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ESTIMATION OF (CO) VARIANCE COMPONENTS OF EWE PRODUCTIVITY TRAITS IN KERMANI SHEEP

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ABSTRACT

The present study was carried out to estimate (co)variance components and genetic parameters for some productivity traits of Kermani ewes using data collected during a 16-year period (1995-2011) at Breeding Station of Kermani sheep, located in Shahrebabak city, Kerman province, Iran. The traits studied were: conception rate (CR), litter size at birth per ewe exposed (LSB/EE), litter size at weaning per ewe exposed (LSW/EE), total litter weight at birth per ewe exposed (TLWB/EE) and total litter weight at weaning per ewe exposed (TLWW/EE). Genetic analysis of the studied traits was performed applying restricted maximum likelihood (REML) procedure under uni- and multivariate repeatability models. Ewe age at lambing and lambing year had significant effects on all the studied traits ($P<0.01$). Weaning age of lambs had significant effect on TLWW/EE as a linear covariate ($P<0.01$). Estimates of direct heritability for CR, LSB/EE, LSW/EE, TLWB/EE and TLWW/EE were 0.08, 0.06, 0.07, 0.11 and 0.15, respectively, while corresponding repeatability estimates were 0.25, 0.19, 0.18, 0.25 and 0.31, respectively. There were found no antagonist relationship among the studied traits in terms of phenotypic, genetic and environmental effects. Direct genetic correlation estimates among the studied traits varied from low estimate of 0.16 for CR-TLWB/EE to high estimate 0.95 for CR-LSB/EE. Low to medium phenotypic correlation estimates of 0.07 (LSB/EE-TLWW/EE) and 0.46 (TLWB/EE-TLWW/EE) were found. It seems that selection based on TLWW/EE, as an efficient selection criterion bring about genetic progress for ewe productivity traits in Kermani sheep.

Key words: reproductive performance; heritability; genetic correlation; sheep

INTRODUCTION

Small ruminants, especially native breed types, play an important role to the livelihoods of a considerable part of human population in the tropics from socio-economic aspects. Therefore, integrated attempt in terms of management and genetic improvement to enhance production is of crucial importance (Kosgey and Okeyo, 2007). Economical and biological efficiency of sheep production enterprises generally improves by increasing productivity and reproductive performance of ewes. The profitability per ewe is mainly determined by reproductive rate and ewe productivity, where mutton and lamb production have sizable influences on profitability (Wang and Dickerson, 1991). Mutton is the main source of red meat in Iran and its production does not meet the increasing demand of the consumers. Generally, the more intensive mutton production system requires the more production of large numbers of lamb per breeding ewe. Reproductive characteristics are of outstanding importance in sheep production enterprises due to their effect on profitability (Matos *et al.*, 1997), especially when meat production is the chief target. The Iranian indigenous sheep breeds are mainly kept by local pastoralists under extensive production systems based on rangelands of low quality and quantity. In such production system low efficiency is common and is caused by several factors, e.g. low reproductive efficiency (Esmailizadeh *et al.*, 2009).

Litter weight weaned per ewe exposed considered as an appropriate indicator of overall ewe productivity and one of the most important economic contributions

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that genetics can made to any sheep breeding system (Vanimisetti *et al.*, 2007). It is a complex trait, influenced by several factors such as age at puberty, ovulation rate, mothering ability, lamb growth and survival (Snowder and Fogarty, 2009). Duguma *et al.* (2002) stated that improvement in ewe productivity could to some extent be achieved by increasing the number and weight of lambs produced per ewe within a specific year. Knowledge of genetic parameters for these decisive traits is of great importance from genetic improvement standpoint. Genetic parameters for reproductive traits of several sheep breeds have been reported (Rosati *et al.*, 2002; Ekiz *et al.*, 2005 Vatankhah *et al.*, 2008; Rashidi *et al.*, 2011). The genetic characterization of the native breeds is of crucial importance for the conservatory considerations and building up efficient selection and breeding programs (Matika *et al.*, 2003). Efficient genetic improvement programs can boost profitability and efficiency for smallholders, within breed selection is an alternative for genetic improvement of small ruminants in the traditional, low-input production systems of the tropics (Kosgey and Okeyo, 2007). Accurate estimates of (co)variance components for economically important traits, such as reproductive ones, are pre-requisites for efficient designing of such strategy.

