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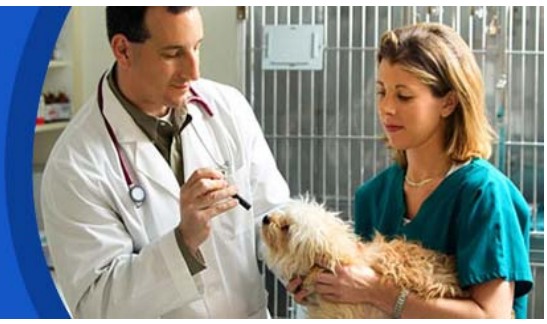

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Comparison of effectiveness of various methods of sire evaluation-A review

CV Singh

Abstract
This paper reviews experiences with evaluating the sires using different sire evaluation methods. The different studies were compiled from oldest to latest published literature on different sire evaluation methods used by different workers and compared effectiveness of various methods of sire evaluation. During the past, different methods like simple daughters average index (i), contemporary comparison method (CC), least squares method (LSM), simplified regressed least squares method (SRLS) and best linear unbiased prediction (BLUP) and derivative free restricted maximum likelihood (DFREML) method and WOMBAT. The different sire evaluation methods like simple daughters average index (i), contemporary comparison method (CC), least squares method (LSM), simplified regressed least squares method (SRLS) and best linear unbiased prediction (BLUP) have been used to evaluate sires but still the application of latest and complex method of sire evaluation like derivative free restricted maximum likelihood (DFREML) and WOMBAT is scanty. However, with the advancement of computational facilities, complex methodologies like DFREML have been used during last few years for sire evaluation in different countries. The effectiveness of different sire evaluation methods was judged by using the various criteria like within sire variance or error variance, coefficient of determination (%), coefficient of variation (%) and rank correlations. The most efficient method had the lowest error variance. Higher the coefficients of determination (R2-value) from fitting a model, higher the accuracy. The sire evaluation method, which retains the coefficient of variation (CV %) of the population near to the CV (%) unadjusted data was the most stable method. Higher (near to unity) rank correlation amongst the sires from different sire evaluation methods revealed higher degree of similarity of ranking from different methods.
The breeding values of sires using derivative free restricted maximum likelihood method (DFREML), best linear unbiased prediction (BLUP), least squares methods (LSM) and WOMBAT were estimated in different studies. In some studies on the basis of some traits the highest breeding value of sires was obtained by LSM and lowest by BLUP than average breeding value. The estimated breeding values estimated by BLUP showed small genetic variation in compare to WOMBAT, LSM and REML method. The error variance estimated by BLUP was found lowest than the other methods. The BLUP method was found to be more efficient, accurate and stable with lowest genetic variation amongst all four methods of sire evaluation used in the some studies. While in other studies the error variance of DFREML method was lowest and therefore, it was considered to be most efficient method than the other sire evaluation methods.

Keywords: Least squares method, SRLS, BLUP, DFREML, WOMBAT, sire evaluation, breeding values

Introduction
The effectiveness of sire evaluation is the backbone of any breed improvement programme as the contribution of sire path is higher than the dam path for the overall genetic improvement for a trait. In addition to this, very intense selection can be practised in case of males, as few males are required for breeding purpose. So, one of the main criteria of enhancing the genetic potential of animals in a herd is to use proven sires to transmit superior genetic potential for higher milk production. During the past, different methods like least squares (LS) and best linear unbiased prediction (BLUP) have been used to evaluate sires of indigenous breeds (Parekh and Singh, 1989; Gandhi and Gurnani, 1991; Sahana, 1996; Deb *et al.,* 1998) [53, 23, 58, 16], still the application of latest and complex method of sire evaluation like derivative free restricted maximum likelihood (DFREML) in Indian breeds is scanty. However with the advancement of computational facilities, complex methodologies like DFREML as described

by Meyer (1989) [47] have been used during last few years for sire evaluation in different countries. On the other hand, this method has been used scarcely in India (Jain and Sadana, 2000) [41]. The effectiveness of different sire evaluation methods was judged by using the various criteria like within sire variance or error variance, coefficient of determination (%), coefficient of variation (%) and rank correlations. The most efficient method had the lowest error variance. Higher the coefficients of determination (R2-Value) from fitting a model, higher the accuracy. The sire evaluation method, which retains the coefficient of variation (CV %) of the population near to the CV (%) unadjusted data was the most stable method. Higher (near to unity) rank correlation amongst the sires from different sire evaluation methods revealed higher degree of similarity of ranking from different methods.

