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GENETIC ANALYSIS OF BASIC AND COMPOSITE REPRODUCTION TRAITS IN GUILAN SHEEP

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Abstract

The objective of the present study was to estimate genetic parameters for reproductive traits in Guilan sheep. Data were comprised of 14,534 records of lambs from 136 sires and 2,021 dams which were collected during 1994 to 2011 by the Agriculture Organization of Guilan Province in the north of Iran. The basic reproductive 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). The composite reproductive traits were total litter weight at birth per ewe lambing (TLWB) and total litter weight at weaning per ewe lambing (TLWW). The general linear model procedure of SAS was used for determining the fixed effects which had significant effect on the traits under study. The flock-year-season of lambing had significant effect on studied traits (P<0.01). The genetic parameters were estimated with repeatability animal model using restricted maximum likelihood (REML) procedure of the Wombat program. Direct heritability estimates were 0.00, 0.00, 0.01, 0.01, and 0.03 for LSB, LSW, LMWLW, TLWB, and TLWW, respectively, and corresponding repeatabilities were 0.2, 0.00006, 0.01, 0.972 and 0.034, respectively. Genetic correlation estimates between traits ranged from –0.99 for LSB–LSW to 0.99 for LMWLW–TLWW. Phenotypic correlations ranged from –0.09 for LSB–TLWB to 0.98 for LMWLW–TLWW and environmental correlations ranged from –0.03 for LSW–TLWW to 0.98 for LMWLW–TLWW. The results showed that strong positive genetic correlations of LMWLB and LMWLW with other traits may improve meat production efficiency in Guilan sheep. The low estimates of heritability and repeatability obtained for ewe productivity traits indicate that selection based on the ewe's own performance may result in slow genetic improvement.

Key words: fat-tailed sheep, genetic correlation, heritability, reproductive traits

The Guilan sheep is a fat-tailed breed of domestic sheep in Iran, numbering some 400,000 animals in the north of the country, and distributed in the northern and western parts of Guilan province in the mountains between Assalem, Khalkhal, Oshkourat, and Deilaman. This breed can also be found in some areas of Guilan-Zanjan border. Mean adult live weight of Guilan sheep is 35 kg for rams and 31 kg for ewes. The coat color for this breed is yellowish-white to pure white, but brown patches are found on the head, face and at the bottom of the legs. This breed is valued mainly due to its ability to live in mountainous areas with rain-fed foothills and foothill steppes with 1300 mm annual rainfall (Eteqadi et al., 2014). The location of Guilan province in the moderate climatic region of Iran makes this region the wettest and most fertile part of Iran.

The objective of a breeding program is to maximize the rate of genetic progress for economically important traits in livestock. In sheep production, reproductive traits such as fertility, litter size and lamb survival are the most important traits in all systems of sheep production and in all environments (Gallivan, 1996; Matika et al., 2003; Vatankhah, 2005). Improvement in number or total weight of lamb weaned per ewe is a key target in sheep breeding and could partly be attained by increasing the number of lambs weaned and weight of lambs weaned per ewe within a specific year (Duguma et al., 2002). Ekiz et al. (2005) pointed out the major source of income and profitability in any sheep production system is lamb production. Improvement of ewe productivity and growth of lambs increases meat production.

Productivity of a ewe may be measured by litter size at birth, litter size at weaning or litter weight of lambs weaned per ewe lambing (More O'Ferrall, 1975). Litter size at birth is directly related to ovulation rate, which is influenced by only a few hormones and the responsible genes, but selection for only litter size at birth would not be effective for increasing lamb production, since it does not include the survival rate and weight of the individual lambs at weaning (Rosati et al., 2002). Litter size at weaning includes survival of lambs at weaning but not the weight. On the other hand, litter weight of lambs weaned per ewe lambing combines ewe's fertility, litter size at birth, survival rate and growth performance of lambs from birth to weaning. Therefore this trait is considered as the most important factor in determining a ewe's reproduction and the economic efficiency of a lamb enterprise (Mohammadi et al., 2013). Also, ewe productivity, defined as the total weight of lambs weaned by ewe, is one of the most important economic traits and has been proposed as a biologically optimum index for improving overall flock productivity (Snowder, 2002). The number of weaned lambs, which is highly correlated to flock productivity, is considered as one of the most important components of reproductive performance (Menéndez Buxadera et al., 2004).

