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Estimates of Phenotypic and Genetic Parameters for Pre-Weaning Growth Traits of Arabi Lambs

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Abstract: Genetic parameters and (co) variance components were estimated on 2445 lambs from 139 sires and 804 dams for Birth Weight (BW) on 2237 lambs from 127 sires and 784 dams for Weaning Weight (WW) and on 2098 lambs from 115 sires and 739 dams for Average Daily Gain (ADG). The data collected from Animal Science Research Station of Agricultural and Natural Resources Ramin (Khuzestan) University during 2001-2008. Analyses were carried out by Restricted Maximum Likelihood (REML) method. Six different animal models including or ignoring maternal genetic or permanent environmental effects were fitted for traits. The Model 3 with only maternal additive effects seemed most suitable. Influencing factors such as birth year, birth type, lamb's sex and dam's age were investigated as the fixed effects for the models. Estimates of direct heritability from model 3 were 0.194 for birth weight, 0.163 and 0.149 for weaning weight and average daily gain, respectively. Maternal heritability estimates for birth weight, weaning weights and average daily gain were 0.15, 0.11 and 0.09, respectively. For these traits, correlation estimates between direct additive and maternal genetic (r_{am}) effects were high and negative ranging from -0.57 to 0.93. Bivariate analysis by Model 3 was also used to estimate genetic correlations between traits. The estimates of genetic, phenotypic and environmental correlations among traits were positive and intermediate to high in value. The results indicate that in addition to additive direct effect, additive maternal effect for all traits was important.

Key words: Arabi lamb, growth, environmental effects, direct heritability, maternal heritability, genetic correlation

INTRODUCTION

The growth traits are important factors influencing profitability in any meat producing enterprise. Rapid growth during the early period can minimize the cost of rearing and thus provide more profit to the farmer. The birth weight and early growth rate of animals are determined not only by genetic potential but also by maternal and environmental factors (Mandal *et al*., 2006). Body weights and growth rates in pre-weaning are often considered as an early indicator of the late growth and economic benefit (Hanford *et al*., 2006).

In Khuzestan Province, there are approximately 1.88 million Arabi sheep which has a satisfactory lambing of 76% (Animal Breeding Center of Iran). The Arabi sheep is among the indigenous breeds raised in southwestern region of Iran. Because of increasing demand for sheep's meat, body weight and growth rate are economically important breeding objectives that need particular attention in order to improve meat production of Arabi sheep. One way to improve growth performance is to select the best animals to be used as parents of the next generation. Estimation of heritability for traits and their correlations with each other are therefore essential for successful selection in a genetic improvement program. The objective of this study was to estimate the genetic parameters for pre-weaning growth traits of Arabi sheep by fitting six animal models, attempting to separate direct genetic, genetic maternal and permanent environmental effects.

MATERIALS AND METHODS

Data and management: The data used in this study were collected between 2001 and 2008 and included 2445 lambs from 139 sires and 804 dams for Birth Weight (BW), 2237 lambs from 127 sires and 784 dams for Weaning Weight (WW) and 2098 lambs from 115 sires and 739 dams for Average Daily Gain (ADG).

The Arabi sheep in this study were raised at Animal Science Research Station of Agricultural and Natural Resources Ramin (Khuzestan) University (Southwestern

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of Iran). All animals were raised under similar environmental, nutritional and management conditions. They were first exposed to rams at about 18 months of age and kept in the flock until death or the apparent infertility. The animals managed following semi-moving. They were grazed and supplemented by concentrates during the day and housed at night. The mating period began from early August to early October and continued as controlled. Lambing was from early January and continued until early February. Lambs were weighed and ear-tagged at birth. Weaning was at approximately 4 months of age. The structure of data used in the study is shown in Table 1.

