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Performance Evaluation, Genetic Parameter and Genetic Trend Estimation of Production and Reproduction Traits of Sahiwal Cattle in Chhattisgarh

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ABSTRACT

Background: Performance evaluation is necessary for formulation of suitable breeding plans for genetic improvement in a population. Therefore, this study aimed to assess the production, reproduction performances and estimate the genetic parameter and genetic trend on 649 lactation records of 238 Sahiwal cows at an organized farm in Chhattisgarh.

Methods: The analysis was performed by using fixed model in LSML. Genetic trend for traits was estimated through linear regression of breeding values over the years.

Result: Least-squares means for total lactation milk yield (TLMY), 305day or less milk yield (305DMY), lactation length (LL), dry period (DP) and peak yield (PY) were 1385.1±26.7 kg, 1331.4±23.6 kg, 291.0±3.7 days, 214.8±6.0 days, 7.5±0.1 kg, while for reproduction traits; age at first calving (AFC), service period (SP) and calving interval (CI), the means were 1522.8±19.1 days, 212.4±5.9 days and 498.3±6.0 days, respectively. All the traits were significantly influenced by period of calving/birth whereas season had significant effect only on PY. The highest heritability (0.29 ± 0.05) was estimated for 305DMY and lowest (0.11 ± 0.07) for SP in Sahiwal cows. Very high and positive genetic correlations was found among production traits. The first lactation 305DMY showed positive genetic trend, while LL, DP, SP and CI showed a negative genetic trend.

Key words: Genetic trend, Heritability, Production trait, Reproduction trait, Sahiwal cattle.

INTRODUCTION

Total milk production in India was 187.7 million tonnes in 2018-19 (DAH&D, Ministry of Animal Husbandry and Dairying, GoI). Sahiwal is considered as one of the best indigenous dairy cattle breed of India due to high genetic potential for milk production, disease resistance and heat tolerance (Deb *et al.,* 2014). This unique genetic resource is limited to very few central and state Govt. livestock farms as indiscriminate crossbreeding reduced the population. There is serious deterioration in the quality of germplasm due to lack of availability of superior progeny tested bulls. Therefore, genetic improvement in their performances is going to be helpful for strengthening the population and simultaneously will conserve the native cattle. Development of a suitable breeding strategy for genetic improvement depends upon a fair understanding of the performances of the production and reproduction traits in Sahiwal cattle (Singh *et al.,* 2005; Gandhi *et al.,* 2009).

Before undertaking any breeding practices, the genetic parameters of the population are estimated for formulation of selection indices and prediction of genetic response to selection processes (Kaushik and Khanna, 2003). These genetic parameters change with the change in genetic structure of the population and also over the time period. Hence, there is a need to evaluate these parameters periodically to monitor the effectiveness of selection programme in a herd.

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Genetic trend is defined as the change in mean performance per unit of time in a trait due to change in mean breeding value (Smith, 1962). The estimates of genetic trend in a breed vary from herd to herd, which might be due to variation in the genetic structure of population, agro-climatic condition and management practices. Studies on first lactation total milk yield of Sahiwal cattle showed negative genetic trend at cattle breeding farm, Nagpur veterinary college, Nagpur (Tripude *et al.,* 1995), but positive trend at

National Dairy Research Institute, Karnal (Singh and Nagarcenkar, 2000; Raja, 2004). Therefore, the analysis of these trends is useful to assess the effectiveness of breeding strategy and also helps in developing or modifying appropriate breeding policy for bringing further improvement in traits (Nehara *et al.,* 2013; Chaudhary *et al.,* 2014; Parveen *et al.,* 2018).

There is dearth of literature on the performance evaluation as well as genetic trends of important economic traits in Sahiwal cattle population of Chhattisgarh, a state in the central part of India. Therefore, this study was undertaken to assess the performance of various production and reproduction traits, to estimate the genetic parameter and genetic correlations for those traits under study and also to analyze the genetic trend for first lactation traits of Sahiwal cattle at an organized farm in Chhattisgarh.

