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Research Article

Lambing Season and Birth Type Influence on the Relationship Between Ewe Early Growth and Lifetime Lamb Production in Rahmani Sheep

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Abstract

Lifetime lamb production is a crucial measure of ewe efficiency and overall flock profitability. Therefore, the study investigated the relationship between early ewes' growth traits (birth weight, weaning weight, yearling weight) and lifetime lamb production in Rahmani ewes across lambing seasons and birth types. This study meticulously examined a substantial dataset comprising 2371 records from 880 Rahmani ewes (105 sires and 495 dams). Results revealed significant variability in both growth and reproductive performance. Higher birth weight (>3.5 kg) generally improved further lifetime lamb production, particularly in single-bearing ewes and warmer seasons, while weaning weight showed seasonal-dependent effects. Interestingly, higher yearling weight (≥31 kg) was significantly associated with higher productivity in multiple-bearing ewes. While weaning and yearling weights have little significant impact on the lifetime lamb productivity of single-born ewes, higher weaning and yearling weights are positively associated with better lifetime lamb production, particularly prolificacy traits for ewes born in multiple litters. Genetic analyses indicated moderate heritability for both trait categories and positive genetic correlations between early growth and lifetime reproductive success. Estimated breeding values demonstrated substantial genetic diversity within the flock. Collectively, these findings underscore the complex interplay between early growth, lambing season, and lifetime productivity in Rahmani ewes. They provide valuable insights for developing effective breeding strategies focused on enhancing both growth and reproductive efficiency to improve the economic sustainability of Rahmani sheep production in Egypt.

Keywords

Ewes' Growth Traits, Lifetime Lamb Production, Lambing Seasons, Birth Type, Genetic Analyses, Rahmani Sheep

1. Introduction

The Rahmani breed is vital for Egyptian sheep production, especially in the Nile Delta. Rahmani adaptability to local environmental conditions and role in smallholder farming are significant. Therefore, improving animals' productivity is crucial for maximizing farm efficiency and profitability and is key for farmer livelihoods and meeting product demand. This is particularly evident in semi-intensive sheep farming systems in areas facing seasonal reproductive challenges [1]. However, the productivity and profitability of sheep farming are significantly influenced by the ewe's productive perfor-

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mance throughout its lifetime. Increasing ewe productive longevity can contribute to decreased annual flock replacement costs and improved overall welfare of the animals [2]. Therefore, it is essential to identify the genetic and non-genetic factors affecting functional longevity for consideration as a trait in breeding programs [3].

Lifetime lamb production is a crucial measure of ewe efficiency and overall flock profitability. Understanding the factors influencing these complex traits are essential for effective breeding and management strategies. Tracking total lambs weaned annually and over an ewe's lifetime directly enhances farm profitability and productivity [4, 5] and aligns with the benefits of extending ewe productive life, contributing to greater efficiency by reducing frequent flock replacements [2]. Utilizing early production data allows for strategic selection of replacement females [6], which can accelerate genetic gain through increased selection pressure and a shorter generation interval [6], compounding the advantages of a more productive and longer-lasting flock.

Early growth traits (birth, weaning, yearling weight) are often considered as potential predictors of future reproductive performance in sheep [7]. The hypothesis suggests faster-growing lambs are more likely to become productive adults. Birth weight reflects the maternal environment and initial viability. Weaning weight indicates early postnatal growth and nutritional status. Yearling weight represents growth up to sexual maturity and reproductive capacity.

Lambing season significantly impacts ewe reproduction and lamb growth due to environmental variations [8]. These seasonal factors, such as temperature, humidity, and forage availability, can interact with an ewe's early growth to shape its lifetime productivity. Understanding this interaction is essential for optimizing lambing schedules and resource allocation. Moreover, the ewe's inherent prolificacy (single vs. multiple lambs) is a critical aspect influencing lifetime lamb production. The optimal growth and body condition for rearing different litter sizes may vary. This can lead to different relationships between early growth and lifetime productivity based on typical litter size.

The study examined the influence of lambing season and birth type on the relationship between ewe’s early growth and lifetime lamb production in Rahmani sheep. The study also delved into the genetic basis of these traits by examining heritability estimates, genetic correlations, and breeding values. The purpose of this research is to provide valuable information for sheep producers to improve the flock breeding strategies and management practices.

2. Materials and Methods

2.1. Animal Management

This study meticulously examined a substantial dataset comprising 2371 records from 880 Rahmani ewes (105 sires and 495 dams). The data spanned the years 1991 to 2001 and originated from the El-Serw Experimental Station in Egypt. The sheep husbandry at the station followed an intensive production schedule, implementing three mating seasons every two years, occurring approximately every eight months and resulting in lambing cycles in October, June, and February.

Both ewes and rams were first mated at approximately 18 months of age. For each breeding period, ewes were randomly grouped (30-35 per group) and exposed to a fertile ram for 35-45 days in separate pens. Ewes were weighed before mating and at lambing. Rams were checked for mating drive and semen quality before each breeding season and replaced if needed.

