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Genetic evaluation of wool quality parameters in Harnali sheep

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ABSTRACT

The current research focused on genetic evaluation of wool quality parameters in Harnali sheep and the data were recorded from pedigree sheets of 1048 animals. The study focused on four characteristics of wool: medullation percentage (MP), fibre diameter (FD), staple length (SL), and greasy fleece weight (GFW). For GFW, SL, FD, and MP, the corresponding least-squares means were 1729.48±13.9 g, 5.08±0.02 cm, 25.24±0.12 microns, and 26.21±0.29%, respectively. GFW and MP were significantly affected by the lamb's birth period. Sex of lamb and dam's weight at lambing was found to have significant effect on GFW. By leveraging the sire component of variance and covariance from mixed model analysis, the paternal half-sib correlation method was used to estimate genetic and phenotypic parameters. The heritability estimates were 0.32±0.07, 0.17±0.05, 0.27±0.06, and 0.29±0.06 for GFW, SL, FD, and MP, respectively. Favourable genetic and phenotypic trends over the years were observed for FD, MP and GFW, though, more attention is required for SL where the trend observed was not favourable. Sire breeding values for various traits under the study indicated genetic variability and it is recommended to use top ranking sires for further genetic improvement in wool traits. Although heritability for some wool quality traits was moderate, the index selection could be a better choice for the improvement of these traits.

Key words: Breeding value, Genetic parameters, Genetic trend, Harnali sheep, Wool quality

Crossbreeding of indigenous sheep with exotic breeds has long been practiced in India to enhance wool and mutton production, resulting in the development of improved breeds such as Hissardale, Kashmir Merino and Bharat Merino. Harnali is a synthetic breed developed with the objective of improving carpet wool quality, growth rate and adaptability, possessing 37.5% inheritance from the Nali breed and 62.5% from Russian Merino and Corriedale. The population has attained genetic stability, an essential prerequisite for its large-scale utilization.

Assessment of genetic trends is a key component in evaluating the effectiveness of breeding programmes, as it reflects changes in average breeding values over time and indicates both the direction and rate of genetic improvement (Bosso *et al*. 2007). Such evaluations help to ensure that selection pressure is effectively applied to economically important traits. Although, wool production may be of limited importance in small, intensively managed flocks, it plays a significant role in large, extensive production systems (Mandal *et al*. 2009). Moreover, wool traits are generally easy to measure and exhibit moderate to high heritability (Kumar *et al*. 2016), making them suitable for selection. Improvement in growth and wool characteristics contributes substantially to the economic returns of commercial sheep enterprises (Schoeman *et al*. 2010).

Formulation of effective breeding strategies requires clear breeding objectives, knowledge of genetic variability and reliable estimates of genetic parameters. However, information on genetic trends in wool quality traits of Harnali sheep remains limited. Therefore, the present study was undertaken to estimate genetic parameters and evaluate genetic trends in wool quality traits of Harnali sheep, with a view to assess the efficiency of existing breeding programmes and provide inputs for future selection strategies.

MATERIALS AND METHODS

Source of data and farm management: The development of Harnali sheep is the result of long term sheep breeding under the project entitled "Estimating the cross-combining ability of Corriedale and Russian Merino rams with Nali ewes" at Sheep Breeding Farm, Department of Animal Genetics and Breeding. Data related to wool traits were recorded from the pedigree sheets of 1048 sheep. The animals were kept in loose housing system having brick flooring. The animals were allowed to graze for about 6-8 hours daily on natural pastures depending upon the availability and supplemented with concentrate feeding. Feeding practices during summer season included grazing

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on fresh pastures along with dry fodder. Animals were provided with *ad lib* clean water in the shed. Lambs were vaccinated against enterotoxaemia, sheep-pox and PPR at three months of age. Deworming of the flock was done regularly at an interval of four months.

