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Lifetime reproductive performance of Chokla sheep at an organized farm in semi-arid conditions

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ABSTRACT

The Chokla sheep, renowned as the finest carpet wool producer of India, plays an important role in supporting the rural economy of the arid and semi-arid regions of its native state of Rajasthan. This study was carried out to assess the lifetime reproductive efficiency of Chokla ewes by analyzing the records of 1,001 ewes bearing 3,541 lambs over a period of 22 years (1994–2016) to assess five traits, namely total lambs born (TLB; 3.38±0.11 lambs), total lambs weaned (TLW; 2.97±0.11 lambs), cumulative lamb weights at birth (TLBW; 9.59±0.37 kg), weaning (TLWW; 39.59±1.68 kg) and 12 months of age (TLAW; 50.15±2.51 kg) produced by an ewe in her lifetime. Period of birth of ewe had a significant effect on all the traits whereas season of birth, inbreeding coefficient and birth weight of ewe had no influence. REML procedures were employed to estimate the genetic parameters through an animal model. Analysis revealed low heritability estimates for the lifetime reproductive traits (TLB; 0.06±0.04, TLW; 0.05±0.04, TLBW; 0.09±0.05, TLWW; 0.05±0.04 and TLAW; 0.02±0.04), suggesting greater role of environmental and managemental factors. Positive correlation among cumulative lamb weights (0.51–0.92) suggested selection for birth weights would result in higher weights at subsequent life stages of lambs. The low heritability estimates and high CV% for all the traits suggest the suitability of a management focussed approach for improvement of lifetime reproductive performance of ewes.

Key words: Chokla sheep, Ewe efficiency, Heritability, Least squares, Lifetime productivity

The Chokla sheep, native to the arid and semi-arid regions of Rajasthan, is renowned for producing the finest carpet wool in the country. The breed is of crucial economic importance to the farmers and landless labourers by acting as a safeguard against crop failure due to irregular monsoon and lack of irrigation facilities. The animals true to the breed are light to medium sized. The face, generally devoid of wool, is reddish brown or dark brown, and the colour may extend up to the middle of the neck. This breed is found in Churu, Nagore and Sikar districts of Rajasthan (Jain *et al.* 2009).

The reproductive efficiency of different breeds of sheep in India is relatively low (Arora and Garg 1998) as they are raised mostly under harsh and unfavourable climatic conditions. The reproductive efficiency of flock has direct bearing on economic returns to sheep farmers for sale (Narula *et al.* 2009). A number of indices have been suggested by different authors to measure lifetime ewe reproductive performance with examples being number of lambs born and weaned, cumulative lamb weights at weaning and selective value (Olivier *et al.* 2001, Duguma *et al.* 2002, Gowane *et al.* 2014, Jafari and Manafiazar 2016). For the design of an effective selection programme to improve lifetime ewe efficiency, the knowledge of different indices and their genetic parameters is essential. There is a paucity of information in the literature regarding the lifetime reproductive performance of Indian sheep and there have been no such studies carried out for the Chokla breed. This study aims to supplement the literature and contribute towards breeders' knowledge by assessing the lifetime reproductive performance of Chokla through five traits.

MATERIALS AND METHODS

Data and flock management: The data were collected from the Chokla database maintained by ICAR-CSWRI. The study analysed the performance of 1,001 ewes descending from 164 sires and bearing 3,541 lambs over a period of 22 years (1994–2016). To gain a fair assessment of lifetime performance, only the ewes born up to the year 2010 were included in the study which allowed them to

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complete their production life. 227 ewes had a single lamb, 155 had two and 619 had three or more lambs. The data from 1994–2012 was collected from ICAR-CSWRI, Avikanagar station at Malpura district of Rajasthan. The temperature ranges from –2°C to 48.5°C with annual rainfall averaging about 615.93 millimeters at this place. The data from 2013–2016 was collected from ICAR-CSWRI, Arid Region Complex at Bikaner district of Rajasthan state due to the relocation of the flock in 2013. The temperature ranges from 0 to 49.5°C. Low and erratic rainfall is a common feature with an annual precipitation varying between 39 to 392 mm.

The breeding season generally commenced towards the middle of August and continued for 2–3 oestrus cycles (up to the beginning of November). The flock was closed for maintaining the purity of the breed, and for proper execution of breeding plans. Mating between parent and offspring, between full sibs and within same sire line was avoided. The ewes were mated randomly to rams belonging to a selection line only once during an oestrus cycle. Repeat breeders were again mated to rams in subsequent cycles randomly within a selection line. The mating was continued for three oestrus cycles. The average litter size of the flock was 1.02. Weaning was carried out at 3 months of age.

