Comparative study of sire evaluation methods for breeding value estimation in Jersey x Sahiwal crossbred sires under field conditions

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Abstract

This study utilized 4,877 first lactation records of Jersey x Sahiwal crossbred cattle, under field progeny testing programme across 24 mandals in Chittoor district, Andhra Pradesh. Breeding values of sires were estimated using first lactation 305-day milk yield data through three methods: Least Squares Means (LSM), Best Linear Unbiased Prediction (BLUP) and Derivative-Free Restricted Maximum Likelihood (DFREML). Given the variability in the efficiency of these methods, the study aimed to assess their effectiveness in accurately predicting the breeding values of Jersey x Sahiwal sires. The average breeding values for 176 sires were 2249.26 kg (LSM), 2242.87 kg (BLUP) and 2242.87 kg (DFREML). While LSM showed the highest average value, DFREML displayed the largest range between maximum and minimum breeding values (1368.57 kg), indicating its superior ability to differentiate among sires. The methods were compared using critical evaluation parameters, including within-sire variance (error variance), coefficient of determination (%), coefficient of variation (%) and rank correlations. DFREML emerged as the most precise method with the lowest error variance (160,916.26 kg²) and the highest coefficient of determination (66.53%), reflecting its accuracy. Moreover, DFREML showed the smallest CV (26.71%), signifying its stability, while BLUP was the least stable with a CV of 32.80%. High rank correlation between LSM and DFREML indicated that either method could be used to achieve similar sire rankings. However, considering its superior precision, accuracy and stability, DFREML proved to be the most efficient and accurate method, making it the preferred choice for sire evaluation in Jersey x Sahiwal crossbred cattle.

Keywords: Breeding value, Jersey x Sahiwal crossbred cattle, Lactation traits, Sire evaluation methods.

Introduction

Sire evaluation plays a vital role in dairy breed improvement programs, as the genetic contribution of sires far exceeds that of dams in enhancing economically important traits. For this reason, developing effective methodologies for sire evaluation remains a primary goal for animal breeders striving for rapid genetic improvement in desirable traits. Breeding value (BV) is the genetic merit of an individual for a specific trait, estimated based on the performance of its progeny, parents, or relatives (Falconer and Mackay, 1996). Upgradation of local cattle breeds (Zebu) for milk production traits by crossbreeding with Bos taurus cattle breeds like Jersey and HF is practiced in developing and undeveloped countries of Asian and African subcontinent (Boma *et al* 2021; Getahun *et al* 2021; Toor & Kaur, 2023). The crossbreeding between different Bos taurus breeds is also practiced in developed countries for specific milk traits (Bonifácio *et al* 2023). In dairy breeding, sire evaluation involves estimating the breeding value of bulls based on the first lactation 305-days milk yield of their daughters and ranking them accordingly. This process is critical, as the use of genetically superior bulls in artificial insemination programs accelerates genetic progress and improves the overall productivity of dairy herds. Under Indian conditions, conventional sire evaluation methods such as Least Squares Means (LSM), Best Linear Unbiased Prediction (BLUP) and Derivative-Free Restricted Maximum Likelihood (DFREML) have been employed for decades, yet the choice of the most effective approach continues to be an area of active investigation. These methods differ in their statistical approaches: LSM is a fixed-effect model particularly employed for handling unbalanced data that estimates breeding values without considering genetic relationships among individuals (Dongre and Gandhi, 2014). BLUP utilizes a mixed model approach by incorporating both genetic and environmental effects, making it more precise than LSM (Kumar *et al.,* 2018). DFREML is an advanced likelihood-based method that estimates variance components and breeding values more accurately (Lodhi *et al.,* 2016). Due to these variations, comparing their efficiency in field conditions is essential for identifying the most reliable method for sire selection. Hence, the present study was conducted to determine the most reliable and efficient method for evaluating sires in Jersey x Sahiwal crossbred cattle. By identifying the optimal evaluation strategy, this research aims to contribute to more precise selection decisions and drive sustainable genetic improvement in dairy cattle under field conditions.