The feeding regimen varied seasonally, from December to May, the flock primarily grazed on Egyptian clover (Berseem) and received supplementary pelleted concentrate feed. During the summer and autumn months, their diet shifted to hay, potentially augmented with available crop stubble or green fodder, and consistently included the pelleted concentrate supplement. The animals were fed twice daily, at 7 am and 4 pm. Water access was provided twice a day during the winter and increased to three times daily in the summer. Mineralized salt blocks were continuously available to all sheep. The animals were housed in semi-open sheds that allowed for free movement and exercise. A routine vaccination program was in place to protect against infectious diseases. Shearing was conducted twice annually, in March and September. To optimize reproductive success, ewes received a daily supplement of 0.25 kg of concentrate feed for two weeks leading up to the mating season and again during the final two to four weeks of their pregnancy. Following lambing, each newborn lamb was individually identified, and detailed records were kept regarding its birth type (single or multiple), sex, and pedigree. Lambs were weaned at approximately eight weeks of age, and their weights were precisely recorded within the first 24 hours after birth and subsequently at 30-day intervals.

The studied traits were ewe birth weight, weaning weight, yearling weight, as well as total number of lambs born (TNLB), total number of lambs weaned (TNLW), total birth weight of lambs (TLBW) and total weight of lambs weaned (TLWW) per ewe over six lambing opportunities of ewes.

2.2. Statistical Analysis

Statistical analyses were using general linear model procedure [9]. Data lifetime lamb production was analyzed using the following model (1):

$$Y_{ijkl} = \mu + YR_i + S_j + EB\ W_k + EW\ W_l + EYW_m + ET\ B_n + e_{ijklmno} \quad (1)$$

Where, Y_{ijklmn}= an individual observation; μ= the overall mean; YR_k= fixed effect of k^{th} year of lambing, k=(1990, …. and 2001); S_j= fixed effect of j^{th} season of lambing (February, June, and October); EBW_k= fixed effect of k^{th} ewe's birth weight class (<2.5 kg, 2.5-3.5 kg, and >3.5 kg); EWW_l= fixed effect of k^l ewe's weaning weight class (<13 kg, 13-16 kg, and >16 kg); EYW_m= fixed effect of m^{th} ewe's yearling weight class (<31 kg, 31-36 kg, and >36 kg); ETB_n= fixed effect of n^{th} ewe's type of birth class (single and twins or more), and $e_{ijklmno}$= residual term assumed normally and independent distributed with zero mean and variance σ^2e.

Multiple traits animal models were used for analyses for ewe's birth, weaning, yearling weight and lifetime lamb production to estimate the (Co) variance components estimation (VCE), using restricted maximum likelihood method in VCE6 [10]. The multivariate animal model used was (2):

$$y = Xb + Z_a a + e \tag{2}$$

Where, y= vector of studied trait; X= incidence matrix for fixed effects; b= vector of overall mean and fixed effects; Z_a= incidence matrix for random effects; a= vector of direct genetic effects, and e= vector of random errors normally and independently distributed with mean zero and variance δ^2e. Spearman rank correlations were obtained between estimated breeding values (EBVs) for studied traits from multi-trait animal model.

3. Results

Table 1 summarized the descriptive statistics for dam growth traits and lifetime lamb production in Rahmani ewes. Mean birth weight was 3.12 kg, with moderate variability (CV= 17.75%). Dam weaning weight averaged 14.29 units (CV= 14.03%), and dam yearling weight averaged 35.26 units (CV= 10.89%), showing the least variability. Lifetime production traits showed substantial variation (CV> 56%). The mean of TNLB was 3.561 (CV= 61.49%), TNLW was 3.219 (CV= 57.74%), TLBW was 9.956 (CV= 56.47%), and TLWW was 42.477 kg (CV= 61.53%). However, these high coefficients of variation for lifetime production traits highlight significant individual differences in the reproductive and rearing capabilities of Rahmani ewes.

3.1. Effect of Lambing Season

Table 2 explored the combined influence of ewe birth weight and lambing season (February, June, October) on lifetime lamb production. In February lambing, heavier ewes' birth weight categories (2.5-3.5 kg and >3.5 kg) showed similar TNLW, TLBW, and TLWW, and significantly outperformed lighter ewes (<2.5 kg). June and October lambing revealed a clear positive trend, greater birth weight (>3.5 kg) consistently led to significantly higher values for TNLB, TNLW, TLBW, and TLWW. However, across all seasons, higher ewe birth weight generally correlated with better lifetime lamb production. This positive relationship was most pronounced during the June and October lambing periods. Therefore, birth weight appears to be a beneficial trait for lifetime lamb production in this context.