Traits analyzed: Five lifetime fitness traits were analyzed which included total lambs born (TLB), total lambs weaned (TLW), the cumulative birth (TLBW), weaning (TLWW) and 12 months (TLAW) weights of the lambs borne by an ewe in her lifetime.

Statistical analysis: The GLM procedure of SAS (SAS 2011) was used to analyze the traits for the effects of non-genetic factors considered as fixed effects, namely year of birth of ewe (P_1: 1995–1997, P_2: 1998–2000, P_3: 2001–2003, P_4: 2004–2006 and P_5: 2007–2010), season of birth of ewe (Winter: November–April and Summer: May–October), inbreeding coefficient of ewe (IB_1: 0%, IB_2: <1.25%, IB_3: 1.25–5% and IB_4: >5%) and birth weight of ewes (EBW_1: ≤ 2.3 kg, EBW_2: 2.3 ≤ 2.8 kg, EBW_3: 2.8 ≤ 3.4 kg and EBW_4:> 3.4 kg). Pedigree Viewer 6.5 software (Kinghorn and Kinghorn 2003) was used to calculate inbreeding coefficients. For significant effects, the differences between pairs of level of effects were tested by Duncan's multiple range tests as modified by Kramer (Duncan 1957). The significant (P < 0.05) effects were included in mixed model analysis to estimate the genetic parameters through a Restricted Maximum Likelihood (REML) algorithm using WOMBAT software package (Meyer 2007). Maternal effects were not considered due to the findings in literature (Gowane *et al.* 2014) and our own study on a different dataset suggesting the futility of their inclusion in the analysis of lifetime reproductive performance.

The model accounting for the direct additive effect of the animal was considered as:

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

where, Y is the vector of observations; β, a and ε are vectors of fixed, direct additive and residual effects, respectively; X and Z_a are incidence matrices that relate these effects to observations.

Assumptions in the model: V (a) = $A\sigma_a$, and V (e) = $I\sigma_e$, where, A is the numerator relationship matrix between animals, I is an identity matrix and σ_a and σ_e are additive direct and residual variances, respectively. Subsequently, a series of bivariate animal model analysis was carried out in order to estimate the genetic and phenotypic correlations between the traits.

RESULTS AND DISCUSSION

Descriptive statistics: Similar medium-high CV% estimates for lifetime fitness traits have been reported by Zishiri *et al.* (2013) and Jafari and Manafiazar (2016) in South African Dorper and Makuie sheep. The least squares mean for TLB (3.38±0.11) was within range of that reported in the literature. Vatankhah (2016) reported a similar estimate of 3.31 in Lori-Bakhtiari sheep whereas Gowane *et al.* (2014) and Mishra *et al.* (2007) reported TLB estimates of 3.85 and 3.26 in Malpura sheep. Higher estimates of TLB as 5.47 and 5.2 lambs were reported by Mishra *et al.* (2007) and Duguma *et al.* (2002) in Garole × Malpura and South African Merino, respectively. These higher estimates were due to higher prolificacy of these breeds as compared to Chokla. There was a trend of significant (P≤0.05) improvement from P1 (3.15) to P5 (3.93) which could be due to the optimization of management and nutrition over the years. The exception to this trend was P6 which saw the lowest estimate of TLB because of a disease outbreak and the resultant culling limiting the reproductive performance of ewes born in this period. For TLW, our estimate of 2.97±0.11 was on the lower side of literature estimates. Higher TLW estimates of 3.21, 3.37 and 3.13 lambs have been reported by Vatankhah (2016), Gowane *et al.* (2014) and Mishra *et al.* (2007), respectively. The differences may be due to lower prolificacy of ewes and lower survivability of lambs until weaning in our flock –86.4% as compared to 91.79% reported by Gowane *et al.* (2014). Better management and healthcare measures may result in an increase in TLW estimates of Chokla. Period of birth had a significant (P≤0.05) effect on TLW with the performance peaking in P4 before declining in P6 due to disease and culling. Our estimates for TLBW (9.59±0.37 kg) and TLWW (39.59±1.68 kg) were in concordance with the TLBW estimate (9.55±0.43 kg) reported by Mishra *et al.* (2007) in Malpura sheep and the TLWW estimate (37.6 kg) reported by Olivier *et al.* (2001) in Carnarvon Merino sheep. Higher estimates of TLBW (16.51 kg) and TLWW (92.6 kg) have been reported in more prolific breeds by Vatankhah (2016) and Duguma *et al.* (2002), respectively. The trend of change in these two traits over the periods resembled that of their respective component traits, TLB and TLW. TLAW was estimated as 50.15±2.51 kg and showed a similar trend of peaking in P4 before declining in the periods effected by disease outbreaks. All the traits were significantly influenced by period of birth of ewes which was in agreement with the literature reports (Vatankhah 2016, Gowane *et al.* 2014, Duguma *et al.* 2002).

