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Appraisal and simulation of expected genetic gain for production and reproduction traits in Sahiwal cattle

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ABSTRACT

The present study was undertaken with an objective to assess the expected genetic gain for production and reproduction traits, viz. 305-day milk yield (305DMY), average daily milk yield (ADMY), and calving to first insemination interval (CFI) in Sahiwal cattle. Data spread over a period of 29 years pertaining to production and reproduction traits of Sahiwal cattle maintained at an organized herd of ICAR-National Dairy Research Institute, Karnal, were utilized. Expected genetic gain per generation was assessed based on first and pooled 6 lactation records using 2 different methods, i.e. method I ($\Delta G = h^2S$) and II ($\Delta G = i\sigma_p h^2$). Method II, which considered selection intensity and phenotypic standard deviation of the traits led to better estimation in Sahiwal cattle. Further, different parameters involved in methods I and II were simulated to evaluate the expected genetic gain in first lactation traits, viz. 305DMY, ADMY, and CFI. In method I, generation interval was decreased as well as increased for estimating expected genetic gain. Using method I, expected genetic gain increased by about 33, 33, and 43% for 305DMY, ADMY, and CFI with the reduction of generation interval (GI) from 5.31 to 4 years, whereas the expected genetic gain decreased by about 11, 17 and 14% for the above-mentioned traits, respectively, with the increase of GI from 5.31 to 6 years. In method II, with the increase of selection intensity and reduction of GI, a significant increase in ΔG/year for 305DMY, ADMY, and CFI was observed. Present study indicated that generation interval and proportion of Sahiwal animals selected should be less than 5 years and 75%, respectively, for achieving more than 50% expected ΔG/year for 305DMY, ADMY, and CFI in an organized herd.

Keywords: Expected genetic gain, Generation interval, Production, Reproduction, Sahiwal, Selection intensity

Selection and mating systems are two imperative tools for animal breeders to attain genetic improvement in animals. Existing variability in the population serves as a raw material for operating selection process among different animals. Selection for a specific trait results in the improvement of trait in next generation known as genetic gain or response to selection. Assessment of genetic gain is very crucial in any breeding programme to know the genetic improvement in every generation and it can be predicted with the help of certain parameters like heritability, proportion of selected animals or selection intensity and variability in the population.

Sahiwal is an important indigenous dairy cattle breed originated in Punjab region along the Indian-Pakistan border. Currently, Sahiwal animals are being selected and judged for genetic improvement based on milk production only in the country. Several workers (Ratwan *et al*. 2019a, Pimentel *et al*. 2010, Pryce *et al*. 2004) have reported antagonistic relation among production and reproduction traits in dairy cattle. Literature revealed few studies related to estimation of expected genetic gain for milk yield in Sahiwal cattle but genetic gain estimation is restricted to lactation milk yield only and there is dearth of literature regarding assessment of genetic gain for other performance traits in Sahiwal cattle. Therefore, the present study was an endeavor for the first time in India to assess the genetic gain for average daily milk yield (milk yield per day of lactation length) and calving to first insemination interval (CFI) in addition to 305-day milk yield in Sahiwal cattle using different parameters like heritability, selection differential, intensity of selection and phenotypic standard deviation. Additionally, simulation of different parameters involved in estimation of genetic gain was done to determine the best combination of parameters for obtaining optimum genetic gain for sustainable development of Sahiwal cattle.

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MATERIALS AND METHODS

Study location and data recording: Records related to production and reproduction traits of 386 Sahiwal cattle maintained at organized herd of ICAR-National Dairy Research Institute, Karnal were utilized in this study. Data spread over a span of 29 years (1988–2016) were recorded. Data up to sixth parity of Sahiwal cattle were included in the study as number of observations in succeeding parities

was very less (<30). Data were edited firstly and abnormal records (dystocia, premature birth etc.) were excluded from the present study. Further, animals having lactation length less than 100 days and daily milk yield less than 3 kg were also not considered. Data were standardized using mean and standard deviation of each trait.

Traits: Three production and reproduction traits, viz. 305-day milk yield (305DMY), average daily milk yield (ADMY) and calving to first insemination interval (CFI) were considered for assessment of expected genetic gain. First lactation 305DMY is the most important trait of dairy animals because it is the earliest production record in the herd and is beneficial at the farms for making selection decisions regarding culling of animals. Average daily milk yield up to 305 days or less during lactation of animals is the most conversant and understandable trait for a dairy farmer. Therefore, in Indian situation, average daily milk yield may act as an important trait for selection of dairy animals in field conditions. Calving to first insemination interval is an economically important trait and reflects cow's ability to resume estrus cyclicity after calving. Ismael *et al*. (2016) reported that CFI is correlated with the animal's ability to conceive soon after insemination and become pregnant. A total of 806, 797 and 806 observations up to sixth lactation for 305DMY, ADMY and CFI, respectively, were finally utilized for the analysis.