Table 1. *Arithmetic means, standard deviations (SD), and coefficients of variation (CV%) of dam birth weight, weaning weight, yearling weight of dam, as well as lifetime lamb production per ewe over six lambing opportunities of Rahmani ewes.*

	Means	SD	CV%
Dam birth weight, kg	3.117	0.553	17.75
Dam weaning weight, kg	14.29	2.000	14.03
Dam yearling weight, kg	35.26	3.840	10.89
TNLB, lamb*	3.561	2.190	61.49
TNLW, lamb	3.219	1.859	57.74
TLBW, kg	9.956	5.622	56.47
TLWW, kg	42.48	26.14	61.53

*TNLB, total number of lambs born; TNLW, total number of lambs weaned; TLBW, total birth weight of lambs; TLWW, total weight of lambs weaned.

Table 2. *Lifetime lamb production traits as affect by ewe's birth weight in different seasons of lambing.*

	TNLB*	TNLW	TLBW	TLWW
February season of lambing				
< 2.5 Kg	3.729^a	9.351^b	2.945^b	38.57^b
2.5-3.5 Kg	3.980^a	10.56^a	3.466^a	45.45^a
> 3.5 Kg	3.505^b	10.66^a	3.509^a	45.92^a
SEM	0.341	0.840	0.285	3.95
June season of lambing				
< 2.5 Kg	2.906^b	8.430^c	2.766^b	35.55^b
2.5-3.5 Kg	3.579^b	10.48^b	3.267^b	42.69^b
> 3.5 Kg	4.470^a	12.89^a	3.954^a	53.03^a
SEM	0.362	0.950	0.303	4.10
October season of lambing				
< 2.5 Kg	2.883^b	7.902^b	2.623^b	33.34^b
2.5-3.5 Kg	3.190^b	9.071^b	3.098^{ab}	41.41^b
> 3.5 Kg	4.174^a	12.21^a	3.885^a	54.75^a
SEM	0.375	1.040	0.333	4.69

*TNLB, total number of lambs born; TNLW, total number of lambs weaned; TLBW, total birth weight of lambs; TLWW, total weight of lambs weaned. a-b Means in the same column in each classification with different superscripts are significantly different (p<0.05).

Table 3 explored the influence of ewe weaning weight (<13 kg, 13-16 kg, >16 kg) and lambing season on lifetime lamb production. In February, higher ewes' weaning weight (>16 kg) generally improved lifetime lamb production traits. Ewes with the lowest weaning weight (<13 kg) often had the lowest outcomes in February. June and October lambing showed less clear trends, but higher ewes' weaning weight (>16 kg) tended to benefit TNLW and TLWW in June. This suggests weaning weight's effect varies with the lambing season. February and June saw a positive link between weaning weight and production. However, October showed no significant differences in lifetime lamb production traits across ewes' weaning weight categories. This indicates a potential interaction with environmental or resource conditions specific to October in the study area. The optimal weaning weight for lifetime production may depend on the lambing season.

Table 3. *Lifetime lamb production traits as affect by ewe's weaning weight in different seasons of lambing.*

	TNLB	TNLW	TLBW	TLWW
February season of lambing				
< 13 Kg	3.189[a]	9.06[b]	3.047[b]	39.24[b]
13-16 Kg	3.702[a]	9.96[ab]	3.135[ab]	41.59[ab]
> 16 Kg	4.324[a]	11.55[a]	3.739[a]	49.12[a]
SEM	0.364	0.89	0.302	4.220
June season of lambing				
< 13 Kg	3.468[a]	10.07[b]	3.255[a]	42.41[b]
13-16 Kg	3.762[a]	10.68[ab]	3.227[a]	42.66[b]
> 16 Kg	3.725[a]	11.05[a]	3.506[a]	46.20[a]
SEM	0.454	1.200	0.381	5.150
October season of lambing				
< 13 Kg	2.911[a]	8.43[a]	2.712[a]	35.74[a]
13-16 Kg	3.556[a]	10.24[a]	3.461[a]	47.28[a]
> 16 Kg	3.779[a]	10.51[a]	3.434[a]	46.49[a]
SEM	0.303	0.840	0.271	3.790

*TNLB, total number of lambs born; TNLW, total number of lambs weaned; TLBW, total birth weight of lambs; TLWW, total weight of lambs weaned. [a-b] Means in the same column in each classification with different superscripts are significantly different ($p<0.05$).

Table 4 investigated the relationship between ewe yearling weight (<31 kg, 31-36 kg, >36 kg) and lifetime lamb production across three lambing seasons. In contrast to birth weight, yearling weight demonstrated a less clear and consistent association with lifetime reproductive performance. In February, lighter yearling ewes (<31 kg) produced significantly more lambs born. The 31-36 kg group tended to wean more lambs in February. The lightest yearling ewes (<31 kg) had the highest TLBW in February. However, February showed no significant difference in TLWW. Notably, the June and October lambing seasons revealed virtually no significant impact of yearling weight on lifetime lamb production. These results suggesting that yearling weight is not a strong predictor of long-term reproductive success under these conditions, especially in warmer season.

