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Estimation of genetic parameters for reproductive traits in Mehraban sheep

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ABSTRACT: Genetic parameters for basic and composite reproductive traits in Mehraban sheep were estimated. Data included 10 257 records on reproductive performances of 5813 lambs from 69 sires and 603 dams which were collected from 1994 to 2011 in the Mehraban breeding station in Hamedan province, western Iran. Studied traits were litter size at birth (LSB), litter size at weaning (LSW), litter mean weight per lamb born (LMWLB), litter mean weight per lamb weaned (LMWLW), total litter weight at birth (TLWB), and total litter weight at weaning (TLWW). Test of significance to include fixed effects in the statistical model was performed using the GLM procedure of SAS. Genetic parameters were estimated with univariate and bivariate repeatability animal models using WOMBAT program. Direct heritability estimates were 0.16, 0.14, 0.03, 0.16, 0.06, and 0.18 for LSB, LSW, LMWLB, LMWLW, TLWB, and TLWW, respectively, and corresponding repeatabilities were 0.02, 0.01, 0.73, 0.41, 0.27, and 0.03. The estimate for animal-dependent permanent environmental variance ranged from 0.01 ± 0.04 for LMWLW to 0.23 ± 0.04 for LSB. Genetic correlation estimates between traits ranged from −0.98 for LSB–LMWLW to 0.99 for LSB–TLWB. Phenotypic and environmental correlations were generally lower than genetic correlations. Phenotypic correlations ranged from −0.50 for LSB–LMWLB to 0.85 for LMWLW–TLWW. Environmental correlations ranged from −0.45 for LSB–LMWLB to 0.87 for LMWLW–TLWW. The results suggested that indirect selection based on TLWW could improve the reproductive performance in Mehraban ewes more effectively than if based on the other traits.

Keywords: heritability; genetic correlation; litter size; fat-tailed sheep

INTRODUCTION

In the world of agriculture, sheep breeding is one of the most important branches of livestock in terms of the number of animals and the value of the products. Sheep are important due to having several desirable features such as compromises in different environmental conditions, low demand for food, and value of sheep products (Ensminger and Parker 1986). Sheep products constitute an important component of livestock production in Iran. There are nearly 50 million sheep with more than 20 breeds in Iran (Vatankhah et al. 2004).

The aims of breeding programs are to maximize the rate of genetic progress for economic traits in livestock species. Reproductive traits are the most important traits in all sheep production systems (Gallivan 1996; Matika et al. 2003). Reproductive efficiency is one of the most important factors affecting production rate in livestock and reproductive traits are the most important traits affecting profitability in sheep breeding (Hanford et al. 2003) and improvement of these traits leads to more efficient lamb production. The improvement of environmental conditions (management and nutrition) and the use of genetic selection were considered as two main ways for improving reproductive efficiency in sheep (Fogarty 1995).

Previously, researchers identified the increasing number of lambs at birth or weaning as the only useful criterion to improve reproductive efficiency or net reproductive rate and total weight of lamb(s) weaned per ewe joined or per lambing was proposed as the trait of interest in sheep breeding (Fogarty 1995; Cloete et al. 2004). Therefore, ewe productivity could be improved by increasing the number and weight of lambs weaned per ewe within a specific year (Duguma et al. 2002).

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The increase in the number of reared lambs per maintained ewes can be considered as the increase of fertility, lambing, number of lambs at birth and lamb weaning.

Estimates of genetic parameters have been published for reproductive characteristics of different sheep breeds by several authors (van Wyk et al. 2003; Ekiz et al. 2005; Hanford et al. 2006; Ghavi Hossein-Zadeh and Ardalan 2010; Mokhtari et al. 2010; Rashidi et al. 2011; Amou Posht-e-Masari et al. 2013; Mohammadabadi and Sattayimokhtari 2013).