Statistical analyses: Effect of non-genetic factors, viz. season of calving, period of calving and age group at calving was studied on the considered traits using least-squares analysis (Harvey 1990). Heritability was calculated using paternal half-sib correlation method (Becker 1975). Expected genetic gain per generation was estimated for first lactation production (305DMY and ADMY) and reproduction traits (CFI) using two different methods as per Falconer (1981).

Method I: $\Delta G = h^2S$; where h^2 is the heritability of trait and S is the selection differential, i.e. average superiority of selected parents.

Method II: $\Delta G = i\sigma_p h^2$; where i is the intensity of selection, i.e. value corresponding to the proportion of animals selected to the second lactation from first lactation; σ_p is the phenotypic standard deviation of the trait.

In both the methods, assessed expected genetic gain was divided by generation interval to get the expected genetic gain per year. Further, genetic gain per generation and per year for the mentioned production and reproduction traits was also assessed using both the methods based on pooled 6 lactation data.

Simulation study: In method I, generation interval (GI) was simulated, i.e. decreased and increased from the existing conditions. In method II, selection intensity and generation interval both were simulated simultaneously and expected genetic gain was assessed for different combinations.

RESULTS AND DISCUSSION

Estimation of expected genetic gain for first lactation production and reproduction traits: Overall means for 305-day milk yield, wet average and calving to first insemination interval were 2209.86 kg, 7.87 kg/day and 83.04 days, respectively, in the Sahiwal cattle. Phenotypic standard deviations for first lactation 305DMY, WA and CFI were 772.21 kg, 2.13 kg and 44.18 days and heritability estimates for corresponding traits were 0.28, 0.36 and 0.18, respectively (Ratwan *et al*. 2018, 2019b). Generation interval was calculated as 5.31 years using same data in the Sahiwal cattle (Ratwan *et al*. 2019c). The observed heritability of first lactation 305DMY in Sahiwal cattle was in correspondence with the reports of Banik and Gandhi (2010) and Raja (2010). However, for the same trait, Rehman and Khan (2012) found comparatively lower and Gupta (2013) observed higher estimates of heritability in Sahiwal cattle. For wet average, comparable heritability estimate was reported by Saha *et al*. (2010) in Karan Fries cattle although, Ratwan *et al*. (2017) in Jersey crossbred cattle reported relatively higher (0.54) estimate of heritability for the same trait. Literature related to heritability of CFI in Sahiwal cattle is lacking though in HF cattle, researchers (Berry *et al*. 2003, Sun *et al*. 2010, Potgieter 2012) observed comparatively lower estimates of heritability for the same trait.

Expected genetic gain (ΔG) per generation and per year for first lactation production and reproduction traits as estimated by method I and II is presented in Table 1. Expected ΔG/year for first lactation 305DMY, WA and CFI was 2.98 kg/year, 0.006 kg/year and 0.007 days/year by method I which was 0.13, 0.07 and 0.01% of the overall average, respectively. Method II estimated expected genetic gain as 17.51 kg/year, 0.06 kg/year and 0.64 days/year which was 0.79, 0.76 and 0.77% of overall average for 305DMY, WA and CFI, respectively. Pundir and Raheja (1995) reported estimated genetic gain for first lactation 300–day milk yield and total milk yield as 6.95 and 17.88 kg/generation, respectively, in Sahiwal cattle. Kumar *et al*. (2014) estimated set wise expected genetic gain for milk yield using method I (h^2S) in 7 sets of Murrah buffaloes under progeny testing programme and reported comparatively less average generation interval (4.73 years) in 7 sets and observed minimum (1.87 kg/year) expected genetic gain in milk yield for set II, however, maximum expected genetic gain (13.51 kg/year) was observed for set III which was 0.78% of the herd average. Using same method, Rahayu *et al*. (2015) reported comparatively higher genetic gain as 38.20 kg/generation and 9.76 kg/year for total milk yield in Baturraden Indonesian dairy cattle maintained at Baturraden Dairy Cattle Breeding and Forage Centre, Indonesia. Ratwan *et al*. (2020) reported expected genetic gain as 43.68 kg/year for 305DMY in Sahiwal cattle through direct selection or path method.