MATERIALS AND METHODS

Source of data

The present study was conducted at Chhattisgarh Kamdhenu Vishwavidyalaya, Durg, Chhattisgarh, which is a centrally located state in India at latitude of 21.16°N and longitude of 81.43°E.

A total of 649 lactation records from 238 Sahiwal cows sired by 51 bulls were collected during 2000 to 2018. Production traits *i.e.* total lactation milk yield (TLMY), 305day or less milk yield (305DMY), lactation length (LL), dry period (DP) and peak yield (PY), while reproduction traits *i.e.* age at first calving (AFC), service period (SP) and calving interval (CI) were generated. Prior to the analysis, this data set was subjected to a number of limiting restrictions relevant to each trait; for instance, TLMY ≤ 500 kg per lactation, LL of ≤100 and > 500 days were excluded from the data. Additionally, DP of < 50 and > 500, SP of < 63 and >500 days were eliminated, whereas the period in between 370 to 700 days were considered for CI in the present study.

Classification of data

After normalization, the data were classified according to different non-genetic factors *i.e.* five parities (1-5), four periods of calving/birth; period 1 (2000-2004), period 2 (2005-2009), period 3 (2010-2014), period 4 (2015-2018) and five seasons of calving/birth; spring (February-March), Summer (April-June), Rainy (July-September), Autumn (October-November) and winter (December-January).

Statistical analysis

Estimation of least-squares means

Least-squares analysis was applied to study the effects of non-genetic factors on the traits and also to estimate the least-squares means for all the performance traits using least-squares maximum likelihood programme (LSML) as suggested by Harvey (1990).

The model considered for the analysis was:

$$Y_{ijkl} = \mu + Pa_i + P_j + S_k + e_{ijkl}$$

Where,

Y_{ijkl}, observation on l^{th} individual belonging to k^{th} season of calving, j^{th} period of calving in i^{th} parity; μ, overall mean; Pa_i, fixed effects of j^{th} parity; P_j, fixed effects due to j^{th} period of calving; S_k, fixed effects of k^{th} season of calving; e_{ijkl}, random error ~ NID (0, $\sigma^2 e$).

The fixed model for analyzing AFC was:

$$Y_{ijk} = \mu + P_i + S_j + e_{ijk}$$

Where,

Y_{ijk}, observation on k^{th} individual belonging to j^{th} season of birth, i^{th} period of birth; μ, overall mean; P_i, fixed effects due to i^{th} period of birth; S_j, fixed effects of j^{th} season of birth; e_{ijk}, random error ~ NID (0, $\sigma^2 e$).

Duncan's multiple range test was used for testing the significant differences among the least-squares means of the traits (Kramer, 1957).

Estimation of heritability and genetic correlations

Least squares maximum likelihood (LSML) mixed model was applied for estimation of genetic parameters for the production and reproduction traits in Sahiwal cattle (Harvey, 1990).

The heritability was also estimated by using the variance-covariance components rom single-trait animal model analysis by REML method using WOMBAT software (Meyer, 2007).

Estimation of genetic trend

Genetic trend in the first lactation traits of 305DMY, LL, DP, SP and CI were obtained as regression of mean breeding values over period of calving. Best Linear Unbiased Prediction estimates of breeding values of individual animal were estimated by fitting single trait animal model using WOMBAT software (Meyer, 2007)

The model was:

$$y = X\beta + Z\mu + e$$

Where,

y, vector of observations for trait; β, vector of observations of fixed effects; μ, vector of observations of random animal effect; e, vector of random residual effects, e ~ NID (0, σ_e^2); X and Z, incidence matrices pertaining to fixed and random animal effects, respectively.

The regression analysis was performed using SPSS version 26.0.

