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Genetic analysis of reproductive characteristics in Iran-Black sheep

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ABSTRACT. This study was conducted to estimate genetic parameters and trends for reproduction traits using data collected at the breeding station of Iran-Black sheep during 1980 to 2004. 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 heritability estimates for LSB, TLWB, LMWLB, LSW, TLWW and LMWLW were 0.11, 0.07, 0.33, 0.08, 0.09 and 0.11, respectively. The permanent environmental effects had significant impact on all traits and ranged from 0.05 to 0.16. Effect of service sire was highly significant ($p < 0.01$) for all traits except LMWLW. Estimates of genetic correlations ranged from -0.76 (LSB-LMWLB) to 0.98 (LSB-LSW). Phenotypic and environmental correlations were generally lower than those of genetic correlations. Environmental correlations ranged from -0.55 (LSW-LMWLW) to 0.99 (LSB-LSW). Also, the estimated correlation for the effect of service sire ranged from -0.77 (LMWLB-TLWW) to 0.96 (LSB-LSW and LSB-TLWW). The results suggest that selection based on TLWB could be more effective than the other traits to enhance reproductive performance in Iran-Black ewes.

Keywords: Iran-Black sheep; reproduction traits; REML.

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Introduction

There are many native sheep breeds in Iran (27 breeds). Iranian native sheep are composed mainly of fat tailed, carpet-wool breeds unique to different regions (Farid, Makarechian, & Sefidbakht, 1977). Due to the high market demand for lamb and mutton in comparison to meat from beef cattle and goats, ovine meat production is the primary economic purpose, with wool and milk yield being of secondary importance. Based on the fact that the meat supply from native sheep does not meet current consumer demands, synthesizing new sheep breeds may be a practical approach to increase the efficiency of sheep production. Iran-Black sheep, originating from a crossing of Balouchi ewes with Chios rams, is a composite breed developed in 1975 at the Abbasabad sheep breeding station located in northeast of Mashhad, RazaviKhorasan province. This new breed is well adapted to harsh conditions (Rashidi, 2013). At the Abbasabad sheep breeding station, two main programs are given high priority: first, improvement of production efficiency and second, the dissemination of genetically superior animals into local flocks. The profitability of sheep breeding systems is greatly influenced by reproductive characteristics (Matos, Thomas, Gianola, Perez-Enciso, & Young, 1997). However, the most important component of the overall productivity of sheep is ewe productivity efficiency. In such case, improving the number of lambs weaned and weight of lambs weaned per ewe per year has been proposed to be the most economically important (Duguma, Schoeman, Cloete, & Jordaan, 2002; Olivier, Cloete, Schoeman, & Muller, 2005; Snyman, Olivier, Erasmus, & Van Wyk, 1997).

To increase economic returns from ewes, genetic improvement of ewe productivity traits is required; therefore, the selection objective should emphasize on these traits (Olivier et al., 2005). Further, to design the effective selection programs for improving the efficiency of ewe production, the knowledge of genetic parameters for ewe traits and the genetic relationships among the traits are of significant importance. Therefore, estimates for genetic parameters, selection criterion, response to selection, and construction of selection indexes are needed (Kamjoo, Baneh, Yousefi, Mandal, & Rahimi, 2014). Previous studies have shown that reproductive traits are not only influenced by the genes of the individual and the environment in which it is raised, but also by the service sire and the maternal environment (Maghsoudi, Torshizi, & Jahanshahi, 2009; Mokhtari, Rashidi, & Esmailizadeh, 2010).

Although there are many reports on estimation of genetic parameters for reproduction traits of sheep, there are currently no estimates of genetic parameters and trends for reproductive traits in Iran-Black sheep. Therefore, the objectives of the current study were to estimate, (i) genetic parameters including service sire and permanent environmental effects via univariate and multivariate analyses, and (ii) genetic trends and genetic progress for considered traits.

