain a higher weight trajectory. While birth weight does have some influence on later weights, its correlation with subsequent stages is less pronounced.

Table 2. Partial Correlation Coefficients of birth weight, weaning weight, weight at 6 months and annual weight traits from the Error SSCP Matrix / Prob. > |r|, (DF = 2251) (Model 1).

Traits	Weaning Weight	Weight at 6 Months	Annual Weight
Birth weight	0.17**	0.07**	0.02^{ns}
Weaning weight		0.36**	0.33**
Weight at 6 months			0.66**

**= highly significant, ns= non-significant.

Analysis of Variance (Type 3) of birth weight, weaning weight, weight at 6 months, and annual weight traits (Model 2) examines how rams, ewes, and lambs (random effects) influence lamb weight at different ages. It shows that rams have the biggest impact on lamb weight, regardless of age, highlighting their importance in breeding for heavier lambs. Ewes also matter, especially for early weight, but their influence decreases over time. The genetics of lambs only significantly affect their weight for one year of age.

Table 3 reveals that maternal factors exert a more significant influence on lamb weight variation than paternal genetics. This is evidenced by the greater weight differences observed among siblings from the same ram compared to those from different rams. While maternal factors play a crucial role, genetic factors also contribute to lamb weight. Heritability estimates suggest a moderate genetic influence, with a stronger impact on weight at 6 months and 1 year of age.

Table 3. Variance component and heritability ± standard error for birth weight, weaning weight, weight at 6 months of age, and annual weight in Awassi rams (Model 2).

Variance component	The weights			
	Birth	**Weaning**	**6 months**	**Annual**
Vs	0.02326	0.694	18.9368	38.8642
Vw	0.53	14.55	40.96	85.48
$h^2 \pm$ SE	0.17±0.08	0.18±0.07	0.32±0.04	0.31±.05

Vs= Variance component of ram, Vw= Variance component of individual within ram, h^2= heritability. Mean of progeny for each ram= 20.34.

Table 4 reveals significant genetic correlations between various weight traits in lambs. Strong, positive associations exist between birth weight, weaning weight, 6-month weight, and annual weight. This indicates that selecting for improvement in one trait can positively influence others. The mean breeding values for these weight traits decrease with age, suggesting that environmental factors become increasingly influential on weight traits as lambs mature. To optimize breeding programs, an index selection approach can be employed to simultaneously improve multiple traits, considering both genetic and environmental factors.

Table 4. Average of breeding values of weights based on rams; and spearman correlation coefficients of breeding values for traits studies (birth, weaning, 6 months, and annual weights), N=110, Prob. > |r| under H0: Rho=0 (Model 2).

Breeding Values	BVBW	BVWW	BVW6M	BVYW	TBV
BV(S)	0.02±0.01	-0.11±0.01	-0.26±0.17	-0.53±0.15	-0.97±0.51
BVBW		0.96**	0.97**	0.96**	0.64**

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2024 doi:10.20944/preprints202411.0256.v1

BVWW	0.92**	0.98**	0.62**
BVW6M		0.93**	0.63**

BV= breeding values; BVBW, BVWW, BVW6M, and BVYW= breeding values for birth, weaning, 6-month, and annual weight, respectively; TBV = total of. Mean of progeny for each ram= 20.34

Table 5 shows the correlation coefficients between various breeding values (BV) and mean weights of Awassi sheep. The high correlation coefficients for birth, weaning, 6-month, and annual weights indicate a strong positive relationship, meaning sheep with higher breeding values for a specific weight trait generally have higher actual weights. Furthermore, the significant correlation between total breeding value (TBV) and mean weights highlights a strong link between overall genetic merit and weight performance. These findings suggest that selecting animals based on breeding values can effectively enhance genetic potential for weight traits, accurately predict future performance, and drive genetic improvement over generations.

Table 5. Spearman correlation coefficients among breeding and phenotypic values (weights) of Awassi Sheep, N = 111, Prob > |r| under H0: Rho=0.