In dairy cattle sire evaluation based on milk yield is most widely used criterion for estimating the genetic merit of a sire. However, other first lactation traits like peak yield, first lactation milk yield as well as reproduction traits like age at first calving, calving interval etc, also included in sire evaluation programme. In order to make rapid genetic progress in performance through selection for traits of economic importance, selected animals must be chosen for their superior breeding value (Dalton, 1985; Bichard, 1988; Dempfle, 1988; Falconer, 1989 and Nicholas, 1993) [13, 7, 14, 21, 52]. There are many sources of information, on which individuals breeding values can be estimated. These include individual performance, family performance and the combined performance of individual and family weighted appropriately after correlation for known environmental effects.

Relative Efficacy of Different Sire Evaluation Methods

Lush (1933) [44] was the first who discussed different sire indices and recommended equal parent index to be the best as it was simple for field use while Robertson and Rendel (1954) [57] found that daughter's average index and contemporary comparison methods were suitable in sire evaluation for random mating and non-random mating. Edward (1932) [19] evaluated breeding value of sire by computing their daughters' average index. I= $\overline{D}$

Where, I is the index and $\overline{D}$, is the average of daughters of the sire.

Cunningham (1965) [10] described the method for obtaining weighted least squares estimates of sires based on non-orthogonal data of progeny test records, where AI was practiced. He reported that it was possible to classify the sires into different groups much earlier in the young age before the proofs were completed. Jain and Malhotra (1971) [40] carried out a study on relative merit of eleven methods for estimating breeding values of dairy sire on the single herd basis. In two methods, only daughter's production was considered, in another three daughters and dam's records were used and in rest six, the information of daughters were used. Their contemporaries, with or without records of their dam, were utilized to get the breeding values of sires. They found that I=A+1/2 h^2 q (D-CD) could be the most efficient for dairy sire evaluation, when dam's records are not available otherwise index I=A=1/2 h^2 Q (D-CD)-b (M-CM) could be the best.

Chander and Gurnani (1976) carried out the sire evaluations by nine different methods in Tharparkar cattle. They suggested that index I=A+2n h^2/4+ (n-1) n^2 (D-CD)-b (M-CM) was the most efficient when the heritability was below 0.3, but in case of high heritability (i.e.>0.3), the index I=A+ n/n+12 [(D-CD)-b (M-CM) was found to be most efficient. Harvey (1979) [27] compared the accuracy of simple regressed least squares (SRLS) with Henderson's BLUP procedure. He found that BLUP method of sire evaluation was 1-7% more efficient than SRLS, when usual assumptions were met. Hagger and Dempfle (1981) compared least-squares and two BLUP methods of sire evaluation for Brown-Swiss bulls. The correlation for the two repeat estimates of the breeding value of bulls were 0.76, 0.83 and 0.80 for three methods, respectively, over sire groups and 0.74, 0.80 and 0.78 within sire group while Parekh and Pande (1982) [54] compared five methods of sire evaluation namely, predicted difference unadjusted data, predicted difference on adjusted data, LS, SRLS and BLUP method. They suggested that LS was the most accurate in crossbred progeny of HF and Jersey sires for milk production. Harvey (1987) [28] gave the concept of least squares analysis for non-orthogonal data. By incorporating sire as a random effect in the model of least squares analysis, the effect of sire can be determined for their genetic merit for effective sire evaluation. The computational simplicity and readily available computer programs have made this method very useful under Indian conditions.

Falconer (1989) [21] and Nicholas (1993) [52] documented the conditions under which the use of these different sources of information was appropriate. A point worth highlighting is that when heritability is low, combining individual and family performances, appropriately weighted, provides the maximum response to selection. Traditionally, in the absence of random mating, the breeding values are estimated as the individual or progeny deviation from contemporary performance within an environment (Dalton, 1985; Falconer, 1989 and Nicholas, 1993) [13, 21, 52] after adjusting for most identifiable environmental sources, viz. birth rank, rearing rank, age of dam and age of the individual. Estimation of breeding value would be biased from traditional method in selected population. Best linear unbiased prediction (BLUP) developed by Henderson (1949; 1973) [29, 30] is better method (Henderson, 1973, 1980; Falconer, 1989 and Nicholas, 1993) [35, 21, 52], particularly, when individual animal model (IAM) has been employed for the analysis. The model of analysis under BLUP takes into account the fixed effects and relatedness between animals, therefore, breeding value estimated from this method are less biased (Falconer, 1989; Henderson, 1973, 1990b and Nicholas, 1993) [35, 36, 21, 52]. Henderson (1973) [30] gave the concept of Best Linear Unbiased Prediction (BLUP) method for sire evaluation for mixed model equations. This method combines the feature of least squares and selection index techniques and was reported to be most powerful and flexible (Henderson, 1974) [31]. The BLUP method is unbiased and gives the predicted value nearly equal to expected value of sires with minimum error variance. The method is also easy to modify if the condition changes. The availability of powerful software for BLUP helped its worldwide acceptance for evaluation of genetic merit of sire.