However, genetic parameters for reproductive traits of Mehraban sheep have not been estimated until now. Hence, the reliable estimates of genetic parameters are needed for constructing breeding programs in this breed of sheep. Thus, the objective of this study was to estimate heritability, repeatability, and genetic correlations of reproductive traits for Mehraban sheep which are essential for developing efficient selection programs for the improvement of reproduction.

MATERIAL AND METHODS

Data. The data set and pedigree information used in this research were reproductive traits of Mehraban ewes collected at the Breeding Station of Mehraban Sheep, located at Kabudarahang City, Hamedan province, Iran during a 18-year period (1994–2011). Data included 10 257 records on reproductive performance of 5813 lambs from 69 sires and 603 dams. This breed of sheep originates from the western province of Iran known as Hamedan and is adapted to harsh and rocky environments. The Mehraban (approximately three million heads) is the predominant breed in this province, reared primarily for meat production. Mehraban is a fat-tailed carpet wool sheep with light brown, cream or grey colour, with dark face and neck. Ewes were exposed to rams at about 18 months of age. There was a controlled mating system and each mating group including 10–15 ewes was set aside to a ram. Rams were selected at one year of age from some purebred flocks and were assigned to local flocks under supervision of the Breeding Station of Mehraban Sheep. The mating period was from the end of September to the end of October. Lambing was commenced in March. During the lambing season, the ewes were indoors and carefully managed. After lambing, the ewes and their lamb(s) were placed in separate pens and kept there for a few days, depending on the number of lambs born and the ewe's rearing ability. Then a flock composed of suckling lambs and their dams was formed. During the suckling period, lambs were kept indoors and additionally fed with hay grass. Ewes were kept in the flock up to 7 years of age. Ewes usually give birth to lambs three times every two years. All lambs were weighed and ear tagged within 12 h after the birth. The lambs were weaned at around 90 days of age. Flocks were grazing during the daytime and housed at night.

Studied traits. The analyzed traits can be classified as basic and composite traits. Basic traits were litter size at birth (LSB), litter size at weaning (LSW), litter mean weight per lamb born (LMWLB), and litter mean weight per lamb weaned (LMWLW). LSB was the number of lambs born alive per ewe lambing (1, 2) and LSW was the number of lambs weaned per ewe lambing (0, 1, 2). LMWLB and

Table 1. Descriptive statistics of data used in the analysis

	Traits					
	LSB	LSW	LMWLB (kg)	LMWLW (kg)	TLWB (kg)	TLWW (kg)
No. of records	10 275	10 275	10 275	10 275	10 275	10 275
Mean (kg)	1.12	0.76	3.67	22.07	4.35	28.04
SD (kg)	0.33	0.72	0.76	4.24	1.28	12.52
CV (%)	29.46	94.73	20.74	19.21	29.33	44.65
Min.	1	0	1.4	9	1.4	9
Max.	2	3	6	35.70	15	105

LSB = litter size at birth, LSW = litter size at weaning, LMWLB = litter mean weight per lamb born, LMWLW = litter mean weight per lamb weaned, TLWB = total litter weight at birth, TLWW = total litter weight at weaning, SD = standard deviation, CV = coefficient of variation

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LMWLW were the average weights of lambs from the same parity at birth and weaning, respectively. Composite traits were total litter weight at birth per ewe lambing (TLWB) and total litter weight at weaning per ewe lambing (TLWW). TLWB refers to the sum of the birth weights of all lambs born per ewe lambed and TLWW refers to the sum of the weights of all lambs weaned per ewe lambed.

Statistical analyses. Fixed factors affecting reproductive traits were identified by preliminary analysis using the GLM procedure of SAS (Statistical Analysis System, Version 9.1, 2003). The fixed effects included in the final statistical models were flock-year-season, lamb sex in 2 classes (male and female), dam age at lambing in 6 classes (2–7 years), and interaction between them for all traits as well as effect of birth type in 3 classes (single, twin, and triplet) for LBWLW, LMWLW, TLWB, and TLWW. Lamb age at weaning (in days) was fitted as a covariate for LMWLW and TLWW. Descriptive statistics of the data set is shown in Table 1. Also pedigree information of the Mehraban sheep is presented in Table 2.

