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Performance evaluation and trends estimation of production and reproduction traits in Frieswal cattle under field progeny testing

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ABSTRACT

The objective of animal breeding is to optimize the genetic gain per unit time and to assess this gain per unit time, it is therefore, necessary to separate the environmental component from overall phenotypic gain. The data spanning over a period of nine years (2013-2021), pertaining to Frieswal cattle maintained at Pantnagar centre of AICRP-FPT was analyzed and the overall means of 806.30±6.93, 1084.17±6.93, 277.87±0.17, 12.89±0.07, 3060.12±15.66, 3.51±0.01, 310.53±0.43, 373.15±0.44, 95.28±0.48, 1.46±0.03 and 62.62±0.15 for age at sexual maturity (ASM), age at first calving (AFC), gestation period (GP), test day peak yield (TDPY), 305-days milk yield (305D-MY),fat percentage (FP), lactation length (LL), calving interval (CI), service period (SP), number of services per conception (NSPC) and dry period (DP), respectively. The corresponding overall breeding values for these traits were observed as 800.61, 1064.51, 277.64, 13.02, 3163.24, 3.474, 310.00, 372.58, 94.42, 1.468 and 62.57, respectively. The product moment correlations and Spearman rank correlations ranged from low to very high. The estimated phenotypic, genetic, and environmental trends were in positive direction for ASM, AFC, TDPY, 305D-MY and DP whereas in negative direction for GP, FP, LL, CI, SP and NSPC. The results revealed that improvement in the herd has been achieved with respect to TDPY and 305D-MY, however, some deterioration in traits viz. ASM, AFC, Fat % and DP.

Keywords: Environmental trend, Frieswal, Genetic trend, Phenotypic trend, Production traits, Reproduction traits

The objective of animal breeding is to optimize the genetic gain per unit of time for various economically significant traits within a breed enhancement programme. Assessing trends is crucial as it enables the comparison between realized and expected trends in a given context, allowing for the evaluation of advancements in a specific characteristic or trait. In order to assess the genetic trend in production and reproduction traits, it is necessary to separate the environmental and genetic components from the overall phenotypic trend (Kour *et al.* 2021).

The fluctuation in the average performance of a herd over time serves as an indicator of the phenotypic trend and doesn't necessarily reflect enhancements in the genetic potential of the animals. The magnitude and direction of change in the trend within a herd reflect the efficacy of the breeding programme and aid in the formulation or adjustment of strategies to achieve further improvement (Nehara *et al.* 2012).

Frieswal cattle, a synthetic breed, comprises 5/8 Holstein Friesian and 3/8 Sahiwal bloodlines. Frieswal cattle show favorable reproductive characteristics and outstanding milk production which establishes it as a valuable asset in the domain of dairy farming (Annual Report 2019). The purpose of this study was to investigate the genetic, phenotypic and environmental trends across various production and reproduction traits in Frieswal cattle in order to provide valuable insights for the development of selection programs aimed at enhancing the genetic improvement of the breed.

MATERIAL AND METHODS

The data spanning over a period nine years (2013-2021), pertaining to Frieswal cattle maintained at Pantnagar centre under All India Coordinated Research Project (AICRP) on progeny testing were used for present study. The data were classified in nine years (2013 to 2021) and three seasons viz. winter, summer and rainy. The traits studied were age at sexual maturity (ASM), age at first calving (AFC), gestation period (GP), 305-days milk yield (305D-MY), test day peak yield (TDPY), fat percentage (FP), lactation length (LL), calving interval (CI), service period (SP), number of services per conception (NSPC) and dry period (DP). As the data were non-orthogonal owing to unequal and disproportionate subclass frequencies, therefore, to overcome this problem, the data were subjected analyzed by Mixed Model Least Squares and Maximum Likelihood Computer Programme PC-2 of Harvey (1990) with

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Table 1. Estimate of Means for Production and Reproduction traits in Frieswal Cattle

