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Enhancing production through optimized sire evaluation methods in Tharparkar cattle: Insights from arid regions of India

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Abstract
First lactation records of 91 Tharparkar cows, offspring of 10 sires, were analyzed using four sire evaluation methods: Simple Daughter's Average (D), Contemporary Comparison (CC), Least-Squares Method (LSM), and Best Linear Unbiased Prediction (BLUP). The study estimated variance components and breeding values for first lactation traits: milk yield, lactation length, and dry period. Results showed varying average breeding values among methods for milk yield (1849.10 kg to 1860.03 kg), lactation length (285.82 days to 291.33 days), and dry period (146.45 days to 156.07 days). LSM demonstrated the lowest error variance and highest coefficient of determination, indicating its superior efficiency in sire evaluation compared to BLUP. High rank correlation between LSM and BLUP further supported their similarity in sire ranking.

Keywords: Tharparkar cattle, sire evaluation, breeding values, LSM, BLUP

Introduction

Domestic cattle are known for their robust adaptation to diverse climates and environments where they are bred. Particularly notable are their heat tolerance, disease resistance, and ability to thrive under extreme weather conditions. The Tharparkar breed, specifically, has evolved to withstand harsh environments characterized by severe weather fluctuations, storms, scarcity of food, and dry vegetation. In arid and semi-arid regions, Tharparkar cattle play a pivotal role in milk production and are primarily reared in northwestern India.

Effective sire selection is crucial for improving desirable traits in these cattle. Scientists have developed various methods over time for evaluating sires, with notable approaches including the simple daughter's average method (D), contemporary comparison method (CC), least-squares method (LSM), and best linear unbiased prediction (BLUP). These methods aim to assess the breeding value of bulls based on their progeny's performance.

This study focuses on evaluating first lactation production traits of Tharparkar cattle using the aforementioned methods. It examines variance components and calculates breeding values of sires for traits such as first lactation milk yield (FLMY), first lactation length (FLL), and first dry period (FDP). By comparing the effectiveness of D, CC, LSM, and BLUP, the research seeks to determine which method best aids in selecting superior sires for enhancing production traits in Tharparkar cattle.

Materials and Methods

In this study, data from ninety-one Tharparkar dairy cattle in their primary lactation, daughters of ten bulls spanning from 2006 to 2016 and housed at the Livestock Research Station in Beechwal, Bikaner, Rajasthan, were analyzed to assess the breeding values of sires. The study employed four methods for sire evaluation: Simple Daughter's Average Method (D), Contemporary Comparison Method (CC), Least-Squares Method (LSM), and Best Linear Unbiased Prediction (BLUP). To determine the most effective method among these approaches, comparisons were based on error variance, coefficient of determination (R^2), and rank correlations. The method with the lowest error variance typically indicates higher accuracy and efficiency in evaluating sire performance. Below are the specific methodologies and formulas utilized in this study.

The Simple Daughter's Average method (D)- It is a straightforward approach proposed by Edward (1932) [2] for calculating the breeding value of a sire based on the average milk yield of all its daughters. Mathematically, it is represented as:

S=D

Where:
- S, represents the breeding value of the sire.
- D, is the average milk yield of all daughters of the sire

Contemporary Comparison (CC) method- This method calculates the sire index (S) using the formula:

$S = A + (\bar{D}-\bar{C}i) = 2nh^2\backslash 4 + (n-1)\ h^2$

- A = Herd average for the trait being evaluated.
- $\bar{D}$ = Average value (e.g., milk yield) of all daughters of the sire.
- $\bar{C}i$ = Average value of daughters in the contemporary group (those born in the same year and managed under similar conditions).
- n = Number of daughters of the sire.
- h^2 = Heritability of the trait.

This method provides an adjusted breeding value (S) for the sire by comparing its offspring's performance with the herd average and contemporaneous group average, considering the genetic potential ($\bar{D}$) and environmental influences.
Least-Squares Method (LSM): The Least-Squares Method (LSM) calculates the least-square breeding values (LSBV) using the following model:
The model is represented as:

$Yijk = \mu + Si + Aj + eijk$

In this equation:
- YijkY_{ijk}Yijk represents the observed value (e.g., milk yield) for the ith sire, jth contemporary group, and kth individual.
- μ denotes the overall mean of the trait under consideration.
- Si stands for the fixed effect of the ith sire.
- Aj represents all other fixed effects included in previous models
- eijk represents the residual or error term.

The least-squares breeding value (LSBV) for the ith sire is calculated as:

$LSBVi=\mu+ Si$

- LSBVi denotes the least-squares breeding value for the ith sire.
- Si represents the least-squares estimate (effect) of the ith sire.

This method determines the breeding value of a sire by fitting a linear model to the observed data, considering fixed effects such as sire and contemporary group effects, and estimating the genetic merit based on deviations from the overall mean.
Best Linear Unbiased Prediction (BLUP)- It is a method devised by Henderson in 1973 [4] for evaluating sire breeding values.
For judging the effectiveness of various sire evaluation methods following methods were used.
To assess the effectiveness of various sire evaluation methods, relative efficiency is calculated as the percent of error variance of each method relative to the variance of the most efficient method (which has the lowest error variance). The formula for relative efficiency (%) is:
Error variance of most efficient method×100/Error variance of other method
This calculation provides a quantitative measure of how each method performs in terms of accuracy and precision in estimating sire breeding values. Higher relative efficiency indicates that a method has less variability in its estimates, making it more effective for sire evaluation compared to methods with higher error variances.
Coefficient of determination (R2-Value): For calculating the accuracy of sire evaluation method The R2 value of different methods is calculated. The accuracy is related directly to R2 value.
Spearman's rank correlation: $rs= 1 - 6\Sigma di^2 / [n(n^2 - 1)]$ Where, rs= Spearman's rank correlation n = Number of sires under observation di= Difference between the ranking of a sire by the two methods.