Henderson (1975a) [32] described various criteria that were desirable in a sire evaluation method. BLUP method has the following desirable properties:

- It is unbiased in the sense that the predictor has the same expectation as the unknown variable that is known to be predicted.
- It minimizes the variance of error of prediction in the class of linear unbiased predictors.
- It maximizes the correlation between the predictor and the predict and in the class of linear unbiased predictors.

- When the distribution is multivariate normal.
- It yields the maximum likelihood and the best linear unbiased estimators of the conditional mean of predict and.
- In the class of linear unbiased predictors, it maximizes the probability of correct pair wise ranking.

Henderson (1975b) [33] described the incorporation of numerator relationship matrix, which had the benefit of increase in accuracy and accounting for genetic and environmental trends. Henderson (1976) [34, 36] extended the BLUP procedure for multiple traits and later on Henderson and Quass (1976) [34, 36] derived methods of BLUP for estimating breeding value using multiple traits utilizing individual's own records as well as large number of relatives of sires with numerator relationship matrix. The records of the relatives are of greatest use when heritability of the traits is low and in particular when the trait cannot be observed in the individual, which is the candidate for selection. This was an extension of Henderson's single trait model for evaluating genetic merit of sire. Henderson (1974) [31] and Chauhan (1991) [9] reviewed various sire evaluation methods and recommended the use of BLUP method in view of its various favorable features over the other methods. In Russia, Ivanov and Konstantinove (1989) [38] used BLUP method of sire evaluation and concluded that with optimum BLUP model, the accuracy of sire evaluation increased ranging from 18-37%.

Cameron (1997) [8] described the properties of the BLUP procedure as follows:

- Best: maximization of the correlation between the true breeding value and the predicted breeding value
- Linear: predicted breeding values are linear functions of the observations
- Unbiased: estimates of fixed effects are unbiased and the unknown, true breeding values are distributed about the predicted breeding values.
- Prediction: the procedure predicts the true breeding values.
- Several workers used this method of sire evaluation to estimate the breeding value of bulls in India.

Different sire evaluation methods for Sahiwal and HF bulls were analyzed by Tajne and Rao (1990). The BLUP procedure was found most superior in appraisal of genetic merit of Sahiwal and Friesian sires for milk yield Anacker and Diete (1990) [1] reported that there were advantages of best linear unbiased prediction over the contemporary comparison method for the prediction of breeding value of dairy bulls. Based on the performance of the daughters of 1361 bulls, the estimated breeding value for milk yield, milk fat yield and milk protein yield were 10.9, 9.6 and 12.5 per cent more accurate using best linear unbiased prediction than contemporary comparison.

While Gandhi and Gurnani (1991) [23] compared the breeding value of Sahiwal sires using BLUP and least-squares method on the basis of 305 days or less milk yield of 1500 Sahiwal daughters maintained at five farms. They utilize error variance, coefficient of determination, coefficient of variation and rank correlation methods for estimating efficiency, accuracy and stability of different indices. The BLUP method was inferior in accuracy than least-squares method as the coefficient of variation by BLUP method was very high as compared to the coefficient of variation by least-squares model. The coefficient of determination of least-squares model showed gradual decline when data were adjusted for farms, period and both farms and periods. The rank correlations of both methods of sire evaluation were high (0.88 to 1.00) and statistically highly significant ($P<0.01$). Gandhi and Gurnani (1992) [24] studied 37 Sahiwal bulls on the basis of 305 days milk production and various production efficiency traits over lactation. They found that the selection of bulls on the basis of production efficiency traits would bring more genetic improvement in herd, because of high heritability and favourable correlation with lactation traits while Raheja (1992) [56] reported least squares (LS) method to be more accurate than best linear unbiased prediction(BLUP)method. Singh *et al.* (1992) [62] compared BLUP, LS, SRLS and CC methods for ranking of Hariana sires for part lactation milk yield. The BLUP method was considered to be more appropriate method than others, due to its sound theoretical properties and lesser prediction error variance and Kishore (1993) [42] compared least-squares, simplified regressed least-squares and best linear unbiased prediction methods of sire evaluation and concluded that least- square gave maximum accuracy of sire evaluation and proposed that least-squares methods for estimating the breeding value of bulls should be used under field conditions of Kerala. Parekh *et al.* (1994) studied LS, PD, SRLS and BLUP procedure for evaluation of HF sires using two models viz., model one and model two. Not much difference was observed in ranking under two models. They observed that under model I, BLUP was most suitable while under model II, LS, SRLS and PD were more appropriate methods for ranking the sires.

