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Estimates of genetic and phenotypic parameters for reproductive traits in Iranian native Kordi sheep

Davoud Ali Saghi[*] and Ali Reza Shahdadi

*Animal Science Research Department, Khorasan Razavi Agricultural and Natural Resources Research and Education Center, Mashhad, Iran. *Author for correspondence. E-mail: davoudali@yahoo.com*

ABSTRACT. The data set for estimation of genetic and phenotypic parameters of reproductive traits in Kordi sheep were collected from 1996 to 2013. The reproductive traits included age at first lambing (AFL), number of lambs born (NLB/EL) and weaned (NLW/EL) per ewe in each lambing, total weight of lambs born (TWLB/EL) and weaned (TWLW/EL) per ewe in each lambing, total number of lambs born (TNLB) and weaned (TNLW) per ewe, total weight of lambs born (TWLB) and weaned (TWLW) per ewe. The genetic parameters were estimated through restricted maximum likelihood method using WOMBAT. The effects of environmental factors (year of lambing, type of birth, maternal age at lambing) on all reproductive traits were significant ($p < 0.01$). Direct heritability, maternal heritability and the ratio of maternal permanent environmental variance to phenotypic variance for reproductive traits were estimated in the range from 0.07 to 0.18, 0.03 to 0.08 and 0.01 to 0.03, respectively. Genetic and phenotypic correlations between reproductive traits were estimated to be positive and within the range of 0.09 to 0.96 and 0.02 to 0.29, respectively. The results suggest that selection based on number of lambs born per ewe can be more effective than other traits in improving reproductive performance in Kordi ewes.

Keywords: heritability, direct and maternal effect, genetic and phenotypic correlation, animal models.

Estimativas de parâmetros genéticos e fenotípicos para características reprodutivas em ovinos Kordi nativos do Irã

RESUMO. O conjunto de dados para a estimativa de parâmetros genéticos e fenotípicos de características reprodutivas em ovinos Kordi foi coletado de 1996 a 2013. As características reprodutivas incluíram idade ao primeiro parto, número de cordeiros nascidos e desmamados por ovelha em cada parição, peso total de cordeiros nascidos e desmamados por ovelha em cada parição, número total de cordeiros nascidos e desmamados por ovelha, peso total de cordeiros nascidos e desmamados por ovelha. Os parâmetros genéticos foram estimados pelo método de máxima verossimilhança restrita usando WOMBAT. Os efeitos dos fatores ambientais (ano de parto, tipo de nascimento, idade materna de parição) em todas as características reprodutivas foram significativos ($p < 0,01$). A herdabilidade direta, a herdabilidade materna e a razão entre variância ambiental permanente materna e variância fenotípica para características reprodutivas foram estimadas na faixa de 0,07 a 0,18; de 0,03 a 0,08 e de 0,01 a 0,03, respectivamente. As correlações genéticas e fenotípicas entre as características reprodutivas foram estimadas como sendo positivas e na faixa de 0,09 a 0,96 e de 0,02 a 0,29, respectivamente. Os resultados sugerem que a seleção baseada no número de cordeiros nascidos por ovelha pode ser mais eficaz do que outras características para melhorar o desempenho reprodutivo em ovelhas Kordi.

Palavras-chave: hereditariedade, efeito direto e materno, correlação genética e fenotípica, modelos animais.

Introduction

Kordi sheep is an Iranian fat-tailed native breed which develop to produce meat. The main distribution area of this breed is North Khorasan Province of Iran with a population of over 325,350 head which are mainly grown traditionally by nomadic people in pastures (Saghi et al., 2014). The main source of protein in Iran is mutton because of the special taste of people, so that 42% of total red meat production comes from the sheep (Vatankhah,Talebi, & Edriss, 2008). Since this amount of produced meat does not meet the needs of the growing population, increased efficiency in its production is of great importance that can be influenced by sheep reproductive function. Therefore, economic efficiency of sheep breeding is significantly influenced by the ewes' reproductive performance. The increase of reproductive performance compared with faster growth rate or decrease of body fat is far more effective in reduction of economic costs of meat production which could result from an increase in the number and weight of reared lambs reared per productive ewes due to the increase of conception rate, number of born lambs per lambing, survival of lambs until weaning and their growth (Fogarty, 1995).