Data recording: Data spanning over a period of 14 years were recorded for the present study. Classification of data was done as per period of birth (07 periods of two years duration each), sex of lamb and dam's weight at lambing (DW 1 ≤ 23.0 kg, DW 2 23.01-26.00 kg, DW 3 26.01-29.00 kg, DW 4 >29.0 kg) in order to study the effect of these factors on wool traits. Wool traits studied were greasy fleece weight (GFW), staple length (SL), fibre diameter (FD) and medullation percent (MP). GFW indicates wool quantity while SL, FD and MP reflect wool quality.

Statistical analysis: As the data of present study were with unequal subclass frequencies causing the different classes of effects to be non-orthogonal, so to study the effects of various factors on different traits, mixed model and maximum likelihood computer programme (Harvey 1990) was used and least-squares means were compared using DMRT as modified by Kramer (1957).

The following mixed model was used to study the effect of various factors:

$$Y_{ijklm} = \mu + S_i + P_j + B_k + D_l + e_{ijklm}$$

Where Y_{ijklm} = observation on m^{th} animal belonging to l^{th} weight group of dam, having k^{th} sex, j^{th} period of birth and i^{th} sire; μ = overall mean; S_i = random effect of i^{th} sire; P_j = fixed effect of j^{th} period of birth (j = 1 to 7); B_k = fixed effect of k^{th} sex (k = 1, 2); D_l = fixed effect of l^{th} weight group of dam (l = 1 to 4) and e_{ijklm} = random residual error associated with each observation

Genetic and phenotypic parameters were estimated by paternal half-sib correlation method using sire component of variance and covariance from mixed model analysis. The standard error of phenotypic correlations was computed by the formula given by Snedecor and Cochran (1968).

Single trait animal model was used for estimation of breeding values using WOMBAT software (Meyer, 2007) as:

$$Y = X\beta + Zu + e$$

where, Y is vector of observations on the considered traits; X is the design matrix for fixed effects; β is the vector of fixed effects; Z is the design matrix for random animal effects; u is the vector of random animal effects and e is the vector of random residual errors.

Assumptions of the model were: E (Y) = Xb; E (u) = 0; E (e) = 0; V(μ) = A σ^2_a; V(e)= I σ^2_e

where, A is numerator relationship matrix; I is identity matrix of order equal to number of records; σ^2_a = additive genetic variance; σ^2_e = residual variance

Regression analysis was used to evaluate genetic and phenotypic trends using SPSS (2007). By regressing breeding values and phenotypic values of the trait on the year of the animals' birth, respectively, the genetic and phenotypic trends of the traits were computed. Selection indices were constructed according to Hazel (1943). The phenotypic and genetic variance and

The index was calculated as follows:

$$I = b_1X_1 + b_2X_2 + b_3X_3 + \dots\dots\dots\dots + b_nX_n = \Sigma\, b_iX_i$$

where, b_i = partial regression coefficient and X_i = phenotypic value of i^{th} trait incorporated in an index.

The aggregate genetic value of the index is defined as:

$$H = a_1g_1 + a_2g_2 + \dots\dots.. a_ng_n$$

where, a_i = relative economic value and g_i = genetic value of i^{th} trait

The b_i was estimated in such a way that the correlation between I and H was maximized. The b_i values were obtained by solving simultaneous equations for each trait represented in matrix form as follows: Pb = Ga and b = P^{-1} G a

where, P = phenotypic variance and co-variances matrix of traits in index; G = genetic variance and co-variances matrix of the traits included in I and H; b = vector of weighting coefficients and a = vector of relative economic weights.

RESULTS AND DISCUSSION

Analysis of variance showing partitioning of variations for traits GFW, SL, FD and MP are shown in Table 1. Least-squares means for GFW, SL, FD and MP were estimated as 1729.48±13.90 g, 5.08±0.02 cm, 25.24±0.12 micron, and 26.21±0.29%, respectively (Table 2). Jafari and Hashemi (2014) in Makuie sheep (1210 g), Khan *et al.* (2015) in Rambouillet crossbred (1510 g), Kumar *et al.* (2016) and Lalit *et al.* (2016) in Harnali sheep (1620 g