In present study, expected genetic gain per generation and per year for first lactation production and reproduction traits was found better using method II, i.e. by considering selection intensity and phenotypic standard deviation of the traits in Sahiwal cattle. Method II was 82.98, 90 and 98.90%

Table 1. Expected genetic gain for first lactation production and reproduction traits in Sahiwal cattle

Trait	Method I			Method II		
	ΔG/generation	ΔG /year	% of overall average	ΔG/generation	ΔG /year	% of overall average
305DMY	15.83	2.980	0.13	92.97	17.51	0.79
ADMY	0.03	0.006	0.07	0.33	0.06	0.76
CFI	0.04	0.007	0.01	3.38	0.64	0.77

Method I: ($\Delta G = h^2S/GI$); Method II: ($\Delta G = i\sigma_p h^2/GI$); p= 75%; i=0.43; GI=5.31 years. ΔG, expected genetic gain; h^2, heritability; S, selection differential; i, selection intensity; p, proportion selected; GI, generation interval.

more efficient than method I for estimation of expected genetic gain per year for 305DMY, ADMY and CFI in Sahiwal cattle. Theoretically, the expected genetic gain calculated by method I and method II should be same but practically it was found different in the present study. It may be due to the reason that the assumptions of normal distribution curve in method II considering selection intensity and phenotypic standard deviation were not fulfilled due to small data size.

Estimation of expected genetic gain for production and reproduction traits (pooled 6 lactation data)

Expected genetic gain was also assessed based on pooled 6 lactation data for production and reproduction traits using method I and II (Table 2). Phenotypic standard deviations used for 305-day milk yield (305DMY), wet average (WA) and calving to first insemination (CFI) based on 6 lactation data were 830.59 kg, 2.27 kg and 41.69 days and heritability estimates for the corresponding traits were 0.46, 0.47 and 0.08, respectively. Expected genetic gain for 305-day milk yield was 9.94 and 35.97 kg/year by two methods in Sahiwal cattle which was about 0.45 and 1.62% of the overall average (Table 2). Expected genetic gain per year for wet average was 0.02 and 0.10 kg/year by method I and II. For calving to first insemination interval, expected genetic gain was observed as –0.01 and 0.31 days/year, respectively by two methods. Negative expected genetic gain obtained for CFI by method I was desirable as it is essential to minimize CFI for good reproduction of animals. Expected genetic gain for 305-day milk yield, wet average and calving to first insemination interval up to sixth lactation was also found better using method II considering selection intensity and phenotypic standard deviation of the traits in Sahiwal cattle.

Simulation study

Expected genetic gain was assessed for first lactation 305-day milk yield (305DMY), wet average (WA) and calving to first insemination interval (CFI) by simulating different parameters involved in method I and II to pinpoint the optimum combination of selection intensity and generation interval for Sahiwal cattle at organized herds so that maximum expected ΔG can be attained.

Expected genetic gain by method I on simulation

Generation interval decreased (4 years) and increased (6 years) as compared to the existing conditions (5.31 years) for estimating expected genetic gain by method I (Table 3). Expected genetic gain increased by about 33, 33 and 43% for 305DMY, ADMY and CFI with the reduction of generation interval (GI) from 5.31 to 4 years, whereas expected genetic gain decreased by about 11, 17 and 14% for 305DMY, ADMY and CFI with increase of GI from 5.31 to 6 years by method I.

Expected genetic gain by method II on simulation

Selection intensity (i) and generation interval (GI) both were simulated simultaneously in method II. Expected ΔG for first lactation 305DMY, ADMY and CFI on simulating selection intensity and generation interval is presented in Tables 4-6, respectively.

With increase of selection intensity, i.e. decline in the proportion of Sahiwal animals selected (p) from 90 to 60% and reduction of GI up to 4 years, ΔG/year for first lactation 305-day milk yield increased from (Table 4), 10.81 to 34.60 kg/year by method II were observed. Correspondingly, with the increase of selection intensity (p = 90 to 60%) and considering estimated GI (5.31 years), expected ΔG/year

Table 2. Expected genetic gain based on pooled 6 lactation data for production and reproduction traits in Sahiwal cattle

Trait	Method I			Method II		
	ΔG/generation	ΔG /year	% of overall average	ΔG/generation	ΔG /year	% of overall average
305DMY	52.77	9.94	0.45	191.04	35.97	1.62
ADMY	0.1	0.02	0.25	0.53	0.10	1.27
CFI	–0.05	–0.01	0.01	1.67	0.31	0.37

Method I, ($\Delta G = h^2S/GI$); Method II, ($\Delta G = i\sigma_p h^2/GI$); p= 70%; i= 0.50; GI= 5.31 years; ΔG, expected genetic gain, h^2, heritability, S, selection differential; i, selection intensity; p, proportion selected; G, generation interval.

