

**REPEATABILITY OF GENETIC EVALUATION OF
CROSSBRED COWS AND BULLS UNDER
VARIOUS SAMPLING SCHEMES AND
LACTATION COMPONENTS**

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**DEDICATED TO
MY
BELOVED PARENTS**


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CERTIFICATE

This is to certify that the thesis entitled "REPEATABILITY OF GENETIC EVALUATION OF CROSSBRED COWS AND BULLS UNDER VARIOUS SAMPLING SCHEMES AND LACTATION COMPONENTS" submitted by MR. RAN VIR SINGH in partial fulfilment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY in DAIRYING (ANIMAL GENETICS AND BREEDING) of the National Dairy Research Institute (Deemed University), Karnal (Haryana), India is a bonafide research work carried out by him under my supervision and guidance and no part of the thesis has been submitted for any other degree or diploma.


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ABSTRACT

Investigations were made on effectiveness of two sampling schemes, part lactation yields and cumulative yields for estimation of lactation milk yield on the basis of fortnightly, monthly and bimonthly recording. The data considered was 2,96,496 first lactation daily milk records of 1044 Karan Swiss and 2,38,810 first lactation daily records of 835 Karan Fries cows. The two sampling schemes were systematic sampling and stratified random sampling. It was found that the prediction of lactation milk yield (PMY) on the basis of sampling schemes was slightly higher than observed milk yield (OMY). The effects of various non-genetic factors on OMY as well as PMY's were generally similar indicating that the sampling schemes did not distort such effects on milk yield. For the purpose of prediction of lactation milk yield on the basis of a single record by ratio method, the test record taken during 9th to 10th fortnight or fourth to sixth month or second bimonth gave highest accuracy of prediction; whereas by regression method the maximum accuracy of prediction was obtained on the basis of 12th and 13th fortnight test record and part yield or sixth/seventh month or 3rd bimonth. Similarly, for the purpose of prediction of lactation milk yield on the basis of two test records by forward selection stepwise regression method, the maximum accuracy was obtained on the basis of 3rd/4th and 12th/13th fortnight test records or 2nd and 6th/7th month test records and part yields or 1st and 3rd bimonth test records and part yields. Further, for the purpose of prediction of lactation milk yield on the basis of three test records by forward selection stepwise regression method the maximum accuracy was obtained during 3rd/4th, 12th/13th and 17th fortnight test records and part yields or 2nd, 6th, 9th month or 1st, 3rd and 4th bimonth test records and part yields. When more number of test records or part records were considered as independent variables, there was increase in accuracy of prediction but at slower rate. The accuracy of prediction of lactation milk yield was highest at shorter interval of recording, the error variance of prediction increased with

increase in testing interval. The systematic sampling scheme gave slightly better precision of estimates as compared to stratified random sampling scheme. The highest estimates of heritability were obtained for 10th fortnight yield, 5th month yield and 1st bimonth yield for KS and 13th fortnight yield, 7th month yield and 1st bimonth yield in KF. The heritability estimate of cumulative part yield was highest for first 180 days part yield for KS and for first 210 days part yield for KF. The estimates of genetic correlations between OMY and PMY's under various sampling schemes were very high (> 0.95). The breeding value of 51 KS sires and 54 KF sires were estimated by four methods, viz., daughter's average (I_1), contemporary comparison (I_2), least square analysis (I_3) and best linear unbiased prediction (BLUP; I_4). For KS sires, highest average breeding values were obtained by method I_4 , whereas for KF sires, highest average breeding values were obtained by method I_1 . The ranking of methods on the basis of average breeding value of OMY and PMY under two sampling schemes and three testing intervals were similar. The contemporary comparison method was found to be most efficient for both breeds. The part yield for which heritability was higher less number of daughters were required. The number of part records around mid lactation (9th to 13th fortnight) was nearer or slightly higher than number required for complete lactation milk yield for the purpose of sire evaluation with same accuracy, it was found that for organised farms, minimum 12 daughters per sire should be available. Comparing the cost of recording and number of daughters required under various sampling schemes, it was concluded that bimonthly stratified random sampling scheme would be optimum.