BV(S) / Weights	BVBW	BVWW	BVW6M	BVYW	TBV
MBW	0.96**				0.97**
MWW		0.97**			0.98**
MW6M			0.99**		0.99**
MYW				0.95**	0.97**

BVBW, BVWW, BVW6M and BVYW = Breeding values of birth, weaning, 6 months and annual weights, respectively. TBV= Total breeding values. MBW, MWW, MW6M and MYW= Means of birth, weaning, 6 months and annual weights, respectively. Mean of progeny for each ram= 20.34.

Table 6 provides valuable insights into the genetic performance and growth characteristics of rams' progeny. The breeding values (BV) for birth, weaning, six-month, and annual weights help identify rams with desirable genetics for weight gain. Farmers can select rams with higher BV scores to improve growth rates in future generations. The mean weights provide a benchmark for the average performance of each ram at various growth stages. By focusing on rams with higher TBV, breeders can enhance the overall genetic potential of their flock. Rams with higher mean weights and positive BVs could yield more profitable livestock, while those with negative BVs might be excluded from breeding programs to prevent introducing less productive traits.

Table 6. Ranking of Awassi rams by genetic merit and performance.

Rams rank / Traits	1st	2nd	3rd	and so on	109th	110th	111th
MBW	5.22	5.34	5.14	…	3.83	3.91	2.00
BVBW	0.52	0.50	0.49	…	-0.48	-0.56	-0.64
MWW	20.99	20.83	20.39	…	15.50	15.39	15.52
BVWW	2.29	2.21	1.99	…	-2.06	-2.30	-2.34
MW6M	43.19	42.89	42.93	…	27.70	15.50	26.24
BVW6M	6.32	6.15	5.83	…	-7.15	-8.00	-8.52
MYW	71.68	71.60	71.90	…	43.78	43.89	40.54
BVYW	10.97	10.78	10.52	…	-11.33	-11.70	-13.48
TBV	20.11	19.63	18.83	…	-21.02	-22.56	-24.98

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2024 doi:10.20944/preprints202411.0256.v1

MBW, MWW, MW6M and MYW= Means of birth, weaning, 6 months and annual weights, respectively. BVBW, BVWW, BVW6M and BVYW = Breeding values of birth, weaning, 6 months and annual weights, respectively; TBV= Total breeding values. Mean of progeny for each ram= 20.34.

4. Discussion

Lamb weight is influenced by various factors, including lambing type, sex, and ewe's age and parity. Single lambs often grow faster than twins due to better access to resources, leading to higher birth, weaning, and annual weights. Male lambs typically grow faster than females due to hormonal differences, resulting in higher weights at birth, weaning, and annually. Older ewes generally provide better growth conditions for lambs compared to younger ewes, leading to improved weight gain across all stages of development. These factors collectively influence lamb weight at birth, weaning, and throughout their life (Table 1).

Early lamb weight is crucial because it strongly predicts future growth, with weights at weaning, six months, and one year being particularly indicative. Heavier lambs at these stages typically maintain their advantage, leading to more efficient growth and productivity. While birth weight has some influence, later weights are more reliable for predicting growth potential, allowing for better management and breeding decisions that enhance overall flock performance. This understanding helps in selecting and nurturing lambs with the best prospects, ultimately improving productivity and profitability in sheep farming (Table 2).

Non-genetic factors, such as age at first calving, influence Galunki sheep productivity [14]. Furthermore, Avicalin sheep exhibit rapid initial growth, followed by a decline, highlighting the importance of environmental management [15]. Additionally, genetic and environmental factors influence lamb birth and weaning weights, with breed groups affecting only birth and weaning weights [16]. Consequently, improving management and health is crucial for pre-weaning performance and survival. Moreover, high-yielding Lacaune sheep require effective nutritional strategies, especially for maiden ewes carrying multiple lambs [17]. Similarly, for Pelibuey ewes, management improvements are more beneficial than genetic changes due to the low repeatability of reproductive traits and the significant effects of flock, and parity [18]. Likewise, Rahmani ewes in late pregnancy demonstrate increased nutrient requirements and weight loss in multiparous ewes, positively influencing lamb birth weight and growth, with high-protein diets further enhancing lamb performance [19]. In addition, body condition traits are vital for improving maternal performance and feed efficiency in genetic evaluations [20]. Yet, lamb weight is linked closely to dam's body weight, especially at 30 days and weaning, while sire's weight has minimal impact, suggesting other factors influence lamb growth [21]. Live weight and body measurements are key indicators of growth in Indigenous and crossbred sheep, with breed, birth type, and sex affecting these growth patterns [22].

