J. Agr. Sci. Tech. (2019) Vol. 21(6): 1423-1431

Improvement of Reproductive and Growth Traits by Selecting Ewes Based on Reproductive Composite Traits in Baluchi Sheep

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ABSTRACT

In this study, 1973-2003 data of 12,328 animals from Abbasabad Baluchi Sheep Breeding Station, Iran, were used to estimate genetic and phenotypic correlations between Total Weight of lambs Weaned per Ewe Joined in the first, 2nd, 3rd and 4th lambing (TWW1/EJ, TWW2/EJ, TWW3/EJ, and TWW4/EJ, respectively), and *TWW* of the total four lambing (TWWt/EJ). Also, the study aimed to estimate correlations of *TWW1/EJ...TWW4/EJ* and Birth Weight (BW) as well as Weaning Weight (WW). The (co)variance components and genetic correlations were estimated by DFREML procedures. Genetic correlation between *TWW1/EJ* and *TWWt/EJ* was high and positive (0.76). Genetic correlations of *TWW/EJ* in different lambing with BW and WW ranged from 0.16 to 0.32 and 0.95 to 0.97, respectively. Repeatability of *TWW/EJ* for lambing 1-4 was 0.15. Results suggested that selection for increased lifetime reproductive performance could be based on *TWW1/EJ* in the first lambing. Overall, results indicate that *TWW/EJ*, as an important but sex-limited trait, may be used in selection criterion to indirectly improve the related traits.

Keywords: Birth weight, **C**omposite traits, Heritability, Weaning weight.

INTRODUCTION

Baluchi sheep, a fat-tailed and small sheep, encompasses about 20% of the sheep population in Iran and can be found mostly in the arid and semi-arid regions (Vaez *et al*., 1993). This breed, as the most numerous native breed of Iran, is well adapted to dry and hot climatic conditions as well as low quality pasture in the eastern part of this country (Yazdi *et al*., 1997). Selling lambs is the most important source of income in this production system. Hence, an effective way of improving production efficiency is to increase total weight of lambs weaned per ewe in a given period as a composite trait. This composite trait can be determined by litter size as well as several other traits such as maternal ability, milk production of ewes, and growth potential of lambs.

Although in harsh conditions, with restrictions on food sources, increasing the number of born lambs may increase the total weight of lambs weaned per ewe, the quality of these lambs is not acceptable because of inappropriate nutrition. Total weight of weaned lambs is affected by many factors including numbers of born lambs, maternal capacity, ewe's milk production, and lamb's growth potential (Snyman *et al*., 1998a). Therefore, the genes affecting these traits may have

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effects on total weight of lamb weaned and lamb number or total weight of lamb weaned per ewe, as a criteria target in sheep breeding. This could partly be obtained by increasing the number of lambs weaned and weight of lambs weaned per ewe during a specific year (Duguma *et al*., 2002). Since, improvement in ewe productivity can promote meat productions, lamb production would be the major source of profitability in sheep production system (Ekiz *et al*., 2005). Litter size at weaning includes the number of lambs survived at weaning, but not the weight. It would be kept in mind that selection for only litter size at birth would not be effective for increasing lamb production, so it could not include the survival rate and the individual lamb's weight at weaning (Rosati *et al*., 2002). Therefore, the litter weight of lambs weaned per ewe can be considered as the most important factor for ewe's reproduction and the economic efficiency of lamb production (Mohammadi *et al*., 2013; Sakthivel *et al*., 2017).

Many research groups have reported genetic improvement in reproductive traits, but reported results are very variable, mainly due to the low heritability of these traits. Therefore, indirect selection for improving reproductive traits will be more effective than direct selection. Therefore, estimation of genetic and phenotypic correlation between traits will be necessary to construct (co)variance components and genetic and phenotypic correlations among composite reproductive and productive traits for harsh system-living breeds such as Baluchi sheep. Estimation of repeatability can be useful for prediction of producing ability of animals in their repeated records (Bourdon, 2000). The purpose of the present study was evaluation of selection based on reproductive composite traits (total weight of lamb weaned per ewe joined in the first, second, third and fourth lambing) and related production traits (birth and weaning weight).

