UTILIZATION OF HALF-SIBS INFORMATION TO INCREASE THE ACCURACY OF YOUNG BULL SELECTION

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DECLARATION

I hereby declare that the thesis entitled **"UTILIZATION OF HALF-SIBS INFORMATION TO INCREASE THE ACCURACY OF YOUNG BULL SELECTION"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **"UTILIZATION OF HALF-SIBS INFORMATION TO INCREASE THE ACCURACY OF YOUNG BULL SELECTION"** is a record of research work done independently by **Dr. Sajeev Kumar. T** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

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Sajeev Kumar, T.

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Introduction

1. INTRODUCTION

Cattle rearing in Kerala state have long back been integrated with rice farming system to the advantage of both. Due to the high density of human population, conversion of land for house construction and shift in cropping pattern, the area under rice cultivation has come down to 50 per cent over the last three decades. This has lead to the drastic reduction in the availability of straw for feeding cattle. Farmers of Kerala seldom have separate areas for fodder cultivation. It is estimated that the state produces only 60 per cent of the roughage requirement for cattle in Kerala. Regarding concentrate cattle feed, state is not producing even half the requirement. Shift to animal unfriendly cropping pattern, increased labour cost, scarcity of raw materials for cattle feed etc. are forcing the cattle sector of Kerala to heavily depend on "imported cattle feed". In spite of all these hostile components rearing cows for milk is still an occupation for many farmers in the state, though they own only one or two cows. It is estimated that about 32 lakh out of 55 lakh households in Kerala are engaged in livestock rearing for supplementing their income (Anon, 2002). Livestock sector has an important role even now in creating opportunities for augmenting income and employment in the rural households of Kerala.

Cattle in Kerala accounts for 1.75 per cent of the total cattle population in the country. About 68 per cent of the breedable cattle in the state are crossbreds. As a result of planned continuous crossbreeding programme implemented in the state, milk production in the state increased from 9.82 lakh tonnes in 1981-82 to 22.58 tonnes in 1996-97 and 27.18 lakh tonnes in 2001-02 (Anon, 2002). The share of gross domestic product (GDP) from animal husbandry and dairying increased from 5.95 per cent in 1986-87 to 10.26 per cent in 1995 -'96 (Anon, 1998). The tenth plan envisages stepping up of milk production to 35 lakh metric tonnes and per capita availability to 280 gram per day. Per capita availability of milk in the state at present is 234 gram per day compared to the national average of 226 gram per day.

Kerala is the first state, which formulated a breeding policy for cattle improvement in our country. The present breeding policy envisages crossbreeding of cattle, limiting the level of exotic inheritance around 50 per cent. The exotic donor breeds recommended for use in the state are Jersey and Holstein Friesian. Kerala Livestock Development (KLD) Board has been entrusted with the supply of frozen semen from superior bulls throughout the state. Since 1977, KLD Board has been undertaking field Progeny Testing programme to evaluate the genetic potential of young crossbred bulls. One hundred and sixty bulls are required for artificial insemination (AI) programme in the state. From each bull only 50,000 doses of semen are used within the state to reduce inbreeding. The bull families used are also rotated within three different zones in the state. Since the productive life span of bulls is four to five years, 40 bulls are being replaced every year. Top 10 per cent from each batch of bulls put into progeny test are selected as proven bull and is used to produce next generation bulls. Top three per cent of cows in the field performance recording (FPR) area are selected as elite cows and used for bull production. The elite cows of KLD Board farm are inseminated with proven bull semen to produce male calves. There is a F_1 bull production programme also, in which the local non descript cattle is inseminated with imported proven bulls' semen with the objective of widening the genetic base. Import of exotic bulls as well as embryos are also sources of bulls, which is used for crossbreeding the local cattle population in the state. Multiple Ovulation and Embryo Transfer Technology (MOET) is also used for bull production.

Ninety four per cent of total herd improvement comes from the breeding of young bulls from tested sires and only six per cent from the selection of dam (Robertson and Rendel, 1950). Hence selection of breeding bull is very important in dairy cattle improvement programme. Evaluation of bulls based on the performance of their daughters is considered as the most accurate method. The accuracy of progeny test increases with the increase in the progeny group size, but concurrent with this increase, it decreases the possibility of testing more number of bulls and reduces the intensity of selection. Therefore an optimal balance between the progeny group size and the young bulls tested has to be fixed in order to select a constant number.

Presently, sons of proven bulls are used for large scale AI in field. The improvement in milk production can be achieved by increasing the accuracy of estimation of animal's breeding value by using relative records in various combinations (Young, 1961). In young bull programme, the information of dam and paternal half-sibs are available even before the birth of the bulls to be tested. However these information are not being utilized. Therefore it is necessary to test whether the information on dam and paternal half-sibs can be utilized effectively to increase the accuracy of sire evaluation based on actual field data.

Keeping this in view, the present study was undertaken:

1. To detect the important sources of non-genetic and genetic variability in milk production among crossbred cattle of Kerala
2. To compare the relative efficiency of different sire evaluation techniques and rank them according to their merit
3. Utilization of dam and half-sib information in addition to progeny information for sire evaluation for increasing the accuracy of selection.

Review of Literature

2. REVIEW OF LITERATURE

2.1 MILK YIELD

Milk yield is the most important economic trait in dairy cattle. As native cattle of India were very low milk yielders, exotic inheritance was introduced through massive crossbreeding programme to enhance milk yield. The exotic inheritance was mainly from Jersey, Brown Swiss and Holstein Friesian. This resulted in various levels of exotic inheritance in native cattle. In Kerala, Jersey bulls were used initially for crossbreeding of local cattle. Subsequently Brown Swiss bulls were used and later Holstein Friesian bulls were also introduced (Iype *et al.*, 1993). This has resulted in a mosaic inheritance among the present cattle.

The 305-day milk yield of crossbred cattle of Kerala increased from 1483 kg in 1983 to 2196 kg in 1996 (Breeding policy report, 1998). Hiremath and Stephen (2000) reported that the overall mean first lactation milk yield of crossbred cows born to the test bulls of ICAR-FPT scheme was 1958.5 ± 30.74 litres. The average 305-day milk yield in crossbred cattle reported from Kerala and other parts of India are presented in Table 2.1. The milk yield reported by various research workers ranged from 1140 kg in the year 1973 to 2502 kg in the year 2000.

Table 2.1. Average 305-day milk yield of crossbred cattle of Kerala

Breed group	Average 305-day milk yield, kg	Reference
½ J x ½ ND	1140 ± 46	Nair (1973)
Crossbred	1636 ± 590 (SD)	Deriaz (1981)
½ J x ½ ND	1359 ± 57	Stephen *et al.* (1985)
J x local	1566.5 ± 101	Iype *et al.* (1986)
BS crosses	1549 ± 0.3374	Chacko *et al.* (1984)
1/2 BS x ½ ND	1492 ± 20	Stephen *et al.* (1985)
BS crosses	1513.3 ± 130.2	Thomas *et al.* (1987)
Crossbred progenies of test bulls of ICAR-FPT scheme	1829.7 ± 34.13	Radhika (1997)
BS crossbred	1665.9	Deb *et al.* (1998)
J crossbred	1689.9	Deb *et al.* (1998)
Sunandini	2502 ± 712(SD)	Anon (2000)
Crossbred progenies of test bulls of ICAR-FPT scheme	2069.3	Iype and Stephen (2002)
Crossbred cattle of Kerala	2295.16 ± 6.2	Shyju *et al.* (2002)

Note:
J - Jersey

BS - Brown Swiss

ND - Non descript

FPT - Field Progeny testing

Year-wise milk production in Kerala for the period from 1993-1994 to 2001-2002 is given in Table 2.2 (Economic review, 2002). The milk production of the state was increased from 18.89 to 27.18 lakh tonnes in the same period.

Table 2.2. Year-wise milk production in Kerala for the period from 1993-1994 to 2001-2002 (Economic review, 2002)

Year	Milk production in Kerala, lakh tonnes
1992-93	18.89
1993-94	20.01
1994-95	21.18
1995-96	21.92
1996-97	22.58
1997-98	23.43
1998-99	24.20
1999-00	25.25
2000-01	26.05
2001-02	27.18

2.2 NON-GENETIC FACTORS AFFECTING MILK YIELD

2.2.1 Centre

Deriaz (1981) studied first lactation milk yield (FLMY) of crossbred cattle in Mavelikkara and Kattappana area (Kerala) and reported that milk yields in different centres were significantly different.

Chacko *et al.* (1984) studied the influence of environmental effect on lactation under field conditions of Kerala and found that AI centres were one of the major non-genetic factors influencing milk yield of crossbred cattle of Kerala.

Iype *et al.* (1986) reported that farms, year and farm x season interaction had significant influence on milk yield of crossbred cattle.

Thomas *et al.* (1987) also reported that centre-wise differences in milk yield of cows of Kerala were significantly different.

Jadhav *et al.* (1991) observed that lactation and 300 days milk yield were significantly influenced by farm and other non-genetic factors like period of calving.

Iype *et al.* (1993) reported significant influence of centers on milk yield. They also found higher milk yield in centres closeness to the town.

Deb *et al.* (1998) reported mean first lactation milk yield of crossbred cattle in different AI centres ranged between 2407.4 (Nooranad) to 1220.9, kg (Kalketty) and they have also observed that generally cows raised in.the areas attached with AI centre under Mavellikkara and Kottayam progeny testing units were higher than those under Kattappana unit.

Delukar and Kothekar (1999) also reported the significant effect of farm on first lactation milk yield.

In the ICAR field progeny testing scheme implemented by the Centre for Advanced Studies in Animal Genetics and Breeding, Kerala Agricultural University, centers showed highly significant effect on milk production. The centers nearer to Thrissur had a higher milk production (Iype and Stephen, 2002).

Rajeev *et al.* (2002) studied 15012 first standard lactation records of crossbred cattle spread over nine years in 54 AI centers of Kerala and found that the centres had highly significant effect on milk yield.

From the above reports it can be concluded that differences in the management levels in different places / centres is a source of variation in milk yield of cows.

2.2.2 Year of Calving

Years of calving influenced the milk yield of crossbred cattle of Kerala significantly (Chacko *et al.*, 1984).

Significant effect of period or year of calving was reported in HF x Sahiwal cattle by Jadhav *et al.* 1991; in Sahiwal cows (Mishra and Prasad, 1994); in HF x Deoni and Jersey x Deoni (Thalkari *et al.*, 1995); in crossbred cattle of Kerala (Deb *et al.*, 1998) and in Jersey, HF or Danish Red crossed with Red Sindhi, Hallikar or Amrith Mahal (Shettar and Govindaiah, 1999).

Iype and Stephen (2002) reported that calving year influenced the milk yield of crossbred cow significantly. Rajeev *et al.* (2002) also recorded that year of calving was highly significant for FLMY.

The above studies show that year of calving is a source of variation in milk yield of cows.

2.2.3 Age at First Calving (AFC)

Deriaz (1981) studied milk yield of cattle of Kerala and found that AFC were highly significant ($P \leq 0.01$). Significant effect of AFC on milk yield was also reported by Stephen *et al.* (1985) in Jersey and Brown Swiss crosses and Thomas *et al.* (1987) in Brown Swiss crosses, Deb *et al.* (1998) and Rajeev *et al.* (2002) under field conditions of Kerala. Similar observation was also made by Garcha and Dev (1994) in HF crossbreds, Turkamut and Kumuk (1994) in Holstein Friesians. On the contrary, Sreemannarayana and Rao (1994) in Jersey cows (Andhra Pradesh) reported non-signifiant effect of AFC on milk yield.

2.2.4 Season of Calving

Singh and Pandey (1970) observed that the cows calving in the spring season were found to produce 3.7 per cent more milk than the average of animals calving in other seasons. Nair (1976) noticed that season of calving did not significantly affect lactation length or yield.

Deriaz (1981) analyzed different effects on milk yield of cows in Kerala and found seasons of calving exerted significant effect on milk yield. For this analysis the year was classified to four seasons.

Subramanian (1984) reported that the environmental factors, period and season of calving and their interaction effects were not found to affect significantly 180 to 305-day milk yield of first lactation.

Stephen *et al.* (1985) made a comparison of milk production of Jersey and Brown Swiss crossbreds and reported that there was no significant effect for season on milk yield.

Vij and Basu (1986) and Jadhav *et al.* (1991) observed that the season of calving had significant effect on first lactation milk yield.

Kurlakar *et al.* (1995) while identifying the non-genetic source of variation influencing first lactation milk yield found that the effects of farm and season were non-signifiant. The non-signifiant effect of season may_be due to the fact that animals were raised on cultivated green fodder available round the year from irrigated land. The effect of period on first lactation milk yield was highly significant.

Shetter and Govindaiah (1999) studied the performance of crossbred cattle (Jersey, HF or Danish Red crossed with Red Sindhi, Hallikkar or Amrith Mahal) and found that milk yield was lower in animals calved in summer than in winter and monsoon seasons.

Iype and Stephen (2002) recorded that season of calving did not influence the milk yield. Rajeev *et al.* (2002) studied 15012 crossbred cattle in their first lactation and found that month of calving did not have significant effect on milk yield.

The above studies indicate that season of calving is not a source of variation in milk yield of cows in Kerala unlike in other states of India.

2.3 HERITABILITY

Heritability of milk yield estimated were low to medium in crossbreds. Johnson (1957) reported that heritability of milk yield in Holstein herd was 0.30. Amble *et al.* (1967) showed that the value for heritability for milk production obtained for most of the Indian dairy herds was in the neighbourhood of 0.25. Chander and Gurnani (1976) in the review of efficiency of sire evaluation methods stated that the estimate of heritability of first lactation production generally vary between 0.2 and 0.4 for Indian cattle. Rahumathulla (1992) reported that the heritability estimates of milk yield and milk production efficiency traits in Jersey crossbreds of Tamil Nadu ranged between 0.17 and 0.53. Nair *et al.* (1994) observed that heritability estimate of first lactation milk yield ranged from 0.273 and 0.378 in different grades of HF crossbreds. Appannavar *et al.* (1995) calculated heritability of second, fourth and tenth test day milk yield and first ten test day cumulative yield as 0.49 ± 0.22, 0.35 ± 0.20, 0.56 ± 0.30 and 0.39 ± 0.29 respectively. Jadhav and Khan (1995) estimated the heritability as 0.377 ± 0.07 for first lactation milk yield in various Holstein x Sahiwal grades.

