RESEARCH ARTICLE

Genetic and Non-Genetic Factors Affecting Performance Traits in Crossbred Dairy Cattle

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Abstract

Data on performance records of 529 crossbred animals available from organised herd of Instructional dairy farm of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (India) spread over a period of 30 years (1990-2019) were analysed to determine the effect of several genetic and non-genetic factors on performance traits*, viz.,* age at first calving (AFC), first service period (FSP), first dry period (FDP), first calving interval (FCI), first lactation period (FLP), first lactation milk yield (FLMY), first lactation 305 days milk yield (FL305DMY), first lactation peak yield (FLPY) and first lactation days to attain peak yield (FLDAPY). The random effect of sire was statistically significant ($p<0.01$) on AFC, FLMY, FL305DMY and FLPY. Genetic group had statistically significant effect on FSP ($p<0.05$), FL305DMY ($p<0.01$) and FLDAPY ($p<0.05$). Season of calving significantly ($p<0.05$) affected the FL305DMY and FLDAPY. The significant differences of period of calving were observed on AFC ($p<0.01$), FSP ($p<0.05$), FLP ($p<0.01$), FLMY ($p<0.01$), FL305DMY ($p<0.01$) and FLDAPY ($P<0.01$). Variability in the traits due to various factors might be attributed to the differences in genetic groups and management practices. Therefore, satisfactory management and appropriate genetic improvement strategies would result in ameliorating the performance of animals.

Key words: Crossbred cattle, Genetic, Non-genetic factors, Performance traits.

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Introduction

The animal husbandry has emerged as a vital sector for ensuring a more inclusive and sustainable agriculture in India. Livestock sector plays a pivotal role in boosting the national economy by contributing 4.90% (at constant prices) of total Gross Value Added (GVA). Livestock Sector has continuously been growing with Compound Annual Growth Rate (CAGR) of 7.93% (at constant price) from 2014-15 to 2020-21. Total milk production during 2022-23 was 230.58 million tonnes with an annual growth rate of 3.83% over the previous year 2021-22. Out of total cattle population of 193.46 million in India, the numbers of exotic/crossbred cattle are 51.36 million and yield 8.55 kg milk per day (BAHS, 2023). Crossbreeding native non-descript cattle with exotic breeds of high genetic potential is thought to be a quick and effective technique of improving milk output to satisfy the expanding demands of the human population.

The production performance of crossbreds is not optimal owing to a variety of circumstances, including the direct influence of climate as well as different farm management issues. Improvements aimed at these issues may assist to significantly improve cattle performance (Alex *et al*., 2017). Both genetic and non-genetic variables impact a dairy cow's capacity to produce. Production efficiency is influenced by three factors namely the growth of offspring, reproduction, and female production. Reproduction is economically important because it stimulates lactation in dairy cattle, reduces reproductive illnesses, and increases profitability via early calf crop (Kaur *et al*., 2023). Knowledge about the lactation traits are also required for the establishment of any selection or breeding program (Ratwan *et al*., 2018). Thus, the purpose of the current study was to evaluate the impact of genetic and non-genetic factors on performance traits in crossbred cows in an organised farm.

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Materials and Methods

The data pertained to performance traits were obtained from records of 529 crossbred dairy cattle sired by 79 sires maintained at the Instructional dairy farm of G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand), India. Performance traits under present investigation were: age at first calving (AFC), first service period (FSP), first dry period (FDP), first calving interval (FCI), first lactation period (FLP), first lactation milk yield (FLMY), first lactation 305 days milk yield (FL305DMY), first lactation peak yield (FLPY) and first lactation days to attain peak yield (FLDAPY). The performance records related to different genetic groups, season and period of calving were classified into eight genetic groups, three seasons of calving and six periods of calving.

