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Estimating Genetic Parameters of Body Weight Traits in Kourdi Sheep

Research Article

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ABSTRACT

For estimating genetic parameters for body weight traits in Kourdi sheep data were collected from 1996 to 2013 in Kourdi Breeding Station in Northern Khorasan province of Iran. Studied traits were birth weight (BW), weaning weight (WW), six-month weight (6MW), nine-month weight (9MW) and yearling weight (YW). The fixed effects in the model were lambing year, sex, type of birth and age of dam. (Co)variance components and corresponding genetic parameters were obtained with the univariate and multivariate analyses fitting animal models using the restricted maximum likelihood (REML) methods. The most appropriate model for each trait was determined based on log likelihood values. Model including maternal genetic effects as well as direct genetic effects, without considering covariance between them, was chosen as the most appropriate model for BW and WW. Model which included only direct genetic effects was the best model for other traits (6MW, 9MW and YW). Year of birth, lamb sex and type of birth were significant sources of variation on body weight traits ($P<0.01$). Direct heritability estimates of 0.10, 0.28, 0.32, 0.22 and 0.20 were obtained for BW, WW, 6MW, 9MW and YW, respectively. The estimate of maternal heritabilities for BW and WW were 0.27 and 0.13, respectively. Direct genetic correlation estimates between body weight traits were positive and varied from 0.56 for BW-YW to 0.97 for 6MW-9MW. Estimates of maternal genetic correlations between body weight traits were positive and ranged from 0.84 to 0.99. The estimates of correlations between body weight traits suggest that selection for any of these traits could result in genetic progress for the other traits.

KEY WORDS body weight, heritability, Kourdi sheep, variance component.

INTRODUCTION

There are more than 50 million heads of sheep in Iran, including 27 breeds and ecotypes (Zamani et al. 2013; Zamani et al. 2015). One of the most important breeds of Iranian sheep is Kourdi sheep. They are fat-tailed, large-sized, well adapted to the regions in northen Khorasan province, Iran and mainly raising for mutton production under rural and pastoral system (Tavakolian, 1999). Mutton is a traditional source of protein in Iran but meat production from the sheep does not cover the increasing consumer demand (Rashidi et al. 2008). Yazdi et al. (1997) pointed out that the improvement in efficiency of any sheep production enterprises can be achieved by enhancing economically important traits such as litter size and body weight of lamb. To determine optimal breeding strategies to increase the efficiency of sheep production, knowledge of genetic parameters for weight traits at various ages and also the genetic relationships between the traits are needed (Bahreini Behzadi et al. 2007). Numerous studies have demonstrated that live body weight and growth rate of lambs of different breeds considerably are affected by maternal as well as the direct genetic effects (Yazdi *et al*. 1997; Neser *et al*. 2001; Abegaz *et al*. 2005; Bahreini Behzadi *et al*. 2007; Rashidi *et al*. 2008; Mokhtari *et al*. 2008).

Most of these studies concluded that ignoring maternal effects in genetic analysis of these traits, especially for pre-weaning ones, resulted in upward biases in estimation of direct heritability. Hence, to achieve optimum genetic progress in a selection program both the direct and maternal components should be taken into account (Meyer 1992; Maria *et al*. 1993). Furthermore, it is important to try to characterize genetically indigenous breeds. Genes affecting polygenic traits and characterizing milk or meat productions are difficult to identify. However, several potential candidate genes have been recognized. They may be selected on the basis of a known relationship between physiological or biochemical processes and production traits, and could be tested as quantitative trait loci (QTLs) (Shojaei *et al*. 2011). The most important trait is body weight and also there was no information regarding (co)variance components and genetic parameters for such important traits in Kourdi sheep. Thus, the objective of the present study was to estimate the genetic parameters of body weight traits in Kourdi sheep.