Results and Discussion

Table 1: Average and range of sire's breeding values for FDP, FLL and FLMY (Figures in the parenthesis represent the percent higher/lower than the average breeding value.)

Traits	Methods	Average breeding value	No. of sires above average	No. of sires below average	Maximum breeding value	Minimum breeding value	Range of breeding value	Range of % of average breeding value
First Dry Period	$\bar{D}$	156.07	6	4	198 (26.87)	125.3 (19.72)	72.7	46.58%
	CC	146.45	7	3	149.66 (2.19)	134.94 (7.86)	14.72	10.05%
	LSM	153.07	7	3	153.39 (0.21)	151.88 (0.78)	1.51	0.99%
	BLUP	153.19	6	4	156.66 (2.27)	150.06 (2.04)	6.6	4.31%
First Lactation Length	$\bar{D}$	291.28	4	6	341.70 (17.31)	236.10 (18.94)	105.6	36.25%
	CC	285.82	5	5	351.99 (23.15)	210.25 (26.44)	141.74	49.59%
	LSM	290.42	4	6	327.41	270.58	56.83	19.57%

					(12.74)	(6.83)		
	BLUP	291.33	3	7	324.75 (11.47)	266.49 (8.52)	58.26	19.99%
First Lactation Milk Yield	$\bar{D}$	1849.1	5	5	2158 (16.71)	1463 (20.89)	695	37.59%
	CC	1836.17	5	5	2077.60 (13.15)	1227.20 (33.16)	850.4	46.31%
	LSM	1858.65	7	3	1993.66 (7.26)	1651.06 (11.17)	342.6	18.43%
	BLUP	1860.03	6	4	1992.97 (7.20)	1673.45 (9.98)	319.52	17.19%

Table 2: Error variances, relative efficiency and coefficient of determination (%) of sire evaluation methods for First Lactation production Traits (FLMY, FLL, FDP).

Method	Error variances	relative efficiency	Coefficient of determination (%)
First lactation milk yield			
$\bar{D}$	61352.77	14.59	10.96
CC	59532.53	15.04	12.70
LSM	8952.17	100.00	27.49
BLUP	9729.79	92.01	15.74
First Lactation Length			
$\bar{D}$	1316.96	16.60	5.00
CC	1331.67	16.41	18.78
LSM	218.56	100.00	39.67
BLUP	247.04	88.47	25.56
First Dry Period			
$\bar{D}$	456.31	0.26	14.18.
CC	18.27	6.51	21.09
LSM	1.19	100.00	39.33
BLUP	3.06	38.89	28.35

Table 3: Rank correlations among sire breeding value for FLMY, FLL, FDP by different methods.

First lactation milk yield			
Method	CC	LSM	BLUP
$\bar{D}$	0.76	0.87	0.88
CC		0.87	0.79
LSM			0.98
First lactation period			
$\bar{D}$	0.96	0.84	0.88
CC		0.92	0.94
LSM			0.99
First dry period			
$\bar{D}$	0.85	0.66	0.79
CC		0.75	0.75
LSM			0.95

The mean breeding values of sires for first lactation production traits estimated by various methods are presented in Table 1. The average breeding values for first lactation milk yield were 1849.10 kg (D), 1836.17 kg (CC), 1858.65 kg (LSM), and 1859.03 kg (BLUP). Similarly, for first lactation period, the values were 291.28 days (D), 285.82 days (CC), 290.42 days (LSM), and 291.33 days (BLUP). For the first dry period, the values were 156.07 days (D), 146.45 days (CC), 153.07 days (LSM), and 153.19 days (BLUP).

LSM exhibited the smallest error variance across traits (8952.17 for milk yield, 218.56 for lactation length, and 1.19 days for dry period), establishing it as the most effective method, followed closely by BLUP (Table 2). Various researchers, including Gaur and Raheja (1995) [3], Sahana and Gurnani (1999) [8], Mukherjee (2005) [6], Banik and Gandhi (2006) [1], Singh and Singh (2011) [10], Kishore (2012) [5], and Singh (2015) [9], have also supported LSM as the optimal approach.

In terms of efficiency, LSM and BLUP methods demonstrate comparable performance in partitioning variance, as indicated in Table 2. High rank correlations between breeding values derived from LSM and BLUP further validate their similarity (Table 3). Parekh and Singh (1989) [7] also noted a strong correlation between these two methods.

Conclusion

Based on the findings of this study, it can be concluded that the Least-Squares Method (LSM) emerges as the most accurate and efficient approach for evaluating Tharparkar sires for first lactation production traits. This conclusion is supported by LSM consistently exhibiting the smallest error variance across various traits, indicating its superior precision in estimating breeding values.

Additionally, the high rank correlation observed between the Least-Squares Method (LSM) and Best Linear Unbiased Prediction (BLUP) methods suggests that both methods are comparable in terms of efficiency and accuracy for ranking Tharparkar sires based on their genetic potential for first lactation traits. This correlation implies that the rankings of sires derived from LSM are largely consistent with those obtained from BLUP, reinforcing the reliability of both methodologies.

In summary, while LSM is identified as marginally more accurate due to its lower error variance, BLUP remains a robust alternative that also provides reliable evaluations of sire breeding values. Therefore, either LSM or BLUP can be effectively utilized depending on specific needs and preferences in breeding program management for Tharparkar cattle.

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