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RESEARCH ARTICLE

Genetic parameters of first lactation production traits and test day milk records in Hardhenu cattle

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Abstract: This study employed the 486 Hardhenu crossbred cattle, focusing on first production traits and test day milk yields collected from history-pedigree records maintained at the Department of Animal Genetics and Breeding (AGB) at Lala Lajpat Rai University of Veterinary and Animal Sciences (LUVAS) in Hisar, to estimate the genetic parameters of production performance traits. The overall least -squares means for age at first calving (AFC), first lactation milk yield (FLMY), first lactation milk yield at 300 day (FMY300D), first peak yield (FPY), first lactation length (FLL), first dry period (FDP), first service period (FSP), first calving interval (FCI) were 1232.95±11.80 days, 2806.95±60.1 kg, 2595.38±46.99 kg, 11.96±1.84 kg/day, 303.77±3.45 days, 113.02 ±4.28 days, 126.51±3.19 days, 410.12±3.56 days, respectively. The overall least-squares means for different test days milk records were 5.16±0.15, 8.43±0.18, 9.55±0.18, 10.02±0.17, 9.89±0.17, 9.03±0.14, 7.92±0.15, 6.96±0.16, 5.9±0.17 and 4.19±0.11 kg/day for TD_1, TD_2, TD_3, TD_4, TD_5, TD_6, TD_7, TD_8, TD_9 and TD_{10}, respectively. Test day milk yields (TDMY) peaked at 10.02 kg/day during the fourth test day (TD4). Significant effects of period of calving and season of calving on several traits were noted to underscoring their importance in management practices. Heritability estimates for production traits varied, with FLMY showing the highest at 0.27, while test day milk records ranged from 0.04 (TD10) to 0.24 (TD2). Strong genetic correlations were found between FLMY, FLMY-300, TD4 and other traits, although negative correlations with AFC and first dry period (FDP) were observed. For test-day milk records, genetic correlations ranged from 0.11 to 0.78, with the lowest correlation seen between the most distant test days. The phenotypic correlations for test-day yields varied from 0.12 to 0.82. The findings suggest that early test day records (TD4) can effectively predict overall lactation performance, emphasizing the relevance of genetic parameters in developing breeding strategies for enhanced productivity in Hardhenu cattle.

Keywords: Genetic parameters; Heritability; Univariate animal model; Test day milk yield, Hardhenu

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Introduction

Livestock is a vital and fundamental component of the agricultural system in India. About 70% of individuals are employed in the production of animals. In India, there are 53 recognized breeds of cattle (NBAGR, 2023). According to the 20th livestock census cattle constitute about 35.94% of total livestock with 193.46 million cattle. Out of these, 142.07 millions are indigenous cattle while 50.42 million are crossbred cattle. Milk production during 2022-23 and 2023-24 was 230.58 and 239.3 million tonnes respectively, showing an annual growth rate of 5.7%. The per capita availability of milk was around 471 grams/person/day in 2023-24 (BAHS, 2024). According to the 20th Livestock Census, conducted in 2019, the crossbred cattle population in India was 50.42 million, marking a significant increase of 26.9% since the previous census in 2012 (39.73 million). Considering the rising trend of the number of crossbred cattle in India, LUVAS, Hisar, Haryana, developed the Hardhenu crossbred cow strain for commercial use. This is synthetic population of crossbreds having 62.5% exotic inheritance with predominance of Holstein Friesian and 27.5% Sahiwal and 10% Hariana blood developed through selection and interbreeding since 1986 (Verma, 2016).

To meet the rising demand for high quality sustainably produced dairy products, genetic improvement of cattle is an essential tool. For economically significant traits in a population, effective breeding programs are essential for genetic improvement. Breeding strategies are based on genetic criteria like estimation of genetic parameters. The main objective of any breed development program is to bring about genetic improvement through the selection of superior sires and dams. To allow earlier selection decisions, records from single and early test days (TD) have been used (Schaeffer et al. 2000). The test-day milk yield model takes into consideration genetic influences connected to particular animals as well as environmental variation unique to individual test-day milk yields. Estimating how non-genetic factors affect test-day and complete lactation milk outputs is useful for forecasting selection responses and can be applied to further breeding programmes for general advancement and genetic gains in organized farms.