Statistical models: Variance components and genetic parameters were estimated for each trait using the DFREML3.1 program (Meyer, 2000) by fitting six single trait animal models that ignore or include additive maternal or permanent environmental effects. The models used to estimate genetic parameters included random effects and fixed effects that were found significant in the general model analyses. Firstly, the GLM procedure (SAS, 2003) was used for determining the fixed effects that have significant influence on the traits investigated assuming interactions negligible.

The analysis of variance showed that fixed effects of birth type in 2 levels (single and twin), lamb's sex in 2 levels (male and female), birth year in 8 levels (2001-2008) and dam's age in 6 levels (2-7 old) were significant for weights at birth and weaning and average daily gain and age of lamb at weaning weight (in days) as a covariate for WW. Consequently, those effects were included in all six models for those traits. The six models were:

Model 1:

$$y = Xb + Z_1a + e$$

Model 2:

$$y = Xb + Z_1a + Z_3c + e$$

Model 3:

$$y = Xb + Z_1a + Z_2m + e \quad Cov(a,m) = 0$$

Model 4:

$$y = Xb + Z_1a + Z_2m + e \quad Cov(a,m) = A\sigma_{am}$$

Model 5:

$$y = Xb + Z_1a + Z_2m + Z_3c + e \quad Cov(a,m) = 0$$

Model 6:

$$y = Xb + Z_1a + Z_2m + Z_3c + e \quad Cov(a,m) = A\sigma_{am}$$

Table 1: Description of data set

Characters	BW[a]	WW[a]	ADG[a]
No. of records	2445.00	2237.00	2098.00
No. of sire	139.00	127.00	115.00
No. of dams	804.00	784.00	739.00
No. of dam with own records	398.00	336.00	322.00
Average no. of progeny per dam	3.04	2.85	2.84
Mean (kg)	4.18	20.06	0.137
SD (kg)	0.86	3.30	0.03
CV (%)	18.87	14.98	23.60

[a]BW: Birth Weight, WW: Weaning Weight, ADG: Average Daily Gain from birth to weaning, SD: Standard Deviation and CV: Coefficient of Variation

Where:

y = A vector of records on the different traits
b, a, m, c, e = Vectors of fixed effects, direct additive genetic effects, maternal additive genetic effects, maternal permanent environmental effects and the residual effects, respectively
X, Z_1, Z_2, Z_3 = Corresponding design matrices associating the fixed effects, direct additive genetic effects, maternal additive genetic effects and maternal permanent environmental effects to vector of y

It is assumed that direct additive genetic effects, maternal additive genetic effects, maternal permanent environmental effects and residual effects to be normally distributed with mean 0 and variance $A\sigma_a^2$, $A\sigma_m^2$, $I_d\sigma_c^2$ and $I_n\sigma_e^2$, respectively. That σ_a^2, σ_m^2, σ_c^2 and σ_e^2 are direct additive genetic variance, maternal additive genetic variance, maternal permanent environmental variance and residual variance, respectively. A is the additive numerator relationship matrix, I_d and I_n are identity matrices that have order equal to the number of dams and number of records, respectively and σ_{am} denotes the covariance between direct additive genetic and maternal additive genetic effects. In univariate analysis, log likelihood ratio tests were applied to choose the most appropriate model for each trait (Meyer, 1992).

Genetic and phenotypic correlations were estimated using two-trait analysis. The fixed effects included in the biivariate animal models were those in univariate analyses estimates from single-trait analyses were used to obtain starting values for bivariate analyses. If the value of -2 logs likelihood variance in the simplex function below 10^{-8}; it was assumed convergence had been achieved.

RESULTS AND DISCUSSION

Description of environmental effects: The least square means and standard errors for BW, WW and ADG are shown for each subclass in Table 2.

