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Factors Affecting Awassi Sheep Weight and Breeding Strategies in Arid Environments

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Simple Summary: This research delves into the effectiveness of sheep farming, specifically examining the Awassi breed in the harsh conditions of the Middle East. Data collected from a Jordanian sheep station were analyzed to study the effects of various factors, such as lambing type, sex, age, and ram influence on weight traits. The findings reveal that both genetic selection and environmental management are key to improving flock performance. By focusing on selective breeding and optimizing environmental conditions, farmers can significantly improve weight traits, boost profitability, and ensure sustainable sheep farming practices.

Abstract: This research provides an in-depth analysis of the effectiveness of sheep farming, with a particular focus on the Awassi breed in the harsh environments of the Middle East. Investigations were conducted at the Fjaj sheep station in Jordan, with emphasis on how various factors, including lambing type, lamb sex, parity, age at lambing, and the ram affect the weight characteristics of 2,263 records. Advanced statistical models, both fixed and mixed were employed to estimate genetic and breeding values, particularly in relation to the number of lambs per ram. The findings underscore the crucial role that both genetic and environmental factors play towards improving weigh traits and overall flock performance. Similar strategies may be effective in other breeds and in other regions with diverse environmental conditions. The study concludes that when farmers prioritize selective breeding and environmental management they can significantly enhance weight traits, boost profitability, and achieve sustainable economic success in sheep farming.

Keywords: Awassi sheep, Weight, heritability, selective breeding

1. Introduction

Sheep farming is successful in diverse environments, from humid highlands to arid regions, across both developed and developing countries. Arid regions pose significant health challenges for sheep and goats, with both dry and wet seasons presenting risks to their well-being [1]. Awassi sheep, renowned for their distinctive fat tails, are native to the Middle East, including Jordan, Syria, Iraq, the West Bank, Egypt, Lebanon, and Turkey. This breed adapts to harsh conditions and is herded traditionally to find pasture. Their adaptability has led to their successful introduction in other regions, such as Europe, Australia, New Zealand, and China.

In the Middle East, selecting for higher yield early in lactation is beneficial [2]. Improved practices, such as selecting ewes aged 3–7 years and providing specialized nutrition, can enhance lamb growth rates [3]. While environmental factors significantly affect production, using superior rams and selecting females can boost overall yield [4]. Additionally, better prenatal nutrition and care for newborn lambs can further improve productivity [5].

The Awassi breed, while well-adapted to arid conditions and economically significant, encounters challenges such as limited prolificacy. Selective breeding has led to improvements in milk production and body weight [6 - 8]. In Jordan, the breed's productivity, important for milk and meat, is influenced by factors such as arid climate, water scarcity, limited pasture, high feed costs, economic stress, disease management issues, and insufficient technological resources and training [9]. Addressing these challenges requires enhanced herd management practices and improved genetic traits.

This study aims to investigate how factors such as birth type, sex, parity, and the ewe's age impact weight traits in Awassi sheep. It examines weight variations over time, analyzes relationships between weights at different growth stages, and assesses the roles of rams, ewes, and lambs. Additionally, the study explores potential genetic improvements through selective breeding by measuring heritability and breeding value trends, thereby informing breeding strategies.

2. Materials and Methods

2.1 The sheep

The study conducted at Al-Fjaj sheep station in Jordan, situated 1.8 kilometers south of Amman, focused on ewes housed in semi-open pens and managed under a semi-intensive system. 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 salt and minerals. The study tracked lamb weights at birth, weaning, 6 months, and yearling, with both lambs and their mothers following a controlled lactation program and receiving supplementary feed to ensure optimal growth.

Data Analyses

The dataset, which consisted of 2,263 records of Awassi sheep weights, was analyzed using SAS [10]. It encompassed 111 rams, 1,714 ewes, and 1,908 lambs, providing a comprehensive overview of sheep growth and management in the given environment. The weight data were analyzed using the General Linear Model, applying the following fixed model:

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

Where, Y_{ijk} = Birth weight, weaning weight, weight at 6 months, and yearling weight of ijklth 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 yearling weight of ijklth observations on the ewe's age at lambing. X_{ijkl}= the kth 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 (1955) 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 [11]. 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 yearling weight of ijklth 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:

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

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

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 [12].