In cattle production, using first parity traits, those expressed during a cow's first lactation, are significant because it provide an early indicator of a young animal's lifetime potential. This information is critical for making informed and timely breeding and culling decisions that drive genetic improvement and farm profitability. The several research workers Nehra (2011), Divya (2012), Kokate et al. (2013), Kumar (2015), Verma (2016), Kokate et al. (2017) and Singh et al. (2019) reported genetic parameters of production traits in various traits in different crossbred cattle in India. The present study was conducted to estimate the genetic parameters of production performance traits and test day milk yield (TDMY) of first lactation in Hardhenu cattle.

Materials and Methods

Source of data

The research dataset includes information from 486 Hardenu cattle meticulously recorded over a span of 21 years (2001-2021). These invaluable data, pertaining to crucial first lactation production and TDMY traits, were sourced from history-pedigree-sheets maintained at Department of Animal Genetics and Breeding (AGB) at Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar. Which is geographically located at 29°102 N latitude and 75°402 E longitude, at an elevation of 215.2 meters above sea level. The region experiences a semi-arid, subtropical climate, influencing the environmental conditions under which the data were recorded.

Traits under study

The first lactation production traits under this study included were age at first calving (AFC), first lactation milk yield (FLMY), first lactation milk yield at 300 day (FMY300D), first peak yield (FPY), first lactation length (FLL), first dry period (FDP), first service period (FSP), first calving interval (FCI) and having 4810 test day records at monthly intervals were collected for first lactation from day 6 onwards and were used as TD1-TD10. Cows with lactation periods shorter than 150 days or yielding less than 500 kg of milk were excluded, as were those flagged as outliers based on abnormal records such as abortion, mastitis, and chronic illnesses.

Statistical analysis

The general linear model was utilized to detect significant non-genetic influences on economic traits, particularly focusing on the period of calving (POC), season of calving (SOC), and age at first calving (AFC) as covariates. Estimations of (co)variance components and heritabilities and Genetic parameters for various traits were computed using a univariate and bivariate animal models. The analysis utilized the average information restricted maximum likelihood (AIREML) algorithm implemented with WOMBAT software (Meyer, 2007). The primary focus was on first lactation production efficiency traits. Each trait underwent a univariate analysis in which variance and (co)variance components were estimated.

Y= Xb + Zu + e

Y is the vector of observations for i^{th} trait; **B** is the vector of observations of unknown i^{th} fixed effect of period of calving (i=1….5), season of calving (1….4) and age group; **U** is a vector of observations of unknown i^{th} random effects; **X and Z** are the incidence matrices pertaining for fixed and random animal effects respectively and e

e is the random error associated with each and every observation and assumed to be normally and independently distributed with mean zero and variance $ó^2$. Genetic and phenotypic correlations were estimated by bivariate analysis.

Results and Discussion

least squares means of first lactation production traits and test day milk yields

The overall least -squares means of age at first calving (AFC), first lactation milk yield (FLMY), first lactation milk yield at 300 day (FMY300D), first peak yield (FPY), first lactation length (FLL), first dry period (FDP), first service period (FSP), first calving interval (FCI) are provided in Table 1 and the overall least-squares means for different test days milk records are shown in Table 2. Perusal of the table showed that the highest monthly test day milk records was observed in TD_4 (10.02±0.17 kg/day) followed by TD_5 (9.89±0.17kg/day) and the lowest in TD_{10} (4.19±0.15 kg/day). These values indicated that the mean yield per test day exhibited the typical lactation curve for dairy cattle with a peak around 50 to 60 days for milk yield. The study reported an overall least-squares mean for AFC valued as 1232.95±11.80 days, aligned with Kumar (2015) and Verma (2016), but differed from estimates reported by Singh et al. (2014). For first FLMY, similarity was found withto the estimates by Kumar et al. (2018), but higher than estimates by Nehra. (2011) and Divya et al. (2014). The mean for FLMY-305 was consistent with Saha et al. (2010) but higher than Kokate et al. (2009) and Divya (2012), with significant effects noted for the fifth period.