Estimates of heritability of milk yield of crossbred cows in Kerala were found to be very low. Deriaz (1981) reported that heritability estimate of milk yield of cattle of Kerala as 0.077 and Chacko (1992) suggested that the possible reason for low heritability in crossbreds were due to heterogeneous genetic group, small herd size and variation in the management level. Radhika (1997) reported that the heritability of milk yield in crossbred cattle of Kerala as 0.169 ± 0.240. Deb *et al.* (1998) estimated the heritability of milk yield of crossbred cattle of Kerala as 0.086 ± 0.028 whereas Hiremath and Stephen (2000) observed a zero estimate and opined that the very low heritability estimate from the field data could be attributed to the wide fluctuations in the management of cows even within a centre / place.

2.4 AIDS TO SELECTION

Lush (1947) first derived optimal weighting coefficient for selection based on individual record and family average and concluded that selection on such a combined score was never less efficient than selection based on the individual records only.

Jardine (1958) presented formulas for the regression coefficients, simple or partial, of the genetic value of an individual on the various mean phenotypic values of its relative and for the relative selective advance from the use of those means. These formulae being derived on the assumption that phenotypic value was due to independent additive factors with random and non random, non interacting environmental effects.

By paying reasonable amount of attention to the relatives, it may be possible to increase the accuracy of selection more than enough to offset the decrease in the intensity of selection for individual merit (Lush, 1958).

Young (1961) investigated the use of records of the dam and the sire in various combinations with the record of the individuals, sibs average and progeny average. Explicit formulas for 16 different combinations were given. This index was desirable to select animals early in life or when additional accuracy was required. Records of the dams in combination with other information are particularly useful in selection for sex-limited characters. The accuracy of estimation of an animal's breeding value could be increased by using its relatives' records.

Owen (1974) and Dempfle (1975) had compared progeny testing and sib testing and confirmed that only small differences exist between the two methods. In the early stages, sib testing can even be advantageous, since progeny testing entails a longer time lag before bearing the result (Owen, 1974).

The progress possible with half-sib testing could be quite large and in cattle breeding it need not be much smaller than progress by progeny testing. The genetic progress per year with half-sib test was little less than with progeny testing, but the cost should be reduced, since no long-term conservation of sperm or the laying off of bulls were necessary (Pirchner, 1983).

Skjervold and Langholz (1964) found heavy use of young bulls was advantageous since it permits strong selection of bull sires. Genetic progress can be manipulated by changing its four components: selection intensity, genetic variability, generation interval and accuracy. Altering the first three of these components frequently was difficult or even impossible in the short run; it was improvement in accuracy on which most attention was focused. In general aids to selection become necessary if (a) they permit early selection eg. by the use of pedigree information; (b) the accuracy of selection is improved, eg. by repeated measurement or progeny testing. The improvement in estimation of breeding value can be achieved in two ways: by reduction or removal of non-genetic influences and by considering the relatives, which share genes with the candidate. Non-genetic influences are taken care of basically in two ways: (a) standardization of the environmental influences, and (b) reduction of random errors by repeated measurements (Pirchner, 1983).

Wiggans and Powell (1984) opined that reliability of prediction of daughter performance could be improved with information on ancestors especially if progeny size is less.

VanVleck *et al.* (1987) described the following properties for selection index.

1. Average squared error of prediction should be minimized.
2. The accuracy of evaluation should be maximized.
3. The probability of correctly ranking the animals for additive genetic value should be maximized
4. The average additive genetic value of the selected animals should be maximized.

The selection index to predict the additive genetic value of animal has the general form of

$$A=b_1X_1+b_2X_2+\ldots\ldots\ldots\ldots+b_nX_n$$

where X's are averages of adjusted records of animals and /or its relatives and the b's are the selection index weighting factor (VanVleck *et al.*, 1987).

The use of information from relatives was of great importance in the application of selection to animal breeding, for two reasons. First, the characters to be selected were often ones of low heritability, and with these the mean value of a number of relatives often provide a more reliable guide to breeding value than the individual's own phenotypic value. And, second, when the outcome of selection was a matter of economic gain even quite a small improvement of the response will repay of applying the best technique (Falconer and Mackay, 1996).

Pandit (2002) suggested that selection of young bulls for progeny test based on their sister's performances should be explored in India.

2.5 SIRE EVALUATION

Edwards (1932) discussed the merits and demerits of different sire evaluation methods. Various indices discussed by him were

1. Sire Index: (Daughter's average – Dam's average production)
2. Sire Index: (2*Daughter's average – Dam's average production). This index was based on the assumption that daughter's average was intermediate to that of their sire's and dam's hereditary.
3. Sire = $A+(n/(n+2))(2\,d-D-A)$

where, A = Population mean yield

n = Number of Dam-Daughter pair

d = Daughter's average yield

D = Dam's average yield

4. Mount Hope index: It was suggested by Goodale (1927) and was used at Mount Hope farm. When daughter's performance exceed their dam's performance then, Milk Index = D + 0.429(D-d) whereas when dam's performance exceeded their daughter's performance,

Milk Index = D - 2.33(d-D)

where D = Daughter's average

d = Dam's average

5. Simple Average Index

Sire Index = Average production of daughters.

In Contemporary Comparison (CC), bull's daughters were compared with daughters of other bulls having their first lactation in the same herd and the same year, thus avoiding age corrections and special measures for the elimination of herd effects. For each herd, the difference was calculated between the average yield of the bull's daughters, Y, and their contemporaries, H, and each difference was weighted according to the harmonic mean of the number of daughters, n_1, and their contemporaries, n_2, in the same herd: the weighted factor $W=(n_1*n_2) / (n_1+n_2)$. The weighted differences were added and their sum was divided by the sum of the weights: $\Sigma W (Y-H)/ \Sigma W$ is the contemporary comparison (CC) index. The number of 'effective daughters' is ΣW and the breeding value is 2b (CC). The proposed index was termed as relative breeding value (RBV).

$$\text{RBV} = \frac{(2b\,(CC) + 0.2\,(A-P) + P)^{*}\,100}{P}$$

Where, A and P were the average of herds and population respectively. b was the regression coefficient for yield of predicted bull's daughters on yield of his actual daughters and was calculated as

$$b = \frac{0.25\;h^2\;\Sigma W}{1+(\Sigma W-1)0.25\,h^2}$$

Mc Arthur (1954) refined the method, that aimed for calculating the relative genetic value (RGV).

$$\text{RGV} = \frac{(2b(Y-H) + h^2_A\,(A-B) + B)\,100}{B}$$

where Y, H, A and B were the averages of daughters, contemporaries of daughters, herd and breed for the country respectively, b was regression of future daughters on those tested, and h^2_A was heritability of herd average for milk yield.

The advantage of contemporary comparison is that age correction can be avoided since the daughters of the bulls and their stable mates on an average, start their first lactation at same age and the daughters were compared to the contemporaries in the same herd (Robertson *et al.,* 1956). However in small herds there may not be enough contemporaries to compare the daughters of the test bulls.

Krishnan (1956) proposed corrected daughter's average or corrected index as

$$S = D - b(M - A)$$

S = Sire index

D = Daughters average

A = Herd average

M = Dams average

B = Intrasire regression of daughters on dams production

Searle (1964) reviewed sire proving method in New Zealand, Great Britain and New York state and reported that significant change in the method of progeny testing by discarding daughter dam comparison in favour of comparing daughters with their herd mates. Contemporary comparison or sometime stable-mate comparison were first used on a wide spread scale in New Zealand in 1950. With refinement added in 1957, they were introduced in Great Britain in 1954 and were also used in New York state at about the same time. The paper discussed principles of progeny testing based on contemporary comparison and presented details of the method used in these places.

Sunderesan *et al.* (1965a,b) proposed "Dairy Search Index" which according to them suits best to Indian conditions.

$$I = U + (n/n+12)(D - C_A) - b(M - C_{MA})$$

where,

U = Herd average

D = Daughters average

C_A = Contemporary average for daughters

M = Dam's average

C_{MA} = Contemporary dam's average

b = Intrasire regression of daughters on dam

n = Number of daughters

Jain and Malhotra (1971a) suggested the following nine indices in which they compared efficiency of indices using a data set of 17 bulls of Kangayam breed having progenies calved over a period of 30 years (1922-1952) at Livestock Research Station, Hosur. The average progeny group size was 18.9 ranging from six to fifty four. The different indices examined by them were,

1. $I_1 = A+2(D-A)$
2. $I_2 = 2D-M$
3. $I_3 = A+2[[D-b(M-A)]-A]$
4. $I_4 = A+2(D-C_D)$
5. $I_5 = A+0.5h^2 Q(D-A)$
6. $I_6 = A+0.5h^2 Q(D-C_D)$
7. $I_7 = A+0.5h^2 Q[(D-A)-b(M-A)]$

8. $I_8 = A + 0.5h^2 Q[(D - C_D) - b(M - C_M)]$

9. $I_9 = A + (2n/(n+12))(D - C_D)$

10. $I_{10} = A + (2n/(n+12))[(D - C_D) - b(M - C_M)]$

where, A = Population average

D = Average yield of daughters

C_D = The average of contemporary daughters

C_M = The average of contemporary dams

B = The regression coefficient of daughters yield on that of dam

Q = $n/(1+(n-1)h^2/4)$

Daughters' average performance based on unadjusted data is the simplest method to compute and is preferred by many workers (Powell *et al.*, 1972; Gandhi and Gurnani, 1991 and Murida and Tripathi, 1992).

Mixed model approach for sire evaluation though known earlier, became popular after 1976. Since then a lot of improvement had taken place. Efforts to increase the accuracy of Best Linear Unbiased Prediction (BLUP) were being made through inclusion records of relative and removal of the bias due to selection. With BLUP approach, it is possible to evaluate bulls without records of its daughters (Henderson,1975). The BLUP method eliminates biases due to genetic and non-genetic trends, differences between AI sires and non random distribution of sires among herds (Everett, 1974).

Slanger and Henderson (1975) suggested that BLUP estimate was not seriously affected by incorrected ratio within certain limits. Perfect adjustment for non-genetic and management effects are not known, so BLUP procedure could be used to adjust these effects and to predict additive genetic value simultaneously (VanVleck *et al.*, 1987).

In India, the least squares method has been used commonly for analysis for animal breeding data. On the basis of suggestion from Jawaharlal Nehru Krishi Viswa Vidyalaya (JNKVV), Jabalpur, the Department of Agricultural Research and Education, Govt. of India in the annual report of 1989-90, recommended that progeny testing data should be evaluated by the LS method using a model with effects of herd-year-season of calving, genetic group of dam and sires as fixed effects, and sire within genetic group and genetic error both as random effect.

Tajane and Rai (1990) ranked Sahiwal and HF sires least squares and BLUP methods and reported that BLUP method was the best method.

Chauhan (1991) reviewed the efficiency of following procedures used for genetic evaluation of cattle and buffalo bulls in India.

1. Equivalent parent or intermediate index (I_1) = 2D- M
2. Simple daughter average index (I_2) = D
3. Corrected daughter average index(I_3) = D-b(M-A)
4. Dairy search index (I_4)
5. I_5 =A+2(D-A)
6. I_6 =A+2[[D-b(M-A)]-A]
7. I_7 =A+2(D-C_D)
8. I_8 =A+0.5h^2 Q(D-A)

9. $I_9 = A + 0.5h^2 Q(D - C_D)$

10. $I_{10} = A + 0.5h^2 Q[(D - A) - b(M - A)]$

11. $I_{11} = A + 0.5h^2 Q[(D - C_D) - b(M - C_M)]$

12. $I_{12} = A + (2n/(n+12))\,(D - C_D)$

13. $I_{13} = A + (2n/(n+12))\,[(D - C_D) - b(M - C_M)]$

14. $I_{14} = A + 0.5h^2 Q(D - b(M - A) - A)$

15. $I_{15} = A + 0.5h^2 Q((D - C_D) - (M - C_M))$

In this review Chauhan suggested that effort should be made to use the BLUP procedure for evaluation of cattle and buffalo bulls in our country, since other procedures are obsolete.

Because relationships among animals across the generation can be included in the model, the animal model can account for the change in the genetic mean and variance and is the optimal way to analyze data from selection experiments (Falconer and Mackay, 1996).

Dalal *et al.* (1999) estimated the breeding value of Hariyana bulls for first lactation and life time traits using BLUP in which year-season of calving and sire genetic group as fixed effects and sire within genetic group as random effects. Ranks of sires for different traits revealed that 4-5 per cent of sires almost had similar rank for first lactation and life time traits.

2.6 COMPARISON OF SIRE INDICES

2.6.1 Accuracy

The progeny test can become more accurate than a pedigree estimate in a population, when there are more than three offsprings. But this depends on whether the individual merits of the offspring are certainly known as the individual merit of the ancestors, on how much environment the offspring have had in common and on how much variation among the ancestors has already been reduced by selection among them (Lush, 1958).

VanVleck *et al.* (1987) reported that in progeny testing accuracy of prediction would approach to one as the number of progeny becomes large. He also opined that effort made to increase the accuracy of prediction results in a decrease in selection intensity.

The accuracy of KLD Board method is n/(n+k) where k is the ratio of error to sire components of variances (σ^2_e / σ^2_s) (Deb *et al.*, 1998).

Raheja (1992) opined that the methods based on deviations of the daughters records were inferior to the method based on least squares and Mixed model methodology in terms of accuracy.

2.6.2 Correlations

Chauhan (1991) opined that least squares method is not an optimum and efficient method for evaluation of sires because it has several undesirable properties of evaluation of progeny test data.

Raheja (1992) compared six methods of sire evaluation using data consisting of 556 first lactation milk yield records of three Sahiwal herds. The methods compared were Simple Daughter Average (SDA), Herd Mate Comparison (HMC), CC, Ordinary Least Squares (OLS), Regressed Least Squares (RLS) and BLUP. The model used to evaluate sires included the fixed effect of farm, year-season of calving and random effect of sire within farm. Rank and product-moment correlation were used to assess relative efficiency of different methods. He reported that BLUP had high product-moment correlation with HMC, CC, OLS and RLS whereas medium rank correlation with HMC, CC and OLS.

