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Heritabilities, genetic, and phenotypic correlations among first lactation milk yield and various reproductive traits in hardhenu cattle

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Abstract
This study aims to estimate heritabilities, genetic correlations, and phenotypic correlations among first lactation milk yield and various reproductive traits in Hardhenu cattle. Records pertaining to first latation of 341 cows, the progeny of 51 sires; calved during the year 1995-2018, maintained at Cattle breeding farm, LUVAS, Hisar are analysed by using mixed model of Harvey. The reproductive traits considered include service period, dry period, first calving interval, number of inseminations for first successful conception, and number of inseminations for second successful conception. FLMY had a moderate heritability while SP, FCI, NIF and NIS had high heritabilities.
The results provide insight into the genetic and phenotypic relationships between milk production and reproductive performance, which are crucial for informed breeding strategies.

Keywords: Hardhenu cattle, reproduction traits, heritability, genetic and phenotypic correlation and first lactation milk yield

Introduction
Reproductive efficiency and milk production are pivotal traits in dairy cattle breeding programs. The balance between these traits determines the overall productivity and economic viability of dairy operations. In this study, we focus on Hardhenu cattle, a breed known for its adaptability and resilience. Understanding the genetic and phenotypic relationships among milk yield and reproductive traits is essential for designing effective selection programs aimed at improving both productivity and reproductive performance.

Materials and Methods
Data for this study were collected from a population of Hardhenu cattle. The traits analyzed include first lactation milk yield (FLMY), service period (SP), dry period (DP), first calving interval (FCI), number of inseminations for first successful conception (NIF), and number of inseminations for second successful conception (NIS).
Statistical Analysis: The heritabilities, genetic correlations, and phenotypic correlations were estimated using mixed model methodology. This research investigates heritability, genetic and phenotypic correlations between various traits in Hardhenu cattle by using relevant data of 341 animals collected from history cum pedigree sheets over a period of 24 years (1995-2018). Data were collected pertaining to the traits under study. Genetic and Phenotypic correlations were estimated and the estimates were provided with their corresponding standard errors to indicate the precision of the estimates by using least squares maximum likelihood computer program of Harvey (1990) [3] using Henderson's Method III (Henderson, 1973) [4]. Non genetic effects of season and period were also taken into due consideration. Entire study was divided into six periods having four years each and every year was further divided into four seasons. The following mixed mathematical model were used to find the results.

$$Y_{ijkl} = \mu \pm S_i \pm h_j + c_k + b_1(A_{ijkl} - \bar{A}) + b_2(A_{ijkl} - \bar{A})^2 + e_{ijkl}$$

Where; Y_{ijkl} = i^{th} record of individual pertaining to i^{th} sire calved in j^{th} period and k^{th} season, μ = is the overall population mean, S_i = is the random effect of i^{th} sire, h_j = is the fixed effect of j^{th} period of calving, c_k = is the fixed effect of k^{th} season of calving, b_1&b_2 = are linear and quadratic partial regression coefficients of age at first calving on trait(s), respectively, A_{ijki} = is the age at first calving, $\bar{A}$ = is the mean for age at first calving, e_{ijkl} = is the random error associated with each and every observation and assumed to be normally and independently distributed with mean zero and variance σ^2_e.

Results

Table 1: Heritabilities (diagonal), genetic (below the diagonal) and phenotypic correlations (above the diagonal) among various performance traits in Hardhenu cattle

	FMY	SP	DP	CI	FNI	SNI
FMY	0.25 ±0.17	0.36** ±0.05	-0.32** ±0.05	0.35** ±0.05	-0.03 ±0.05	0.23** ±0.05
SP	0.39 ±0.34	0.54 ±0.20	0.56** ±0.05	0.93** ±0.02	-0.07 ±0.05	0.69** ±0.04
DP	-0.06 ±0.64	0.70 ±0.29	0.17 ±0.16	0.58** ±0.04	0.04 ±0.05	0.38** ±0.05
CI	0.57 ±0.34	0.96 ±0.03	0.72 ±0.30	0.42 ±0.19	-0.02 ±0.05	0.66** ±0.04
FNI	-0.03 ±0.38	0.35 ±0.28	0.36 ±0.44	0.26 ±0.31	0.62 ±0.21	0.04 ±0.05
SNI	0.54 ±0.37	0.94 ±0.09	0.50 ±0.40	0.89 ±0.13	0.08 ±0.31	0.42 ±0.19

** Significant at p more then 0.01

Heritability Estimates

Heritability is a measure of the proportion of total variation in a trait that is attributable to genetic differences among individuals. The heritability estimates for the traits studied are as follows:

First lactation milk yield (FLMY): The heritability of FLMY was found to be 0.25, indicating that 25% of the variation in milk yield can be attributed to genetic factors. This moderate heritability suggests that there is potential for genetic improvement through selective breeding, although environmental factors also play a significant role. Das *et al.* (2016) [1] and Manjeet *et al*. (2017) also reported moderate heritability in Karan Faries and Hardhenu cattle for FLMY

Service period (SP): The heritability of SP was estimated high, showing that high variation in the service period is due to additive genetic factors in the current herd. This high heritability indicates a strong genetic influence on the duration between calving and successful conception. It may be due to a quality rearing and minimizing the environmental effects due to better management. Verma *et al.* (2017) reported moderate heritability in Hardhenu cattle.