Kermani sheep is one of the most important Iranian native sheep breeds and is well-adapted to harsh environmental conditions of south-eastern part of country, where dry and hot weather is prevalent and pastures are of low quality and quantity. Kermani sheep is fat-tailed, dual purpose (meat and wool) with mutton production is of primary importance, medium-sized and white-wool breed. In a previous study genetic parameters for some reproductive traits of Kermani sheep, in a ewe lambed basis, were estimated by Mokhtari *et al.* (2010). However, estimation of genetic parameters and (co)variance components for reproductive traits in a ewe exposed basis has not been reported. Such estimates are of biological importance and provide more realistic measures for genetic improvement of ewe productivity with considering conception rate. Therefore, the present study was performed at aiming estimation of genetic parameters including heritability, repeatability and genetic correlation for reproductive traits of Kermani ewe in a ewe-exposed basis using animal model.

MATERIAL AND METHODS

The data set and pedigree information used in the present study were collected for 16 year period from 1995 to 2011 from experimental flock at the Breeding Station of Kermani sheep, located in Shahrebabak city, Kerman province, south-east of Iran.

A controlled mating strategy was designed. During the breeding season - period lasting from mid-August to mid-September, single sire pens were used allocating 25-35 ewes per a fertile ram. The ewes were kept in a flock for a maximum of 5 parities (approximately until the age of 7 years old). In order to avoid inbreeding, rams were allocated rotationally to each group of the ewes in different years. The flock was mainly kept on pastures of low quality and quantity, supplementary feeding was offered especially around mating and during winter (animals kept indoors). The supplemental feeds consist of 1.5 kg alfalfa, 0.5 kg wheat straw and 0.2 kg barley per head per day. The maiden ewes were exposed to the rams at the age of 18 months. Lambing occurs from mid-January to mid- February and new-born lambs were weighed and ear-tagged at the birth time. The lambs were kept indoors during the winter and fed manually. Flocks were grazed during the day and housed at night. Weaning

Table 1: Descriptive statistics for the studied reproductive traits

Item	Traits [a]				
	CR	LSB/EJ	LSW/EJ	TLWB/EJ	TLWW/EJ
No. of records	2683	2683	2683	2658	2597
No. of ewes	993	993	991	991	989
No. of sire of the ewes	71	71	71	71	71
No. of dams	535	535	535	534	534
No. of dams with progeny	507	507	507	504	499
Mean	0.87	0.91	0.84	2.96	17.02
S.D.	0.32	0.40	0.47	1.35	8.96
C. V. (%)	36.78	43.96	47.62	45.61	52.64

[a] CR: conception rate LSB/EJ: litter size at birth per ewe exposed; LSW/EJ: litter size at weaning per ewe exposed; TLWB/EJ: total litter weight at birth per ewe exposed; TLWW/EJ: total litter weight at weaning per ewe exposed

was at approximately 3 months of age. All lambs were weaned at the same day, without necessity at the same age.

Traits investigated can be categorized into two classes; basic and composite. Conception rate (CR) was a basic and binary trait that is measured with values of 0 (a ewe exposed to a ram did not lamb) and 1 (a ewe exposed to a ram did lamb). Other considered traits were composite including litter size at birth per ewe exposed (LSB/EE=CR x LSB), litter size at weaning per ewe exposed (LSW/EE=CR x LSW), total litter weight at birth per ewe exposed (TLWB/EE=CR x TLWB) and total litter weight at weaning per ewe exposed (TLWW/EE=CR x TLWW). LSB/EE was the number of lambs born per ewe exposed within a specific year (0, 1 or 2) and LSW/EE was the number of lambs weaned per ewe exposed within a specific year (0, 1 or 2). TLWB/EE refers to the sum of the birth weights of all lambs born per ewe exposed and TLWW/EE refers to the sum of the weights of all lambs weaned per ewe exposed. The data structure of the studied traits is presented in table 1.