The variance components for the investigated traits were estimated by restricted maximum likelihood method, using WOMBAT (2006) program using the following repeatability animal model:

$$Y = \mathbf{X}b + \mathbf{Z}a + \mathbf{W}pe + e$$

where:

Y = vector of observations
b = vector of fixed effects
a = vector of direct additive genetic effects
pe = vector of permanent environmental effects
e = vector of residual effects
$\mathbf{X}, \mathbf{Z}, \mathbf{W}$ = incidence matrices relating the corresponding effects to observations

Repeatability (r) was calculated as:

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

where:

σ_a^2 = additive genetic variance
σ_{pe}^2 = permanent environmental variance
σ_p^2 = phenotypic variance

Genetic, phenotypic, and environmental correlations were estimated using bivariate analyses with the same fixed effects fitted in univariate models.

RESULTS AND DISCUSSION

Fixed effects. The Least Squares Means and their standard errors are presented in Table 3. Flock-year-

Table 2. Characteristics of the pedigree structure

	Traits					
	LSB	LSW	LMWB	LMWW	TLWB	TLWW
No. of records	10 257	10 257	10 257	10 257	10 257	10 257
No. of ewes with 1 record	5 813	5 813	5 813	5 813	5 813	5 813
No. of ewes with 2 records	3 221	3 221	3 221	3 221	3 221	3 221
No. of ewes with 3 records	1 533	1 533	1 533	1 533	1 533	1 533
No. of ewes with 4 records	590	590	590	590	590	590
No. of ewes with 5 records	260	260	260	260	260	260
No. of ewes with 6 records	79	79	79	79	79	79
No. of sire of the ewes	69	69	69	69	69	69
No. of dam of the ewes	603	603	603	603	603	603
No. of dam of the ewes with records	578	578	578	578	578	578
No. of animals with sire unknown	5 445	5 445	5 445	5 445	5 445	5 445
No. of animals with dam unknown	5 126	5 126	5 126	5 126	5 126	5 126
No. of animals with both parents unknown	4 817	4 817	4 817	4 817	4 817	4 817
No. of animals with records and both parents unknown	4 723	4 723	4 723	4 723	4 723	4 723

LSB = litter size at birth, LSW = litter size at weaning, LMWLB = litter mean weight per lamb born, LMWLW = litter mean weight per lamb weaned, TLWB = total litter weight at birth, TLWW = total litter weight at weaning

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Table 3. Fixed effects of environmental factors on reproductive traits in Mehraban sheep

Fixed effects	Class	Traits					
		LSB	LSW	LMWLB	LMWLW	TLWB	TLWW
Flock-year-season		**	**	**	**	**	**
Lamb sex		ns	ns	**	**	**	**
	male			3.79 ± 0.01[a]	22.24 ± 0.16[a]	4.51 ± 0.02[a]	28.55 ± 0.24[a]
	female			3.58 ± 0.01[b]	21.90 ± 0.15[b]	4.20 ± 0.02[b]	27.52 ± 0.23[b]
Birth type		–	–	**	**	**	**
	single			3.89 ± 0.001[a]	21.94 ± 0.06[c]	3.89 ± 0.01[c]	21.94 ± 0.06[c]
	twins			2.98 ± 0.001[b]	22.40 ± 0.10[b]	5.96 ± 0.03[b]	44.77 ± 0.21[b]
	triplet			2.48 ± 0.05[c]	23.16 ± 0.33[a]	7.43 ± 0.15[a]	69.56 ± 0.99[a]
Dam age		ns	ns	*	*	*	*
	2			3.67 ± 0.001[c]	21.12 ± 0.19[bc]	4.28 ± 0.02[b]	26.75 ± 0.28[d]
	3			3.76 ± 0.01[b]	22.08 ± 0.20[ab]	4.35 ± 0.02[ab]	28.42 ± 0.36[a]
	4			3.87 ± 0.01[a]	22.41 ± 0.24[a]	4.40 ± 0.03[a]	28.84 ± 0.29[a]
	5			3.74 ± 0.01[bc]	22.83 ± 0.35[a]	4.31 ± 0.04[ab]	27.75 ± 0.50[b]
	6			3.69 ± 0.02[bc]	21.95 ± 0.60[b]	4.32 ± 0.06[ab]	26.08 ± 0.86[b]
	7			3.66 ± 0.005[c]	20.59 ± 1.08[c]	4.18 ± 0.10[c]	23.838 ± 1.44[c]
Lamb age at weighing		–	–	–	**	–	**
					0.04 ± 0.003		0.28 ± 0.002