Material and methods

Data and flock management

Data and pedigree information were collected at the Abbasabad sheep breeding station which is located in northeast of Mashhad, RazaviKhorasan province (arid and hot climates) during the period 1980–2004. The data was from the first synthetic sheep breed in Iran originated from a crossing of Balouchi ewes with Chios rams and vice versa. Mating occurred from mid-August to September. A controlled mating strategy was designed. Mating ratio was one breeding ram to 10-12 ewes. Lambing began in mid-January and ended in February (Kamjoo et al., 2014). Lambs were weighed and ear-tagged shortly after birth and weaned at 90 days of age. In this study, investigated traits were classified as basic and composite. Traits considered as basic 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 (0, 1 or 2)), litter mean weight per lamb born (LMWLB) and litter mean weight per lamb weaned (LMWLW).Composite traits were total litter weight at birth per ewe lambing (TLWB, refers to the sum of the birth weights of all lambs born per ewe lambed) and total litter weight at weaning per ewe lambing (TLWW, refers to the sum of the weights of all lambs weaned per ewe lambed). A summary of data and statistical description of the investigated traits are presented in Table 1.

Table 1. Structure of pedigree and data set for reproductive traits of Iran-Black sheep.

Trait	LSB[a]	LSW	LMWLB (kg)	LMWLW(kg)	TLWB (kg)	TLWW (kg)
Animal in pedigree	1239	1202	1239	1202	1239	1202
No. records	2806	2827	2806	2827	2806	2827
No. sires	72	72	72	72	72	72
No. dams	612	613	612	613	612	613
No. service sires	92	98	92	98	92	98
Mean	1.57	1.48	3.88	23.94	5.86	34.33
S.D	0.63	0.59	0.83	5.11	1.98	12.68
Min	1	1	1.65	8.36	1.81	8.36
Max	5	4	6.7	43.63	16.42	110.89

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

Statistical analysis

Least squares analyses were used to determine fixed effects with significant effects on the traits (Statistical Analysis Software [SAS], 2004). Significant fixed effects ($p < 0.05$) as evidenced by GLM analysis were fitted in the subsequent models for estimating genetic parameters and consequently predict direct breeding values. All the fixed effects, except for lambing season for all traits and ewe age for LMWLW, were significant ($p < 0.01$) for all traits. Therefore, the final statistical model included lambing year in 24 classes (1980–2004) and ewe age at lambing in 6 classes (2–7 years old). The interaction between lambing year and ewe age was not significant therefore excluded from the final model analysis.

As indicated by Van Wyk, Fair, and Cloete (2003), the traits of TLWB, TLWW, LMWLB and LMWLW must be pre-adjusted for sex of lambs using multiplicative adjustment factors. Therefore, using least squares analysis, the adjustment factors were determined for the effect of sex on birth and weaning weight of lambs. Estimates of variance components and consequently genetic parameters were achieved by the Restricted Maximum Likelihood (REML) method applying a univariate repeatability linear model (Rashidi, Mokhtari, Esmailizadeh, & Fozi, 2011; Vatankhah & Talebi, 2008) using DMU 4.7 package (Madsen& Jensen, 2007), fitting the following univariate models for each trait as:

1) $y = \mathrm{Xb} + \mathrm{Z_a a} + \mathrm{e}$

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

3) $y = \mathrm{Xb} + \mathrm{Z_a a} + \mathrm{Z_s s} + \mathrm{e}$

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

where *y* is a vector of records on the respective traits; 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, Za, Zs and W stand for design matrices associating the corresponding effects with vector of y. The (co)variance structure for the random effects was:

$$\mathrm{Var}\begin{bmatrix} \mathrm{a} \\ \mathrm{s} \\ \mathrm{pe} \\ \mathrm{e} \end{bmatrix} = \begin{bmatrix} \mathrm{A}\sigma_a^2 & 0 & 0 & 0 \\ 0 & \mathrm{I_s}\sigma_s^2 & 0 & 0 \\ 0 & 0 & \mathrm{I_d}\sigma_{pe}^2 & 0 \\ 0 & 0 & 0 & \mathrm{I_n}\sigma_e^2 \end{bmatrix}$$

in which σ_a^2, σ_s^2, σ_{pe}^2 and σ_e^2 are direct additive genetic variance, service sire variance, permanent environmental variance related to repeated records of the ewes and residual variance, respectively. Hence $\mathrm{I_s}$, $\mathrm{I_d}$ and $\mathrm{I_n}$ are identity matrices with order equal to the number of sires, ewes and records, respectively. A is the numerator relationship matrix. It was assumed that additive genetic effects, service sire effects, permanent environmental effects related to repeated records of ewes and residual effects to be normally distributed with mean of zero. Additional random effects in the final model analysis were tested using log likelihood criterion (LogL).