SYMBOLS AND ACRONYMS USED

AFC	: Age at first calving - days.
OMY	: Observed first lactation milk yield 300 days or less - kg.
PMY	: Predicted first lactation milk yield 300 days or less - kg.
S ₁	: Fortnightly systematic sampling scheme.
S ₂	: Monthly systematic sampling scheme.
S ₃	: Bimonthly systematic sampling scheme.
S ₄	: Fortnightly stratified random sampling scheme.
S ₅	: Monthly stratified random sampling scheme.
S ₆	: Bimonthly stratified random sampling scheme.
CMY	: Monthly cumulative milk yield.
I ₁	: Sire index by daughter's average index method.
I ₂	: Sire index by contemporary comparison method.
I ₃	: Sire index by least square analysis method.
I ₄	: Sire index by best linear unbiased prediction (BLUP) method.
KS	: Karan Swiss breed.
KF	: Karan Fries breed.
b	: Regression coefficient.
d.f.	: Degree of freedom.
NS	: Not significant.
MS	: Mean sum of square.
DCB	: Dairy Cattle Breeding Division.
ICAR	: Indian Council of Agricultural Research.
NDRI	: National Dairy Research Institute.
NBAGR/NIAG	: National Bureau of Animal Genetic Resources and National Institute of Animal Genetics.
DEMS	: Dairy Economics, Management & Statistics Division.

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CHAPTER - 1

INTRODUCTION

1. INTRODUCTION

The genetic improvement of indigenous cows for higher milk production can be brought about at faster rate by crossbreeding them with progeny tested bulls of exotic breeds known for higher milk production. According to Dairy India (1992) statistics, out of 201 million cattle in India, 10 million were crossbreds. It is estimated that in India over one million inseminations with exotic or crossbred bulls are currently being carried out every year and that the rate of production of crossbreds in Intensive Cattle Development Project areas and other areas covered by Operation Flood is on the increase. The agencies involved in cross-breeding programme in India are Military Dairy Farms, Indian Council of Agricultural Research, National Dairy Development Board, State Agricultural Universities, Livestock Farms under Animal Husbandry Departments of central and state Governments, the Bharatiya Agro-Industries Foundation (BAIF), Kerala Livestock Development Corporation, private breeding farms, co-operative milk societies etc.

The performance of crossbred cattle at various regions of the country is different. For example, in Kerala where the progeny testing programme on crossbred bulls had been initiated in field conditions, the first lactation milk yield of 9,956 recorded cows during 1977-87 was 1,550 kg (KLD and MMB, Annual Report, 1985-86). The average first lactation yield of 449 Holstein Friesian (HF) x local crossbreds cows, born out of 23 HF bulls, was 2142.8 kg in Ludhiana district (Garcha and Dev, 1985).

Some of the results of investigations at organised farms on crossbreeding indicate that there is decline in milk production among F-2 cows as compared to F-1 cows. However, proper selection of females and males has been recommended for improvement among crossbreds over subsequent generations (Gurnani

et al., 1986b). Singh and Gurnani (1981) reported that the body weights and growth rates of Brown Swiss x Sahiwal females were higher in half-breds in subsequent generations as compared to F-2. They concluded that the fall in average body weight gain from F-1 to F-2 might be attributed to the effect of heterosis but higher body weights of F-3 and 1/2 miscellaneous as compared to F-2 indicated that heterotic effects are not of much importance. The increase in body weight from F-2 to F-3 and 1/2-bred miscellaneous crosses indicates that there might be the effect of involuntary selection for higher body weights wherein the additive genetic effects are exploited. Therefore, for maintaining high level of milk production of crossbred cattle and their further improvement, it is necessary to execute proper programmes of genetic evaluation of females and males and selection of animals of high genetic merit. The investigations on modes of genetic improvement around the world indicate that proper genetic evaluation and selection of bulls brings about more than 75 per cent of the actual genetic improvement. Further, genetic evaluation of the bulls should be conducted at minimum possible cost. For bringing about improvement of farmers' cows, it is necessary to evaluate the performance of the bull's daughters in farmers' herds. The recording of milk yield of farmers' cows on daily basis will obviously be more costly. Therefore, a sound and economic field level milk recording system has to be evolved.