General linear model (GLM) procedure of SAS package (SAS, 2002) was employed for least square analyses and determining of significant fixed effects to be included in final model. The model accounting for fixed effects included lambing year in 17 levels (1995–2011) and ewe age at lambing in 6 classes (2–7 years old). Age of lamb at weaning (in days) was fitted as a linear covariate for corresponding traits. The interaction between lambing year and ewe age was not significant and was removed from the final model. All traits contained lamb weights at birth and/or at weaning were pre-adjusted for sex of lambs using appropriate multiplicative adjustment factors.

The (co)variance components and genetic parameters were estimated by restricted maximum likelihood (REML) method, applying AI-REML method with a convergence criterion of 10^{-8} using WOMBAT program of Meyer (2007) fitting the following repeatability model:

y= Xb+ Za+Wpe+ e

where **y** is a vector of records for each traits; **b**, **a**, **pe** and **e** are vectors of fixed effects, direct additive genetic effects, permanent environmental effects related to repeated records of ewes and residual effects, respectively. Design matrices of **X**, **Z** and **W** relate the corresponding effects to the vector of **y**.

It was assumed that additive genetic effects, permanent environmental effects related to repeated records of ewes and residual effects to be normally distributed with mean of zero and variances of $\boldsymbol{A}\sigma^2_a$, $\boldsymbol{I}_d\sigma^2_{pe}$ and $\boldsymbol{I}_n\sigma^2_e$ respectively. Also $\boldsymbol{\sigma}^2_a$, $\boldsymbol{\sigma}^2_{pe}$ and $\boldsymbol{\sigma}^2_e$ are direct additive genetic variance, service sire variance, permanent environmental variance related to repeated records of the ewes and residual variance, respectively. $\boldsymbol{A}$ is the additive numerator relationship matrix, $\boldsymbol{I}_d$ and $\boldsymbol{I}_n$ are identity matrices with order equal to the number of ewes and records, respectively. In order to estimate the genetic, environmental and phenotypic correlations a multivariate analysis was performed. The fixed effects included in the multivariate animal model were those in univariate analyses.

Table 2: Least square means with standard error for the studied reproductive traits

Fixed effects	Traits [a]				
	CR	LSB/EJ	LSW/EJ	TLWB/EJ	TLWW/EJ
Overall mean	0.86±0.02	0.94±0.03	0.87±0.01	2.95±0.05	18.26±0.34
Ewe age (year)	**	**	**	**	**
2	0.63±0.02[c]	0.69±0.01[c]	0.62±0.03[c]	1.94±0.05[c]	11.21±0.34[d]
3	0.88±0.01[b]	0.92±0.03[ab]	0.86±0.01[b]	2.90±0.04[b]	17.43±0.36[c]
4	0.91±0.01[ab]	0.95±0.01[a]	0.88±0.01[b]	3.23±0.06[a]	18.61±0.35[b]
5	0.94±0.02[a]	0.99±0.01[a]	0.94±0.02[a]	3.24±0.07[a]	18.90±0.33[b]
6	0.95±0.03[a]	1.00±0.04[a]	0.96±0.03a	3.36±0.09[a]	20.11±0.42[a]
7	0.86±0.05[b]	0.87±0.06[b]	0.84±0.07[b]	2.91±0.19[b]	17.54±1.06[c]
Lambing year	**	**	**	**	**
Birth date [b]	-	ns	ns	-	0.04**±0.01

[a] Abbreviations of the traits are described in footnote of Table 1.
[b] Regression coefficient on day of lamb birth.
[c] resulted from multivariate analysis
Means with similar letters in each subclass within a column do not differ.
ns Non significant (P > 0.05).
** Significant effect at P < 0.01.

RESULTS AND DISCUSSION

The least square means for studied traits are shown in table 2. All traits significantly influenced by lambing year and ewe age at lambing (P<0.01). Age of the lamb at weaning (in days) significantly influenced TLWW/EE (P<0.01). Lambing date turned out not to have any significant effect on LSB/EE and LSW/EE (P>0.05).