Statistical Analysis:

The statistical analysis of the data was done using mixed model Least Squares and Maximum Likelihood Computer Program PC-1 (Harvey, 1990). The following model was used to discern the significance of genetic groups of animals, season of calving and period of calving on various performance traits:

$Y_{ijklm} = \mu + S_i + L_j + G_k + P_l + e_{ijklm}$

Where, Y_{ijklm} = Observation of m^{th} progeny of i^{th} sire of j^{th} genetic group calved in k^{th} season and l^{th} period, μ = Overall population mean, S_i = Random effect of i^{th} sire (i= 1 to 79), L_j = Fixed effect of j^{th} genetic group (j= 1 to 8), G_K= Fixed effect of k^{th} season of calving (k= 1 to 3), P_l = Fixed effect of l^{th} period of calving (l= 1 to 6) and e_{ijklm} = Random error assumed to be normally and independently distributed with mean zero and constant variance, *i.e.,* NID $(0,\sigma^2)$.

Wherever, the effects were found significant, the difference between pairs of level of effects were tested for significance by Duncan's Multiple Range Test (DMRT) using software SPSS 25.0 version 2017.

Results and Discussion

Average Values of Performance Traits

The least squares means for various factors studied are presented in Table 1. The least squares analysis of variance for various performance traits are depicted in Table 2.

Age at first calving: The average age at first calving in the present study was found as 1170.62 ±31.50 days. Lower estimates (906±15.00 days to 1153.10±24.84 days) were reported by Lodhi *et al*. (2016), Khan *et al.* (2018) in crossbred dairy cattle and Ambhore *et al.* (2017) and Kuchekar *et al.* (2021) in Phule Triveni, while higher estimate (1445.34 ± 30.77 days) was reported by Girimal *et al.* (2020) in crossbred cattle. Perusal of Table 1 revealed that winter calvers had shortest AFC. Availability of green fodder enabled faster growth rate and early AFC during winter season.

First service period: The average first service period in the present study found was 263.94±3.40 days. Lower estimates for FSP (122.43±11.30 days to 261.34±1.77 days) were reported by Arya *et al.* (2022) in crossbred cows, Deokar *et al.* (2017) and Kuchekar *et al.* (2021) in Phule Triveni, while higher estimate (272.0±17.1 days) was reported by Hassan and Khan (2013) in HF cross.

First dry period: Least squares mean of first dry period was 115.90±19.84 days. Comparatively lower estimate (113.06±5.12 days) was reported by Kuchekar *et al.* (2021) in Phule Triveni, while higher estimate (124.29±3.67 days) was reported by Arya *et al.* (2022). The lowest mean (105.18±24.60 days) was shown by winter calvers that might be attributed to better adaptability of crossbred cattle in winter season.

First calving interval: The least squares mean of first calving interval in the present study was 513.00±22.60 days. Lower estimate (450.80±4.5 days) was reported by Arya *et al.* (2022) in crossbred dairy cattle. Perusal of Table 1 discerned the variation in calving interval during different seasons might be due to the differences in efficiency of estrus detection and artificial insemination, thermal stress management, disease handling and quality of fodder offered to the animals.

First lactation period: The average of first lactation period was 397.25±9.19 days. Lower estimates (233.38±0.00 days to 365.10±3.34 days) were reported by Arya *et al.* (2022) in crossbred cows, Ratwan *et al.* (2016) in Jersey crossbred, Ambhore *et al.* (2017) in Phule Triveni and Verma *et al.* (2017) in Red Sindhi×Jersey.

First lactation milk yield: The variation in FLMY is attributed to the physiology of lactating animal. The interaction of set of genes and non-genetic factors influence the total milk yield in dairy animal. The least squares mean for first lactation milk yield in the present study was 3584.92±118.42 kg. Lower estimates (1136.56±21.04 kg to 3140.0±81.90 kg) were obtained by Verma *et al.* (2017) in Red Sindhi×Jersey, Prakash *et al.* (2018) and Arya *et al.* (2022) in crossbred dairy cattle, while higher estimate (4677.84±50.35 kg) was reported by Puhle *et al.* (2015) in Karan Fries cows.