increased from 8.14 to 26.06 kg/year but with increase in both selection intensity (p = 90 to 60%) and GI up to 6 years, expected ΔG/year increased from 7.21 to 23.06 kg/year. In India, most of the animals are culled involuntarily at organized herds and voluntary culling is almost negligible, thus, we can reduce the proportion of selected animals up to 70% only. Expected ΔG for 305DMY increased between 33 to 54% with increase of selection intensity (p = 75 to 70%) and reduction of GI from 5.31 to 4 years, whereas, with the increase in both selection intensity (p = 75 to 70%) and GI from 5.31 to 6 years, the expected

Table 3. Expected genetic gain for production and reproduction traits on simulating generation interval by method I ($\Delta G = h^2S/GI$)

Trait	ΔG/generation	GI	ΔG/year	% of overall average
305DMY	15.83	4.00	3.960	0.18
		5.31	2.980	0.13
		6.00	2.640	0.12
ADMY	0.03	4.00	0.008	0.10
		5.31	0.006	0.07
		6.00	0.005	0.06
CFI	0.04	4.00	0.010	0.01
		5.31	0.007	0.01
		6.00	0.006	0.01

305DMY, 305-day milk yield; ADMY, average daily milk yield; CFI, calving to first insemination interval.

Table 4. Expected genetic gain for first lactation 305-day milk yield (305DMY) on simulating intensity of selection and generation interval by method II ($\Delta G = i\sigma_p h^2/GI$)

p	i	GI	ΔG/generation	ΔG/year	% of overall average
60	0.64	4	138.38	34.60	1.57
65	0.57		123.24	30.81	1.39
70	0.50		108.11	27.03	1.22
75	0.43		92.97	23.24	1.05
80	0.35		75.68	18.92	0.86
85	0.28		60.54	15.14	0.68
90	0.20		43.24	10.81	0.49
60	0.64	**5.31**	138.38	26.06	1.18
65	0.57		123.24	23.21	1.05
70	0.50		108.11	20.36	0.92
75*	**0.43**		**92.97**	**17.51**	**0.79**
80	0.35		75.68	14.25	0.64
85	0.28		60.54	11.40	0.52
90	0.20		43.24	8.14	0.37
60	0.64	6	138.38	23.06	1.04
65	0.57		123.24	20.54	0.93
70	0.50		108.11	18.02	0.82
75	0.43		92.97	15.50	0.70
80	0.35		75.68	12.61	0.57
85	0.28		60.54	10.09	0.46
90	0.20		43.24	7.21	0.33

σ_p= 772.21; h^2=0.28; overall average= 2209.86 kg, *Figures in bold represent genetic gain in existing conditions

Table 5. Expected genetic gain for first lactation average daily milk yield (ADMY) on simulating intensity of selection and generation interval by method II ($\Delta G = i\sigma_p h^2/GI$)

p	i	GI	ΔG/generation	ΔG/year average	% of overall
60	0.64	4	0.49	0.12	1.56
65	0.57		0.44	0.11	1.40
70	0.50		0.38	0.1	1.21
75	0.43		0.33	0.08	1.05
80	0.35		0.27	0.07	0.86
85	0.28		0.21	0.05	0.67
90	0.20		0.15	0.04	0.48
60	0.64	**5.31**	0.49	0.09	1.17
65	0.57		0.44	0.08	1.05
70	0.50		0.38	0.07	0.91
75*	**0.43**		**0.33**	**0.06**	**0.79**
80	0.35		0.27	0.05	0.65
85	0.28		0.21	0.04	0.50
90	0.20		0.15	0.03	0.36
60	0.64	6	0.49	0.08	1.04
65	0.57		0.44	0.07	0.93
70	0.50		0.38	0.06	0.80
75	0.43		0.33	0.06	0.70
80	0.35		0.27	0.05	0.57
85	0.28		0.21	0.04	0.44
90	0.20		0.15	0.03	0.32

σ_p= 2.13; h^2=0.36; overall average=7.87 kg/day. *Figures in bold represent genetic gain in existing conditions.