Table 1. Analysis of variance for wool traits in Harnali sheep

Source of Variation	D.F.	Means Sum of Squares			
		GFW	SL	FD	MP
Sire	85	107773.72	0.24	8.37	48.20
Period of birth	6	300621.96**	0.40	9.18	94.46**
Sex	1	808032.20**	0.02	0.89	0.74
Dam's weight at lambing	3	210611.63*	0.61	9.83	80.94
Error		79841.50 (952)	0.26 (952)	7.06 (952)	38.30 (952)

* Significant at P<0.05, ** Significant at P<0.01

Table 2. Least-squares means along with standard error for wool traits in Harnali sheep

Traits	GFW (g)	SL (cm)	FD (μ)	MP (%)
Overall mean	1729.48±13.95 (1048)	5.08±0.02 (1048)	25.24±0.12 (1048)	26.2±0.29 (1048)
		PERIOD OF BIRTH		
P1	1648.86[ab]±26.29 (132)	4.89±0.05 (132)	25.27±0.28 (132)	28.21[b]±0.59 (132)
P2	1716.22[bc]±21.67 (183)	5.01±0.05 (183)	25.12±0.17 (183)	26.45[a]±0.42 (183)
P3	1759.44[c]±26.42 (125)	5.01±0.05 (125)	24.94±0.23 (125)	25.26[a]±0.50 (125)
P4	1746.47[c]±21.09 (170)	5.12±0.03 (170)	25.32±0.21 (170)	26.85[ab]±0.59 (170)
P5	1667.58[ab]±20.45 (165)	5.17±0.03 (165)	25.53±0.24 (165)	26.38[a]±0.48 (165)
P6	1638.43[a]±25.36 (127)	5.24±0.04 (127)	25.58±0.22 (127)	25.24[a]±0.62 (127)
P7	1868.29[d]±27.96 (146)	5.33±0.04 (146)	25.59±0.19 (146)	25.80[a]±0.38 (146)
		SEX		
Male	1759.65[a]±18.05 (396)	5.08±0.03 (396)	25.21±0.16 (396)	26.23±0.38 (396)
Female	1699.30[b]±15.60 (652)	5.09±0.02 (652)	25.27±0.13 (652)	26.18±0.33 (652)
		DAM'S WEIGHT AT LAMBING		
D1	1713.65[b]±33.27 (89)	5.01±0.06 (89)	24.80±0.31 (89)	26.17±0.72 (89)
D2	1725.04[ab]±21.04 (246)	5.05±0.03 (246)	25.31±0.19 (246)	25.64±0.45 (246)
D3	1708.58[b]±19.24 (329)	5.15±0.03 (329)	25.34±0.17 (329)	26.04±0.41 (329)
D4	1770.64[a]±18.52 (384)	5.12±0.03 (384)	25.51±0.16 (384)	26.97±0.39 (384)

Means with different superscripts for an effect differ significantly ($P<0.05$)

and 1600 g) had earlier reported similar range of greasy fleece weight. On contrary, Akhtar *et al.* (2014) in Buchi sheep (3720 g) and Mallick *et al.* (2017) in Bharat Merino (2130 g) had reported comparatively higher greasy fleece weight. Variation in greasy fleece weight (GFW) among different studies and sheep breeds is mainly due to genetic differences, with breeds like Rambouillet crossbreds and Bharat Merino producing higher wool than indigenous breeds. It is also influenced by body size, nutrition, and environmental conditions, as better feeding and favorable climates promote wool growth. Additionally, factors such as age, sex, physiological status, and management practices like shearing interval and health care might also contribute to these differences.

