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SHORT COMMUNICATIONS

Multivariate quantitative genetic analysis of body weight traits in Corriedale sheep

Sheikh Firdous Ahmad [1,4] · Nusrat Nabi Khan [2] · Nazir Ahmad Ganai [2] · Syed Shanaz [2] · Mubashir Ali Rather [3] · Safeer Alam [2]

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Abstract

In the present study, an attempt was made to elucidate the genetic parameters for body weight traits of lambs from Corriedale sheep population at different ages. Data were collected from 6874 lambs born over a span of 49 years from 1969 to 2017. The traits under study included body weight at birth (BW), weaning (WW), 6 months of age (6MW), 9 months of age (9MW) and yearling stage (YW). Data were statistically analyzed using restricted maximum likelihood (REML) algorithm in WOMBAT program. A multi-variate animal model was fitted to the data incorporating season and period of lambing, sex of lamb and litter size as fixed effects. Variance and covariance components were estimated using the animal model after incorporating direct additive genetic effect of animal as random factor. Genetic and phenotypic correlations with corresponding standard errors were also estimated. The heritability estimates for BW, WW, 6MW, 9MW and YW were 0.130 ± 0.023, 0.300 ± 0.029, 0.292 ± 0.030, 0.191 ± 0.025 and 0.169 ± 0.024, respectively. The genetic correlation between different traits under study was high, except between BW and 9MW for which the estimate was moderate. Phenotypic correlation ranged from low to high for different trait combinations. Among different traits under study, only two traits showed moderate heritability i.e. WW and 6MW while heritability of other traits was low. Both these traits showed high correlation with all subsequent traits. Selection programme for Corriedale sheep should be based on WW which is expressed early in life and shall lead to moderate genetic response to selection.

Keywords Variance · Correlation · Heritability · Selection · Corriedale · Body weight

Introduction

Corriedale breed of sheep has been an important part of breeding policy for small ruminants in several regions of India. Corriedale sheep possess huge potential to cater to the growing demand for meat and meat products in India, which is, in turn, attributable to changing food habits in the country. Important economic traits of this breed include improved meat production, early maturity and efficient growth rate. Mutton is a rich source of protein and helps in ensuring nutritional security of poorest sections of the society. Adaptability of this breed to harsh temperate climatic conditions is an added advantage. Body weight is one of the best indices of growth and adaptability of sheep breeds in harsh environmental conditions. Besides mortality and occurrence of different diseases, inaccurate breeding strategies have been considered responsible for less improvement in economic traits of sheep. Ewe productivity can be enhanced by increasing the weight of lambs within a specific period of time (Rashidi et al. 2011). Economic traits expressed early in life, possessing moderate to high estimates of heritability and favourable correlation with other economic traits may prove to be of immense significance in any breeding programme. In Corriedale sheep, selection focusses mainly on growth traits; the accurate estimates of genetic parameters vis-a-vis these traits will, therefore, be

✉ Sheikh Firdous Ahmad
firdousa61@gmail.com

1 Animal Genetics and Breeding, ICAR-National Research Centre on Pig, Rani, Guwahati 781131, Assam, India

2 Division of Animal Genetics and Breeding, FVSc & AH, SKUAST-K, Shuhama, Ganderbal, Kashmir 190006 J&K, India

3 Department of Sheep Husbandry Kashmir, Srinagar 190001 J&K, India

4 Division of Animal Genetics, ICAR-Indian Veterinary Research Institute, Izatnagar, Bareilly 243122, UP, India

immensely helpful. Targeting body weight at different life stages (ages) may be helpful in improving mutton productivity in sheep (Miraei-Ashtiani et al. 2007). Pre-weaning body weight traits are important for selection of lambs and economic success later at their slaughter age. Knowledge of variance components and accurate determination of genetic parameters are important for evaluation and efficacy of different selection programmes (Safari et al. 2005). Animal models are considered best for evaluation of economic traits when compared with other genetic models as it takes complete relationship of animals into account (Ferraz and Eler 2000). Genetic parameter estimates based on univariate analysis may be marred by undesirable correlation between the traits.

