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ESTIMATION OF GENETIC AND PHENOTYPIC TRENDS FOR IMPROVING BODY WEIGHT TRAITS IN SOHAGI SHEEP

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SUMMARY

The objective of this study was to estimate the genetic and phenotypic trends of birth weight (BW), weaning weight (WW) and yearling weight (YW) in a Sohagi sheep flock at Sohag University's experimental farm from 2001 to 2021. Data from 1284 lambs, which the progeny of 44 sires and 488 dams, were used to assess the impact of various environmental factors on these traits. The averages of BW, WW and YW were found to be 2.98±0.01 kg, 15.05±0.07 kg and 32.61±0.17 kg, respectively. The heritability (h^2), animal breeding values (BVs), and genetic and phenotypic correlations were estimated. Genetic and phenotypic trends were assessed by regressing breeding values and phenotypic values on year of birth. Genetic correlations among BW, WW, and YW were found to be higher than phenotypic correlations. Throughout the study period the breeding values ranged from -0.047 kg to 0.0834 kg for BW, -0.2487 kg to 0.9820 kg for WW, and -0.5529 kg to 1.7732 kg for YW. Genetic and phenotypic trends have changed significantly over time. Positive and significant genetic trends were observed for BW at 0.006 kg/year, WW at 0.038 kg/year and YW at 0.080 kg/year, indicating genetic improvement. However, negative phenotypic trends were noted for BW at -0.009 kg/year, WW at -0.073 kg/year and YW at -0.095 kg/year. These declines likely result from the more significant negative environmental trends which may reflect challenges such as disease, inadequate nutrition, and harsh climatic conditions.

Keywords: Sohagi sheep, Body weights, Genetic and Phenotypic trends, Heritability

INTRODUCTION

In Upper Egypt, Sohagi sheep are a significant breed valued for both meat and wool in the Sohag Governorate. The economic traits in sheep like birth, weaning, and yearling weights are influenced by both genetic and non-genetic factors. These include birth type, season, sex, year and parity. Notably seasonal variations can impact the overall performance of the flock, while the birth type affects the performance of individual sheep (Hussain *et al*., 2006). By estimating genetic and non-genetic parameters associated with BW traits, we can craft targeted and effective breeding strategies that ensure the prosperity of sheep farming in the region (Boujenane and Diallo, 2017). The future of the Sohagi sheep relies on our commitment to understand and optimize these factors.

The primary goal of any breeding program is to maximize the use of genetic variation across various traits (Mohammadi *et al*., 2015). Splitting the phenotypic variance of an animal economic traits into its genetic and non-genetic components is essential for assessing the potential progress achievable (Abou-Bakr, 2009). Selection based on single growth trait requires an understanding the relationship between traits to ensure enhancements across other traits (Behzadi *et al*., 2007, and Areb *et al*., 2021). Selection is based on the heritability estimates of the trait, estimated breeding values (EBVs) and inbreeding within the farm.

Genetic trend estimation, measures the change in mean of EBVs over the years, which provides valuable insight into the progress of the farm and the effectiveness of its selection and breeding practices. Periodical monitoring the genetic and phenotypic trends of a breed can reveal important information about its development, including the direction of selection and the rate of genetic improvement (Bosso *et al*., 2007, and Hamadani *et al*., 2021). Comparing the genetic trends with the phenotypic ones could reveal whether the farm's progress results could be attributed to effective utilization of genetic variation (Hamadani *et al*., 2019). Accurate genetic parameters estimates are typically achieved by adjusting with the environmental factors, which aid in estimating breeding values and predicting genetic progress (Santus *et al*., 1993 and El-Wakil and Elsayed, 2013). The genetic progress of the Sohagi sheep breed remains under studied. Therefore, this study aims to estimate genetic and phenotypic trends to enhance body weight traits in Sohagi sheep.

MATERIAL AND METHODS

Farm location and management:

This research was conducted following the guidelines established by the Sohag Institutional Animal Care and Use Committee (Sohag-IACUC), with approval number 6-12-1/2025-01. Data for this study was collected from the flock of Sohagi sheep at the experimental farm of the Faculty of Agriculture, Sohag University, between 2001 and 2021. This flock was managed using a lambing system designed to produce three lamb crops every two years. The mating seasons occurred January, May and September. Additionally, during the winter, the flock was fed concentrates such as soybeans and corn, along with green fodder (*Trifolium Alexandrium*).