Table 6. Expected genetic gain for calving to first insemination interval (CFI) on simulating intensity of selection and generation interval by method II ($\Delta G = i\sigma_p h^2/GI$)

p	i	GI	ΔG/generation	ΔG/year	% of overall average
60	0.64	4.00	5.09	1.27	1.53
65	0.57		4.53	1.13	1.36
70	0.50		3.98	1.00	1.20
75	0.43		3.42	0.86	1.03
80	0.35		2.78	0.70	0.84
85	0.28		2.23	0.56	0.67
90	0.20		1.59	0.40	0.48
60	0.64	**5.31**	5.09	0.96	1.15
65	0.57		4.53	0.85	1.03
70	0.50		3.98	0.75	0.90
75*	**0.43**		**3.42**	**0.64**	**0.78**
80	0.35		2.78	0.52	0.63
85	0.28		2.23	0.42	0.51
90	0.20		1.59	0.30	0.36
60	0.64	6.00	5.09	0.85	1.02
65	0.57		4.53	0.76	0.91
70	0.50		3.98	0.66	0.80
75	0.43		3.42	0.57	0.69
80	0.35		2.78	0.46	0.56
85	0.28		2.23	0.37	0.45
90	0.20		1.59	0.27	0.32

σ_p= 44.18; h^2=0.18; overall average=83.04 days. *Figures in bold represent genetic gain in existing conditions.

ΔG varied between –11 to +4% in Sahiwal cattle. Assuming 80% selection (selection intensity=0.35), Murdia and Tripathi (1991) estimated direct response by utilizing 1064 lactation records of Jersey cattle, and found that the genetic gain for 305-day milk yield was 73.23 kg. Singh (1996) found expected genetic gain per generation for total lactation yield as 34.27, 78.14 and 97.92 kg, respectively at selection intensity of 0.35, 0.80 and 1.00 and for 300–day lactation milk yield the expected genetic gain was 66.17, 150.88 and 189.07 kg, respectively, at the corresponding selection intensities in Sahiwal cattle. Bara *et al.* (2010) estimated the expected genetic gain for milk yield using method II ($i\Delta_p h^2$) in Sahiwal cattle and reported genetic gain per year as 20.17, 11.60 and 16.33 kg after first, second and third lactation. Expected genetic gain observed after first lactation in their study was similar to the present findings (17.51 kg/year) although they assumed slightly higher selection intensity and generation interval was comparatively low. In Pabna cattle of Bangladesh, Khan *et al*. (2016) estimated expected annual genetic gain for 305 DMY under progeny testing and parent average testing schemes as 13.5 kg/year and 15.3 kg/year, respectively.

It is evident from Table 5 that with the increase of selection intensity, i.e. proportion of Sahiwal animals selected (p) reduced from 90 to 60% and decrease of GI up to 4 years, ΔG/year for first lactation average daily milk yield increased from 0.04 to 0.12 kg/year. Likewise, with the increase of selection intensity (p = 90 to 60%) and considering estimated GI (5.31 years), expected ΔG/year increased from 0.03 to 0.09 kg/year. Expected ΔG/year increased from 0.03 to 0.08 kg/year on increasing both selection intensity (p = 90 to 60%) and GI (6 years). For organized herd, with the increase of selection intensity (p = 75 to 70%) and decrease of GI from 5.31 to 4 years, the expected ΔG for average daily milk yield increased between 38 and 59% while, with the increase of selection intensity (p = 75 to 70%) as well as GI from 5.31 to 6 years, the expected ΔG varied between –8 and +5% in Sahiwal cattle.

With the increase of selection intensity (p = 90 to 60%) and reduction of GI up to 4 years, ΔG/year for calving to first insemination interval increased from 0.40 to 1.27 days/year (Table 6). Similarly, with the increase of selection intensity (p = 90 to 60%) and considering estimated GI (5.31 years), expected ΔG/year increased from 0.30 to 0.96 days/year. Expected ΔG/year increased from 0.27 to 0.85 days/year on increasing selection intensity (p = 90 to 60%) and GI (6 years). Literature was scanned but there was dearth of references regarding estimation of genetic gain for average daily milk yield and calving to first insemination interval in cattle by using same methods. However, Ratwan *et al.* (2020) reported expected genetic gain as 0.13 kg/year and 1.68 days/year for ADMY and CFI, respectively, in Sahiwal cattle using direct selection method.

In conclusion, expected genetic gain for production and reproduction traits was found better using method II ($i\sigma_p h^2$) considering selection intensity and phenotypic standard deviation of the traits in Sahiwal cattle. For organized herd, with the reduction of proportion of selected animals (p = 75 to 70%), i.e. increase of selection intensity and reduction of GI from 5.31 to 4 years, the expected genetic gain for 305DMY increased between 33 and 54%, whereas with the increase of GI from 5.31 to 6 years, the expected genetic gain varied between –11 and +4% in Sahiwal cattle. Expected genetic gain for ADMY and CFI revealed almost similar trend in Sahiwal cattle. Present study suggested that the generation interval and proportion of Sahiwal animals selected should be less than 5 years and 75%, respectively, for attaining more than 50% expected ΔG/year for 305 DMY, ADMY and CFI in organized herd.

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