RESULTS AND DISCUSSION

Performance evaluation of production and reproduction traits

The genetic improvement of Sahiwal cattle in an organized farm depends on genetic evaluation of their production and reproduction traits over the years. The least-squares means of production traits such as TLMY, 305DMY, LL, DP and PY were 1385.1 ± 26.7 kg and 1331.4 ± 23.6 kg, 291.0 ± 3.7 days, 214.8 ± 6.0 days and 7.5 ± 0.1 kg, respectively (Table 1). Our findings showed lower than earlier workers (Kumar

et al., 2017; Dhawan *et al.,* 2014), however Parveen *et al.* (2018) and Pandey *et al.* (2019) reported increased in 305DMY in Sahiwal cows. The reasons for lower mean milk yield could be due to impact of heat stress in summer in the central part of India as well as lack of feed and fodder availability in summer (Das *et al.,* 2016). The least-squares mean of LL in the present study concurs with the findings of Gandhi *et al.* (2009) and Kumar *et al.* (2017) in Sahiwal, Pundir and Singh (2007) in Red Sindhi cattle. Our study revealed that the overall mean of DP (214 days) was higher than the contemporary results (Kumar *et al.,* 2017), but corresponds with that of Upadhyay *et al.,* 2011; Dhawan *et al.,* 2014).

The least-squares means of reproduction traits *i.e.* SP, CI and AFC were 212.4 ± 5.9 days and 498.3 ± 6.0 days, 1522.8 ± 19.1 days, respectively (Table 2). The age at first calving is closely related with generation interval and therefore, influences the response to selection. The lower estimate of AFC (1103.76 ± 23.78 days) was reported by Singh *et al.* (2005) in Sahiwal cattle. On the contrary, Singh and Singh (2016) reported a higher value for AFC in the same breed. The lower AFC results in increase in the number of progenies and the number of lactations in the lifetime of a dairy animal resulting in higher profits in dairy enterprise. The SP and CI display the reproductive performance in a dairy herd with a huge variability in the traits. Our findings corroborate with that of earlier workers (Dhawan *et al.,* 2014; Upadhyay *et al.,* 2011) whereas a shorter SP and CI were observed by Kumar *et al.* (2017) in Sahiwal cattle.

Our study revealed that parity had significant ($p<0.01$) effect on DP, PY, SP and CI. The highest DP (264.2 ± 10.5 days), SP (246.1 ± 9.7 days) and CI (531 ± 9.8 days) were observed in the first parity of animals than the subsequent lactations, whereas the PY was found highest (7.9 ± 0.33 kg) in the fifth parity in Sahiwal cattle (Table 1 and 2). Singh and Singh (2018) also revealed the significant effect of parity on the pooled lactation production and reproduction traits in Sahiwal cattle.

Effect of period of calving/birth had significant effect ($p<0.01$) on all the traits (Table 1 and 2). The highest 305DMY (1505.5 ± 37.3 kg) was observed during 2010-2014, whereas the lowest 305DMY (1205.22 ± 43.76 kg) was found during 2005-2009. The cows calving during 2010-2014 had the longest LL (313.5 ± 6.2 days), DP (236.0 ± 10.2 days), SP (239.1 ± 10.0) and CI (528.3 ± 10.1 days) whereas cows calving during 2005-2009 had the highest PY of 8.7 ± 0.18 kg. The longest AFC of 1667.16 ± 30.41 days was found during 2010-2014, whereas the shortest AFC of 1341.04 ± 36.53 days was found during 2005-2009 in Sahiwal cattle. Similar to the present findings, the significant effect of period of calving on the pooled lactation production and reproduction traits was obtained by Singh and Singh (2018) in Sahiwal cattle.

The season of calving had significant effect on the peak yield in the way that the winter calvers had the highest PY of 8.5 ± 0.20 kg and the summer calvers had the lowest PY of 6.6 ± 0.24 kg. Similar results were reported by Gandhi *et al*. (2009) and Parveen *et al.* (2018). The non-significant effect of season of calving on the production and reproduction traits except PY indicated that the animals are adequately managed in different seasons by providing favourable environment to combat the adverse seasonal

Table 1: Least-Squares means and standard errors of production traits in Sahiwal cattle.