Singh *et al.* (1992) reported high rank correlation between least squares and BLUP method.

Vivekanandan (1994) reported that rank correlation between least squares and BLUP methods was 0.42 or less whereas the rank correlation between BLUP methods were 0.97.

Gokhale and Mangurkar (1995) studied data on 4185 lactations in Holstein crossbreds. The estimated sire merit was calculated using different sire evaluation methods viz. SDA, HMC, CC, LS and BLUP. The product-moment and rank correlations between different methods ranged from 0.7101 to 0.9297.

Radhika (1997) and Delukar and Kothekar (1999) reported that ranking of sires in SDA and LS were almost similar.

Parekh and Singh (1989), Delukar and Kothekar (1999), and Dhaka and Raheja (2000) reported low correlation between BLUP and LS.

2.6.3 Standard Error (SE)

Singh *et al.* (1992) compared different methods of sire evaluation using the first lactation records of 867 purebred progenies of 88 Hariyana bulls in three farms viz. Madhurikund, Babugarh and Mathuram. BLUP, Least Squares (LS), Simple Regressed Least Squares (SRLS) and CC methods were used for comparison. BLUP method was found to be more efficient because the estimated predicted errors by BLUP were smaller than LS method and correlation between BLUP predictions of part and complete lactation yields were highest followed by the predictions from LS, SRLS and CC method.

Raheja (1992) reported that there were very small changes in the rank of the first six to eight per cent top sires under different methods (SDA, HMC, CC, OLS, RLS and BLUP). OLS, RLS and BLUP were the most accurate methods, as estimate of sire merit obtained from these methods followed normal distribution. He suggested that BLUP can be recommended in a situation were correct ratio of residual to sire variance is known, whereas OLS can be recommended in a situation where ratio of residual variance is unknown.

Vivekanandan (1994) reported the average standard error of LS, BLUP-1 and BLUP-2 was 103.99, 79.90 and 79.08 respectively.

Kuralkar *et al.* (1995) opined that BLUP ranking could be considered as more efficient due to minimum range between lowest to highest sire values. The BLUP-2 was considered more efficient than BLUP-1 because standard error of prediction was small and error mean sum of squares was minimum for the former.

Gokhale and Mangurkar (1995) reported that the standard error of sire estimate for BLUP was least when compred to SDA or LS.

Deb *et al.* (1998) studied 2623 crossbred cows born out of 56 sires under field conditions in Kerala state, extended over a period of eight years and compared daughters average, contemporary group formed within group and AI centre and LS method presently used in Kerala by KLDB. Contemporary comparison and daughters average methods were found to be less efficient in field than other methods and they suggested LS method as the best method.

Tailor *et al.* (2000) compared different sire evaluation techniques viz HMC, CC, LS, RLS and found that LS, RLS and BLUP were superior to HMC and CC.

Materials and Methods

3. MATERIALS AND METHODS

3.1 GENERAL APPRAISAL OF DATA

3.1.1 Source of Data

The data used in the present study were collected from progeny testing scheme of Kerala Livestock Development Board (KLD Board). KLD Board has been undertaking field progeny testing and sire evaluation programme since 1977 to evaluate the genetic potential of young crossbred bulls in collaboration with Animal Husbandry Department of Kerala and with complete financial assistance from Government of India. At present, there are six progeny testing units viz Mavellikkara I, Mavellikkara II, Kottayam, Kanjirappally, Vaikom and Kattappana. These areas were selected due to their geographical diversity and dense crossbred population. Geographically Kerala can be divided into three areas or Zones viz coastal area, mid land and highranges. Each progeny testing unit is headed by an Assistant Manager and assisted by one or two supervisors. These six progeny testing units are coordinated and controlled by Manager, Muvattupuzha.

3.1.2 Breeding, Feeding and Management

The cows under the jurisdiction of each artificial insemination centres are inseminated with frozen semen of test bull at random. The distribution of test inseminations were arranged in such a way that the resultant calving occurred through out the year and across the regions. In these centres semen of test bulls and proven bulls were only made available for insemination. Proven bull's semen was used for inseminating the selected elite cows of that area to produce next generation young bulls. The AI centres were under the control of Animal Husbandry Department, milk society, or by private agencies.

Animals in the field are fed with oil cakes, compounded feed, green grass and paddy straw. Some farmers gives cotton seed also to the lactating cows.

Weaning of calves is not practiced by the farmers. The calves are allowed to suckle before milking since it helps letting down of milk.

3.1.3 Quantum of Data

Twenty five bulls belonging to seventeenth and eighteenth batch of progeny testing scheme were selected based on the availability of records of their dams, half-sibs and progenies. Bulls with minimum of fifteen progeny and ten half-sibs were considered for the present study. There were 847 records of progeny and 365 records of half-sibs. The progenies and half-sibs were distributed in 43 AI centres under six progeny testing units.

3.1.4 Type of Data

The present study was based on standard first lactation milk yields of progenies and half-sibs of the test bulls in the field progeny testing scheme of KLD Board. Milk yields of these animals in the field are recorded both in morning and evening once in every months. From these recordings at monthly intervals, 305-day lactation yield of each animal was estimated by centering a date method (O'Conner and Lipton, 1960). Animals with lactation length of less than 280 days were removed from the present study and milk yield for 305 day or less was taken as standard lactation milk yield for making various analysis. Information of bulls such as identification number, sire, dam, and dam's yield and details of progenies and half-sibs of each bull such as first lactation yield, date of birth, date of calving, sex of calf, were collected.

3.1.5 Classification of Data

The bulls under study were numbered from one to twenty five and sires of bulls were numbered from twenty six to thirty three. The lowest number of progeny (15) was for sire number 3661.Classification of sires along with number of progenies and half-sibs is presented in Table. 3.1.

Table. 3.1. Classification of sires along with number of progenies and half-sibs

Serial number	Bull number	Sire code	Number of progeny	Number of half-sibs
1	3436	SIRE 1	33	90
2	3440	SIRE 2	38	43
3	3444	SIRE 3	24	12
4	3529	SIRE 4	27	43
5	3563	SIRE 5	44	12
6	4355	SIRE 6	55	90
7	3661	SIRE 7	15	46
8	3688	SIRE 8	44	12
9	3703	SIRE 9	25	43
10	3718	SIRE 10	19	12
11	3732	SIRE 11	41	12
12	3827	SIRE 12	26	68
13	3987	SIRE 13	35	68
14	3994	SIRE 14	34	68
15	4057	SIRE 15	21	68
16	4135	SIRE 16	22	56
17	4146	SIRE 17	53	68
18	4158	SIRE 18	44	56
19	4159	SIRE 19	55	43
20	4167	SIRE 20	46	90
21	4205	SIRE 21	31	90
22	4215	SIRE 22	19	38
23	4217	SIRE 23	27	90
24	4301	SIRE 24	41	68
25	4325	SIRE 25	28	68

3.1.5.1 Non-genetic Factors

The data on each sire were classified on the basis of centre, year of calving, season of calving, and age at first calving of progenies and half-sibs.

3.1.5.1.1 Centre

Based on the AI centre in which progeny and half-sibs of each sire belonged the data were classified from one to fourty three. Distribution of progeny and half-sibs of bulls in different AI centers are shown in Table 3.2.

Table 3.2. Distribution of progenies and half-sibs of bulls in different AI centers

Centre code	Centre name	No. of observation
CE 1	Arunnottimangalam	51
CE 2	Charumood	45
CE 3	Lakkattor II	11
CE 4	Chennithala	25
CE 5	Cheriyanadu	41
CE 6	Harippadu	30
CE 7	Kannamangalam	11
CE 8	Kuttor	19
CE 9	Elamkulam	20
CE 10	Mavelikara	17
CE 11	Kanjirappally	11
CE 12	Muttam	18
CE 13	Noornadu I	10
CE 14	Pallickal	20
CE 15	Pandalam	19
CE 16	Pathiyoor	43
CE 17	Peringala I	22

Table 3.2 continued

Centre code	Centre name	No. of observation
CE 18	Mundakkayam	12
CE 19	Paika	11
CE 20	Perumpanachy	36
CE 21	Vettiyar I	46
CE 22	Mattukatta	28
CE 23	Kochara I	51
CE 24	Chakkupallam	46
CE 25	Lebbakkada	17
CE 26	Ponkunnam	48
CE 27	Kallara	29
CE 28	Kattappana I	19
CE 29	Peringala II	41
CE 30	Kandallor	46
CE 31	Thalayazhum	32
CE 32	T.V.Puram	19
CE 33	KS Mangalam II	34
CE 34	Ayarkunnam	33
CE 35	Vechoor II	16
CE 36	Kurichy	60
CE 37	Manarcadu	22
CE 38	Kochara II	28
CE 39	Puthuppally	29
CE 40	Kumaranalloor	29
CE 41	Mannar I	17
CE 42	Mannar II	26
CE 43	Noornadu II	24
Total no. of observations		1212

3.1.5.1.2 Year of Calving

The whole duration of 1992 to 2001 was classified into 10 years and classification of data and number of observations in each year is presented in Table. 3.3.

Table. 3.3. Classification of data and number of observation based on year of calving

Year of calving	Year code	Number of observations
1992	YR 1	22
1993	YR 2	76
1994	YR 3	72
1995	YR 4	78
1996	YR 5	76
1997	YR 6	86
1998	YR 7	252
1999	YR 8	313
2000	YR 9	167
2001	YR 10	70
Total no of observations		1212

3.1.5.1.3 Age at First Calving (AFC)

The progenies and half-sibs were grouped into five age groups based on their AFC. Classification of data based on different age groups is presented in Table. 3.4.

Table. 3.4. Classification of data based on different age group

Serial number	Age group	Age at first calving code	Number of observation
1	Less than 2 ½ years	AFC 1	152
2	2 ½ - 3 years	AFC 2	315
3	3 -3 ½ years	AFC 3	333
4	3 ½ - 4 years	AFC 4	228
5	Above four years	AFC 5	184
Total number of observations			1212

3.1.5.1.4 Season of Calving

The whole year was divided into two seasons as done by Stephen *et al.* (1985)

a) SE 1 - Dry season - This included November, December, January, February, March and April

b) SE 2 - Rainy season – This included May, June, July, August, September and October.

3.2 ANALYTICAL METHODS

3.2.1 Least Squares Analysis of Variance

The significant source of non-genetic variation was detected by least squares analysis of variance (Harvey, 1986). To study the effect of non-genetic factors on milk yield, the model used was

$$Y_{ijklm} = \mu + C_i + Y_j + Se_k + A_l + e_{ijklm}$$

Y_{ijklm} = The observation of mth cow belonging to ith centre, calved in jth year, calved in kth season, and lth age at first calving

μ = Over all mean

C_i = effect of to ith centre (i = 1,.........,43)

Y_j = effect of to jth year (i = 1,..........,10)

Se_k = effect of to kth season (k =1,2)

A_l = effect of to lth age at first calving (l = 1,....., 5)

e_{ijklm} = Random error associated with Y_{ijklm}. Random error were assumed to be independently and normally distributed with mean zero and variance, σ^2_e.

Progeny and half-sibs data were pooled and then used for least squares analysis of variance to estimate the non-genetic influence on first standard lactation yield. The standard programme LSML (Harvey, 1986) was used for computation.

3.2.2 Adjustment of Records

For the efficient genetic analysis, adjustment of data for non-genetic effects was needed. The data were adjusted for significant non-genetic factors.

3.2.3 Heritability

Heritability of first lactation milk yield was studied on adjusted data. Having obtained a very low value, heritability was estimated on raw data also by paternal half-sib method using model 2 of standard programme Least Squares Maximum Likelihood (LSML) (Harvey, 1986).

Model 2;

$$Y_{ij} = \mu + S_i + e_{ij} \text{ \\ BETWEEN = 0.25 WITHIN 0.75}$$

where, Y_{ij} = Observation on j^{th} progeny on i^{th} sire

μ = Over all mean

S_i = Effect of i^{th} sire assumed to be random with mean zero and variance, σ^2

e_{ij} = Random error of each observation

Table 3.5. Analysis of variance for estimation of heritability

Source	DF	MSS	EMS
Between sires	S-1	MS_s	$\sigma^2_e + K^* \sigma^2_s$
Progeny within sire	N-S	MS_e	σ^2_e

where,

$$K = \frac{1}{S-1}\left(N - \Sigma n_i^2/N\right)$$

K = Average number of progeny per sire

S = Number of sires

Σn_i = Number of progeny within ith sire

N = Total number progenies

σ^2_s = Sire component of variance

σ^2_e = Variance among progeny within sire

$\sigma^2_s = (MS_s - MS_e) / K$

t = Intraclass correlation between half-sibs

$t = \sigma^2_s / (\sigma^2_s + \sigma^2_e)$

Heritability (h^2) = 4 t

The standard error of heritability was estimated by the following formula given by Swiger *et al.* (1964).

$$SE(h^2) = 4\sqrt{\frac{2(N-1)(1-t)^2[1+(K-1)t]^2}{K^2(N-S)(S-1)}}$$

3.2.4 Sire Evaluation, Estimation of Breeding Value and Ranking of Bulls

Breeding Value (BV) of sires were computed using the following ten methods

I_1 = Based on records of performance of dam (M)

I_2 = Based on performance of paternal half-sibs (HS)

I_3 = Based on performance of dam and paternal half-sibs (M+HS)

I_4 = Based on performance of dam, paternal half-sibs and progeny (M+HS+P)

I_5 = Simple daughter average (SDA)

I_6 = Contemporary comparison (CC)

I_7 = Least squares method (LS)

I_8 = KLD Board method

I_9 = Best Linear Unbiased Prediction without considering relationship of sires (BLUP-1)

I_{10} = Best Linear Unbiased Prediction with considering relationship of sires (BLUP-2)

The records of progenies and half-sibs adjusted for non-genetic factors were used for estimation of sire indices HS, M+HS, M+HS+P, LS and KLD Board method and non adjusted data were used for M, SDA, CC, BLUP-1 and BLUP-2 .