The overall least squares means for lamb weight and average daily gain were lower than reported for Zandi

Table 2: Least squares means and standard error for pre-weaning growth traits in Arabi lambs

	Traits[a]					
Fix effects	N	BW (kg)	N	WW (kg)	N	ADG
Sex		**		**		**
Male	1205	4.30±0.02[a]	1066	20.96±0.09[a]	1018	0.146±0.001[a]
Female	1240	4.07±0.02[b]	1171	19.24±0.10[b]	1080	0.129±0.001[b]
Birth type		**		**		**
Single	1674	4.31±0.02[a]	1497	20.22±0.07[a]	1399	0.140±0.000[a]
Twin	771	3.74±0.04[b]	740	19.16±0.18[b]	699	0.123±0.002[b]
Dam's age (year)		**		**		**
2	475	3.90±0.04[d]	565	19.58±0.14[d]	475	0.127±0.001[d]
3	467	4.07±0.04[c]	387	19.81±0.15[cd]	351	0.133±0.002[c]
4	417	4.22±0.04[b]	355	19.98±0.19[cd]	350	0.135±0.002[c]
5	450	4.34±0.04[ab]	340	20.16±0.18[bc]	345	0.140±0.002[b]
6	336	4.36±0.04[a]	289	20.52±0.20[ab]	278	0.144±0.002[b]
7	300	4.29±0.05[ab]	301	20.84±0.18[a]	299	0.151±0.002[a]
Birth year		**		**		**
2001	303	4.08±0.05[cd]	196	20.62±0.25[ab]	247	0.135±0.002[b]
2002	296	4.37±0.04[a]	248	20.18±0.22[bc]	231	0.140±0.002[ab]
2003	238	4.08±0.03[cd]	206	18.99±0.21[e]	304	0.125±0.002[c]
2004	292	4.05±0.06[d]	218	19.35±0.25[de]	161	0.121±0.002[c]
2005	349	4.27±0.06[ab]	337	20.52±0.19[ab]	281	0.143±0.002[a]
2006	366	4.23±0.04[b]	370	20.86±0.17[a]	302	0.139±0.002
2007	300	4.20±0.05[bc]	326	19.69±0.15[bc]	288	0.142±0.002[a]
2008	301	4.10±0.05[cd]	336	19.79±0.16[cd]	284	0.145±0.002[a]

Within column, within each factor, least square means with different superscripts are different at $p<0.01$, [a]BW: Birth Weight, WW: Weaning Weight, ADG: Average Daily Gain from birth to weaning, SD: Standard Deviation and CV: Coefficient of Variation; **$p<0.01$

sheep in the previous study (Mohammadi *et al*., 2010). All of these fixed effects were significant ($p\leq 0.01$) for traits and were then included in the models. Single born lambs were heavier than lambs born as twin. The weights at BW, WW and ADG of twin-born lambs represented 86.77, 94.76 and 87.86%, respectively of those of single born lambs. These differences may be caused by the amount of milk available to lambs of different litters. In the previous research on Zandi sheep (Mohammadi *et al*., 2010) observed that single lambs weighed 0.720 kg at birth, 1.17 kg at weaning and 0.015 kg for average daily gain more than lambs born as twins. Male lambs were always heavier than female ones. The difference between the two sexes increased with age from 0.27 kg at birth, 1.72 kg at weaning and 0.017 kg for average daily gain. Rashidi *et al*. (2008) observed that Kermani male lambs were 0.16 kg heavier at birth, 1.92 kg at weaning and 0.017 kg for average daily gain higher than female lambs. Birth year had a significant effect on all body weight traits, probably because of changes that affect the prevailing climatic conditions, feeding and general management practices. Lambs born from young ewes had lower weights than those born to adult dams. The highest weights were recorded for lambs born 5-7 years old. Bahreini *et al*. (2007) also observed that body weight from birth to 9 months weight increased with increasing age of sheep until 4-5 years old. In general, the effects of fixed effects on body weight traits of Arabi lambs are in agreement with those reported by other researchers for other sheep breeds (Lavvaf *et al*., 2007; Rashidi *et al*., 2008).