The estimates of correlation were calculated using multivariate analysis applying the same model used for the univariate analysis. The fixed effects included in the multivariate and univariate animal models were the same. Also, repeatability (r: the correlation between performance records in different recordings) was estimated as follows:

$$\mathrm{r} = \frac{\sigma_a^2 + \sigma_{pe}^2}{\sigma_p^2}$$

Genetic trends were obtained by regression means of predicted breeding values on year of birth for each trait by using regression procedure of the SAS software package (SAS, 2004). Genetic progress was defined as difference of means of predicted breeding values for the last and first years.

Results and discussion

Fixed effects

The least squares means and standard errors of traits for Iran-Black sheep are shown in Table 2. The effects of ewe age (except for LMWLW) and year were significant (p < 0.01). The results show that there was a slight tendency for ewe productivity to improve with increasing age, reaching a maximum between four and six years of age due to differences in maternal effects, nursing and maternal behavior of ewe. Lambing season was not a significant effect on any trait and was excluded from the final model analysis.

Table 2. Least squares means (LSM)± standard error (S.E) for reproductive traits of Iran-Black sheep.

	LSB[a]	LSW	LMWLB (kg)	LMWLW (kg)	TLWB (kg)	TLWW (kg)
Lambing Year	**[b]	**	**	**	**	**
Lambing Season	ns	ns	Ns	ns	ns	ns
Ewe age	**	**	**	ns	**	**
2	1.36±0.06b	1.37±0.07c	3.91±0.08b	24.35±0.59	5.13±0.19c	33.05±1.47c
3	1.58±0.06a	1.58±0.07b	4.09±0.08a	24.85±0.59	6.22±0.19b	38.48±1.49b
4	1.63±0.06a	1.63±0.07ab	4.11±0.08a	24.87±0.58	6.47±0.20a	39.90±1.46a
5	1.64±0.07a	1.70±0.08a	4.15±0.09a	24.55±0.63	6.61±0.21a	41.20±1.57a
6	1.63±0.07a	1.62±0.08ab	4.20±0.10a	24.58±0.67	6.61±0.23a	39.58±1.67ab
7	1.54±0.08a	1.55±0.09b	4.19±0.11a	24.05±0.73	6.23±0.26ab	37.25±1.83b

[a]LSB, litter size at birth; TLWB, total litter weight at birth; LMWLB: litter mean weight per lamb born; LSW: litter size at weaning; TLWW: total litter weight at weaning and LMWLW: litter mean weight per lamb weaned. [b]* = p < 0.05, ** = p < 0.01, ns=not significant.

(Co)variance components and genetic parameters

Estimates of (co)variance components, heritability (h^2), ratio of variance due to permanent environmental effects to the total phenotypic variance (pe^2) and service sire variance as a proportion of phenotypic variance (s^2) for traits along with the most appropriate model (Table 3). Direct heritability for traits mentioned by significant model was low to moderate and ranged from 0.07 (TLWB) to 0.33 (LMWLB). For LSB, model 4 was significant. Based on the model, direct heritability, ratio of permanent environmental variance on phenotypic variance, service sire variance as a proportion of phenotypic variance and repeatability were 0.11, 0.05, 0.01, and 0.16, respectively.

For all traits, except for LMWLW, the model 4 was the most appropriate to estimate (Co)variance components and genetic parameters. Based on model 2 for LMWLW, direct heritability, ratio of permanent environmental variance on phenotypic variance, and repeatability were 0.11, 0.16, and 0.27, respectively. Hence, the estimates of repeatability for studied traits ranged from 0.14 (TLWB and TLWW) to 0.39 (LMWLB), respectively. The lower estimates of heritability, ratio of permanent environmental variance on phenotypic variance resulted in low estimates of repeatability for traits.

Table 3. Estimates of variance components and genetic parameters for reproductive traits of Iran-Black sheep (significant models are in bold).