Effect	N	ASM (days)	AFC (days)	GP (days)	TDPY (kg)	305D-MY (kg)	FAT (%)	LL (days)	CI (days)	SP (days)	NSPC (Nos.)	DP (days)
Overall		806.30±6.93	1084.17±6.93	277.87±0.17	12.89±0.07	3060.12±15.66	3.51±0.01	310.53±0.43	373.15±0.44	95.28±0.48	1.46±0.03	62.62±0.15
Year	*p*-Value	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.007**	0.356NS
2013	70	640.40±25.11a	919.17±25.12a	278.78±0.63b	12.61±0.26c	2529.34±56.74a	3.86±0.04e	312.22±1.55a	374.49±1.58d	95.71±1.73c	1.30±0.09b	62.26±0.55
2014	130	776.10±18.44b	1054.73±18.4b5	278.63±0.46b	10.93±0.19a	2414.27±41.67a	3.80±0.03e	316.65±1.14	379.88±1.16e	101.25±1.27e	1.48±0.07cf	63.22±0.41
2015	170	826.51±16.13bc	1105.69±16.13c	279.18±0.40b	11.44±0.17b	2675.76±36.44b	3.54±0.03d	318.61±0.99	381.28±1.01e	102.10±1.11e	1.60±0.06f	62.67±0.35
2016	140	830.46±17.89bc	1109.74±17.90bc	279.28±0.45b	12.40±0.19c	3079.69±40.43c	3.48±0.03cd	311.90±1.10	374.17±1.13d	94.89±1.23c	1.67±0.07b	62.27±0.39
2017	183	873.90±15.62c	1152.61±15.63c	278.70±0.39b	13.34±0.16dd	3235.80±35.31d	3.42±0.03cdb	310.30±0.96c	372.23±0.98d	93.53±1.07c	1.48±0.06b	61.94±0.34
2018	167	801.69±16.27b	1081.14±16.28b	279.45±0.41b	13.45±0.17de	3288.47±36.76de	3.21±0.03a	306.10±1.00b	368.25±1.02	88.79±1.12ab	1.40±0.06a	62.15±0.36
2019	141	834.00±17.81bc	1112.01±17.82bc	278.01±0.45b	14.13±0.19e	3629.45±40.25ef	3.35±0.03b	302.22±1.10	364.71±1.12	86.71±1.22a	1.49±0.07a	62.50±0.39
2020	117	782.56±19.48b	1057.27±19.49b	274.71±0.49b	13.88±0.20de	3399.38±44.01	3.46±0.03cd	309.11±1.20bc	372.29±1.22d	97.58±1.34c	1.32±0.07bd	63.18±0.43
2021	45	891.07±31.57c	1165.17±31.58c	274.09±0.79b	13.86±0.33de	3288.96±71.33de	3.46±0.05cd	307.67±1.94bc	371.05±1.99	96.96±2.17bc	1.41±0.12b	63.38±0.69
Season	P. Value	0.161 NS	0.182 NS	0.024 NS	0.609 NS	0.014 NS	0.763 NS	0.276 NS	0.487 NS	0.275 NS	0.659 NS	0.285 NS
Winter	416	805.75±10.53	1084.00±10.53	278.25±0.26	12.79±0.11	3061.18±23.79	3.50±0.02	309.60±0.65	372.30±0.66	94.05±0.72	1.42±0.04	62.69±0.23
Summer	462	792.07±10.28	1070.40±10.29	278.32±0.26	12.85±0.11	3004.24±23.24	3.52±0.02	311.18±0.63	373.82±0.65	95.50±0.71	1.48±0.04	62.64±0.23
Rainy	285	821.07±13.00	1098.11±13.01	277.03±0.33	13.04±0.14	3114.95±±29.38	3.51±0.02	310.81±0.80	373.33±0.82	96.29±0.89	1.49±0.05	62.52±0.29
Year *Season		0.635N	0.604 NS	0.352 NS	0.002**	0.001**	0.054 NS	0.722 NS	0.622 NS	0.355 NS	0.438 NS	0.022NS

Means with different superscripts in the columns differ significantly. NS indicates non-significant. * indicates significant at 5% level. ** indicates significant at 1% level.

following mathematical model to determine the effect of non-genetic factors on the traits under study:

$$Y_{ijkl} = \mu + S_i + P_j + G_k + e_{ijkl}$$

Where, Y_{ijkl} = observation on l^{th} progeny of i^{th} sire calved during j^{th} period and k^{th} season of calving; μ = overall mean; S_i = effect of i^{th} sire (i = 1, 2, 3...69); P_j = effect of j^{th} period of calving (j = 1, 2…9); G_k = effect of k^{th} season of calving (k = 1, 2, 3); e_{ijkl} = random error ~NID (0, σ_e^2).

The statistical significance of various fixed effects in the least squares model was determined by 'F' test using SPSS software. For significant effects, the differences between pairs of levels of effects of period were tested by Duncan's multiple range test (DMRT) as modified by Kramer (1957).

Breeding values of sires were estimated by Restricted Maximum Likelihood (REML) procedure described by Meyer (2007) using Harvey (1990). Product moment correlations between estimated breeding values and Spearman rank correlations between ranks assigned to sires were calculated Spearman (1904) using SPSS package.