Rams play a crucial role in enhancing lamb weight, as their genetic influence significantly influences growth across all stages. While ewes contribute to early weight through maternal care, the lamb's genetic potential becomes more pronounced later on. Prioritizing ram selection in breeding programs can optimize flock productivity and profitability. In Awassi sheep, both genetic and environmental factors influence weight variability. Heritability for weight increases with age, indicating a growing genetic influence. Rams contribute more to weight variation than ewes or lambs, making them a key target for selective breeding to improve weight-related traits in this breed (Table 3).

Strong correlations between breeding values for different weight traits in Awassi sheep rams indicate potential for simultaneous improvement through selective breeding. However, declining average breeding values, especially for annual weight (Table 4), suggest a need to focus on improving later-stage growth to optimize overall weight gain and production. While this suggests the potential for efficient genetic improvement through single-trait selection, a more nuanced approach is necessary. Prioritizing birth weight alone may compromise annual weight gain. A balanced selection strategy, considering multiple traits, could yield superior outcomes.

A strong correlation between breeding values (BVs) and actual weight in Awassi sheep suggests that BVs are reliable predictors of genetic potential for weight traits. The positive association between total breeding value (TBV) and mean weights further supports the use of BVs in selection decisions to improve genetic merit (Table 5). The high correlations between BVs and actual weights underscore their reliability in identifying superior individuals. Moreover, the strong link between total breeding value (TBV) and mean weights provides compelling evidence that BVs directly translate into improved productivity. Therefore, selecting animals based on BVs is not merely a promising strategy but an imperative for achieving consistent genetic progress and maximizing the economic value of Awassi sheep flocks.

Breeding values (BVs) for key weight measurements help identify top genetic rams. Consequently, prioritizing rams with higher Total-BVs enhances flock genetic potential, leading to increased productivity and profitability. Furthermore, careful selection of rams based on BVs ensures consistent genetic and economic gains. Table (6) proves the critical role of genetic performance data in maximizing ram progeny growth. BVs are essential for identifying elite rams. Therefore, prioritizing rams with higher Total-BVs is imperative for elevating flock genetic potential. Moreover, the deliberate selection of rams based on BVs is a necessity for sustained genetic and economic advancements.

Lambing number, lambing year, and ram effect influence litter size, birth weight, and weaning weight in hair sheep [23]. Crossbreeding Barki sheep with Awassi rams enhances crossbred lambs' weights, allowing them to reach puberty earlier and at heavier weights [24]. Improving ewe nutrition, especially for first-time lambs, boosts lamb growth [25]. Optimal nutrition and environment are crucial for sheep health, growth, and productivity. Ewe age influence birth weight [26]. Optimizing lamb growth requires attention to both environment and genetics [27]. A breeding program focused on genetic merit, coupled with sound management and selection, can improve Barki sheep [28]. Selecting sheep with superior genetic traits can further boost growth and weight.

Substantial additive genetic variability in Menz sheep suggests that selective breeding can significantly improve genetics, with high correlations between traits indicating the feasibility of earlier ram selection [29]. Gizaw [30] recommends a two-stage selection process, starting with selecting breeding values in nucleus centers, followed by farmers choosing the top rams. This method aligns with farmers' preferences, accelerates genetic progress, and is adaptable for participatory breeding programs in similar settings. Sustainable breeding strategies should integrate farmers' preferences and environmental conditions, as shown in Ethiopian sheep farming, to create more effective and adaptable programs [31]. Sánchez-Molano [32] identified sufficient genetic variation in meat sheep for improvement through selective breeding and recommended incorporating these traits into future breeding goals. Additionally, combining genomic selection and managing inbreeding significantly boosts genetic gain in sheep, with optimal contribution selection effectively balancing inbreeding and genetic gain [33].