Different Indian sheep breeds have been evaluated for their genetic parameters using different genetic models (Mandal et al. 2003; Gowane et al. 2011; Prakash et al. 2012; Baba 2016; Chandra Sharma et al. 2019). Till date, no extensive study has been undertaken to elucidate genetic parameters for body weight traits in the Corriedale sheep population maintained under temperate climatic conditions using animal model. Therefore, we made an attempt to estimate the variance components and subsequently genetic parameters (heritability, genetic and phenotypic correlations) in Corriedale sheep population maintained under organized conditions.

Material and methods

The current study involved no experimentation on human patients or animals and thus needed no special permission from ethical authorities. However, due consideration was given to maintenance of ethical and animal welfare standards followed at national and international levels.

Flock management and mating system

The present study was based on data pertaining to body weight at different ages of Corriedale sheep maintained at Mountain Sheep and Goat Research Station (MSGRS), SKUAST-K, Shuhama, Kashmir, under organized conditions. The farm is located at Ganderbal District of J&K, India, with longitude and latitude coordinates of 74.47 °E and 34.14 °N, respectively, and an altitude of 5300 ft above the mean sea level. The farm experiences a temperate climate with cool winters (average daytime temperature of 2.5 °C with night temperatures below freezing point) and warm summers (average temperature of 24 °C). Spring season is wet with regular rainfall while autumn season mostly remains dry. The animals are reared under semi-migratory and semi-intensive production system. During daytime, animals are let out for grazing and maintained in closed paddocks at night. The animals migrate to highland pastures (Laderwas, Sonamarg, with an altitude of 11,800–14,000 ft above mean sea level) from mid-June to mid-September for summer grazing. The animals are fed indoors during the period between mid-November and mid-April. Concentrate supplementation is done at 600 g/day/adult male, 500 g/day/ewe and 300 g/day for sheep under yearling age. Standard practices related to healthcare, management and welfare of animals are maintained in the farm. Vaccination against enterotoxaemia, FMD and sheep pox is regularly practiced while dipping is performed twice a year i.e. before and after migration to highland pastures. Lambing occurs mainly between mid-January and mid-April while weaning is undertaken at the age of 4 months.

The farm is closed for any inheritance from outside sires (rams). Breeding season commences from September and lasts till November and flushing is undertaken prior to commencement of mating season. Ewes are put into the breeding plan after 18 months of age. The rams are separated from ewes during grazing, and tupping is allowed inside paddocks during night time only. Matings are followed by brisket painting of rams with different wool colours and follow-up of rump stamps on ewes every morning. Close inbreeding is discouraged by planned and controlled matings via housing of ewes with particular rams only; male and female flocks are reared separately during daytime.

Data—collection and classification

The collected data pertained to 6874 lambs born to 234 sires (rams) and 2145 dams (ewes) in different generations and spanned over a 49-year period from 1969 to 2017. Information regarding animal codes and their inheritance (sires and dam records) were collected from history-cum-pedigree sheets maintained at the farm. Other information collected included the date of birth, sex of birth and litter size. The data pertained to body weight of lambs at five ages: birth, weaning and 6, 9 and 12 months. Digital balance was used for recording body weight of the lambs. The data were classified based on season of lambing (2 classes; Jan-Feb and Mar-Apr), period of lambing (10 classes, each spanning 5-year period, with the last period spanning only 4 years), sex of lamb (male and female) and litter size (single, twin/triplet).

Statistical analysis

Data were statistically analyzed using restricted maximum likelihood (REML) algorithm in WOMBAT program (Meyer 2007). A multi-trait animal model was fitted to the data incorporating season (1, 2) and period (1–10) of lambing, sex of lamb (1–2) and litter size (1–2) as fixed effects. Variance and covariance components were estimated using the model after incorporating animals' own genetic effect as random factor. The complete model accounting for fixed effects and direct additive genetic effect of animal is provided as under:

$$Y = X\beta + Z_a a + e$$

where Y = vector of records of five traits on lambs, X and Z_a = the incidence matrices relating the effects with records, β = vector of fixed effects, a = vector of direct additive genetic effect, and e = error term.

Random effects were sampled from a normal distribution with zero mean and variance assumptions as:

$$V(a) = A\sigma^2{}_a \text{ and } V(e) = I\sigma^2{}_e$$

where A = numerator relationship matrix among animals, I = identity matrix, $\sigma^2{}_a$ = direct additive genetic variance, and $\sigma^2{}_e$ = residual variance.