LSB = litter size at birth, LSW = litter size at weaning, LMWLB = litter mean weight per lamb born, LMWLW = litter mean weight per lamb weaned, TLWB = total litter weight at birth, TLWW = total litter weight at weaning

*significant at $P < 0.05$, **significant at $P < 0.01$, ns = non-significant ($P > 0.05$)

[a–c]different letters within the same column indicate significant differences

season significantly affected all traits ($P < 0.01$). The significant influence of lambing year can be described by the variation in the climate conditions and dependence of sheep to pastures, management and breeding conditions of mothers and lambs feeding in various years. Significant effects of year on reproductive traits have been reported by several authors (Vatankhah et al. 2008; Mohammadi et al. 2012; Amou Posht-e-Masari et al. 2013; Mohammadabadi and Sattayimokhtari 2013). All traits except LSB and LSW were significantly influenced by lamb sex, birth type ($P < 0.01$), and dam age ($P < 0.05$). LMWLW and TLWW were significantly influenced by lamb age ($P < 0.01$). The mean value for males was higher than for females for LMWLB, LMWLW, TLWB, and TLWW, which is consistent with the results reported by Vatankhah and Talebi (2008). LMWLB for single-born lambs was significantly ($P < 0.05$) higher than that for the twin- and triplet-born lambs. This result is similar to the results reported by Vatankhah et al. (2008) and can be explained by low body weight, unfavourable body condition, and a limited amount of available milk for twin and triplet lambs. Triplet-born lambs showed higher performance for LMWLW, TLWB, and TLWW than single- and twin-born. The highest performance was recorded approximately in 3-year-old dams for LMWLB, LMWLW, TLWB, and TLWW. The lowest performance was recorded in 2- and 7-year-old dams for LMWLB and 7-year-old dams for LMWLW, TLWB, and TLWW. There was a tendency for the productivity of ewes to improve with age, generally reaching a maximum between three and six years of age for LMWLB, LMWLW, TLWB, and TLWW. There was a general tendency for LMWLB, LMWLW, TLBW, and TLWW to improve with an increase in dam age. Differences in maternal effects and maternal behaviour of ewe at different ages are the reasons for the significant effects of dam age on reproductive traits. Significant effects of dam age on reproductive traits of sheep have been reported in literature (Ceyhan et al. 2009; Rashidi et al. 2011; Mohammadi et al. 2012; Amou Posht-e-Masari et al. 2013; Mohammadabadi and Sattayimokhtari 2013).

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Table 4. Variance components and genetic parameter estimates for reproductive traits

	LSB	LSW	LMWB	LMWW	TLWB	TLWW
σ_a^2	0.02	0.03	0.01	0.72	0.03	1.88
σ_{pe}^2	0.04	0.02	0.05	0.00004	0.03	0.45
σ_p^2	0.15	0.20	0.31	4.42	0.45	10.45
σ_e^2	0.09	0.15	0.25	3.70	0.39	8.12
h_a^2 ± SE	0.16 ± 0.04	0.14 ± 0.04	0.03 ± 0.01	0.16 ± 0.04	0.06 ± 0.04	0.18 ± 0.05
pe^2 ± SE	0.23 ± 0.04	0.08 ± 0.04	0.16 ± 0.04	0.001 ± 0.04	0.07 ± 0.04	0.04 ± 0.05
r	0.40	0.25	0.19	0.16	0.13	0.22