Effects	Least-squares means				
	TLMY (kg)	305DMY (kg)	LL (days)	DP (days)	PY (kg)
Overall (μ)	1385.1 ± 26.7 (348)	1331.4 ± 23.6 (348)	291.0 ± 3.7 (348)	214.8 ± 6.0 (348)	7.5 ± 0.11 (348)
Parity					
1	1313.1 ± 46.5 (99)	1331.4 ± 23.6 (99)	306.1 ± 6.4 (99)	264.2^{b} ± 10.5 (99)	6.8^{a} ± 0.20 (99)
2	1383.4 ± 45.2(96)	1248.1 ± 41.1 (96)	291.6 ± 6.2 (96)	221.9^{a} ± 10.2 (96)	7.2^{ab} ± 0.19 (96)
3	1421.7 ± 52.3(70)	1328.9 ± 40.0 (70)	295.2 ± 7.2 (70)	198.8^{a} ± 11.8 (70)	7.6^{ab} ± 0.22 (70)
4	1381.6 ± 62.5(50)	1354.6 ± 46.3 (50)	276.6 ± 8.6 (50)	200.5^{a} ± 14.1 (50)	7.8^{ab} ± 0.26 (50)
5	1425.7 ± 78.3(33)	1348.9 ± 55.3 (33)	285.5 ± 10.7 (33)	188.4^{a} ± 17.7 (33)	7.9^{b} ± 0.33 (33)
Period of calving					
2000-2004	1253.8^{a} ± 49.5(79)	1376.7^{a} ± 69.3 (79)	278.5^{a} ± 6.8 (79)	234.2^{bc} ± 11.2 (79)	7.1^{a} ± 0.21 (79)
2005-2009	1564.4^{b} ± 42.1(119)	1205.2^{c} ± 43.8 (119)	296.1^{b} ± 5.8 (119)	185.4^{a} ± 9.5 (119)	8.7^{b} ± 0.18 (119)
2010-2014	1350.0^{a} ± 45.3(100)	1505.5^{ab} ± 37.3 (100)	313.5^{b} ± 6.2 (100)	236.0^{c} ± 10.2 (100)	7.0^{a} ± 0.19 (100)
2015-2018	1372.1^{a} ± 63.4(50)	1267.2^{b} ± 40.1 (50)	276.0^{a} ± 8.7 (50)	203.5^{ab} ± 14.3 (50)	7.2^{a} ± 0.27 (50)
Season of calving					
Spring	1327.7 ± 55.4(65)	1347.8 ± 56.1 (65)	291.9 ± 7.6 (65)	226.2 ± 12.5 (65)	7.7^{b} ± 0.23 (65)
Summer	1337.2 ± 55.8(66)	1263.6 ± 49.0 (66)	298.3 ± 7.6 (66)	219.3 ± 12.6 (66)	6.6^{a} ± 0.24 (66)
Rainy	1398.3 ± 62.7(49)	1258.3 ± 49.4 (49)	285.1 ± 8.6 (49)	205.8 ± 14.2 (49)	7.2^{ab} ± 0.26 (49)
Autumn	1398.2 ± 53.8(72)	1363.6 ± 55.5 (72)	279.9 ± 7.4 (72)	208.4 ± 12.2 (72)	7.6^{b} ± 0.23 (72)
Winter	1464.1 ± 46.4(96)	1369.7 ± 47.6 (96)	299.9 ± 6.3 (96)	214.2 ± 10.5 (96)	8.5^{c} ± 0.20 (96)

*Figures within parentheses indicates number of observations and means bearing different superscript differ significantly ($p<0.01$)

Table 2: Least-Squares means and standard errors of reproduction traits in Sahiwal cattle.