Variance components and genetic parameters for considered traits under univariate analysis are presented in table 3. Low direct heritability (h^2_d) estimates were obtained for all traits ranging from 0.06 for LSB/EE to 0.15 for TLWW/EE. Estimates of ratio of permanent environmental variance due to repeated records of ewe on phenotypic variance (pe^2) were also low and varied from 0.11 for LSW/EE to 0.17 for CR and repeatability estimates from 0.18 for LSW/EE to 0.31 for TLWW/EE.

Estimates of direct heritability, obtained from multivariate analysis, are presented in table 4 (on-diagonal values). Corresponding estimated values were lower than those of obtained under univariate analysis and were 0.06, 0.04, .0.04, 0.07 and 0.08 for CR, LSB/EE, LSW/EE, TLWB/EE and TLWW/EE, respectively. Correlation estimates (phenotypic, genetic and environmental) among the traits are presented in table 4. Low to high genetic correlation estimates found among the traits that were ranged from 0.16 for CR-TLWB/EE to 0.95 for CR-LSB/EE. While, phenotypic correlation estimates were low (0.07 between LSB/EE and TLWW/EE) to medium (0.46 between TLWB/EE and TLWW/EE). Also, environmental correlation estimates were low to medium in magnitude and varied from 0.06 for LSW/EE to 0.31 for CR-LSB/EE.

Table 3: Estimates of genetic parameters and variance components for the studied reproductive traits

Traits [a]	σ^2_a	σ^2_{pe}	σ^2_e	σ^2_p	$h^2_d \pm$ S.E.	$pe^2 \pm$ S.E.	r
CR	0.0085	0.0180	0.0795	0.1060	0.08 ± 0.03	0.17 ± 0.03	0.25
LSB/EJ	0.0085	0.0184	0.1148	0.1417	0.06 ± 0.02	0.13 ± 0.03	0.19
LSW/EJ	0.0119	0.0188	0.1400	0.1707	0.07 ± 0.03	0.11 ± 0.02	0.18
TLWB/EJ	0.1632	0.2078	1.1131	1.4841	0.11 ± 0.02	0.14 ± 0.05	0.25
TLWW/EJ	8.2101	8.7474	37.7766	54.7341	0.15 ± 0.04	0.16 ± 0.02	0.31

σ^2_a: direct genetic variance; σ^2_{pe}: permanent environmental variance; σ^2_e: residual variance; σ^2_p: phenotypic variance; h^2_d: direct heritability; pe^2: ratio of permanent environmental variance on phenotypic variance; r: repeatability; S. E.: standard error.
[a] Abbreviations of the traits are described in footnote of Table 1.

Table 4: Phenotypic, genetic and environmental correlation [b] estimates and direct heritability [c] estimates for the studied reproductive traits

Traits [a]	CR	LSB/EJ	LSW/EJ	TLWB/EJ	TLWW/EJ
CR	0.06±0.05	0.95±0.26	0.74±0.34	0.16±0.21	0.34±0.23
LSB/EJ	0.44±0.08 0.28±0.17	(0.31±0.06)	0.04±0.03	0.76±0.29	0.35±0.19
LSW/EJ	0.27±0.09 0.39±0.27	(0.16±0.04) 0.49±0.26	0.36±0.09	(0.16±0.02)	0.04±0.01
TLWB/EJ	0.11±0.04 (0.06±0.02)	(0.08±0.02) 0.07±0.05	0.21±0.06 0.87±0.15	(0.12±0.02)	0.23±0.04
TLWW/EJ	0.15±0.04 (0.14±0.04)	(0.19±0.05) 0.46±0.04	0.07±0.03 (0.22±0.05)	(0.14±0.04) 0.08±0.04	0.32±0.03

[a] Abbreviations for the traits are presented in footnote of Table 1.
[b] Genetic correlations (above diagonal), phenotypic (below diagonal) and environmental in the parenthesis
[c] resulted from multivariate analysis

A general tendency for improvement of the studied traits with the increase of ewe age was observed until the age of 7 years old (Table 2) and it can be explained partly by differences in maternal effects, nursing and maternal behavior of ewe at different ages. Fourie and Heydenrych (1983) reported that twinning rate and conception rate generally increase with age, followed by a decrease in reproductive performance after approximately 5 parities. Significant effects of ewe age on reproductive traits of sheep have been reported in the literature (Rosati *et al.*, 2002; Ekiz *et al.*, 2005, Rashidi *et al.*, 2011). The significant effect of lambing year may be ascribed to variation in climatic conditions and managerial practices through different years. Significant effect of lambing year on ewe productivity traits has been well documented by others (Boujenane *et al.*, 1991; Bromley *et al.*, 2001; Ekiz *et al.*, 2005; Vatankhah *et al.*, 2008; Mokhtari *et al.*, 2010; Rashidi *et al.*, 2011).