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

Table (1) shows that birth type, lamb sex, parity, and ewe age at lambing significantly affect weight traits (birth, weaning, 6-month, and yearling weights). Birth type and parity had the most substantial impact on all weights. Lamb sex influenced birth, weaning, and yearling weights but not 6-month weight. While ewe age was particularly important for weaning and 6-month weights.

Table 1. Variance of analyses of Birth weight, Weaning weight, Weight at 6 months and Yearling weight traits (Model 1).

Source of variance	DF	Mean Square			
		Birth weight	Weaning weight	Weight at 6 months	Yearling weight
Birth type	1	173.87**	1159.93**	1552.77**	2089.89**
Sex	1	22.71**	375.77**	90.38ns	493.98*
Parity	7	3.30**	54.15**	603.47**	560.54**
Age of ewe at lambing	1	0.23ns	69.47*	2354.36**	0.41ns
Errors	2251	0.56	15.23	59.45	123.43

Table (2) shows that single lambs are heavier than twins throughout their lives, with males generally heavier than females. Lambs born to younger ewes tend to be lighter at birth but compensate by the yearling weight. Lambs born to ewes with more lambs are heavier at birth but lighter at weaning. Weight variation is greatest at weaning and six months. All regression coefficients of weights on the age of ewes at lambing were positive. While ewe age influence weights, its impact is most noticeable at weaning and six months.

Table 2. Least-square means of birth weight, weaning weight, weight at 6 months and yearling weight traits (Model 1).

Traits / Factors		Birth weight	Weaning weight	Weight at 6 months	Yearling 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
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

The presence of at least one identical letter means that there is no significant difference between the means. The regression coefficient of weights on age of ewe at lambing: for birth weight= 0.015±0.023, weaning weight= 0.263±0.123, weight at 6 months= 1.532±0.243, and yearling weight= 0.020+0.351. Coefficient of Variation: for birth weight= 16.38, weaning weight= 21.59, weight at 6 months= 21.71, and yearling weight= 18.98.

Table (3) shows how closely related lamb weights are at different ages. It found that lambs that are heavier at one stage tend to be heavier later on. The connection between weights at weaning, six months, and one year is very strong, meaning lambs that are heavier at these times are likely to stay heavier. While birth weight also influences later weight, the relationship is not as strong.

Table 3. Partial Correlation Coefficients of birth weight, weaning weight, weight at 6 months and yearling weight traits from the Error SSCP Matrix / Prob. > |r|, (DF = 2251) (Model 1).

Traits	Weaning weight	Weight at 6 months	Yearling weight
Birth weight	0.17**	0.07**	0.02ns
Weaning weight		0.36**	0.33**
Weight at 6 months			0.66**

Table (4) examines how rams, ewes, and lambs 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. Lambs themselves only significantly affect their weight for one-year age.

Table 4. Analysis of Variance from Type 3 of birth weight, weaning weight, weight at 6 months and yearling weight traits (Model 2).

Random Effects	**Mean Square**			
	Birth weight	**Weaning weight**	**Weight at 6 months**	**Yearling weight**
Rams	0.99**	28.42**	419.35**	862.05**
Residual	0.53	14.55	40.96	85.48
Ewes	0.57*	15.69**	60.81*	120.50ns
Residual	0.47	12.71	51.90	139.66
Lams	0.56ns	14.80ns	58.29ns	127.28*
Residual	0.52	16.59	63.15	111.21

Table (5) shows that for all weight traits in Awassi sheep, variance within individual rams is consistently greater than variance between rams, indicating more weight variability among offspring of the same ram. Heritability estimates reveal a moderate genetic contribution, with higher heritability at 6 months and 1 year.

Table 5. Variance component and heritability ± standard error for birth weight, weaning weight, weight at 6 months and yearling weight traits of Awassi sheep rams (Model 2).

Variance component	**Birth weight**	**Weaning weight**	**Weight at 6 months**	**Yearling weight**

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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.

Table (6) shows strong positive correlations (above 0.90) between breeding values for birth, weaning, 6-month, and yearling weights in Awassi sheep rams, suggesting that improving one trait can enhance others through selective breeding. However, increasingly negative average breeding values, especially for yearling weight (-0.53), indicate potential declines in growth rates with age, which may require adjustments in breeding strategies.