Table 4. *Lifetime lamb production traits as affect by ewe's yearling weight in different seasons of lambing.*

	TNLB	TNLW	TLBW	TLWW
February season of lambing				
< 31 Kg	4.152[a]	10.21[ab]	3.517[a]	42.07[a]
31- 36 Kg	3.684[b]	10.51[a]	3.351[b]	44.93[a]
> 36 Kg	3.378[b]	9.85[b]	3.053[b]	42.95[a]
SEM	0.359	0.880	0.306	4.240
June season of lambing				
< 31 Kg	3.636[a]	10.53[a]	3.079[a]	39.60[a]
31- 36 Kg	3.606[a]	10.56[a]	3.448[a]	47.10[a]
> 36 Kg	3.713[a]	10.71[a]	3.461[a]	44.56[a]
SEM	0.354	0.93	0.309	4.010
October season of lambing				
< 31 Kg	3.413[a]	9.66[a]	3.194[a]	43.74[a]
31- 36 Kg	3.539[a]	10.03[a]	3.216[a]	41.17[a]
> 36 Kg	3.295[a]	9.48[a]	3.197[a]	44.60[a]
SEM	0.344	0.950	0.310	4.300

*TNLB, total number of lambs born; TNLW, total number of lambs weaned; TLBW, total birth weight of lambs; TLWW, total weight of lambs weaned. [a-b] Means in the same column in each classification with different superscripts are significantly different ($p<0.05$).

3.2. Effect of Birth Type

Table 5 contrasted the impact of ewe birth weight and ewe birth type on lifetime lamb production. Single-lambing ewes showed consistently better lifetime production across all traits with the heaviest ewes' birth weight (>3.5 kg). Multiple-birth ewes, however, performed best with a moderate birth weight (2.5-3.5 kg) for TLWW and TLBW. This moderate birth weight group (2.5-3.5 kg) significantly outperformed lighter and heavier ewes in TLWW. These results indicate that higher birth weight generally benefits single-lambing ewes, while a moderate birth weight appears optimal for maximizing

TLWW in multiple-birth ewes. Optimal birth weight for lifetime weaning success differs based on ewe prolificacy. This highlights divergent optimal birth weights for maximizing lifetime weaning success based on ewe prolificacy.

Table 5. Lifetime lamb production traits as affect by ewe's birth weight in single and twins or more ewe type births.

	TNLB*	TNLW	TLBW	TLWW
Single				
< 2.5 Kg	2.630[c]	7.630[b]	2.496[c]	33.55[b]
2.5-3.5 Kg	3.351[b]	9.431[b]	3.101[b]	40.94[b]
> 3.5 Kg	4.348[a]	12.787[a]	3.973[a]	54.81[a]
SEM	0.231	0.617	0.195	2.715
Twin or more				
< 2.5 Kg	3.147[a]	8.494[a]	2.849[a]	35.25[b]
2.5-3.5 Kg	4.005[a]	11.159[a]	3.619[a]	46.92[a]
> 3.5 Kg	3.941[a]	10.249[a]	3.382[a]	39.07[b]
SEM	0.649	1.549	0.526	7.002

*TNLB, total number of lambs born; TNLW, total number of lambs weaned; TLBW, total birth weight of lambs; TLWW, total weight of lambs weaned. [a-b] Means in the same column in each classification with different superscripts are significantly different ($p<0.05$).

Table 6 compared the effect of ewe weaning weight category (<13 kg, 13-16 kg, >16 kg) on lifetime lamb production, separated by primary birth type (single vs. twins or more). Single-lambing ewes showed no significant impact on lifetime production traits. However, multiple-birth ewes with >16 kg weaning weight had numerically higher TNLB and significantly higher TNLW and TLBW. This heavier weaning group (>16 kg) also produced considerably higher TLWW, suggesting a positive influence of higher weaning weight on the lifetime productivity of ewes prone to multiple births.

Table 7 investigated the influence of dam yearling weight category on lamb production traits, separated by primary birth type (single vs. twins or more). For single-lambing ewes, yearling weight showed no significant impact on lifetime lamb production traits. However, multiple-birth ewes with >36 kg yearling weight performed significantly better. These heavier dams had more lambs born and weaned per lambing and had heavier litters both at birth and weaning. This suggests yearling weight is a good indicator for future reproductive success in multiple-birth ewes. Ewes in the 31-36 kg range generally showed intermediate performance. The influence of yearling weight on reproductive success differs by ewe prolificacy.

Table 6. Lifetime lamb production traits as affect by ewe's weaning weight in single and twins or more ewe type births.