Safari et al. (2005) showed that designing efficient selection and breeding strategies for genetic improvement and appropriate genetic evaluation of local breeds requires accurate estimation of genetic parameters. Knowledge on genetic parameters including heritability and repeatability for economically important traits is crucial for the genetic evaluation and for choosing the best selection schemes (Safari et al., 2005). Estimates of genetic parameters for reproductive traits of sheep are generally low and reproductive characteristics of different sheep breeds have been published by several authors (van Wyk et al., 2003; Ekiz et al., 2005; Hanford et al., 2006; Afolayan et al., 2008; Mokhtari et al., 2010; Rashidi et al., 2011; Amou Posht-e-Masari et al., 2013). Low heritability of reproductive traits is probably due to the greater proportional influence of environmental effects as well as little genetic variability for fertility, litter size, lamb survival and lambing frequency and other reproductive traits (Rosati et al., 2002).

Repeatability estimates are generally useful in prediction of producing ability to properly weight the contributions in repeated records (Bourdon, 2000). There is no published research on genetic parameters for reproductive traits of Guilan sheep. Hence, reliable estimates of genetic parameters are needed to establish an efficient selection program for ewe productivity in this breed of sheep. Thus, the objective of this study was to estimate heritability and genetic correlations of reproductive traits for Guilan sheep.

Material and methods

The data on reproductive performance was collected from 1994 to 2011 at the Agriculture Organization of Guilan Province, Iran. Young ewes were randomly exposed to the rams for the first time at approximately 18 months of age. Ewes are kept in the flock up to 7 years old. Ewes are supplemented, depending upon the ewes' requirements, for a few days after lambing. Rams are kept until a male offspring is available for replacement. During the breeding season, single-sire pens are used allocating 20–25 ewes per ram. Lambs remain with their dam until weaning. Lambs are ear-tagged and weighed immediately after lambing. During the suckling period, lambs suckle their mothers while being allowed dry alfalfa after 3 weeks of age. Lambs are weaned at approximately 90 days of age. Animals are kept on the natural pasture during spring, summer and autumn seasons. During the winter due to the harsh condition of the weather the animals are kept in. The flock was fed cereal pasture, but supplemental feed, including alfalfa and wheat straw, are provided especially around breeding season.

The traits analyzed were assigned as basic and composite traits. The 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). The LSB trait was the number of lambs born alive per ewe lambing and LSW was the number of lambs weaned per ewe lambing. LMWLB and LMWLW were the average weights of lambs from the same parity at birth and weaning, respectively. Based on the observations from basic traits, composite traits were derived. The 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. The characteristics of the data set used in this study are presented in Table 1.

After data verification, defective and doubtful data were deleted (e.g., lambs without weight records or with incomplete records of parentage or with registration numbers lower than the numbers of their parents were left out). Test of significance to include fixed effects in the statistical model for each trait was performed using general linear model (GLM) procedure of SAS 9.1 program (SAS Institute, 2003). The significance level for the inclusion of fixed effects into the model was declared at $P<0.05$. The fixed effects were: flock-year-season of lambing, lamb's sex (in

2 classes: male and female), type of birth (in 3 classes: single, twin and triplet), dam's age at lambing (in 6 classes: from 2 through 7 years old), random effect of animal and ewe permanent environment. All the interactions except flock-year-season of lambing were included in the initial models.

Table 1. Characteristics of data set for Guilan sheep

	Traits[a]					
	LSB	LSW	LMWLB (kg)	LMWLW (kg)	TLWB (kg)	TLWW (kg)
No. of records	14534	14534	14534	14534	14534	14534
No. of sires	136	136	136	136	136	136
No. of dams	2021	2021	2021	2021	2021	2021
No. of ewes with one record	4047	4047	4047	4047	4047	4047
No. of ewes with two records	2113	2113	2113	2113	2113	2113
No. of ewes with three records	1053	1053	1053	1053	1053	1053
No. of ewes with four records	451	451	451	451	451	451
No. of ewes with five records and greater	238	238	238	238	238	238
No. of animals with both parents unknown	5285	5285	5285	5285	5285	5285
Mean	1.05	0.81	3.15	15.35	3.28	15.91
S.D.	0.23	0.46	0.61	3.96	0.81	5.03
C.V. (%)	21.90	56.79	19.37	25.80	24.70	31.62

[a]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; S.D.= standard deviation; C.V.= coefficient of variation.