MATERIALS AND METHODS

Data and Pedigree

Information of Baluchi sheep were collected between 1973 and 2003 (30 years) from Abbasabad Baluchi Sheep Breeding Station, Iran. The data set for all traits included 12,328 animals, 229 sires, 3671 dams, and 1428 ewes. A detailed description of management and executed selection procedures has been given by Sanaee *et al.* (2002). Briefly, selection was based on body weight, body conformation score, and type of birth. Mating was random for each ram with 15 to 25 ewes. In this flock, about 50% of sires were kept for 2 to 3 mating seasons and the rest were used just once, and the longevity of ewes were up to 7 lambing (about 8 years of age). Data such as sex, birth date, birth type, birth weight, sire ID and dam ID were recorded after lambing. Also, records of body weights for weaning (90 days on average), 6 and 9 months of age were registered. Flock was fed in pasture during spring and summer, but in autumn and winter, they were fed with a ration based on wheat and barley stubble, alfalfa hay, dry sugar beet pulp, and concentrate. Traits analyzed were Birth Weight (BW) and Weaning Weight (WW), and the composite traits included Total Weight of lamb Weaned per Ewe Joined in the first (TWW1/EJ), second (TWW2/EJ), third (TWW3/EJ) and fourth (TWW4/EJ) lambing and also Total Weight of lamb weaned per Ewe Joined for all four lambing (TWWt/EJ).

Statistical Analysis

At first, data were verified after deleting out-of-range data and lambs without weight records or with incomplete parentage records. For fixed effects, significance level was considered at $P< 0.05$. *TWW1/EJ* to *TWW4/EJ* were calculated by adding the weaning weight of lambs of each ewe in each lambing considering the continuity of lambing after correction for sex effect. Therefore, a limitation of data preparation for *TWW1/EJ*..., *TWW4/EJ* was that the data needed to be continuous. For example, for providing *TWW2/EJ* data, ewes should have had *TWW1/EJ* and *TWW2/EJ* records, for *TWW3/EJ* data, ewes should have had *TWW1/EJ*, *TWW2/EJ*, and *TWW3/EJ*; and for *TWW4/EJ* data, ewes should have had *TWW1/EJ*, *TWW2/EJ*, *TWW3/EJ*, and *TWW4/EJ* records. This undesirably decreases the number of *TWW* records for the third and fourth lambing. For *TWW1/EJ* to *TWW4/EJ*, at the first step, sex differences of lambs were corrected, but the age of lambs was considered as a covariate. To avoid overestimation of the total weaning weight of twin per ewe, birth type was not corrected.

Correlation coefficients among *BW*, *WW* and *TWW/EJ* in different lambing were estimated using the available records in ewes. Co(variance) components and genetic and phenotypic correlations were estimated using bivariate animal models and DFREAL program (Meyer, 2000). Likelihood ratio test was used to determine the most suitable model for each trait. The following models were fitted for *TWW1/EJ*, *TWW2/EJ*, *TWW3/EJ*, *TWW4/EJ* and *TWWt/EJ*:

$$y= Xb+Z_a+e \quad (1)$$

$$y= Xb+Z_a+W_s+e \quad (2)$$

Where, *y* is the vector of observed records; *b* is the vector of fixed effects (year-season, age of dam as well as age of weaning weight for *TWW1/EJ*, *TWW2/EJ*, *TWW3/EJ* and *TWW4/EJ* fitted as covariates), *a* and *s* are the vectors of direct additive genetic effects and random effect of service sire effects, respectively. X, Z_a and W_s are the corresponding incidence matrices related to *y*, and *e* is the vector of residuals.