The genetic trends described by Smith (1962) and phenotypic trends (Yadav *et al*. 2018) of the traits were estimated by regressing breeding values and phenotypic values of the trait on year of the calving, respectively. The breeding values were estimated by subtraction from phenotypic ones, and the regression of obtained values on year of calving was considered as environmental trend (Roshanfekr *et al*. 2015). The regression analysis was carried out using Minitab Statistical Software.

RESULT AND DISCUSSION

Least squares mean: The least squares mean for production and reproduction trait of Frieswal cattle are presented in Table 1. The data were corrected for significant effects of non-genetic factors. The results obtained in the present investigation were within the range of the results reported for different cattle genetic resources by various workers (Ratwan *et al.* 2018, Gupta *et al.* 2019, Girimal *et al.* 2020, Prasanna *et al.* 2023). However, (Ratwan *et al.* 2018) in Sahiwal cattle reported comparatively lower estimate for 305D-MY and higher estimate for LL and DP. Similarly, higher estimates for AFC, 305D-MY and Fat % in Frieswal cattle were observed by Kumar *et al.* (2017). Higher estimates for NSPC, AFC, SP and CI in Frieswal cattle were observed by Minj *et al.* (2016). Lower estimates for 305D-MY, LL and PY in Sahiwal and crossbred cattle were observed by Girimal *et al.* (2020) and in Sahiwal cattle by Ratwan *et al.* (2024) for 305D-MY, LL and PY. Gupta *et al.* (2019) observed overall mean estimate for 305D- MY, LL, DP, AFC and SP of 2128.64±18.65 (Kg), 282.60±1.96 (Days), 146.13±5.14 (Days), 1366.90±9.39 (Days) and 158.06±7.64 (Days), respectively, in Kankrej cattle.

Breeding value: The average breeding value for each trait across all sires and the minimum and maximum breeding values for each trait, along with the percentage difference from the average breeding value are reflected in Table 2. The average breeding values of Frieswal cattle conformed to the results observed by researchers for different cattle genetic resources (Singh *et al.* 2002, Sahin *et al.* 2012, Nehra *et al.* 2012, Dash *et al.* 2016, Gupta *et al.* 2019). Number of sires above and below the average displays the number and percentage of sires whose breeding values fall above and below the average breeding value, respectively. The average breeding value for TDPY (305-day milk yield) is much higher compared to other traits, indicating that sires vary significantly in their genetic potential for milk production. Traits viz. TDPY and 305D-MY have relatively wider ranges, indicating greater variation in genetic potential among sires for these traits. The distribution of sires above and below the average breeding value varied for different traits and are crucial for breeding programmes. Traits with higher average breeding values and a larger proportion of sires above the average might be targeted for selection to improve overall genetic potential in this cattle population. Therefore, this information can be helpful to make informed decisions regarding sire selection and breeding strategies. The estimates of breeding values

Table 2. Average Breeding Value (B.V) of Sires in Frieswal cattle

Trait	No of sires (Progeny)	Minimum and maximum progeny/sire	Average Breeding	Minimum B.V (% below average)	Maximum B.V (% above average)	No. of sires above average (% of sires)	No. of sires below average (% of sires)
ASM (days)	67 (1159)	4/70	800.61	716.93 (10.45)	899.69 (12.38)	29(43.28)	38 (56.72)
AFC (days)	67 (1159)	4/70	1064.51	994.74 (6.55)	1177.02 (10.57)	30(44.78)	37 (55.22)
GP (days)	67 (1159)	4/70	277.64	269.20 (3.04)	281.12 (1.25)	37(55.22)	30 (44.78)
TDPY (kg)	67 (1159)	4/70	13.02	10.55 (18.97)	15.25 (17.13)	39(58.21)	28 (41.79)
305D-MY (kg)	67 (1159)	4/70	3163.24	2208.17 (30.19)	3660.49 (15.72)	44(65.67)	23 (34.33)
FAT%	67 (1159)	4/70	3.474	3.34 (3.77)	3.73 (7.47)	36(53.73)	31 (46.27)
LL (days)	67 (1159)	4/70	310.00	305.65 (1.40)	316.74 (2.17)	29(43.28)	38 (56.72)
CI (days)	67 (1159)	4/70	372.58	368.06 (1.21)	379.56 (1.87)	31 (46.27)	36 (53.73)
SP (days)	67 (1159)	4/70	94.42	89.26 (5.46)	100.84 (6.80)	38(56.72)	29 (43.28)
NSPC	67 (1159)	4/70	1.468	1.35 (8.01)	1.71 (16.52)	32(47.76)	35 (52.24)
DP (days)	67 (1159)	4/70	62.57	61.69 (1.40)	63.33 (1.22)	34(50.75)	33 (49.25)

provide insight regarding selection pressure to be applied for improvement of these traits in Frieswal cattle under study.