Research has identified several factors influencing lamb and sheep growth. Vlahek [34] found birth type, sex, and birth number significantly affect Romanov lamb birth weight, while Al-Qasimi [35] observed minimal impact on overall production. Lupi [36] highlighted flock management and multiple births, and Nirban [37] and Singh [38] pointed to ram, sex, parturition period, parity, and maternal weight as key factors for body weight and pre-weaning traits. Vatankhah and Salehi [39] noted selecting for mating weight benefits Lori Bakhtiari sheep weight, while Assan and Makusa [40] found that singletons and males are typically heavier. These studies highlight the complex factors requiring targeted growth strategies.

However, the current research has not thoroughly analyzed the effects of nutrition and climate and has largely overlooked the interactions between environmental and genetic factors. Future studies should focus on gene-environment interactions and the impacts of selective breeding on genetic diversity and health. Effective management strategies, including environmental control and healthcare, are vital for reducing rearing stress and enhancing flock health, to improve productivity and profitability.

5. Conclusions

 doi:10.20944/preprints202411.0256.v1

This study underscores the diverse factors that significantly influence lamb weights, particularly emphasizing birth type, lamb sex, ewe parity, and ewe age. The single lambs consistently achieve higher weights than twins, with male lambs exhibiting superior growth compared to females. Furthermore, the age of the ewe at lambing plays a crucial role, especially in determining weights at weaning and six months of age. The observed strong correlations among various weight traits suggest that early weight measurements serve as reliable predictors of future growth, providing essential guidance for effective breeding and management decisions. Additionally, the moderate heritability estimates highlight the importance of rams in breeding programs aimed at enhancing lamb growth. To optimize genetic improvement, it is essential to implement a selection strategy that considers multiple traits, as focusing solely on birth weight may limit overall growth potential. An index selection approach that integrates genetic merit with environmental factors will be vital for achieving sustainable lamb production. These insights are valuable for sheep farmers and breeders, offering a foundation for improving lamb growth and productivity through a better understanding of the genetic and environmental influences.

Funding: This research was conducted without any external financial support.

Institutional Review Board Statement: The study adhered to the guidelines of the Declaration of Helsinki and received approval from the Institutional Review Board of the Arab Center for the Studies of Arid Zones and Dry Lands, ACSAD (protocol code z2/12/25, approval date 30 December 2023).