In this study, the calving period significantly affected several traits, including FLMY, FLMY-300, FLL, FPY, FDP, FSP, FCI and TDMY at days TD6 and TD7, with a significance level of $p < 0.05$

Table 1: Least-squares means and their standard errors for various production performance traits

Effects	Obs	AFC (days)	FLMY (kg)	FLMY-300 (kg)	FPY (kg)	FLL (days)	FDP (days)	FSP (days)	FCI (days)
OVERALL MEAN (μ)	486	1232.95±11.8	2806.95±60.1	2595.38±46.99	11.96±1.84	303.77±3.45	113.02±4.28	126.51±3.19	410.12±3.56
Period of calving									
2002-2005(P1)	102	1219.26±26	1863.75^{a} ±156.44	1762.24^{a} ±127.01	9.4^{a} ±4.02	280.21^{ab} ±11.26	111.83^{ab} ±10.82	113.66^{a} ±10.87	402.64^{a} ±11.19
2006 -2009(P2)	99	1190.03±25.17	2279.6^{a} ±151.06	2121.4^{a} ±122.58	9.84^{ab} ±3.89	282.34^{a} ±10.85	122.64^{ab} ±10.46	118.9^{a} ±10.47	403.97^{a} ±10.78
2010-2013(P3)	80	1283.95±27.46	2755.39^{b} ±165.85	2473.73^{b} ±134.74	10.78^{b} ±4.25	327.49^{c} ±11.98	90.83^{a} ±11.47	132.71^{ab} ±11.57	417.7^{b} ±11.89
2014-2017(P4)	86	1204.17±26.94	3525.83^{c} ±162.48	3224.88^{c} ±131.98	13.23^{c} ±4.17	326.38^{c} ±11.73	82.09^{a} ±11.24	115.64^{a} ±11.32	402.35^{a} ±11.64
2018-2022(P5)	102	1267.33±29.96	3610.19^{c} ±181.86	3394.65^{c} ±147.89	16.55^{d} ±4.63	280.21^{ab} ±11.26	111.83^{ab} ±10.82	113.66^{a} ±10.87	402.64^{a} ±11.19
Season of calving									
Summer (Apr-Jun)	142	1215.84±16.37	2813.66±92.85	2554.65±74.51	11.96±2.54	311.03±6.29	119.06±6.49	138.72^{b} ±6.01	418.89^{b} ±6.3
Rainy (Jul-Sept.)	113	1212.2±17.54	2739.89±100.81	2553.16±81.12	11.97±2.72	305.22±6.93	113.27±7.03	124.45^{b} ±6.64	410.16^{b} ±6.93
Autumn (Oct-Nov)	75	1280.68±20.4	2846.32±119.86	2682.3±96.88	11.94±3.16	292.37±8.44	100.56±8.32	106.95^{a} ±8.11	395.44^{a} ±8.4
Winter (Dec-Mar.)	156	1223.08±15.88	2827.94±89.47	2591.42±71.69	11.96±2.47	306.46±6.01	119.2±6.26	135.93^{b} ±5.73	416.01^{b} ±6.03

Age at first calving (AFC), first lactation milk yield (FLMY), first lactation milk yield at 300 day (FMY300D), first peak yield (FPY), first lactation length (FLL), first dry period (FDP), first service period (FSP) and first calving interval (FCI). Means superscripted with different letters with in a column differed significantly

Table 2: Least-squares means with standard errors for various test day milk records (kg/day)