The total weaning weight of each ewe's lambs per each lambing is one of the best criteria for their reproductive performance. In fact, since this trait can show the total capacity of the ewe in terms of fertility, prolificacy, lamb survival and maternal power, it is considered as one of the major goals to breed them, so that the increase of the number or weight of weaned lambs per ewe (in each lambing) is emphasized (Duguma, Schoeman, Cloete, & Jordaan, 2002). The effect of the number of lambs born per ewe in each lambing on the efficacy of sheep breeding system is quite obvious; therefore, the number of lambs per lambing is also considered as another important economic trait in relation to the sheep (Maxa, Norberg, Berg, & Pederson, 2007).

In a study on Baluchi sheep, the heritability of the number of lambs born per ewe in each lambing, total birth weight and total weaning weight of lambs per ewe per lambing have been reported as 0.20, 0.19, and 0.02, respectively (Saneei, Nejati-Javaremi, & Kiani-Manesh, 2002). Rashidi, Mokhtari, Esmailizadeh, and AsadiFozi (2011) analyzed the reproductive traits of Moghani sheep by linear models and estimated the heritability of certain traits such as the number of born lambs and the number of weaned lambs as 0.11, and 0.02, respectively. Hanford, Van Vleck, and Snowder (2003) estimated the rate of direct heritability of the number of born lambs and weaned lambs as 0.10 and 0.07 in Targhee sheep. Since no study has been done yet to estimate genetic parameters of reproductive traits in Kordi ewes of Northern Khorasan, this study aimed to estimate variance components as well as genetic parameters of reproductive traits in Kordi ewes.

Material and methods

Geographical location of the station and herd management

Kordi sheep breeding station is located in Shirvan city, North Khorasan Province, Iran. This station was established and began to work in 1988. The breeding system in this station is semi-intensively. With regard to the local weather conditions, lambs and ewes are usually sent to the pastures around the station for daily grazing in late April. Considering the pasture forage conditions, the sheep are grazed in the pasture until early July and during the wheat and barley harvest in farm lands of the town. With the onset of the cold season the herd is transferred to the station, and by setting appropriate diets each animal group (pregnant ewes, male and female lambs and rams) is fed separately and manually three meals a day. Mating season is from mid August to late October and the lambing begin in early January are and continues until late March (Saghi et al., 2014).

Data and the studied traits

In this study, pedigree information and records related to reproductive traits of 4568 Kordi ewes and their results that were collected during 1996 to 2013 in the Kordi sheep breeding station (Saghi et al., 2014). The dataset contained the animals, animal's parents, date of birth, sex of lamb, type of birth, age of dam when lambing and records of body weight at different ages. Preliminary data were edited and prepared for analysis using R software (R Core Team, 2015).

The traits reviewed in this study included age at first lambing (AFL), number of lambs born per ewe in each lambing (NLB/EL), number of lambs weaned per ewe in each lambing (NLW/EL), total weight of lambs born per ewe in each lambing (TWLB/EL), total weight of lambs weaned per ewe in each lambing (TWLW/EL), total number of lambs born per ewe (TNLB), total number of lambs weaned per ewe (TNLW), total weight of lambs born per ewe (TWLB), total weight of lambs weaned per ewe (TWLW). The statistical summary of the studied traits is presented in Table 1.

Statistical analysis

In order to identifying the effect of environmental factors on the studied traits, normality test was used and in order to apply them in the model, least squares were analyzed using GLM procedure by Statistical Analysis System [SAS] (2008), version 9.2. After significance test of fixed effects, the applied statistical model included fixed effects of ewe's lambing year, type of birth and the age of dam at lambing. Variance components and genetic parameters of the examined traits were estimated using restricted maximum likelihood (REML) and WOMBAT program (Meyer, 2012). The model used for the analysis of reproductive traits of Kordi ewes was as follows:

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

in this model, y: vector of observations, b: vector of fixed effects, a: vector of direct additive genetic effects, m: vector of maternal additive genetic effects, pe: vector of maternal permanent environmental effects, X, Z_a, Z_m and Z_{pe}: the coefficients matrices which linked fixed effects, direct additive genetic effects, maternal additive genetic effects and maternal permanent environmental effects to the observations, and e: vector of residual effects. Mathematical hopes and (co) variance matrices include:

$$E(y) = Xb, E(a) = E(m) = E(pe) = E(e) = 0$$

$$Var(y) = ZAZ'\sigma_a^2 + WAW'\sigma_m^2 + ZAW'\sigma_{am} + WAZ'\sigma_{am} + SIS'\sigma_{pe}^2 + R$$