Acknowledgments: The authors are grateful for the valuable contributions of the University of Turku, the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), the University of Lapland, the National Center for Agricultural Research (NARC), and the General Commission for Scientific Agricultural Research (GCSAR), whose unwavering support was indispensable for the realization of this research.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Al-Barakeh, F., Khashroum, A.O., Tarawneh, R.A., Al-Lataifeh, F.A., Al-Yacoub, A.N., Dayoub M, Al-Najjar, K. Sustainable Sheep and Goat Farming in Arid Regions of Jordan. Ruminants, **2024**, 4, 241-255. https://doi.org/10.3390/ruminants4020017
2. Kassem, R., W. Al-Azzawi, Khaled Al-Najjar, Y. Masri, S. Salhab, Z. Abdo, I. El-Herek, H. Omed, and M. Saatci. Factors influencing the milk production of Awassi sheep in a flock with the selected lines at the Agricultural Scientific Research Centre. Kafkas Univ. Vet Fak Derg., **2010**, 16, 425-430. https://vetdergikafkas.org/ uploads/pdf/pdf_KVFD_667.pdf
3. Al-Momani, Ahmad, Mysa Ata and Khaled Al-Najjar. Evaluation of Weight and Growth Rates of Awassi Sheep Lambs. Asian Journal of Research in Animal and Veterinary Sciences, **2020**, 5, 26-32. https://www.journalajravs.com/ index.php/ AJRAVS/article/view/114/227
4. Al-Najjar, K., A.Q. Al-Momani, A.N. Al-Yacoub, A. Elnahas, Reda Elsaid. Estimation of Genetic Parameters and Non-Genetic Factors for Milk Yield and Litter Size at Birth of Awassi Sheep in Drylands, **2022**, Vol. 17, No. 2, P: 19-26. https://ejsgs.journals.ekb.eg/article_266898.html
5. Al-Najjar, Khaled, Al-Momani, A., Al-Yacoub, A., and Elsaid, R. Evaluation of Some Productive Characteristics of Jordanian Awassi. International Journal of Livestock Research, **2021**, 11, 1-6. https://ijlr.org/ ojs_journal/ index.php/ ijlr/ article/view/480/260
6. Alkass, J.E., Hermiz, H.N. and Baper, M.I. Some aspects of reproductive efficiency in Awassi ewes: A review. Iraqi Journal of Agricultural Sciences, **2021**, 52, 20-27. https://jcoagri.uobaghdad.edu.iq/index.php/intro/article/view/1232
7. Gootwine, E., Zenu, A., Bor, A., Yossafi, S., Rosov, A. andPollott, G.E. Genetic and economic analysis of introgression of the B allele of the FecB (Booroola) gene into the Awassi and Assaf dairy breeds. Livest. Prod. Sci., **2001**, 71, 49-58, http://dx.doi.org/10.1016/ S0301-6226(01)00240-8
8. Galal, S., Gürsoy, O., and Shaat, I. Awassi sheep as a genetic resource and efforts for their genetic improvement—A review. Small Ruminant Research, **2008**, 79, 99-108. https://doi.org/10.1016/j.smallrumres.2008.07.018
9. Al-Karablieh, E.K., & Jabarin, A.S. Different rangeland management systems to reduce livestock feeding costs in arid and semi-arid areas in Jordan. Quarterly Journal of International Agriculture, **2010**, 49, 91-109. https://ageconsearch.umn.edu/record/155543/?v=pdf
10. SAS, Institute Inc.: SAS/STAT User's Guide: Version 9.1, **2003**, SAS Institute Inc., and Cary, NC, USA. https://www.sas.com/en_us/software/stat.html

