The Journal of Animal & Plant Sciences, 30(1): 2020, Page: 239-245
ISSN: 1018-7081

GENETIC EVALUATION OF COMPOSITE REPRODUCTIVE TRAITS IN GHEZEL SHEEP

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ABSTRACT

This study was carried out to estimate genetic parameters and trends for reproductive performances of Ghezel sheep. The traits included in the analyses were litter size at birth (LSB) and weaning (LSW), and litter mean weight per lamb born (LMWLB) and weaned (LMWLW) as basic traits, and total litter weight at birth (TLWB) and weaning (TLWW) as composite traits. Direct genetic trends were obtained by regressing means of predicted breeding values from the best model on birth year. Direct heritability estimates for LSB, TLWB, LMWLB, LSW, TLWW and LMWLW were 0.06, 0.04, 0.06, 0.01, 0.06 and 0.06, respectively. The permanent environmental effect was significant for LSW (0.09) and TLWB (0.04) and the service sire effect (0.14) influenced TLWB. Effects of service sire were highly significant ($P<0.01$) for LSB, TLWB, LMWLB, TLWW and LMWLW traits; proportions of phenotypic variance explained by the service sire effect were 0.03, 0.14, 0.21, 0.25 and 0.33, respectively. A significant genetic trend was found only for LMWLB ($P<0.05$).These results suggested that inclusion of permanent environmental and service sire effects in the model for ewe productivity traits may improve the accuracy of genetic evaluation. Also, improvement of reproductive traits in this breed may be achieved by selecting the elite rams.

Key words: Ghezel sheep, genetic evaluation, reproductive performance, service sire effect, REML.

INTRODUCTION

Reproduction is a complex process affected by many components including puberty, ovulation, estrus, fertilization, embryo implantation, pregnancy, parturition, lactation, and mothering ability (Safari *et al*., 2005). However, the profitability of sheep breeding systems is strongly influenced by reproductive characteristics (Matos *et al*., 1997). Therefore, female reproductive efficiency is likely to be a primary component of overall productivity in sheep. As pointed out by Cloete *et al*. (2002), the demand for wool products has declined in recent years, and more attention has been paid to meat production. Increasing the number and weight of lambs weaned per ewe per year has therefore been recommended as the most effective strategy to enhance meat products (Snyman *et al*., 1997; Duguma *et al*., 2002; Olivier *et al*., 2005). Therefore, to design and implementation of selection programs to improve efficiency of sheep reproduction knowledge of genetic parameters for reproductive traits is required. Estimates of genetic trends are also needed to assess the efficacy of applied breeding program and motivate breeders to develop more efficient breeding programs (Jurado *et al*., 1994). Reproductive traits are not only influenced by the genes of the individual for reproduction and by the environment, in which it is raised, but also by the service sire and by permanent environmental effects on the mother (Maghsoudi *et al*., 2009; Mokhtari *et al*., 2010). Estimates of genetic parameters and trends for reproductive performance in sheep have been reported based on different commercial populations and limited field data by several authors (Ingham and Ponzoni, 2000; Chen *et al*., 2003; Mokhtari *et al*., 2010; Mohammadi *et al*., 2012).

The Ghezel breed is one of the 27 sheep breeds identified in Iran and has a population of about 2 million heads. This breed is found in the northwestern part of Iran and is well adapted to mountainous condition in this region (Baneh *et al*., 2010).The breed is mainly used for meat production; milk and wool production are of secondary importance (Baneh *et al*., 2010). Recently, Nabavi *et al*. (2014) have studied some reproductive traits of this breed as lamb's trait. However, there are no published reports on estimation of service sire effect, permanent environmental effect of ewe on the reproduction traits in Ghezel sheep. Also genetic trend for these traits haven't reported so far. Therefore, the objectives of the present study were to estimate (1) genetic parameters, including service sire and permanent environmental effects, and (2) genetic trends for the studied traits.