	TNLB*	TNLW	TLBW	TLWW
Single				
< 13 Kg	3.224[a]	9.505[a]	3.104[a]	42.57[a]
13-16 Kg	3.812[a]	10.911[a]	3.424[a]	46.49[a]
> 16 Kg	3.293[a]	9.432[a]	3.043[a]	40.25[a]
SEM	0.243	0.649	0.206	2.856
Twin or more				
< 13 Kg	3.409[a]	9.099[ab]	3.042[ab]	36.36[a]
13-16 Kg	3.405[a]	8.787[b]	2.837[b]	35.80[a]
> 16 Kg	4.279[a]	12.016[a]	3.971[a]	49.09[a]
SEM	0.646	1.541	0.522	6.962

*TNLB, total number of lambs born; TNLW, total number of lambs weaned; TLBW, total birth weight of lambs; TLWW, total weight of lambs weaned. [a-b] Means in the same column in each classification with different superscripts are significantly different ($p<0.05$).

Table 7. Lifetime lamb production traits as affect by ewe's yearling weight in single and twins or more ewe type births.

	TNLB*	TNLW	TLBW	TLWW
Single				
< 31 Kg	3.540[a]	9.862[a]	3.152[a]	41.07[a]
31- 36 Kg	3.343[a]	9.830[a]	3.159[a]	42.53[a]
> 36 Kg	3.446[a]	10.156[a]	3.259[a]	45.70[a]
SEM	0.250	0.665	0.215	2.929
Twin or more				
< 31 Kg	2.593[b]	7.605[b]	2.596[b]	30.53[b]
31- 36 Kg	3.778[a]	10.553[a]	3.448[ab]	44.15[a]
> 36 Kg	4.721[a]	11.743[a]	3.805[a]	46.56[a]
SEM	0.470	1.121	0.400	5.149

*TNLB, total number of lambs born; TNLW, total number of lambs weaned; TLBW, total birth weight of lambs; TLWW, total weight of lambs weaned. [a-b] Means in the same column in each classification with different superscripts are significantly different ($p<0.05$).

3.3. Genetic Analysis

Table 8 presented the genetic architecture of growth and lifetime production traits in Rahmani ewes, with heritability estimates on the diagonal and genetic correlations above it. Moderate heritability was observed for early dam growth traits and lifetime production traits, indicating a moderate degree of genetic influence. Positive genetic correlations were found between ewe birth weight and later growth/lifetime production traits, and similarly between yearling weight and weaning weight/lifetime production. Weaning weight showed weaker positive genetic correlations with lifetime production traits. Within lifetime production traits, TNLB showed positive genetic correlations with TNLW (0.353), TLBW (0.353), and TLWW (0.253) (Table 8). TNLW had a small positive genetic correlation with TLBW (0.037) and a moderate positive correlation with TLWW (0.365). A strong positive genetic correlation (0.377) was observed between TLBW and TLWW. These moderate heritability estimates suggest that genetic selection can improve both growth and lifetime production. The positive genetic correlations indicate that selecting for enhanced early growth can favorably influence reproductive performance, with the strong correlation between total birth weight and total weight weaned emphasizing the importance of early lamb growth for overall productivity and informing targeted breeding strategies for economic efficiency in Rahmani sheep in Egyptian regions.

Table 8. *Heritability estimates ± standard error (on diagonal) and genetic correlations ± standard error (above diagonal) among birth, weaning, yearling weights and lifetime production traits of Rahmani ewes.*

	DBW	DYW	DWW	TNLB	TNLW	TLBW	TLWW
DBW	0.304±0.017	0.452±0.027	0.244±0.029	0.228±0.004	0.159±0.005	0.228±0.008	0.154±0.002
DYW		0.315±0.015	0.388±0.028	0.221±0.021	0.155±0.013	0.171±0.016	0.159±0.015
DWW			0.274±0.014	0.200±0.009	0.155±0.003	0.036±0.011	0.021±0.007
TNLB				0.261±0.029	0.353±0.052	0.353±0.055	0.253±0.058
TNLW					0.269±0.030	0.037±0.018	0.365±0.042
TLBW						0.319±0.033	0.377±0.017
TLWW							0.289±0.031

*DBW, dam birth weight; DYW, dam yearling weight; DWW, dam weaning weight; TNLB, total number of lambs born; TNLW, total number of lambs weaned; TLBW, total birth weight of lambs; TLWW, total weight of lambs weaned.

Table 9 showed a statistical summary of the estimated breeding values (EBVs) for various growth and lifetime production traits in the Rahmani ewe population. Mean EBVs for all traits were near zero, indicating average genetic merit of the population aligns with the breed average. However, significant genetic variation was evident through standard deviations. Substantial EBV ranges, especially for growth traits and TLWW, highlight considerable genetic diversity. This diversity offers significant potential for genetic selection and improvement. Breeders can use EBVs to identify superior animals and enhance flock productivity.

