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Genetic Analysis of Ewe Productivity Traits in Baluchi Sheep

Research Article

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ABSTRACT

The present study was carried out to estimate (co)variance components and genetic parameters for some productivity traits of Baluchi ewes. The data were collected during a 31 year period (1984-2014) at the experimental breeding station of Baluchi sheep, which is located in north-east of Mashhad, Iran. The analysis was based on 14030 records of lambs and 4371 records of ewes. Investigated traits were litter size at birth (LSB), litter size at weaning (LSW), litter mean weight per lamb born (LMWLB) and litter mean weight per lamb weaned (LMWLW) as basic traits, total litter weight at birth (TLWB) and total litter weight at weaning (TLWW) as composite traits. Genetic analysis of the studied traits was performed applying restricted maximum likelihood (REML) procedure by fitting a linear mixed animal model. Direct heritability estimate for LSB, LSW, LMWLB, LMWLW, TLWB and TLWW were 0.10, 0.08, 0.13, 0.07, 0.12 and 0.05, respectively. Corresponding values for repeatability estimates were 0.18, 0.17, 0.19, 0.15, 0.18 and 0.15, respectively. Direct genetic correlation estimates among the studied traits varied from -0.52 for LSW and LMWLB to 0.99 for TLWB and TLWW. Phenotypic and environmental correlation estimates were generally lower than those of genetic ones. Although low direct heritability's were estimated for the reproductive traits, as these traits are of interest then they used as the primary selection criterion to bring about genetic improvement in ewe productivity traits.

KEY WORDS genetic parameters, Baluchi sheep, heritability, repeatability, reproduction traits.

INTRODUCTION

Baluchi sheep, numbering about 15 million head, is one of the most important meat breeds among Iranian sheep being well known for their medium size and tolerance to harsh environment (Jafaroghli *et al.* 2013). Native sheep breeds have important function in animal production in the tropics (Kosgey *et al.* 2006) but their performance indexes are lower than those required to guarantee efficiency and competitiveness compared with other animal sectors. Baluchi sheep are mainly raised on range-lands of low quality and quantity under extensive production systems. The low efficiency common in this production system derives from several factors, e.g. low reproductive efficiency (Esmailizadeh *et al.* 2009). Dickerson (1970) suggested that increasing the number of lambs marketed per ewe per year is an important measure to improve the efficiency of meat sheep production and Ekiz *et al.* (2005) pointed out the major source of income in any sheep production system is lamb production. Ewe productivity, defined as the total weight of lambs weaned by ewe, is one of the most important economic traits and has been proposed as a biologically optimum index for improving overall flock productivity (Snowder, 2002). Therefore, improvement in ewe productivity is a key target in sheep breeding and could be attained to some extent by increasing the number of lambs weaned and weight of lambs weaned per ewe within a specific year (Duguma *et al.* 2002). (Co)variance components and genetic parameter estimates for growth traits in Baluchi sheep were previously reported by Jafaroghli *et al*. (2013). There is not any published study on genetic parameters for reproduction traits of Baluchi sheep and information to use in successful breeding programs for Baluchi sheep is scarce and hence, the objective of this study was to estimate heritability, repeatability and genetic correlations between reproductive traits in Baluchi sheep. Such estimates are important in designing optimal selection program and breeding strategies for Baluchi sheep population.

MATERIALS AND METHODS

Flock management and studied traits

The data set and pedigree information used in the present study were collected during a 31 year period (1984–2014) in the Abbas Abad Sheep Breeding Station, located in Khorasan Razavi province, north-eastern, Iran. Breeding rams and ewes are selected based on the weaning weight, breed characteristics (white coat color with black pigment in the head and legs), visual body conformation, wool quality scores and birth type (twin preference). Before expose to rams, estrous ewes were identified by teaser rams using marking harness. Annually, around 30 rams were randomly allocated to 15 to 25 ewes each and 55% of sires were used once and the rest were kept for 2 to 3 breeding season. Ewes were kept for a maximum of 7 parities (up to 8.5 years of age) depending on ewe health and reproductive performance. The annual ewe replacement rate was 25-30%. The breeding season started from late August to late October. Maiden ewes (first-lambing) were first exposed to fertile rams at approximately 18 months of age and lambing was commenced in late January to late March. The ewes and their lambs were kept in separate pens. The lambs were fed on natural pastures, mainly Festuca and Poa, and kept together until weaned at approximately three months of age. During the spring and the summer, the flocks were kept on pastures and in the autumn were fed on wheat and barley stubble. Supplementary feed was offered during the winter and late pregnancy and included a diet composed of wheat and barley straw, alfalfa hay, dry sugar beet pulp, and concentrate.