 doi:10.20944/preprints202411.0256.v1

11. Duncan, D.B. Multiple range and multiple F tests: Biometrics, **1955**, 11, 1-42. http://176.9.41.242/doc/statistics/1955-duncan.pdf
12. Becker WA. A Fortran Program for testing and analyzing multiple comparisons. Journal of Educational Statistics, **1992**, 17, 344-353.
13. Hardjosubroto P. Breeding value of sires based on offspring weaning weight as a recommendation for selecting kebumen ongole grade cattle. Journal of Animal Science, **1994**, 72, 3456-3463.
14. Gbangboche, A., Adamou-Ndiaye, M., Youssao, A., Farnir, F., Detilleux, J., Abiola, F., & Leroy, P. Non-genetic factors affecting the reproduction performance, lamb growth, and productivity indices of Djallonke sheep. Small Ruminant Research, **2006**, 64, 133-142. https://doi.org/10.1016/j.smallrumres. 2005.04.006
15. Mahala, S., Saini, S., Kumar, A., Prince, L., & Gowane, G. Effect of non-genetic factors on growth traits of Avikalin sheep. Small Ruminant Research, **2019**, 174, 47-52. https://doi.org/10.1016/j.smallrumres.2019.03.006
16. Hagan, B.A., Salifu, S., Asumah, C., Yeboah, E.D., & Boa-Amponsem, K. Effects of genetic and non-genetic factors on body weight, pre-weaning growth, birth type and pre-weaning survivability of lambs in a sheep nucleus station. Department of Animal Production and Health, **2022**, 34. https://www.lrrd. cipav.org.co/ lrrd34/4/3430bern.html
17. Luis, J., Victoria, M., Feyjoo, P., Cáceres, E., Hernández, F., Vicente, J., & Astiz, S. Influence of Maternal Factors (Weight, Body Condition, Parity, and Pregnancy Rank) on Plasma Metabolites of Dairy Ewes and Their Lambs. Animals, **2019**, 9, 122. https://doi.org/10.3390/ani9040122
18. Magaña-Monforte, J.G., Huchin-Cab, M., Ake-López, R.J. et al. A field study of reproductive performance and productivity of Pelibuey ewes in Southeastern Mexico. Trop Anim Health Prod 45, **2013**, 1771–1776 (2013). https://doi.org/10.1007/s11250-013-0431-2
19. Abd-Allah, M. Effects of parity and nutrition plane during late pregnancy on metabolic responses, colostrum production and lamb output of Rahmani ewes. Egyptian Journal of Animal Production, **2013**, 50, 132-142. https://ejap. journals.ekb.eg/article_93673_fefee43ee4a0271dfca101a8809e7527.pdf
20. Walkom, S.F., & Brown, D.J. Genetic evaluation of adult ewe bodyweight and condition: relationship with lamb growth, reproduction, carcass and wool production. Animal Production Science, **2016**, 57, 20-32. https://www. publish. csiro.au/AN/AN15091
21. Caro-Petrović, V., Petrović, M. P., Ružić-Muslić, D., Maksimović, N., Sycheva, I. N., Cekić, B., & Ćosić, I. Interrelation between body weights of sire, dam and their lambs at early stage of growth. Biotechnology in Animal Husbandry, **2020**, 36, 205-214. https://doiserbia.nb.rs/Article.aspx?id=1450-91562002205C
22. Kader Esen, V., & Elmacı, C. The Estimation of Live Weight from Body Measurements in Different Meat-Type Lambs. Journal of Agricultural Sciences, **2021**, 27, 469-475. https://doi.org/10.15832/ankutbd.719037
23. Sánchez-Dávila, F., Bernal-Barragán, H., Padilla-Rivas, G. et al. Environmental factors and ram influence litter size, birth, and weaning weight in Saint Croix hair sheep under semi-arid conditions in Mexico. Trop Anim Health Prod., **2015**, 47, 825–831. https://doi.org/10.1007/s11250-015-0795-6
24. Eissa, M.M; El-wakeel, EL.A; Ahmed, M.H; Zahran, S.M and EL-Rewany, A.M. Effect of breed of ram on reproductive performance of Barki ewes and their lambs. Alexandria Science Exchange Journal, 34(April-June), **2013**, 222-227. https://journals.ekb.eg/article_3041_607f55a38b44d551da923d70fad00e79.pdf
25. Aktaş, A. H., Dursun, Ş., Doğan, Ş., Kiyma, Z., Demirci, U., and Halıcı, İ. Effects of ewe live weight and age on reproductive performance, lamb growth, and survival in Central Anatolian Merino sheep, Arch. Anim. Breed., **2015**, 58, 451–459, https://aab.copernicus.org/articles/58/451/2015/aab-58-451-2015. pdf
26. Petrovic, M.P., Muslic, D.R., Petrovic, V.C., & Maksimovic, N. Influence of environmental factors on birth weight variability of indigenous Serbian breeds of sheep. African journal of Biotechnology, **2011**, 10, 4673-4676. https://www.ajol.info/index.php/ajb/article/view/94136
27. Kramarenko, A.S., Markowska, A.V., Salamatina, O.O., Kravchenko, O.O., & Kramarenko, S.S. Genetic and environmental factors influenced the birth and weaning weight of lambs. Ukrainian Journal of Ecology, **2021**, 11, 195-201, https://cyberleninka.ru/article/n/genetic-and-environmental-factors-influenced- the-birth-and-weaning-weight-of-lambs
28. El-Wakil, S.I. and Elsayed, M. Genetic, phenotypic and environmental trends towards improving body weight in Barki sheep. Egyptian Journal of Sheep and Goats Sciences, **2013**, 8, 1-10. https://journals.ekb.eg/article_26769_ d92ae6e0a45a44fecc73b3aa1ce12cfc.pdf
29. Gizaw, S., Lemma, S., Komen, H., & Van Arendonk, J.A. Estimates of genetic parameters and genetic trends for live weight and fleece traits in Menz sheep. Small Ruminant Research, **2007**, 70, 145-153. https://doi.org/10.1016/ j.smallrumres.2006.02.007
30. Gizaw S, Getachew T, Tibbo M, Haile A, Dessie T. Congruence between selection on breeding values and farmers' selection criteria in sheep breeding under conventional nucleus breeding schemes, animal, **2015**, 5, 995-1001. https://doi.org/10.1017/S1751731111000024
31. Gizaw, S., Komen, H., & Van Arendonk, J. A. Participatory definition of breeding objectives and selection indexes for sheep breeding in traditional systems. Livestock Science, **2010**, 128, 67-74, https://doi.org/10.1016/ j.livsci.v 2009.10.016