MATERIALS AND METHODS

Geographical location and flock management: Pedigree information and data on reproductive performance for Ghezel ewes were obtained from the breeding station for Ghezel sheep during the period 1986 to 2009. The breeding station was established in 1985 in West Azerbaijan province (at 46º06'E and 36º58'N) in the northwestern part of Iran. The temperature at the station ranged from -22.8°C in winter to 38.3°C in summer. The main activities at the station were the enhancement of production efficiency and the dissemination of superior animals into local flocks. Lambs were weighed and ear-tagged at birth and pedigree and birth information was recorded for each lamb. Ewe and ram lambs were first mated at 18 months of age. Ewes could be retained for up to 6 years. All animals grazed during the day on natural pasture, with occasional additional access to alfalfa, wheat straw, barley straw, barley bran, and other supplemental forages when they were available, and were housed at night. In the winter, animals were hand-fed, mainly with lucerne, barley, wheat straw, barley straw and fodder. Matings were controlled. Mating of ewes with selected rams began in October and continued for 51 days (i.e., three estrous cycles). The lambing season was from March to May, but there is a small number lambing out of lambing season. Pedigree information for each lamb including the animal ID, sire and dam ID, date of birth, sex, and type of birth, were recorded at birth. Lambs were weaned at approximately 3 months of age (Baneh *et al*., 2010). More information for management of the flock is available in Baneh *et al*. (2010) and Nabavi *et al*. (2014).

Data: In the current study, the traits of interest were considered as trait of ewe. The basic traits that were analyzed were litter size at birth (LSB, the number of lambs born alive per ewe lambing within a year (1, 2 or 3), litter size at weaning (LSW, the number of lambs weaned per ewe lambing within a year (1, 2 or 3), litter mean weight per lamb born (LMWLB), and litter mean weight per lamb weaned (LMWLW). We also analyzed two composite traits: the total litter weight at birth (TLWB) was the sum of the birth weights of all lambs born to each ewe in each year and the total litter weight at weaning (TLWW) was the sum of the weights of all lambs weaned by each ewe in each year. Descriptive statistics for each of the studied traits are shown in Table 1.

Statistical analysis: Preliminary least-squares analyses to determine fixed effects to be included in the final models were carried out using the generalized linear models (GLM) procedure of SAS (SAS 2002; SAS Institute Inc., Cary, NC). The model accounted for fixed effects of lambing year (with 23 levels; 1986 through 2009), lambing season (2 classes, Oct-15th Nov and out of this period), and ewe age at lambing (with 6 classes corresponding to 2 to 7-years old ewes). Interactions among fixed effects were not significant and were not considered in the final models. As recommended by Van Wyk *et al*. (2003), TLWB, TLWW, LMWLB and LMWLW were pre-adjusted for sex of the lambs by applying multiplicative adjustment factors to individual lamb weights. These factors were determined from least-squares analysis of effects of sex on birth and weaning weight of lambs. The weaning weights were adjusted for three months of age.

Estimates of variance components and genetic parameters were derived by restricted maximum likelihood (REML) using univariate linear model (e.g. Rosati *et al*., 2002; Vatankhah *et al*., 2008; Ceyhan *et al*., 2009; Rashidi *et al*., 2011) in the WOMBAT statistical package (Meyer, 2007). Four models were fit for each trait:

1) $y = Xb + Z_a a + e$ (1)

2) $y = Xb + Z_a a + W_{pe} pe + e$ (2)

3) $y = Xb + Z_a a + Z_s s + e$ (3)

4) $y = Xb + Z_a a + W_{pe} pe + Z_s s + e$ (4)

where **y** is a vector of records for each trait; **b**, **a**, **s**, **pe** and e denote vectors of fixed effects, direct additive genetic effects, service sire effects, permanent environmental effects related to repeated records of ewes, and residual effects, respectively. Also, **X**, $\mathbf{Z_a}$, $\mathbf{Z_s}$ and $\mathbf{W_{pe}}$, are design matrices associating corresponding effects (of **b**, **a**, **s**, and **pe**, respectively) with vector **y**. The (co) variance structure for the random effects was:

$V(a) = A\sigma^2_a, V(s) = I_s\sigma^2_s, V(pe) = I_d\sigma^2_{pe}$, and $V(e) = I_n\sigma^2_e$

where σ^2_a, σ^2_s, and σ^2_{pe} are direct additive genetic, service sire, and permanent environmental variances, respectively, related to repeated records of the ewes and "σ^2_e" is the residual variance,. Hence, I_s, I_d and I_n are identity matrices with order equal to the number of sires, ewes and records, respectively. **A** is the numerator relationship matrix. Effects of service sire and permanent environment were tested using the Akaike information criterion (AIC) as AIC=−2 Log L+2p, in which p denote the number of random (co)variance parameters to be estimated and Log L is the maximum likelihood. The model yielding the smallest AIC fits the data was considered as best model. Genetic trends were estimated by regressing the means of predicted breeding values on year of birth using the regression procedure (PROC REG) of SAS.