Least squares means (LSM) were used for means comparisons between subgroups. The (co)variance components and corresponding genetic parameters for each trait were estimated by the Average Information Restricted Maximum Likelihood (AIREML) algorithm of Wombat program (Meyer, 2006) and fitting the following repeatability animal model:

$$y = Xb + Za + Wpe + e$$

where:

y is a vector of records for each trait;

b, a, pe, and e are vectors of fixed effects, direct additive genetic effects, ewe permanent environmental effects and residual random effects, respectively;

X, Z, and W are design matrices relating the corresponding effects to observations.

The phenotypic variance of live weight (σ_p^2) was calculated as the sum of additive genetic variance (σ_a^2), permanent environmental variance (σ_{pe}^2) and residual variance (σ_e^2) (Ramatsoma et al., 2015):

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

The heritability (h^2) was calculated as the ratio of animal additive genetic variance to phenotypic variance (Ramatsoma et al., 2015):

$$h^2 = \frac{\sigma_a^2}{\sigma_e^2}$$

Repeatability (r) was calculated using the following formula:

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

where σ_a^2, σ_{pe}^2 and σ_e^2 are direct additive genetic variance, ewe permanent environmental variance and phenotypic variance, respectively.

To estimate the genetic, phenotypic and environmental correlations between reproductive traits, bivariate analyses were performed. The fixed effects included in the bivariate animal model were those in univariate analyses.

Results

The least squares means and their standard errors of fixed effects for studied traits are shown in Table 2. All traits except LSB were significantly affected by the lamb's sex ($P<0.05$). All traits except LSB and LSW were significantly affected by the type of birth ($P<0.05$). The LMWLB trait was lower in twins and triplets than singles. Also, the TLWW trait was greater in twins and triplets than singles. The dam's age at lambing had significant effect on all traits ($P<0.05$). The flock-year-season of lambing was fixed effect which significantly affected all studied traits. Lamb's sex and type of birth were fixed effects which significantly affected all studied traits except LSB and LSW. The dam's age at lambing and interactions between the lamb's sex and dam's age at lambing, type of birth and dam's age were fixed effects which significantly affected LMWLB. Dams which lambed at the age of 7 years had the greatest LMWLB but they had not significant difference with LMWLB of dams which lambed at the age of 3 years. The dam's age at lambing was fixed effect which significantly affected LMWLW. The dam's age at lambing and interactions between type of birth and the lamb's sex, type of birth and dam's age at lambing, the lamb's sex and dam's age at lambing were fixed class effects which significantly affected TLWB. The dam's age at lambing and interactions between type of birth and dam's age at lambing were fixed effects which significantly affected TLWW.

Table 2. Least squares means±S.E.[1] for fixed effects of reproductive traits[a]

Effect	Class	Frequency	LSB	LSW	LMWLB (kg)	LMWLW (kg)	TLWB	TLWW
Lamb's sex	Male	5321	1.05 a±0.003	0.79 b±0.006	3.17 a±0.007	15.71 a±0.056	3.32 a±0.009	15.71 a±0.056
	Female	6043	1.04 a±0.003	0.83 a±0.005	3.12 b±0.007	15.03 b±0.049	3.25 b±0.009	15.03 b±0.049
Type of birth	Single	10948	-	-	3.17 a±0.005	15.36 a±0.038	3.17 b±0.005	15.36 c±0.038
	Twin	409	-	-	2.74 b±0.023	15.05 a±0.195	5.48 a±0.046	30.10 b±0.39
	Triplet	7	-	-	1.87 c±0.151	13.40 b±0.941	5.60 a±0.454	40.20 a±2.82
Dam's age at lambing	2	5038	1.05 a±0.003	0.81 abc±0.006	3.09 d±0.008	15.60 a±0.056	13.23 b±0.009	16.15 a±0.070
	3	3170	1.05 a±0.003	0.81 abc±0.007	3.20 ab±0.009	15.26 ab±0.072	13.33 a±0.013	15.73 ab±0.090
	4	1864	1.06 a±0.005	0.84 ab±0.009	3.19 bc±0.012	15.10 b±0.091	13.34 a±0.017	15.76 ab±0.120
	5	896	1.06 a±0.007	0.79 b ±0.014	3.13 cd±0.016	14.84 b±0.118	13.31 ab±0.025	15.58 b±0.167
	6	328	1.04 a±0.011	0.76 c±0.023	3.17 bc±0.027	14.99 b±0.187	13.28 ab±0.034	15.53 b±0.249
	7	68	1.00 b±0.000	0.86 a±0.039	3.26 a±0.068	15.62 a±0.502	13.26 ab±0.068	15.62 b±0.502