$$Var\begin{bmatrix} a \\ m \\ pe \\ e \end{bmatrix} = \begin{bmatrix} g_{11}A & g_{12}A & 0 & 0 \\ g_{21}A & g_{22}A & 0 & 0 \\ 0 & 0 & I\sigma_{pe}^2 & 0 \\ 0 & 0 & 0 & I\sigma_e^2 \end{bmatrix}$$

here, g_{11}: additive genetic variance for direct effects of animal, g_{12} and g_{21}: additive genetic covariance between direct and maternal effects, g_{22}: additive genetic variance for maternal effects, σ^2_{pe}: variance of random maternal permanent environmental effects, σ^2_e: variance of remaining random effects, and A and I are matrices of relationships and Identity matrices, respectively. Bivariate analysis in WOMNAT software (Meyer, 2012) was used to estimate direct additive genetic and phenotypic correlations, maternal additive genetic correlation, and maternal permanent environmental correlation.

Results and discussion

The results of this study showed that the effects of fixed factors such as lambing year, type of birth, and age of dam at lambing on all reproductive traits were significant ($p < 0.01$). Therefore, the effect of environmental (fixed) factors allocates a majority of the observed variation in these traits to itself. The results are consistent with the findings of Ekiz, Ozcan, Yilmaz, and Ceyhan (2005), Rashidi, Mokhtari, Safi Jahanshahi, and Mohammad Abadi (2008), Ceyhan, Sezenler, and Erdogan (2009), and Mohammadi, Moradi-Sharbabak, and Moradi-Sharbabak (2012). Various climatic, nutritional and management conditions in different years cause changes and fluctuations in livestock's production and reproduction performance. Changeable weather conditions such as rainfall and temperature influence the quality and quantity of forage which leads to significant changes in the amount of available food to animals and satisfaction of necessary requirements and thus affects the ewes' reproductive performance directly or indirectly. The effect of type of birth on the studied traits was significant ($p < 0.01$). Because of the use of all maternal and uterine conditions, single lambs have higher birth weights, while in twin lambs or more, the energy and nutrients needed by the embryo are divided between the twins. The effect of ewe's age on reproductive traits was significant ($p < 0.01$). Lactation effects and maternal behavior of ewes at different ages may be the reasons of the significant effect of ewe's age at birth on the studied traits. Significant effects of ewe age can be due to nursing and maternal behavior of ewe at different ages (Afolayan et al., 2008).Several authors (Ceylan et al., 2009; Mokhtari, Rashidi, & Esmailizadeh, 2010; Rashidi et al., 2011) have reported the significant effect of ewe's age on reproductive traits.

Descriptive statistics of reproductive traits in Kordi ewes are presented in Table 1. The average of AFL in Kordi ewes is estimated as 940.08 days (2.57 years). Berhanu and Aynalem (2009) reported the mean AFL as 404 days in Ethiopian sheep which is much lower than the value obtained in this research. The mean of NLB/EL and NLW/EL were 1.10 and 0.98, respectively. The results are partly consistent with the values reported by Mokhtari, Rashidi, and Esmailizadeh (2010) who reported that the mean of NLB/EL and NLW/EL for Kermani ewes as 1.05 and 0.91, respectively. Moreover, Vatankhah et al. (2008) reported that the mean of NLB/EL and NLW/EL for Lori-Bakhtiari sheep as 1.12 and 1.05, respectively. The average of TWLB/EL and TWLW/EL of Kordi ewes were estimated 4.82 and 20.52 kg, respectively. Vatankhah and Talebi (2008) and Mokhtari et al. (2010) reported that TWLB/EL was 4.86 and 3.21 kg and TWLW/EL was 25.73 and 24.45 kg, respectively.

Table 1. Description of the data set used in the study.

Traits[a]	No. of records	No. of sires	No. of Dams	Mean	S.D.	C.V. (%)
AFL (day)	4568	160	1948	940.08	361.96	38.50
NLB/EL	4568	160	1948	1.10	0.30	27.55
NLW/EL	4568	160	1948	0.98	0.38	38.77
TWLB/EL (kg)	4568	160	1948	4.82	1.11	23.05
TWLW/EL (kg)	4568	160	1948	20.52	8.38	40.82
TNLB	1758	116	1244	2.72	1.68	61.85
TNLW	1758	116	1244	2.44	1.55	63.68
TWLB (kg)	1758	116	1244	11.91	7.34	61.67
TWLW (kg)	1758	116	1244	50.73	33.67	66.37

[a] AFL: age at first lambing, NLB/EL: number of lambs born per ewe in each lambing, NLW/EL: number of lambs weaned per ewe in each lambing, TWLB/EL: total weight of lambs born per ewe in each lambing, TWLW/EL: total weight of lambs weaned per ewe in each lambing, TNLB: total number of lambs born per ewe, TNLW: total number of lambs weaned per ewe, TWLB: total weight of lambs born per ewe, TWLW: total weight of lambs weaned per ewe.