3.2.4.1 Based on Records of Performance of Dam

The estimated sire merit (ESM) based on performance of dam was estimated as described in manual of quantitative genetics (Becker, 1984)

$I_1 = 0.5\,h^2D$

D = Deviation of dam's yield from its population

h^2 = heritability

Accuracy of the estimate was calculated using following formula as described by VanVleck *et al.* (1987).

$$\text{Accuracy, r} = \sqrt{h^2}\,/\,2$$

3.2.4.2 Based on Performance of Paternal Half-sib

The estimated sire merit based on performance of paternal half-sibs was estimated using the following formula described by VanVleck *et al.* (1987). The data were adjusted for significant non-genetic effects and was used for estimation.

$$I_2 = \left(\frac{nh^2}{4+(n-1)\,h^2}\right) S$$

where, n = number of daughters

h^2 = heritability

$S = S_i - S_2$

S_i = Least Squares mean of paternal half-sibs first lactation yield of i^th^ bull

S_2 = Overall mean of paternal half-sibs first lactation yields

Accuracy (r) of the estimate was calculated as described by VanVleck *et al.* (1987)

$$r = 0.25\sqrt{\frac{nh^2}{1+(n-1)0.25h^2}}$$

3.2.4.3. Based on Performance of Dam and Paternal Half-sibs

The estimated breeding value based on performance of dam and paternal half-sibs was estimated using following formula described by Young (1961). The adjusted data for significant non-genetic factors were used for estimation.

$$I_3 = 0.5\,h^2 {*} D + 0.25\,h^2 N {*} S$$

where,

N = $n / [1+(n-1)t]$

n = number of half-sibs

t = $0.25\,h^2$

h^2 = heritability

D = Deviation of dam's yield from its population

S = $S_i - S_2$

S_i = Least Squares mean of paternal half-sib first lactation yield of i^th^ bull

S_2 = Overall mean of paternal half-sib first lactation yields

Accuracy (r) of the estimate was calculated using following formula as described by Young (1961).

$$r = 0.25h\sqrt{4+N}$$

where

h^2 = heritability

N = $n / [1+(n-1)t]$

n = number of half-sibs

t = $0.25\,h^2$

3.2.4.4 Based on Performance of Dam, Paternal Half-sibs and Progeny

The estimated breeding value based on performance of dam and paternal half-sib was estimated using following formula described by Young (1961). The records of progenies and half-sibs were adjusted for non-genetic factors and was used for estimation of breeding value based on performance of dam, paternal half-sib and progeny.

$$I_4 = b_1D + b_2\,S + b_3\,X$$

$$b_1 = \frac{8h^2(4-h^2Q)}{64 - h^4\,Q\,(4+N)}$$

$$b_2 = \frac{4h^2N(4 - h^2Q)}{64 - h^4\,Q\,(4+N)}$$

$$b_3 = \frac{2h^2Q(16 - h^2(4+N)}{64 - h^4 Q (4+N)}$$

where

$$Q = \frac{q}{1 + (q-1)t}$$

q = number of progeny

N = $n / [1+(n-1)t]$

n = number of half-sibs

t = $0.25\ h^2$

h^2 = heritability

D = Deviation of dam's yield from its population

S = $S_i - S_2$

S_i = Least squares mean of paternal half-sib first lactation yield of i^{th} bull

S_2 = Overall mean of paternal half-sib first lactation yields

X = $X_1 - X_2$

X_1 = Least squares mean of daughters first lactation yields

X_2 = population Least squares mean

Accuracy (r) of the estimate was calculated using following formula as described by Young (1961).

$$r \quad = \quad h\sqrt{\frac{2[8Q+(4+N)(2-h^2 Q)]}{64-h^4Q(4+N)}}$$

3.2.4.5 Simple Daughter Average (SDA)

Simple daughter average were calculated as described by Edwards (1932).

$$I_5 \quad = \quad \overline{D}$$

where, $\overline{D}$ = daughters average for each sire (on raw data)

3.2.4.6 Contemporary Comparison

The bull's daughters were compared with daughters of other bulls having their first lactation in the same AI centre and the same year. For each centre the difference was calculated between the average yield of the bull's daughters, Y and their contemporaries, H, (progenies of other bulls except the sire under consideration in that AI centre as taken as contemporaries) and each difference was weighted according to the harmonic mean of the number of daughters, n_1, and their contemporaries, n_2, in the same herd: the weighted factor $W=(n_1*n_2)/(n_1+n_2)$. The weighted differences were added and their sum was divided by the sum of the weights: $\Sigma W\ (Y\text{-}H)/\ \Sigma W$ = the contemporary comparison (CC) index. The number of 'effective daughters' = ΣW and the breeding value was estimated as described by Pirchner (1983).

$$I_6 \quad = \quad 2b\,(CC)$$

$$CC \quad = \quad \Sigma W\,(Y\text{-}H)/\,\Sigma W$$

$$W \quad = \quad (n_1*n_2)\,/\,(\,n_1+n_2)$$

b was the regression coefficient for yield of predicted bull's daughters on yield of his actual daughters and was calculated as

$$b = \frac{0.25 \ h^2 \ \Sigma W}{1+(\Sigma W-1)0.25\, h^2}$$

3.2.4.7 Least Squares Method

The data were adjusted for significant non-genetic factors and then effect of sire was estimated using following model.

$$Y_{ij} = \mu + S_i + e_{ij}$$

where Y_{ij} = Observation on j^{th} progeny on i^{th} sire

μ = Over all mean

S_i = Effect of i^{th} sire assumed to be random with mean Zero and variance, σ^2

e_{ij} = Random error of each observation

The standard programme LSML (Harvey, 1986) was used for computation. The sire effect derived by this model were doubled to get the estimated breeding value.

3.2.4.8 KLD Board Method

The data were adjusted for significant non-genetic factors and then used for estimation of breeding value (I_2)

$$I_8 = \frac{2^* n \quad ((X_1-X_3)+0.2(X_2-X_3))}{n+k}$$

where,

X_1=Least squares mean of daughters First lactation yields

X_2= Least squares mean of three best centers

X_3= population Least squares mean

n = number of daughters

$k = (4 - h^2) / h^2$

h^2 = heritability.

Accuracy of the estimate was calculated using following formula

$$r = \sqrt{n / (n+k)}$$

n = number of daughters

$k = (4 - h^2) / h^2$

Where h^2 is the heritability

3.2.4.9 Best Linear Unbiased Prediction (BLUP) Without Considering Relationship of Sires (BLUP-1)

The set of normal equations were prepared as outlined by Henderson (1975) and VanVleck (2003). The following mathematical model was assumed

$$Y = X\beta + Zs + e$$

where, $Y = n \times 1$ vector of observable milk yield

$\beta = p \times 1$ vector of the fixed effect (centre and year)

$s = q \times 1$ vector of transmitting abilities (0.5 genetic value of sire)

$X = n \times p$ incidence matrix which associate elements of β with Y.

$Z = n \times q$ incidence matrix which associate elements of s with Y.

e = Vector of random error with mean zero and variance $\sigma^2 e$

$$\begin{pmatrix} X^1X & X^1Z \\ X^1Y & Z^1Z + I\lambda \end{pmatrix} \begin{bmatrix} \beta \\ s \end{bmatrix} = \begin{pmatrix} Z^1X \\ Z^1Y \end{pmatrix}$$

Where, I is the identity matrix with order equal to that of Z.

$$\lambda = \sigma^2 e / \sigma^2 s$$

$\sigma^2 e / \sigma^2 s = (4 - h^2) / h^2$, was added to the diagonal elements of the sire equations to assume the mixed model. The random sire effects from this model were doubled to obtain the estimated breeding value by BLUP –1.

Accuracy and standard error were estimated as described by Morde (1996).

$$\text{Accuracy, r} = \sqrt{1 - d_1 * \lambda}$$

$$\text{Standard error, SE} = \sqrt{d_i * \sigma^2 e}$$

where d_i is the i^{th} diagonal element of the inverse matrix

3.2.4.10 Best Linear Unbiased Prediction (BLUP) Considering Relationship of Sires (BLUP-2)

BLUP-2 is the BLUP–1 with numerator relationship matrix. The model considered the additive genetic relationship among sires along with BLUP-1 model.

The inverse of numerator relationship matrix was multiplied with $\sigma^2 e / \sigma^2 s$ and then added to the Z matrix of BLUP – 1. The random sire effect from this model were doubled to obtain the estimated breeding value by BLUP –2.

Accuracy and standard error were estimated as described by Morde (1996).

3.2.5 Comparison of Sire Indices

In order to rank the superior and relatively efficient index, the following criteria were considered.

1. Accuracy of indices
2. Correlations
3. Standard error of indices

3.2.5.1 Accuracy of Sire Indices

Accuracy of different indices were estimated as per the formulae already explained along with different indices.

3.2.5.2 Correlations

3.2.5.2.1 Rank Correlation

Rank correlation among different sire indices were estimated as described by Steel and Torrie (1960). The following formula was used for estimation of rank correlation.

$$R = 1 - [(6\Sigma d_i^2) / n\,(n^2 - 1)]$$

Where $d_i = R1_i - R2_i$: the difference of rank in two indices of a sire.

3.2.5.2.2 Product-moment Correlation

Product-moment correlations among different sire indices were estimated as described by Steel and Torrie (1960).

3.2.5.3 Standard Error (SE) of Indices

Standard errors of SDA, LS, KLD Board, BLUP-1 and BLUP-2 were estimated. The Standard error of KLD Board method was estimated as done by Deb *et al.* (1998). Standard errors of BLUP-1 and BLUP-2 were estimated as described by Morde (1996).

Results

4. RESULTS

4.1 MILK YIELD

The overall arithmetic mean of first lactation milk yield of progenies and half-sibs of the bulls considered was found to be 2311.3 ± 20.00 kg. The mean 305-day milk yields of progeny was 2389.0 ± 23.46 kg whereas that of half-sibs was 2131.0 ± 36.34 kg. The difference in milk yield of progeny and half-sibs was statistically significant.

4.2 NON-GENETIC FACTORS AFFECTING MILK YIELD

The least squares analysis of variance of non-genetic factors affecting first lactation 305-day milk yield is presented in Table 4.1. The analysis revealed that different centres and year of calving exerted significance effect on first lactation milk yield whereas season of calving and age at first calving was non-signifiant.

Table 4.1. Least squares analysis of variance for non-genetic effect on 305-day first lactation milk yield of crossbred cattle in Kerala

Source	D.F.	SS	MSS	F	P
CE	42	125012833.83	2976496.04 **	7.96	0.00
YR	9	17968546.62	1996505.18 **	5.34	0.00
SE	1	433525.76	433525.76	1.16	0.28
AFC	4	3354812.69	838703.17	2.24	0.06
REMAINDER	1155	431821321	373871.274		
TOTAL	1212	586854785.24			

** $P \leq 0.01$

Mean = 2311.3 kg

Error standard deviation = 611.45

Coefficient of variation = 26.46

R squared = 0.264.

4.2.1 Centre

The centre-wise average 305-day first lactation milk yields are given in Table 4.2. The highest average first standard lactation milk yield (3111.3 ± 133.74 kg) was in Manarcadu and the highest second was in Kurichy (3092.8 ± 81.67 kg). Both these places belong to Kottayam progeny testing unit. The lowest average milk yield (1629.95 ± 179.21kg) was in Mundakkayam centre which belongs to Kattappana progeny testing unit.

Table 4.2. Centre-wise least squares means of 305- day first lactation milk yields crossbred cattle in Kerala

Sl.No	Centre name	No. of observation	Mean	±	SE, kg
1	Arunnottimangalam	51	2174.65	±	89.86
2	Charumood	45	1891.41	±	94.37
3	Lakkattor II	11	1966.64	±	187.13
4	Chennithala	25	2420.61	±	124.81
5	Cheriyanadu	41	1849.96	±	99.63
6	Harippadu	30	2035.48	±	113.73
7	Kannamangalam	11	2470.56	±	186.31
8	Kuttor	19	1833.70	±	142.12
9	Elamkulam	20	1976.55	±	138.94
10	Mavelikara	17	2108.49	±	150.22
11	Kanjirappally	11	2157.75	±	187.59
12	Muttam	18	2129.89	±	146.78
13	Noornadu I	10	2634.67	±	196.48
14	Pallickal	20	2012.51	±	139.19
15	Pandalam	19	1897.41	±	142.42
16	Pathiyoor	43	2157.37	±	96.00
17	Peringala I	22	2235.15	±	131.42

Table 4.2 continued

Sl.No	Centre name	No. of observation	Mean	±	SE, kg
18	Mundakkayam	12	1629.95	±	179.21
19	Paika	11	1717.24	±	186.30
20	Perumpanachy	36	2313.40	±	104.09
21	Vettiyar I	46	1978.54	±	94.51
22	Mattukatta	28	2496.39	±	119.73
23	Kochara I	51	2294.91	±	88.90
24	Chakkupallam	46	2009.45	±	92.66
25	Lebbakkada	17	2122.27	±	150.22
26	Ponkunnam	48	2105.85	±	91.51
27	Kallara	29	2038.81	±	118.44
28	Kattappana I	19	2350.89	±	144.60
29	Peringala II	41	2358.54	±	97.45
30	Kandallor	46	2136.51	±	93.14
31	Thalayazhum	32	2196.16	±	110.99
32	T.V.Puram	19	2329.79	±	143.26
33	KS Mangalam II	34	2171.62	±	108.59
34	Ayarkunnam	33	2961.91	±	108.53
35	Vechoor II	16	2517.46	±	156.16
36	Kurichy	60	3092.76	±	81.67
37	Manarcadu	22	3111.31	±	133.74
38	Kochara II	28	2360.02	±	117.53
39	Puthuppally	29	2493.22	±	116.22
40	Kumaranalloor	29	2582.17	±	116.44
41	Mannar I	17	2395.67	±	149.91
42	Mannar II	26	2417.66	±	122.37
43	Noornadu II	24	2221.28	±	127.02

Note: Centre-wise mean were highly significant ($p \leq 0.01$)

4.2.2 Year of Calving

The least squares means of 305-day first lactation milk yields of cows calved in different years are presented in Table 4.3. The effect of year of calving was highly significant. The least squares means for 305-day milk yield, according to different years of calving ranged from 1958.9±77.35 kg in the year 1994 to 2448.7±77.16, kg in the year 2001.