Spearman's Rank Correlation and Product Moment correlations: The Spearman's rank correlation is presented above diagonal whereas estimates of Product Moment correlations are reflected below diagonal in Table 3. A value closer to 1 or -1 indicates a stronger monotonic relationship on either side, while a value closer to 0 indicates a weaker relationship. A strong positive monotonic relationship between ASM and AFC (0.87), indicated that cattle reaching sexual maturity earlier tend to calve earlier as well. The relationship between GP and TDPY is weak and negative, suggesting that longer gestation periods may slightly correlate with lower peak milk yields and also the association between 305D- MY and LL was strong and negative (-0.56), indicating that higher milk yield tends to be associated with shorter lactation periods. Service period and calving interval were found to have significant positive correlation. Such similar correlations have also been reported by Kumar *et al.* (2017). The association between ASM and AFC was found to be moderate and positive (0.55), while there was a weak negative linear relationship between gestation period and test day peak yield i.e. -0.18. Similarly, the relationship between 305 days milk yield and lactation length was observed as moderate and negative. Service period was also observed to have highly significant product moment correlation with lactation length and calving interval which were supported by findings of Kumar *et al.* (2017). However, Lodhi *et al.* (2015) have reported medium to negligible correlations among SP, AFC, DP etc. Strong positive correlations between certain traits (ASM and AFC) suggest a potential genetic association or common underlying factors influencing these traits and negative correlations between traits like milk yield and lactation length shows back and forth manipulation in selection decisions suggesting that breeders may need to prioritize certain traits over others based on their breeding objectives and management practices.

Trends for various production and reproduction traits: Three key trends viz genetic, phenotypic, and environmental help us understand how traits change over time. Genetic trends track changes in the underlying DNA, phenotypic trends focus on observable changes in traits and environmental trends examine the impact of external factors on the trait. Various researchers from India have estimated trends in quantitative traits across different livestock species (Gupta *et al.* 2019, Baba *et al*. 2020). The estimated phenotypic, genetic, and environmental trends were in positive direction for ASM, AFC, TDPY, 305D-MY and DP but in negative direction for GP, FP, LL, CI, SP and NSPC (Table 4). The positive phenotypic and genetic trends for age at sexual maturity (ASM) and age at first calving (AFC) suggest slight increase in these traits over years, therefore indicating increase in onset of sexual maturity over the years. The significant (p<0.05) positive environmental trend of magnitude 0.3573 days/ year suggests the influence of external factors such as nutrition and management on both the traits. Therefore, improving nutrition and management will improve these traits in favorable direction. Contradictory to the present study, Balasubramaniam *et al.* (2013) and Gupta *et al.* (2019) estimated negative phenotypic, genetic and environmental trends in multi-breed cattle, Sahiwal cattle and Kankrej cattle, respectively. Ibrahim *et al.* (2009) reported positive genetic (0.02 months/year) and negative phenotypic (-0.04 months/year) trends in Holstein cows. The trends of very low magnitude of less than 0.55 days/ year might be due to increased milk production as indicated by test day peak yield and 305-days milk yield during 2021 and 2022.The positive trends for test day peak yield and 305-days milk yield indicated an overall improvement in milk production over the years. The positive phenotypic change in 305-days milk yield over the years was in agreement with the findings of Nehara *et al.* (2012) and Dash *et al.* (2016) in Karan Fries cattle and Gupta *et al.* (2019) in Kankrej cattle whereas the negative trends were observed by Singal (1993) in Tharparkar and Sahiwal herds and Singh *et al.* (2002) in Hariana cattle. The obtained phenotypic trend (Fig. 1) was in conformity with the least squares estimate of the total milk yield. Conversely, magnitude of genetic changes did not exactly match with genetic

Table 3. Estimates of Spearman's Rank Correlation (above diagonal) and Product Moment (below diagonal) between EBVs among Production and Reproduction traits in Frieswal Cattle