Additionally, genetic and phenotypic correlations along with corresponding standard errors were also estimated among different trait combinations using the WOMBAT software.

Throughout this manuscript, classification of genetic parameters (heritability and correlation) as low, moderate and high was followed as per Ahmad et al. (2019). The estimates lower than 0.20 were considered low, that between 0.20 and 0.40 were considered moderate and estimates above 0.40 were considered high.

Results and discussion

Descriptive statistics

The descriptive statistics of whole data pertaining to body weight of lambs at five different ages are presented in Table 1. The number of records was the highest for birth weight and decreased thereafter due to culling, mortality and other management reasons. Variations in birth weight have important implications as too small or too heavy lambs are more prone to mortality and hinder the optimal management at farm level.

Variance components and heritability estimates

The genetic variance estimates ranged from 0.07 for BW to 16.42 for YW with gradual increase across different stages, except for 9MW for which it decreased slightly (Table 2). Similarly, the residual and phenotypic variance estimates were minimum for BW and maximum for YW and constantly increased across different life stages of lambs. Low additive genetic and high phenotypic variances at early age of lambs (BW) are attributable to harsh environmental conditions experienced during this life-stage and less adaptive capacity of the lambs (Mousa et al. 2013).

The estimates of heritability ranged from 0.130 (BW) to 0.300 (WW). Most traits under study showed low heritability estimates except for WW and 6MW for which the heritability estimates were moderate (Table 2). Heritability estimate for birth weight of lambs was low (0.130). Amarilho-Silveira et al. (2017) reported low heritability estimate for Texel sheep maintained under an extensive production system. Similarly, Mandal et al. (2003), Norberg et al. (2005), Öztürk et al. (2018) and Sallam et al. (2019) reported low estimates of heritability for birth weight of lambs in Muzaffarnagri, Nordic, Akkaraman and Bakri sheep population, respectively. In concurrence with our results, Di et al. (2011), Hanford et al. (2006) and Mohammadi et al. (2010) also reported low heritability estimate for birth weight in Chinese superfine merino, Polypay, and Iranian Sanjabi sheep population, respectively. However, moderate heritability for birth weight of lambs has been reported by Arthy et al. (2018), Everett-Hincks et al. (2014), Gamasaee et al. (2010) and Jafari et al. (2014) in different sheep populations. Low heritability for birth weight of lambs implies that most of the variation in this trait is attributable to factors other than the additive genetic makeup of the lamb itself. Environmental factors have considerable contribution in the variation of birth weight in lambs. Therefore, selection based on phenotype may not be beneficial at this stage.

Weaning weight showed moderate heritability (0.300) and selection based on this trait shall yield moderate genetic response. Moderate heritability for body weight of lambs at weaning has also been reported by Aguirre et al. (2016), Assan et al. (2002), Gamasaee et al. (2010), Hassen et al. (2003), Lalit et al. (2016) and Shahdadi and Saghi (2016) in Santa Ines, Sabi, Mehraban, Ethiopian, Harnali and Kourdi sheep population, respectively. However, lower heritability estimates have also been reported for weaning weight in sheep

Table 1 Descriptive statistics showing general and sex-wise body weight estimates of lambs at five ages

Lamb body weight (Kg/lamb) at	No. of records (n)	Mean ± SD (Kg)	CV (%)	Mean (Kg, male lambs)	Mean (Kg, female lambs)
Birth	6874	3.72 ± 0.74	19.89	3.70	3.74
Weaning	6074	13.24 ± 2.82	21.29	13.36	13.25
Six months	5632	18.65 ± 3.51	18.80	18.53	18.78
Nine months	5100	22.15 ± 3.20	14.44	22.02	22.30
Twelve months	4919	25.84 ± 3.91	15.14	25.68	26.04

Table 2 Variance components and heritability estimates for different body weight traits under study

Lamb body weight (Kg/lamb) at	Direct additive variance (σ^2_a)	Residual variance (σ^2_e)	Phenotypic variance (σ^2_p)	Heritability (h^2)
Birth	0.07	0.47	0.54	0.130 ± 0.023
Weaning	4.68	10.90	15.58	0.300 ± 0.029
Six months	11.06	26.85	37.91	0.292 ± 0.030
Nine months	10.28	43.42	53.70	0.191 ± 0.025
Twelve months	16.42	80.91	97.33	0.169 ± 0.024

populations (Mandal et al. 2003; Tariq et al. 2010; Sallam et al. 2019). Weaning weight being moderately heritable would yield optimal results when employed in selection programmes, if no undesirable correlation exists with other economic traits.