First lactation 305 days milk yield: The average for FL305DMY was observed as 2854.26±59.61 kg. Lower values (2225.6±71.0 kg to 2729.04±669.3 kg) were reported by Ratwan *et al.* (2016) in Jersey crossbred, Arya *et al.* (2022) in crossbred cows and Kuchekar *et al.* (2021) in Phule Triveni cows, while higher estimate (4113.61±55.90 kg) was reported by Puhle *et al.* (2015) in Karan Fries cows.

First lactation peak yield: The average first lactation peak yield in the present study found was 14.18±0.27 kg. Lower estimates (7.53±0.38 kg to 13.86±0.27 kg) were reported by Ratwan *et al.* (2016) in Jersey crossbred, Raja *et al.* (2018) in Holstein Friesian×Sahiwal, while higher estimate (14.22±0.14 kg) was reported by Bhoite *et al.* (2020) in Vrindavani cattle.

First lactation days to attain peak yield: The average FLDAPY was 48.42±0. 87 days. Lower estimates (36.95± 0.30 days to 46.60±2.29 days) than the present study were reported by Anarase *et al.* (2015) in HF×Deoni and Raja *et al.* (2018) in Frieswal.

Effect of Genetic and Non-genetic Factors on Performance Traits

Effect of sire:

The perusal of Table 2 revealed that sire had statistically significant (p<0.01) effect on AFC, FLMY, FL305DMY and FLPY. Significant effect of sire on AFC was also reported by

Table 1: Least squares means along with their standard errors for performance traits of crossbred cattle as influenced by genotype, season of calving and period