The supplementary diet contained 2.0 Mcal ME per kg, 11.5% crude protein, 1.02% calcium and 0.28% phosphorus on dry matter basis (NRC, 1985). All animals had free access to mineral blocks and fresh water. Lambs were weaned on average, at 90 days.

Traits analyzed were classified as basic and composite. The basic traits used in the present study were litter size at birth (LSB), litter size at weaning (LSW), litter mean weight per lamb born (LMWLB) and litter mean weight per lamb weaned (LMWLW).

LSB was the number of lambs born alive per ewe lambing within a specific year (1 or 2) and LSW was the number of lambs weaned per ewe lambing within a specific year (0, 1 or 2). LMWLB and LMWLW were the average weight of lambs from the same parity at birth and weaning, respectively. Composite traits were total litter weight at birth per ewe lambing (TLWB) and total litter weight at weaning per ewe lambing (TLWW). TLWB refers to the sum of the birth weights of all lambs born per ewe lambed and TLWW refers to the sum of the weights of all lambs weaned per ewe lambed. The structure of data set used in this research is presented in Table 1.

Statistical and genetic analyses

Test the significance ($P<0.05$) to include the fixed effects in the statistical model for each trait was performed using generalized linear model (GLM) procedure of SAS (SAS, 2003). The final mode included the fixed effects" of lambing year (1984-2014), lambing month in 3 classes (January, February and March), flock effect in 2 classes (flock 1 and flock 2) and ewe age at lambing (2-8 years old). The interaction effect of lambing year and ewe age was not significant ($P>0.05$) and was excluded from the final model of analysis. The model for all mentioned traits also included a random service sire effect, but genetic relationships among service sires were not considered. Tests of significance for random effects in single-trait models were performed using likelihood ratio tests after deleting each random term from the model. To compare the difference between subgroups, Duncan's multiple range test was used. Genetic analyses were carried out using single trait obtained from univariate analyses and (Co)variance components. Genetic parameters for the various traits were estimated by restricted maximum likelihood method, using WOMBAT program (Meyer, 2006) and following repeatability animal model that included direct additive effects as well as permanent environmental effects related to repeated records of ewe as random effects:

$$y= Xb + Za + Wpe + e$$

Where:

y: vectors of observations, b: fixed effects.

a: direct additive genetic effects.

pe: permanent environmental effects of ewes.

e: residual random effects, respectively.

X, Z, and W: design matrices relating the corresponding effects to observations.

Repeatability (r) was calculated as (Falconer, 1981):

$$r= (\sigma^2_a+\sigma^2_{pe}) / \sigma^2_p$$

Table 1 Characteristics of the data structure

Item	LSB	LSW	LMWLB (kg)	LMWLW (kg)	TLWB (kg)	TLWW (kg)
	Traits					
No. of records	11140	8606	11140	8606	11140	8606
No. of ewes	4371	3604	4371	3604	4371	3604
No. of sires of the ewes	334	251	334	251	334	251
No. of dam of the ewes	1772	1416	1772	1416	1772	1416
No. of dam of the ewes with records	1772	1410	1772	1410	1772	1410
No. of animals with both parents unknown	2272	1966	2272	1966	2272	1966
No. of animals with records and both parents unknown	1987	1750	1987	1750	1987	1750
Mean	1.27	1.28	4.55	23.72	5.60	28.40
SD	0.44	0.46	0.70	4.87	1.66	9.22
CV (%)	35.18	35.94	15.38	20.53	29.55	32.46

LSB: litter size at birth; LSW: litter size at weaning; LMWLB: litter mean weight per lamb born; LMWLW: litter mean weight per lamb weaned; TLWB: total litter weight at birth and TLWW: total litter weight at weaning.
SD: standard deviation and CV: coefficient of variation.