Trait1	Model	$^b\sigma^2_a$	σ^2_{Pe}	σ^2_S	σ^2_e	σ^2_p	h^2_a	Pe^2	S^2	r	-2LogL	Sig.
LSB[a]	1	0.0573			0.3270	0.3843	0.15			0.15	107.356	
	2	0.0410	0.0193		0.3200	0.3803	0.11	0.05		0.16	103.468	
	3	0.0566		0.0048	0.3237	0.3851	0.15		0.01	0.15	103.056	
	4	0.0404	0.0193	0.0048	0.3166	0.3811	0.11	0.05	0.01	0.16	99.108	$p < 0.01$
LSW	1	0.0389			0.3031	0.3419	0.11			0.11	-153.559	
	2	0.0272	0.0162		0.2960	0.3395	0.08	0.05		0.13	-157.391	
	3	0.0383		0.0037	0.3006	0.3425	0.11		0.01	0.11	-156.478	
	4	0.0268	0.0163	0.0037	0.2934	0.3402	0.08	0.05	0.01	0.13	-160.384	$p < 0.01$
LMWLB	1	0.2925			0.4312	0.7238	0.40			0.40	1355.40	
	2	0.2335	0.0409		0.4263	0.7007	0.33	0.06		0.39	1352.51	
	3	0.2906		0.0049	0.4280	0.7235	0.40		0.01	0.40	1352.94	
	4	0.2342	0.0392	0.0046	0.4234	0.7014	0.33	0.06	0.01	0.39	1350.25	$p < 0.05$
LMWLW	1	6.9361			17.1487	24.0847	0.29			0.29	11217.46	
	2	2.5931	3.6286		16.4703	22.6921	0.11	0.16		0.27	11197.70	$p < 0.01$
	3	6.9303		0.0360	17.1219	24.0882	0.29		0.00	0.29	11217.36	
	4	2.5935	3.6246	0.0290	16.4490	22.6962	0.11	0.16	0.00	0.27	11197.63	
TLWB	1	0.4755			3.1206	3.5961	0.13			0.13	6342.83	
	2	0.2415	0.2802		3.0170	3.5388	0.07	0.08		0.15	6333.47	
	3	0.4627		0.0729	3.0744	3.6100	0.13		0.02	0.13	6334.34	
	4	0.2406	0.2712	0.0713	2.9724	3.5554	0.07	0.08	0.02	0.14	6325.25	$p < 0.01$
TLWW	1	18.2302			125.0106	143.2408	0.13			0.13	16360.72	
	2	13.0583	6.5471		122.4480	142.0534	0.09	0.05		0.14	16357.37	
	3	18.1405		1.7112	123.7410	143.5928	0.13		0.01	0.13	16356.69	
	4	12.8638	6.7406	1.7393	121.0595	142.4032	0.09	0.05	0.01	0.14	16353.10	$p < 0.01$

[a]LSB, litter size at birth; TLWB, total litter weight at birth; LMWLB: litter mean weight per lamb born; LSW: litter size at weaning; TLWW: total litter weight at weaning and LMWLW: litter mean weight per lamb weaned. $^b\sigma^2_a$ = 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 on phenotypic variance; s^2 = Service sire variance as a proportion of phenotypic variance; r=Repeatability; LogL= Log likelihood; and SE= Standard errors.

Correlation estimates

The estimates of phenotypic, genetic, permanent environmental and service sire correlation between the traits are presented in Table 4. Genetic correlation estimates ranged from -0.76 (between LSB and LMWLB) to 0.98 (between LSB and LSW). Phenotypic correlation estimates tended to be lower than those of genetic ones. Permanent environmental and service sire correlation between the studied traits was ranged from -0.77 to 0.99. Therefore, the range of correlations was similar for all correlation types.

Genetic trend

Estimates of direct genetic trend and genetic progress for ewe productivity traits in Iran-Black sheep obtained from multi-trait analyses are shown in Table 5. Direct genetic trend estimates were positive and highly significant ($p < 0.01$) for all traits (except for TLWW and LMWLW). Estimated direct genetic trend inferred that selection would be effective for the improvement of reproductive performance of this sheep breed. Also, Means of direct breeding value estimates by year of birth for traits mentioned are plotted in

Figures 1A, B, C, D, E, and F, respectively. As indicated in figures, the mean predicted breeding values of Iran-Black ewes generally appear to be progressive except for TLWW and LMWLW which seems to be flat (Figures D and F). For other traits, the mean predicted breeding values appear to be progressive from 1984 to 2004.