Materials and Methods

In the present study, first lactation performance records of 4,877 daughters sired by 176 Jersey x Sahiwal crossbred bulls, maintained by selected field farmers under progeny testing programme across 24 mandals of Chittoor district, Andhra Pradesh, over a period of 10 years (2014 to 2023) were utilized for sire evaluation. Sires were evaluated for their breeding values using first lactation 305-days milk yield using three methods: LSM (Least Squares Mean), BLUP (Best Linear Unbiased Prediction) and DFREML (Derivative-Free Restricted Maximum Likelihood). Season and period of calving as fixed effects and sire as random effect were used in all the three methods of sire evaluation. The effectiveness of these three sire evaluation methods was judged using the criteria viz., within sire variance (error variance), coefficient of determination (R^2), coefficient of variation (%) and rank correlations. Sire evaluation method with lowest error variance was considered as the most efficient and appropriate. The most accurate method showed the highest coefficient of determination (R^2–value). The coefficient of variation (%) of first lactation 305-days milk yield from different methods of sire evaluation was estimated for judging the stability of sire evaluation methods. The nearer the CV (%) of adjusted data to CV (%) of unadjusted data of first lactation 305-days milk yield, the more stable was the method. After estimation of breeding value of sires, the sires were given rank as per their genetic merit. Spearman's rank correlations (Steel and Torrie, 1960) between breeding values of sires derived by various methods were also used to judge the effectiveness of different methods.

Results

The average breeding value, distribution of sires above and below the average and the difference of breeding values under three different sire evaluation methods are summarized in Table 1. The average breeding values of Jersey x Sahiwal crossbred sires for the first lactation 305-days milk yield were found to be 2249.26 kg (LSM), 2242.87 kg (BLUP) and 2242.87 kg (DFREML).

The effectiveness of different sire evaluation methods for first lactation 305-days milk yield was compared using key estimates, including error variance, coefficient of determination (%) and coefficient of variation (%), as presented in Table 2.

Spearman's rank correlation was used to assess the relationship between the breeding values of 176 Jersey x Sahiwal sires, as estimated by three different sire evaluation methods for first lactation 305-days milk yield and the results are presented in Table 3.

Table 1: Average breeding values (BV) of sires for first lactation 305-day milk yield by different methods of sire evaluation

Sire evaluation method	Average BV (kg)	No. of sires above ABV	No. of sires below ABV	Maximum BV (kg)	Minimum BV (kg)	Difference of BV (kg)
LSM	2249.26	88	88	2925.64	1607.00	1318.64
BLUP	2242.87	93	83	2463.74	2054.50	409.24
DFREML	2242.87	85	91	3081.07	1712.50	1368.57

LSM- Least squares method; BLUP- Best linear unbiased prediction; DFREML- Dreivative-free restricted maximum likelihood

Table 2: Error variance, Coefficient of determination (R^2-Value) and Coefficient of variation (C.V) of different sire evaluation methods

Sire evaluation method	Error variance (Kg^2)	R^2 value (%)	C.V (%)
LSM	331321.78	48.70	30.02
BLUP	345714.33	54.34	32.80
DFREML	160916.26	64.33	26.71

Table 3: Spearman's rank correlations between different methods of sire evaluation

Sire evaluation method	LSM	BLUP	DFREML
LSM	1.000	0.907*	0.992**
BLUP		1.000	0.882*
DFREML			1.000

*Significant at P≤0.05, ** Significant at P≤0.01

Discussion

Using the LSM method, the average breeding value for first lactation 305-days milk yield was 2249.26 kg. This estimate was higher than those reported by Pandey *et al.* (2013), Dongre and Gandhi (2014), Singh and Singh (2016) and Mallick *et al*. (2018) for different dairy cattle breeds. However, Bajetha *et al.* (2015) in Sahiwal Crossbred cattle reported higher values. The highest breeding value observed was 2925.64 kg, which was 30.07% above the average, while the lowest was 1607.00 kg that was 28.55% below the average, with a difference of 1318.64 kg. Out of 176 sires, an equal proportion (88 sires, 50%) had breeding values above and below the average.