Trait	ASM	AFC	GP	TDPY	305D-MY	FP	LL	CI	SP	NSPC	DP
ASM		0.75**	0.22	-0.24	-0.36**	0.05	0.46**	0.23	0.15	0.28*	0.06
AFC	0.87**		0.55**	-0.25*	-0.33**	-0.02	0.77**	0.20	0.03	0.22	-0.03
GP	0.21	0.45**		-0.10	-0.09	-0.18	0.52**	-0.10	-0.44**	-0.05	-0.23
TDPY	-0.25*	-0.28*	-0.18		0.87**	-0.37**	-0.53**	-0.54**	-0.48**	-0.24*	-0.16
305D-MY	-.42**	-0.46**	-0.20	0.63**		-0.42**	-0.56**	-0.55**	-0.48**	-0.28*	-0.13
FP	0.09	0.08	-0.11	-0.41**	-0.50**		0.27*	0.44**	0.41**	0.37**	0.03
LL	0.21	0.21	-0.01	-.41**	-.576**	0.41**		0.33**	0.14	0.20	-0.11
CI	0.22	0.21	-0.05	-0.38**	-.574**	0.41**	0.99**		0.89**	0.28*	0.26*
SP	0.14	0.06	-0.32**	-0.30*	-.489**	0.42**	0.93**	0.97**		0.27*	0.32**
NSPC	0.33**	0.30*	-0.01	-0.08	-.319**	0.31*	0.40**	0.37**	0.35**		0.00
DP	0.07	0.02	-0.19	0.08	-0.08	0.05	0.09	0.25*	0.30*	-0.07	

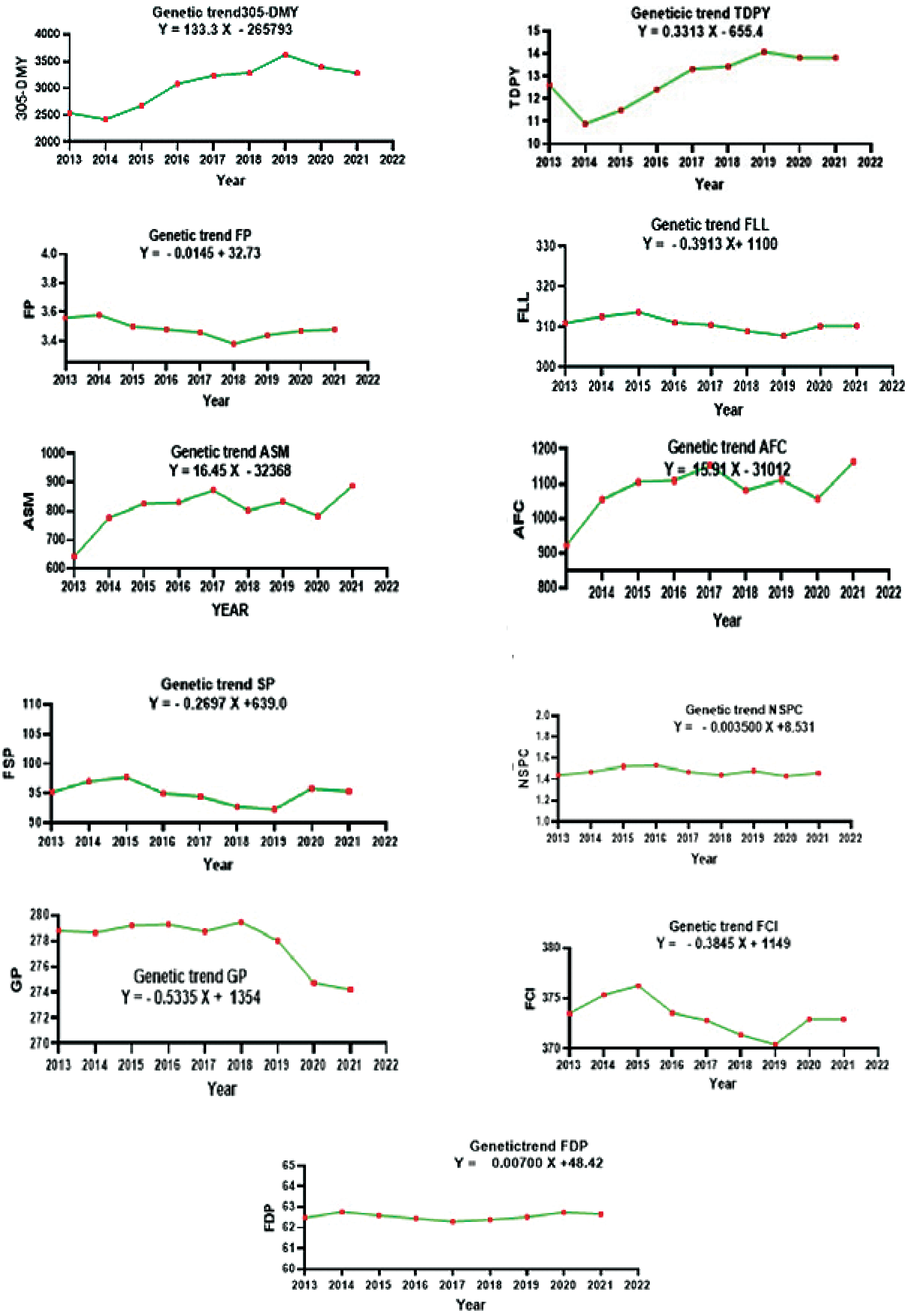

Fig. 1. Genetic trends of various production and reproduction traits in Frieswal cattle