Effect	Obs.	TD_1	TD_2	TD_3	TD_4	TD_5	TD_6	TD_7	TD_8	TD_9	TD10
Overall Mean	486	5.16±0.15	8.43±0.18	9.55±0.18	10.02±0.17	9.89±0.17	9.03±0.14	7.92±0.15	6.96±0.16	5.9±0.17	4.19±0.15
Period of calving											
2002-2005(P1)	102	4.45±0.36	6.19±0.43	7.04±0.4	8.03±0.37	8.23±0.42	6.05^{a}±0.43	4.94^{a}±0.42	4.37±0.45	3.54±0.48	2.46±0.5
2006 -2009(P2)	99	4.66±0.34	6.92±0.41	8.12±0.38	9.06±0.36	9.02±0.41	7.46^{a}±0.41	5.79^{a}±0.41	5.42±0.43	4.38±0.46	2.74±0.48
2010-2013(P3)	80	4.97±0.38	7.56±0.45	8.8±0.42	9.42±0.39	9.59±0.45	8.96^{b}±0.45	8.46^{b}±0.45	7.32±0.48	6.65±0.51	4.92±0.53
2014-2017(P4)	86	4.93±0.37	8.92±0.44	10.12±0.41	11.01±0.38	10.51±0.44	10.99^{c}±0.44	9.81^{c}±0.44	8.74±0.47	7.28±0.5	5.34±0.52
2018-2022(P5)	119	6.78±0.41	12.56±0.49	13.68±0.46	12.59±0.42	12.08±0.49	11.7^{d}±0.5	10.6^{d}±0.49	8.92±0.52	7.66±0.56	5.48±0.59
Season of calving											
Summer (Apr-Jun)	142	5.33^{b}±0.22	8.57^{b}±0.26	9.79±0.25	10.17±0.23	10.22±0.25	9.37±0.24	8.6^{b}1±0.24	7.21±0.26	5.93±0.28	3.97±0.28
Rainy (Jul-Sept.)	113	5.37^{b}±0.23	8.53^{b}±0.28	9.43±0.27	10.01±0.25	9.81±0.27	8.72±0.26	7.7^{a}±0.27	6.75±0.29	5.81±0.3	4.08±0.31
Autumn (Oct-Nov)	75	4.96^{a}±0.28	8.09^{a}±0.33	9.38±0.31	9.97±0.29	9.6±0.32	8.92±0.32	7.86^{a}±0.32	6.9±0.34	5.89±0.36	3.87±0.37
Winter (Dec-Mar.)	156	5.47^{b}±0.21	8.54^{b}±0.25	9.61±0.24	9.94±0.22	9.92±0.24	9.13±0.23	7.82^{a}±0.24	6.96±0.25	5.99±0.27	4.82±0.26

Test day (TD); Means superscripted with different letters with in a column differed significantly

Table 3. Estimates of heritability (diagonal), genetic correlation (below diagonal) and phenotypic correlation (above diagonal) among various production performance traits

Trait	FLMY	FLMY-300	FLL	FPY	AFC	FSP	FCI	FDP
FLMY	0.27± 0.03	0.92±0.01	0.72±0.06	0.59±0.07	-0.01±0.11	0.32±0.09	0.33±0.09	-0.24±0.12
FLMY-300	0.94± 0.02	0.22± 0.02	0.55±0.07	0.54±0.08	0.16±0.11	0.18±0.1	0.20±0.1	-0.23±0.12
FLL	0.67± 0.10	0.58±0.14	0.20± 0.09	0.34±0.09	0.13±0.11	0.52±0.08	0.50±0.08	-0.32±0.13
FPY	0.84± 0.06	0.81±0.07	0.3±0.17	0.24± 0.05	0.05±0.11	0.08±0.11	0.13±0.11	-0.21±0.12
AFC	-0.26±0.62	-0.18±0.17	-0.11±0.19	-0.13±0.16	0.16±0.04	0.10±0.11	0.05±0.11	0.02±0.11
FSP	0.30± 0.20	0.3±0.20	0.42±0.20	0.07±0.21	-0.32±0.20	0.20± 0.08	0.86±0.03	0.44±0.08
FCI	0.42± 0.16	0.36±0.18	0.5±0.16	0.26±0.17	-0.03±0.18	0.82±0.08	0.21± 0.02	0.38±0.09
FDP	-0.28± 0.17	-0.15±0.18	-0.55±0.19	-0.03±0.17	0.06±0.17	0.32±0.2	0.08±0.19	0.12±0.03