Pundir and Raheja (1994) used multi trait BLUP procedure for estimating breeding values of Sahiwal sires for first lactation and lifetime performance traits. The rank and product moment correlation ranged between 0.22 to 0.91 and 0.21 to 0.84, respectively, between first lactation and life time performance traits. They evaluated the Hariana and Sahiwal sires for first lactation and lifetime productivity. They applied multi-trait best linear unbiased prediction (BLUP) procedure to estimate the breeding value of sires for different first lactation and life time traits. Multi trait mixed animal model included the year and season of calving as fixed effect and sire genetic group as random effect. They found that rank of sire for different traits were found almost similar for 4-5 per cent of top sires for first lactation and life time traits. Further, they suggested that sire should be selected on the basis of first lactation traits and selection or evaluation of dairy sires for lifetime could be used as additional criteria.

Gokhale and Mangurkar (1995) used five methods simple daughter average (SDA), herd mate comparison (HMC), CC, LS and LBUP for sire evaluation in Holstein crossbreds. They evaluated the sires on the basis of 305 day lactation milk yield. They reported that sire which ranked superiors by HMC, CC and BLUP methods, was ranked second by SDA and LS methods. Since rank correlation and simple product moment correlation under CC and BLUP method were highly correlated, they revealed that BLUP and/or CC methods can well be used for evaluation of sires under field conditions. Thus they concluded that the BLUP including the fixed effect of year and the random effect of sire are recommended. Kuralkar *et al.* (1995) [43] compared five models of BLUP for evaluating 323 progeny of 23 Sahiwal bulls on the basis of first lactation milk yield. The model one (BLUP) was more efficient than other models which includes fixed effects of herd (farm), season, year and sires as random effects. The rank correlation among models ranged from 0.64 to 1.00. He

evaluated sire using different non-genetic fixed effects in BLUP models for first lactation milk yield in Sahiwal. For this they used five best linear unbiased prediction (BLUP) models. Model I included fixed effects of herd (Farm), season, year and random effect of sires. Years were grouped into period in model II. The BLUP model I was found more efficient than the other models because standard errors of prediction in model were lower.

Gaur and Raheja (1995) further evaluated the sires on the basis of peak yield, lactation length and lactation yield under LS and BLUP methods. They observed that there was not much difference in ranking of sires for all 3 traits. They reported low product moment and rank correlations between LS and BLUP for lactation length, while both product moment and rank correlations among estimates for peak yield and lactation yield were high (0.83 to 0.88). Finally, they concluded that due to complexity of BLUP procedure, the simple least squares constants of sires would be better for genetic evaluation of sires. Thakur (1997) [70] compared four methods (BLUP, LS, SRLS, and CC) to evaluate Jersey sires. On the basis of results the BLUP was categorized more appropriate followed by SRLS/ LS and Deulkar and Kothekar (1999) [15] evaluated sires on the basis of first lactation yield and lifetime milk production of their daughters. Least-squares (LS) and best linear unbiased prediction (BLUP) were used to estimate breeding value of sires. Sire ranking for first lactation milk yield calculated using LS and BLUP were similar and comparison of ranking of sires for lifetime production showed positive and significant associations. It was concluded that sires ranked on first lactation yield using any method would have a direct impact on lifetime production. Sahana and Gurnani (1999) evaluated the Karan Fries sire on the basis of lactation milk yield trait. The rank correlation between breeding values estimated using auxiliary traits were high i.e. varied from 0.77-0.78. Dhaka and Raheja (2000) [12] used DLS, RLS and BLUP procedures to evaluate the Sahiwal bulls. They observed estimates of breeding value obtained from RLS showed perfect normal distribution followed by BLUP. Further, RLS has the minimum standard error followed by BLUP and OLS methods. But due to cost of computations and relative computational difficulties they suggested BLUP is the best method.