Heritability estimates: Table 3 shows the estimates of variance components and parameters from univariate analysis, regarding the most appropriate model for each trait based on likelihood ratio test. The most appropriate model for BW, WW and ADG was model 3 which included direct and maternal additive genetic effect. Direct heritability estimates for BW, WW and ADG were 0.194, 0.163 and 0.149, respectively. The direct heritability estimate (0.194) for BW in present study are within the range of those published in the literature which varied from 0.04 (Maria *et al*., 1993) to 0.46 (Gizaw *et al*., 2007). The results in the present study were similar to the results reported by Abegaz *et al*. (2005) and Ghafouri *et al*. (2008) for Horro and Mehrban lambs, respectively. The results of WW and ADG in the study were similar to the results reported by Miraei-Ashtiani *et al*. (2007) for WW and Lavvaf and Noshary (2008) for ADG, respectively. In current study direct and maternal heritability estimates with appropriate models for body weight of lambs 15.98 and 21.9% reduced with age from birth to weaning, respectively.

Estimates of maternal heritability for BW, WW and ADG were 0.146, 0.114 and 0.096, respectively. These results were within the range reported from 0.05 (Koyuncu and Duru, 2009) to 0.65 (Miraei-Ashtiani *et al*., 2007) for BW, 0.04 (Ozcan *et al*., 2005) to 0.19 (Bahreini *et al*., 2007) for WW and 0.03 (Yazdi *et al*., 1997) to 0.16 (Larsgard and Olesen, 1998), respectively. Generally, the moderate magnitude of the maternal additive genetic effects for BW, WW and ADG will mean that ignoring them in a selection model will bias upwards the estimates of direct heritability.

Table 3: Estimates of (co) variance components, genetic parameters and log likelihood ratio with best model in bold for birth weight, weaning weight and average daily gain from birth to weaning with different models

Traits	Models	σ^2_a	σ_m^2	σ_c^2	σ_{am}	σ_e^2	σ_p^2	h_d^2	h_m^2	c^2	r_{am}	Log L
BW	1	0.1492	-	-	-	0.3156	0.4648	0.321	-	-	-	-1057.15
	2	0.1195	-	0.0494	-	0.2924	0.4613	0.259	-	0.107	-	-1043.88
	3	0.0900	0.0677	-	-	0.3063	0.4640	0.194	0.146	-	-	-1034.23
	4	0.1282	0.0571	-	-0.0488	0.3350	0.4715	0.272	0.121	-	-0.57	-1039.12
	5	0.1006	0.0503	0.0397	-	0.2709	0.4615	0.218	0.109	0.086	-	-1041.76
	6	0.1059	0.0567	0.0440	-0.0519	0.3141	0.4686	0.226	0.121	0.094	-0.67	-1052.17
WW	1	2.6849	-	-	-	7.4852	10.1701	0.264	-	-	-	-5658.54
	2	2.1092	-	0.8355	-	7.2447	10.1894	0.207	-	0.082	-	-5653.77
	3	1.6570	1.1589	-	-	7.3500	10.1659	0.163	0.114	-	-	-5647.42
	4	2.2332	0.9790	-	-1.3160	8.3013	10.1975	0.219	0.096	-	-0.89	-5651.04
	5	1.8749	0.7540	0.7031	-	6.8577	10.1897	0.184	0.074	0.069	-	-5655.36
	6	2.0328	0.9507	0.8900	-0.9314	7.1713	10.1134	0.201	0.094	0.088	-0.67	-5656.95
ADG	1	0.000256	-	-	-	0.000845	0.001101	0.233	-	-	-	8263.15
	2	0.000205	-	0.000072	-	0.000824	0.001101	0.186	-	0.065	-	8266.44
	3	0.000164	0.000106	-	-	0.000831	0.001101	0.149	0.096	-	-	8273.38
	4	0.000219	0.000099	-	-0.000143	0.000947	0.001122	0.195	0.088	-	-0.93	8265.73
	5	0.000201	0.000083	0.000064	-	0.000753	0.001101	0.183	0.075	0.058	-	8266.05
	6	0.000234	0.000101	0.000080	-0.000143	0.000851	0.001123	0.208	0.090	0.071	-0.93	8268.19