[1]Means within a column (for each effect) that do not have a common letter are significantly different ($P<0.05$).
[a]For these traits abbreviations see footnote of Table 1.

Table 3. Variance components and genetic parameter estimates for reproductive traits in Guilan sheep

Trait[a]	σ^2_a	σ^2_{pe}	σ^2_e	σ^2_p	h^2_a±*S.E.*	pe^2±*S.E.*	*r*
LSB	0.000001	0.01	0.03	0.05	0.00±0.025	0.2±0.027	0.2
LSW	0.000001	0.000009	0.18	0.18	0.00±0.017	0.00005±0.019	0.00006
LMWLW	0.07	0.00003	6.72	6.79	0.01±0.020	0.000005±0.024	0.01
TLWB	0.003	0.24	0.01	0.25	0.01±0.035	0.96±0.035	0.972
TLWW	0.27	0.000007	7.59	7.85	0.03±0.022	0.00000008±0.024	0.034

σ^2_a: additive genetic variance, σ^2_{pe}: permanent environmental 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, *r*: repeatability, : standard error.

[a]For these traits abbreviations see footnote of Table 1.

Table 4. Estimates of genetic (above diagonal; ± S.E.), phenotypic (below diagonal) and environmental (in the parentheses) correlations among reproductive traits in Guilan sheep

Trait[a]	LSB	LSW	LMWLB	LMWLW	TLWB	TLWW
LSB	-	–0.99	0.98±0.178	0.40*	–0.81*	0.95*
LSW	0.15 (0.15)	–	0.93*	0.37±0.123	0.54±0.157	0.42±0.130
LMWLB	0.70 (0.86)	0.04 (0.02)	–	0.89*	0.98±0.283	0.03*
LMWLW	0.04 (0.03)	0.05 (–0.02)	0.01 (–0.003)	–	0.62±0.042	0.99±0.001
TLWB	–0.09 (0.27)	0.05 (0.05)	0.32 (0.24)	0.30 (0.01)	–	0.33*
TLWW	0.04 (0.02)	0.04 (–0.03)	0.001 (0.001)	0.98 (0.98)	0.08 (0.05)	–

*The software is not able to estimate S.E.

[a] For these traits abbreviations see footnote of Table 1.

Estimates of (co)variance components, heritability and variance ratio of permanent environmental effects to the phenotypic variance as well as repeatability for considered traits are presented in Table 3. Estimate of direct heritabilities for LSB (0.00±0.025) and LSW (0.00±0.017) showed no significant differences from zero. Therefore, the possibility to achieve rapid genetic gain through selection for these traits would be limited.

The univariate analysis of LMWLB did not converge. Direct heritability estimates for LMWLW and TLWB were 0.01±0.020 and 0.01±0.035 in this study, respectively (Table 3). Direct heritability estimate for TLWW (0.03) had the highest value among the studied traits. The estimated fraction of variance due to permanent environmental effects of the ewe for LSB and TLWB was higher than direct heritability while, for the other traits these estimates were lower or equal to heritability estimate. The repeatability estimates for LSW, LMWLW and TLWW were equal or higher than heritability estimates, due to the low contribution of permanent environmental effects.