A low estimate of 0.08 was obtained for direct heritability of CR, which was in accordance with estimates of Rosati *et al.* (2002) and Safari *et al.* (2005). Lower estimate of 0.01 was found by Vatankhah *et al.* (2008) for direct heritability of CR in Lori-Bakhtiari sheep that was lower than estimated value in the present study. The low estimate may be due to the effect of random environmental factors on variability of the observations and because of the categorical expression of the trait. Therefore, improvement of CR through selection would be difficult even though CR is of great economic importance. Low estimates of direct heritability were found for LSB/EE (0.06) and LSW/EE (0.07) that generally agreed with several authors (Fogarty, 1995; Rosati *et al.*, 2002; Safari *et al.* 2005; Vatankhah *et al.*, 2008). Therefore, the possibility to achieve rapid genetic gain through selection for these traits would be limited. Direct additive genetic variance constitutes 11 % and 15 % of phenotypic variance for TLWB/EE and TLWW/EE, respectively. TLWB/EE indicates the capacity of the ewes to produce weight of lambs at birth after exposure to the ram without taking the number of lambs born into account (Rosati *et al.*, 2002). Direct heritability estimate of TLWB/EE (0.11) was in general congruence with estimate of Rosati *et al.* (2002) and Vatankhah *et al.* (2008).

TLWW/EE measures the ability of the ewe to produce weaning weight of lamb after exposure to the ram and is a trait of great economic importance in any sheep breeding production system. Obtained direct heritability (0.15) was concordant with estimate of Rosati *et al.* (2002) and Safari *et al.* (2005). Lower estimate of 0.07 was obtained by Vatankhah *et al.* (2008) in Lori-Bakhtiari sheep. The TLWW/EE could be considered as an efficient selection criterion because it is in a sense, a measure of total productivity of the ewe for lamb-meat production during a specific breeding year (Rosati *et al.*, 2002). Furthermore, it is a high economic importance composite trait (Ercanbrack and Knight, 1998) and had components such as fertility, number of lambs at weaning per ewe exposed and number of lambs born. For all practical purposes, it is more desirable to select a component trait than a composite one when a component trait bears a high genetic correlation with composite trait, higher heritability and coefficient variation compared to the composite one (Snowder and Fogarty, 2009).

Comparison between a component trait and a composite one in terms of selection response can be done by comparing the product of the heritability and coefficient of variation (Smith, 1969). Such product can be useful in determining the credence of selection based on a composite trait relative to selection based on its components (Snowder and Fogarty, 2009). Using the obtained values in the present study, the product of the heritability and coefficient variation for TLWW/EE is 7.89, compared with 2.94 for CR, 2.64 for LSB/EE and 3.33 for LSW/EE. Therefore, response to selection for TLWW/EE would be greater than the responses expected for its component traits.

Estimates of repeatability were higher than the heritability ones suggesting that traits are affected more by non-additive genetic effects (dominance and epitasis) and permanent environmental effects. Therefore, the accuracy of selection for these traits especially for TLWW/EE on the first lambing should be medium as repeatability measures correlation between performance records in different lambing of the ewe. Repeatability estimate of CR (0.25) was medium. Contrary to us, Vatankhah *et al.* (2008) estimated low estimate of 0.10 for repeatability of CR in Lori-Bakhtiari sheep. LSB/EE and LSW/EE have relatively similar in magnitude repeatability values of 0.19 and 0.28, respectively. Higher estimates were obtained for repeatability of TLWB/EE (0.25) and TLWW/EE (0.31). Corresponding lower estimates were found by Vatankhah *et al.* (2008).