Table 4. Estimate of correlations between reproductive traits.

Trait 1	Trait 2	r_g	r_{pe}	r_s	r_e	r_p
LSB	LSW	0.98	0.99	0.96	0.80	0.83
LSB	TLWB	0.43	0.83	0.95	0.86	0.83
LSB	TLWW	0.67	0.63	0.96	0.01	0.67
LSB	LMWLB	-0.76	-0.13	-0.29	-0.50	-0.47
LSB	LMWLW	-0.49	-0.57	-	-0.40	-0.38
LSW	TLWB	0.74	0.76	0.85	0.74	0.72
LSW	TLWW	0.82	0.57	0.95	0.89	0.85
LSW	LMWLB	-0.60	-0.23	-0.61	-0.42	-0.39
LSW	LMWLW	-0.34	-0.58	-	-0.42	-0.37
LMWLB	LMWLW	0.89	0.95	-	0.48	0.54
LMWLB	TLWB	0.32	0.31	-0.09	-0.07	0.05
LMWLB	TLWW	-0.08	0.66	-0.77	-0.25	-0.13
LMWLW	TLWB	0.32	0.13	-	-0.25	-0.13
LMWLW	TLWW	0.28	0.33	-	-0.01	0.14
TLWB	TLWW	0.92	0.88	0.95	0.68	0.71

[a]LSB, litter size at birth; TLWB, total litter weight at birth; LMWLB: litter mean weight per lamb born; LSW: litter size at weaning; TLWW: total litter weight at weaning and LMWLW: litter mean weight per lamb weaned. [b]r_g; genetic correlation, r_{pe}; correlation due to permanent environmental effects of ewe, r_s; correlation due to service sire effect and r_e; environmental correlation, r_p; Phenotypic correlation.

Table 5. Genetic trend and genetic progress for reproduction traits of Iran-Black sheep.

Trait	GT±S.E.[b]	p value	GP
LSB[a] (No.)	0.010±0.001	<0.0001	0.192
LSW (No.)	0.010±0.001	<0.0001	0.177
TLWB (g)	0.027±0.002	<0.0001	0.567
TLWW (g)	-0.004±0.002	0.09	-0.067
LMWLB (g)	0.188±0.019	<0.0001	3.440
LMWLW (g)	-0.005±0.007	0.5	-0.198

[a]LSB, litter size at birth; TLWB, total litter weight at birth; LMWLB: litter mean weight per lamb born; LSW: litter size at weaning; TLWW: total litter weight at weaning and LMWLW: litter mean weight per lamb weaned. [b]GT: Genetic Trend, GP: Genetic Progress.