RESULTS

Least square analysis: Significance levels, least-squares means, and standard errors for fixed effects influencing TLWB, LSB, LMWLB, TLWW, LSW and LMWLW are presented in Table 2. Ewe productivity improved as the ewes became older, and particularly after 4 years of age. Lambing season did not have significant effect on any of the measured traits.

Genetic parameter estimates: Estimates of variance components, heritabilities (h^2), and ratios of variance components associated with permanent environmental and service sire to the total phenotypic variance (pe^2 and s^2, respectively), for the most suitable model for each trait are presented in Table 3. Direct heritabilities were low, but sometimes significant, and ranged from 0.01 to 0.07.

All traits except LSW were significantly affected by service sire effects. The estimates of service sire variance as a proportion of phenotypic variance (s^2) for the studied traits was low to medium and ranged from 0.03 for LSB to 0.33 for LMWLW. Service sire effects were often larger than direct genetic effect. Also, estimates of pe^2 for LSW and TLWB in the best model were 0.09 and 0.04, respectively.

Genetic trend: Estimated additive genetic trends (g or number per year) for reproductive traits are shown in Table 4 and plotted in Figures 1 and 2. As shown in Figure 1, genetic trends for LSB, TSWB, and LMWLB in Ghezel ewes were essentially flat from 1989 to 2002, although a significant negative trend was observed for LMWLB and the negative trend for LSW approached significance (P = 0.08). Plots of the mean predicted breeding values for LSW, TLWW and LMWLW followed similar patterns (Figure 2). Patterns of changes in TLWW and LSW were especially close to zero.

Table 1. Structure of pedigree and data set for reproductive traits of Ghezel sheep.

Trait[1]	TLWB	LSB	LMWLB	TLWW	LSW	LMWLW
Animal in pedigree	1372	1372	1372	1473	1473	1473
No. records	1608	1608	1608	2196	2196	2196
No. sires	131	131	131	129	129	129
No. dams	533	533	533	518	518	518
No. service sires	133	133	133	141	141	141
Mean	4.91	1.11	4.47	24.38	1.06	23.09
S.D	1.25	0.32	0.65	6.37	0.24	3.56
Min	2.5	1	2.5	14.51	1	14.51
Max	14.21	3	6.5	88.15	3	33.69

[1]TLWB = total litter weight at birth; LSB = litter size at birth; LMWLB = litter mean weight per lamb born; TLWW = total litter weight at weaning; LSW = litter size at weaning; and LMWLW = litter mean weight per lamb weaned.

Table 2.Significance levels and least squares means ± standard errors for fixed effects influencing reproductive traits of Ghezel sheep.

Fixed effects	Traits[1]					
	TLWB	LSB	LMWLB	TLWW	LSW	LMWLW
Lambing Year	**	**	**	**	**	**
Lambing Season	Ns	ns	Ns	ns	Ns	Ns
Ewe age:	**	**	**	**	**	**
2	4.02±0.40[c]	1.03±0.11[d]	3.90±0.20[c]	20.79±1.88[d]	1.02±0.08[d]	20.30±0.97[b]
3	4.33±0.41[b]	1.04±0.11[cd]	4.16±0.20[a]	22.24±1.89[c]	1.03±0.08[cd]	21.50±0.98[a]
4	4.37±0.40[b]	1.08±0.11b[c]	4.05±0.20[b]	23.10±1.87[b]	1.06±0.08[bc]	21.86±0.96[a]
5	4.71±0.41[a]	1.12±0.11[ab]	4.19±0.20[a]	23.71±1.90[b]	1.09±0.08[ab]	21.74±0.98[a]
6	4.60±0.41[a]	1.11±0.11[ab]	4.16±0.21[a]	23.23±1.90[b]	1.07±0.08b[c]	21.74±0.98[a]
≥7	4.75±0.41[a]	1.18±0.11[a]	4.02±0.21[bc]	25.20±1.95[a]	1.14±0.08[c]	21.59±1.01[a]

[2] For trait abbreviations, see footnote of Table 1.
**P<0.01, ns=not significant

Table 3.Estimates of variance components and genetic parameters for reproductive traits of Ghezel sheep using the best model[1].