Dry period (DP): The heritability of DP was found to be low, suggesting that low variation in dry period length is additive genetically determined. This low heritability implies that environmental management practices are more critical in influencing the dry period. Verma *et al*. (2016) [6] found moderate heritability in Hardhenu.

First calving interval (FCI): The heritability of FCI was estimated high, indicating this moderate heritability suggests that genetic selection can be effective in reducing the calving interval.

Number of inseminations for first successful conception (NIF): The heritability of NIF was high. This high heritability points to a significant potential for genetic improvement.

Number of inseminations for second successful conception (NIS): The heritability of NIS was high, similar to that of FCI, indicating significant potential genetic influence on the number of inseminations required for second successful conception.

Genetic Correlations

Genetic correlations quantify the degree to which genetic factors affect two traits simultaneously. Positive genetic correlations indicate that selection for one trait will result in a correlated increase in the other trait, whereas negative genetic correlations indicate that selection for one trait will result in a correlated decrease in the other trait.

FLMY and SP

The genetic correlation between FLMY and SP was 0.39, suggesting a moderate positive relationship. This indicates that cows with higher milk yield tend to have longer service periods.

FLMY and DP

The genetic correlation between FLMY and DP was -0.06, indicating a very weak negative relationship. This suggests that the genetic factors influencing milk yield have a minimal impact on the dry period. Goshu *et al.* (2014) [1] in HF, Narwaria *et al.* (2015) [5] in Sahiwal and Verma *et al.* (2016) [6] in Hardhenu also reported negative correlations between FLMY and DP

FLMY and FCI

The genetic correlation between FLMY and FCI was 0.57, showing a strong positive relationship. This implies that selecting for higher milk yield could result in longer intervals between calvings.

FLMY and NIF

The genetic correlation between FLMY and NIF was -0.03, indicating a very weak negative relationship. This suggests that milk yield and the number of inseminations for first successful conception are nearly independent genetically.

FLMY and NIS

The genetic correlation between FLMY and NIS was 0.54, indicating a strong positive relationship. This suggests that higher milk yield is associated with a greater number of inseminations for the second successful conception.

SP and DP

The genetic correlation between SP and DP was 0.70, showing a strong positive relationship. This implies that the same genetic factors that extend the service period also tend to lengthen the dry period.

SP and FCI
The genetic correlation between SP and FCI was extremely high at 0.96, indicating that these two traits are almost entirely influenced by the same genetic factors.

SP and NIF
The genetic correlation between SP and NIF was 0.35, suggesting a moderate positive relationship. This implies that cows with longer service periods tend to require more inseminations for first successful conception.

SP and NIS
The genetic correlation between SP and NIS was 0.94, indicating a very strong positive relationship. This suggests that longer service periods are associated with more inseminations for second successful conception.

DP and FCI
The genetic correlation between DP and FCI was 0.72, indicating a strong positive relationship. This suggests that longer dry periods are genetically associated with longer calving intervals.

DP and NIF
The genetic correlation between DP and NIF was 0.36, suggesting a moderate positive relationship. This implies that cows with longer dry periods tend to require more inseminations for first successful conception.

DP and NIS
The genetic correlation between DP and NIS was 0.50, indicating a moderate to strong positive relationship. This suggests that longer dry periods are associated with more inseminations for second successful conception.

FCI and NIF
The genetic correlation between FCI and NIF was 0.26, indicating a weak positive relationship. This suggests that cows with longer calving intervals may require more inseminations for first successful conception.

FCI and NIS
The genetic correlation between FCI and NIS was 0.89, indicating a very strong positive relationship. This suggests that cows with longer calving intervals also require more inseminations for second successful conception.

NIF and NIS
The genetic correlation between NIF and NIS was 0.08, indicating a very weak positive relationship. This suggests that the number of inseminations required for first and second successful conception are nearly independent genetically.

Phenotypic correlations
Phenotypic correlations measure the degree to which two traits vary together in a population, considering both genetic and environmental factors. These correlations provide insight into how selection for one trait may impact other traits due to the combined influence of genetics and environment. The phenotypic correlations among first lactation milk yield (FLMY), service period (SP), dry period (DP), first calving interval (FCI), number of inseminations for first successful conception (NIF), and number of inseminations for second successful conception (NIS) are described as follows:

FLMY and SP
The phenotypic correlation between FLMY and SP was 0.36, indicating a moderate positive relationship. This suggests that cows with higher milk yield tend to have longer service periods. This could be due to the increased metabolic demands of higher milk production potentially impacting reproductive performance.

