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Genetic improvement study on pre-weaning body weight of Egyptian Rahmani lambs under a pure breeding production system

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Abstract. Body weight records of 2824 purebred Egyptian Rahmani lambs born from 946 ewes sired by 109 rams were collected from 1991 till 2001 to estimate genetic parameters and to predict breeding values (BV) for birth weight (BW), 60-day (W60) and 120-day body weight (W120) using two statistical models. The 1st model included direct additive genetic variance and residual. The 2nd model included (beside model 1) maternal genetic variance, direct-maternal genetic covariance and permanent environmental variance. Genetic parameters and breeding values were estimated by a multiple-trait animal model using derivative-free restricted maximum likelihood method (MTDFREML). Direct heritability estimates for BW, W60 and W120 were 0.40, 0.42 and 0.40, respectively using the 1st model and 0.64, 0.26 and 0.29 using the 2nd model. For BW, W60 and W120, maternal heritability estimates were 0.47, 0.17, and 0.10, total heritability estimates were 0.50, 0.53 and 0.34. Direct-maternal genetic correlations were -0.40, 0.59 and 0.01. Repeatability estimates were 0.57, 0.79 and 0.58, respectively. Phenotypic variance due to maternal permanent environmental effects (c2) increased with decreasing maternal heritability with old ages. The Spearman correlation between estimated breeding values of studied body weights by both models was high (0.52 to 0.99). These results indicate a strong maternal influence in this herd and the presence of sufficient genetic variation to allow mass selection for growth traits.

Keywords. Animal model – Maternal effect – Heritability – Breeding value – Rahmani sheep.

Étude d'amélioration génétique sur le poids corporel pre-sevrage chez des agneaux de race égyptienne Rahmani dans un système de production en race pure

Résumé. *Les relevés de poids corporel de 2824 agneaux de race pure égyptienne Rahmani nés de 946 brebis fécondées par 109 béliers, ont été collectés de 1991 à 2001 pour estimer les paramètres génétiques et prédire les valeurs génétiques (BV) concernant le poids à la naissance (BW), le poids corporel à 60 jours (W60) et à 120 jours (W120) en utilisant deux modèles statistiques. Le premier modèle comprend la variance génétique additive directe et la résiduelle. Le deuxième modèle comprend (en plus du modèle 1) la variance génétique maternelle, la covariance génétique maternelle directe et la variance environnementale permanente. Les paramètres génétiques et les valeurs génétiques ont été estimés par un modèle animal multi-caractères en utilisant la méthode du maximum de vraisemblance restreinte sans dérivée (MTDFREML). Les estimations d'héritabilité directe pour BW, W60 et W120 ont été respectivement de 0,40, 0,42 et 0,40 en utilisant le premier modèle, et de 0,64, 0,26 et 0,29 en utilisant le deuxième modèle. Pour BW, W60 et W120, les estimations d'héritabilité maternelle ont été de 0,47, 0,17, et 0,10, les estimations d'héritabilité totale ont été de 0,50, 0,53 et 0,34. Les corrélations génétiques maternelles directes ont été de –0,40, 0,59 et 0,01. Les estimations de répétabilité ont été respectivement de 0,57, 0,79 et 0,58. La variance phénotypique due aux effets environnementaux permanents du côté maternel (c2) a augmenté avec une héritabilité maternelle décroissante avec des âges avancés. La corrélation de Spearman entre les valeurs génétiques estimées pour les poids corporels objet d'étude, pour les deux modèles, était élevée (0,52 par rapport à 0,99). Ces résultats indiquent une forte influence maternelle au sein de ce troupeau et la présence d'une variation génétique suffisante pour permettre une sélection de masse pour les caractères de croissance.*

Mots-clés. *Modèle animal – Effet maternel - Héritabilité – Valeur génétique – Ovins Rahmani.*