Data:

This study examined various body weight traits at different stages; at birth (BW); weaning; 90 days (WW); and at yearling age, 360 days (YW). The data set comprised 1284 lamb records from 44 sires and 488 dams.

Statistical analysis:

Data from the years 2004 and 2005 were excluded due to insufficient records. Additionally, records with triples were removed because they had limited representation. The General Linear Models (GLM) procedure using SAS (version 9.1, 2003) was employed to identify the fixed factors affecting the studied traits. Non-significant interactions from the initial model were eliminated in the final model, which is structured as follows:

$$Y_{ijklmn}=\mu+G_i+R_j+S_k+T_l+P_m+e_{ijklmn} \quad (1)$$

Where, Y_{ijklmn} is the response variable observation (BW, WW or YW) of n^{th} animal of i^{th} sex, j^{th} year of birth, k^{th} season of birth, l^{th} type of birth and m^{th} parity; μ is the overall mean; G_i is the fixed effect of i^{th} sex (i=1,2; 1=male and 2=female); R_j is the fixed effect of j^{th} year of birth (2001 to 2021), S_k is the fixed effect of the k^{th} season of birth (winter, summer and autumn), T_l is the fixed effect of the L^{th} type of birth (single and twins), P_m is the fixed effect of the m^{th} parity (1,2, …and 8) and e_{ijklmn} is the random residual error assuming to be NID $(0,\sigma^2 e)$.

Genetic parameters for the traits under investigation were estimated using the Multiple Traits Animal Model (MTDFREML) proposed by Boldman *et al*. (1995). This model was used to estimate heritability (h^2), as well as genetic and phenotypic parameters. The same fixed effects included in Model (1) were also accounted for in this model, along with the effects of the animal, sire, and dam. The following linear model was utilized:

$$Y = X\beta + Z_a a + e \quad (2)$$

Where: Y is the vector of observations, X is the incidence matrix for fixed effects, β is the vector of an overall mean and fixed effects, Z_a is the incidence matrix for random effects, a is the vector of direct genetic effects of animal and e is a vector of random errors normally and independently distributed with zero mean and variance $\sigma^2 eI$.

EBVs were derived from model (2). The mean EBVs were calculated based on the years of birth to determine the annual genetic gain, performing a regression analysis of EBVs in relation to the birth years, using the regression procedure (SAS, 2003).

$$y = b_0 + bx$$

Where y represents the average EBVs for a given year of birth; x is the years of birth; b_0 and b_1, refer to the intercept and the linear regression coefficient, respectively. The overall genetic gain was represented by the regression coefficient of EBVs.

To obtain the genetic and phenotypic trends, we plotted the least-square means of EBVs along with least-square means of a specific trait against birth years.

RESULTS AND DISCUSSION

Fixed factors:

Analysis of variance for fixed effects influencing the traits under investigation is presented in Table 1. The results indicate that the sex of the lambs, year of birth, season, and type of birth significantly affected the traits under investigation. However, parity does not have a significant impact on those examined traits.

Table 1. Analysis of variance for body weight at birth (BW), weaning (WW) and yearling (YW) in Sohagi sheep

Source of variation	Df	BW	WW	YW
		MS	MS	MS
Total	1283			
Sex	1	1.61^{**}	319.60^{**}	11139.58^{**}
Year of Birth	18	1.48^{**}	41.77^{**}	93.03^{**}
Season of birth	2	1.59^{**}	124.50^{**}	131.06^{**}
Type of Birth	1	27.40^{**}	506.91^{**}	662.59^{**}
Parity	7	0.31^{NS}	11.37^{NS}	40.50^{NS}
Residual	1254	0.22	5.79	25.57

** Significant at P<0.01; NS = Not significant

Table 2, displays the least square means for the studied traits. The results indicated that males had significantly higher body weights (P<0.01) than females across all the analyzed traits in this study. This difference may be attributed to physiological and hormonal variations between the two genders (Tibbo, 2006, and Areb *et al*., 2021). Males have higher levels of testosterone, which influences muscle growth and the development of secondary sexual characteristics. In contrast, female hormones (such as estrogen and progesterone) fluctuate during estrous cycles and pregnancy, affecting reproductive metabolic functions (Guyton and Hall., 2021)**.** Furthermore, singles-born lambs exhibited significantly higher body weights (P<0.01) compared to those born as twins lambs. Additionally, lambs born in winter were significantly heavier (P<0.01) than those born in summer and autumn. This result is consistent with those studies reported by Norouzian (2015), and Stritzke and Whiteman (1982), which indicated that winter-born lambs had greater weights at both birth and weaning compared to those born in summer or autumn.