FLMY and DP
The phenotypic correlation between FLMY and DP was -0.32, indicating a moderate negative relationship. This suggests that cows with higher milk yield tend to have shorter dry periods. This could reflect management practices where high-yielding cows are dried off earlier to allow for a longer lactation period in the subsequent cycle.

FLMY and FCI
The phenotypic correlation between FLMY and FCI was 0.35, showing a moderate positive relationship. This indicates that cows with higher milk yield tend to have longer intervals between calving. The increased energy demands of high milk production may delay the return to estrus and successful conception.

FLMY and NIF
The phenotypic correlation between FLMY and NIF was -0.03, suggesting a very weak negative relationship. This indicates that the number of inseminations required for first successful conception is almost independent of the milk yield phenotypically.

FLMY and NIS
The phenotypic correlation between FLMY and NIS was 0.23, indicating a weak positive relationship. This suggests that cows with higher milk yield may require more inseminations for the second successful conception, potentially due to the increased reproductive challenges associated with high milk production.

SP and DP
The phenotypic correlation between SP and DP was 0.56, showing a strong positive relationship. This indicates that cows with longer service periods tend to have longer dry periods, reflecting a consistent delay in reproductive events.

SP and FCI
The phenotypic correlation between SP and FCI was 0.93, indicating a very strong positive relationship. This suggests that cows with longer service periods have significantly longer calving intervals, as both traits are measures of reproductive efficiency and are closely linked.

SP and NIF
The phenotypic correlation between SP and NIF was -0.07, indicating a weak negative relationship. This suggests that cows with longer service periods may require slightly fewer inseminations for first successful conception, though this relationship is weak.

SP and NIS
The phenotypic correlation between SP and NIS was 0.69, showing a strong positive relationship. This suggests that cows with longer service periods require more inseminations for second successful conception, indicating a consistent delay in achieving successful conception.

DP and FCI
The phenotypic correlation between DP and FCI was 0.58, indicating a strong positive relationship. This suggests that cows with longer dry periods have longer calving intervals, reflecting an overall delay in reproductive processes.

DP and NIF
The phenotypic correlation between DP and NIF was 0.04, suggesting a very weak positive relationship. This indicates that the number of inseminations for first successful conception is almost independent of the dry period phenotypically.

DP and NIS
The phenotypic correlation between DP and NIS was 0.38, indicating a moderate positive relationship. This suggests that cows with longer dry periods may require more inseminations for second successful conception, reflecting an overall delay in reproductive efficiency.

FCI and NIF
The phenotypic correlation between FCI and NIF was -0.02, indicating a very weak negative relationship. This suggests that the number of inseminations for first successful conception is almost independent of the first calving interval phenotypically.

FCI and NIS
The phenotypic correlation between FCI and NIS was 0.66, indicating a strong positive relationship. This suggests that cows with longer first calving intervals require more inseminations for second successful conception, indicating a consistent delay in reproductive events.

NIF and NIS
The phenotypic correlation between NIF and NIS was 0.04, indicating a very weak positive relationship. This suggests that the number of inseminations required for first and second successful conception are almost independent phenotypically.

Discussion
FLMY had a moderate heritability (0.25), indicating potential for genetic improvement through selection. SP had a high heritability (0.54), suggesting strong genetic influence. DP showed low heritability (0.17), implying significant environmental influence. FCI had moderate heritability (0.42), indicating genetic selection can reduce calving interval. NIF had high heritability (0.62), showing significant potential for genetic improvement. NIS had moderate heritability (0.42), indicating genetic influence.
Positive genetic correlations between FLMY and reproductive traits (SP, FCI, NIS) suggest selection for higher milk yield may extend reproductive intervals. SP showed strong genetic correlations with DP (0.70), FCI (0.96), and NIS (0.94), indicating shared genetic factors affecting these traits. DP had positive genetic correlations with FCI (0.72) and NIS (0.50), suggesting longer dry periods are associated with longer calving intervals and more inseminations.
FLMY showed moderate positive phenotypic correlations with SP (0.36) and FCI (0.35), indicating higher milk yield is associated with longer service periods and calving intervals. Negative phenotypic correlation between FLMY and DP (-0.32) suggests higher milk yield is associated with shorter dry periods. SP had strong positive phenotypic correlations with DP (0.56) and FCI (0.93), indicating consistent delays in reproductive events.

Summary
This study investigated the heritabilities, genetic correlations, and phenotypic correlations among first lactation milk yield (FLMY) and various reproductive traits in Hardhenu cattle, including service period (SP), dry period (DP), first calving interval (FCI), number of inseminations for first successful conception (NIF), and number of inseminations for second successful conception (NIS) and found them varying from low to high. The findings provide important insights into the genetic and phenotypic relationships between milk production and reproductive performance in this breed.

Conclusion
The study provides comprehensive insights into the genetic and phenotypic relationships among first lactation milk yield and reproductive traits in Hardhenu cattle. The moderate heritability of milk yield and the strong heritability of certain reproductive traits indicate potential for genetic improvement through selective breeding. The genetic and phenotypic correlations highlight the complex interplay between milk production and reproductive performance which may be used for developing selection index.

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