I – Introduction

The total sheep population in Egypt is 4,200,000 heads which contribute about 6% of the total red meet produced in Egypt and Rahmani sheep are of the main breeds with a population of 990,000 (Galal *et al.*, 2005). Egyptian sheep are subtropical fat-tailed sheep characterised by satisfactory fertility and ability to breed all year round, but have low prolificacy and growth rate (Aboul-Naga, 2000). Genetic parameters are necessary to estimate breeding values and compare responses from different selection programs. The lack of systematic record keeping by Egyptian sheep breeders means that there have been few studies of the genetic parameters related to growth and maternal traits in the Egyptian flock. Growth traits of farm animals are determined not only by an animal's genetic potential for growth but also by maternal genetic and permanent and temporary environmental effects. Studies of various sheep breeds have shown that both direct and maternal genetic influences are of importance for lamb growth (Maria *et al.*, 1993). The purpose of this study was to estimate direct and maternal genetic parameters among lambs weight at birth, 60-d and 120-d of age and breeding values of all animals (rams, ewes and lambs) using animal model. Such parameters are important in designing breeding strategies for Egyptian Rahmani sheep population.

II – Materials and methods

Birth weight, 60-d and 90-d body weight records of 2428 pure Rahmani lambs born from 946 ewes sired by 109 rams from 1990 to 2001 raised in El-Serw Research Station located at Damiettta governorate (north East of Nile Delta) belonging to Animal Production Research Institute, Ministry of Agriculture, Egypt were used in the present study.

Management: Rahmani ewes flocks were bred under an accelerated lambing system (3 matings/24 month) by mating every eight months. Mating seasons for Rahmani were in May, January and September. Consequently, the corresponding lambing seasons took place in October, June and February, respectively, each mating lasting for 35 days. Ewes and rams were first mated at 18 months of age. Ewes were assigned to ram breeding groups at random. The number of 30-35 ewes was exposed to a fertile ram in separate mating pen. Rams were tested for libido and semen quality before mating season. If the ram was unable to serve the ewes, he was substituted by another ram. Ewes were weighed before mating season and at lambing. In the period from December to May, the flock was grazed Egyptian clover (*Trifolium alexandrinum*). In summer and autumn seasons the flock was fed on hay or by grazing stubble whenever possible, and supplemented with pelleted concentrate mixture. Allowances feed were offered twice per day at 7 am and 4 pm. Drinking water was available twice daily during winter and three times during summer. Mineralized salt blocks were available to all ewes. The animals were housed in semi-open sheds and freely allowed to exercise. Animals were subjected to the routine vaccination program against infection diseases. Sheep were sheared twice a year, in March and September. Before the beginning of mating season, 0.25 kilograms concentrate supplement were fed each ewe/day. The concentrates were given two weeks before mating and also during the last of 2-4 weeks of pregnancy. At lambing, new born lambs were identified and their type of birth, sex and pedigree were recorded. Weights were recorded within twenty-four hour of birth and at 30 days intervals. Lambs were weaned at approximately eight weeks of age.

Statistical analysis: Least squares procedures based on mixed model methodology (Harvey, 1990) were used to analyze data on body weight. Fixed effects due to sex of lamb, birth type and lambing year were included in the general statistical model. Genetic parameters and breeding values were estimated by multiple-trait animal model using derivative-free Restricted Maximum Likelihood method (MTDFREML) (Boldman et al, 1995). The general model for growth traits was:

$$Y = X\beta + Z_1 a + Z_2 m + Z_3 pe + e$$

where Y is a N x 1 vector of observations, β is the vector of fixed effects related to the incidence matrix X, *a* is the vector of direct genetic effects related to the incidence matrix Z_1, *m* is the vector of maternal genetic effects related to the incidence matrix Z_2, *pe* is the vector of permanent environmental maternal effects related to the incidence matrix Z_3, and *e* is the vector of random residuals (temporary environmental effect). The following fixed models were used: lamb sex (male, female), birth type (single, twin, triplets, quarters) and lambing year (1990, 1991, 1992, ….2001). Convergence was considered reached when the simplex variance was less than 10^{-8}. To ensure that a global maximum was reached, several other rounds of iterations were used using results from the previous round as starting values. When estimates did not change, convergence was confirmed.