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

Traits	BW	WW	W6M	YW
BV	0.02±0.01	-0.01±0.11	-0.26±0.37	-0.53±0.51
BW		0.96**	0.97**	0.96**
WW			0.92**	0.98**
W6M				0.93**

BV= Average of breeding values, BW= birth weight, WW= weaning weight, W6M= 6 months weight, YW= yearling weights.

4. Discussion

The type of lambing influences weight due to initial growth conditions. Greater food resources and attention from the ewe, which promotes early growth compared to multiple pregnancies where the lambs share resources, often accompany single pregnancies. The sex of lambing influences birth, weaning, and yearling weights due to growth rate differences, although it does not influence 6-month weight. Males usually grow faster than females due to hormonal effects on growth, as males have a greater ability to store protein and grow muscle. Parity and age of the ewe at lambing influence all weight traits, with older ewes generally providing better growth conditions. Older ewes provide a better environment for growth due to experience in care and provision of resources, while younger ewes may be less effective in meeting the needs of the lamb. Low error rates (Table 1) suggest that these factors account for most of the weight variation, which can help improve breeding and management practices.

Single lambs are consistently heavier than twins, and males generally outweigh females. Lambs born to younger ewes are lighter at birth but tend to catch up in weight later. In contrast, lambs from ewes with higher parity are heavier from weaning onwards. The ewe's age has a significant impact on lamb weight, particularly at weaning and six months, which are critical growth stages (Table 2). These findings highlight the importance of considering these factors in managing and optimizing lamb growth, as they can inform strategies to improve weight outcomes and overall flock productivity.

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 (Table 3), 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.

Non-genetic factors like age at first calving affect the Galunki sheep's productivity, with single and male lambs weighing more than twins and females [13].Avicalin sheep grow faster for up to three months, with growth declining afterward; thus, managing environmental factors is key for economic gains [14]. Genetic and environmental factors influence lamb body weight at birth and weaning, with breed groups affecting only BWT and WWT, and improving management and health is vital for pre-weaning performance and survivability [15].

In high-yielding Lacaune sheep, effective nutritional strategies are crucial for maintaining maternal health, with maiden ewes carrying multiple lambs facing greater challenges [16]. For Pelibuey ewes, the low repeatability of reproductive traits and significant effects of flock, season, and parity suggest that management improvements are more beneficial than genetic changes [17]. Rahmani ewes in late pregnancy showed that multiparous ewes required more nutrients and experienced greater weight loss, improving lamb birth weight and growth, with high-protein diets further enhancing lamb performance [18].

Body condition traits play a vital role in improving maternal performance and feed efficiency in genetic evaluations [19]. The weight of lambs is linked closely to the body weight of their dams, especially at 30 days and weaning, while the sire's weight has little impact, suggesting other factors influence lamb growth [20]. Furthermore, 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 [21].

The roles of rams, ewes, and lambs in influencing lamb weight underscore the importance of targeted breeding (Table 4). Rams have the greatest impact on weight across all stages due to their ability to pass on growth-enhancing traits, making them crucial for producing heavier, healthier lambs. Ewes primarily affect early weight through nurturing and milk production, but their influence wanes as lambs mature. Lambs themselves influence weight mainly as yearlings when their genetic potential is expressed fully. Given rams' greater contribution to weight variability and moderate heritability, focusing on them in selective breeding can effectively enhance flock productivity and profitability.

Awassi sheep reveals genetic and environmental factors influencing weight (Table 5). Variance within offspring of single ram is lower than variance between different rams. Individual differences and environmental factors significantly influence weight.

Heritability values for weight increase with age, reaching moderate levels. Genetic factors play a role in weight variation, but environmental factors also have a substantial impact. Rams contribute more to weight variability than ewes and lambs. Focusing on rams in selective breeding programs could improve weight-related traits in Awassi sheep.

The strong positive correlations (above 0.90) between breeding values for birth, weaning, 6-month, and yearling weights in Awassi sheep rams highlight the potential for simultaneous improvements across these traits through selective breeding. This suggests that enhancing one weight trait can lead to improvements in others, making breeding efforts more efficient. However, the trend of increasingly negative average breeding values, especially for yearling weight (-0.53), raises concerns about declining growth rates as sheep age. This decline may necessitate strategic adjustments in breeding programs to improve weight gain during later growth stages, ensuring that overall growth and production are optimized throughout the sheep's life (Table 6).