Table 9. *Means, standard deviations (S.D), minimum, maximum, and range of estimated breeding values (EBV) for birth, weaning, yearling weights and lifetime production traits of Rahmani ewes.*

	Mean	SD	Minimum	Maximum	Range
DBW	0.029	0.295	-1.189	0.937	2.127
DYW	0.033	2.804	-10.712	10.655	21.367
DWW	-0.016	1.293	-4.586	5.623	10.209
TNLB	0.001	0.040	-0.102	0.193	0.295
TNLW	0.001	0.025	-0.084	0.095	0.180
TLBW	0.003	0.094	-0.329	0.461	0.790
TLWW	0.031	0.436	-1.355	1.799	3.154

* DBW, dam birth weight; DYW, dam yearling weight; DWW, dam weaning weight; TNLB, total number of lambs born; TNLW, total number of lambs weaned; TLBW, total birth weight of lambs; TLWW, total weight of lambs weaned.

Table 10 presented the rank correlation coefficients among the estimated breeding values (EBVs) for various growth and lifetime production traits of Rahmani ewes. Birth weight EBV moderately correlates with later growth EBVs. Birth and yearling weight EBVs show weak to moderate positive links with lifetime production EBVs. Weaning weight EBV has minimal correlation with prolificacy EBVs. Strong positive genetic ranking exists between EBVs for TNLB and TNLW. A strong positive rank correlation links EBV for lambs weaned and TLWW. Moderate positive rank correlations link EBV for lambs born and TLWW, and birth weight and TLWW. However, these rank correlations suggest that while early growth has some positive genetic association with lifetime production, the strongest genetic relationships exist among the different measures of lifetime reproductive success, particularly between the TNLB and TNLW and the TLWW. Selecting ewes with higher genetic merit for prolificacy traits is likely to be most effective in improving the overall lifetime productivity of the Rahmani flock.

Table 10. Rank correlation coefficients among estimated breeding values (EBVs) of animals for ewe birth, weaning, yearling weight and lifetime production traits of Rahmani ewes.

	DYW	DWW	TNLB	TNLW	TLBW	TLWW
DBW	0.344	0.429	0.262	0.238	0.214	0.223
DYW		0.282	0.364	0.318	0.346	0.351
DWW			0.049	-0.077	0.191	0.017
TNLB				0.728	0.427	0.479
TNLW					0.085	0.585
TLBW						0.425

* DBW, dam birth weight; DYW, dam yearling weight; DWW, dam weaning weight; TNLB, total number of lambs born; TNLW, total number of lambs weaned; TLBW, total birth weight of lambs; TLWW, total weight of lambs weaned.

4. Discussion

Effective enhancement of lamb growth and development relies on selecting ewes with excellent genetic profiles. However, environmental factors are also key determinants of animal performance and growth traits. These environmental effects include maternal factors and external influences such as the season, birth type, year of birth, dam's age, and lamb sex, all known to strongly affect growth characteristics [11, 12]. Prior research has revealed genetic variation in growth traits among various sheep breeds, with heritability estimates ranging from low to high [13]. Consequently, careful planning of genetic improvement schemes for lamb growth traits must involve a thorough consideration of both genetic and non-genetic factors. Particular attention must be paid to evaluating maternal effects properly and not neglecting the dam's additive genetic and permanent environmental influences, which is vital for obtaining accurate variance estimates.

Based on the results obtained, the study offered valuable insights into factors influencing the long-term productivity of Rahmani ewes. Table 1 highlighted a critical aspect, while the ewes exhibit relatively consistent growth patterns up to yearling age with moderate variability in birth, weaning, and yearling weights, their lifetime lamb production is vastly different from one individual to another. The exceptionally high coefficients of variation for lifetime lamb production traits underscore significant inherent differences in the reproductive and mothering abilities within the flock. This substantial variation is a key takeaway, as it signifies a strong potential for improving flock productivity through selective breeding and targeted management.

The current results indicated that a higher birth weight in ewes is generally advantageous for lifetime lamb production, with this positive effect being particularly pronounced in June and October lambing periods. This suggests that ewes starting with more initial vigor may be better equipped to handle the demands of reproduction, especially under potentially more challenging seasonal conditions. However, the positive effect of higher weaning weight is less consistent, varying with the lambing season and notably absent in October. This points to possible interactions with environmental resources or conditions specific to that time of year that might overshadow the benefits of higher weaning weight. This highlights the importance of considering the lambing season when evaluating the role of weaning weight in selection decisions. On the other hand, results demonstrated that yearling weight is not a reliable or consistent predictor of lifetime reproductive success. In fact, in the February lambing season, lighter yearling ewes surprisingly showed higher numbers of TNLB and TLBW, challenging the intuitive notion that simply being heavier at a year old equates to better lifetime prolificacy.