Effect of non-genetic factors: In the present study, GFW and MP were significantly ($P<0.01$) affected by the lambs' birth period. Similarly, Mir *et al.* (2000), Kumar and Singh (2011) and Narula *et al*. (2017) reported a significant relationship between the yearly weight of greasy fleece and the period of birth. However, Kumar *et al*. (2016) in Harnali sheep reported non-significant influence of time of birth on yearly greasy fleece weight. It might be due less variation in environmental conditions throughout the year, which minimized the impact of birth period on greasy fleece weight. Khan *et al.* (2015) reported significant effect ($P<0.01$) of year of lambing for all the wool traits (GFW, SL and FD). In the present study, sex of lamb had significant effect on GFW. Males produced greasier fleece than the females per year. This difference was well supported by earlier studies, which attributed this difference mainly to larger body size and higher live weight in males. Heavier animals have greater skin surface area and more wool follicles, leading to increased wool production. Similar findings have been reported by Kumar *et al*. (2016) and Lalit *et al*. (2016) in Harnali sheep, and by Khan *et al*. (2015) in Rambouillet crossbreds, where rams showed significantly higher fleece yield than ewes. These studies concluded that sexual dimorphism in growth and hormonal influence contributes to enhanced wool production in males. Gowane and Arora (2010) and Gupta *et al*. (2015) had documented a noteworthy impact of gender on the yearly weight of greasy fleece. However, Mishra *et al.* (2009) reported a non-significant effect of sex on greasy fleece yield in Garole-Malpura crossbred sheep. Chopra *et al.* (2010) also reported non-significant effect of sex of lamb on FD and SL in Bharat Merino sheep. Khan *et al.* (2015) reported similar findings in Rambouillet crossbred sheep. The current study revealed that dam's weight at lambing had significant effect ($P<0.05$) on GFW. The dam's weight at lambing significantly influenced the body weight of lambs at different ages and also had direct effect on the quantity of wool per animal.

Estimates of genetic and phenotypic parameters: Heritability estimates for wool traits as obtained by paternal half-sib correlation method are presented in Table 3. Heritability estimates for GFW, SL, FD, and MP were 0.32±0.07, 0.17±0.05, 0.27±0.06 and 0.29±0.06, respectively. The estimated values of heritability were moderate for GFW, FD and MP while low for SL. Similar heritability estimates (0.31) for GFW were reported by Chauhan *et al*. (2021) in Harnali sheep. Higher heritability estimates for greasy fleece weight were reported by Umeel

Table 3. Estimates of heritability (diagonal), genetic (above diagonal) and phenotypic (below diagonal) correlations along with standard error among wool traits in Harnali sheep

Traits	GFW	SL	FD	MP
GFW	0.32±0.07	-0.01±0.2	0.24±0.17	0.13±0.17
SL	0.06±0.03	0.17±0.05	-0.07±0.2	-0.32±0.19
FD	0.07±0.01	-0.03±0.03	0.27±0.06	0.41±0.15
MP	0.03±0.04	-0.05±0.04	0.32*±0.04	0.29±0.06

et al. (2018) reported in Munjal sheep. Heritability estimates for FD in the present study were in close agreement with those reported by Rather *et al.* (2019) in Kashmir Merino sheep as 0.23±0.04, however, they reported higher heritability estimates for GFW and SL. Lalit *et al.* (2017) also reported heritability estimates for wool traits (GFW, SL and FD) as moderate to high.

Estimated breeding values (BV) of top ten sires for wool traits are presented in Table 4. It was found that out of top 10 ranked Harnali sires, sire number 66 had highest EBV for GFW as 1355.85 gm and lowest estimated breeding value was observed for sire no. 10 as 1130.08 gm. Sire no. 70 had highest EBV for SL as 8.732 cm and lowest EBV was observed for sire no. 89 as 4.48 cm. Sire no. 65 had highest EBV for FD as 9.16 micron and lowest EBV was observed for sire no. 45 as 14.41 micron. Sire no. 65 had highest EBV for MP as 0.91 per cent and lowest EBV was observed for sire no. 45 as 1.44 per cent. The estimates of breeding value for GFW in the present study were lower than the estimates reported by Umeel *et al.* (2018) in Munjal sheep. Comparatively lower breeding values estimates for different wool traits viz., greasy fleece yield of first clip (GFY-1), greasy fleece yield of second clip (GFY-2), FD and SL were also reported by Mallick *et al.* (2016) in Bharat merino rams. Breeding values for the greasy fleece yield of the first clip and the greasy fleece yield of the second clip were estimated by Rather *et al.* (2019) to range from -0.21±0.05 kg to 0.47±.04 kg and -0.44±0.05 kg to 0.35±0.05 kg, respectively. Between the sire's predicted breeding values for various wool qualities, the product moment correlations ranged from negative (-0.67) to positive (1.00). For GFW-FD (0.38), GFW-MD (0.38), and FD-MD (1.00), the product moment correlations between the sire's EBV were found to be extremely high, positive, and significant. It was, nevertheless, negative and notably greater between GFW-SL (-0.67). Rank correlations between the sire's EBV and the various wool qualities ranged from low to high (0.02 to 0.57) as shown in Table 5. The rank correlations between the sire's EBV were discovered to be low and positive for SL with FD (0.02) and MD (0.02), and negative and significant for GFW with SL (-0.26), FD (-0.57), and MD (-0.57).