σ_a^2 = additive genetic variance, σ_{pe}^2 = permanent environmental variance, σ_e^2 = residual variance, σ_p^2 = phenotypic variance, h_a^2 = direct heritability, pe^2 = ratio of permanent environmental variance to phenotypic variance, r = repeatability, SE = standard error, LSB = litter size at birth, LSW = litter size at weaning, LMWLB = litter mean weight per lamb born, LMWLW = litter mean weight per lamb weaned, TLWB = total litter weight at birth, TLWW = total litter weight at weaning

Variance components and genetic parameters. Estimates of variance components, heritability, ratio of permanent environmental variance to phenotypic variance, and repeatability for each trait are shown in Table 4. The estimate of direct heritability for LSB (0.16) was higher than the estimates reported by previous authors (Rashidi et al. 2011; Mohamadi et al. 2012; Amou Posht-e-Masari et al. 2013; Mohammadabadi and Sattayimokhtari 2013).

Direct heritability estimate for LSW was 0.14, which was in the range of estimates reported by previous authors. Heritability estimate for this trait varied from 0.01 to 0.189 (Bromley et al. 2001; Rosati et al. 2002; van Wyk et al. 2003; Vanimisetti et al. 2007; Ceyhan et al. 2008; Amou Posht-e-Masari et al. 2013). Lower heritability for LSW, compared with the heritability estimate for LSB, suggested that the loss of lambs from birth to weaning is influenced mainly by environmental factors such as a particular disease and mortality of lambs.

The estimate of direct heritability for LMWLB was 0.03. The reported estimates of heritability for LMWLB were 0.47, 0.07, and 0.13 in Shall sheep (Amou Posht-e-Masari et al. 2013), Moghani sheep (Rashidi et al. 2011), and in Kermani sheep (Mokhtari et al. 2010), respectively, i.e. they were higher than the current estimate. Lower heritability estimate for LMWLB showed that this trait has been more affected by environmental factors and by the genotypes of lambs than by the own genotypes of dams. The selection of superior animals probably has led to a lower genetic variance of the desired trait (Falconer and Mackay 1996; Matika et al. 2003). The estimate of direct heritability for LMWLW (0.16) was in the range of estimates reported by previous authors (Mokhtari et al. 2010; Rashidi et al. 2011; Amou Posht-e-Masari et al. 2013).

TLWB shows the reproductive potential of the ewes for the weight of lambs born per birth regardless of their number (Rosati et al. 2002; Vatankhah et al. 2008; Mokhtari et al. 2010; Rashidi et al. 2011). Direct heritability of TLWB (0.06) was identical to the estimated value of this trait by Mokhtari et al. (2010) in Kermani sheep (0.06) and it was lower than that reported in the literature (Rashidi et al. 2011; Mohamadi et al. 2012; Amou Posht-e-Masari et al. 2013; Mohammadabadi and Sattayimokhtari 2013). The low heritability of the reproductive traits indicates that a direct selection based on each of these traits does not considerably improve reproductive efficiency in this population.

TLWW is an economically important trait that reflects the reproductive and maternal ability of the ewe for lamb survival and growth during the pre-weaning period (Rashidi et al. 2011). The heritability estimate for TLWW was 0.18. Mokhtari et al. (2010) reported that the direct heritability for this trait was 0.18 which was the same value as calculated in the present research. This estimate was in the range of 0.03–0.4 as reported by several authors (Rosati et al. 2002; van Wyk et al. 2003; Mohamadi et al. 2012; Amou Posht-e-Masari et al. 2013; Mohammadabadi and Sattayimokhtari 2013). The heritability of TLWW was higher than of the other traits, which may be due to genetic variation in this trait according to the increase in the weaning weight of lambs (Mokhtari et al. 2010; Rashidi et al. 2011). The higher heritability

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estimate for TLWW than for TLWB indicated that selection based on TLWW would be more effective.