Then bivariate analyses were performed to evaluate the interrelationships among traits and genetic, phenotypic, and environmental correlations were estimated with the same fixed effects of univariate model.

RESULTS AND DISCUSSION

Fixed effects

Least square means and respective standard errors for investigated traits are presented in Table 2. Lambing year, lambing month, flock effect and ewe age at lambing had significant effects on all studied traits (P<0.01). These fixed effects were shown to be significant in many previous studies (Mokhtari *et al.* 2010; Rashidi *et al.* 2011; Mohammadabadi and Settayi-Mokhtari, 2013). The significant influence of lambing year on reproductive traits in the present study can be explained by variation in climate conditions at different years. Significant effect of year on reproductive traits of different sheep breeds has been reported by several author (Boujenane *et al.* 1991; Bromley *et al.* 2001; Ekiz *et al.* 2005; Vatankhah *et al.* 2008). Significant effects of ewe age and lambing year on reproductive traits has been reported by several authors (Hanford *et al.* 2005; Hanford *et al.* 2006; Vatankhah *et al.* 2008; Mokhtari *et al.* 2010). There was a general tendency for the improvement of traits with the increasing age of the ewe at lambing. Differences in maternal effects, nursing, and maternal behavior of ewe at different ages are reasons for the significant effects of age of the ewe at lambing. Significant effects of age of ewe at lambing on reproductive traits of sheep have been reported by Rosati *et al.* (2002), Ekiz *et al.* (2005), and Rashidi *et al.* (2011) different breeds. Coefficient of variation for a particular trait is a criterion to determine the trait variation. The lowest and the highest coefficients of variations were for LMWLB (15.38%) and LSW (35.94%), respectively that was due to the nature of these traits.

Matika *et al.* (2003) reported coefficients of determination in Sabi sheep for conception rate, number of lambs born, number of lambs at weaning, number of lambs born per ewe exposed, and number of lambs weaned per ewe exposed 35.9, 30.5, 48.9, 47.8, and 62.9%, respectively. The notable significant effect of the fixed factors can be partly due to the differences in the management system and climatic conditions over years could be main reasons for significant effects of birth year on studied traits.

Univariate analysis

Estimates of variance component and corresponding genetic parameters of the investigated traits are given in Table 3.

Low direct heritability (h^2_d) estimates were obtained for the prolificacy traits ranging from 0.05 for TLWW to 0.13 for LMWLW. Estimates of the permanent environmental variance due to the repeated records of the were also low and varied from 0.06 for TLWB to 0.1 for TLWW and repeatability estimates varied from 0.15 for TLWW to 0.19 for 160 LMWLB.

In the present research estimated heritability for LSB was 0.10 ± 0.016. In general, the estimates of the direct heritability of LSB was in agreement with those reported by other (Safari *et al.* 2005; Vanimisetti *et al.* 2007; Vatankhah *et al.* 2008; Rashidi *et al.* 2011) though lower estimates have been reported by some studies (Mokhtari *et al.* 2010; Amou Posht-e- Masari *et al.* 2013). In two separate studies the heritability for weighted means of LSB Were reported as 0.13 and 0.10 by Fogarty, (1995) and Safari *et al.* (2005), respectively that was similar to the values with the results in this study.

Direct heritability estimates for LSW ranged from 0.01 to 0.07 in the literature (Bromley *et al.* 2001; Rosati *et al.* 2002; Van Wyk *et al.* 2003; Safari *et al.* 2005; Hanford *et al.* 2005; Hanford *et al.* 2006; Vanimisetti *et al.* 2007).