Table 2. Least Square Means (LSM) and their standard error (±SE) for body weights at birth (BW), weaning (WW) and yearling (YW) according to sex, year of birth, season, type of birth and parity

	N	BW LSM±SE	WW LSM±SE	YW LSM±SE
Overall	1284	2.98±0.01	15.05±0.07	32.62±0.17
Sex:				
Male	605	3.03^{a}±0.03	15.56^{a}±0.17	36.31^{a}±0.35
Female	679	2.95^{b}±0.03	14.53^{b}±0.16	30.20^{b}±0.33
Year of birth:				
2001	49	2.91^{efg}±0.07	16.62^{a}±0.38	35.12^{abc}±0.82
2002	121	3.06^{bcdef}±0.05	15.71^{abc}±0.26	33.33^{bcde}±0.56
2003	75	2.76^{efg}±0.06	14.52^{abcd}±0.31	33.56^{ab}±0.66
2006	27	2.84^{edfg}±0.09	15.22^{abcd}±0.48	33.53^{cde}±0.99
2007	13	3.02^{bcdef}±0.13	14.64^{bcd}±0.67	34.97^{bcde}±1.42
2008	13	3.21^{bcde}±0.13	15.30^{bcd}±0.68	32.66^{e}±1.44
2009	12	3.14^{b}±0.13	15.17^{abc}±0.70	32.64^{bcde}±1.47
2010	17	3.59^{a}±0.11	15.55^{a}±0.59	35.45^{a} ±1.24
2011	66	2.97^{bcde}±0.06	14.72^{abc}±0.32	33.09^{abcd}±0.69
2012	26	3.09^{bc}±0.09	15.70^{a}±0.50	32.17^{cde}±1.04
2013	105	3.13^{bcd}±0.05	15.27^{abcd}±0.27	32.64^{bcde}±0.58
2014	84	3.06^{bcde}±0.05	14.93^{abcd}±0.29	31.78^{bcde}±0.62
2015	57	2.64^{g}±0.06	15.71^{ab}±0.35	34.81^{abc}±0.72
2016	88	2.89^{cdefg}±0.05	15.35^{abcd}±0.28	34.65^{abc}±0.60
2017	142	2.90^{bcdefg}±0.04	15.95^{a}±0.23	33.53^{abcd}±0.50
2018	126	2.89^{cdefg}±0.04	14.27^{bcd}±0.24	32.30^{bcd}±0.51
2019	130	2.98^{bcdef}±0.04	13.98^{cd}±0.24	30.84^{de}±0.50
2020	113	2.98^{bcdef}±0.04	13.69^{d}±0.24	32.69^{abcd}±0.51
2021	20	2.56^{fg}±0.10	13.48^{abcd}±0.55	32.07^{abcd}±1.17
Season of birth:				
Winter	444	3.06^{a}±0.03	15.66^{a}±0.17	33.37^{a}±0.37
Summer	392	2.94^{b}±0.03	14.96^{b}±0.17	33.78^{a}±0.37
Autumn	448	2.94^{b}±0.03	14.51^{b}±0.18	32.61^{a}±0.38
Type of Birth:				
Single	756	3.14^{a}±0.03	15.71^{a}±0.15	34.01^{a}±0.32
Twins	528	2.83^{b}±0.03	14.38^{b}±0.16	32.50^{b}±0.35
Parity:				
1	489	2.94^{a}±0.02	14.83^{a}±0.13	32.70^{ab}±0.28
2	301	3.02^{a}±0.03	15.06^{a}±0.15	33.14^{ab}±0.33
3	215	2.97^{a}±0.03	15.02^{a}±0.18	32.25^{b}±0.38
4	142	3.03^{a}±0.04	15.68^{a}±0.21	33.76^{ab}±0.46
5	68	2.94^{a}±0.05	14.99^{a}±0.31	33.66^{a}±0.64
6	33	2.88^{a}±0.08	14.83^{a}±0.42	33.32^{ab}±0.89
7	24	3.06^{a}±0.09	14.68^{a}±0.51	32.96^{ab}±1.06
8	12	3.02^{a}±0.13	15.27^{a}±0.71	34.25^{ab}±1.50

Different letters a, b and c in the same column are significantly different (P<0.05).