Table 4.3. Year-wise least squares means for 305-day first lactation milk yield of crossbred cattle in Kerala

Sl.No	Year of calving	No. of observation	Mean ± SE, kg
1	1992	22	2224.44 ± 139.63
2	1993	76	2043.48 ± 75.82
3	1994	72	1958.93 ± 77.35
4	1995	78	2120.64 ± 73.22
5	1996	76	2232.68 ± 74.05
6	1997	86	2329.06 ± 71.23
7	1998	252	2263.92 ± 42.06
8	1999	313	2346.24 ± 38.81
9	2000	167	2440.43 ± 51.13
10	2001	70	2448.69 ± 77.16

Note: Year-wise differences were highly significant ($p \leq 0.01$)

4.2.3 Age at First Calving

The least squares means of 305-day milk yield for various groups of age at first calving is shown in Table 4.4. The least squares mean of 305-day milk yield for different age groups ranged from 2180.3 ± 56.39 to 2339.2 ± 40.85 kg. The highest milk yield was in animals that calved in the age between two and a half years and three years while animals calved below two and a half years of age recorded lowest milk yield. However analysis of variance revealed that age at first calving did not influence 305-day milk yield.

Table 4.4. Least squares mean of age at first calving on 305- day milk yield

Sl.No	Age groups	No. of observation	Least squares mean ± SE, kg
1	Less than 2 ½ years	152	2180.27 ± 56.39
2	2 ½ -3 years	315	2339.22 ± 40.85
3	3 - 3 ½ years	333	2224.07 ± 40.38
4	3 ½ - 4 years	228	2246.35 ± 46.11
5	Above 4 years	184	2214.35 ± 52.42

Note: Age group-wise difference were non-significant

4.2.4 Season of Calving

Season of calving did not affect 305-day milk yield. The least squares mean of 305-day first lactation milk yield for the two seasons considered is shown in Table 4.5. The average first standard lactation yield in dry season (November, December, January, February, March and April) was 2221.0 ± 33.45 kg and in rainy season (May, June, July August September and October) was 2260.7 ± 28.97 kg.

Table 4.5. Least squares mean of seasons of calving on 305- day milk yield

Sl.No	Season of calving	No. of observation	Least squares mean	±	SE, kg
1	Dry Season	548	2221.00	±	33.45
2	Rainy Season	664	2260.70	±	28.97

Note: Season-wise difference not significant

4.3 Heritability

Heritability estimate of 305-day milk yield was 0.221 ± 0.077 in the non adjusted data and was used for sire evaluation, whereas heritability when estimated with the adjusted data was 0.08.

4.4.2 Based on Performance of Paternal Half-sibs (HS)

The estimated sire merit based on first lactation milk yield of half-sib is shown in Table 4.7. Sire number five and 11 which are son of grand sire 26 ranked top whereas sire number 12, 13, 14, 15, 17, 24 and 25 of grand sire 33 ranked least.

Table 4.7. Estimated sire merit based on first lactation milk yield of half-sib

Sl. No	Sire code	Grand sire code	No. of half- sibs	Estimated sire merit, kg
1	SIRE 1	28	90	-23.3801
2	SIRE 2	30	43	-28.1533
3	SIRE 3	31	12	-127.9740
4	SIRE 4	30	43	-28.1533
5	SIRE 5	26	12	287.3584
6	SIRE 6	28	90	-23.3801
7	SIRE 7	27	46	36.0700
8	SIRE 8	31	12	-127.9740
9	SIRE 9	30	43	-28.1533
10	SIRE 10	31	12	-127.9740
11	SIRE 11	26	12	287.3584
12	SIRE 12	33	68	-157.1690
13	SIRE 13	33	68	-157.1690
14	SIRE 14	33	68	-157.1690
15	SIRE 15	33	68	-157.1690
16	SIRE 16	32	56	86.4438
17	SIRE 17	33	68	-157.1690
18	SIRE 18	32	56	86.4438
19	SIRE 19	30	43	-28.1533
20	SIRE 20	28	90	-23.3801
21	SIRE 21	28	90	-23.3801
22	SIRE 22	29	38	76.3709
23	SIRE 23	28	90	-23.3801
24	SIRE 24	33	68	-157.1690
25	SIRE 25	33	68	-157.1690

4.4 SIRE EVALUATION

4.4.1 Based on Records of Performance of Dam (M)

The estimated sire merit based on based on milk yield of dam is shown in Table 4.6. Sire number 16 ranked top, sire number six ranked second and sire number 23 ranked last.

Table 4.6. Estimated sire merit based on milk yield of dam

Sl. No	Sire code	Bull number	Estimated sire merit, kg
1	SIRE 1	3436	192.0490
2	SIRE 2	3440	122.2130
3	SIRE 3	3444	84.9745
4	SIRE 4	3529	106.8535
5	SIRE 5	3563	169.2860
6	SIRE 6	4355	352.9370
7	SIRE 7	3661	187.9605
8	SIRE 8	3688	206.9665
9	SIRE 9	3703	184.6455
10	SIRE 10	3718	119.0085
11	SIRE 11	3732	140.4455
12	SIRE 12	3827	198.0160
13	SIRE 13	3987	154.9210
14	SIRE 14	3994	187.9605
15	SIRE 15	4057	100.9970
16	SIRE 16	4135	396.8055
17	SIRE 17	4146	202.7675
18	SIRE 18	4158	123.2075
19	SIRE 19	4159	122.2130
20	SIRE 20	4167	110.5000
21	SIRE 21	4205	90.8310
22	SIRE 22	4215	247.4095
23	SIRE 23	4217	62.8745
24	SIRE 24	4301	176.0265
25	SIRE 25	4325	191.2755

4.4.2 Based on Performance of Paternal Half-sibs (HS)

The estimated sire merit based on first lactation milk yield of half-sib is shown in Table 4.7. Sire number five and 11 which are son of grand sire 26 ranked top whereas sire number 12, 13, 14, 15, 17, 24 and 25 of grand sire 33 ranked least.

Table 4.7. Estimated sire merit based on first lactation milk yield of half-sib

Sl. No	Sire code	Grand sire code	No. of half- sibs	Estimated sire merit, kg
1	SIRE 1	28	90	-23.3801
2	SIRE 2	30	43	-28.1533
3	SIRE 3	31	12	-127.9740
4	SIRE 4	30	43	-28.1533
5	SIRE 5	26	12	287.3584
6	SIRE 6	28	90	-23.3801
7	SIRE 7	27	46	36.0700
8	SIRE 8	31	12	-127.9740
9	SIRE 9	30	43	-28.1533
10	SIRE 10	31	12	-127.9740
11	SIRE 11	26	12	287.3584
12	SIRE 12	33	68	-157.1690
13	SIRE 13	33	68	-157.1690
14	SIRE 14	33	68	-157.1690
15	SIRE 15	33	68	-157.1690
16	SIRE 16	32	56	86.4438
17	SIRE 17	33	68	-157.1690
18	SIRE 18	32	56	86.4438
19	SIRE 19	30	43	-28.1533
20	SIRE 20	28	90	-23.3801
21	SIRE 21	28	90	-23.3801
22	SIRE 22	29	38	76.3709
23	SIRE 23	28	90	-23.3801
24	SIRE 24	33	68	-157.1690
25	SIRE 25	33	68	-157.1690

4.4.3 Based on Performance of Dam and Paternal Half-sibs (M+HS)

The estimated sire merit based on milk yield of dam and paternal half-sibs is presented in Table 4.8. Sire number 11 ranked top, sire number five ranked second whereas sire number 14 ranked last.

Table 4.8. Estimated sire merit based on milk yield of dam and paternal half-sibs

Sl. No.	Sire	No. of half-sib	b1	b2	Estimated sire merit, kg
1	SIRE 1	90	0.1105	0.84034	172.4018
2	SIRE 2	43	0.1105	0.71548	102.0699
3	SIRE 3	12	0.1105	0.41238	32.2007
4	SIRE 4	43	0.1105	0.71548	86.7104
5	SIRE 5	12	0.1105	0.41238	287.7862
6	SIRE 6	90	0.1105	0.84034	168.3133
7	SIRE 7	46	0.1105	0.72901	233.2618
8	SIRE 8	12	0.1105	0.41238	131.8717
9	SIRE 9	43	0.1105	0.71548	98.8654
10	SIRE 10	12	0.1105	0.41238	87.6717
11	SIRE 11	12	0.1105	0.41238	316.5162
12	SIRE 12	68	0.1105	0.79906	29.3330
13	SIRE 13	68	0.1105	0.79906	62.3725
14	SIRE 14	68	0.1105	0.79906	-24.5910
15	SIRE 15	68	0.1105	0.79906	271.2175
16	SIRE 16	56	0.1105	0.76608	268.9902
17	SIRE 17	68	0.1105	0.79906	-2.3805
18	SIRE 18	56	0.1105	0.76608	188.4357
19	SIRE 19	43	0.1105	0.71548	90.3569
20	SIRE 20	90	0.1105	0.84034	71.1838
21	SIRE 21	90	0.1105	0.84034	227.7623
22	SIRE 22	38	0.1105	0.68966	115.5445
23	SIRE 23	90	0.1105	0.84034	156.3793
24	SIRE 24	68	0.1105	0.79906	65.6875
25	SIRE 25	68	0.1105	0.79906	227.3490

4.4.4 Based on Performance of Dam, Paternal Half-sib and Progeny (M+HS+P)

The estimated sire merit based on performance of dam, paternal half-sib and progeny is shown in Table 4.9. Sire number 22 ranked top, sire number 18 ranked second and sire 21 ranked last.

Table 4.9. Estimated sire merit based on milk yield of dam, paternal half-sib and progeny

Sire code	No. of half-sibs	No. of progeny	b1	b2	b3	Estimated sire merit, kg
SIRE 1	90	33	0.0441	0.3354	1.1728	129.3025
SIRE 2	43	38	0.0393	0.2541	1.2598	124.9069
SIRE 3	12	24	0.0494	0.1842	1.0831	23.4582
SIRE 4	43	27	0.0486	0.3146	1.0947	-69.2399
SIRE 5	12	44	0.0333	0.1242	1.3682	83.9678
SIRE 6	90	55	0.0309	0.2353	1.4053	135.0551
SIRE 7	46	15	0.0652	0.4299	0.8016	178.0061
SIRE 8	12	44	0.0333	0.1242	1.3682	-103.1400
SIRE 9	43	25	0.0508	0.3286	1.0565	118.9377
SIRE 10	12	19	0.0560	0.2088	0.9665	-8.0026
SIRE 11	12	41	0.0350	0.1307	1.3373	186.2050
SIRE 12	68	26	0.0504	0.3644	1.0622	-37.9396
SIRE 13	68	35	0.0421	0.3048	1.2079	-69.1494
SIRE 14	68	34	0.0429	0.3104	1.1940	-7.5874
SIRE 15	68	21	0.0564	0.4080	0.9556	21.4515
SIRE 16	56	22	0.0548	0.3800	0.9843	10.2080
SIRE 17	68	53	0.0315	0.2279	1.3956	171.6646
SIRE 18	56	44	0.0359	0.2486	1.3193	217.4845
SIRE 19	43	55	0.0300	0.1946	1.4225	-77.8267
SIRE 20	90	46	0.0353	0.2686	1.3280	107.0822
SIRE 21	90	31	0.0458	0.3485	1.1423	-193.8770
SIRE 22	38	19	0.0583	0.3637	0.9237	307.6007
SIRE 23	90	27	0.0497	0.3779	1.0741	66.7873
SIRE 24	68	41	0.0379	0.2743	1.2822	-52.1276
SIRE 25	68	28	0.0483	0.3493	1.0991	57.9685

4.4.5 Simple Daughter Average (SDA)

Simple daughter average of all sires is presented in Table 4.10. Sire number 23 ranked top, sire 3 ranked second and sire 10 ranked last.

Table 4.10. *Simple daughter average*

Sl. No	Sire code	No. of progeny	SDA, kg
1	SIRE 1	33	2518.606
2	SIRE 2	38	2324.605
3	SIRE 3	24	2639.792
4	SIRE 4	27	2168.444
5	SIRE 5	44	2598.682
6	SIRE 6	55	2493.927
7	SIRE 7	15	2337.067
8	SIRE 8	44	2208.068
9	SIRE 9	25	2402.040
10	SIRE 10	19	2153.842
11	SIRE 11	41	2486.610
12	SIRE 12	26	2220.269
13	SIRE 13	35	2377.800
14	SIRE 14	34	2259.206
15	SIRE 15	21	2261.762
16	SIRE 16	22	2340.545
17	SIRE 17	53	2475.774
18	SIRE 18	44	2425.705
19	SIRE 19	55	2387.509
20	SIRE 20	46	2500.239
21	SIRE 21	31	2156.806
22	SIRE 22	19	2596.316
23	SIRE 23	27	2663.148
24	SIRE 24	41	2218.146
25	SIRE 25	28	2267.679

4.4.6 Contemporary Comparison (CC)

The estimated breeding value based on Contemporary comparison is shown in Table 4.11. Sire number 17 ranked top, sire number 22 ranked second and sire 8 ranked last.

Table 4.11. Breeding value of bulls based on contemporary comparison

Sire Code	No. of progeny	Effective No. of progeny	CC	b	Breeding Value, kg
SIRE 1	33	21.2	-96.78	2.29	-442.74
SIRE 2	38	31.44	60.27	3.42	412.14
SIRE 3	24	20.12	-30.82	2.17	-133.64
SIRE 4	27	21.95	-205.76	2.37	-975.54
SIRE 5	44	31.68	110.14	3.45	759.01
SIRE 6	55	40.87	71.87	4.46	641.26
SIRE 7	15	12.87	37.45	1.37	102.38
SIRE 8	44	35.92	-208.1	3.91	-1628.8
SIRE 9	25	21.58	92.28	2.33	429.92
SIRE 10	19	16.8	-38.84	1.8	-139.92
SIRE 11	41	32.53	-18.25	3.54	-129.18
SIRE 12	26	21.72	-56.61	2.35	-265.53
SIRE 13	35	26	-24.59	2.82	-138.62
SIRE 14	34	29.54	-30.55	3.21	-196.12
SIRE 15	21	16.61	-68.4	1.78	-243.57
SIRE 16	22	18.5	-106.78	1.99	-424.84
SIRE 17	53	40.92	210.08	4.47	1876.58
SIRE 18	44	36	126.22	3.92	990.2
SIRE 19	55	40.04	-47.83	4.37	-417.98
SIRE 20	46	40.04	-47.83	4.37	-417.98
SIRE 21	31	27.11	-258.79	2.94	-1521.77
SIRE 22	19	15.77	406.74	1.69	1372.37
SIRE 23	27	22.43	-33.97	2.42	-164.61
SIRE 24	41	32.45	5.03	3.53	35.54
SIRE 25	28	24.22	28.34	2.62	148.58

4.4.7 Least Squares Method

Estimated breeding value based on least squares method is shown in Table 4.12. Sire number 23 ranked top, sire number three second and sire number 10 ranked last.