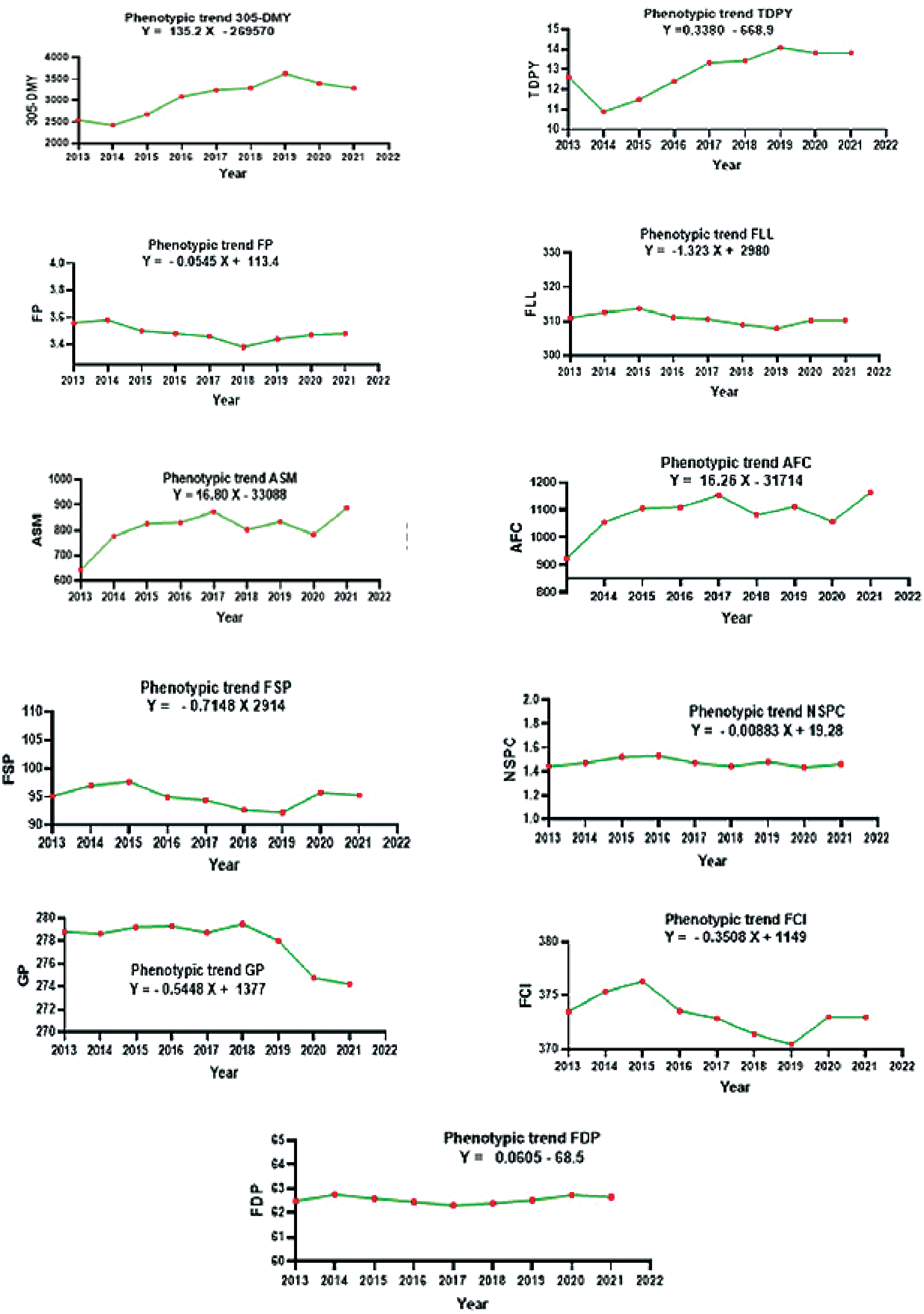

Fig. 2. Phenotypic trends of various production and reproduction traits in Frieswal cattle