Table 4. Estimates of heritability (diagonal), genetic correlation (below diagonal) and phenotypic correlation (above diagonal) amongst test day milk records

Traits	TD_1	TD_2	TD_3	TD_4	TD_5	TD_6	TD_7	TD_8	TD_9	TD_{10}
TD_1	0.21±0.09	0.64±0.13	0.40±0.18	0.40±0.17	0.35±0.20	0.18±0.22	0.16±0.22	0.19±0.22	0.20±0.20	0.23±0.21
TD_2	0.42±0.06	0.24±0.06	0.82±0.15	0.43±0.20	0.43±0.19	0.24±0.21	0.26±0.23	0.22±0.23	0.29±0.20	0.34±0.21
TD_3	0.26±0.06	0.65±0.05	0.16±0.10	0.65±0.21	0.45±0.20	0.45±0.19	0.26±0.23	0.33±0.22	0.49±0.22	0.53±0.24
TD_4	0.27±0.06	0.40±0.05	0.78±0.05	0.23±0.12	0.67±0.17	0.40±0.22	0.16±0.27	0.50±0.23	0.41±0.21	0.27±0.25
TD_5	0.22±0.06	0.37±0.06	0.47±0.06	0.53±0.05	0.19±0.04	0.70±0.14	0.62±0.17	0.74±0.15	0.16±0.23	0.25±0.24
TD_6	0.27±0.06	0.25±0.06	0.40±0.06	0.35±0.07	0.61±0.05	0.14±0.13	0.74±0.12	0.64±0.16	0.38±0.23	0.41±0.25
TD_7	0.19±0.07	0.18±0.07	0.35±0.06	0.30±0.07	0.53±0.06	0.69±0.05	0.11±0.01	0.71±0.13	0.23±0.22	0.12±0.09
TD_8	0.26±0.07	0.18±0.07	0.34±0.07	0.27±0.07	0.48±0.06	0.56±0.06	0.47±0.06	0.13±0.04	0.55±.20	0.43±0.21
TD_9	0.27±0.07	0.15±0.07	0.22±0.07	0.27±0.07	0.29±0.07	0.23±0.07	0.44±0.07	0.55±0.06	0.11±0.24	0.56±0.11
TD_{10}	0.11±0.08	0.16±0.07	0.17±0.08	0.27±0.07	0.21±0.08	0.21±0.08	0.30±0.07	0.39±0.07	0.49±0.07	0.04±0.21

Table 5. Estimates of genetic correlations between various production performance and test day milk records

Trait	FLMY	FLMY-300	FLL	FPY	AFC	FSP	FCI	FDP
TD_1	0.43±0.06	0.24±0.11	0.20±0.10	0.26±0.1	-0.06±0.12	0.10±0.11	0.15±0.10	-0.11±0.12
TD_2	0.50±0.05	0.34±0.10	0.22±0.10	0.54±0.08	0.03±0.11	0.10±0.11	0.12±0.11	-0.02±0.11
TD_3	0.53±0.05	0.39±0.09	0.22±0.10	0.61±0.07	-0.01±0.11	0.10±0.11	0.12±0.11	-0.04±0.12
TD_4	0.59±0.05	0.44±0.09	0.27±0.10	0.56±0.07	0.01±0.11	0.06±0.11	0.08±0.11	-0.10±0.12
TD_5	0.48±0.05	0.40±0.09	0.35±0.09	0.57±0.07	0.05±0.11	0.11±0.11	0.12±0.11	-0.21±0.12
TD_6	0.40±0.06	0.47±0.08	0.38±0.09	0.52±0.08	-0.03±0.11	0.09±0.11	0.11±0.11	-0.25±0.13
TD_7	0.42±0.06	0.35±0.08	0.46±0.08	0.48±0.08	0.03±0.11	0.13±0.11	0.16±0.10	-0.27±0.13
TD_8	0.49±0.05	0.43±0.08	0.54±0.08	0.40±0.09	0.01±0.11	0.24±0.10	0.25±0.10	-0.24±0.12
TD_9	0.45±0.06	0.48±0.08	0.54±0.08	0.33±0.09	0.08±0.11	0.23±0.10	0.27±0.10	-0.26±0.13
TD_{10}	0.27±0.06	0.47±0.08	0.59±0.07	0.30±0.1	0.04±0.11	0.33±0.09	0.36±0.09	-0.20±0.12