Table 4.12. Breeding value of bulls based on least squares method

Sire Code	No. of progeny	LS mean	Breeding Value, kg
SIRE 1	33	2518.61	278.61
SIRE 2	38	2324.61	-109.40
SIRE 3	24	2639.79	520.98
SIRE 4	27	2168.44	-421.72
SIRE 5	44	2598.68	438.76
SIRE 6	55	2493.93	229.25
SIRE 7	15	2337.07	-84.47
SIRE 8	44	2208.07	-342.47
SIRE 9	25	2402.04	45.47
SIRE 10	19	2153.84	-450.92
SIRE 11	41	2486.61	214.61
SIRE 12	26	2220.27	-318.07
SIRE 13	35	2377.80	-3.01
SIRE 14	34	2259.21	-240.20
SIRE 15	21	2261.76	-235.08
SIRE 16	22	2340.55	-77.52
SIRE 17	53	2475.77	192.94
SIRE 18	44	2425.70	92.80
SIRE 19	55	2387.51	16.41
SIRE 20	46	2500.24	241.87
SIRE 21	31	2156.81	-444.99
SIRE 22	19	2596.32	434.02
SIRE 23	27	2663.15	567.69
SIRE 24	41	2218.15	-322.31
SIRE 25	28	2267.68	-223.25

4.4.8 KLD Board Method

The estimated breeding value based on KLD Board method is presented in Table 4.13. Sire number 23 ranked top, sire number five second and sire number 21 ranked last.

Table 4.13. Breeding value of bulls estimated by KLD Board method

Sl. No.	Sire code	No. of progeny	LS mean	Breeding value, kg
1	SIRE 1	33	2518.61	362.33
2	SIRE 2	38	2324.61	111.78
3	SIRE 3	24	2639.79	462.75
4	SIRE 4	27	2168.44	-91.98
5	SIRE 5	44	2598.68	511.47
6	SIRE 6	55	2493.93	381.97
7	SIRE 7	15	2337.07	87.39
8	SIRE 8	44	2208.07	-51.12
9	SIRE 9	25	2402.04	188.22
10	SIRE 10	19	2153.84	-94.45
11	SIRE 11	41	2486.61	343.03
12	SIRE 12	26	2220.27	-28.11
13	SIRE 13	35	2377.80	180.36
14	SIRE 14	34	2259.21	20.81
15	SIRE 15	21	2261.76	20.06
16	SIRE 16	22	2340.55	109.14
17	SIRE 17	53	2475.77	351.13
18	SIRE 18	44	2425.70	262.33
19	SIRE 19	55	2387.51	219.61
20	SIRE 20	46	2500.24	374.24
21	SIRE 21	31	2156.81	-111.83
22	SIRE 22	19	2596.32	371.32
23	SIRE 23	27	2663.15	513.78
24	SIRE 24	41	2218.15	-35.87
25	SIRE 25	28	2267.68	29.94

4.4.9 Best Linear Unbiased Prediction Without Considering Relationship of Sires (BLUP-1)

The estimated breeding values of bulls on BLUP-1 method is shown in Table 4.14. Sire number 22 ranked top, sire number 17 ranked second and sire 21 ranked last.

4.4.10 Best Linear Unbiased Prediction Considering Relationship of Sires (BLUP-2)

The estimated breeding values of based BLUP-2 method is shown in Table 4.14. Sire number 22 ranked top, sire number 17 ranked second and sire 21 ranked last.

Table 4.14. Breeding value of sires based on BLUP –1 and BLUP –2

SL.No	Sire Code	BLUP – 1,kg	BLUP – 2, kg
1	SIRE 1	-88.8	-127.0
2	SIRE 2	116.6	89.8
3	SIRE 3	-47.8	-83.0
4	SIRE 4	-180.4	-173.6
5	SIRE 5	119.6	108.2
6	SIRE 6	84.4	39.4
7	SIRE 7	60.0	53.8
8	SIRE 8	-204.8	-220.2
9	SIRE 9	105.8	76.6
10	SIRE 10	-31.6	-67.8
11	SIRE 11	23.0	18.8
12	SIRE 12	-67.4	-61.2
13	SIRE 13	18.4	17.6
14	SIRE 14	20.8	11.8
15	SIRE 15	-92.0	-82.4
16	SIRE 16	-97.8	-82.6
17	SIRE 17	253.6	223.4
18	SIRE 18	183.6	163.8
19	SIRE 19	-100.6	-106.4
20	SIRE 20	-3.0	-42.0
21	SIRE 21	-329.8	-332.8
22	SIRE 22	370.0	362.6
23	SIRE 23	-73.4	-110.4
24	SIRE 24	-4.8	-9.4
25	SIRE 25	-33.6	-34.6

4.5 RANKING OF SIRES

Ranks of sires based on different sire evaluation methods are presented in Table 4.15.

Table 4.15. Ranking of sires based on different methods

Rank	M	HS	M+HS	M+HS+P	SDA	CC	LS	KLDB	BLUP-1	BLUP-2
1	S 16	S 5	S 11	S 22	S 23	S 17	S 23	S 23	S 22	S 22
2	S 6	S 11	S 5	S 18	S 3	S 22	S 3	S 5	S 17	S 17
3	S 22	S 16	S 15	S 11	S 5	S 18	S 5	S 3	S 18	S 18
4	S 8	S 18	S 16	S 7	S 22	S 5	S 22	S 6	S 5	S 5
5	S 17	S 22	S 7	S 17	S 1	S 6	S 1	S 20	S 9	S 2
6	S 12	S 7	S 21	S 6	S 20	S 9	S 20	S 22	S 6	S 9
7	S 1	S 6	S 25	S 1	S 6	S 2	S 6	S 1	S 7	S 7
8	S 25	S 1	S 18	S 2	S 11	S 25	S 11	S 17	S 11	S 6
9	S 7	S 20	S 1	S 9	S 17	S 7	S 17	S 11	S 14	S 11
10	S 14	S 21	S 6	S 20	S 18	S 24	S 18	S 18	S 13	S 13
11	S 9	S 23	S 23	S 5	S 9	S 11	S 9	S 19	S 20	S 14
12	S 24	S 9	S 8	S 23	S 19	S 3	S 19	S 9	S 2	S 24
13	S 5	S 2	S 22	S 25	S 13	S 13	S 13	S 13	S 24	S 25
14	S 13	S 19	S 2	S 3	S 16	S 10	S 16	S 2	S 10	S 20
15	S 11	S 4	S 9	S 15	S 7	S 23	S 7	S 16	S 3	S 12
16	S 18	S 8	S 19	S 16	S 2	S 14	S 2	S 7	S 25	S 10
17	S 2	S 10	S 10	S 14	S 25	S 15	S 25	S 25	S 12	S 15
18	S 19	S 3	S 4	S 10	S 15	S 12	S 15	S 14	S 1	S 16
19	S 10	S 17	S 20	S 12	S 14	S 19	S 14	S 15	S 23	S 3
20	S 20	S 12	S 24	S 24	S 12	S 20	S 12	S 12	S 15	S 19
21	S 4	S 25	S 13	S 13	S 24	S 16	S 24	S 24	S 16	S 23
22	S 15	S 14	S 3	S 4	S 8	S 1	S 8	S 8	S 19	S 1
23	S 21	S 24	S 12	S 19	S 4	S 4	S 4	S 4	S 4	S 4
24	S 3	S 13	S 17	S 8	S 21	S 21	S 21	S 10	S 8	S 8
25	S 23	S 15	S 14	S 21	S 10	S 8	S 10	S 21	S 21	S 21

4.5 COMPARISON OF SIRE INDICES

4.5.1 Accuracy of Sire Indices

The accuracy of sire evaluation M,HS, M+HS, M+HS+P, KLDB, BLUP-1 and BLUP-2 are presented in table 4.16.

Table 4.16. Accuracies of ESM of different bulls in different methods

Sire Code	M	HS	M+HS	M+HS+P	KLDB	BLUP-1	BLUP-2
SIRE 1	0.1105	0.45835	0.515107	0.834353	0.811596	0.726664	0.71838
SIRE 2	0.1105	0.42293	0.483859	0.846493	0.830458	0.785468	0.773402
SIRE 3	0.1105	0.321083	0.397925	0.783677	0.764165	0.723125	0.71838
SIRE 4	0.1105	0.42293	0.483859	0.808295	0.782465	0.731355	0.721942
SIRE 5	0.1105	0.321083	0.397925	0.856817	0.848608	0.790892	0.782196
SIRE 6	0.1105	0.45835	0.515107	0.884051	0.873404	0.823723	0.806945
SIRE 7	0.1105	0.426909	0.487341	0.736958	0.683591	0.64567	0.641685
SIRE 8	0.1105	0.321083	0.397925	0.856817	0.848608	0.799494	0.78981
SIRE 9	0.1105	0.42293	0.483859	0.799181	0.770604	0.734854	0.726664
SIRE 10	0.1105	0.321083	0.397925	0.751718	0.725481	0.691701	0.690464
SIRE 11	0.1105	0.321083	0.397925	0.849192	0.840051	0.793051	0.784379
SIRE 12	0.1105	0.446952	0.504991	0.806656	0.776695	0.737177	0.731355
SIRE 13	0.1105	0.446952	0.504991	0.839607	0.819628	0.763387	0.757766
SIRE 14	0.1105	0.446952	0.504991	0.836517	0.815701	0.777811	0.76674
SIRE 15	0.1105	0.446952	0.504991	0.781638	0.74242	0.685493	0.682993
SIRE 16	0.1105	0.43763	0.496759	0.785795	0.750111	0.711203	0.707587
SIRE 17	0.1105	0.446952	0.504991	0.880265	0.869522	0.821645	0.804823
SIRE 18	0.1105	0.43763	0.496759	0.862346	0.848608	0.808004	0.798423
SIRE 19	0.1105	0.42293	0.483859	0.882534	0.873404	0.817472	0.804823
SIRE 20	0.1105	0.45835	0.515107	0.867851	0.853819	0.805885	0.793051
SIRE 21	0.1105	0.45835	0.515107	0.827616	0.802806	0.76674	0.756637
SIRE 22	0.1105	0.415229	0.477143	0.764433	0.725481	0.684244	0.679228
SIRE 23	0.1105	0.45835	0.515107	0.812331	0.782465	0.739493	0.727839
SIRE 24	0.1105	0.446952	0.504991	0.855934	0.840051	0.795204	0.781102
SIRE 25	0.1105	0.446952	0.504991	0.81511	0.78794	0.741802	0.732523

4.5.2 Correlations

Spearman rank correlation and product-moment correlation coefficients of different sire indices are presented in Table 4.17. The rank correlation ranged from –0.06 to one whereas the product- moment correlation coefficient ranged from -0.15 to one

Table 4.17. Rank and product-moment correlation among coefficients between different indices

	M	HS	M+HS	M+HS+P	SDA	CC	LS	KLDB	BLUP-1	BLUP-2
M		0.39	0.03	0.27	0.02	0.02	0.02	0.02	0.29	0.36
HS	0.11		0.64	0.49	0.26	0.83	0.26	0.29	0.93	0.96
M+HS	0.14	0.65		0.29	0.14	0.03	0.05	0.09	-0.06	-0.01
M+HS+P	0.22	0.45	0.18		0.64	0.71	0.64	0.63	0.77	0.72
SDA	0.02	0.45	0.09	0.63		0.42	1.00	0.99	0.44	0.34
CC	0.23	0.18	-0.11	0.77	0.50		0.42	0.46	0.88	0.91
LS	0.02	0.45	0.09	0.63	1.00	0.50		0.99	0.44	0.34
KLDB	0.02	0.47	0.10	0.61	0.99	0.52	0.99		0.48	0.37
BLUP-1	0.25	0.25	-0.15	0.84	0.51	0.94	0.51	0.50		0.97
BLUP-2	0.27	0.26	-0.12	0.81	0.46	0.93	0.46	0.45	0.99	

Note: Above diagonal elements are rank correlations and below diagonal elements are product moment correlations.

4.5.3 Standard Error of Indices

Standard error of Simple daughter average, least squares, BLUP-1 and BLUP-2 indices were estimated and presented in Table 4.19. The average standard error for SDA, LS, KLD Board, BLUP-1 and BLUP-2 indices were 122.28, 119.47, 120.23, 106.54, 108.32, kg respectively.