Body weight traits exhibited significant fluctuations (P<0.01) throughout the year of birth lacking a specific trend. These results may be linked to factors such as feeding level, management practices of the herd during the study years, and changes in environmental conditions (Elsaid *et al*., 2018). A similar pattern was noted concerning parity where no significant differences existed (P>0.05). The influence of sex, birth type, and birth year was deemed significantly in studies by Matika *et al*. (2003) on Sabi sheep and Rahimi and Rafat (2014) on Makuie sheep.

Genetic parameters:

The heritability estimatesas well as the genetic and phenotypic correlations for the body weights studied are presented in Table 3. It was observed that heritability estimates tends to increase with age. These findings align with those of El-Wakil and Elsayed (2013), and Ngere *et al*. (2017) who stated that as animals mature; the impact of environmental factors on body weight diminishes, allowing their genetic potential to become more evident. The moderate to high heritability estimates observed in this study indicate a significant genetic variability, which could be utilized to improve the breed through selection (Areb *et al*., 2021).

The estimated h^2 values for BW (0.13), WW (0.40) and YW (0.45) in this study. These figures are higher than those reported by El-Wakil and Elsayed (2013) for Barki sheep, which were 0.10, 0.24, and 0.39, respectively. Also, Besufkad *et al*. (2024) reported a higher heritability estimate (0.29) for BW compared to current study. They also found similar heritability estimates in Menz sheep for WW (0.45) and YW (0.42). The discrepancies in the h^2 estimates across different sheep breeds may be attributed to variations in data structure, model selection, environmental conditions and management practices reported in the literature. All phenotypic and genetic correlations were found to be positive. The genetic correlation ranged from 0.80 to 0.99, while the phenotypic correlation ranged from 0.16 to 0.57. Notably, the genetic correlations between any two traits were consistently greater than the corresponding phenotypic correlations. Numerous studies have reported strong positive and genetic correlations among body weights in sheep (Boujenane *et al*., 2015; Oyieng *et al*., 2022, and Altincekic *et al*., 2022). These strong correlations indicate that selecting for one trait is likely to produce favorable responses in others traits, allowing some traits to be used as indicators for breeding. Consequently, in a breeding program aimed at improving growth performance in sheep; it is unnecessary to measure all growth traits for genetic evaluation and selection. However; early expressed traits such as birth weight could be utilized to predict and select for later weights, including weaning and mature weights (Rajkumar *et al*., 2021).

The low phenotypic correlations observed between body weight traits in this study are consistent with findings from previous research on Bonga sheep (Areb *et al*., 2021) and Doyogena sheep (Habtegiorgis *et al*., 2020).

Table 3. Heritability estimates (on diagonal), Phenotypic (below diagonal) and genetic correlation (above diagonal) for body weights at birth (BW), weaning (WW) and yearling (YW) of Sohagi sheep

Traits	BW	WW	YW
BW	**0.13±0.05**	0.80	0.81
WW	0.17	**0.40±0.07**	0.99
YW	0.16	0.57	**0.45±0.07**

Genetic and phenotypic trends:

The genetic trends for body weight traits (BW, WW and YW) have demonstrated positive genetic improvement over the years. The average rates of improvement are 0.006 kg/year for BW, 0.038 kg/year for WW and 0.080 kg/year for YW (Table 4). The average annual genetic trends, which were calculated by regressing the mean EBVs against the year of birth, were statistically significant (P<0.01) for all body weight traits. The observed positive genetic trends in BW, WW, and YW likely result from correlated responses, as there has not been direct selection for these traits (Besufkad *et al*., 2024). According to Hamadani *et al*. (2021), the lack of effective selection criteria for body weight traits likely resulted in slow genetic improvement. The results of this study showed significant genetic gains in BW, WW, and YW, suggesting that long-term selection efforts could yield favorable results in Sohagi sheep. Similarly study by Shaat *et al*. (2004) conducted over 30 years reported comparable results for local Rahmani and Ossimi breeds. The estimated genetic trends for lamb weights at two months, four months and six months of age were 0.038, 0.092 and 0.135 kg/year in Rahmani breed (P<0.01) and 0.020, 0.021 and 0.021 kg/year in Ossimi breed (P<0.01), respectively. Also, Jeichitra *et al*. (2015) revealed a consistent annual positive genetic trend in the body weights of Mecheri sheep. The breeding values slopes for lamb weights at birth, 180 and 360 days of age were -0.21 ± 0.00012, 0.68 ± 0.00045, and 1.48± 0.00093 gm/year, respectively.

The results showed in Table 4, indicate negative phenotypic trends in body weight traits with significant differences observed. These findings suggest that management and environmental conditions may play a role in the trends observed in this study. The significant trends imply that these factors could greatly impact the improvement of the flock. The significant downward phenotypic trends for BW, WW, and YW observed in this study are in agreement with previous findings reported by Malik (2017) and Hamadani *et al*. (2021) in Munjal and Kashmir Merino sheep, respectively.

EBVs were determined for each animal and the mean EBVs were estimated for each birth year. Table 5 presents the least-squares means of these EBV's. Throughout the study period, the least-squares means ranged from -0.047 kg to 0.0834 kg for BW,-0.2487 kg to 0.9820 kg for WW and-0.5529 kg to 1.7732 kg for YW. The genetic trends represented by estimated breeding values (EBVs) for BW, WW, and YW are illustrated in Figs. 1 to 3. Annual genetic trends showed fluctuations over years with a notable increase following 2014. The decreases observed in some years indicate limited or no genetic selection for these traits (Altincekic *et al*., 2022).

Table 4. Genetic and Phenotypic trends for body weights at birth (BW), weaning (WW) and yearling (YW) of Sohagi sheep

Trend	BW				WW				YW			
	Intercept±SE	Slope±SE	R^2	P value	Intercept±SE	Slope±SE	R^2	P value	Intercept±SE	Slope±SE	R^2	P value
Genetic	-0.062±0.013	0.006±0.001	0.676	0.001	-0.120±0.139	0.038±0.011	0.429	0.002	-0.305±0.269	0.080±0.021	0.473	0.001
Phenotypic	3.086±0.112	-0.009±0.009	0.058	0.321	15.90±0.348	-0.073±0.027	0.309	0.014	34.362±0.584	-0.095±0.044	0.211	0.048

Table 5. Least square Means (kg) of animal breeding values for body weights at birth (BW), weaning (WW) and yearling (YW) of Sohagi sheep

Years of birth	BW±SE	WW±SE	YW±SE
2001	-0.0250±0.01	0.1523±0.13	0.3603±0.30
2002	-0.0317±0.01	0.1391±0.08	0.3333±0.18
2003	-0.0434±0.01	0.1251±0.09	0.3064±0.19
2006	-0.0218±0.01	0.1269±0.15	0.3008±0.34
2007	-0.0552±0.02	-0.1566±0.18	-0.3337±0.41
2008	-0.0246±0.02	-0.0029±0.16	0.0045±0.37
2009	-0.0374±0.02	-0.2487±0.23	-0.5529±0.51
2010	0.0269±0.02	0.2036±0.24	0.4789±0.55
2011	0.0218±0.01	0.2399±0.10	0.5399±0.23
2012	-0.0470±0.02	0.5933±0.17	1.3382±0.39
2013	-0.0167±0.01	0.0982±0.09	0.2326±0.21
2014	0.0168±0.01	0.1147±0.09	0.2552±0.21
2015	-0.0039±0.01	-0.0003±0.11	0.0011±0.24
2016	0.0062±0.01	0.3261±0.11	0.7444±0.25
2017	0.0572±0.01	0.6625±0.09	1.4922±0.21
2018	0.0513±0.01	0.5714±0.09	1.2860±0.20
2019	0.0690±0.01	0.7875±0.08	1.7732±0.17
2020	0.0773±0.01	0.7803±0.08	1.7529±0.19
2021	0.0834±0.02	0.7497±0.23	1.6799±0.53