Fact-or	Source	N	AFC (days)	FSP (days)	FDP (days)	FCI (days)	FLP (days)	FLMY (kg)	FL305D-MY (kg)	FLPY (kg)	FLDAPY (days)
-	Overall mean	529	1170.62 ±31.50	263.94 ±3.40	115.90 ±19.84	513.00 ± 22.60	397.25 ±9.19	3584.92 ±118.42	2854.26 ±59.61	14.18 ±0.27	48.42 ±0.87
Genotype	G_1 (HF×RD×S)	66	1152.77 ±51.16^{a}	267.69 ±4.24^{b}	122.70 33.14	529.33 ±61.61^{a}	401.05 ±15.35^{a}	3624.00 ±487.22^{a}	2953.86 ±99.57^{b}	14.48 ±0.33^{bc}	44.33 ±2.39^{a}
	G_2 (HF×J×RD×S)	251	1142.73 ±39.29^{ab}	266.23 ±13.99^{b}	127.59 ±24.75	533.44 ±28.19^{a}	405.51 ±11.46^{a}	3623.25 ±192.34^{cd}	2906.31 ±74.36^{bc}	14.01 ±1.11^{a}	44.61 ±1.09^{a}
	G_3 (J×HF×S)	85	1165.61 ±52.61^{ab}	268.07 ±9.26^{ab}	114.54 ±30.02	553.38 ±58.50^{a}	405.65 ±13.90^{ab}	3770.02 ±179.14^{bc}	2956.53 ±90.18^{bcd}	14.6 ±1.40 ^{bcd}	45.09 ±1.33^{a}
	G_4 (H×S)	18	1116.78 ±85.86^{a}	262.93 ±5.68^{b}	140.06 ±54.09	519.40 ±34.19^{a}	396.63 ±23.78^{a}	3541.58 ±197.79^{ab}	2812.91 ±154.28^{b}	13.85 ±0.43^{d}	42.93 ±3.61^{a}
	G_5 (J×S)	9	1549.66 ±189.42^{a}	276.67 ±8.80^{b}	68.87 ±81.65	524.14 ±37.75^{a}	392.51 ±37.81^{a}	3644.08 ±147.71^{b}	2959.67 ±245.27^{a}	14.89 ±0.45^{abc}	46.05 ±1.46^{a}
	G_6 (HF×J×R×S)	66	1073.15 ±47.65^{ab}	263.34 ±5.52^{b}	127.83 ±32.23	527.55 ±36.71^{a}	399.75 ±14.93^{ab}	3510.23 ±306.47^{b}	2756.70 ±96.82^{d}	13.80 ±2.73^{d}	42.71 ±2.27^{a}
	G_7 (HF×R×S)	18	1024.84 ±81.52^{a}	241.89 ±20.44 ^{ab}	156.69 ±51.36	461.57 ±93.00^{a}	389.59 ±25.05^{a}	3241.15 ±322.78^{b}	2619.35 ±162.49^{cd}	13.64 ±1.62^{d}	40.53 ±5.28^{b}
	G_8 (HF×S)	16	1139.45 ±129.61^{b}	264.71 ±5.14^{b}	68.92 ±119.34	455.19 ±135.92^{a}	387.28 ±55.27^{b}	3725.05 ±712.08^{d}	2868.74 ±358.47^{d}	14.10 ±0.69^{ab}	44.42 ±1.42^{a}
Season	S_1 (March-June)	189	1178.73 ±39.05^{a}	265.55 ±3.83^{b}	128.50 ±22.39	520.27 ±25.51^{a}	410.01 ±10.95^{b}	3555.20 ±133.65^{a}	2785.77 ±71.02^{a}	14.18 ±0.32^{a}	43.16 ±1.04^{a}
	S_2 (July-October)	113	1186.55 ±35.55^{a}	260.49 ±4.21^{b}	114.02 ±23.64	495.41 ±28.02^{a}	389.49 ±11.39^{a}	3565.88 ±146.82^{a}	2872.75 ±67.28^{ab}	14.10 ±0.33^{a}	56.39 ±1.09^{b}
	S_3 (November – February)	227	1146.59 ±37.53^{a}	265.78 ±4.05^{b}	105.18 ±24.60	523.32 ± 26.93^{a}	392.24 ±10.37^{a}	3633.67 ±141.08^{a}	2904.24 ±73.91^{b}	14.24 ±0.30^{a}	45.70 ±0.99^{c}
Period	P_1 (1990-1995)	55	946.26 ±83.92^{cd}	248.37 ±11.69^{a}	144.05 ±52.87	507.30 ± 45.11^{a}	393.46 ±24.48^{a}	3047.36 ±315.48^{a}	2327.98 ±158.82^{a}	13.82 ±0.71^{a}	40.81 ±2.02^{a}
	P_2 (1996-2000)	136	1027.07 ±75.52^{d}	261.07 ±7.16^{ab}	160.97 ±68.25	536.56 ±60.22^{a}	424.74 ±22.03^{b}	3075.06 ±407.26^{d}	2791.96 ±142.91^{b}	13.90 ±0.62^{b}	43.26 ±1.75^{b}
	P_3 (2001-2005)	124	1095.53 ±62.86^{a}	263.70 ±6.78^{b}	105.39 ±45.63	490.76 ±51.97^{a}	385.11 ±21.13^{ab}	3653.53 ±272.26^{bc}	2852.79 ±137.06^{c}	14.04 ±0.53^{c}	45.90 ±2.10^{bc}
	P_4 (2006-2010)	102	1107.49 ±72.42^{cd}	266.38 ±9.06^{ab}	101.04 ±39.60	522.51 ±77.74^{a}	406.09 ±18.34^{ab}	3843.06 ±249.38^{d}	2932.65 ±205.0^{e}	14.29 ±0.64^{a}	46.11 ±2.34^{bc}
	P_5 (2011-2015)	59	1523.51 ±108.34^{b}	272.75 ±8.15^{b}	109.98 ±47.58	533.38 ±54.19^{a}	413.31 ±19.35^{c}	4003.44 ±236.33^{c}	3232.80 ±125.54^{e}	14.51 ±0.92^{c}	47.90 ±3.02^{d}
	P_6 (2016-2019)	53	1323.89 ±66.34^{bc}	271.36 ±7.81^{b}	73.97 ±41.79	487.47 ±47.60^{a}	360.77 ±31.61^{c}	3887.06 ±283.89^{b}	2987.35 ±118.97^{d}	14.50 ±0.56^{c}	46.51 ±1.85^{c}