And the model for *BW* and *WW* was:

$$y= Xb+Z_a a+Z_m m+Z_{Pe}Pe+e \text{ (Cov a, m}\neq 0) \quad (3)$$

Where, *y* is the vector of observed records; *b* is the vector of fixed effects (year-season, sex, type of birth and age of lamb at weaning for *WW* fitted as a covariate), and *a*, *m* and *Pe* are the vectors of direct additive genetic effects, maternal additive genetic, and maternal permanent environmental effects, respectively. X, Z_a, Z_m and Z_{Pe} are the corresponding incidence matrices related to *y*, and *e* is the vector of residuals.

The heritability (h^2) was calculated as the ratio of animal additive genetic variance to phenotypic variance (Ramatsoma *et al*., 2015):

$$h^2= \sigma^2_a/\sigma^2_P \quad (4)$$

Repeatability (r) for total weight of lamb weaned per ewe joined in four lambing was calculated using the following formula:

$$r= \sigma^2_a+\sigma^2_{Pe}/\sigma^2_P \quad (5)$$

Where, σ^2_a, σ^2_{Pe} and σ^2_P were direct additive genetic variance, ewe permanent environmental variance, and phenotypic variance, respectively. To estimate the genetic, phenotypic, and environmental parameters and correlations between composite reproductive traits, univariate and bivariate analyses were performed, respectively. The fixed effects for both univariate and bivariate animal models were the same and included year-season, age of dam, and age of lamb at weaning for *WW* fitted as a covariate. For bivariate analysis, the estimation of parameters was carried out in two steps, using Powell´s method. In the first step, variance components were fixed at univariate estimates and the likelihood was maximized only with respect to the covariance, then, a second run was performed to estimate all parameters. The convergences criterion was set for the first and second steps.

RESULTS

The number of records, mean, and *CV* for each trait is presented in Table 1. The coefficient of variance and standard deviation increased with increase in number of records. Estimates of (co)variance components, heritability, variance ratio of permanent environmental effects to the phenotypic variance, and repeatability for composite reproductive traits are presented

Table 1. Number of records, mean standard deviation, and coefficient of variance for production and composite reproductive traits in Baluchi sheep.

Traits	No of records	Mean (kg)	*SD*	*CV*
BW	12328	4.28	0.67	15.78
WW	11044	22.65	4.55	20.12
TWW1/EJ	2593	23.65	5.44	19.70
TWW2/EJ	1402	26.17	6.89	23.36
TWW3/EJ	808	27.36	7.75	26.03
TWW4/EJ	417	27.60	8.07	26.14

Table 2. Estimation of variance components and genetic parameters for composite reproductive traits based on univariate analysis.[a]

Traits	Model	σ^2_a	σ^2_s	σ^2_e	σ^2_p	h^2_a *(SE)*	S^2 *(SE)*	*LogL*
TWW1/EJ	1	2.44	-	19.26	21.70	0.11(0.03)	-	-5259.4
	2	2.44	0.000	19.26	21.70	0.11(0.03)	0.000	-5259.4
TWW2/EJ	1	1.04	-	36.33	37.38	0.03(0.03)	-	-3206.0
	2	1.04	0.000	36.34	37.38	0.03(0.03)	0.000	-3206.0
TWW3/EJ	1	3.79	-	46.95	50.76	0.07(0.06)	-	-1953.0
	2	3.51	2.745	45.14	51.03	0.06(0.07)	0.054(0.025)	-1951.0
TWW4/EJ	1	7.05	-	45.00	52.05	0.13(0.12)	-	-993.4
	2	7.07	0.000	44.98	52.05	0.14(0.12)	0.000	-993.4
TWWt/EJ	1	14.71	-	137.67	152.33	0.096(0.061)	-	-3561.2
	2	14.72	0.000	135.65	152.32	0.096(0.061)	0.000	-3561.1

[a] σ^2_a: Direct additive genetic variance; σ^2_s: Permanent environmental variance; σ^2_e: Residual variance; σ^2_p: Phenotypic variance; h^2_a *(SE):* Heritability; S^2 *(SE):* Service sire effect.