σ_a^2: direct additive genetic variance; σ_m ? maternal additive genetic variance; σ_c ? maternal permanent environmental variance; σ_{am}: direct-maternal genetic covariance; σ_e^2: residual variance; σ_p^2: phenotypic variance; h_d^2: direct heritability; h_m^2: maternal heritability; c^2: ratio of maternal permanent environmental effect; r_{am}: direct-maternal genetic correlation; log L: Log likelihood

Estimates of the correlation between direct and maternal genetic effects varied between traits and ranged from -0.57 to -0.67 for BW and -0.67 to -0.89 for WW, whilst fixed for ADG and was -0.93.

Negative genetic correlations between direct and maternal effects have been reported in literature ranged from -0.13 (Tosh and Kemp, 1994) to -1.0 (El-Falidi *et al*., 2000) for BW, -0.39 (Mousa *et al*., 1999) to -0.54 (Miraei-Ashtiani *et al*., 2007) and -0.02 (Larsgard and Olesen, 1998) to -0.90 (Ozcan *et al*., 2005) for ADG. The high negative correlation between direct and maternal genetic effects is an indication of how difficult it is to simultaneously improve both these traits in a selection program.

Correlation estimates: The results of two-trait analyses of traits are shown in Table 4. Bivariate analyses were carried out between the traits to estimate the correlations. The same model (Model 3) was used for all traits. Direct genetic correlation estimates between traits were positive, high and ranged from 0.77 for BW-WW to 0.91 for WW-ADG. In the present study estimate of genetic correlation between BW-ADG was 0.86. The result was higher than the range reported in literature from -0.42 (Dixit *et al*., 2001) to 0.57 (Bromley *et al*., 2000) for BW-ADG but were within range of those reported in the literature from 0.44 (Ghafouri *et al*., 2008) to 0.82 (Bahreini *et al*., 2007) for BW-WW and within range of 0.59 (Maria *et al*., 1993) to 0.99 (Duguma *et al*., 2002) for WW-ADG. The estimates of maternal genetic correlations for BW-WW, BW-ADG and WW-ADG were 0.93, 0.80 and 0.74. The estimates of phenotypic correlations between traits were generally lower than those of genetic correlation and varied from 0.58 for BW-WW to 0.77 for WW-ADG. The environmental correlations estimates between traits were positive and ranged from 0.44 for BW-WW to 0.79 for WW-ADG.

Table 4: Correlations between traits (1 and 2) resulted from bi-variate DFREML with appropriate models

Trait 1	Trait 2	r_d	r_m	r_p	r_e
BW	WW	0.80	0.93	0.58	0.44
BW	ADG	0.86	0.80	0.71	0.57
WW	ADG	0.91	0.74	0.77	0.79

r_d: direct genetic correlation between direct effects of traits 1 and 2; r_m: maternal genetic correlation between traits 1 and 2; r_p: phenotypic correlations between traits 1and 2; r_e: environmental correlations between traits 1 and 2; BW: Birth Weight, WW: Weaning Weight, ADG: Average Daily Gain from birth to weaning, SD: Standard Deviation and CV: Coefficient of Variation

CONCLUSION

This study showed that the environmental factors were significant sources of variation for body weight and average daily gain and play an important role in expression of genetic potential.

Ignoring maternal effects in the model caused overestimation of direct heritability. Maternal effects are significant sources of variation for growth traits and ignoring maternal effects in the model would cause inaccurate genetic evaluation of lambs. The large direct genetic correlation between birth and weaning weights indicates that selection on weaning weight may lead to an increase in birth weight.

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