Genetic and phenotypic trends of wool traits: Genetic trends for GFW were positive and obtained as 6.171764 gm/year and genetic trends for SL, FD and MP were negative obtained as -0.0018 cm/year, -0.0366 micron/year and -0.0227 per cent/year, respectively. Phenotypic trends for GFW were positive and obtained as 19.2266 gm/year. Phenotypic trends for SL, FD and MP were negative obtained as -0.0108 cm/year, -0.1381 micron/year and -0.7858 percent/year, respectively. On the other hand, the phenotypic and genetic gains varied annually. The annual change in the strength of selection applied to the rams used for mating accounts for variations in both genetic and phenotypic gains. The genetic advantage was reduced in these cases because rams with slightly lower EBVs mated with proportionately higher ewes. Consequently, having a sufficient number of replacement stocks is just as critical as maintaining an effective number of quality rams for

Table 5. Product moment (above diagonal) and Spearman's rank (below diagonal) correlations between the EBVs among wool traits in Harnali sheep

Traits	GFW	SL	FD	MD
GFW		-0.67**	0.38**	0.38**
SL	-0.263*		-0.20	-0.20
FD	-0.575**	0.02		1.00**
MD	-0.575**	0.02	1.00**	

Table 4. Estimated breeding values and ranking of top ten sires for wool traits using single trait animal model in Harnali sheep

Sr. No.	GFW		SL		FD (low to high)		MP (low to high)	
	Sire no.	BV	Sire no.	BV	Sire no.	BV	Sire no.	BV
1	66	1355.085	70	8.732	65	9.163	65	0.916
2	63	1312.108	73	8.372	51	10.040	51	1.004
3	69	1259.428	71	8.264	66	10.067	66	1.007
4	74	1228.192	76	6.957	77	10.529	77	1.053
5	61	1199.137	79	6.579	79	11.431	79	1.143
6	49	1188.277	75	5.045	98	11.982	98	1.198
7	81	1159.240	85	5.036	68	13.622	68	1.362
8	72	1144.555	105	4.740	52	14.108	52	1.411
9	64	1135.006	83	4.515	43	14.176	43	1.418
10	67	1130.083	89	4.485	45	14.416	45	1.442

the purpose of maintaining an annual positive genetic advancement. Mallick *et al.* (2016) and Kumar *et al.* (2016) also reported positive genetic trend for GFW in Bharat Merino and Malpura sheep, respectively. However, in Munjal sheep, unfavourable genetic trends for GFW were discovered by Yadav *et al.* (2018) and Malik *et al*. (2018). In Kashmir Merino sheep, Rather *et al*. (2019) found positive genetic trends for FD and negative genetic trends for GFY-2 and SL. However, positive phenotypic trend was reported for GFY-1 whereas a negative phenotypic trend was reported for GFY-2, FD and SL in Kashmir Merino sheep.