in Table 2. Estimations of direct heritability for *TWW1/EJ* to *TWW4/EJ* and *TWWt/EJ* were in the range of 0.03 to 0.14. Direct heritability estimate for *TWW4/EJ* (0.14) had the highest value among composite reproductive traits. Estimates of the genetic and phenotypic correlations among the composite reproductive traits are presented in Table 3. In general, genetic correlations for composite reproduction traits were positive and moderate to high; and ranged from 0.362 (between second and fourth lambing) to 0.955 (between first and second lambing). High positive genetic correlations (0.959, 0.948, 0.971, and 0.961) were estimated between *WW* and *TWW1/EJ*, *TWW2/EJ*, *TWW3/EJ*, and *TWW4/EJ*, respectively.

Estimated co(variance) components and genetic and phenotypic correlations among production traits (BW and WW) and composite reproduction traits (TWW1/EJ to TWW4/EJ) are shown in Table 4. Estimates of (co)variance components, heritability, genetic parameters, and repeatability for Total Weight of lamb Weaned per Ewe Joined from first to fourth lambing (TWWt/EJ) using repeated records model are presented in Table 5.

DISCUSSION

Total weight of lamb weaned is a composite reproductive trait with components of lamb growth and survival until weaning and ewe reproductive performance. Despite the low heritability of *TWW/EJ* in the present study, high coefficient of variance indicates that selection may have the possibility to improve these traits. Also, heritability for composite reproductive traits were in the range of estimates reported by several authors for other breeds (Rosati *et al*., 2002; Van Wyk *et al*., 2003; Ekiz *et al*., 2005; Mokhtari *et al*., 2010). Also, Vatankhah *et*

Table 3. The genetic and phenotypic correlations among the composite reproductive traits.[a]

Trait 1	Trait 2	σ_a12	σ_e12	σ_p12	r_a12	r_e12	r_p12
TWW1/EJ	*TWW2/EJ*	1.549	3.784	5.333	0.955	0.143	0.187
	TWW3/EJ	2.120	3.410	5.530	0.673	0.114	0.166
	TWW4/EJ	1.838	3.377	5.215	0.454	0.114	0.155
TWW2/EJ	*TWW3/EJ*	0.344	5.434	6.778	0.674	0.131	0.156
	TWW4/EJ	1.069	7.939	9.008	0.362	0.198	0.204
TWW3/EJ	*TWW4/EJ*	2.845	4.735	7.580	0.563	0.102	0.147

[a] σ_a12: Direct additive genetic covariance of traits 1 and 2; σ_e12: Residual covariance of traits 1 and 2; σ_p12: phenotypic covariance of traits 1 and 2; r_a12: Direct additive genetic correlation of traits 1 and 2; r_e12: Residual correlation of traits 1 and 2; r_p12: Phenotypic correlation of traits 1 and 2.

Table 4. The genetic and phenotypic correlations between birth weight or weaning weight and the composite reproductive traits.[a]

Trait 1	Trait 2	σ_a12	σ_e12	σ_p12	r_a12	r_e12	r_p12
BW	*TWW1/EJ*	0.119	0.407	0.526	0.261	-0.201	0.189
	TWW2/EJ	0.423	0.048	0.462	0.572	-0.021	0.124
	TWW3/EJ	0.061	0.329	0.391	0.159	-0.106	0.097
	TWW4/EJ	0.644	0.159	0.484	0.320	-0.775	0.101
WW	*TWW1/EJ*	5.095	1.187	3.908	0.959	-0.104	0.219
	TWW2/EJ	0.886	14.797	13.913	0.948	-0.596	0.491
	TWW3/EJ	3.452	1.635	5.082	0.971	-0.083	0.212
	TWW4/EJ	3.225	0.185	3.045	0.961	-0.009	0.125

[a] σ_a12: Direct additive genetic covariance of traits 1 and 2; σ_e12: Residual covariance of traits 1 and 2; σ_p12: phenotypic covariance of traits 1 and 2; r_a12: Direct additive genetic correlation of traits 1 and 2; r_e12: Residual correlation of traits 1 and 2; r_p12: Phenotypic correlation of traits 1 and 2.