Sahana and Gurnani (2000) [59] used first lactation performance records of Karan Fries cows to examine the efficiency, accuracy and repeatability of 5 sire evaluation methods viz. SDA, CC, LSQ, SRLS, and BLUP. The CC method was observed to be the most efficient sire evaluation method and SDA the least efficient. Though BLUP method was considered to be most efficient method, had lower efficiency than CC method under Indian farm conditions, due to small data size. The rank correlation of CC method with other 4 methods ranged between 0.77 with SRLS and 0.85 with BLUP. Further,they suggested that sire should be selected on the basis of first lactation traits and selection or evaluation of dairy sires for life-time could be used as additional criteria. Singh (2000) [61] compared three methods (BLUP, LS, SRLS) to evaluate the Sahiwal bulls. The sound theoretical properties of BLUP categorized as most suitable followed by SRLS and LS method for ranking of Sahiwal bulls. He further observed maximum rank correlation between LS and SRLS method (0.991) on the basis of different trait where as minimum correlation was estimated between LS-BLUP and SRLS-BLUP method (0.634) indicating maximum and minimum, respectively, between these methods. He also reported rank correlation between FLPY and F300 (0.983 to 0.920), between FLPY and FLMY (0.737 to 0.779) and between F 300 and FLMY (0.815 to 0.857) by different methods of sire evaluation and found similarities between traits for sire evaluation. Further, he suggested that sire should be selected on the basis of FLPY. Gaur *et al.* (2001) [26] carried out a study to estimate the sire solutions using SDA, CC, LS and BLUP procedures. They suggested that either of the methods can be used for the selection of sires for breeding purpose to improve total lactation milk yield. However, due to complexity of BLUP, LS and CC can be used in practice for genetic evaluation of sires. Misztal *et al.* (2004) [49] developed BLUPF90 and related programmes were providing the purpose of comprehensive computing capabilities to problems related with mixed models in animal breeding. The main objective of BLUPF90- *Dairy Pack,* 2004 version-2 is to accomplish various models generally used in dairy cattle evaluation with friendly graphic interface for PC and windows users. Using powerful features from programmes of BLUPF90, Dairy Pack can accomplish a wide range of genetic evaluation. It provides basic animal model which allows data of animals in the pedigree to be included in the analysis so that all known relationships can be taken into account. Other effects, (fixed and random), can be included for comprehensive use of mixed model. Fixed effects such as herd, year and season can be performed during the analysis; therefore, no adding step of data preparation is required.

Mukherjee (2005) [51] evaluated 72 Frieswal sires for milk yield using least-squares, best linear unbiased prediction (BLUP) and derivative free restricted maximum likelihood (DFREML) method. The error variance of DFREML method was lowest and therefore, it was considered to be most efficient out of all three sire evaluation methods. Dubey *et al.* (2006) best linear unbiased prediction (BLUP) procedure was used to obtain the estimates of breeding values. The estimated breeding values (EBV's) showed large genetic variation between sires for both first lactation and lifetime traits. The EBV's of sire for AFC had negative product moment correlation with EBV's for FLP an FSP, while, low and positive with EBV's for FLMY, FDP and FCl. The product moment correlation among sires estimated breeding values for HL, PL, TLL, LTMY were positive and moderately high (0.39 to 0.86). Rank correlation among EBY's of sires indicated that all sires would not rank same for first lactation and life time performance traits. However, the ranks of sires for different traits revealed that 4-5% top sires had similar rank for first lactation and life time traits. These results suggested that to improve lifetime productivity major culling of bulls should be done on the basis of their daughter's first lactation milk yield.

Banik and Gandhi (2006) [4] estimated the breeding value of Sahiwal sires using least squares, BLUP and derivative free restricted maximum likelihood (DFRELM). The highest and lowest overall average breeding value of Sahiwal sires for first lactation 305d FLY was obtained by BLUP (1520.72 kg) and LS method (1502.22 kg), respectively. The accuracy, efficiency and stability of different sire indices were compared to judge their effectiveness. The error variance of univariate DFREML model was lowest (1910112 kg) and the coefficient of determination of fitting the model was highest (33.39%) revealing that this method of sire evaluation was most efficient and accurate as compare to other methods. However, the BLUP method was most stable amongst all the methods having coefficient of variation (%) very near to unadjusted data (18.72% versus 19.89%). The highest rank correlation (0.7979 to 0.9568) between different sire

evaluation methods indicated that there was higher degree of similarity of ranking sires by different methods ranging from about 80 to 96%. However, the DFREML method seemed to be the most effective sire evaluation as compared to other methods for the present set of data. Singh *et al*. (2006) estimated breeding value of Ongole bulls by BLUP procedure and ranked on the basis of their total lactation milk yield (TLMY).

The maximum likelihood method based on estimation of variance and covariance matrix was first proposed by Thompson (1962) [72], later on Patterson and Thompson (1971) [55] and Thompson (1973) [71] applied the restricted maximum likelihood method to animal breeding data by fitting a sire model. This requires expected values of the second derivatives of likelihood to be evaluated which proved computationally highly demanding for all, but, the simplest analysis. Hence, Expectation-Maximization (EM) type algorithms gained popularity and found widespread use in fitting a sire model. Effectively, these algorithms used first derivatives of likelihood function. Except for special cases, however, they required the inverse of a matrix of size equal to the number of random effects fitted, e.g. number of sires times number of traits, which severely limited the size of analyses feasible.

For analyses under sire model, Graser *et al.* (1987) [22] used derivative free restricted maximum likelihood (DFRML) algorithm for solving the mixed model equations. This only requires factorizing the coefficient matrix of the mixed model equations rather than inverting it, and can be implemented effectively using sparse matrix technique. Moreover, it is readily extendable to animal models including additional random effects and multivariate analyses Meyer (1989, 1991) [47]. Dopp *et al.* (1992) [17] suggested that estimation of breeding value by best linear unbiased prediction using an animal model did not result in any major changes in the breeding value of older bulls with a large numbers of daughters, but resulted in increased breeding values for the sons of younger bulls and gave more accurate breeding value estimation for cows. The multivariate, multidimensional analysis of animal model for evaluating merit of sire was proposed by Meyer and Smith (1996) [48].