III – Results and discussion

Least squares means and standard errors (SE) of 2824 Rahmani lambs for birth weight (BW), 60-d (W60) and 120-d (W120) were 2.47 ± 0.15, 11.0 ± 1.04 and 17.9 ± 1.19 kg, respectively. The estimates of (co)variance, heritabilities and genetic correlations for a multiple trait analysis for three studied traits are summarized in Table 1 and covariances and correlations between direct additive and maternal additive genetic effects are given in Tables 2 and 3 respectively. Negative genetic covariance was observed between direct and maternal effects for BW (-0.54), while the covariances between direct and maternal effects were positive at the later ages (w60 and w90). The correlations indicated that selection for one trait would positively affect the response to the other. The direct heritabilities for BW, w60 and w90 were moderate (0.40-0.42). The maternal heritability was higher for BW (0.47), and decreased with advanced ages (0.17 and 0.10 for body weight at 60-d and 0.90-d, respectively) indicating moderate genetic maternal variability in the flock that could be used to select for maternal ability, also indicate that expected genetic improvement would be speed. Direct additive variances and heritabilities were higher than maternal genetic variances and heritabilities for all growth traits. In general, direct heritabilities tend to be higher than maternal heritabilities for early growth traits (Hassen *et al.*, 2003). Genetic parameters depend on the historical formation, selective forces and environmental aspects of a population, which partly explains differences among the results of different studies. Estimates of h^2m tended to decline from birth to w60 to w120d. Maternal genetic effects expressed during gestation and lactation were expected to have a diminishing influence on weight as lambs became older. Variance due to permanent environmental effects (c^2), coded as an effect of the dam (possibly due to uterine capacity, feeding level at late gestation, and maternal behavior of the ewe), was 0.02 of the total variance for BW and 0.26 and 0.24 for w60 and w90, respectively (Table 1).

Birth weight had a high maternal heritability (0.47) and direct heritability of 0.64 and c^2 of 0.02, while w60d had maternal heritability of 0.17 and direct heritability of 0.26 and c^2 0.26. The same trend also was found in w120. A possible interpretation of differences on c^2 between BW and both w60 and w90 could be that suckling lambs are still dependent on mothers, whereas weaned lambs depend on themselves; furthermore, the influence of the non-permanent environmental factors becomes more important after weaning (Maria *et al.*, 1993). The values of c^2 tended to decline from birth to w120d which was expected because environmental effects associated with litters would decrease in importance as lambs became increasingly independent of the ewe. Estimates of total heritability of the total additive genetic effects (0.50, 0.53 and 0.34 for BW, w60 and w120, respectively) were less variable than estimates of either the direct or maternal heritability (Table 2). The repeatability (correlations between multiple records of the same animal) were high for all traits ranging from 0.57 (BW) to 0.79 (W60) (Table 1). This indicates that growth of the lamb in his early age is a good indicator of his future performance.

Estimates of direct and maternal genetic correlations (ra and rm) and direct-maternal (ram) genetic correlations between different traits investigated ranged between 0.36 (BW and w120d) to 0.58 (w60d and w120d) similar correlation also between BW and w60d (0.53) (Table 3). The greater heritability of BW, w60d and w90d and the high correlation between the three traits suggested that animals may be selected at an early age. The negative correlations between direct and maternal effects of BW (-0.40) (Table 3) can be due to environmental and management circumstances. Meyer *et al.* (1993) pointed out that large negative estimates of rdm are usually induced by environmental and management circumstances. In some cases, it could be a problem in partitioning the direct and the maternal variation correctly. The ram for BW (-0.40) in this study was in agreement with those reported by Tosh and Kemp (1994) in Pollet Dorset (-0.35) and Van Wyk *et al.* (1993) in Dormer (-0.35).

Table 1. Estimates of (co)variance components (kg^2) and genetic parameters for birth weight (BW), body weight at 60-d (W60) and 120-d (W120) of Rahmani lambs.