as depicted in Table 1. However, it had no significant impact on AFC or other TDMY. The season of calving also significantly influenced service period, calving interval, and various test records (TD1, TD2, TD5, TD6 and TD7) with $p < 0.05$. However, it did not significantly affect FLMY, FLMY-300, FLL, FPY, AFC or FDP. Furthermore, AFC as a covariant was found to have a non-significant effect on FLMY, FLMY-300, FLL, FPY, FDP, FSP, FCI and all total daily milk yields in Hardhenu cattle. Overall, the study highlights the importance of period of calving and season of calving in influencing key reproduction and production traits in Hardenu cattle, suggesting that management practices and environmental factors play crucial roles.

Heritability and Genetic parameters estimates of production performance traits and test day milk records

The heritability and genetic parameters estimates for the various production performance traits namely FLMY, FLMY-300, FLL, FPY, AFC, FSP, FCI and FDP are depicted in Table 3. Heritability estimates were found to ranged from low to high, from 0.12±0.03 (FDP) to 0.27±0.03 (FLMY), for a variety of production performance traits. The heritability and genetic parameters estimates for test day milk record presented in Table 5 ranged from 0.04±0.21 (TD_{10}) to 0.24± 0.06 (TD_2). The heritability for various test day milk records from test day 1 to 10 has been shown in Table 4 diagonally along with genetic correlation below the diagonal line and phenotypic correlation above the diagonal line. High heritability for FLMY, FLMY-300, and FPY corresponded with previous findings by Nehra (2011). Similar values for FLMY-300 were noted by Kokate (2009), while Lodhi et al. (2016) reported lower estimates for FLMY. The heritability of FLL matched Kumar et al. (2014), though Kokati et al. (2017) found lower values. FPY contrasted with lower figures from Lakshmi et al. (2009). For AFC, moderate heritability was corroborated by Singh et al. (2014), while Divya et al. (2012) found lower estimates. FSP exhibited low heritability (0.20± 0.08), with varied estimates from Divya et al. (2014) and Chaudhari et al. (2013). The calving interval was similar to Saha et al. (2010), whereas Divya et al. (2012) reported lower values. The estimate for FDP, differing from moderate to high estimates by Kumar et al. (2014). These estimates of heritability were in consonance with those reported by Druet et al. (2003). However, lower to moderate estimates were reported by Dongre et al. (2011) and Munde et al. (2015) in different test day monthly records. Kumar (2015) reported heritability estimates for various test day milk record ranged from 0.04 (TD_{10}) to 0.26 (TD_2) in Frieswal cattle.

The study on genetic and phenotypic correlations among production performance traits indicated that first lactation milk yield (FLMY) and FLMY-300 demonstrated strong genetic correlations with all assessed traits, except for notable negative correlations with age at first calving (AFC) and first dry period (FDP) (Table 3). Specifically, the phenotypic correlations for FLMY ranged from -0.24 (with FDP) to 0.92 (with FLMY-305),

Table 6. Estimates of phenotypic correlations among various production performance and test day milk records