MATERIALS AND METHODS

Flock management

In general, animals were managed following semi-intensively. Natural pasture is the main source of feed. The quantity and quality of the pasture varies considerably during the year. With the dry season, the quantity and quality of the pasture decreases and supplemental feeding comprising dried alfalfa and barley grains has to be provided especially at the time of the flushing and late pregnancy. A controlled mating strategy was designed during mating period (early September to mid-November) and ewes were mated to fertile rams at the rate of 20 ewes per ram. Lambing was in January and March. At birth time and / or within 24 h afterwards lambs were weighted and ear-tagged. Lambs were kept indoors from mid January to late April and manually fed afterwards lambs were grazed on pastures of low quality and productivity. The lambs were weaned about 3 months of age. The female lambs were exposed to the rams about 18 months of age (Saghi *et al*. 2014).

Data and the studied traits

Data and pedigree information on Kourdi sheep were collected at the Breeding Station of Khourdi sheep (Shirvan, northern Khorasan, Iran) over the period from 1996 to 2013, (Saghi *et al*. 2014).

The maximum of data which were available for analysis included 5069 lamb records born from 162 sires and 1966 dams at birth, whereas at yearling it reduced to 2595 lamb records born from 88 sires and 1215 dams (Table 1). Traits investigated were body weight at birth (BW), weaning (WW), six months of age (6MW), nine months of age (9MW) and yearling weight (YW). All body weights, except BW, were pre-adjusted for the effect of weighing age assuming a linear growth rate and weighing ages of 120, 180, 270 and 365 days for WW, 6MW, 9MW and YW, respectively. The structure of data used in the analysis is given in Table 1.

Statistical analysis

The model accounting for environmental (fixed) effects were included year of lambing (1996-2013), sex of lamb (male and female), type of birth (single and twin) and age of ewe (2-7 years old). Least square analyses were performed using the GLM procedure of the SAS software package (SAS, 2008). The interactions between the fixed effects were not significant and therefore excluded from the model.

The (co)variance components and genetic parameters were estimated applying the restricted maximum likelihood (REML) method fitting six animal models using WOMBAT (Meyer, 2012):

$y = Xb + Z_a a + e$ Model 1

$y = Xb + Z_a a + Z_{pe} pe + e$ Model 2

$y = Xb + Z_a a + Z_m m + e$ Model 3

$Cov(a, m) = 0$

$y = Xb + Z_a a + Z_m m + e$ Model 4

$Cov(a, m) = A\sigma_{am}$

$y = Xb + Z_a a + Z_m m + Z_{pe} pe + e$ Model 5

$Cov(a, m) = 0$

$y = Xb + Z_a a + Z_m m + Z_{pe} pe + e$ Model 6

$Cov(a, m) = A\sigma_{am}$

Where:

y: vector of records.

b: vector of fixed effects.

a: vector of direct additive genetic effects.

m: vector of maternal additive genetic effects.

pe: vector of permanent environmental effects due to ewe.

X, Za, Zm and Zpe: corresponding design matrices relating the fixed effects, direct additive genetic effects, maternal additive genetic effects and permanent environmental effects due to ewe to vector of y, respectively.

e: vector of residual effects.

Cov(a, m): covariance between direct additive genetic and maternal additive genetic effects.

It is assumed that:

$$Var\begin{bmatrix} a \\ m \\ pe \\ e \end{bmatrix} = \begin{bmatrix} A\sigma_a^2 & A\sigma_{am} & 0 & 0 \\ A\sigma_{ma} & A\sigma_m^2 & 0 & 0 \\ 0 & 0 & I_d\sigma_{pe}^2 & 0 \\ 0 & 0 & 0 & I_n\sigma_e^2 \end{bmatrix}$$

It was assumed that the direct additive genetic effects, maternal additive genetic effects, permanent environmental effects due to ewe and residual effects to be normally distributed with mean 0 and variance $A\sigma_a^2, A\sigma_m^2, I_d\sigma_{pe}^2, I_n\sigma_e^2$, respectively.

$\sigma_a^2, \sigma_m^2, \sigma_{pe}^2, \sigma_e^2$: direct additive genetic variance, maternal additive genetic variance, permanent environmental variance due to ewe and residual variance, respectively.