Table 5. Estimates of variance components, heritability, and repeatability for *TWWt/EJ* from the first to fourth lambing using repeated records model.[a]

Trait	σ^2_a	σ^2_{Pe}	σ^2_e	σ^2_p	h^2 (SE)	Pe (SE)	r
TWWt/EJ	2.234	2.786	27.68	32.701	0.068(0.012)	0.085(0.032)	0.153

[a] σ^2_a: direct additive genetic variance; σ^2_{Pe}: Permanent environmental variance; σ^2_e: Residual variance; σ^2_p: Phenotypic variance; *h2 :* Heritability; *Pe :* Maternal permanent environmental effect; *SE: Srandard error; r*: Repeatability.

al. (2008) reported that estimation of heritability of total litter weight at weaning (TLWW) was 0.10, which was in the reported range.

In total weight of lamb weaned, phenotypic correlations were less than genetic correlation and varied from 0.147 (between the third and fourth lambing) to 0.513 (between the first and the sum of the four consecutive lambing). High correlations between *TWW/EJ* in all lambing suggested that selection for *TWW* in the first lambing would be more useful than later lambing. Also, this indicated that the ability of ewes to produce lambs with high weight at weaning was correlated with *WW* of the lambs, because the growth of lambs from birth to weaning and mothering ability are affected by individual genotype of lambs (Rosati *et al*., 2002).

Composite reproductive traits, as combinations of other estimable traits, are expected to have high genetic correlation with each component trait. Genetic correlation of *BW* with *TWW/EJ* ranged from 0.159 (with TWW3/EJ) to 0.574 (with

TWW2/EJ) in different lambing and phenotypic correlations among these traits were low and positive (ranging from 0.097 to 0.189). Bromley *et al*. (2001) reported that genetic correlation between body weight (at birth, weaning and 9th month) and *TWW* ranged from -0.22 to 0.28, but their definition of total weight of lamb weaned was slightly different from what we used in this study. The low but positive genetic correlations between *TWW/EJ* and body weights suggest that selection to improve genetic merit in either of these two traits would result in some response in the other trait. High genetic correlations between *WW* and *TWW/EJ* in different lambing were reported in previous studies (Snyman *et al*., 1998b; Olivier *et al*., 2001). Phenotypic correlations between *WW* and *TWW/EJ* in different lambing were lower than genetic correlations and varied from 0.125 (with TWW3/EJ) to 0.491 (with TWW2/EJ). Similar results were obtained by Snyman *et al*. (1997). Estimates of genetic and phenotypic correlations varied noticeably, but they were within the reported range (Fogarty *et al*., 1995; Rosati *et al*., 2002). Positive and high genetic correlations estimated between *WW* and *TWW/EJ* were expected, because ewes with more TWW of lambs in each litter would have higher mean WW per lamb at weaning. Several studies have shown that ewe age can affect reproductive traits significantly (Hanford *et al*., 2006; Vatankhah and Talebi, 2008; Rashidi *et al*., 2011; Amou Posht-e-Masari *et al*., 2013). The genetic correlation of composite reproductive traits with *BW* and *WW* indicated that selecting ewes based on these traits could improve the other related traits. Estimated phenotypic correlations between production and composite traits were considerably lower than the corresponding genetic correlations.

The estimated fraction of variance due to permanent environmental effects for the Number of Litter Birth (NLB) and Number of Litter Weaning (NLW) were higher than heritability. These estimates indicate that *NLB* and *NLW* traits were affected by non-additive genetic effects (dominance and epistasis) and permanent environmental effects (nutrition, management, etc.). Therefore, the first way to improve these traits is to improve environmental effects. The repeatability estimation for composite reproductive traits obtained in our study was 0.153, which was in the range of previously reported studies (Fogarty *et al*., 1995; Ekiz *et al*., 2005; Vatankhah *et al*., 2008). The repeatability estimate was higher than heritability estimates. The accuracy of selection for composite reproductive traits on the first lambing was medium; hence, repeatability can be a measure ofcorrelation between composite reproductive traits in different lambing.