Least square means within subclasses with different superscripts (a, b, c) are significantly ($p< 0.05$) different from each other; N: number of animals; AFC: age at first calving, FSP: first service period, FDP: first dry period, FCI: first calving interval, FLP: first lactation period, FLMY: first lactation milk yield, FL305DMY: first lactation 305 days milk yield, FLPY: first lactation peak yield and FLDAPY: first lactation days to attain peak yield.

Ambhore *et al.* (2017) in Phule Triveni and Jadhav *et al.* (2019) in HF×Gir. Significant effect of sire on FLMY was reported by Jadhav *et al.* (2019) in Holstein Friesian×Gir and Jersey and Arya *et al.* (2022) in crossbred cattle. The effect of sire on FL305DMY was reported as statistically significant by Jadhav *et al.* (2019) in Holstein Friesian×Gir and Arya *et al.* (2022) in crossbred dairy cattle. The random effect of sire on FLPY was observed by Ratwan *et al.* (2016) in Jersey crossbred cows. The significant effect of sire on various performance traits revealed that superior sire could be used effectively to improve the traits under consideration. The non-significant effect of sire on FSP, FDP, FCI, FLP and FLDAPY indicated that performance of these traits were independent of the types of sires used for selection.

Table 2: Least square analysis of variance for performance traits

Source of variation	df	Mean sum of squares								
		AFC	FSP	FDP	FCI	FLP	FLMY	FL305DMY	FLPY	FLDAPY
Sire	78	141414.26**	1087.71	20167.69	25419.87	8546.13	1799937.37**	534817.85**	13.82**	94.17
Genetic Group	7	109163.31	575.40*	6378.14	7194.71	733.61	510614.95	246054.99**	3.76	33.73*
Season	2	70968.53	914.794	18118.81	24051.44	17460.54	281363.52	496208.78*	0.54	226.87*
Period	5	256047.87**	495.09*	16488.25	17508.56	18103.24**	3937106.60**	1358442.49**	2.19	234.64**
Error	436	77677.92	905.21	30832.27	39995.65	6613.65	1097686.69	278181.75	5.70	60.47

* and ** represent significant difference at 5% and 1% level of significance, respectively.

Effect of genetic group:

The genetic group of cattle under study had significant effect ($p<0.05$) on FSP which was comparable with the Lodhi *et al.* (2016) in crossbred cows. In general, FSP for G_7 (Holstein Friesian × Rathi × Sahiwal) was minimum, *i.e.* 241.89±20.44 days, while for G_5 (Jersey×Sahiwal) it was maximum, *i.e.* 276.67±8.80 days. Perusal of Table 2 revealed that daughters with genetic group had significant effect ($p<0.01$) on FL305DMY and cows with G_5 had highest (2959.67±245.27 kg) FL305DMY, while daughters with genetic group of G_7 had lowest FL305DMY (2619.35±162.49 kg). Significant effect of genetic group on FL305DMY was also reported by Kumar *et al.* (2014) in HF crossbreds. The genetic group had significant ($p<0.05$) effect on FLDAPY. Similar significant effect was also reported by Hussain *et al.* (2012) in crossbred cows. The cows with genetic group G_7 attained peak yield earlier (40.53±5.28 days) than the cows with genetic group G_5 that took 46.05±1.46 days. Aforesaid results suggested that Jersey breed may be effectively used in crossbreeding for augmenting the reproductive efficiency and curtailing the unproductive life of Indian dairy cattle. The non-significant effect of genetic groups on AFC, FDP, FCI, FLP, FLMY and FLPY under present investigation, suggested that animals were able to express their full genetic potential irrespective of their genetic groups.