Table 2 Least squares means and their standard errors for the studied traits

Item	LSB	LSW	LMWLB (kg)	LMWLW (kg)	TLWB (kg)	TLWW (kg)
Overall mean	1.29±0.06	1.26±0.05	4.28±0.10	21.17±0.53	5.25±0.23	24.75±1.03
lambing year	**	**	**	**	**	**
lambing month	**	**	**	**	**	**
January	1.32±0.04[b]	1.31±0.06[a]	4.45±0.06[b]	25.48±0.60[a]	5.55±0.14[b]	30.75±1.18[a]
February	1.35±0.03[a]	1.28±0.05[a]	4.48±0.05[b]	22.71±0.50[b]	5.77±0.12[a]	27.09±0.97[b]
March	1.32±0.03[b]	1.25±0.05[b]	4.57±0.05[a]	19.84±0.51[c]	5.76±0.12[a]	22.94±0.98[c]
Herd	**	**	**	**	**	**
1	1.27±0.06[a]	1.24±0.05[a]	4.34±0.09[a]	21.17±0.53[a]	5.27±0.23[a]	24.22±0.14[a]
2	1.30±0.06[b]	1.29±0.05[b]	4.22±0.09[b]	21.18±0.52[b]	5.24±0.23[b]	25.28±0.14[b]
Dam age (year)	**	**	**	**	**	**
2	1.09±0.05[d]	1.13±0.02[c]	4.21±0.08[a]	22.57±0.20[cd]	4.46±0.20[e]	24.21±0.39[c]
3	1.20±0.05[c]	1.25±0.02[b]	4.42±0. 08[b]	23.16±0.20[a]	5.16±0.19[d]	26.96±0.40[b]
4	1.27±0.05[b]	1.32±0.02[a]	4.45±0.08[b]	22.94±0.21[ab]	5.50±0.20[bc]	28.23±0.41[a]
5	1.31±0.05[a]	1.35±0.02[a]	4.44±0.08[b]	22.64±0.22[bc]	5.66±0.20[a]	28.55±0.43[a]
6	1.31±0.06[ab]	1.36±0.03[a]	4.44±0.08[b]	22.34±0.25[cd]	5.65±0.20[ab]	28.48±0.49[a]
7	1.26±0.06[bc]	1.32±0.03[a]	4.45±0.09[b]	22.21±0.33[cd]	5.44±0.22[bc]	27.43±0.64[ab]
8	1.23±0.07[bc]	1.28±0.05[ab]	4.41±0.11[b]	21.70±0.48[d]	5.18±0.26[cd]	25.93±0.94[bc]

LSB: litter size at birth; LSW: litter size at weaning; LMWLB: litter mean weight per lamb born; LMWLW: litter mean weight per lamb weaned; TLWB: total litter weight at birth and TLWW: total litter weight at weaning.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
* (P<0.05) and ** (P<0.01).

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

Traits	Variance components and genetic parameters						
	σ^2_a	σ^2_{pe}	σ^2_e	σ^2_p	h^2_e±SE	pe^2±SE	r
LSB	0.020	0.016	0.162	0.198	0.10±0.016	0.08±0.017	0.18
LSW	0.017	0.018	0.167	0.202	0.08±0.018	0.09±0.020	0.17
LMWLB (kg)	0.058	0.029	0.347	0.458	0.13±0.018	0.06±0.017	0.19
LMWLW (kg)	1.157	1.560	14.689	17.641	0.07±0.018	0.09±0.020	0.15
TLWB (kg)	0.333	0.151	2.179	2.730	0.12±0.017	0.06±0.017	0.18
TLWW (kg)	3.188	6.792	58.507	68.488	0.05±0.016	0.1±0.019	0.15

LSB: litter size at birth; LSW: litter size at weaning; LMWLB: litter mean weight per lamb born; LMWLW: litter mean weight per lamb weaned; TLWB: total litter weight at birth and TLWW: total litter weight at weaning.
σ^2_a: direct additive genetic variance; σ^2_{pe}: permanent environmental variance; σ^2_e: residual variance; σ^2_p: phenotypic variance; h^2_e: direct heritability; pe^2: ratio of permanent environmental variance on phenotypic variance.
r: repeatability and SE: standard error.

Estimates heritability for LSW in the current study are similar to those reported for the Columbia breed by Hanford *et al.* (2002) and for Zandi sheep reported by Mohammadi *et al.* (2012) are 0.09 for both breeds. Lower heritability for weaning weight traits, comparing to birth weight traits, suggested that the loss of lambs from birth to weaning is influenced mainly by environmental factors and lamb's genotype rather than ewe's genotype. Because of low estimates of heritability for the prolificacy traits direct selection could not result in considerable genetic improvement in reproductive efficiency in Baluchi sheep.

The estimates of heritability for LMWLB was similar to the values reported by Rosati *et al.* (2002), Vatankhah *et al.* (2008) and Mokhtari *et al.* (2010). Estimates of direct heritability of LMWLB were higher than the other traits implying the possibility of genetic change in this trait to increase birth weight of lambs. In general, the high heritability estimates for this trait allow direct selection to be more effective.