Item	BW (1)		W60 (2)		W120 (3)	
	Model1	Model2	Model1	Model2	Model1	Model2
σ^2a	0.185	1.59	3.51	4.14	5.68	5.50
$\sigma_{a(1)-a(2)}$	0.544	1.36	0.54	1.36	0.54	1.36
$\sigma_{a(1-)a(3)}$	0.618	1.07	0.62	1.07	0.62	1.07
$\sigma_{a(2)-a(3)}$	4.238	2.75	4.24	2.75	4.24	2.75
σ^2m		1.16		2.78		1.85
σam		-0.54		1.99		0.03
σ^2e	0.25	0.23	4.76	2.94	8.63	7.11
σ^2pe		0.05		4.14		4.55
σ^2p	0.43	2.48	8.28	15.1	14.3	19.0
r_{am}		-0.40		0.59		0.01
h^2a	0.40	0.64	0.42	0.26	0.40	0.29
h^2m		0.47		0.17		0.10
h^2t	0.50		0.53		0.34	
r	0.57		0.79		0.58	
c^2		0.02		0.26		0.24
e^2	0.50	0.09	0.58	0.18	0.60	0.37

σ^2_a = direct additive genetic variance; $\sigma_{a(1)a(2)}$ = additive genetic covariance between trait 1 and trait 2, etc.; σ^2_m = maternal genetic variance; σ_{am} = direct maternal genetic covariance; σ^2_e = residual (temporary environmental variance); σ^2_{pe} = maternal permanent environmental variance; σ^2_p = phenotypic variance; r_{am} = direct-maternal genetic correlation; h^2_a = direct heritability and h^2_m = maternal heritability; h^2_t = total heritability $[(\sigma^2_a + 0.5\sigma^2_m + 1.5\sigma_{dam})/ \sigma^2_p]$; r = repeatability $[(\sigma^2_d + 0.5\sigma^2_m + 1.5\sigma_{dm} + \sigma^2_c)/ \sigma^2_p]$; c^2 = fraction of phenotypic variance due to maternal permanent environmental effects; and e^2 = fraction of phenotypic variance due to residual effects.

Spearman correlation coefficients between model 1 and 2 to estimate breeding values of rams, ewes and lambs for different traits studied are presented in Table 4. All correlation among different body weight traits for all animal were high, positive and significant (P<0.01) (Table 4). Correlation coefficients of breeding values of rams, ranged from 0.69 (BW and w120) to 0.93 (w60 and w120), for ewes, ranged from 0.73 (BW and w60) to 0.97 (w60 to w120) and for lambs, ranged from 0.72 (BW and w60) to 0.96 (w60 and W120). On the other hand, within each weight (BW, w60 and w120) there was strong correlation between breeding values from model 1 and those obtained from model 2. The correlations indicated that selection for one body weight trait would positively affect the response to the other.

Table 2. Covariances between direct additive and maternal additive genetic effects for birth weight (BW), body weight at 60 days (W60) and 120 days (W120) of Rahmani sheep lambs

Item	Direct additive		
Maternal additive	BW_a	$W60_a$	$W120_a$
BW_m	-0.54	0.46	1.26
$W60_m$	1.38	1.99	2.61
$W120_m$	0.66	1.72	0.03

Table 3. Estimates of direct and maternal genetic correlations and direct-maternal genetic correlations between different traits investigated

Item	BWa	W60a	W120a	BWm	W60m
$W60_a$	0.53				
$W120_a$	0.36	0.58			
BW_m	-0.40	0.21	0.50		
$W60_m$	0.66	0.59	0.67	0.37	
$W120_m$	0.39	0.62	0.01	-0.12	0.42

Table 4. Spearman Correlation coefficients between model 1 and 2 to estimate breeding values of rams, ewes and lambs for different traits studied*

Item	Model 2								
	Breeding values of rams			Breeding values of ewes			Breeding values of lambs		
Model 1	BW	W60d	W120d	BW	W60	W120d	BW	W60d	W120d
BW	0.92	0.61	0.52	0.99	0.80	0.75	0.97	0.75	0.68
W60d	0.56	0.98	0.93	0.73	0.99	0.97	0.72	0.99	0.96
W120d	0.69	0.76	0.87	0.90	0.82	0.84	0.86	0.79	0.83

*All correlation coefficients were significant at P<0.01.

IV – Conclusions

These results indicate a strong maternal influence in this herd and the presence of great genetic variation to allow mass selection for growth traits of Rahmani lambs. The results also confirm the importance of implementing the correct model regarding random effects for parameters estimation. It was clearly shown that the maternal environmental effets should be considered in breeding values estimations. Ignoring these effects in breeding value predictions of birth and later weights might result in inappropriate breeding values.

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