Trait	FLMY	FLMY-300	FLL	FPY	AFC	FSP	FCI	FDP
TD_1	0.32±0.18	0.14±0.11	0.20±0.10	0.26±0.10	-0.06±0.12	0.1±0.11	0.15±0.10	-0.11±0.12
TD_2	0.57±0.17	0.24±0.10	0.22±0.10	0.54±0.08	0.03±0.11	0.1±0.11	0.12±0.11	-0.02±0.11
TD_3	0.62±0.18	0.41±0.09	0.22±0.10	0.61±0.07	-0.01±0.11	0.1±0.11	0.12±0.11	-0.04±0.12
TD_4	0.67±0.15	0.46±0.09	0.27±0.10	0.56±0.07	0.01±0.11	0.06±0.11	0.08±0.11	-0.10±0.12
TD_5	0.57±0.18	0.42±0.09	0.35±0.09	0.57±0.07	0.02±0.11	0.11±0.11	0.12±0.11	-0.21±0.12
TD_6	0.32±0.20	0.47±0.08	0.38±0.09	0.52±0.08	-0.03±0.11	0.09±0.11	0.11±0.11	-0.25±0.13
TD_7	0.37±0.21	0.54±0.08	0.46±0.08	0.48±0.08	0.03±0.11	0.13±0.11	0.16±0.10	-0.27±0.13
TD_8	0.46±0.15	0.53±0.08	0.54±0.08	0.40±0.09	0.01±0.11	0.24±0.10	0.25±0.10	-0.24±0.12
TD_9	0.50±0.14	0.48±0.08	0.54±0.08	0.33±0.09	0.08±0.11	0.23±0.10	0.27±0.10	-0.26±0.13
TD_{10}	0.45±0.13	0.47±0.08	0.59±0.07	0.3±0.10	0.04±0.11	0.33±0.09	0.36±0.09	-0.2±0.12

while FLMY-300 showed similar patterns, reflecting a strong association with most traits. The genetic correlations for first lactation length (FLL) and peak yield (FPY) were moderate to high, ranged from 0.30 to 0.67 for FPY and from 0.07 to 0.84 for FLL, though both traits exhibited low to negative correlations with FDP and AFC. These results were consistent with previous researchers, such as studies by Lakshmi et al. (2009) and Singh et al. (2011), which highlighted significant genetic and phenotypic correlations between lactation milk yield and FLMY-305 in crossbred cattle. Conversely, Machado et al. (2000) reported moderate genetic correlations between FLMY and AFC, while Divya (2012) found low negative correlations. Variability in these estimates may arise from differences in genetic backgrounds and management practices across studies. Additionally, Patond and Bhoite (2014) and Verma et al. (2016) observed high genetic correlations between lactation milk yield and peak yield (PY), whereas other studies, such as Lakshmi et al. (2009), reported low to moderate correlations.

For test-day milk records, genetic correlations ranged from 0.11 to 0.78, with the lowest correlation seen between the most distant test days (Table 4). The phenotypic correlations for test-day yields varied from 0.12 to 0.82, suggesting that adjacent test-day records were more strongly correlated, which aligned with findings from Pander et al. (1992) and Kokate et al. (2013). These correlations imply the possibility of predicting overall lactation performance based on early test-day records, as supported by Kumar (2015) and Machado et al. (2000).

Moreover, the analysis revealed generally positive genetic correlations between test-day milk records and overall production traits, varied from 0.03 to 0.61 presented in table 5 and 6. However, negative associations were found between AFC and certain test days, along with negative correlations of all test-day yields with FDP. The analysis revealed primarily positive genetic correlations between test-day milk records and overall production traits, with correlation values ranged from 0.03 to 0.61, as detailed in Tables 5 and 6. This finding indicated that enhancements in test-day milk yields were generally associated with improvements in overall production traits. Conversely, the analysis identified negative associations between age at first calving (AFC) and certain test days, suggesting that a later AFC may correspond to reduced performance on those specific days. Additionally, negative correlations were observed between all test-day yields and first-day production (FDP), indicating that higher test-day yields could be linked to lower performance on the first day of production. These results highlighted the intricate relationships among these traits and point to potential areas for further research in breeding and management strategies. This highlighted the complex interplay between these traits, indicating that certain factors like AFC may negatively impact overall productivity.

Conclusion

The findings emphasized the significance of understanding both genetic and phenotypic correlations among traits in livestock production. The findings suggested that early test day records particularly at TD4 can effectively predict overall lactation performance, emphasized the relevance of genetic parameters in developing breeding strategies for enhanced productivity in Hardhenu cattle. Such insights could act as an informative base to selection strategies aimed at enhancing productivity and efficiency in breeding programs, particularly by utilizing early test-day records to forecast later lactation performance.

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