Genetic correlation estimates among the studied traits were positive and higher than those of phenotypic and environmental ones. CR had high genetic correlation with LSB/EE (0.95) and LSW/EE (0.74), probably because it is a major component of these traits. Lower genetic correlation estimates of CR with TLWB/EE (0.16) and TLWW/EE (0.34) could be explained to some extent by the fact that these traits have records different from zero, only if conception rate is successful (Rosati *et al.*, 2002; Vatankhah *et al.*, 2008). Obtained genetic correlations among CR and other studied traits were in general agreement with estimates of Rosati *et al.* (2002). LSB/EE and LSW/EE have positive and relatively high genetic correlation (0.76). Similar to our estimate, Vatankhah *et al.* (2008) obtained a corresponding value of 0.77 in Lori-Bakhtiari sheep. A lower estimate of 0.29 was found by Rosati *et al.* (2002). Medium estimates of genetic correlations for LSB/EE-TLWB/EE (0.35) and LSB/EE-TLWW/EE (0.28) were generally lower than those of obtained by Vatankhah *et al*. (2008) but generally were in agreement with Rosati *et al.* (2002). Estimates of genetic correlations for LSW/EE-TLWB/EE (0.39) and LSW/EE-TLWW/EE (0.49) were generally agreed with those of obtained by Vatankhah *et al*. (2008) and higher than estimates of Rosati *et al.* (2002). A high genetic correlation (0.87) was estimated between TLWB/EE and TLWW/EE. This high genetic correlation suggests that genes resulting in heavy birth weight of litters, through number and weight of lambs are responsible for genes affecting milk production performance and maternal behavior of ewes throughout pre-weaning period. Selection for TLWB/EE may be desirable, even if the direct heritability is not high because of the high genetic correlation between TLWB/EE and TLWW/EE. Recording of TLWB/EE have taken some weeks earlier than records of TLWW/EE. This time period can be of breeding decision making important, due to the typical seasonal breeding activity of sheep, saving a few weeks may advance selection by one breeding season (Rosati *et al.*, 2002).

CONCLUSION

Large influences of non-genetic effects on the studied traits were observed. Therefore, concentrating on managerial practices such as improvement in ewe nutrition around mating and late pregnancy can result in the improvement of reproductive performance of ewes. In spite of low genetic variations observed for the studied traits building an appropriate breeding program needs to include these traits as an integral part of the program, due to their considerable influence on the profitability of production system. In this account, TLWW/EE is a composite trait incorporating growth ability of lambs as well as their survival from birth to weaning, maternal ability of the ewes and conception rate. The existence of positive genetic correlation estimates between TLWW/EE and the other traits suggests that using TLWW/EE as a selection criterion in plotting out breeding program would be beneficial and could promote the overall productivity of the ewes.

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REFERENCES

BOUJENANE, I. – KERFAL, M. – KHALLOUK, M. 1991. Genetic and phenotypic parameters for litter traits of D'man ewes. *Anim. Prod.*, vol. 52, 1991, p. 127-132.

BROMLEY, C. M. – VAN VLECK, L. D. – SNOWDER, G. D. 2001. Genetic correlations for litter weight weaned with growth, prolificacy, and wool traits in Columbia, Polypay, Rambouillet, and Targhee sheep. *J. of Anim. Sci.*, vol. 79, 2001, p. 339-346.

DUGUMA, G. – SCHOEMAN, S. J. – CLOETE, S. W. P. – JORDAAN, G. F. 2002. Genetic and environmental parameters for productivity in Merinos. *South African J. of Anim. Sci.*, vol. 32, 2002, p. 154-159.

EKIZ, B. – OZCAN, M. – YILMAZ, A. – CEYHAN, A. 2005. Estimates of phenotypic and genetic parameters for ewe productivity traits of Turkish Merino (Karacabey Merino) sheep. *Turkish J. of Veterinary and Anim. Sci.*, vol. 29, 2005, p. 557-564.

ERCANBRACK, S. K. – KNIGHT, A. D. 1998. Responses to various selection protocols for lamb production in Rambouillet, Targhee, Columbia and Polypay sheep. *J. of Anim. Sci.*,vol. 61, 1998, p. 1311-1325.