The information on use of DFREML in estimation of variance and covariance components of sire merit in Indian conditions is scanty. Jain (1996) [39] used DFREML method under multiple trait models (two and three traits combination) for estimation of variance and covariance components and heritability. The variance components derived by these models were used for estimating breeding value of sires by BLUP method. He suggested that REML method should be used for estimation of genetic parameters and genetic evaluation of bulls. However, this would require information on pedigree and, therefore, maintenance of records. He also reported that when the target would be to improve more than one trait, all the traits should be included in model. However, the traits having very low heritability should not be taken in the model. Espinosa *et al.* (2001) [20] used data on 2618 records of milk production from 1991 to 1998 to estimate the breeding values in a Holstein dairy herd. The variance components were estimated by a REML with a derivative-free algorithm. It was concluded that the variance components of this study were reliable for prediction of breeding values of the animals. Smith (2002) [67] described the procedure of restricted or residual maximum likelihood (REML) for linear models. He also described an explicit algorithm given for REML scoring which yielded the REML scoring together with their standard errors and likelihood values. The algorithm included a Levenberg-Marquardt restricted step modification, which ensured the REML, increase at each iteration. Sahana and Gurnani (2000) [59] utilized first lactation performance records of Karan Fries cows to judge the efficiency, accuracy and compared with 5 sire evaluation methods, viz., Simple Daughters Average Index (I), Contemporary Comparison method (CC), Least Squares Method (LSM), Simplified Regressed Least Squares Method (SRLS) and Best Linear Unbiased Prediction (BLUP). The rank correlations of CC method with other 4 methods ranged between 0.77 with SRLS and 0.85 with BLUP. The least relative efficiency was judged in Simple Daughters Average Index compared with other 4 methods. Atil and Khattab (2000) [3] analyzed 1931 first lactation records of Holstein-Friesian cows by three methods of evaluating sire-transmitting abilities. Sires were evaluated by Best Linear Unbiased Prediction (BLUP), Least Squares Means (LSM) and regression of the future daughters mean on the present daughters mean methods, respectively. The product moment correlations between estimates of sire transmitting abilities for different methods were high and positive (0.96).

Tailor *et al.* (2000) [68] estimated breeding value of 41 Surti buffalo bulls based on first lactation 305-days milk yield of 507 daughters by 5 sire evaluation methods viz. herd-mate comparison, contemporary comparison, ordinary least squares, regressed least squares and BLUP. The accuracy of sire evaluation was judged by the correlation between the actual progeny average for each sire and the estimated breeding value of sires and by rank correlations and coefficients of skewness and kurtosis. Herd-mate comparison and contemporary comparison methods had high and significant rank correlations; their correlations with least squares and BLUP methods were moderate. The rank correlations for two least squares methods with true sire effects were close to 1 and that for BLUP was lower. BLUP had a lower standard error than other methods. The least squares and BLUP methods had near perfect normal distribution. The accuracies of ordinary least squares, regressed least squares, BLUP, contemporary comparison and herd-mate comparison were 0.99, 0.97, 0.63, 0.52 and 0.45, respectively. The ordinary least squares method was found the most accurate method of sire evaluation. They recommended that BLUP could be used for evaluating the breeding value of sires.

Jain and Sadana (2000) [41] used first lactation records of 683 Murrah buffaloes for comparing the sire evaluation for age at first calving, first lactation 305-day or less milk yield and first service period. The sires were evaluated using Simple Daughters average, contemporary comparison, Least Squares and Best Linear Unbiased Prediction Methods. The BLUP evaluations were obtained under single, two and three trait individual animal models. The results revealed that for taking a decision regarding the method of sire evaluation to be used for selecting sires with high breeding values, criteria of the rank correlation could be misleading and comparison of the selected sires is likely to give a actual picture. They reported that the best linear unbiased prediction method under multi-trait animal model incorporating first lactation milk yield with first service period and age at first calving as covariable in the model was found to be more efficient and accurate for sire selection in Murrah buffaloes.

Aswathanarayana *et al.* (2003) [2] estimated relative efficiency of the sire evaluation procedures based on minimum standard error of procedures indicated that both BLUP and MCC

procedures were more appropriate and efficient in estimating the breeding value of sires compared to Simple Daughter's average (SDA) and CC. The finding strongly recommended the usage of BLUP procedure for evaluating sires under field and farm conditions. Vinoo *et al*. (2005) [73] evaluated 17 sires using simple daughter average, dairy search index and adjusted least-squares method on the basis of 305daysFLMY of their daughters. Positive and highly significant correlations indicated that these 3 methods of sire evaluation could be used with equal efficiency.