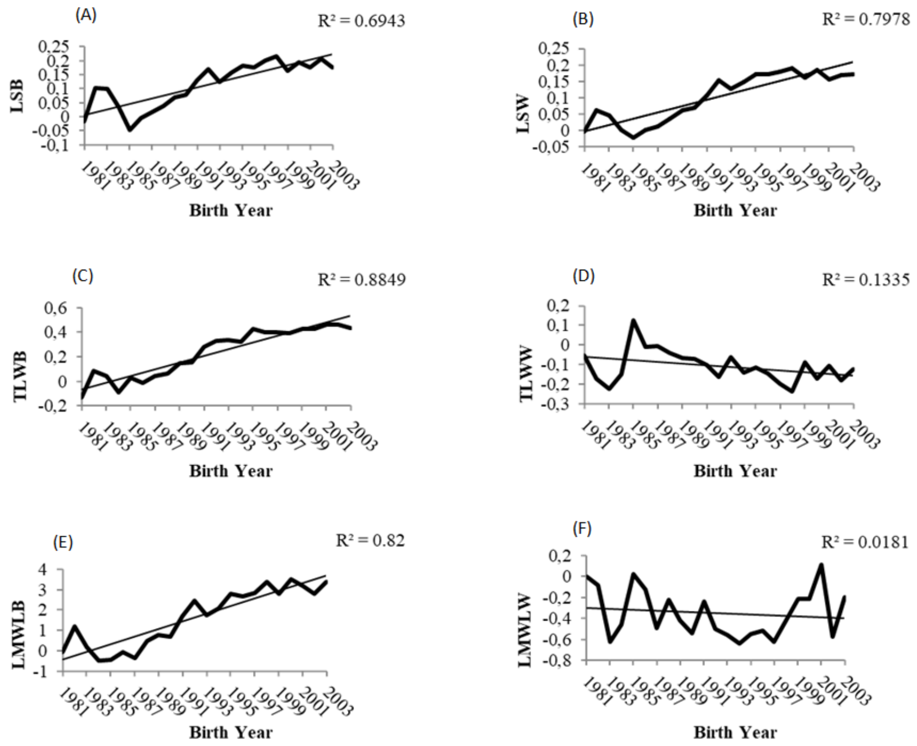

Figure 1. Direct trend of mean breeding values by year of birth for LSB, LSW, TLWB, TLMW, LMWLB and LMWLW traits in Iran-Black sheep.

The significant influence of lambing year on reproductive traits for different sheep breeds has been previously reported (Boujenane, Kerfal, & Khallouk, 1991; Bromley, Van Vleck, & Snowder, 2001; Ekiz, Özcan, Yilmaz, & Ceyhan, 2005; Vatankhah & Talebi, 2008). There was a slight tendency for the productivity of ewes to improve with aging, especially reaching a maximum between four and six years of age. The significant effect age on maternal effects, nursing and maternal behavior of ewe were discussed by Nouman and Abrar (2013) and reproductive efficiency of ewes from six years old onwards may tend to decrease. Decreasing reproductive performance after approximately 5 parities can be explained by an increase in twinning rate and conception rate with age (Fourie & Heydenrych, 1983). The results from this study were in agreement with those reported by Baneh, Hafezian, Rashidi, Gholizadeh, and Rahimi (2009). As reported by Ekiz et al. (2005), effect of ewe age on reproductive traits of different sheep breeds is common. Also, Nouman and Abrar (2013) showed significant effects of lambing year and flock on TLWB, LSB, TLWW, and LSW in Lohi sheep.

For Iran-Black sheep, the estimate of direct heritability of LSB (0.11) was similar with that reported by Rashidi et al. (2011) in Moghani sheep. This value for LSW (0.05) was lower than LSB. Direct heritability estimate of LSW for other sheep breeds has been well documented in the literature (Hanford, Van Vleck, & Snowder, 2006; Hanford, Van Vleck, & Snowder, 2005; Safari, Fogarty, & Gilmour, 2005). The highest value of direct heritability was obtained for LMWLB (0.33) including the possibility of genetic change in the trait to improve lambs' birth weight. Lower estimates were reported by Rashidi et al. (2011) in Moghani sheep and Mokhtari et al. (2010) in Kermani sheep. Also, direct heritability of LMWLW (0.11) was in agreement with the estimate of Vatankhah and Talebi (2008) in Lori-Bakhtiari sheep (0.10) but lower than estimates reported by Mokhtari et al. (2010). The potential of ewes to produce lambs' birth weight regardless of the number of lambs born can be indicated by TLWB. In the present study, estimated direct heritability of TLWB (0.7) was in agreement with those reported by Rashidi et al. (2011) in Moghani sheep. Direct heritability estimates for TLWB were reported in the literature and varied from 0.05 to 0.40 (Ekiz et al., 2005). The combined effects of reproductive and mothering ability of ewes, pre-weaning growth and survival of lambs are indicated by TLWW (Rashidi et al., 2011). Direct heritability estimate of TLWW in the current study (0.07) was consistent with those of Van Wyk et al. (2003) and Ekiz et al. (2005).

As indicated in Table 3, service sire and permanent environmental effects related to repeated records of ewe had significant effect on reproductive performances of Iran-Black ewes. The service sire effect for all traits, accounted for 1 to 2%, was approximately equal to zero but highly significant. As shown in the literature, service sire effect may affect fertilization, prenatal survival rate and litter weight in several species (Nagamine & Sasaki, 2008; Robinson, 2008). Bromley et al. (2001) indicated the significant service sire effect, accounted for 0 to 3%, for litter weight weaned in Columbia, Polypay, Rambouillet, and Targhee sheep. Also, Vanimisetti, Notter, and Kuehn (2007) reported the service sire effect of 0 to 5% for average lamb weaning weight and total litter weight weaned Katahdin sheep. However, our estimate of service sire effect in Iran-Black sheep falls within the range of the values reported in the literature.