The low estimates of heritability for reproductive traits in this study may be attributed to the high phenotypic variance arising from a large environmental variation. This therefore implies that much of the improvement in reproductive traits could be attained by the improvement of production environment, such as nutrition of ewes before mating and after pregnancy, rather than by the genetic selection.

The ratio of permanent environmental variance to phenotypic variance estimates for the investigated traits ranged from 0.01 for LMWLW to 0.23 for LSB. Estimates of the ratio of permanent environmental variance to phenotypic variance were lower than the estimates of direct heritability for LSW, LMWLW, and TLWW traits, suggesting that additive genetic effects on these traits are more significant. These results are consistent with reports of Rashidi et al. (2011) and Mohammadi et al. (2012). On the other hand, estimated ratios of permanent environmental variance to phenotypic variance for LSB, LMWLB, and TLWB were greater than the estimated direct heritabilities for these traits. This result is consistent with the reports of Amou Posht-e-Masari et al. (2013) and Mohammadabadi and Sattayimokhtari (2013).

Repeatability estimates were 0.40, 0.25, 0.19, 0.16, 0.13 and 0.22 for LSB, LSW, LMWLB, LMWLW, TLWB, and TLWW, respectively. These estimates are generally similar to the reports of Amou Posht-e-Masari et al. (2013) and Mohammadabadi and Sattayimokhtari (2013) in different sheep breeds. Repeatability estimates for LSB, LSW, LMWLB, TLWB, and TLWW were higher than the heritability estimates. Therefore, the accuracy of selection for these traits using the first lambing record can be high as repeatability evaluates the correlation between performance records in repeated lambing of the ewe. Repeatability estimate for LMWLW was equal to heritability estimate, due to the low ratio of permanent environmental variance to phenotypic variance. Therefore, we can say that the permanent effects of observations have a genetic aspect. Repeatability estimates varied from low to moderate; therefore obtaining more records may lead to achieving a higher accuracy, as the prediction accuracy is a function of the repeatability estimate and the number of records.

Correlation estimates. Estimates of direct genetic, phenotypic, permanent environmental, and

Table 5. Estimation of direct genetic, phenotypic, permanent environmental, and residual correlations between reproductive traits

Trait 1	Trait 2	Correlation			
		direct genetic	phenotypic	permanent environmental	residual
LSB	LSW	0.90 ± 0.10	0.59 ± 0.01	0.67 ± 0.12	0.53 ± 0.01
LSB	LMWLB	–0.004 ± 0.58	–0.50 ± 0.01	–0.99 ± 0.11	–0.45 ± 0.02
LSB	LMWLW	–0.98 ± 0.12	0.09 ± 0.001	0.99 ± 0.06	0.39 ± 0.03
LSB	TLWB	0.99 ± 0.41	0.05 ± 0.01	–0.54 ± 0.28	0.03 ± 0.01
LSB	TLWW	0.11 ± 0.22	–0.04 ± 0.01	–0.63 ± 0.36	0.02 ± 0.01
LSW	LMWLB	–0.19 ± 0.76	–0.31 ± 0.01	–0.83 ± 0.19	–0.24 ± 0.02
LSW	LMWLW	–0.97 ± 0.31	–0.39 ± 0.01	–0.99 ± 0.16	–0.29 ± 0.02
LSW	TLWB	0.90 ± 0.75	–0.06 ± 0.01	–0.59 ± 0.28	–0.07 ± 0.01
LSW	TLWW	0.14 ± 0.18	0.06 ± 0.02	–0.67 ± 0.65	0.12 ± 0.02
LMWLB	LMWLW	0.41 ± 0.51	0.07 ± 0.01	0.99 ± 0.13	0.02 ± 0.01
LMWLB	TLWB	nc	nc	nc	nc
LMWLB	TLWW	0.29 ± 0.48	0.03 ± 0.01	0.28 ± 0.39	–0.02 ± 0.01
LMWLW	TLWB	0.26 ± 0.25	0.05 ± 0.01	0.69 ± 0.12	0.02 ± 0.01
LMWLW	TLWW	0.86 ± 0.14	0.85 ± 0.004	0.99 ± 0.59	0.87 ± 0.005
TLWB	TLWW	0.29 ± 0.29	0.02 ± 0.01	–0.02 ± 0.54	–0.01 ± 0.01