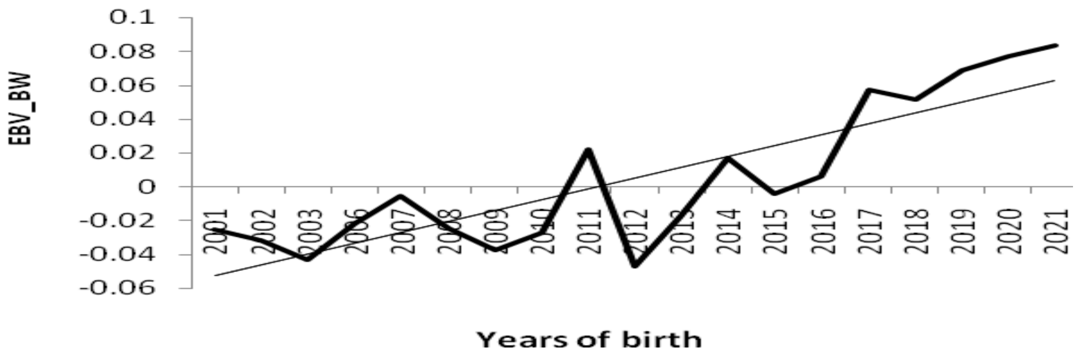

Fig. 1. Genetic trends (estimated breeding values, EBVs) for birth weights (BW) from 2001 to 2021.

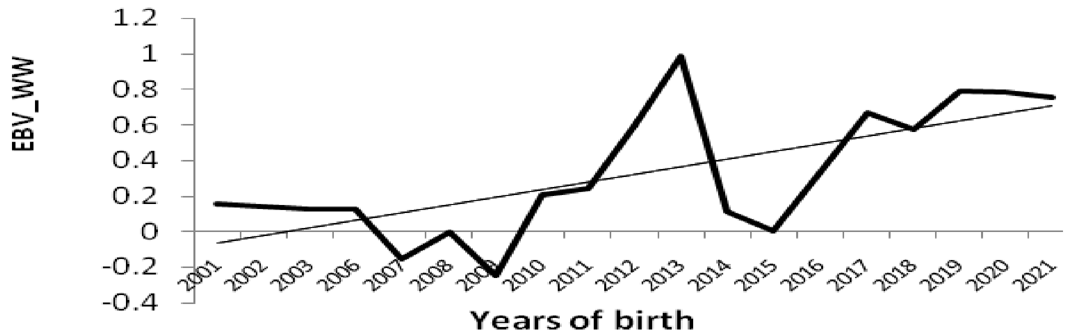

Fig. 2. Genetic trends (estimated breeding values, EBVs) for weaning weights (WW) from 2001 to 2021.

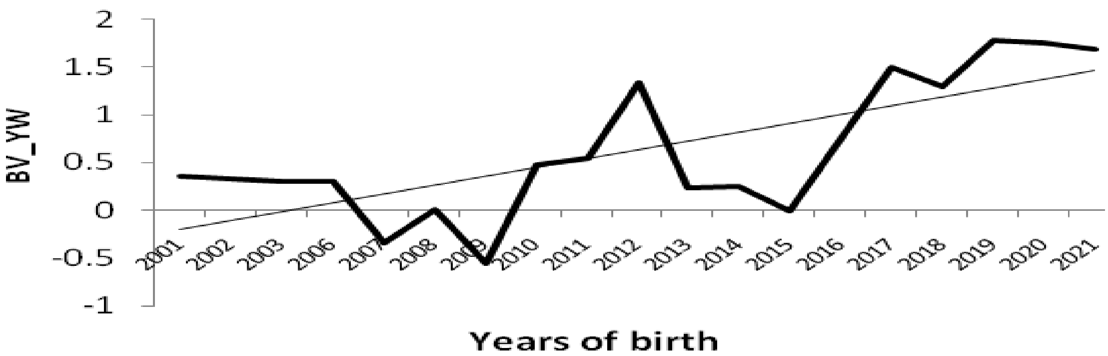

Fig. 3. Genetic trends (estimated breeding values, EBVs) for Yearling weights (YW) from 2001 to 2021.