Table 4.18. Standard error of SDA, LS, KLD Board BLUP-1 and BLUP-2

		SDA	LS	KLDB	BLUP-1	BLUP-2
1	SIRE 1	112.83	115.68	116.41	112.53	113.95
2	SIRE 2	91.17	108.18	108.84	101.37	103.83
3	SIRE 3	184.08	134.8	135.69	113.14	113.95
4	SIRE 4	122.59	127.36	128.19	111.71	113.34
5	SIRE 5	109.23	100.95	101.54	100.24	102.05
6	SIRE 6	85.16	90.97	91.47	92.87	96.74
7	SIRE 7	182.52	169.43	170.61	125.08	125.63
8	SIRE 8	90.01	100.95	101.54	98.39	100.47
9	SIRE 9	141.31	132.17	133.04	111.09	112.53
10	SIRE 10	164.63	150.97	152.00	118.29	118.49
11	SIRE 11	92.43	104.36	104.98	99.78	101.6
12	SIRE 12	159.73	129.7	130.54	110.68	111.71
13	SIRE 13	123.11	112.49	113.18	105.8	106.88
14	SIRE 14	89.6	114.05	114.76	102.95	105.15
15	SIRE 15	142.88	143.81	144.77	119.26	119.64
16	SIRE 16	139.84	140.6	141.54	115.15	115.74
17	SIRE 17	84.59	92.54	93.06	93.36	97.22
18	SIRE 18	99.16	100.95	101.54	96.51	98.62
19	SIRE 19	107.73	90.97	91.47	94.34	97.22
20	SIRE 20	110.68	98.86	99.44	96.98	99.78
21	SIRE 21	123.92	119.19	119.95	105.15	107.1
22	SIRE 22	169.38	150.97	152.00	119.45	120.22
23	SIRE 23	121.05	127.36	128.19	110.26	112.32
24	SIRE 24	107.37	104.36	104.98	99.32	102.28
25	SIRE 25	102.08	125.15	125.96	109.85	111.5
	Average	122.28	119.47	120.23	106.54	108.32

Discussion

5. DISCUSSION

5.1 MILK YIELD

The overall average first lactation 305-day milk yield (2311.3 ± 20.00 kg) of the crossbred cattle observed in the present study was in close proximity with the average milk yields in annual reports of KLD Board (2372 ± 677(SD) kg and 2502 ± 712 (SD) kg in 1998 and 2000 respectively). Shyju *et al.* (2002) also had reported the average first lactation milk yield of crossbred cattle of Kerala as 2295.16 ± 6.2 kg. Higher milk yield of progenies (2389.03 ± 23.46 kg) when compared to the half-sibs (2131 ± 36.34 kg) in the present study indicate the genetic improvement of crossbred cattle over the years since paternal half-sibs were calved in earlier years and progeny in latter years. This was in agreement with livestock breeding policy report of Kerala (1998) in which it was stated that first standard lactation milk yield of crossbred cattle of Kerala was increased from 1483 kg in 1983 to 2196 kg in1996. The present estimate is higher than the reports of Chacko *et al.* (1984), Stephen *et al.* (1985), Iype *et al.* (1986), Radhika (1997), Deb *et al.* (1998) and Hiremath and Stephen (2000). As per the annual progress report of the ICAR-FPT scheme for the year 2002 the average first lactation milk yield of the progenies in the scheme was 2069.3 litres (Iype and Stephen, 2002).

5.2 NON-GENETIC FACTORS AFFECTING MILK YIELD

5.2.1 Centre

Significant variation observed in the milk yield in different AI centre in the present study indicates differences in management in different centres. The effect of centre on first lactation milk yield had been observed earlier by Deriaz (1981), Chacko *et al.* (1984) Thomas *et al.* (1987) who conducted the studies in Mavellikkara and Kattappana, Deb *et al.* (1998) who conducted studies in crossbred cattle of

Kerala, Iype and Stephen (2002) who conducted studies in crossbred cattle of Thrissur area and Rajeev *et al.* (2002) who conducted a study in all the six progeny testing units (Mavellikkara, I and II, Kottayam, Vaikom, Kanjirappally and Kattappana) of KLD Board.

Out of total 43 centres, nine centres had average milk yields less than 2000 kg, two centres had above 3000 kg and remaining 32 centres had average first lactation milk yield between 2000 and 3000, kg (Table 4.2). The highest average first lactation milk yield was in Manarcadu (3111.3 ± 133.74 kg) followed by Kurichy (3092.8 ± 81.67 kg) and lowest was in Mundakkayam (1630.0 ± 179.21kg). Manarcadu and Kurichy are township areas, with better milk marketing facilities and therefore, animals in these centres are managed better. Iype *et al.* (1993) recorded higher milk yield in centres closeness to the town. Mundakkayam which recorded lowest milk yield is a centre under Kattappana progeny testing unit. Proportionate reduction in dairy consciousness of farmers, lower level of dairy breed inheritance and agro-climatic conditions could be the reasons for low production level in Kattappana, which is located in higher altitude (Chacko *et al.*, 1984). Deb *et* al. (1998) reported that mean first lactation milk yield in different AI centres ranged between 2407.4 (Noornad) to 1220.9, kg (Kalketty) and they have also made an observation that generally milk yields of cows raised in the areas attached with AI centre under Mavellikkara and Kottayam progeny testing units were higher than those under Kattappana unit.

5.2.2 Year of Calving

There was constant increase in first lactation milk yield over the years from 1994 onwards. The higher milk yield recorded in the year 1992 and 1993 when compared to the year 1994 may be due to the small number of observation and also due to the fact that all these animals were half-sib sisters of test bull, which in turn were the daughters of proven bulls.

The significant influence of year of calving on milk yield in the present study concurs with the finding of Chacko *et al.* (1984), Deb *et al.* (1998) and Iype and Stephen (2002). Year-wise increase in the milk yield was due to the improvement of cows through crossbreeding programme (Breeding policy report, 1998 and Rajeev *et al.*, 2002). Significant effect of period of calving had been reported in HF X Sahiwal cattle by Jadhav *et al.* (1991), in Sahiwal (Mishra and Prasad, 1994), in HF x Deoni and Jersey x Deoni (Thalkari *et al.*, 1995) and in Jersey, HF or Danish Red cross with Red Sindhi, Hallikar, Amrith Mahal (Shettar and Govindaiah, 1999).

5.2.3 Age at First Calving

The absence of influence of AFC on milk yield observed in the present study was in conformity with Sreemannarayana and Rao (1994) in Jersey cows (Andhra Pradesh) who reported non-signifiant effect of AFC on milk yield. But the present finding contradicts the reports of Deriaz (1981), Stephen *et al.* (1985), Thomas *et al.* (1987), Deb *et al.* (1998), Hiremath and Stephen (2000) and Rajeev *et al.* (2002) who studied the effect of AFC on milk yields of crossbred cattle under field condition of Kerala.

5.2.4 Season of Calving

The present observation that seasons of calving did not influence 305-day milk yield was in line with Nair (1976), Chacko *et al.* (1984), Stephen *et al.* (1985) and Rajeev *et al.* (2002). Iype and Stephen (2002) opined that the lack of influence of season of calving on milk yield could be attributed to system of management, in which, when green grass is scarce, additional concentrates are fed to the cattle to compensate green. The present finding was in disagreement with the findings from other states (Singh and Pandey, 1970; Deriaz, 1981; Subramanian, 1984; Vij and Basu, 1986; Jadhav *et al.*, 1991 and Kurlakar *et al.*, 1995).

5.3 HERITABILITY

Heritability estimate of 305-day milk yield observed in the present study was medium (0.221± 0.077) in the non adjusted data whereas heritability when estimated with the adjusted data was very low (0.08). The former estimate is very close to the value reported by Amble *et al.* (1967) who showed that the value for heritability for milk production obtained for most of the Indian dairy herds is in the neighbourhood of 0.25. Chander and Gurnani (1976) in the review of efficiency of sire evaluation methods stated that the estimate of heritability of first lactation production generally vary between 0.2 and 0.4 for Indian cattle. Nair *et al.* (1994) observed that heritability estimate of first lactation milk yield ranged from 0.273 and 0.378 in different grades HF crossbreds and Jadhav and Khan (1995) who observed the heritability of 0.377 ± 0.07 for first lactation milk yield. The reported on the estimates of heritability on milk production of crossbred cattle of Kerala are generally low. Deriaz (1981) reported a low heritability (0.077) of FLMY in crossbred cattle of Kerala. Radhika (1997) also reported a low heritability (0.169 ± 0.240) of milk yield in crossbred cattle in Thrissur area. Deb *et al.* (1998) estimated heritability of milk yield of crossbred cattle of Kerala as 0.086 ± 0.028. Similarly Hiremath and Stephen (2000) observed a zero estimate and opined that the very low heritability estimate from the field data could be attributed to the wide fluctuations in the management of cows even within a centre / place. Chacko (1992) had also suggested that the possible reason for low heritability in crossbreds were due to heterogeneous genetic group, small herd size and variation in the management level.

5.4 SIRE EVALUATION

The estimated sire merit based on performance of dam (M) ranged from +62.875 to +396.806, kg (Table 4.6). Sire number 16 ranked top, sire number six ranked second and sire number 23 ranked last (Table 4.15). The estimated sire merit based on performance of paternal half-sibs (HS) ranged from -157.169 to +287.358, kg (Table 4.7). Sire number five and 11 both ranked first followed by sires 16 and 18 whereas sire number 12, 13, 14, 15, 17, 24 and 25 ranked least (Table 4.15). When bulls were ranked based on half-sibs, the sons of common sire would be ranked equally as their paternal half-sibs were same. The estimated sire merit based on combined index of performance of dam and paternal half-sibs (M+HS) ranged from -24.591to +316.516, kg (Table 4.8). Sire number 11 ranked top, sire number five ranked second whereas sire number 14 was ranked last (Table 4.15). The estimated sire merit based on combined index of performance of dam, paternal half-sib and progeny (M+HS+P) ranged from -193.877 to + 307.601, kg (Table 4.9). Sire number 22 ranked top, sire number 18 ranked second and sire 21 ranked last (Table 4.15). According to Wiggans and Powell (1984) reliability of prediction of daughter performance could be improved with information on ancestors especially if progeny size is less.

Simple daughter average (SDA) of sires ranged from 2153.8 to 2663.2, kg (Table 4.10). Sire number 23 ranked top, sire 3 ranked second and sire 10 ranked last (Table 4.15). Six sires had the simple daughter average above 2500 kg. Daughters' average performance based on unadjusted data is the simplest method to compute and is preferred by many animal breeders (Powell *et al.*, 1972; Gandhi and Gurani, 1991 and Murida and Tripathi, 1992). It is likely that there could be some bias in this method, as no adjustments were made. In the present study, the sire comparison was made in the same period and hence period-to-period difference was absent. All the sires had progenies in all the centers through out different years and seasons. Hence there is every chance of nullifying the centre, year and season effect.

The estimated breeding value based on contemporary comparison ranged from -1628.80 to 1876.58, kg (Table 4.11). Sire number 17 ranked top, sire number 22 ranked second and sire 8 ranked last (Table 4.15). The contemporary comparisons (CC) index ranged from –258.79 to +406.74, kg. Many research workers were of the opinion that CC was less subjected to errors when compared to other methods of sire evaluation (Sundaresan *et al.*, 1965a; Jain and Malhotra, 1971b; and Raheja, 1992). Deb *et al.* (1998) studied monthly test day milk yields of 2623 crossbred cows born out of 56 sires under field conditions in Kerala state, extended over a period of 8 years and compared daughters average, with contemporary group formed within group and AI centre as in present study. They had concluded that CC and daughters average methods were found to be less efficient in field because of their higher variance compared to least squares method. In contemporary comparison age correction can be avoided since the daughters of the bulls and their stable mates on an average, start their first lactation at same age and the daughters were compared to the contemporaries in the same herd (Robertson *et al.*, 1956). However in small herds there may not be enough contemporary to compare the daughters of the test bulls.

The estimated breeding values based on least squares method (LS) had the widest range from -450.92 to +567.69, kg (Table 4.12). Sire number 23 was ranked top, sire number three second and sire number 10 ranked last (Table 4.15). The estimated breeding value based on KLD Board method ranged from –111.83 to +513.78, kg. Sire number 23 was ranked top, sire number five second and sire number 21 ranked last.

In India, the least squares method has been used commonly for analysis for animal breeding data. In the annual report of 1989-90 of the department of Agricultural Research and Education, Govt. of India, it has been mentioned that the progeny testing data should be evaluated by the least squares method using a model with effects of herd- year-season of calving, genetic group of dams of sires as fixed effects, and sire within genetic group and residual error both as random effect.

The estimated breeding value based on best linear unbiased prediction without considering relationship of sires (BLUP –1) ranged from –329.8 to +370, kg (Table 4.14). Sire number 22 ranked top, sire number 17 ranked second and sire 21 ranked last (Table 4.15). The estimated sire merit based on best linear unbiased prediction with considering relationship (BLUP –2) of sires was –332.8 to +362.6, kg (Table 4.14). Sire number 22 ranked top, sire number 17 ranked second and sire 21 ranked last (Table 4.15). The BLUP method eliminates biases due to genetic and non-genetic trends, differences between AI sires and non random distribution of sires among herds (Everett, 1974). Thus, sire comparison by BLUP method is mathematically most rigorous approach to evaluate the sires using progeny testing. Efforts to increase the accuracy of BLUP were being made through inclusion of relatives' records and removal of the bias due to selection genetic trend. With BLUP approach it is possible to evaluate bull without record on its daughters (Henderson, 1975).

BLUP estimates are not seriously affected by incorrected ratio within certain limits (Slanger and Henderson, 1975). Since perfect adjustment for non-genetic and management effects are not known, BLUP procedure can be used to adjust these effects and to predict additive genetic value simultaneously (VanVleck *et al.*, 1987). Chauhan (1991) after reviewing various sire evaluation methods, suggested that effort should be made to use the BLUP procedure for evaluation of cattle and buffalo bulls in our country.

Sire number 22 was ranked top while estimating sire merit based on M+HS+P, BLUP – 1, and BLUP –2 methods. This animal was ranked second best by contemporary comparison, third by the method based on performance of dam alone, fourth by simple daughter average and least squares, fifth by the method based on performance of half-sibs alone, sixth by KLD Board method and thirteenth by the method based on dam and half-sibs.

Sire number 23 was ranked first by the simple daughter average, least squares methods and KLD Board method and this animal was ranked least by the method based on performance of dam alone. Sire number 17 was ranked first by contemporary comparison and second in the both BLUP method.

Sire number 16 was ranked top by the method based on performance of dam alone while this animal was ranked third and fourth by method based on performance of half-sibs and combined index of dam and half-sibs, fourteenth by SDA and LS, fifteenth by KLD Board method, sixteenth by M+HS+P method, eighteenth by BLUP-2 and twenty first by CC and BLUP-1. Sire number 11 was ranked first by method based on half-sibs only and combined index of dam and half-sibs, but this animal was ranked third by combined index of dam, half-sibs and progeny, eighth by SDA, LS and BLUP-1, ninth by KLD Board method and BLUP-2 and eleventh by CC.

Sire number three, five and 23 were common among the top ranking five sires in SDA, LS and KLD board method. Sire number five came in the top five sires in all the methods except in method based on dam alone and M+HS+P. Similarly sire number 22 was included among top fives in all the methods except M+HS and KLD Board method.

5.5 COMPARISON OF SIRE INDICES

5.5.1 Accuracy

The highest accuracy was for M+HS+P method followed by KLD Board method. The accuracy of method based on performance of dam was lowest and this can be improved by taking more records of dam. Sire number 6 had the highest accuracy and the accuracy was 0.88 in M+HS+P method and 0.87 in KLD Board method. This animal had 55 progeny and 90 half- sibs. The accuracy can be improved by increasing the number of progeny, and increasing number of half-sibs have limited advantage when progeny records are available. Sire number seven had the lowest accuracy which had only 15 progenies and 46 half-sibs. In HS method and

M+HS method highest accuracy was 0.46 and 0.52 respectively was for sire numbers one, six, twenty, twenty one and twenty three which had 90 half-sibs.