Dahiya *et al*. (2005) [11] estimated breeding values using auxiliary traits on daughters in combination with FLMY in relation to sire evaluation for individual trait by Simple daughter average, Contemporary comparison, Least Squares, SRLS and BLUP methods in 617 Hariana cows. The result showed that BLUP was the most efficient method of sire evaluation having the lowest error variance and highest relative efficiency. While Bajetha (2006) estimated association between the BLUP and other methods of sire evaluation the value of association ranging from 0.7219 to 0.9547 (product movement correlation) and 0.7186 to 0.9693 (rank correlation) for first lactation traits and from 0.7433 to 0.9502 (product movement correlation) and 0.7441 to 0.9380 (rank correlation) for lifetime traits. All the estimates of simple and rank correlation were highly significant ($p<0.01$). The EBV's of sire revealed that BLUP method showed small genetic variation in comparison to Daughter's Average and LS method. Because of its desirable properties, the BLUP method may be considered to be more appropriate than that of Daughter's Average and Least Square Method. Singh (2007) estimated breeding values of sires for first lactation and lifetime traits by $\overline{\mathbf{D}}$, LSM, BLUP and DFREML methods revealed that EBV's of sires estimated by LSM method showed small genetic variation followed by BLUP and DFREML methods in comparison to $\overline{\mathbf{D}}$ method. Moges *et al.* (2009) carried out a study to evaluate the sire on the basis of single and multi traits of their progeny and the accuracy, efficiency and stability of different sire indices were compared to judge their effectiveness and reported that the error variance of single trait BLUP method was found to lowest and, therefore, it was considered to be most efficient out of all sire evaluation method. Singh and Singh (2011) [60] estimated the breeding value of sires by LSM, DFREML and BLUP method and observed that the estimated breeding values of sire estimate for first lactation milk yield by LSM showed less genetic variation than DFREML and BLUP methods and therefore LSM was considered as the most efficient method out of all three methods of sir evaluation. Singh *et al. (*2014) [18, 63] estimate the breeding values of sires using LSM, BLUP, and DFREML. The breeding values estimated by all three methods were similar. The estimated breeding values of sires estimated for first lactation and lifetime traits by LSM method showed small genetic variation in comparison to BLUP and DFREML methods. The estimated breeding values (EBV'S) of sires had very high and significant product moment correlations and rank correlations among all the first lactation and lifetime traits estimated by all the methods. Dubey and Singh (2014) [18, 63] the estimated breeding values (EBVs) of sires showed large genetic variation between sires for both first lactation and life time traits. The product moment correlations among the EBVs of sires for first lactation traits were ranged from very low to moderate. The first lactation traits also showed same trend with life time performance traits. While product moment correlations among estimated breeding values of sires for life time traits were medium to very high. The rank correlation between the EBVs of sires for first lactation traits ranged from –025 to 0.60. The range of rank correlation among EBVs for life time traits was found to be –0.17 to 0.88. The rank correlations between EBVs of sires for first lactation traits with life time performance traits ranged from –0.28 to 0.38 respectively. Rank correlation among EBVs of sire's indicated that all sire's would not rank same for first lactation and life time performance traits. However, the ranks of sire's for different traits revealed that 4–5 % top sire's had similar rank for first lactation and life time performance traits.

Bajetha *et al.* (2015) [5, 6] estimated sire's breeding value for first lactation traits and traits included were age at first calving, first lactation milk yield, first lactation period, first dry period, first calving interval, and first service period. The Best Linear Unbiased Prediction (BLUP) was used to obtain the estimates of breeding values. The estimated breeding values (EBVs) of sires showed large genetic variation between sires for all first lactation traits. There were changes in the rank of first few top sires by BLUP method of sire evaluation. These results indicated that all Sires would not rank same for first lactation traits. However, the rank of sires for different traits revealed that 4-5% of top Sires almost had similar rank for first lactation traits.

Bajetha *et al.* (2015) [5, 6] the breeding value of sires estimated by three methods viz. Daughters average, Least squares and Simplified regressed least squares methods. The estimated breeding values (EVB's) showed large genetic variation between sires for first lactation traits. The association among the methods of sire evaluation ranging from 0.786 to 0.998 (product moment correlation) and 0.832 to 0.967 (rank correlation) for first lactation traits. Rank correlation among EBV's of sires indicates that all sires would not rank same for all first lactation traits. However, the ranks of sires for different traits revealed that 4-5 % top sires had similar rank for all first lactation traits. These results suggested that to improve productivity of herd major culling of bulls should be done on the basis of their daughter's first lactation milk yield.