Environmental factors such as lambing number, breeding season, lambing year, and ram effect significantly influence litter size, birth weight, and weaning weight in hair sheep under a semi-arid climate [22]. Crossbreeding local Barki sheep with Awassi rams enhances reproductive performance, with crossbred lambs reaching puberty earlier and at heavier weights, emphasizing the role of early puberty in sheep productivity [23]. Additionally, while heavier ewes typically produce heavier lambs, improving the nutrition and weight of ewes, particularly first-time lambs, can further boost reproductive performance and lamb growth [24].

Providing optimal nutrition and climate enhances health and growth, leading to better weight and productivity. Environmental factors like proper nutrition and disease protection significantly affect herd performance.

Environmental factors, especially the age of the mother and season, significantly affect sheep birth weight [25]. Kramarenko [26] highlight that optimizing lamb growth necessitates management and breeding strategies addressing both environmental and genetic factors. To enhance genetic merit and productivity in Barki sheep, a targeted breeding program based on breeding values, combined with effective animal management and selection pressure, is essential [27].

Selecting sheep with desirable genetic traits can improve growth and weight characteristics by enhancing genes that support rapid growth and feed efficiency.

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 [28]. Gizaw [29] recommend a two-stage selection process, starting with selecting breeding values in nucleus centers and 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 [30]. Sánchez-Molano [31] identified sufficient genetic variation in meat sheep for improvement through selective breeding and recommended incorporating these traits into future breeding goals. Additionally, combining female reproductive technologies with genomic selection and managing inbreeding significantly boosts genetic gain in sheep, with optimal contribution selection effectively balancing inbreeding and genetic gain [32].

Many studies offer significant insights into factors affecting lamb and sheep growth and production. Vlahek [33] found that birth type, sex, and number of births significantly influence the birth weight of Romanov lambs, emphasizing their importance in breeding programs. Conversely, Al-Qasimi [34] reported that lamb sex, birth type, and ewe age do not significantly influence overall production, suggesting these factors may be less critical compared to others. Lupi [35] highlighted the importance of effective flock management and birth type, noting that multiple births, particularly of female lambs, result in slower growth rates. Nirban [36] identified a broad range of factors—such as ram, sex, parturition period, parity, and maternal birth weight—that significantly affect body weights from birth to 12 months. Additionally, Singh [37] observed that while ram, sex, and parturition period impact pre-weaning traits, parity and maternal weight specifically affect birth weight and overall traits. Vatankhah and Salehi [38] demonstrated that selecting for body weight at mating could improve Lori Bakhtiari sheep weight, supported by strong correlations. Assan and Makusa [39] found that singletons are heavier than twin and males are generally heavier than females at birth and weaning, with insemination weight also significantly affecting these measures. These findings underscore the need to consider a range of factors and apply tailored strategies to enhance sheep growth and productivity.

A shortcoming of the current research is the lack of analysis on environmental factors like nutrition and climate and does not assess the accuracy of predictions from early weight measurements or consider seasonal variations and unmeasured genetic factors. Current studies may not include all influencing factors such as interactions between environmental and genetic factors, limiting our understanding of the factors that influence weight. Henceforth, further studies will be needed to explore genetics-environment interactions and the impact of selective breeding on genetic diversity and health within the herd. Further research could uncover these understudied factors. Further exploration of thematic areas such as the influence of micronutrients and environmental management could lead to significant improvements in understanding how to achieve optimal performance, supporting the development of new and effective strategies.

Good management strategies, such as environmental control and health care, play a major role in reducing stress and improving flock health, which contributes to increased productivity and profitability. Improving nutrition can enhance growth rates and weight by providing the essential nutrients that sheep need to achieve maximum growth.

5. Conclusions

Lambing type, sex, and ewe age significantly affect weight traits, with older ewes providing optimal growth conditions. Effective management of these factors is crucial for enhancing growth and flock productivity. This will ensure that dairy farmers are able to make good economic return on their investment and enhance their livelihood. Early weight and measurements at key growth stages are essential for guiding management and breeding decisions. Selective breeding programs should prioritize rams due to their substantial impact on weight variability while also considering ewes and lambs. Strategic adjustments are needed to address the decline in average breeding values for yearling weight and improve growth rates at later stages. Both genetic and environmental factors must be considered to optimize breeding strategies for Awassi sheep.

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