The average breeding value estimated using the BLUP method was 2242.87 kg, exceeding the estimates reported by Pandey *et al.* (2013), Dongre and Gandhi (2014), Singh and Singh (2016) and Mallick *et al*. (2018) across various dairy cattle breeds. In contrast, Bajetha *et al.* (2015) reported higher estimates for Sahiwal Crossbred cattle. Breeding values ranged from 2054.50 kg (minimum) to 2463.74 kg (maximum) with a lowest range of 409.24 kg, indicating BLUP method was least effective in discriminating between Jersey x Sahiwal sires. Among 176 sires, 93 (52.84%) have breeding values above the average, while 83 (47.16%) fell below the average.

The DFREML method also provided an average breeding value of 2242.87 kg, exceeding estimates reported by Kumar *et al.* (2011), Raja and Gandhi (2012) and Dongre and Gandhi (2014) in Sahiwal cattle; Haile (2010) in Holstein Friesian cattle and Mallick *et al.* (2018) in Vrindavani cattle. However, the observed breeding value was lower than those noticed by Singh and Singh (2011) and Lodhi *et al.* (2016) in crossbred cattle and Singh *et al.* (2010) in Vrindavani cattle. The highest breeding value was 3081.07 kg, while the lowest was 1712.50 kg, resulting in the largest range of 1368.57 kg among the three methods. This finding was in conformity with the report of Dash *et al.* (2014) in Holstein Friesian crossbred cattle. Out of 176 sires, 85 (48.30%) have breeding values higher than the average, while 91 (51.70%) were lower than the average. The top-ranking sire demonstrated a genetic superiority of 37.37% above the average, while the lowest-ranking sire had a breeding value that was 23.65% below the average.

Among the methods, DFREML exhibited the lowest error variance (160,916.26 kg^2), marking it as the most efficient approach, followed by LSM (331,321.78 kg^2) and BLUP (345,714.33 kg^2) (Table 3). These results align with the findings of Raja and Gandhi (2012) in Sahiwal cattle, who identified DFREML as the most precise method due to its minimal error variance. The accuracy of the sire evaluation methods was assessed using the coefficient of determination (R^2 value). DFREML emerged as the most accurate method, with an R^2 value of 64.33%, surpassing BLUP (54.34%) and LSM (48.70%). These findings were consistent with earlier studies by Raja and Gandhi (2012), which also highlighted DFREML as the most reliable method, followed by BLUP and LSM. Stability of the methods was evaluated through the coefficient of variation, focusing on the changes in CV between adjusted and unadjusted data. DFREML demonstrated the smallest alteration (26.71%), indicating it as the most stable method, followed by LSM (30.02%) and BLUP (32.80%). Similar conclusions were reported by Raja and Gandhi (2012) in Sahiwal cattle, reaffirming DFREML's superior stability in sire evaluation.

The rank correlations were statistically highly significant (P<0.01) and very high ranging from 0.882 (BLUP with DFREML) to 0.992 (LSM with DFREML). These findings are consistent with the reports of Raja and Gandhi (2012) in Sahiwal cattle, who reported similar high correlations in the evaluation of dairy cattle based on first lactation 305-day milk yield.

Conclusion

As far as discrimination of Jersey x Sahiwal crossbred sires is concerned, DFREML method proved to be the most effective, as evidenced by the highest range of breeding values, reflecting its superior ability to differentiate among sires. Based on error variance, R^2 value and coefficient of variation, DFREML emerged as the most efficient and accurate sire evaluation method for first lactation 305-days milk yield in Jersey crossbred sires. Moreover, the high rank correlation observed between LSM and DFREML indicates that either method could reliably produce similar sire rankings.

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Ethical statement

The data for this study were collected from dairy cattle managed under the Progeny Testing Programme (PTP) of Andhra Pradesh Livestock Development Agency (APLDA) in compliance with the ethical guidelines for the care and use of farm animals. The study did not involve any invasive procedures and all practices adhered to standard dairy management protocols to ensure the welfare of the animals. The research utilized routine performance records collected under the Progeny Testing Programme (PTP).

Conflict of interest

Declaration of interest - none

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