Selection indices for improvement of wool traits: Index selection is reported to be the most efficient method of genetic selection for multi traits with maximum accuracy. Selection indices are of interest to breeders for selection of more than a single character. Index selection is generally used when the information on all the traits is available and to improve genetically antagonistic traits. In order to develop selection indices, several combinations of GFW, SL, FD and MP were used. Eight indices were created in the current study by combining various combinations of the four crucial characteristics for wool quality - GFW, SL, FD, and MP. Index weighing factors (b) and accuracy (r_{IH}) of the indices for wool traits is presented in Table 6 and expected genetic gain for wool traits is given in Table 7. I_8 was observed to be most accurate index having measure of accuracy (r_{IH}) = 0.575. Index I_8 enabled us to carry out selection based on all the four traits with high accuracy of selection for improvement in wool quantity and quality. The other combination of wool quality traits in different indices gave less r_{IH} values and seems to be ineffective. The expected genetic gains by index I_8 (SL, FD, MP and GFW) per generation were -0.013 cm, 0.294 micron, 0.451 per cent and 93.430 gm for SL, FD, MP and GFW, respectively. Kannojia (2015) constructed selection index in Marwari sheep using 6 traits i.e. weight at 3 (3WT), 6 (6WT), 9 (9WT), 12 (12WT) months of age, greasy fleece weight at fist (GFW1) and second (GFW2) clips and obtained accuracy of r_{IH} = 0.499, which was higher than the present investigation. Kandalkar *et al.* (2016) in Deccani sheep reported index incorporating weight at 3 and 6 months of age as most useful index with similar accuracy of selection as in present study (r_{IH} = 0.656). Paswan *et al.* (2016) constructed selection indices for Malpura sheep and accounted a similar range genetic gain. Index having 6WT and GFW yields regression coefficients of 0.137 and 0.008 for the corresponding traits, showing that GFW is given far less weight than 6WT. The index with weaning weight (WWT) and GFW had highest accuracy (51.9%). Estimated genetic gain after 1 generation post selection was measured to be 81.753 g in GFW. In Bharat Merino sheep, Gowane *et al*. (2010) reported b value of 0.06 and 0.61 for 6WTand GFW and accuracy of 0.257 for index involving 6WT-GFW.

Table 6. Index weighing factors (b) and accuracy (r_{IH}) of the indices for wool quality traits in Harnali sheep

Index	Traits included	b values				r_{IH}
		SL (1)	FD (2)	MP (3)	GFW (4)	
I_1	1	-0.102				0.003
I_2	2		7.502			0.124
I_3	3			1.856		0.071
I_4	1,2	0.063	7.502			0.124
I_5	1,3	0.028		1.856		0.071
I_6	2,3		6.811	0.923		0.128
I_7	1,2,3	0.489	6.813	0.925		0.129
I_8	1,2,3,4	-11.074	4.643	0.675	0.318	0.575

Table 7. Expected genetic gain in individual wool quality traits in Harnali sheep

Index	ΔGi				r_{IH}
	SL	FD	MP	GFW	
I_1	-0.154	(0.039)	(0.440)	(0.524)	0.003
I_2	(-0.007)	0.709	(0.709)	(20.091)	0.124
I_3	(-0.036)	(0.303)	1.815	(11.612)	0.071
I_4	-0.007	0.709	(0.708)	(20.091)	0.124
I_5	-0.036	(0.303)	1.814	(11.612)	0.071
I_6	(-0.017)	0.705	1.125	(20.823)	0.128
I_7	-0.015	0.705	1.120	(20.824)	0.129
I_8	-0.013	0.294	0.451	93.430	0.575

In conclusion, greasy fleece weight was influenced by period of birth of lamb, sex of lamb and dam's weight at lambing. Heritability estimates of wool traits ranged from 0.17±0.05 to 0.32±0.07 indicating scope of improvement through selection. Sire breeding values for various traits under study indicated genetic variability and it is recommended to use top ranking sires for further genetic improvement in wool quality traits of Harnali sheep. Favourable genetic and phenotypic trends were observed for FD, MP and GFW while more attention is required for SL where the trend observed was not favourable. Although, heritability for wool quality traits was moderate, the index selection could be favourable for improvement of these traits. It is suggested that more emphasis on stringent selection program at early age for wool quality might results in desired genetic progress in Harnali sheep.

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