Heritability estimates: The heritability estimates for all the lifetime reproductive traits were low and ranged from 0.02 to 0.09 (Table 2). These results suggest a greater role of environment and managemental factors in the phenotypic variation of the traits. In the literature, higher estimates of TLB on a lifetime basis have been reported ranging from 0.08 to 0.13 (Zishiri *et al.* 2013, Gowane *et al.* 2014, Vatankhah 2016, Notter *et al.* 2018). There is consensus in literature regarding the low heritable nature of traits associated with total lambings (Zishiri *et al.* 2013) and our findings are no exception. TLB depends on litter size and number of opportunities provided to an ewe for parturition. Owing to the small litter size of Chokla sheep (1.02), the best course of action would involve management measures to increase TLB. For TLW, higher estimates ranging from 0.06 to 0.14 have been reported on a lifetime basis (Zishiri *et al.* 2013, Gowane *et al.* 2014, Vatankhah 2016, Notter *et al.* 2018).

The cumulative lamb weights borne by an ewe are important indicators of its economic potential. According to Olivier (2002), the Net Reproduction Rate per ewe or total weight of lambs weaned over lifetime can be improved by selecting for its component traits. Ovulation rate, embryo survival, mothering ability and milk production of the ewe, growth rate and viability of the lamb are some of the factors affecting TLWW (Falconer 1960). Conversely, it is possible to select for TLWW directly and improve its components (Olivier *et al.* 2001). While designing a selection programme, it is important to determine which approach is more efficient to improve ewe-productivity. We estimated the heritability of TLBW, TLWW and TLAW as 0.09, 0.05 and 0.02, respectively. The progressive decline in additive variance components for these traits is indicative of increasing environmental influence over the lamb weights with age. For TLBW, improvement through direct selection appears to be plausible, albeit at a slower rate. Similar estimates of TLBW were reported by Jafari and Manafiazar (2016) and Vatankhah (2016) as 0.12 and 0.08. For TLWW, higher estimates of 0.09 and 0.10 were reported by Jafari and Manafiazar (2016) and Vatankhah (2016), respectively. The lower estimates in study may be attributed to breed differences and stronger environmental influences. Emphasis on optimal managemental strategies is required to increase the weaning and 12-month weights of lambs per ewe.

Correlation estimates: The genotypic and phenotypic correlations of TLB and TLW with TLBW, TLWW and TLAW were moderate-highly positive, ranging from 0.36 to 0.97 (Table 3). This was in accordance with the results reported in the literature which ranged from 0.68 to 0.85 (Zishiri *et al.* 2013, Jafari and Manafiazar 2016, Vatankhah 2016). We believe these strong correlations are because of TLB being a core component of these traits. Efforts to get more lambings from an ewe will be rewarded by a higher Net Reproduction Rate or TLWW. The strong correlation among TLBW, TLWW and TLAW which ranged from 0.51 to 0.92 suggests that selection for total birth weight of lambs borne by an ewe will also result in an improvement of lamb weights at weaning and twelve-month stages. Jafari and Manafiazar (2016) and Vatankhah (2016) have reported