The mean of TNLB and TNLW was 2.72 and 2.44, respectively. As it can be seen, the mean of TNLW is less than the mean of TNLB, which indicates that a percentage of Kordi lambs after birth and under the effect of environmental and management factors have not reached the weaning stage. The mean of TNLB in this study is lower and the mean of TNLW is higher than the amounts reported by Hanford, Van Vleck, and Snowder (2005) for the Rambouillet sheep. The mean of TWLB and TWLW of Kordi sheep in this study were 11.91 and 50.73, respectively. In general, the differences between the mean of traits in various studies are largely due to differences in the type of information and how the data have been edited.

Estimated the direct additive and maternal heritabilities and ratio of permanent environmental variance on phenotypic variance are presented in Table 2. The values of direct additive and maternal heritabilities and ratio of permanent environmental variance on phenotypic variance for AFL of Kordi ewes were estimated 0.18, 0.08, and 0.01, respectively. The amounts of direct additive and maternal heritabilities for NLB/EL, NLW/EL, TWLB/EL and TWLW/EL were estimated 0.14, 0.08, 0.09, 0.07, and 0.04, 0.05, 0.04, 0.03, respectively. Moreover, ratio of permanent environmental variance on phenotypic variance for NLB/EL, NLW/EL, TWLB/EL and TWLW/EL ranged from 0.01 to 0.03. The estimates for NLB/EL and NLW/EL are within the range of the studies conducted by Fogarty, Brash, and Gilmour (1994) and Mokhtari et al. (2010). Reported estimates of heritability for NLB/EL by Mohammadi et al. (2012) were 0.11 for Makooei sheep and by Ekiz et al. (2005) and Van Wyk, Fair, and Cloete (2003) for Merino and Dormer sheep was 0.053 and 0.059, respectively. According to the results, lower estimate of heritability for NLW/EL compared to the value of heritability for NLB/EL can be due to the death of lambs from birth to weaning which is influenced by direct additive genetic and environmental factors of the lambs and is less related to genetic composition of the ewe. The estimated direct additive heritability for TWLB/EL in this study (0.08) is consistent with the value of heritability reported for this trait by Fogarty (1995). The range of direct additive heritability for TWLB/EL was reported 0.04 to 0.4 by Matika, Van Wyk, Erasmus, and Baker (2003) and vanWyk et al. (2003). TWLB/EL is a combination of the number of lambs born and the weight of lambs in each birth of ewe and indicates the ewe's capacity to produce kg weight of lamb without considering the number of lambs (Vatankhah et al., 2008). Direct additive heritability of TWLW/EL was estimated 0.07. This value is consistent with the findings of Matika et al. (2003). The estimate of direct additive heritability for TWLW/EL was lower than TWLB/EL one. This could be due to the fact that shortly after birth, the lambs have access to forage and concentrate in addition to breast milk. Thus, some changes in weaning weight can be due to differences in the use of supplementary food in addition to the individual genotype.

Table 2. Estimates of heritabilities for reproductive traits.

raits[a]	$h^2_d \pm S.E$	$h^2_m \pm S.E$	$pe^2 \pm S.E$
FL	0.18±0.06	0.08±0.02	0.01±0.01
LB/EL	0.14±0.05	0.04±0.03	0.02±0.01
LW/EL	0.09±0.03	0.04±0.02	0.02±0.01
WLB/EL	0.08±0.03	0.05±0.02	0.03±0.02
WLW/EL	0.07±0.04	0.03±0.02	0.01±0.01
NLB	0.15±0.06	0.07±0.03	0.01±0.01
NLW	0.13±0.07	0.05±0.03	0.01±0.01
WLB	0.12±0.04	0.06±0.03	0.01±0.01
WLW	0.11±0.04	0.04±0.02	0.01±0.01

h^2_d: direct additive heritability, h^2_m: maternal heritability, pe^2: ratio of permanent environmental variance on phenotypic variance, S.E.: standard error. [a] For traits abbreviations see footnote of Table 1.