In this regard, Gül et al. [8] have shown that season significantly influenced the lambs' birth weight, weaning weight and litter size. While the insignificant influence of season on birth weight was observed in Kajli, Thalli, Dorper and Lohi crossbred sheep [11, 14, 15]. Likewise, the non-significant influence of season on yearling weight agreed with the findings of Zaffer et al. [15] and Sharif et al. [11] and in Dorper and Lohi sheep. Contrary, Momoh et al. [16] and Mohammadi and Latifi [17] reported a significant effect of season on yearling weight in different sheep breeds. The effect of season on growth characteristics in farm animals is primarily related to the availability and quality of green fodder, as well as weather factors such as temperature and humidity, especially in hot, grazing-poor areas. Hence, dams which completed their gestation during these seasons had a better chance to avail more fresh fodder, which influenced their milk performance and lambs belonging to these dams were found heavier at weaning [11]. However, the significant influence of season on some growth traits agreed with previous findings [11, 15-17].

Adding another layer of complexity, obtained results reveal a significant interaction between an ewe's own birth type (single vs. multiple) and how its early growth affects lifetime production. Table 5 distinctly showed that for ewes born as singles, higher birth weight is associated with better overall lifetime production. In contrast, ewes born in multiple litters achieve optimal lifetime weaning success (TLWW) with a moderate birth weight, and both lighter and heavier birth weights in this group are less favorable. This critical divergence suggests that the ideal starting weight for an ewe depends on whether it had to compete with siblings in utero. Further, results in Tables 6 and 7 indicated that while weaning and yearling weights have little significant impact on the lifetime productivity of single-born ewes, higher weaning and yearling weights are positively associated with better lifetime production, particularly prolificacy traits for ewes born in multiple litters. This implies that for multiple-born ewes, achieving and maintaining a good growth rate after birth may be more crucial for compensating for their initial birth type and ensuring high future reproductive performance.

In this context, Gabr et al. [7] found that an ewe's origin as a single lamb and its rapid growth from birth or weaning to one year old were beneficial for its future productivity. This advantage likely stems from the greater resources available to single fetuses in the uterus, leading to higher birth weights compared to twins or triplets [18-20]. These single lambs also tend to receive more milk due to the higher demands on mothers with multiple offspring [21], resulting in faster growth rates that persist from early development [22] through weaning and beyond [23]. Consequently, these heavier ewes exhibit improved reproductive performance, affecting both the number and weight of birth and weaning of their lambs. This phenomenon is likely influenced by the ewe's physiological and physical capabilities, uterine environment, and fetal genetics, collectively referred to as "maternal constraint of fetal growth [24].

In contrast, Thomson et al. [25] reported that birth rank in ewes had no effect on the average number of lambs born, lamb birth weight, weaning weight, or total litter weaning weight per ewe present at each pregnancy. Similarly, Loureiro et al. [26] found no difference in the number or weight of lambs weaned between ewes born as singles or twins at their first pregnancy at two years of age. Furthermore, Pettigrew et al. [27] found no difference in lifetime productivity between ewes born as singles or twins. Therefore, it seems likely that when ewes are derived from the same general genetic base, their birth rank has little influence on the weight of lamb weaned.

Heritability estimates can be used to construct selection indices, predict the genetic response to selection, and evaluate the extent to which an individual's phenotype can be relied upon for selection [28]. Heritability estimates for many economic traits are essential for effective livestock breeding operations [29]. Heritability estimates for a trait vary between sheep breeds and change gradually over time; animal performance data and pedigree data are used to uncover genetic links between those animals to evaluate heritability. Additionally, heritability is used to calculate genetic evaluations, predict response to selection, and assist producers in determining whether it is more appropriate to increase traits through management or selection. Heritability also helps explain how genes influence the expression of traits [30].

The study genetic basis provided valuable information for long-term breed improvement. Results showed moderate heritability for both growth and lifetime production traits, indicating that genetic selection can be an effective tool for improvement. The positive genetic correlations between early growth traits (birth and yearling weight) and lifetime production suggest that selecting for improved early growth can indirectly lead to some enhancement in reproductive performance. However, the strongest genetic correlations are observed among the lifetime production traits themselves, particularly between the TNLB and TNLW and the TLWW. This highlights that the genetic factors contributing to an ewe's prolificacy are the most influential drivers of its overall lifetime lamb output by weight.

The findings of the present study regarding moderate heritability for birth and weaning weight align with studies by Hammoud and Salem [31] and Tesema et al. [32] for Rahmani lambs and Boer goats. In contrast to the present study's findings, Ahmad et al. [33], Magotra et al. [34], Sharif et al. [11], and Wang et al. [13] found low heritability for birth wight trait in Corriedale sheep, Beetal goats, Lohi sheep, and Dumeng sheep, while these studies, like the current one, observed moderate heritability for weaning weight. These estimates were lower than those in the present study, potentially influenced by differing environmental factors or greater genetic diversity affecting heritability calculations. Specific examples for weaning weight heritability are 0.21 in Mecheri [35], 0.168 in Awassi [36], and 0.20 in Sangsari sheep [37]. However, the consistently low heritability for lamb birth weight across studies suggests that environmental factors, rather than genetics, are the primary drivers of variation in this trait [13].