A: additive numerator relationship matrix.

I_d and I_n: identity matrices that have order equal to the number of ewes and number of records, respectively.

σ_{am}: covariance between direct additive genetic and maternal additive genetic effects.

Total heritabilities were estimated according to formula of Willham (1972):

$$h_t^2 = \frac{\sigma_a^2 + 0.5\sigma_m^2 + 1.5\sigma_{am}}{\sigma_p^2}$$

In univariate analysis, the log likelihood values were applied to choose the most appropriate model for each trait (Meyer, 1992). Estimation of genetic and phenotypic correlations was accomplished using multi-trait analysis applying the most appropriate model which was determined in univariate analysis. The fixed effects included in the multi-trait animal models were those in single-trait analyses.

RESULTS AND DISCUSSION

The mean values for the different traits (Table 2) are smaller than those of the studies of other breeds (Mohammadi *et al.* 2010), probably due to poor quality of the pasture at the sheep breeding station and the more extensive conditions under which the herd was maintained. The coefficient of variation for birth weight is much less than that for the other traits, which is an indication of the smaller effect of environment on birth weight than on the other traits. About 50% of the lambs were lost from birth until 12 months of age due to mortality and insufficient or low quality of pasture which resulted in some of the lambs being sold. The birth year, sex and birth type of the lambs and influenced the studied traits (P<0.01).

The effect of ewe age was significant for BW and 6MW (P<0.01). However, other traits were not significantly influenced by ewe age. The overall least square means for lamb weights at different ages were higher than those reported for Kermani (Rashidi *et al.* 2008) and Bharat Merino (Dixit *et al.* 2001) breeds.

The environmental effects on body weight traits of Kourdi lambs were in close agreement with different sheep breeds (Miraei-Ashtiani *et al.* 2007; Rashidi *et al.* 2008; Vatankhah and Talebi, 2008; Eskandarinasab *et al.* 2010; Mohammadi *et al.* 2010). Male lambs were heavier and faster growing than female probably because of increasing differences in the endocrine system between males and females. According to the results, single born lambs had better performance than twins. The significant effects of fixed factors on body weight traits can be explained in part by differences in years (differences in environment, feeding and grazing resources), endocrine system of male and female lambs, limited uterine space (especially in young ewes), insufficient availability of nutrients during pregnancy and early lactation, competition for milk consumption between twin lambs and differences in the maternal behavior and mothering ability of the ewes in different parities (Rashidi *et al.* 2008).

Based on log likelihood values for the different models on all traits, the most appropriate model for BW and WW was model 3, which included direct and maternal additive genetic effects, without considering covariance between them (Table 3). In addition, both additive genetic effect and maternal genetic effects had a significant effect on variation for BW and WW that were probably due to uterine environment, milk production and maternal ability of dams in this breed. Based on log likelihood values direct additive genetic effect was significant for 6MW, 9MW and YW, so only model 1 was chosen as the best model for these traits. In the presence of the other components, the permanent environmental component was found to have no significant.

The structure of data (i.e. number of records per dam, the proportion of dams with their own record) has been reported to affect the accuracy of partitioning of maternal genetic and environmental effects (Maniatis and Pollott, 2003). In the current study, the data structure was acceptable since the most of the dams have their own records and on average, each dam has had more than three lambing records.

Several reports have been published on the contribution and importance of the maternal genetic variance, permanent environmental variance and direct-maternal genetic covariance in improving the fit of models for growth performance in sheep (Van Wyk *et al.* 1993; Maria *et al.* 1993; Abegaz *et al.* 2005; Bahreini Behzadi *et al.* 2007; Rashidi *et al.* 2008; Mohammadi *et al.* 2010).