During the study period, phenotypic trends for BW and WW demonstrated minimal change (Figs. 4 and 5). In contrast, the phenotypic trend for yearling weight (Fig. 6) exhibited sharper fluctuations, suggesting a greater impact from inconsistent management and environmental factors on this particular trait.

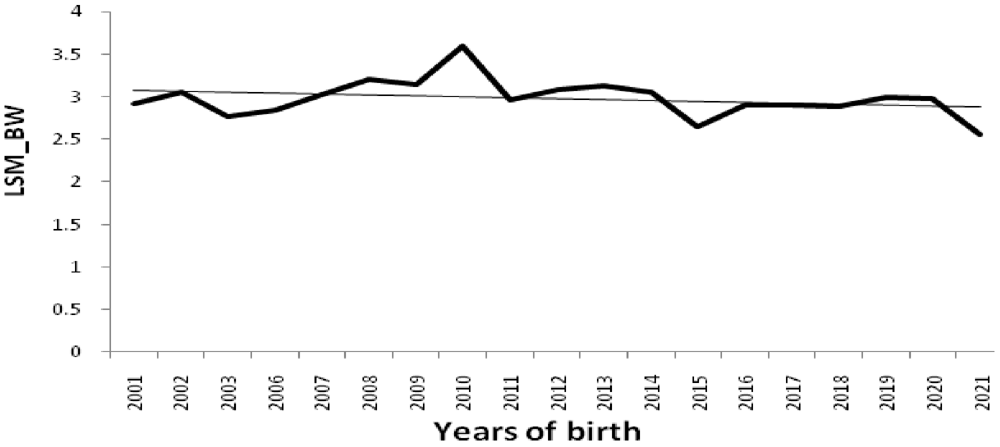

Fig. 4. Phenotypic trends (least square means, LSM)) for body weights (BW) from 2001 to 2021.

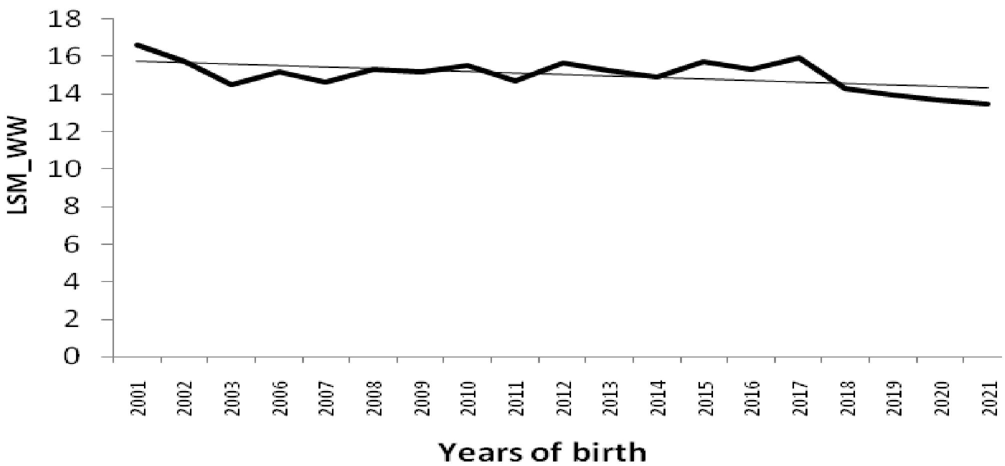

Fig. 5. Phenotypic trends (least square means, LSM)) for weaning weights (WW) from 2001 to 2021.