Effect of season of calving:

The season of calving significantly ($p<0.05$) affected the FL305DMY and FLDAPY. Japheth *et al.* (2015) in Karan Fries cows reported significant effect of season of calving on FL305DMY, while non-significant effect of season was reported by Verma *et al.* (2017) in Red Sindhi× Jersey. The effect of season of calving on FLDAPY was significant ($p<0.05$). Similar finding was reported by Raja *et al.* (2018) in Frieswal, the average FLDAPY being maximum (56.39±1.09 days) for rainy calvers and minimum for summer calvers (43.16±1.04 days). Perhaps the reason was, that during rainy season the crosses were susceptible to heat stress due to increased humidity and high temperature, and the cows that calved during rainy season might have averted their energy to combat the environmental stress as well as to maintain homeothermy and therefore took longer time to attain peak yield. The non-significant effect of season of calving on AFC, FSP, FDP, FCI, FLP, FLMY and FLPY recommended that the animals were not susceptible to the seasonal fluctuations in temperature and humidity.

Effect of period of calving:

Period of calving had significant effect on AFC, FSP, FLP, FLMY, FL305DMY and FLDAPY. Significant effect of period ($p<0.01$) on AFC was also reported by Lodhi *et al.* (2016) in crossbred cows. Cows that calved during P_1 (1990-1995) had shortest AFC (946.26 ± 83.92 days), while longest AFC (1523.51 ± 108.34 days) was for the cows that calved in P_5 (2011-2015). Period of calving had significant ($p<0.05$) influence on FSP, as was observed by Lodhi *et al.* (2016) in crossbred cows. Cows in P_1 had shortest FSP (248.37±11.69 days), while cows in P_5 had longest FSP (272.75±8.15 days). The effect of period on FLP was found significant ($p<0.01$). The present findings were in consonance with the result reported by Ratwan *et al.* (2016). Cows that calved during P_6 (2016-2019) had comparatively low FLP than the cows that calved during P_2 (1996-2000). Significant effect ($p<0.01$) of period on FLMY was discerned in the present study. The variation in FLMY (decrease over the periods) was primarily due to curtailment of FLP (424.74 days) during P_2 to 360.77 days during P_6. The results were in conformation with the reports of Jadhav *et al.* (2019) in HF×Gir and Arya *et al.* (2022) in crossbred cows. The differences in FL305DMY were significant ($p<0.01$) for the period of calving. This result was in conformation with the report of Jadhav *et al.* (2019) in HF×Gir. The effect of period of calving on FLDAPY was significant ($p<0.01$). The cows that calved during P_5 took maximum days to attain peak yield (47.50±3.02 days), cows in P_1 took least time (40.81±2.02 days). The observed significant variations over the period of calving might be attributed to the differences in genetic makeup of the progenies, management and feeding strategies in different periods. The non-significant effect of period of calving found on FDP, FCI and FLPY suggested that the animals were well adapted to the differences in year of calving and this might enable animals to show their maximum genetic potential for the respective trait irrespective of the period of calving.

Conclusion

It may be concluded that the performance traits of crossbred dairy cattle on farm were highly influenced by both genetic as well as non-genetic factors. The random effect like sire and fixed effects like genetic group of animals, season of calving and period of calving had significant influence on most of the performance traits in crossbred cattle. Sire had significant influence on most of the performance traits, therefore superior sires can be used effectively for their genetic improvement. Variability in the traits due to season and over the period of calving might be attributed to the differences in management practices followed at the farm. Finally, it may be concluded that satisfactory management and appropriate genetic improvement strategies would result in ameliorating the performance of animals.

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