Table 1 Summary statistics of the studied traits

Traits	No. of records	No. of ewe	No. of ram	Mean	SD	% CV
BW	5069	1699	162	4.38	0.75	17.06
WW	3968	1608	117	23.47	5.77	24.62
6MW	3519	1467	101	31.99	6.80	21.26
9MW	28.40	1385	89	35.96	7.06	19.63
YW	2595	1215	88	43.23	8.44	19.53

BW: birth weight, WW: weaning weight (three-month weight), 6MW: six-month weight, 9MW: nine-month weight and YW: yearling weight.
CV: coefficient of variation and SD: standard deviation.

Table 2 Lease square means and standard errors for the studied traits

Fixed effect	Traits				
	BW	WW	6MW	9MW	YW
Overall mean	4.49±0.01	25.06±0.11	35.02±0.13	37.17±0.16	44.55±0.21
Birth year	**	**	**	**	**
Sex	**	**	**	**	**
Male	4.26^{a}±0.02	22.58^{a}±0.33	32.86^{a}±0.23	37.07^{a}±0.53	46.38^{a}±0.58
Female	4.01^{b}±0.02	20.52^{b}±0.33	29.11^{b}±0.23	31.05^{b}±0.53	37.54^{b}±0.58
Birth type	**	**	**	**	**
Single	4.62^{a}±0.02	23.72^{a}±0.32	32.65^{a}±0.21	35.53^{a}±0.51	43.41^{a}±0.56
Twin	3.65^{b}±0.03	19.38^{b}±0.39	29.32^{b}±0.37	23.59^{b}±0.56	40.51^{b}±0.62
Ewe age	**	NS	**	NS	NS
2	4.14^{b}±0.02	23.26±0.31	32.11^{ab}±0.19	35.92±0.22	43.59±0.26
3	4.39^{a}±0.01	23.81±0.31	32.41^{ab}±0.18	36.57±0.21	43.46±0.25
4	4.42^{a}±0.02	24.08±0.31	31.79^{ab}±0.19	35.23±0.23	42.57±0.25
5	4.47^{a}±0.02	23.02±0.32	30.93^{b}±0.22	34.59±0.27	42.13±0.31
6	4.55^{a}±0.02	23.30±0.34	32.79^{a}±0.34	37.11±0.28	44.47±0.33
7	4.51^{a}±0.04	23.26±0.44	32.18^{ab}±0.46	36.94±0.56	43.30±0.63

The means within the same column with at least one common letter, do not have significant difference (P>0.01).
BW: birth weight, WW: weaning weight (three-month weight), 6MW: six-month weight, 9MW: nine-month weight and YW: yearling weight.
** (P<0.01).
NS: non significant.

Based on the genetic parameters estimate fitting different models for body weight traits, direct heritability estimates with best models for body weight of lambs were relatively low to medium ranging from 0.10 for BW to 0.32 for 6MW. The direct additive heritability estimate (0.10) of BW in present study is low, but within the range reported by others. The range of direct heritability estimates for BW varies substantially from 0.04 (Rashidi *et al.* 2008) to 0.46 (Gizaw *et al.* 2007). The results in the present study were similar to the results reported by Mohammadi *et al.* (2010) for Iranian Sanjabi lambs. Safari *et al.* (2005), reported estimates of 0.19 and 0.15 for direct heritability of BW in dual-purpose and meat type breeds of sheep, respectively. These estimates were higher than our obtained value in the present study.

The maternal additive genetic variances were low. Maternal effects had substantial influences on pre-weaning traits. Estimates of maternal heritability with appropriate models for BW and WW were 0.27 and 0.13, respectively. According to the results, direct heritability estimate of 0.10 for BW was lower than that of respective maternal heritability (0.27) indicating the importance of genetic maternal effects over direct additive genetic ones for these traits. The maternal effects need to be considered in selecting for growth in Kourdi sheep.