Trait[1]	Model[2]	σ^2_a*	σ^2_{pe}	σ^2_s	σ^2_e	σ^2_p	$h^2_a \pm SE$	$pe^2 \pm SE$	$s^2 \pm SE$
TLWB	4	0.065	0. 068	0.213	1.219	1.567	0.04±0.04	0.04±0.05	0.14±0.03
LSB	3	0.006	-	0.003	0.095	0.105	0.06±0.03	-	0.03±0.02
LMWLB	3	0.024	-	0.086	0.306	0.416	0.06±0.03	-	0.21±0.03
TLWW	3	2.764	-	10.873	29.507	43.145	0.06±0.02	-	0.25±0.04
LSW	2	0.001	0.004	-	0.051	0.056	0.01±0.01	0.09±0.04	-
LMWLW	3	0.603	-	4.388	7.907	13.251	0.07±0.02	-	0.33±0.04

[1] For traits abbreviations, see footnote of Table 1.
[2]Model 2 include direct genetic and permanent environmental effects; Model 3 include direct genetic and service sire effects, and Model 4 include direct genetic, permanent environmental, and service sire effects.
*σ^2_a= direct additive genetic variance; σ^2_{pe}= permanent environmental variance; σ^2_s= service sire variance; σ^2_e= residual variance; σ^2_p = phenotypic variance; h^2_a= direct heritability; pe^2= ratio of permanent environmental variance to phenotypic variance; s^2= ratio of service sire variance to phenotypic variance; and SE= standard error.

Table 4.Genetic trend for reproduction traits of Ghezel sheep.

Trait[1]	DT[2]±S.E.	p value
TLWB (g)	-0.133±3.70	0.97
LSB (No.)	0.001±0.00	0.34
LMWLB (g)	-5.174±2.18	0.02
TLWW (g)	-6.450±6.92	0.36
LSW (No.)	-0.017±0.00	0.08
LMWLW(g)	-0.063±0.32	0.85

[1] For traits abbreviations, see footnote of Table 1.
[2]DT=Additive genetic trend.

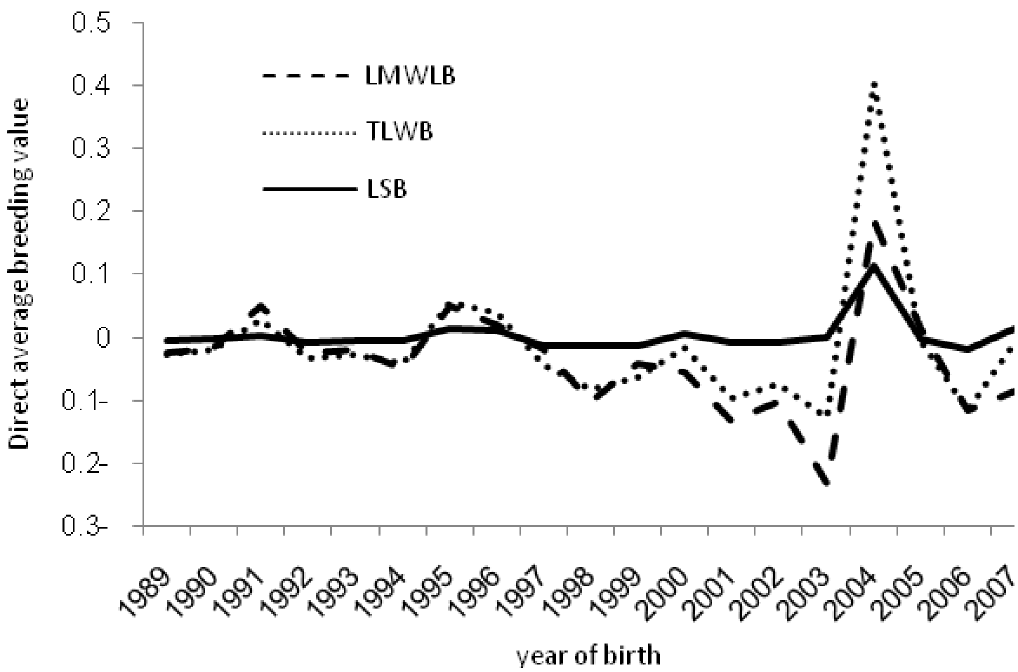

Fig. 1.Direct trend of mean breeding values by year of birth for LSB, TLWB and LMWLB in Ghezel sheep