LSB = litter size at birth, LSW = litter size at weaning, LMWLB = litter mean weight per lamb born, LMWLW = litter mean weight per lamb weaned, TLWB = total litter weight at birth, TLWW = total litter weight at weaning, nc = non-converged

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residual correlations are shown in Table 5. Direct genetic correlation estimates between reproductive traits ranged from –0.98 for LSB–LMWLW to 0.99 between LSB–TLWB. Direct genetic correlation of LSB with LSW (0.90) was positive and high. Mokhtari et al. (2010) reported similar results, but Hanford et al. (2006), Rashidi et al. (2011), and Mohammadabadi and Sattayimokhtari (2013) reported low estimates for this trait. Negative estimates of direct genetic correlation of LSB with LMWLB (–0.004) and LMWLW (–0.98), and LSW with LMWLB (–0.19) and LMWLW (–0.97) were obtained in the current study. These estimates showed that a higher number of lambs in litter is dependent on lower birth weight and weaning weight of lambs. In other words, genotypes producing low lamb numbers presumably produce heavier lambs at birth and weaning and *vice versa*. Vatankhah and Talebi (2008), Mokhtari et al. (2010), and Amou Posht-e-Masari et al. (2013) reported similar results. Direct genetic correlation estimates between LSB and LSW with TLWB and TLWW were positive. This result was expected because the ewes with a higher number of lambs born in each litter would have higher total weight of lambs. This result is consistent with results reported by Rashidi et al. (2011) in Moghani sheep (0.99) and Amou Posht-e-Masari et al. (2013) in Shall sheep (0.98).

Phenotypic and environmental correlations were generally lower than genetic correlations. Phenotypic correlations ranged from –0.50 for LSB–LMWLB to 0.85 for LMWLW–TLWW. Permanent environmental correlation between traits ranged from –0.99 for LSB–LMWLB and LSW–LMWLW to 0.99 for LSB–LMWLW, LMWLB–LMWLW, and LMWLW–TLWW. Permanent environmental correlation between LSW and other reproductive traits except for LSB was negative and high. Permanent environmental correlation between LSB and LMWLB was negative and high, which indicates temporary undesirable environmental conditions due to the ewe uterine environment for multiple lambs leading to a reduction in lambs' weight at birth (Mokhtari et al. 2010). Residual correlations ranged from –0.45 for LSB–LMWLB to 0.87 for LMWLW–TLWW. Direct genetic and phenotypic correlation estimates between LMWLB and LMWLW were positive with other traits. Bivariate analysis of LMWLB–TLWB did not converge in this study.

CONCLUSION

Estimates of genetic parameters for reproductive traits are necessary for genetic evaluation and constructing the best selection programs in Mehraban sheep. Heritability estimates were low for almost all traits in Mehraban sheep, and these estimates were in general consistent with the estimates of other researchers. Therefore, indirect selection could be useful for improving these traits. The results suggested that selection based on TLWW rather than on the other traits could more effectively improve the reproductive performance in Mehraban ewes, due to greater heritability and positive genetic correlation with the other traits. There were significant permanent environmental effects related to repeated records of ewes. Therefore, improvement of environmental conditions in the flocks such as position, management, and nutrition can lead to the improvement of reproductive efficiency.

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