Ignoring of maternal genetic effects in the models leads to over-estimate of direct heritability for BW (Duguma *et al.* 2002). Estimates of maternal heritability tended to decline from birth to yearling weight. Maternal genetic effects expressed during gestation and lactation had been expected to have a diminishing influence on weight as lambs became older. The maternal heritability decreased with age, which confirms the proposal by Robison (1981) that maternal effects in mammals are substantial in young animals but diminish with age. In contrary, the higher direct heritability estimates than the maternal heritability was also reported for BW (Snyman *et al.* 1995; Yazdi *et al.* 1997; Matika *et al.* 2003; Abegaz *et al.* 2005; Rashidi *et al.* 2008; Mohammadi *et al.* 2010). The estimated values for the maternal heritability of BW were well consistent with some of the published values (Maria *et al.* 1993; Bahreini Behzadi *et al.* 2007; Rashidi *et al.* 2008).

Safari *et al.* (2005) reported weighted mean of the maternal heritability estimated for BW of 0.18 in dual-purpose and 0.24 in meat type. Corresponding value for meat type ones was in general agreement with our estimated value. Birth weight is a trait of economical importance mainly due to its effect on pre-weaning growth of lambs and accordingly on economic success of lamb production (Al-Shorepy, 2001).

Table 3 (Co)variance components, genetic parameters estimates for the studied traits with different models

Traits	Models	σ^2_a	σ^2_m	σ^2_{pe}	σ_{am}	σ^2_e	σ^2_p	$h^2_d \pm SE$	$h^2_m \pm SE$	$c^2 \pm SE$	h^2_t	Log$_L$
BW	1	0.16	-	-	-	0.22	0.39	0.42±0.03	-	-	0.42	102.69
	2	0.07	-	0.08	-	0.21	0.37	0.19±0.04	-	0.22±0.02	0.19	195.12
	3	0.03	0.10	-	-	0.24	0.38	0.10±0.03	0.27±0.02	-	0.21	**215.44**
	4	0.03	0.09	-	0.02	0.24	0.38	0.08±0.02	0.23±0.03	-	0.28	207.37
	5	0.07	0.07	0.01	-	0.21	0.37	0.19±0.02	0.19±0.03	0.02±0.02	0.28	195.12
	6	0.03	0.04	0.04	0.02	0.23	0.37	0.10±0.02	0.12±0.02	0.10±0.02	0.22	206.29
WW	1	7.11	-	-	-	11.11	18.22	0.39±0.03	-	-	0.39	-7473.88
	2	6.71	-	1.06	-	10.43	18.21	0.36±0.03	-	0.06±0.02	0.36	-7468.85
	3	5.23	2.33	-	-	10.58	18.14	0.28±0.03	0.13±0.02	-	0.39	**-7436.61**
	4	6.26	1.24	-	-2.58	11.62	14.58	0.37±0.03	0.07±0.02	-	0.21	-7438.06
	5	6.62	0.83	0.42		10.43	18.32	0.36±0.03	0.04±0.02	0.02±0.02	0.38	-7466.11
	6	6.51	1.80	0.86	-2.34	11.42	16.25	0.35±0.04	0.09±0.02	0.04±0.02	0.24	-7438.63
6MW	1	7.27	-	-	-	15.30	22.58	0.32±0.04	-	-	0.32	**-7041.52**
	2	6.71	-	1.06	-	10.43	18.21	0.36±0.03	-	0.06±0.02	0.36	-7042.04
	3	7.08	0.47	-	-	15.09	22.61	0.31±0.04	0.02±0.02	-	0.32	-7047.69
	4	6.63	1.77	-	-2.67	13.91	22.64	0.33±0.04	0.09±0.03	-	0.15	-7047.41
	5	6.97	0.14	0.65	-	14.80	22.56	0.31±0.03	0.01±0.02	0.03±0.02	0.31	-7046.96
	6	6.71	0.95	1.19	-2.64	13.37	19.60	0.34±0.03	0.04±0.02	0.06±0.02	0.16	-7048.43
9MW	1	5.47	-	-	-	19.37	24.85	0.22±0.03	-	-	0.22	**-5888.06**
	2	5.07	1.18	-	-	18.55	24.81	0.20±0.04	-	0.04±0.02	0.20	-5892.88
	3	5.35	0.32	-	-	19.18	24.87	0.21±0.04	0.01±0.02	-	0.22	-5894.85
	4	6.86	1.01	-	-2.15	17.29	21.02	0.29±0.04	0.04±0.02	-	0.20	-5893.65
	5	5.07	0.00	1.17	-	18.55	24.81	0.20±0.02	0.00±0.00	0.04±0.02	0.20	-5892.88
	6	6.28	1.10	0.98	-2.91	16.25	20.72	0.28±0.04	0.05±0.02	0.04±0.02	0.12	-5893.02
YW	1	5.95	-	-	-	23.85	29.80	0.20±0.04	-	-	0.20	**-5634.51**
	2	5.62	-	0.84	-	23.28	29.77	0.19±0.04	-	0.03±0.02	0.19	-5637.85
	3	5.86	0.22	-	-	23.72	29.81	0.19±0.04	0.01±0.02	-	0.20	-5638.42
	4	6.69	1.24	-	-2.81	22.67	29.81	0.24±0.03	0.04±0.02	-	0.10	-5638.48
	5	5.64	0.00	0.85	-	23.28	29.77	0.18±0.03	0.00±0.00	0.03±0.02	0.18	-5637.85
	6	7.65	1.05	1.41	-2.51	22.16	29.76	0.25±0.03	0.03±0.02	0.04±0.02	0.15	-5638.63