Six-month body weight was moderately heritable with an estimate of 0.292. Similar to our estimates, Gamasaee et al. (2010) and Shahdadi and Saghi (2016) reported 6-month body weight in lambs to be moderately heritable with estimates of 0.35 and 0.32 in Mehraban and Kourdi sheep population, respectively. However, Jafari et al. (2014) and Lalit et al. (2016) reported high heritability estimates for 6-month body weight in Makuie and Harnali sheep population, respectively. Selection at this stage (6MW) will be beneficial; however, if a lamb is culled at this stage, considerable investment and costs have already been incurred on its rearing.

The heritability estimate for weight at 9-month age was low (0.191). Selection at this stage will not be fruitful as the trait is expressed late in life and possesses low heritability, thus shall give only meager response if differential reproduction procedure is based on it. The heritability estimate for yearling weight in Corriedale sheep population was low. The trait is expressed nearly at slaughter age, and selection at this age will not be beneficial. Similar to the estimates from present study, Mokhtari et al. (2008) reported low heritability estimate for body weight at 9-month age and yearling age of lambs of Kermani sheep population. Furthermore, Shahdadi and Saghi (2016) and Mandal et al. (2003) also reported low heritability estimate for 9MW and YW in Kourdi and Muzaffarnagri sheep population, respectively. The heritability estimates are for 9MW, and YW were low, implying low scope for direct selection on the basis of individual performance. In other words, environmental conditions are responsible for majority of variation observed in these traits.

Correlation estimates

The genetic correlation between different traits under study was high, except between BW and 9MW where the estimate was moderate. The estimates ranged from 0.383 (between BW and 9MW) to 0.949 ± 0.015 (between 9MW and YW). On the other hand, phenotypic correlation estimates ranged from low to high for different trait combinations (Table 3). The phenotypic correlation was low between BW and 9MW, and between BW and YW. The phenotypic correlation was moderate between BW and WW, and between BW and 6MW. Whereas, phenotypic correlations were high for all other trait combinations (WW-6MW, WW-9MW, WW-YW, 6MW-9MW, 6MW-YW and 9MW-YW).

The breeder always aims at optimal combination of traits that have optimal heritability estimate and favourable correlation with other traits. Among different traits under study, only two traits showed moderate heritability i.e. body weight of lambs at weaning (WW) and 6 months age (6MW). Both these traits showed high correlation with all subsequent traits. Selection programme for Corriedale sheep should, therefore, be based on WW or 6MW which may lead to moderate genetic response. However, priority should be given to WW as it is expressed earlier in life. Correlation between different traits may be exploited in breeding programmes by employing

Table 3 Genetic (upper diagonal) and phenotypic (lower diagonal) correlation estimates for different trait combinations

	BW	WW	6MW	9MW	YW
BW	----	0.413 ± 0.087	0.508 ± 0.086	0.383 ± 0.103	0.417 ± 0.106
WW	0.299 ± 0.012	----	0.913 ± 0.018	0.790 ± 0.038	0.737 ± 0.048
6MW	0.238 ± 0.013	0.752 ± 0.006	---	0.867 ± 0.026	0.813 ± 0.035
9MW	0.193 ± 0.020	0.622 ± 0.011	0.775 ± 0.005	----	0.957 ± 0.013
YW	0.167 ± 0.016	0.573 ± 0.009	0.746 ± 0.006	0.902 ± 0.003	----

BW body weight at birth, *WW* body weight at weaning, *6MW* body weight at 6 months of age, *9MW* body weight at 9 months of age, *YW* body weight at 12 months of age indirect selection. The results from the present study will be useful to formulate effective breeding plans for improvement in body weight traits in Corriedale sheep and shall also be helpful in enhancing the profitability of rearing small ruminants in surrounding areas.

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Data availability Data will be made available from corresponding author on reasonable request.

Code availability Not applicable

Declarations

Ethics approval Not applicable

Consent to participate Not applicable

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Conflict of interest The authors declare that they have no conflict of interest.

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