32. Sánchez-Molano, E., Kapsona, V.V., Oikonomou, S. et al. Breeding strategies for animal resilience to weather variation in meat sheep. BMC Genet, **2020**, 21, 116, https://doi.org/10.1186/s12863-020-00924-5
33. Granleese, T., Clark, S.A., Swan, A.A. et al. Increased genetic gains in sheep, beef and dairy breeding programs from using female reproductive technologies combined with optimal contribution selection and genomic breeding values. Genet. Sel. Evol., **2015**, 47, 70. https://doi.org/10.1186/s12711-015-0151-3
34. Vlahek, I., A. Ekert kabalin, S. Menčik, M. Maurić maljković, A. Piplica, H. Kabalin, J. Šavorić, V. Sušić. The effect of non-genetic factors on the birth weight of Romanov sheep. Vet. arhiv, **2021**, 91, 615-624, https://vetarhiv.vef. unizg.hr/ papers/2021-91-6-5.pdf
35. AL-Qasimi R.H., Shatha M.A, Allawi L.D. K. Effect of Breed and Some Non-Genetic Factors on Milk Production and Some Proportions of Its Chemical Components in Two Breeds of Local Sheep. Al-Qadisiyah Journal for Agriculture Sciences (QJAS), **2020**, 10, 227-231. http://qu.edu.iq/ jouagr/index.php/QJAS/index
36. Lupi, T.M., Nogales, S., León, J. M., Barba, C., & Delgado, J.V. Analysis of the Non-Genetic Factors Affecting the Growth of Segureño Sheep. Italian Journal of Animal Science, **2015**, 14. https://doi.org/ 10.4081/ijas.2015.3683
37. Nirban L.K., Joshi R.K., Narula H.K., Singh H., Bhakar S. Genetic and non-genetic factors affecting body weights in Marwari sheep. Indian Journal of Small Ruminants, **2015**, 21, 106-108. https://doi.org/10.5958/0973-9718.2015. 00029.X
38. Singh H., Pannu U., Narula H.K., Chopra A., Murdia C.K. Influence of genetic and non-genetic factors on pre-weaning growth in Marwari sheep. Indian Journal of Small Ruminants, **2013**, 19, 142-145. https://www. indianjournals.com/ijor.aspx?target=ijor:ijsr&volume=19&issue=2&article=z003
39. Vatankhah, M., & Salehi, S. Genetic and non-genetic factors affecting Lori-Bakhtiari ewe body weight and its relationship with productivity. Small Ruminant Research, **2010**, 94, 98-102. https://doi.org/10.1016/j. smallrumres. 2010.07.006
40. Assan N., S. M. Makuza. The Effect of Non-genetic Factors on Birth Weight and Weaning Weight in Three Sheep Breeds of Zimbabwe. Asian-Australasian Journal of Animal Sciences, **2005**, 18, 151-157. https://doi.org/10.5713/ ajas.2005.151