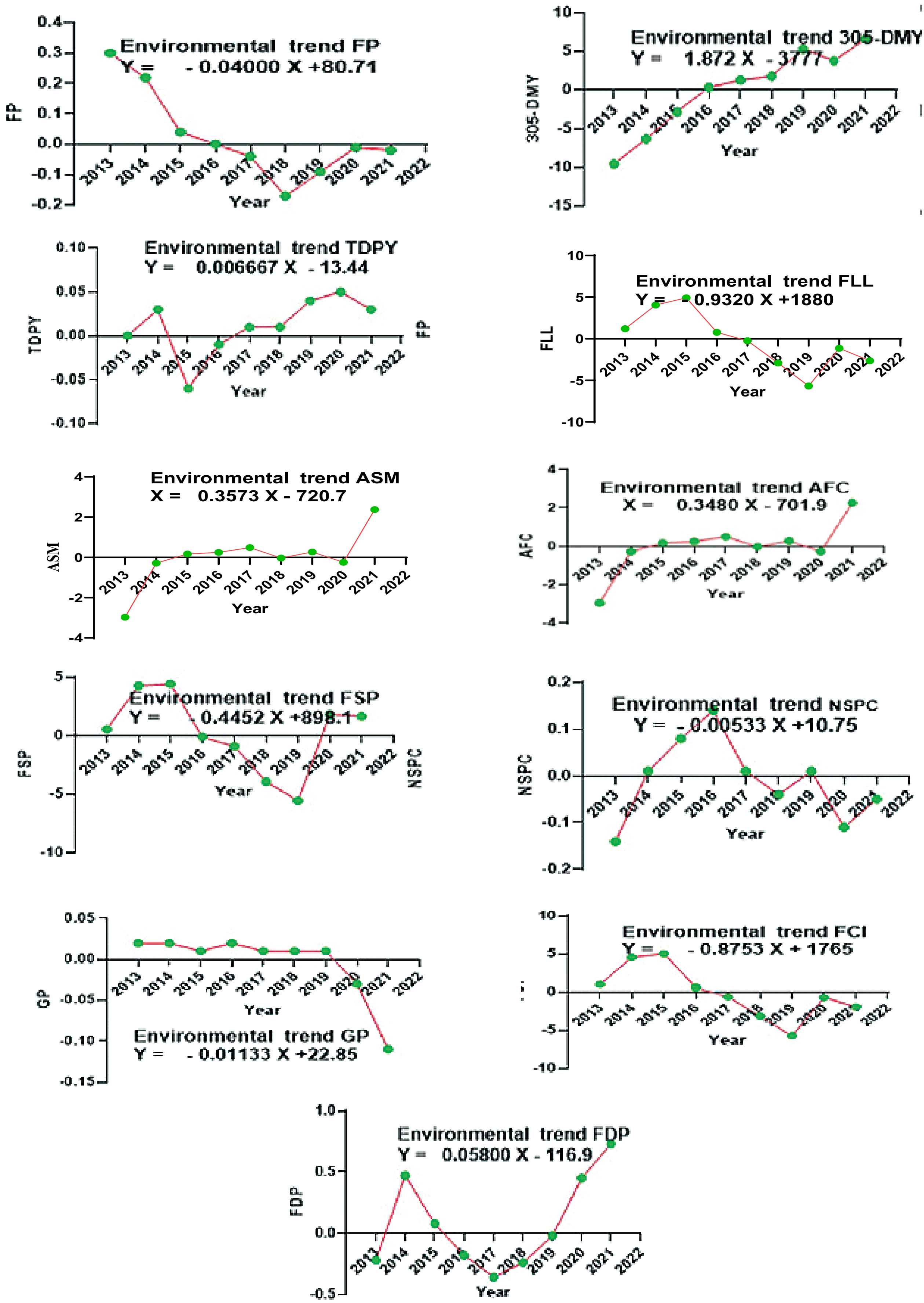

Fig. 3. Environmental trends of various production and reproduction traits in Frieswal cattle

Table 4. Estimates of Trends for Production and Reproduction traits of in Frieswal Cattle