Effects	Least squares means		
	SP (days)	CI (days)	AFC (days)
Overall (μ)	212.4 ± 5.9 (335)	498.3 ± 6.0 (335)	1522.8 ± 19.1 (189)
Parity			
1	246.1^{b} ± 9.7 (103)	531.0^{b} ± 9.8 (103)	-
2	206.2^{a} ± 10.0 (89)	491.9^{a} ± 10.1 (89)	-
3	198.2^{a} ± 11.3 (68)	483.2^{a} ± 11.4 (68)	-
4	203.2^{a} ± 13.4 (49)	492.6^{a} ± 13.5 (49)	-
5	208.3^{a} ± 18.5 (26)	492.7^{a} ± 18.7 (26)	-
Period of calving/birth			
2000-2004	212.7^{ab} ± 11.2 (73)	496.7^{a} ± 11.3 (73)	1420.05^{a} ± 32.27 (57)
2005-2009	199.9^{a} ± 9.1 (120)	487.0^{a} ± 9.2 (120)	1341.04^{a} ± 36.53 (45)
2010-2014	239.1^{b} ± 10.0 (93)	528.3^{b} ± 10.1 (93)	1667.16^{b} ± 30.41 (64)
2015-2018	197.9^{a} ± 13.7 (49)	481.1^{a} ± 13.8 (49)	1663.22^{b} ± 50.73 (23)
Season of calving/birth			
Spring	223.0 ± 11.9 (64)	508.7 ± 12.1 (64)	1552.70 ± 40.38 (37)
Summer	231.8 ± 12.3 (64)	515.8 ± 12.5 (64)	1505.41 ± 38.30 (42)
Rainy	193.9 ± 13.5 (48)	479.2 ± 13.6 (48)	1546.12 ± 42.34 (33)
Autumn	203.9 ± 12.0 (64)	492.3 ± 12.1 (64)	1557.85 ± 43.70 (33)
Winter	209.4 ± 10.0 (95)	495.4 ± 10.1 (95)	1452.25 ± 37.23 (44)

*Figures within parentheses indicates number of observations and means bearing different superscript differ significantly (p<0.01).

Table 3: Estimates of heritability (at diagonal) and genetic correlation (below diagonal) among production and reproduction traits in Sahiwal cattle.

Trait	TLMY	305DMY	LL	DP	SP	CI
TLMY	**0.28±0.04 (0.18±0.12)**	-	-	-	-	-
305 DMY	1.00±0.01	**0.29±0.05 (0.15±0.09)**	-	-	-	-
LL	0.98±0.10	1.008±0.32	**0.13±0.04 (0.16±0.07)**	-	-	-
DP	0.57±0.78	0.27 ± 0.63	0.50±0.75	**0.20 ± 0.06 (0.11±0.09)**	-	-
SP	0.59±0.22	0.17 ± 0.07	0.90±0.16	0.23±0.08	**0.11±0.07 (0.08±0.04)**	-
CI	0.32±0.11	0.22 ± 0.03	0.90±0.15	0.31±0.19	0.91±0.25	**0.13±0.07 (0.09±0.08)**

*Figures without parenthesis is heritability estimate using LSML and within parentheses is heritability estimate using WOMBAT.

effects. In other way, variation in the environmental parameters in different seasons does not prevail in the central part of India.