σ^2_a: direct genetic variance, σ^2_m: maternal additive genetic variance, σ^2_{pe}: maternal permanent environmental variance, σ^2_e: residual variance, σ^2_p: phenotypic variance, σ^2_{am}: covariance between direct genetic and maternal additive genetic, h^2_d: direct heritability, h^2_m: maternal heritability, c^2: ratio of maternal permanent environmental effect to phenotypic variance, h^2_t: total heritability and Log$_L$: log likelihood.
BW: birth weight, WW: weaning weight (three-month weight), 6MW: six-month weight, 9MW: nine-month weight and YW: yearling weight.
The most appropriate model for each trait is shown in bold face.

Estimate of direct heritability for WW (0.28) obtained in the present study was well consistent with Rashidi *et al.* (2008) in Kermani sheep. Also, the estimated direct heritability of WW was within the range of those published in the literature, which varied from 0.09 (Mousa *et al.* 1999) to 0.33 (Snyman *et al.* 1995). A decreasing trend in the maternal effects from birth to later ages has shown. The high magnitude of the maternal additive genetic effects for BW and WW will mean that ignoring them in a selection model will bias upwards the estimates of direct heritability (Snyman *et al.* 1995).

The estimated value of direct heritability declined from weaning to twelve months of age, reached to a value of 0.20 for YW. Consistent with our study, Bahreini Behzadi *et al.* (2007) found such fluctuations for direct heritability estimate of Kermani sheep from birth to nine months of age. Estimate of direct heritability for 6MW (0.32) obtained in the current study were higher than the estimates of Bahreini Behzadi *et al.* (2007), Eskandarinasab *et al.* (2010) and Mohammadi *et al.* (2010). The direct heritability estimate of 9MW (0.22) was in the range of 0.03 (Mokhtari *et al.* 2008) to 0.59 (Snyman *et al.* 1995).

The estimated direct heritability of 0.20 for YW was in the range of the published values for the Iranian sheep breeds (Bahreini Behzadi *et al.* 2007; Miraei-Ashtiani *et al.* 2007; Mokhtari *et al.* 2008). The low estimates of maternal heritability for 6MW, 9MW and YW were expected, because at these ages individuals do not depend on their mother and their weights should reflect only the direct effect of the genes on growth except for carry over maternal effects from before weaning. For animals raised on pasture, the length of time from birth to yearling is probably not enough that compensatory gain could buffer completely the maternal effect existing at birth. Robison (1981) suggested that even if maternal effects tend to diminish with age, some adult traits will nevertheless contain this source of variation.