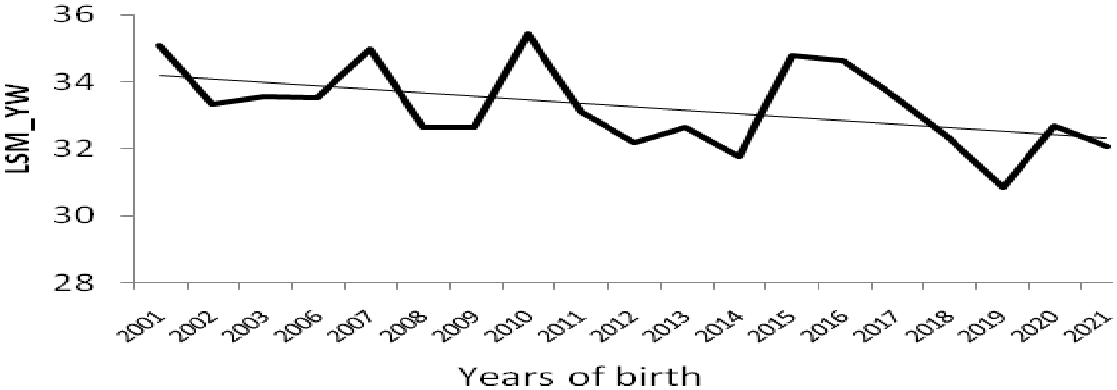

Fig. 6. Phenotypic trends (least square means, LSM)) for yearling weights (YW) from 2001 to 2021.

CONCLUSION

The estimated parameters and breeding values for body weight traits facilitated the comparison of phenotypic and genetic characteristics within the Sohagi sheep flock. However, the inconsistent trends suggest that limited genetic improvement has been achieved; likely due to the lack of effective directional selection. Therefore, implementing of a breeding program as being based on these breeding values seemed essential to improve the genetic merit and overall productivity. Genetic progress in growth performance can be achieved through appropriate management and selection pressures.

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تقدير الإتجاهات الوراثية والمظهرية لتحسين صفات وزن الجسم فى الأغنام السوهاجى

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إستهدفت الدراسة الحالية تقدير الإتجاهات الوراثية والمظهرية لوزن الميلاد ووزن الفطام والوزن عند عمر سنة في قطيع من الأغنام السوهاجى تم تربيتهم فى المزرعة التجريبية لجامعة سوهاج من عام ٢٠٠١ إلى عام ٢٠٢١. تم إستخدام بيانات ١٢٨٤ حملًا، أبناء ٤٤ كبش و٤٨٨ أم وذلك لتقييم تأثير العوامل البيئية المختلفة على هذه الصفات. كان متوسط وزن الميلاد ٢,٩٨ ± ٠,٠١ كجم، ومتوسط وزن الفطام ١٥,٠٥ ± ٠,٠٧ كجم، ومتوسط الوزن عند عمر سنة ٣٢,٦١ ± ٠,١٧ كجم، على التوالي. تم تقديرالمكافئ الوراثى والقيم التربوية للحيوانات وكذلك الإرتباطات الوراثية والمظهرية. تم تحديد الإتجاهات الوراثية والمظهرية عن طريق تحليل إنحدار القيم التربوية والقيم المظهرية على سنة الميلاد. كانت الإرتباطات الوراثية بين وزن الميلاد، ووزن الفطام، والوزن عند عمر سنة أعلى من الإرتباطات المظهرية. تراوحت القيم التربوية من -٠,٠٤٧ كجم إلى ٠,٠٨٣٤ كجم لوزن الميلاد، ومن -٠,٢٤٨٧ كجم إلى ٠,٩٨٢٠ كجم لوزن الفطام، ومن -٠,٥٥٢٩ كجم إلى ١,٧٧٣٢ كجم للوزن عند عمر سنة خلال فترة الدراسة. تذبذبت الإتجاهات الوراثية والمظهرية بشكل ملحوظ. لوحظت إتجاهات وراثية إيجابية ومعنوية لوزن الميلاد (٠,٠٠٦ كجم/سنة)، ووزن الفطام (٠,٠٣٨ كجم/سنة)، والوزن عند عمر سنة (٠,٠٨٠ كجم/سنة)، مما يشير إلى تحسن وراثي. كما لوحظت إتجاهات مظهرية سلبية لوزن الميلاد (-٠,٠٠٩ كجم/سنة)، ووزن الفطام (-٠,٠٧٣ كجم/سنة)، والوزن عند عمر سنة (-٠,٠٩٥ كجم/سنة). من المحتمل أن تكون هذه الإنخفاضات ناتجة عن الإتجاهات البيئية السلبية الكبيرة التي قد تعكس تحديات بيئية مثل الأمراض، وسوء التغذية، والظروف المناخية القاسية.