Estimates of genetic parameter for the traits

The heritability estimates for TLMY, 305DMY, LL, DP, SP and CI in Sahiwal cattle were 0.28 ± 0.04, 0.29 ± 0.05, 0.13 ± 0.04, 0.20 ± 0.06, 0.11 ± 0.07 and 0.13 ± 0.07 from LSML analysis and 0.18 ± 0.12, 0.15 ± 0.09, 0.16 ± 0.07, 0.11 ± 0.09, 0.08 ± 0.04 and 0.09 ± 0.08 from WOMBAT analysis, respectively (Table 3). The comparable results were obtained by Banik and Gandhi (2010); Parveen *et al.* (2018). On the contrary, Raja (2004) reported a higher estimate of heritability for milk production in Sahiwal. The differences in the heritability estimates may be due to the variation in the data size, genetic variation within population, management and environmental conditions and the methods used for parameter estimation (Ayalew *et al.,* 2017). Lowly heritable reproduction traits in the present study indicated that there is less genetic variation existing in the population for its improvement through genetic selection rather these traits are improved though suitable management practices.

In the present study, the genetic correlations were estimated as TLMY and 305DMY (1.00 ± 0.01), TLMY and LL (0.98 ± 0.10), LL and CI (0.90 ± 0.15), SP and CI (0.91 ± 0.25) from LSML as presented in Table 3. The results indicated that total lactation milk yield showed highly positive genetic correlations with the other production traits, which

was also recommended in earlier reports (Banik and Gandhi, 2010). The lower estimates of the genetic correlation were found among 305DMY and SP (0.17 ± 0.07), 305DMY and CI (0.22 ± 0.03), DP and SP (0.23 ± 0.08) in this study. The estimate of genetic correlations among the traits is considered as a component of selection index for selection of the superior individuals to be the parents for next generation.

Genetic trend in the traits of Sahiwal cattle

The genetic trends in the form of Estimated Breeding Values (EBV) for the first lactation traits in Sahiwal cows during 2000 to 2018 were presented in Fig 1-3. There was increase in mean milk yield of 2.12 ± 0.91 kg per year for first lactation 305DMY (Table 4), which shows positive genetic trend for milk yield traits (Fig 1). The positive genetic trend is desirable for milk yield traits which clearly indicates the effectiveness of selection for improvement of milk production traits in Sahiwal cows of Chhattisgarh. Similarly, the phenotypic trend for 305DMY was also found positive with 5.87 ± 1.32 kg per year (Table 4). Both genetic selection strategy and favourable environment act in coherently to show the positive phenotypic trend for milk yield in cows. In accordance with the present study, Parveen *et al.* (2018) in Sahiwal and Dash *et al.* (2016) in Karan Fries cattle obtained positive trend for milk production traits. On the contrary, the negative genetic trend was reported by Singh and Nagarcenkar (2000) for first lactation milk yield in Sahiwal cows in Chhattisgarh.

The phenotypic trend for LL and DP in the first parity were positive as 3.43 ± 1.23 and 0.93 ± 0.14 days per year (Table 4) and the genetic trends were found negative as -0.07 ± 0.03 and -0.04 ± 0.001 days per year, respectively (Table 4 and Fig 2). Positive genetic trend in this trait was obtained by Chaudhari *et al.* (2014) and Parveen *et al.* (2018), whereas the negative trend was reported by Singh and Nagarcenkar (2000) in Sahiwal cattle in Chhattisgarh. Positive genetic trend in the trait indicated slight genetic improvement in the traits over the years, whereas negative genetic trend estimate in LL suggests to bring desirable changes in the genetic structure of the population as well as to inculcate effective management in the herd.

The negative estimate of genetic trend was observed for SP (-0.003 ± 0.0005) and CI (-0.24 ± 0.11) as shown in Table 4 and Fig 3. The phenotypic trend was found positive (1.02 ± 0.50) for SP and negative (-1.23 ± 0.64) for CI in Sahiwal cows (Table 4). The estimate of genetic trend for first lactation DP, SP and CI was found negative in the present study illustrates the favourable genetic gain in these parameters over the years. Pundir and Singh (2007) also reported the similar observations for these traits in cattle.

Table 4: Estimates of phenotypic and genetic trends for first lactation production and reproduction traits in Sahiwal cattle.