Trait	Trends	Trend/ Year	p-Value	R^2
ASM (days)	Phenotypic	16.80	0.068	0.398
	Genetic	16.45	0.070	0.396
	Environmental	0.3573	0.031	0.510
AFC (days)	Phenotypic	16.26	0.078	0.378
	Genetic	15.91	0.079	0.375
	Environmental	0.3480	0.033	0.502
GP (days)	Phenotypic	- 0.5448	0.023	0.547
	Genetic	- 0.5335	0.023	0.544
	Environmental	- 0.01133	0.025	0.534
TDPY (kg)	Phenotypic	0.3380	0.007	0.670
	Genetic	0.3313	0.007	0.665
	Environmental	0.006667	0.122	0.307
305D-MY (kg)	Phenotypic	135.2	0.002	0.738
	Genetic	133.3	0.002	0.768
	Environmental	1.872	0.000	0.920
FP (percent)	Phenotypic	- 0.0545	0.026	0.529
	Genetic	- 0.01450	0.052	0.438
	Environmental	- 0.040	0.021	0.554
LL (days)	Phenotypic	- 1.323	0.031	0.509
	Genetic	- 0.3913	0.074	0.385
	Environmental	- 0.932	0.019	0.569
CI (days)	Phenotypic	- 1.2598	0.051	0.443
	Genetic	- 0.3845	0.094	0.349
	Environmental	- 0.8753	0.036	0.489
SP (days)	Phenotypic	- 0.7148	0.209	0.147
	Genetic	- 0.2697	0.263	0.175
	Environmental	- 0.4452	0.337	0.132
NSPC (days)	Phenotypic	- 0.00883	0.605	0.04
	Genetic	- 0.0035	0.473	0.076
	Environmental	- 0.00533	0.668	0.028
DP (days)	Phenotypic	0.0650	0.372	0.115
	Genetic	0.007	0.748	0.160
	Environmental	0.058	0.267	0.172

trend which indicated importance of several other factors such as management, nutrition, health, etc in controlling the phenotype of the animals. The environmental trend of magnitude of 1.872 days/year and phenotypic change of 135.2 days/year indicated that good selection policy is in vogue for improvement of milk production in Frieswal cattle in Uttarakhand. The negative trends for FP indicated decrease in fat % over the years which might be attributed to its negative association with milk by test day peak yield and 305-days milk yield.

The negative trends for LL in the present study were in consonance with the findings of Ambhore *et al.* (2017) in Karan Fries cattle, Mukherjee (2005) in Frieswal cattle and in Gupta *et al.* (2019) Kankrej cattle. However, a positive genetic trend for LL was reported by Nehara *et al.* (2012) in Karan Fries cattle and Ambhore *et al.* (2017) in Phule Triveni synthetic cow. Low magnitudes of both genetic and phenotypic trends advocate improvement in breeding and managemental interventions. All three trends viz. phenotypic, genetic and environmental for service period were in desirable direction, however, were very low in magnitude. Similar trends of magnitude were reported by Gupta *et al.* (2019) in Kankrej cattle that the genetic, phenotypic and environmental trends for SP of –0.07, –1.61 and –1.54 days/period, respectively. However, Hammoud and Salem (2013) in Holstein cows in Egypt and Dash *et al.* (2016) in Karan Fries cows reported positive phenotypic, genetic and environmental trends in Friesian and Karan Fries cattle. Low, positive and non-significant genetic trend of 0.073±0.346 days was observed in Holstein cows in Egypt (Hammoud and Salem 2013). The phenotypic, genetic and environmental trends indicated a decrease in calving interval (CI) per year, indicating a trend towards shorter intervals between successive calving events (Fig. 2,3). Report of Vergara *et al.* (2009) in Angus-Blanco Orejinegro-Zebu multi-breed cattle population advocates the estimation of negative trends for CI. However, Mostert *et al.* (2010) reported increase in CI in Holstein. Ayrshire, Guernsey breed and Jersey breed. Ibrahim *et al.* (2009) reported positive genetic (0.06 days/year) and negative phenotypic (0.48 days/year) trends in Holstein cows. Almost static and non-significant (p>0.05) trends with very low coefficient of determination (R^2) were observed for NSPC which may be attributed to the fact that this trait mostly depends on insemination techniques. The results of present study are in concord with Duran-Alvarez *et al.* (2023) in Holstein cattle. The positive genetic, phenotypic, and environmental trends for DP as observed in the present study indicated dry period over the years emphasizing upon the need for proper strategy to be adopted for genetic selection of animals through improvement in the management. The positive genetic change was in consonance with Gupta *et al.* (2019). However, contradictory to our finding, Gupta *et al.* (2019) in Kankrej cattle observed estimates of –0.032 and –0.054 days, for phenotypic and environmental changes, respectively. In Phule Triveni cattle, Ambhore *et al.* 2017) also reported positive genetic, phenotypic, and environmental trends for DP.

In the present investigation, the results revealed that there has been an improvement in 305 days milk yield and test day peak yield over the years, however, ASM and AFC did not show any progress, rather reflected, some deterioration. Genetic trends for fat % and dry period are also on the side with little impact on these traits. Improvement in rest of the traits over the years was in desired direction. Age at sexual maturity and age at first calving are important traits for overall productivity of the animal in the long run and, therefore, need to be improved employing correct strategy with respect to genetic variance and environmental factors.

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