Lodhi *et al.* (2015) [45] estimated breeding values of sires using animal model (DFREML), best linear unbiased prediction (BLUP), least squares methods (LSM) and simple daughter average (D) sire evaluation. The average breeding value for age at first calving in crossbred bulls was found to be 1226.17 days by simple daughter's average method (D), 177.65 days by least squares method (LSM), 1998.42 days by best linear unbiased prediction and 1193.77 days by REML. The average breeding value for first lactation period in crossbred bulls was found to be 335.91days by simple daughter's average method (D), 323.7 days by least squares method (LSM), 324.01 days by using best linear unbiased prediction and 322.79 days by REML. The average breeding value for first dry period in crossbred bulls was found to be 131.19 days by simple daughter's average method (D), 102.46 days by least squares method (LSM),106.34 days using best linear unbiased prediction and 101.56 days by REML. The average breeding value for first calving interval in crossbred bulls was found to be 464.02 days by simple daughter's average method (D), 426.24 days least squares method (LSM). 431.27 by best linear unbiased prediction and 424.73days by REML. The average breeding value for first service period was found to be 207.69 by simple daughter's average method (D), 173.93 days by least squares method (LSM), 166.36 days by best linear unbiased prediction and 170.53 days by REML. The estimated breeding values of

sire's for AFC estimated by LSM showed small genetic variation in compare to D, BLUP and REML method. While for FLP, FDP, FCI, and FSP estimated by BLUP showed small genetic variation in compare to D LSM and REML methods, therefore LSM and BLUP was considered as the most efficient methods out of all four methods of sire evaluation used in the present study. The estimated breeding values of sires for all the traits under study showed large variation between EBV'S of sires which revealed more genetic variation in the herd. The simple correlations among all the first lactation traits estimated by four methods of sire evaluation were high and statistically highly significant. Lodhi *et al*. (2016) [46] evaluate sires for first lactation performance traits. The data were analyzed to estimate the breeding values of sires using Derivative Free Restricted Maximum Likelihood Method (DFREML), Best Linear Unbiased Prediction (BLUP), Least Squares Methods (LSM) and WOMBAT. The highest breeding value of sires for first lactation milk yield was obtained by LSM (2779.19kg) and lowest by BLUP (2629.80kg) than average breeding value respectively. The estimated breeding values estimated by BLUP showed small genetic variation in compare to WOMBAT, LSM and REML method. The error variance estimated by BLUP was found lowest than the other methods. Product moment correlation among breeding values of sires estimated by different methods ranged from 0.566 (LSM with BLUP) to 0.997 (WOMBAT with BLUP), where as rank correlations of breeding value of sires ranged from 0.566 (LSM with BLUP) to 0.745 (WOMBAT with LSM). The higher rank correlations (0.566 to 0.745) between different sire evaluation methods revealed that there was higher degree of similarity of ranking sires by different methods ranging from about60 to 75 percent. The BLUP method was found to be more efficient, accurate and stable with lowest genetic variation amongst all four methods of sire evaluation used in the present study. Singh and Singh (2016) [46, 65, 66] estimate breeding values and to compare various methods of sire evaluation viz. BLUP, LSM and sire evaluation methods on the basis of age at first calving, first service period, first lactation period, first dry period, and first calving interval. The accuracy, efficiency and stability of EBV's of sires for the first lactation and lifetime traits were compared by different methods to judge their effectiveness. The estimated breeding values of sires for all the first lactation traits by, LSM and BLUP revealed that EBV's of sires estimated by least squares method showed smaller genetic variation in comparison to and BLUP methods. The LSM was adjudged as the most efficient method of sire evaluation. The LSM had minimum error variance for most of the first lactation traits and considered to be more superior over other two methods i.e., and BLUP. The product moment correlations among the estimated breeding value of sires for first lactation traits by, LSM and BLUP methods ranged from medium to very high and significant ($P<0.01$) in all the three methods of sire evaluation. The rank correlations among the breeding value of sires estimated based on first lactation traits were medium to high and significant ($P<0.01$). The results indicated that least square method (LSM) had the lower error sum of square for all the first lactation traits and least square method (LSM) is relatively more accurate as compared to best linear unbiased prediction (BLUP) method but not overall. The LSM had higher R2 value for the first lactation traits as 40.50% (FLMY), 18.17% (FLL), 23.94% (FCI), 24.59% (FDP) and 48.47% (AFC) than the BLUP method. The estimated R2 values are less which indicates that both methods are less suitable for present data. Therefore as for as stability is concerned among the methods of sire evaluation, the LSM method was most stable being its CV (%) which is closest to the CV (%) of unadjusted data. The rank correlations obtained were highest and statistically significant ($P<0.01$) and ranged from 0.74 (BLUP) to 0.88 (LSM). The highest rank correlations among the breeding values estimated from different methods revealed that rankings of sires were similar to the extent of 74 to 88 per cent from these methods of sire evaluation.

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