According to the results, direct additive heritabilities for TNLB, TNLW, TWLB and TWLW were estimated 0.15, 0.13, 0.12, and 0.11, respectively. The maternal additive heritability for the above traits ranged from 0.04 to 0.08. In general, the estimated heritabilities of reproductive traits for Kordi ewes show that direct additive genetic effect of the animal is more than the maternal genetic effect and permanent environmental effect. This indicates the low effect of the environment on these traits. Vatankhah and Talebi (2008) reported that the values of direct heritability for TNLB, TNLW, TWLB and TWLW of Lori Bakhtiari ewe were 0.10, 0.10, 0.23, and 0.15, respectively. These estimated values (except for TNLB) are within the range of estimated direct additive heritability in this study. Ekiz et al. (2005) reported that estimated direct additive heritabilities of TNLB, TNLW, TWLB and TWLW in Merino sheep in Turkey were 0.02, 0.05, 0.04, and 0.04, respectively. Mohammadi et al. (2012) reported heritability estimate for TWLB and TWLW Makooei sheep 0.17 and 0.12, respectively. In general, the differences in direct additive and maternal heritability estimates of the studied traits in various studies can due to the type of model used, sheep breed, structure and volume of the data used, management used in livestock, and finally application of various breeding strategies of sheep.

Table 3 displays genetic (direct additive) and phenotypic correlations of reproductive traits in Kordi sheep. Generally, the estimated genetic and phenotypic correlations between reproductive traits in this study were positive. Genetic and phenotypic correlation of AFL of ewe with other reproductive traits were estimated positive and within the range of 0.05-0.26 and 0.02-0.13, respectively. These results are consistent with the findings of Safari, Fogarty, and Gilmour (2005), and Vatankhah et al. (2008).

Table 3. Estimations of genetic (above diagonal) and phenotypic (below diagonal) correlations of reproductive traits.

Traits[a]	AFL	NLB/EL	NLW/EL	TWLB/EL	TWLW/EL	TNLB	TNLW	TWLB	TWLW
AFL	-	0.26	0.15	0.13	0.14	0.21	0.09	0.19	0.05
NLB/EL	0.11	-	0.89	0.96	0.92	0.53	0.19	0.42	0.11
NLW/EL	0.08	0.17	-	0.76	0.94	0.17	0.42	0.26	0.33
TWLB/EL	0.09	0.29	0.17	-	0.53	0.23	0.09	0.22	0.13
TWLW/EL	0.05	0.19	0.14	0.09	-	0.13	0.29	0.09	0.39
TNLB	0.13	0.12	0.09	0.11	0.12	-	0.83	0.94	0.81
TNLW	0.02	0.04	0.08	0.10	0.13	0.17	-	0.82	0.96
TWLB	0.08	0.09	0.10	0.14	0.07	0.23	0.19	-	0.79
TWLW	0.03	0.03	0.05	0.09	0.16	0.17	0.18	0.12	-

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

Genetic correlation between NLB/EL and NLW/EL, TWLB/EL, TWLW/EL, TNLB and TWLB was estimated positive and medium to high (range from 0.42 to 0.96) which are consistent with Mohammadi et al. (2012). Genetic and phonotypic correlations between TWLB/EL and TWLW/EL were estimated 0.53 and 0.09, respectively. Also, genetic and phenotypic correlations between TWLB and TWLW were 0.79 and 0.12, respectively. These results are within the range of reported values on other breeds (Vatankhah et al., 2008; Mokhtari et al., 2010). High genetic correlations between the above traits indicate that the gens that are responsible for increasing total birth weight result in increasing of total weaning weight. Moreover, it seems that the genes responsible for increasing total birth weight can increase mother's milk and maternal ability, because weaning weight of lamb in addition to its own genotype depends on maternal ability of ewe, as well. Therefore, with regard to high and positive genetic correlation between the number of lambs born and the number of lambs weaned as well as the total weight of lambs born per ewe and total weight of lambs weaned per ewe it can be expected that genetic improvement in each one of these traits lead to genetic development in another trait.

Conclusion

Although phenotypic variation in reproductive traits is high, but the heritability of these traits is low. Therefore, the response to selection for these traits will not be much. As it was observed, the genetic correlation between reproductive traits in this study was moderate to high, thus the choice for each one of these traits leads to genetic improvement of other traits. The number of lambs born had relatively higher heritability than the other traits; on the other hand, it has ligher correlation with traits associated to lambs weaning (the number and total weight of weaning). Therefore, NLB/EL and TNLB can be used as the selection criterion in breeding programs of Kordi sheep to improve reproductive performance of ewes of this breed.

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