Trait	Type of trend	Method BLUP Animal model
305DMY (kg)	ΔP	5.87 ± 1.32
	ΔG	2.12 ± 0.91
LL (days)	ΔP	3.43 ± 1.23
	ΔG	-0.07 ± 0.03
DP (days)	ΔP	0.93 ± 0.14
	ΔG	-0.04 ± 0.001
SP (days)	ΔP	1.02 ± 0.50
	ΔG	-0.003 ± 0.0005
CI (days)	ΔP	-1.23 ± 0.64
	ΔG	-0.24 ± 0.11

ΔP: Phenotypic trend, ΔG: Genetic trend, BLUP: Best Linear Unbiased Prediction.

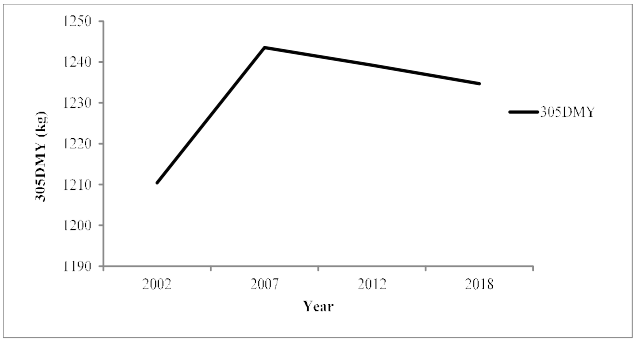

Fig 1: Estimated breeding value (EBV) of first lactation 305 day milk yield (305DMY) in Sahiwal cattle.

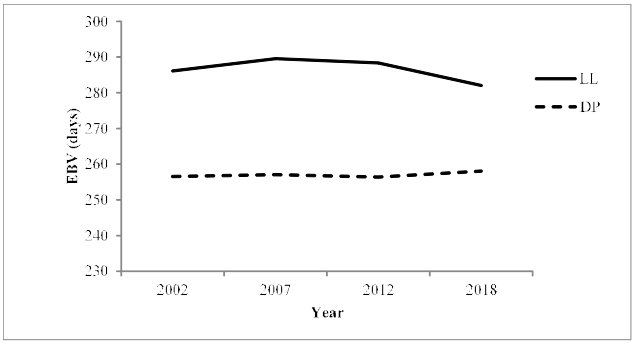

Fig 2: Estimated breeding value (EBV) of first lactation length (LL) and first lactation dry period (DP) in Sahiwal cattle

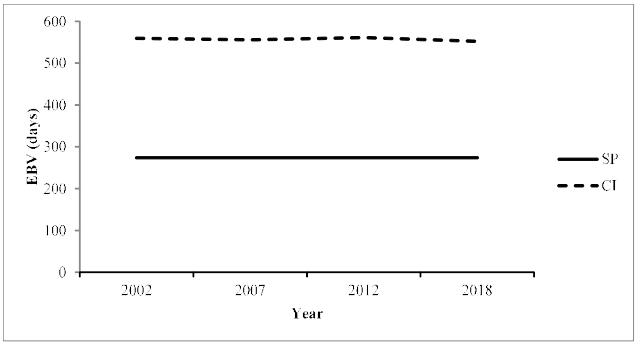

Fig 3: Estimated breeding value (EBV) of first lactation service period (SP) and first lactation calving interval (CI) in Sahiwal cattle.

CONCLUSION

This study represents an extensive work on performance evaluation of Sahiwal cattle in the central part of India. In conclusion, the estimates of heritability suggested a moderate to low genetic variation and possibility of the genetic selection for improving the milk production traits. The favourable genetic correlation among the production traits revealed the simultaneous genetic improvement in more number of traits through correlated response to selection using the selection index. Considering the genetic progress over the years, a steady trend was observed for the traits except for milk production. The positive genetic trend for milk production and negative trend for reproduction traits indicate that the animals in a small and close herd are better and suitably managed than the large herds. This could also decipher the significant genetic improvement in Sahiwal herd in Chhattisgarh in the recent past.

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