In general, different estimates of the direct and maternal heritabilities of body weight traits in various studies can be due to model of analysis, sheep breed, data structure, different management of herds and different breeding strategies in sheep. The relatively low heritability estimates for the studied traits can be perhaps explained by the low nutritional management, low quality of pastures and harsh climatic conditions, which result in a high environmental variance. Sizeable effects of maternal influences on BW and WW traits suggest that these effects need to be considered in selection programs and exclusion of them may lead to biased estimations of direct heritability. When maternal effects are of high importance, total heritability values are more efficient than direct heritabilities for estimation of selection response based on phenotypic values (Abegaz *et al*. 2005).

In the present study, total heritabilities with appropriate models ranged from 0.20 for YW to 0.39 for WW.

There was no antagonist relationship between these traits in terms of phenotypic, genetic and environmental correlations (Table 4).

Direct genetic correlation estimates between various stages of body development were positive, moderate to high and varied from 0.56 for BW-YW to 0.97 for 6MW-9MW. Estimates of maternal genetic correlations between body weight traits were positive and ranged from 0.84 to 0.99 (Table 4). Estimates of environmental correlation ranged from 0.13 for BW-YW to 0.73 for 9MW-YW. Phenotypic correlation estimates varied from 0.18 for BW-WW to 0.81 for 6MW-9MW. Phenotypic correlations were generally less than corresponding genetic correlations. Corresponding correlations among body weights are in general agreement with those reported in the literature (Bahreini Behzadi *et al*. 2007; Miraei-Ashtiani *et al*. 2007; Mokhtari *et al*. 2008; Rashidi *et al*. 2008; Mohammadi *et al*. 2010).

Table 4 Correlation estimates between body weight traits

Trait 1	Trait 2	r_{a12}	r_{m12}	r_{e12}	r_{p12}
BW	WW	0.67	0.93	0.22	0.18
BW	6MW	0.65	0.97	0.22	0.20
BW	9MW	0.62	0.99	0.15	0.26
BW	YM	0.56	0.99	0.13	0.26
WW	6MW	0.94	0.84	0.53	0.69
WW	9MW	0.91	0.99	0.44	0.59
WW	YM	0.86	0.99	0.33	0.46
6MW	9MW	0.97	0.89	0.67	0.81
6MW	YM	0.92	0.99	0.42	0.67
9MW	YM	0.94	0.99	0.73	0.78

r_{a12}: direct genetic correlation between traits 1 and 2, r_{m12}: additive genetic maternal correlation between traits 1 and 2, r_{e12}: environmental correlations between traits 1 and 2 and r_{p12}: phenotypic correlations between traits 1 and 2.
BW: birth weight, WW: weaning weight (three-month weight), 6MW: six-month weight, 9MW: nine-month weight and YW: yearling weight.

The large direct genetic correlation between BW and WW indicates that selection on weaning weight may lead to an increase in birth weight. The direct genetic correlations between weight at weaning and later weights were high, indicating that selection for increased WW in Kourdi sheep will also result in genetic change for 6MW, 9MW and YW. Therefore, it is reasonable to suggest that the traits to be included in the sheep recording scheme could be confined to the traits expressed early in life of the lambs, such as their birth weight and weaning weight in which both the direct and the maternal effects are involved. The positive and strong maternal genetic correlations of birth weight with later weights indicate that maternal influences on the later weights are partly originating from the prenatal period. The results with higher maternal heritability for birth weight than for all later weights also support this conclusion. The genetic correlations among growth traits of Kourdi lambs were, all, positive, indicating that selection for any of the traits should result in positive genetic change in the other traits.

CONCLUSION

The estimates of genetic parameters reported for the Kourdi sheep in were in general agreement with those reported in the literature. Maternal effects were significant sources of variation for BW and WW traits in Kourdi sheep. Therefore, effects of genetic maternal need to be accounted for estimate the best linear unbiased predicted value (BLUP) of Kourdi lambs. The estimates of direct heritability tended to increase from birth to weaning. These results indicated that selection for body weight traits on WW will be effective. The estimates of direct genetic and additive genetic maternal correlations between body weight traits were positive and high. So selection for any of these traits could result in genetic progress for the other traits.

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