Estimates obtained from bivariate analyses are shown in Table 4. Unfavorable estimates of genetic correlation of LSB with LSW (–0.99) and TLWB (–0.81) were obtained in this study. The genetic correlation estimates between LSB with LMWLB and TLWW were positive and high (0.98 and 0.95, respectively). This result was expected because the ewes with more number of lambs born in each litter would have higher litter mean weight per lamb born and total weight of lambs. Due to the low heritability for LSB, indirect selection based on LMWLB could be applied to improve LSB. Estimates of genetic correlation between LSW and the other traits were positive and medium to high with the exception of correlation with LSB that is negative and high, as mentioned above. Genetic correlation estimates between LMWLB with LMWLW and TLWB were positive and high (0.89 and 0.98, respectively). The genetic correlation estimate between LMWLB and TLWW was 0.03 in this study. The estimate of the genetic correlation between TLWB and TLWW was positive and medium (0.33) in the current study. The estimates of genetic correlation between TLWW and other traits were positive and medium to high with the exception of correlation with LMWLB that is positive and low. The environmental correlation estimates of LSW with LMWLW and TLWW were negative. Also, estimate of environmental correlation between LMWLB and LMWLW was negative.

Discussion

Non-significant effect of lamb's sex on LSB has been reported by Vatankhah and Talebi (2008), which was in accordance with the present study. Differences in mothering abilities, nursing, and maternal behavior of ewes at different ages are probably the reasons for significant influence of ewe age (Mohammadi et al., 2012; Amou Posht-e-Masari et al., 2013). Significant effects of ewe age on reproductive traits have been well documented by several authors (Hanford et al., 2005, 2006; Vatankhah et al., 2008; Ghavi Hossein-Zadeh and Ardalan, 2010; Mokhtari et al., 2010; Rashidi et al., 2011; Bayeriyar et al., 2011; Amou Posht-e-Masari et al., 2013). Higher estimates for direct heritability of LSB have been reported by Hanford et al. (2005) in Rambouillet sheep, Hanford et al. (2006) in Polypay sheep, Vatankhah et al. (2008) in Lori-Bakhtiari sheep, Ghavi Hossein-Zadeh and Ardalan (2010) in Moghani sheep, Mokhtari et al. (2010) in Kermani sheep, Mohammadi et al. (2012) in Zandi sheep and Amou Posht-e-Masari et al. (2013) in Shall sheep. Rosati et al. (2002) reported the direct heritability for LSW was 0.01 in five breeds of sheep (Dorset, Finnsheep, Rambouillet, Suffolk and Targhee) and two composite lines. Also, van Wyk et al. (2003), Vanimisetti et al. (2007), Mohammadi et al. (2012) and Amou Posht-e-Masari et al. (2013) reported the direct heritabilities for LSW were 0.03, 0.09, 0.09 and 0.01 in Elsenburg Dormer sheep stud, Katahdin sheep, Zandi sheep and Shall sheep, respectively. Because of low estimates of heritability for LSB and LSW, direct selection could not result in a considerable genetic improvement of reproductive efficiency in Guilan sheep.

Direct heritability estimate for LMWLW (0.01) was lower than the average of those reported for other breeds (Vatankhah et al., 2008; Mokhtari et al., 2010; Amou Posht-e-Masari et al., 2013). The lower heritability estimate for LMWLW in the current study showed this trait has been more affected by environmental factors and probably by the genotypes of lambs rather than the own genotypes of ewes. In general, the high heritability estimates for these traits allow direct selection to be more effective (Amou Posht-e-Masari et al., 2013). TLWB is a combination of LMWLB and total number of lamb born (NLB) and could be considered for selection purposes because it measures the ability of the ewe to produce lamb weight at birth without considering the number of lambs born (Rosati et al., 2002; Vatankhah et al., 2008) and the heritability estimate of TLWB was 0.01 in this study, which was lower than the estimates of 0.15 and 0.07 reported by Amou Posht-e-Masari et al. (2013) in Shall sheep and Rashidi et al. (2011) in Moghani sheep, respectively.

The direct heritability estimate for TLWW was generally consistent with the report of Amou Posht-e-Masari et al. (2013) in Shall sheep (0.03). Also, it was in the range of estimates reported by several authors for other breeds (Rosati et al., 2002; van Wyk et al., 2003; Ekiz et al., 2005; Mokhtari et al., 2010). The TLWW trait can be considered as a primary trait for selection purposes because it measures the ability of the ewe to produce weaning weight of lamb after exposure to the ram and is an economically important trait in any sheep breeding production system (Mohammadabadi and Sattayi Mokhtari, 2013). Heritability estimates for TLWB and TLWW were near together and these estimates indicated that selection based on TLWW would not be so more effective than on TLWB. High difference between the heritability estimates for these traits, compared to LSB and LSW, showed that genetic improvement in reproductive traits through phenotypic selection is not good in Guilan sheep.