ESMAILIZADEH, A. K. – DAYANI, O. – MOKHTARI, M. S. 2009. Lambing season and fertility of fat-tailed ewes under an extensive production system are associated with live weight and body condition around mating. *Anim. Prod. Sci.* vol. 49, 2009, p. 1086-1092.

FOGARTY, N. M. 1995. Genetic parameters for live weight, fat and muscle measurements, wool production and reproduction in sheep: a review. *Animal Breeding Abstr.*, vol. 63, 1995, p. 101-143.

FOURIE, A. J. – HEYDENRYCH, H. J. 1983. Phenotypic and genetic aspects of production in the Dohne Merino. III. The influence of age of ewe on reproductive performances. *South African J. of Anim. Sci.*, vol. 13, 1983, p. 164-166.

KOSGEY, I. S. – OKEYO, A. M. 2007. Genetic improvement of small ruminants in low-input, smallholder production systems: Technical and infrastructural issues. *Small Ruminant Research*, vol. 70, 2007, p. 76-88.

MATIKA, O. – Van WYK, J. B. – ERASMUS, G. J. –BAKER, R. L. 2003. Genetic parameter estimates in Sabi sheep. *Livestock Prod. Sci.*, 2003, vol. 79, p. 17-28.

MATOS, C. A. P. – THOMAS, D. L. – GIANOLA, D. – TEMPELMAN, R. J. – YOUNG, L. D. 1997. Genetic analysis of discrete traits in sheep using linear and nonlinear models: I. Estimation of genetic parameters. *J. of Anim. Sci.*, vol. 75, 1997, p. 76-87

MEYER, K. 2007. WOMBAT: a tool for mixed model analyses in quantitative genetics by Restricted Maximum Likelihood (REML). *J. Zhejiang University Sci.*, 2007, B 11, p. 815-821.

MOKHTARI, M. S. – RASHIDI, A. – ESMAILIZADEH, A. K. 2010. Estimates of phenotypic and genetic parameters for reproductive traits in Kermani sheep. *Small Rum. Res.*, vol. 88, 2010, p. 27-31.

RASHIDI, A. – MOKHTARI, M. S. – ESMAILIZADEH, A. K. – ASADI FOZI, M. 2011. Genetic analysis of ewe productivity traits in Moghani sheep. *Small Rum. Res.*, vol. 96, 2011, p. 11-15.

ROSATI, A. – MOUSA, E. – VAN VLECK, L. D. – YOUNG, L. D. 2002. Genetic parameters of reproductive traits in sheep. *Small Rum. Res.*, vol. 43, 2002, p. 65-74.

SAFARI, E. – FOGARTY, N. M. – GILMOUR, A. R. 2005. A review of genetic parameter estimates for wool, growth meat and reproduction traits in sheep. *Livestock Prod. Sci.*, vol. 92, 2005, p. 271-289.

SAS/STAT (2002).v. 9.1, SAS Institute INC., Cary, NC, USA.

SMITH, C. 1969. Optimum selection procedures in animal breeding. *Animal Prod.*, vol. 11, 1969, p. 433-442.

SNOWDER, G. D. – FOGARTY, N. M. 2009. Composite trait selection to improve reproduction and ewe productivity: a review. *Animal Prod. Sci.*, vol. 49, 2009, p. 9-16.

VANIMISETTI, H. B. – NOTTER, D. R. – KUEHN, A. 2007. Genetic (co)variance components for ewe productivity traits in Katahdin sheep. *J. of Anim. Sci.*, vol. 85, 2007, p. 60-68.

VATANKHAH, M. – TALEBI, M. A. – EDRISS, M. A. 2008. Estimation of genetic parameters for reproductive traits in Lori-Bakhtiari sheep. *Small Rum. Res.*, vol. 74, 2008, p. 216-220.

WANG, C. T. – DICKERSON, G. E. 1991. Simulation of life-cycle efficiency of lamb and wool production for genetic levels of component traits and alternatives management options. *J. of Anim. Sci.*, vol. 69, 1991, p. 4324-4337.