Genetic correlations, which reflect the interplay of genetic elements, are truly heritable, unlike phenotypic correlations that are often shaped by environmental factors like feeding and nutrition and do not directly transfer heritable traits to offspring [38]. However, Wang et al. [13] study examining early growth traits in Dumeng sheep, showed strong positive correlations were found between weaning weight and both average daily gain up to specific periods and their corresponding Kleiber ratios. Magotra et al. [34] proposed that negative genetic correlations observed between birth weight and post-weaning growth traits might be a result of reduced maternal genetic influences and an increase in additive genetic variance. Ahmad et al. [33] highlighted the strong correlation of weaning weight and 6-month weight with other traits in Corriedale sheep, recommending that these traits be prioritized in selection programs to achieve moderate genetic improvement. From a practical standpoint, weaning weight is often preferred for selection because it is expressed earlier in the animal's life, and early-expressed traits tend to respond better to selection [13].

Regarding the estimated breeding values, the significant variation in EBVs confirms the potential for genetic selection to improve current study traits. Breeders can use these EBVs to identify individuals with superior genetic merit for specific traits and select them as parents for the next generation, accelerating genetic progress. The large range in EBVs for growth traits and TLWW indicates that there are individuals with considerable genetic potential for higher growth rates and TLWW. However, selecting animals with superior estimated EBVs as parents is a strategy breeders use to enhance desirable traits in future generations. This is because EBVs serve as indicators of an animal's genetic capacity to pass on these advantageous characteristics [28]. By prioritizing individuals with higher EBVs for breeding, the goal is to elevate the prevalence of beneficial genes within the animal population, thereby improving the overall manifestation of desired traits [39]. When expressed relative to the population's average, an animal's EBV offers an evaluation of its performance potential compared to the mean of its originating group, effectively quantifying its genetic potential [40]. Undoubtedly, using all available records – i.e., information on the animal, dam, half-siblings, progeny, etc. – would be the most beneficial approach for estimating an individual's breeding value [41].

The obtained rank correlations largely support the findings from the genetic correlation analyses. While there is some positive genetic association between early growth and lifetime production, the strongest genetic relationships are observed among the different components of lifetime reproductive success, particularly between the number of lambs born and weaned, and the total weight of lambs weaned. This reinforces the conclusion that selecting for improved prolificacy traits (number of lambs born and weaned) is likely the most effective strategy for genetically improving the overall lifetime productivity (measured by TLWW) of Rahmani ewes. The minimal correlation between weaning weight EBV and prolificacy EBVs suggests that genetic selection for increased weaning weight may not significantly improve the number of lambs a ewe produces over her lifetime.

Collectively, these results underscore that improving lifetime lamb production in Rahmani ewes requires a nuanced approach that goes beyond simply selecting for increased body size. While an ewe's own birth weight can be a beneficial selection criterion, its effect, along with that of weaning and yearling weights, is influenced by lambing season and critically, by the ewe's own birth type. The genetic analysis emphasizes that prioritizing prolificacy traits in breeding programs is likely the most effective strategy for increasing the total weight of lamb weaned over am ewe's lifetime. Therefore, targeted breeding strategies for Rahmani sheep in Egyptian regions should consider the ewe's birth type when making selection decisions based on early growth and heavily emphasize genetic merit for prolificacy, leveraging the observed genetic variation and tools like EBVs to enhance the economic efficiency of the flock.

5. Conclusions

Current study on Rahmani ewes reveals significant variability in both early growth traits and lifetime lamb production. Higher ewes' birth weight generally boosts lifetime output, especially in warmer seasons and single-lambing ewes, though moderate birth weight suits multiple-birth ewes best. In February and June, ewes' weaning weight aids lifetime lamb production success, but no variations occurred in October. Higher ewes' yearling weight surprisingly benefits multiple-birth ewes' lifetime production. Genetically, moderate heritability suggests selection can improve both growth and reproduction. Positive genetic correlations exist between early growth and lifetime lamb production, with strong relations among reproductive traits. Estimated breeding values revealed considerable genetic diversity within the Rahmani flock, particularly for growth traits and total weight of lambs weaned, offering opportunities for targeted selection. Rank correlations among EBVs further supported the positive genetic associations between early growth and lifetime production, with the strongest relationships observed among reproductive traits.

Abbreviations

DBW	Dam Birth Weight
DYW	Dam Yearling Weight
DWW	Dam Weaning Weight
TNLB	Total Number of Lambs Born
TNLW	Total Number of Lambs Weaned
TLBW	Total Birth Weight of Lambs
TLWW	Total Weight of Lambs Weaned
EBVs	Estimated Breeding Values

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Conflicts of Interest

The authors declare no conflicts of interest.

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