In composite reproductive traits, random effect variance of the service sire was low. In addition, in these traits, the effect of service sire was not significant, so, eliminating this effect had no influence on direct heritability. Increasing trend of the heritability in the third and fourth lambing of *TWW/EJ* could be due to reduction in increasing environmental variance. That is because during these periods, ewes reached their total body growth and a steady level of milk production; hence, the effect of environment on individuals could be less. The estimated heritability in the third lambing (0.075) was less than that (0.15) in the study of Cloete *et al*. (2002). Estimated heritability in the fourth lambing (0.135) was similar to that (0.13) of Fogarty *et al.* (1994).

It has been reported that indirect selection based on early-recorded body weight traits related to TWW could be more effective than direct selection on *TWW* in Merino composite Afrino sheep (Snyman *et al*., 1997). On the other hand, indirect selection to increase *TWW/EJ* based on body weight could increase the genetic merit for reproduction. Although the aim of selection for reproduction is initially to improve the reproductive performance for the present flock, increasing the genetic merit for reproduction of the future generations would be more important.

As the total weight of lambs weaned is affected by several factors such as fertility, litter size, and viability of lambs (Snyman *et al*., 1997), if the breeding goal is to increase reproductive efficiency, *TWW/EJ* may be introduced as a selection criterion. On the other hand, moderate to high genetic correlation of *TWW/EJ* between the first and the other lambing indicates that selection based on this trait in the first period leads to the improvement in other periods, and, consequently, the flock performance may increase. For sheep meat industry in harsh systems, having a large number of heavy lambs at weaning may be the best way to increase performances; hence, selection index including fertility, survival traits, and weight traits can be applied to reach this goal.

ACKNOWLEDGEMENTS

We thank Behrouz M. Nazari from National Animal Breeding Center for his help in preparing *TWW* records.

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بهبود صفات تولید مثلی و رشد با انتخاب میشها بر اساس صفات تولید مثلی ترکیبی در گوسفند بلوچی

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چکیده

در این مطالعه، اطلاعات ۱۲۳۲۸ حیوان ایستگاه اصلاح نژاد گوسفند بلوچی عباس آباد ایران، بین سالهای ۱۳۵۱ تا ۱۳۸۱ برای برآورد همبستگی‌های ژنتیکی و فنوتیپی مجموع وزن بره های شیر گیری شده به ازای هر میش تحت آمیزش در زایش‌های اول، دوم، سوم و چهارم (TWW1/EJ، TWW2/EJ، TWW3/EJ و TWW4/EJ)، و مجموع وزن بره های کل چهار زایش هر میش (TWW) و همچنین

برآورد همبستگی‌های زایش های اول تا چهارم با وزن تولد (BW) و شیرگیری (WW) مورد استفاده قرار گرفت. اجزاء کوواریانس و همبستگی‌های ژنتیکی با استفاده از نرم افزار DFREML برآورد شدند. همبستگی ژنتیکی بین TWW1/EJ و TWWt/EJ بالا و مثبت بود (۰/۷۶). همبستگی‌های ژنتیکی TWW/EJ در دوره‌های مختلف زایش با وزن تولد و وزن شیرگیری به ترتیب در دامنه‌ی ۰/۱۶ تا ۰/۳۲ و ۰/۹۵ تا ۰/۹۷ بودند. تکرارپذیری TWW/EJ در زایش‌های اول تا چهارم ۰/۱۵ بود. نتایج پیشنهاد می-کند انتخاب برای افزایش عملکرد تولیدمثلی در طول عمر مفید میش می‌تواند بر اساس TWW1/EJ در اولین دوره‌ی زایش صورت گیرد. به طور کلی این امر نشان می‌دهد TWW/EJ به عنوان یک صفت محدود به جنس شاید بتواند به عنوان معیار انتخاب به صورت غیر مستقیم برای بهبود صفات همبسته مورد استفاده قرار گیرد.