Table 1. Least-squares means (±SE) for lifetime reproductive performance of ewes

Effect	N	TLB (lambs)	TLW (lambs)	TLBW (kg)	TLWW (kg)	TLAW (kg)
Overall mean (μ)±SE	1001	3.38±0.11	2.97±0.11	9.59±0.37	39.59±1.68	50.15±2.51
Coefficient of variation		57.55%	62.20%	62.85%	69.12%	83.72%
Period of birth of ewe		**	**	**	**	**
P_1	113	$3.15±0.23^{b}$	$2.84±0.23^{b}$	$8.38±0.74^{ab}$	$31.04±3.27^{a}$	$43.29±5.06^{b}$
P_2	162	$3.44±0.16^{bc}$	$3.11±0.19^{bc}$	$9.37±0.65^{bc}$	$37.13±2.88^{ab}$	$51.39±4.46^{bc}$
P_3	203	$3.38±0.15^{bc}$	$3.06±0.17^{bc}$	$9.27±0.58^{bc}$	$41.53±2.58^{bc}$	$56.19±4.00^{cd}$
P_4	166	$3.78±0.14^{bc}$	$3.45±0.17^{c}$	$10.91±0.56^{cd}$	$48.86±2.49^{c}$	$64.72±3.85^{d}$
P_5	245	$3.93±0.13^{c}$	$3.23±0.14^{bc}$	$11.80±0.49^{d}$	$46.86±2.28^{c}$	$55.15±3.37^{bcd}$
P_6	112	$2.59±0.26^{a}$	$2.11±0.20^{a}$	$7.8±0.67^{a}$	$32.13±2.98^{a}$	$30.172±4.62^{a}$
Season of birth of ewe		NS	NS	NS	NS	NS
Winter	855	3.38±0.86	2.95±0.97	9.66±0.35	38.97±1.43	50.33±2.21
Summer	146	3.37±0.14	2.98±0.17	9.52±0.58	40.20±2.51	49.97±3.94
Inbreeding coefficient of ewe		NS	NS	NS	NS	NS
IB_1	452	3.55±0.10	3.06±0.12	10.19±0.41	37.44±1.80	50.81±2.79
IB_2	292	3.29±0.12	2.84±0.14	9.28±0.48	39.95±2.13	46.51±3.30
IB_3	215	3.31±0.12	2.98±0.15	9.26±0.51	40.12±2.27	47.90±3.51
IB_4	42	3.36±0.26	2.98±0.29	9.63±0.99	40.85±4.36	55.39±6.74
Ewe's weight at birth		NS	NS	NS	NS	NS
EBW_1	157	3.22±0.10	2.82±0.17	8.64±0.59	37.44±2.60	45.91±4.03
EBW_2	292	3.35±0.12	2.99±0.14	9.52±0.48	39.95±2.12	51.22±3.29
EBW_3	404	3.48±0.12	3.02±0.13	9.98±0.43	40.12±1.91	52.85±2.96
EBW_4	148	3.47±0.26	3.03±0.17	10.22±0.59	40.85±2.61	50.62±4.03

Means bearing different superscripts between rows within column differ significantly. TLB, total lambs born per ewe; TLW, total lambs weaned per ewe; TLBW, total lambs birth weight per ewe; TLWW, total lambs weaning weight per ewe; TLAW, total lambs adult weight per ewe; **Highly significant (P≤0.01); NS, Non–significant.

Table 2. Estimates of variance components, direct heritability and log likelihoods through REML procedures (±standard errors)

Trait	Parameter				
	Direct Additive (σ^2_a)	Residual (σ^2_e)	Phenotypic (σ^2_p)	Heritability (h^2)	Log-L
TLB	0.224622	3.79394	4.01856	0.06±0.04	–1202.781
TLW	0.164168	3.35181	3.51597	0.05±0.04	–1136.769
TLBW	3.44306	36.0605	39.5036	0.09±0.05	–2335.574
TLWW	34.7973	725.477	760.274	0.05±0.04	–3811.553
TLAW	40.3763	1780.47	1820.84	0.02±0.04	–4246.981

Table 3. Matrix of genetic (above diagonal) and phenotypic (below diagonal) correlation estimates for lifetime reproductive traits in Chokla sheep

	TLB	TLW	TLBW	TLWW	TLAW
TLB		0.99±0.05	0.93±0.05	0.93±0.08	0.50±0.46
TLW	0.93±0.01		0.94±0.09	0.93±0.07	0.36±0.71
TLBW	0.97±0.01	0.92±0.01		0.90±0.08	0.67±0.30
TLWW	0.92±0.01	0.97±0.01	0.92±0.01		0.51±0.48
TLAW	0.76±0.01	0.82±0.01	0.77±0.02	0.84±0.01	

similar correlations of 0.88 and 0.80 between TLBW and TLWW. TLAW had slightly lower genetic correlation with other traits (0.36–0.67) which exhibits the increasing environmental influences over lamb weights as they age.

In conclusion, the lifetime reproductive performance of Chokla is at par with other Indian purebreds such as Malpura but lags behind prolific exotic breeds primarily due to its small litter size. The period of birth of ewes had a highly significant (P<0.01) effect on all the traits. The period-wise least squares means exhibited a trend of improvement which declined in the last period due to disease outbreak and culling. Season of birth, inbreeding coefficient and birth weight of ewes had no significant effect on any trait. The low heritability estimates found in this study suggested limited scope for improvement through direct selection. The high genetic correlation estimates among traits suggested that the traits are governed by same set of genes. It seemed plausible that selection for cumulative birth weights of lambs will result in higher cumulative weaning and twelve-month weights. Overall, the low heritability estimates coupled with medium-high CV% for the traits suggest that there is ample scope of improving the lifetime reproductive performance of Chokla ewes by taking a management focussed approach.

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