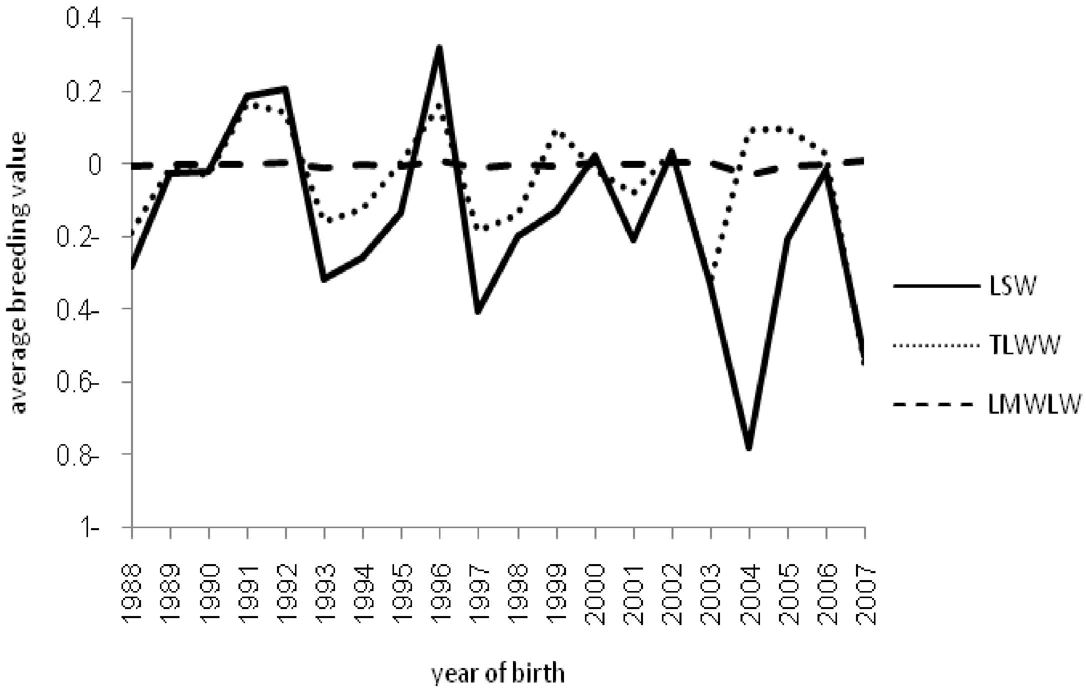

Fig. 2. Direct trend of mean breeding values by year of birth for LSW, TLWW and LMWLW in Ghezel sheep.

DISCUSSION

Several authors has reported significant effect of lambing year on reproductive performances of different sheep breeds (Boujenane *et al*., 1991; Bromley *et al*., 2001; Ekiz *et al*., 2005; Vatankhah *et al*., 2008). As indicated in Table 2, LSB, LSW and TLWB improved as ewes aged. This result can be explained by improvements in maternal effects and nursing and maternal behavior in older ewes (Nouman and Abrar, 2013), and agreed with findings of Baneh *et al*. (2010) who reported that older ewes of this breed had significantly heavier lambs compared to younger ewes. Effect of ewe age on reproductive performance in different sheep breeds has been reported in the literature (Rosati *et al*., 2002; Ekiz *et al*., 2005). Significant effects of lambing year on TLWB, LSB, TLWW, and LSW were reported by Nouman and Abrar (2013) in Lohi sheep.

The estimate of direct heritability for LSB (0.06) was low and in accordance with those reported by Mohammadi and Sattayi Mokhtari (2013) in Kermani sheep and Vatankhah *et al*. (2008) in Lori-Bakhtiari sheep. For TLWB and LMWLB, 4 and 7% of phenotypic variance, respectively, were explained by direct additive genetic variance. As pointed out by Rosati *et al*. (2002), TLBW measures the cumulative capacity of the ewe to produce lambs birth weight. The estimated direct heritability for TLWB in the present study was in agreement with that reported by Mokhtari *et al*. (2010) in Kermani sheep.

The estimate of the direct heritability for TLWW was consistent with those of Rashidi *et al*. (2011) in Moghani sheep, Van Wyk *et al*. (2003) in Elsenburg Dormer sheep and Ekiz *et al*. (2005) in Turkish Merino, but was lower than the estimates reported by Mokhtari *et al*. (2010) in Kermani sheep and Vatankhah *et al*. (2008) in Lori-Bakhtiari sheep. The TLWW combines the influences of reproductive and mothering ability of ewes, and pre-weaning growth and survival of lambs (Rashidi *et al*., 2011). Also, the estimated direct heritability for LSW (0.01) was in agreement with estimates by Rashidi *et al*. (2011) in Moghani sheep and Mokhtari *et al*. (2010) in Kermani sheep. In the literature, the heritability estimates for LSW is low and ranged from 0.01 to 0.07 (Hanford *et al*., 2005; Hanford *et al*., 2006; Safari *et al*., 2005). Our results indicate that, due to low direct heritabilities for investigated traits, opportunities to genetically improve reproductive performance in this breed would be limited.