5.5.2 Correlations

The Spearman rank correlations of method based on performance of dam alone with other nine methods was less than 0.40. Sire evaluation method based on HS method had high correlation with CC (r=0.83), BLUP-1 (r =0.93) and BLUP-2 (r =0.96). However there was difference in the order of ranking of bulls in half-sibs method compared to BLUP methods. The M+HS method had low correlation with all except half-sibs method (r=0.64). The M+HS+P method registered maximum correlation with BLUP-1 (r =0.77) and rest of the coefficients were less. Interestingly it was observed that simple daughter average had perfect correlation with least squares (r=1.00) and KLD Board method (r =0.99). It can be presumed that if there is sufficient number of progeny there is no significant difference in ranking of sires in SDA and LS. Simple daughter average does not require much statistical calculation. The present finding supports line with the findings of Radhika (1997) and Delukar and Kothekar (1999).

The ranking in the KLD Board method and least squares was almost similar. Naturally this could be expected, as the former is a modification of latter. These two methods had produc- moment and rank correlation of 0.99. The rank correlation of these two methods with BLUP methods one and two was 0.48 or less. This finding is in line with report of Vivekanandan (1994) who reported rank correlation between least squares and BLUP methods as 0.42 or less. This can be further substantiated by the finding of Parekh and Singh (1989), Delukar and Kothekar (1999), and Dhaka and Raheja (2000). Similarly the product-moment correlation of these two methods with BLUP methods were also 0.51 or less. Least squares method is not an optimum and efficient method for evaluation of sires because it has several undesirable properties for evaluation of progeny testing data (Chauhan, 1991). However

Singh *et al.* (1992) and Gokhale and Mangurkar (1995) reported high rank correlation between least squares and BLUP method.

The rank correlation of CC with BLUP-1 and BLUP-2 were 0.88 and 0.91 respectively and the product-moment correlations were 0.94 and 0.93 respectively. The top four bulls in CC, BLUP-1 and BLUP-2 were same with a slight change in the order. The first ranking bull (Sire 22) in BLUP methods came as the second in CC method. The ranking order of bulls and correlation between the methods suggests that CC method is more or less equal to that of BLUP methods. This finding is in line with Gokhale and Mangurkar (1995).

The rank and product-moment correlation between.BLUP –1 and BLUP –2 was 0.97 and 0.99 respectively and this finding is in conformity with finding of Vivekanandan (1994) who reported the rank correlation (0.97) between these two methods as highly significant. Out of twenty five sires included in the study Sire 22, 17, 18 and 5 ranked first, second, third and fourth in both BLUP-1 and BLUP-2 methods.

5.5.3 Standard Error

The standard error of BLUP-1 (106.54 kg) was the least and that of BLUP–2 (108.32 kg) was second least and SDA (122.28) had the highest. The standard error of least squares (119.47) was also high compared to BLUP methods. The Standard error of KLD Board method (120.23) was also higher than BLUP method but comparable with that of LS methods. This finding is in conformity with the finding of Deb *et al.* (1998) who reported a slightly higher variance for KLD Board method than LS. The standard error of both BLUP-1 and BLUP-2 were comparable. This indicates the efficiency of BLUP over least squares, KLD Board method and SDA. The present finding is in conformity with report of Vivekanandan (1994). Gokhale Mangurkar (1995) had reported that variance of BLUP estimate was significantly smaller than that of SDA or LS. Tajane and Rai (1990) ranked Sahiwal and Holstein sires using least squares and BLUP methods and concluded that BLUP method was the best. Singh *et al.* (1992) reported that BLUP method was more efficient than least squares, Simple Regressed least squares (SRLS) and contemporary comparison method because estimated predicted errors by BLUP were smaller. Kuralkar *et al.* (1995) also reported that BLUP ranking could be considered as more efficient due to minimum range between lowest to highest sire values. Raheja (1992) observed that OLS, regressed least squares (RLS) and BLUP were the most accurate method, as estimate of sire merit obtained from these methods followed normal distribution but least squares to be more accurate than BLUP when the error variance is not known. He recommended BLUP in situations where correct ratio of residual to sire variance is known and OLS in situation where ratio of residual variance is unknown. However Tailor *et al.* (2000) compared different sire evaluation technique viz, Herd mate comparison, CC, OLS, RLS and BLUP and opined that OLS, RLS and BLUP were superior to Herd mate comparison and contemporary comparison.

The present study revealed that sire rankings estimated by different methods were not same. Ranking sires based on SDA, LS and KLDB method was similar with rank correlations of one or almost one among them. The ranking of sires based on CC, BLUP-1, and BLUP-2 were also similar. The commonly used method, LS had low correlation with BLUP methods. It was also observed that BLUP methods had the lowest standard error. The results are suggestive of opting for BLUP procedures for the evaluation of sires based on performance of progenies under field condition of Kerala.

Summary

6. SUMMARY

1. The objective of the study was to detect the important sources of non-genetic variation in milk production of crossbred cattle of Kerala, to compare the different methods of sire evaluation and rank them according to their merit and to assess the advantage of including of dam and half-sibs information in addition to the records of progenies for sire evaluation.

2. The data used in the present study was collected from Progeny Testing Scheme of Kerala Livestock Development Board (KLD Board).

3. The data of 25 bulls and their sires, dams, progenies and half-sibs were collected for the study. There were 847 records of progeny and 365 records of half-sibs. The progeny and half-sibs were distributed in 43 AI centres under six progeny testing units. The bulls which had minimum of fifteen progeny and ten half-sibs were used for different sire evaluation techniques. Centering date method (CDM) was used to estimate the first lactation milk yield (O'Conner and Lipton, 1960).

4. The overall arithmetic mean of first standard lactation yield of progeny and half- sibs of the bull considered was found to be 2311.3 ± 20.00 kg. The mean 305- day milk yield of progeny was 2389.0 ± 23.46 kg whereas that of half-sib was 2131.0 ± 36.34 kg.

5. The data were adjusted for significant non-genetic factors. The non-genetic influences such as age at first calving, year and season of calving and effect of AI centre were analyzed using pooled data of progeny and half-sibs information.

6. The least squares analysis (Harvey, 1986) of variance revealed that first standard lactation milk yield was influenced by the AI centres and years of calving ($P \leq 0.01$). Seasons of calving and different age groups did not influence the milk yield.

7. Centre-wise means of 305-day milk yield ranged from 1629.95 ± 179.21 to 3111.3 ± 133.74, kg. Year of calving-wise mean 305-day yield ranged from 1958.9 ± 77.35 kg (year 1994) to 2448.7 ± 77.16 kg (year 2001).

8. Heritability was estimated on non adjusted and adjusted data by paternal half-sibs information using the model two of LSML Harvey programme. Heritability estimate of 305-day milk yield was 0.221 ± 0.077 on the non adjusted data and 0.08 ± 0.035 for adjusted data.

9. The sire merit of bulls were estimated using ten indices viz. based on records of performance of dam (M), based on performance of paternal half-sibs (HS), based on performance of dam and paternal half-sibs (M+HS), based on performance of dam, paternal half-sibs and progeny (M+HS+P), simple daughter average (SDA), contemporary comparison (CC), Least Squares method (LS), KLD Board method, Best Linear Unbiased Prediction without considering relationship of sires (BLUP-1) and BLUP considering relationship of sires (BLUP-2). The records of progeny and half-sibs adjusted for non-genetic factors were used for estimation of sire indices HS, M+HS, M+HS+P, LS and KLD Board methods and non adjusted data were used for M, SDA, CC, BLUP-1 and BLUP-2.

10. The estimated sire merit based on of performance of dam alone ranged from +62.8745 to +396.8055, kg.

11. The estimated sire merit based on information from paternal half-sibs (HS) ranged from -157.169 to +287.358, kg.

12. The estimated sire merit based on performance of dam and paternal half-sibs (M+HS) ranged from -24.591to +316.516, kg.

13. The estimated sire merit based on performance of dam, paternal half-sib and progeny ranged from -193.877 to + 307.601, kg. Sire number 22 ranked top, followed by sire 18 and sire 21 ranked last.

14. Simple daughter average of sires ranged from 2153.8 ± 164.63 to 2663.2 ± 121.05 kg. The sire comparison was made in the same period and hence period to period variations were reduced. Since the animals in Kerala are of composite / mosaic nature, there is no breed-to-breed variation and dam effect should be ignored. All the sires had progenies in all the centers through out years and season and hence there is every chance for nullifying the centre, year and season effect.

15. The estimated breeding value based on contemporary comparison ranged from -1628.80 to 1876.58, kg. The contemporary comparison (CC) index ranged from –258.79 to +406.74, kg. In Kerala, since cattle are reared in small holding system and number of animals in a herd is few, comparison of the daughters of bulls to contemporary within a herd is not possible. So for the present study animals belonging to one AI centre was taken as a herd and progenies of other bulls except the sire under consideration in that AI centre was taken as contemporaries. The bull's daughters were compared with daughters of other bulls in their first lactation in the same AI centre and in the same year.

16. The estimated breeding value based on least squares method ranged from 450.92 to +567.69 kg. In India, the LS method has been used commonly for analysis of animal breeding data. The Ministry of Agriculture, Govt. of India (1990) recommended that the progeny testing data should be evaluated by the

LS method using a model with effects of herd- year-season of calving, genetic group of dams of sires as fixed effects, and sire within genetic group and residual error both as random effect. The estimated breeding value based on KLD Board method ranged from –111.83 to +513.78 kg.

17. The estimated breeding value based on Best Linear Unbiased Prediction without considering relationship of sires (BLUP –1) ranged –329.8 to +370 kg. The estimated breeding value based on Best Linear Unbiased Prediction considering relationship of sires (BLUP –2) was –332.8 to +362.6 kg.

18. Sire number 22 was ranked top by estimation of breeding value based on M+HS+P, BLUP–1, and BLUP–2. Sire number 23 was ranked first by the simple daughter average, LS methods and KLD Board method. Sire number five was included in the top five sires except in index based on dam alone and combined index of dam, half-sibs and progeny. Sire number 22 was also included in all the methods except in M+HS and KLD Board methods.

19. In general, rankings of sire estimated by different methods were not the same. Ranking of sires based on SDA, LS and KLDB method was almost similar with rank correlation around one. The ranking of sires based on CC, BLUP-1, and BLUP-2 were almost comparable.

20. The accuracy of sire indices M, HS, M+HS, M+HS+P, KLD Board and BLUP-1 and BLUP-2 were calculated. The highest accuracy was for D+HS+P and followed by KLD Board. The accuracy of sire index M was lowest.

21. The Spearman rank correlations of method M with other nine methods was less than 0.40. Sire evaluation method HS had high correlation with CC (r=0.85), BLUP-1 (r =0.93) and BLUP-2 (r =0.96). Method M+HS had low correlation with all except HS method (r =0.64). Method M+HS+P registered maximum correlation with BLUP-1 (r =0.77) and rest of the coefficients were

less than 0.77. SDA had perfect correlation with LS (r = 1.00) and KLD Board method (r=0.99). BLUP –1 and BLUP –2 methods had rank correlation of 0.97.

22. *Results of the study showed that BLUP methods had the least average* standard errors. The presently used method (KLD Board method) and LS method had low correlations of 0.48 and 0.44 respectively with BLUP-1. The results are suggestive of opting for BLUP procedures for the evaluation of sires based on performance of progenies under field condition of Kerala. There is only little advantage by including the information of dam's yield and half-sibs information along with progeny records, for sire evaluation.

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UTILIZATION OF HALF-SIBS INFORMATION TO INCREASE THE ACCURACY OF YOUNG BULL SELECTION

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ABSTRACT

The present study was conducted to compare the breeding values of bulls in different sire evaluation methods and to explore the possibility of information on dam's yield and half-sibs in sire evaluation methods utilizing the data from Progeny Testing Scheme of KLD Board. Total 25 bulls, which had minimum of fifteen progeny and ten half-sibs were used. Out of 1212 records, progeny and half-sibs had 847 and 365 respectively distributed in 43 centres. The overall mean of first Lactation milk yield (FLMY) of progenies, half-sibs and both together were 2389.0 ± 23.46, 2131.0 ± 36.34 and 2311.3 ± 20.00, kg, respectively. Different centres and years of calving exerted significant effect on FLMY but season and age at first calving did not influence FLMY. Heritability estimate of FLMY was found to be 0.221 ± 0.077.

Estimated sire merit (ESM) of bulls were estimated using ten indices viz. based on performance of dam (M), based on performance of paternal half-sibs (HS), based on performance of dam and paternal half-sibs (M+HS), based performance of dam, paternal half-sibs and progeny (M+HS+P), simple daughter average (SDA), contemporary comparison (CC), least squares (LS), KLD Board method, BLUP without considering relationship of sires (BLUP-1) and BLUP considering relationship of sires (BLUP-2).

The range of ESM were +62.8745 to +396.8055, -157.169 to +287.358, -24.591 to +316.516, -193.877 to + 307.601, kg for M, HS, M+HS and M+HS+P respectively. The SDA and ESM of CC ranges were 2153.8 to 2663.2 and -1628.80 to 1876.58, kg respectively whereas CC index ranged from –258.79 to +406.74, kg. The ESM of LS, KLD Board, BLUP-1 and BLUP-2 ranges were -450.92 to +567.69, –111.83 to +513.78, –329.8 to +370 and –332.8 to +362.6, kg, respectively.

Rankings of sires by different methods were not the same but ranking by SDA, LS and KLD Board method was almost similar with rank and product-moment

correlations around one. Ranking by CC, BLUP-1 and BLUP-2 were similar with very high rank and product-moment correlations.

The average standard error (SE) of SDA, LS, KLD Board, BLUP-1 and BLUP-2 were estimated. BLUP-1 followed by BLUP-2 had lowest SE and SDA had the highest. The results are suggestive of opting for BLUP procedures for sire evaluation in Kerala. Additional information on dam and half-sibs did not have much advantage if more progeny records are available for sire evaluation.