The estimated fractions of variance due to permanent environmental effects for LSB and TLWB were higher than the heritability ones, suggesting that the mentioned traits may be affected by the non-additive genetic factors such as dominance, epitasis and permanent environment (Vatankhah et al., 2008). Thus, the accuracy of selection for these traits using the first lambing record can be high as the correlation between performance records measures by repeatability in repeated records of ewes. The low estimates of repeatability for LSW, LMWLW and TLWW indicated that taking more records for more accurate genetic evaluation would be justified (Amou Posht-e-Masari et al., 2013).

Composite traits are combinations of other estimable traits, so that high genetic correlations are expected with the component traits. Negative estimates of genetic correlation of LSB with LSW (–0.99) and TLWB (–0.81) could be explained by the fact that greater number of lambs in litter is associated with lower number of lambs at weaning and lower total litter weight at birth per ewe lambing. In other words, genotypes producing low lamb numbers maybe produce heavier lambs at birth and vice versa. Hanford et al. (2005) and Amou Posht-e-Masari et al. (2013) reported positive genetic correlation estimates between LSB and LSW (0.76 and 0.94, respectively).

Positive and high genetic correlation estimates between LSB with LMWLB and TLWW were expected because the ewes with more number of lambs born in each litter would have higher litter mean weight per lamb born and total litter weight at weaning per ewe lambing. Due to the low heritability for LSB, indirect selection based on LMWLB could be applied to improve LSB. The genetic correlation estimate between LSB with TLWW was generally consistent with the report of Amou Posht-e-Masari et al. (2013) in Shall sheep (0.98). The genetic correlation estimates between LMWLB with LMWLW and TLWB were positive and high, showing that the ewes having lambs with higher mean birth weight are likely to produce more average weaning weight and total litter weight at birth. Amou Posht-e-Masari et al. (2013) reported positive genetic correlation estimate between LMWLB and TLWW (0.52) but Vatankhah et al. (2008) reported a negative estimate (–0.16). The genetic correlation estimate of 0.99 between LMWLW with TLWW suggested that selection for TLWW is more useful than direct selection for LMWLW, because heritability of TLWW was higher than that of LMWLW. Also, this indicated that ability of the ewes to produce lambs weight at weaning correlated with LMWLW, because the growth of lambs from birth to weaning and also mothering ability was affected by individual genotype of lambs. The positive and medium estimate of the genetic correlation between TLWB and TLWW showed that maybe genes are responsible for number of lambs and maybe their weights at birth are also responsible for controlling milk production and mothering ability of dams from birth to weaning. Also, factors such as the genotype of lamb and manual nutrition for some lambs could influence the estimates of genetic correlation between TLWB and TLWW (Rosati et al., 2002).

The negative environmental correlation estimates of LSW with LMWLW and TLWW showed that the environmental factors increasing the LSW resulted in decreasing of the LMWLW and TLWW. Low environmental correlation estimates between some of traits indicated that the environmental effects may have had different mechanism in influencing the traits.

Estimates of (co)variance components and heritabilities are necessary for genetic evaluation and choosing the best selection programs of sheep. The estimates of genetic correlations between the traits and heritabilities of traits can be used to make a general index. The results indicated reproductive traits have a relatively low heritability. However, this does not mean that genetic improvement in Guilan sheep is impossible, but rather, that it will need a sufficiently designed selection strategy. The low estimates of heritabilities and repeatabilities for LSB and LSW implied that phenotypic or genetic selection based on these traits cannot result in a considerable genetic improvement of reproductive efficiency in Guilan sheep. The estimates of genetic correlations among reproductive traits ranged from low to high. Total weight of lamb weaned should be considered in the selection strategy since it is a composite trait. Higher heritability estimate for TLWW indicated that it could be considered as selection criterion to indirect genetic increase in ewe reproductive traits in Guilan sheep. Furthermore, this trait had high positive genetic correlations with LSB and LMWLW and could be considered as indirect selection criteria for LSB and LM-WLW in this breed of sheep.

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