Estimates of direct heritability for LMWLB and LMWLW traits in the present study (0.06 and 0.07, respectively) were the same. The direct heritability estimate for LMWLW was in accordance with the estimates of Rashidi *et al*. (2011) in Moghani sheep and Vatankhah *et al*. (2008) in Lori-Bakhtiari sheep (0.10), but higher estimates have also been reported (Mokhtari *et al*., 2010; Rosati *et al*., 2002). The heritability estimate for LMWLB was lower than those of Mokhtari *et al*. (2010) in Kermani sheep and Rashidi *et al*. (2011) in Moghani sheep. In general, the differences in genetic parameter estimates in various studies can be due to the type of model used (fixed and random effects), population studied, pedigree structure, data size and flock management.

The estimates of the ratio of permanent environmental variance to phenotypic variance (pe^2) for TLWB and LSW were 0.04 and 0.09, respectively. These values were consistent with those of Mokhtari *et al*. (2010) in Kermani sheep. Service sire effects on LSB, TLWB, TLWW, LMWLB and LMWLW accounted for 3% to 33% of phenotypic variance and were significant in Ghezel sheep. Fertilization, prenatal survival rates, and litter weight in several species have been shown to be affected by the service sire (Bromley *et al*., 2001; Nagamine and Sasaki, 2008; Rastogi *et al*., 2000; Robinson, 2008). A few estimates of service sire effects in sheep were found in the literature. The service sire effect ranged from 0.00 to 0.05 for litter weight weaned, average lamb weaning weight and total litter weight weaned in different sheep breed (Bromley *et al*., 2001; Vanimisetti *et al*., 2007). Estimates of service sire effects in the current study were thus particularly large for TLWW and LMWLW. It seems that genetic improvement for reproductive traits in this breed will be faster when both dams and sires are selected for the interested trait.

Low estimate of heritability for the studied traits can be due to the impact of environmental factors on their variability. On the other hand, the estimates may be affected by the model used for analysis. Some researchers have stated that the univariate threshold models are better for estimating genetic parameters and breeding value predicts of reproductive traits than the univariate linear models. In the current study, we applied linear animal model, therefore, estimating the variance-covariance components for these traits using threshold models and comparing with our findings is strongly recommended for further studies.

There are a few published papers on genetic trends for reproductive performance in sheep. In our study, direct genetic trends for investigated traits were not significant, except for LMWLB, which was negative, suggesting that there has been no measurable genetic improvement in these traits in Ghezel ewes over the period of this study. These results indicated that reproduction traits were not contributed in the selection index of this breed. Hanford *et al*. (2006) reported significant positive genetic trends for LSB and LSW in Polypay sheep. In general, direct genetic trend for LSB, TLWB and LMWLW was more regular than that of LSW, TLWW and LMWLW traits. This result may probably affected by mortality of multiple born lambs during weaning period. It seems that the selection on production traits (body weight at different ages in Ghezel sheep), due to their genetic correlation with reproduction traits, reproductive performances were minimally affected and consequently, expressed negative genetic trend for traits studied (Table 4). Estimates of direct genetic trend indicated that there was not significant genetic improvement in all studied traits and suggest that improvements in reproduction management would be the best available tool to improve reproduction in this flock.

We observed consistently low heritability estimates for litter size at birth, total litter weight at birth, litter mean weight per lamb born, litter size at weaning, total litter weight at weaning and litter mean weight per lamb weaned in Ghezel sheep. Based on the estimated genetic trends, selection has not resulted in genetic improvement in reproductive efficiency in this flock. Improvements in non-genetic factors and management, in the flocks including improvements in ewe nutrition before mating and in late pregnancy appear to be more likely to generate improvements in reproduction. The LMWLB and LMWLW had higher heritability estimates than other traits studied and have some potential to respond to selection to improve reproductive efficiency. Furthermore, permanent environmental and especially service sire effects were highly significant for the traits. It may propose that these effects should be taken in account in evaluations for reproductive traits in this breed.

Acknowledgments: The author wishes to thank the Breeding Station of Ghezel sheep for providing the data.

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