However, Amou Posht-e- Masari *et al.* (2013) and Rashidi *et al.* (2011) reported higher estimate 0.47 and 0.15 for direct heritability of LMWLB in another Iranian local breeds, Shal and Moghani sheep, respectively. Direct heritability of 0.07 for LMWLW agreed with a report by Vatankhah *et al.* (2008) in Lori-Bakhtiari sheep and a report by Rashidi *et al.* (2011) in Moghani sheep. Higher estimates were also reported by Rosati *et al.* (2002) and Mokhtari *et al.* (2010).

TLWB measures the capacity of the ewes to produce lambs weight at birth after exposure to the ram without considering the number of lambs born (Rosati *et al.* 2002; Vatankhah *et al.* 2008). Direct heritability estimate of TLWB (0.12) was in general congruence with estimate of Rosati *et al.* (2002) and Vatankhah *et al.* (2008). Direct heritability estimate for TLWB in our study (0.12) fall in the range of the values reported in the literature which varied from 0.05 (Ekiz *et al.* 2005; Mokhtari *et al.* 2010; Rashidi *et al.* 2011) to 0.40 (Rosati *et al.* 2002).

Estimated direct heritability of 0.12 for TLWB was in general congruence of reported by Amou Posht-e- Masari *et al.* (2013) in Shal sheep (0.15) and Mohammadabadi and Sattayi-Mokhtari (2013) in Kermani sheep (0.11). In general, direct heritability of TLWB was in agreement with the estimates of Rosati *et al.* (2002) and Vatankhah *et al.* (2008). TLWW is a composite trait in ewe productivity and indicate the ability of the ewe to produce weaning weight of lamb and is a trait of great economic importance in breeding production system (Ercanbrack and Knight, 1998) and reflects the combined influences of reproductive and mothering ability of ewes, pre-weaning growth and survival of lambs.

Direct heritability estimates value for TLWW in this study (0.05) was in the range of 0.02-0.18 which was reported in the literatures (Rosati *et al.* 2002; Matika *et al.* 2003; Van Wyk *et al.* 2003; Ekiz *et al.* 2005; Mokhtari *et al.* 2010; Rashidi *et al.* 2011; Amou Posht-e- Masari *et al.* 2013). Higher estimates have also been reported (Rosati *et al.* 2002; Safari *et al.* 2005; Mokhtari *et al.* 2010). However, lower estimate of 0.07 was obtained by Vatankhah *et al.* (2008) in Lori-Bakhtiari, another local sheep breed in Iran. In the present research higher heritability estimates for TLWB indicates that selection for TLWB would be more effective than TLWW.

The estimated repeat abilities for ewe reproductive performance traits and their standard errors are given in Table 3. Repeatability estimates for the considered traits were higher than the direct heritability estimates. The estimated heritability for the birth performance i.e. LSB, LMWLB and TLWB were higher than the estimated fractions of phenotypic variance ratio due to the permanent environment, and were 0.18, 0.19 and 0.18 for these traits, respectively, suggesting that additive genetic effects on these traits are more important, while the estimated direct heritability were lower than the estimated fraction of variance due to permanent environmental effects of ewe for the weaning performance i.e. LSW, LMWLW and TLWW traits and estimated 0.17, 0.15 and 0.15 for these traits, respectively. Safari *et al.* (2005) reported that generally, the permanent environmental effects for reproduction traits were lower than direct heritability. Estimates of pe^2 were low and varied from 0.06 for LMWLB and TLWB to 0.1 for TLWW; resulting in estimates of repeatability to vary from estimate of 0.15 to 0.19. Repeatability estimates for reproductive traits in the current research are slightly higher than the estimates obtained by Rashidi *et al.* (2011) in the Moghani Sheep especially for TLWW trait.

Estimates of repeatability were higher than the heritability ones suggesting that traits are affected more by non-additive genetic effects (dominance and epistasis) and permanent environmental effects. Therefore, the accuracy of selection for these traits on the first lambing should be low as repeatability measures correlation between performance records in different lambing of the ewe.