The estimated fraction of variance due to permanent environmental effects of ewe for investigated traits was highly significant and ranged from 0.05 to 0.16. These results were consistent with those reported by Rashidi et al. (2011) in Moghani sheep. Also, Hanford et al. (2006) reported lower estimates of fraction of variance due to permanent environmental effects for LSB (0.01) and LSW (0.04) in Polypay sheep. Hence, repeatability estimates of Iran-Black sheep in the present study was approximately similar with those reported by Rashidi et al. (2011) in Moghani sheep and Mokhtari et al. (2010) in Kermani sheep. Although estimated repeatability of LSB and LSW in the present study was higher than those reported by Rao and Notter (2000), Ekiz et al. (2005), Hanford et al. (2005) and Vatankhah and Talebi (2008) it was in agreement with Matos et al. (1997) who reported a repeatability of 0.21 for LSB in Rambouillet sheep. Generally, repeatability estimates for the investigated traits shows that the accuracy of selection particularly for LMWLB and LMWLW on the first lambing would be mediocre.

The estimates of genetic correlation among LSB and LSW with LMWLB and LMWLW were −0.74, −0.49 and -0.60 and -0.34, respectively. The negative values indicate that lower number of lambs in litter and weaning was associated with heavier birth weights and weaning weights of lambs. These values were in agreement with Mokhtari et al. (2010) in Kermani sheep, who reported negative correlation in terms of genetic effects. Also, the results were consistent with those of Rashidi et al. (2011) in Moghani sheep. LSB and LSW had highly positive genetic correlation with TLWB and TLWW (see Table 4) which suggests that indirect selection for LSB and LSW may be functional through selection for TLWB and/or TLWW. Also, estimated genetic and phenotypic correlation between LMWLB and LMWLW were greatly positive which was higher than those estimated by Vatankhah and Talebi (2008) and Mokhtari et al. (2010). The high genetic correlation estimate between TLWB and TLWW (0.92) indicates that the same genes are liable for heavier lamb weight, mothering ability of the ewes and milk production from birth to weaning.

Permanent environmental correlation estimates between reproductive traits were different and ranging from -0.58 to 0.99. The negative permanent environmental correlation estimate indicate that reducing number of lambs born and consequently lighter lambs at birth and weaning may affected by adverse temporary environmental effects. These estimates were approximately higher than the genetic correlations. Also the results were similar to those reported Van Wyk et al. (2003) in Elsenburg Dormer sheep and Rashidi et al. (2011) in Moghani sheep. The low estimates of permanent environmental effects, which make denominators of correlation terms extremely small, made high permanent environmental correlation estimates (Bromley et al., 2001; Vanimisetti et al., 2007).

No reported estimates of the service sire correlation were found in the literature. The estimated service sire correlation for LSB, LSW and LMWLB and LMWLB and TLWW in the present study indicates that undesirable service sire effects have a tendency to reduce numbers of lambs born and weaned.

Direct genetic trend estimates were positive and highly significant ($p < 0.01$) for all investigated traits, except for TLWW and LMWLW (Table 5). Estimated direct genetic trend suggests selection would be effective for the enhancement of reproduction traits of this sheep breed. However, no estimate of the direct genetic trend and genetic progress was found in the literature. The estimated direct genetic trend value for LSB and LSW in our study was about 0.01 and 0.01 lambs per year. These results were lower than those reported by Hanford et al. (2006) in Polypay sheep. Low rates of genetic trends could be explained because selection for investigated traits is limited and the selection that was applied was ineffective due to the low heritabilities.

Conclusion

Permanent environmental effects related to repeated records of ewes and service sire effects were highly significant. In addition, impacts of environmental effects on the traits resulted in low direct heritability estimates indirectly suggest that management may have a more effectiveness and faster effect. In such case, TLWB is a composite trait includes lamb's weight, lamb's survival in birth as well as maternal ability of the ewe. The positive genetic correlation estimates between TLWB and the other studied traits indirectly suggest selection for TLWB would be effective and could enhance the reproductive performance of the Iran-Black ewes.

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