The results of bivariate analysis for estimation of correlation (phenotypic, genetic and environmental) among the traits are presented in Table 4. Low and high genetic correlation estimates found among the traits that were -0.09 for LMWLW-TLWB and 0.99 for TLWB-TLWW. While, phenotypic correlation estimates were low (0.17 between LMWLW-TLWW) to high (0.89 between LSB–LSW).

Also, environmental correlation estimates were low to high in magnitude and varied from 0.14 for LMWLW-TLWW to 0.86 for LSB–LSW. Negative estimates of genetic correlation of LSB with LMWLB (−0.39) and LMWLW (−0.28), and LSW with LMWLB (−0.52) and LMWLW(−0.28) were obtained, which could be explained by the fact that greater number of lambs in litter is associated with lower birth weight and weaning weight of lambs. In the other words, genotypes produced low lamb numbers maybe produced heavier lambs at birth and weaning and vice versa. Genetic correlation estimates between LSB with TLWB and TLWW were positive and high and estimated 0.8 and 0.91, respectively. This result was expected because the ewes with more number of lambs born in each litter would have higher total weight of lambs. Due to the low heritability for LSB, indirect selection based on TLWB could be applied to improve LSB.

Genetic correlation estimates between LMWLB with TLWB and TLWW were positive and high (0.65 and 0.81), showing that the ewes having lambs with higher mean birth weight are likely to produce more total litter weight at birth and weaning. Estimated genetic correlation for LMWLB-TLWB and LMWLB-TLWW were 0.65 and 0.81, respectively in this study. Mokhtari *et al.* (2010) reported positive genetic correlation estimate between these traits (0.32), but Vatankhah *et al.* (2008) reported a negative estimate (−0.16). The high and positive genetic correlation estimate for TLWB and TLWW (0.99) in this study showed that genes controlling the number of lambs and their weight at birth may also control milk production and mothering ability of dams from birth to weaning.

Rosati *et al.* (2002) reported that factors such as the genotype of lamb and artificial nursing for some lambs could affect the genetic correlation between TLWB and TLWW. The negative environmental correlation estimates of LSB with LMWLB and LMWLW indicated that unfavorable environmental effects on the number of lambs born may also result in lighter lambs at birth and weaning. Low and negative environmental correlation estimates between some of traits in the current study indicated that environmental effects have different mechanism of influences for these traits.

Table 4 Estimates of correlations between reproductive traits

Pair traits[2]	Correlation coeffietions			
	r_p	r_g	r_{pe}	r_e
LSB–LSW	0.89	0.97	0.99	0.86
LSB–LMWLB	-0.35	-0.39	-0.99	-0.28
LSB–LMWLW	-0.40	-0.28	-0.51	-0.20
LSB–TLWB	0.85	0.80	0.99	0.75
LSB–TLWW	0.61	0.91	0.92	0.56
LSW–LMWLB	-0.48	-0. 52	-0.97	-0.45
LSW–LMWLW	-0.40	-0.28	-0.51	-0.40
LSW–TLWLB	0.75	0.80	0.99	0.75
LSW–TLWW	0.67	0.85	0.68	0.66
LMWLB–LMWLW	0.43	0.65	0.99	0.36
LMWLB–TLWB	0.51	0.65	0.87	0.33
LMWLB–TLWW	0.47	0.81	0.83	0.28
LMWLW-TLWB	-0.21	-0.09	-0.33	-0.22
LMWLW-TLWW	0.17	0.21	0.41	0.14
TLWB-TLWW	0.67	0.99	0.99	0.61

LSB: litter size at birth; LSW: litter size at weaning; LMWLB: litter mean weight per lamb born; LMWLW: litter mean weight per lamb weaned; TLWB: total litter weight at birth and TLWW: total litter weight at weaning.
r_p: phenotypic correlation; r_g: genetic correlation; r_{pe}: correlation due to permanent environmental effects of ewe and r_e: environmental correlation.

CONCLUSION

The genetic parameter estimates for reproductive traits in this study were in general agreement with those reported by others in the literature. The low estimates of heritability and repeatability for studied traits implied that phenotypic mass selection based on these traits cannot result in considerable genetic progress of reproductive performance in Baluchi sheep. Therefore, the improvement of non-genetic factors can lead to the improvement for these characteristics.

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