In some countries advanced in dairying, viz. U.S.A., Denmark, Israel, the Netherlands, Norway and Sweden, more than 50 per cent of the total dairy cow population is recorded, while in most developing countries production figures in individual animals are usually available for only a tiny proportion of total cow population (McDowell, 1972). Nevertheless, importance of herd recording has been keenly felt in developing countries and serious efforts are underway to implement it. Apart from paucity of funds, the problems in establishing sound milk recording system in developing countries are: (i) low educational level of farmers, (ii) lack of qualified extension workers and recorders,

(iii) small herd size, (iv) few incentives for farmers to record their cow, (v) poor communications, (vi) unrecognised need for progeny testing and other breeding programmes, and (vii) poor data collection and processing facilities (Lindstrom, 1976).

It is now well recognised that as long as individual farmer remains unconvinced of the gains of herd recording system, its development would remain a difficult proposition inspite of much needed efforts of the Government agencies and other organisations. This calls for need of devising a recording system which is simple, involves least cost on account of evaluation of production ability of cows of the herd and should provide unbiased and efficient estimate of breeding value of cows and bulls.

Selection of sires to be used for breeding under field conditions in India has been practiced to a limited extent on small number of bulls tested under progeny testing programmes in the organised farm conditions and to some extent in farmers' herds. However, to make the selection of breeding bulls more effective and efficient, it is essential to conduct progeny testing of as many number of bulls as possible and that too by involving large cattle population in rural areas. The main obstacle is that the daily milk recording system is neither economically nor physically feasible because of a large number of cows required to be recorded. It is, therefore, important to explore the possibility of designing an appropriate test-day recording system applicable under prevailing field conditions in India without sacrificing the reliability of results.

Earlier studies conducted in India on periodical recordings mainly used the fitting of lactation curves. The fitting of equation in lactation curves is not only computationally cumbersome, but tends to underestimate or overestimate the lactation yields. Therefore, it was considered appropriate to examine the efficacy of various sampling schemes using alternate

simpler methods like ratio, simple linear and multiple linear regression.

Further, besides use of farmers' cows, it is recommended that some daughters at organised farms should also be obtained to improve the accuracy of sire evaluation. For this purpose, early cows' and bulls' evaluation may be done on the basis of part lactation yields. This approach reduces the generation interval but is expected to reduce the accuracy of sire evaluation specially in our situations where progeny group size is small. Therefore, it is necessary to examine the repeatability of evaluation of breeding value of bulls at different progeny group sizes and to explore the possibility of designing an appropriate recording system which is efficient, cheaper, acceptable to dairyman and adoptable under Indian field conditions.

Therefore, this investigation was undertaken with the following objectives:

1. To examine the efficacy of prediction of lactation milk yield of crossbred cows on the basis of milk recording at different intervals and part yields of varying durations.
2. To examine the efficacy of sire evaluation on the basis of various milk recording schemes and part yields.
3. To determine the progeny group size required for various accuracies of sire evaluation under various milk recording schemes and part yields.

CHAPTER - 2

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 ESTIMATION OF LACTATION MILK YIELD FROM VARIOUS SAMPLING SCHEMES

Recording the performance of an animal is essential for evaluation of its genetic worth for selection purposes. In most of organised herds in India, the milk recording is generally conducted at every time of milking every day. This gives estimate of actual lactation milk yield of cows when there is weaning of calves at their birth. Though daily milk recording gives the actual production, it is very expensive to record all cows every time daily in farmer's/field conditions by any external agency other than the farmer himself. The expenditure of milk recording would be very high especially when the number of cows per farmer is small and the farm holdings are scattered in different places. Therefore, it is advisable to record the milk performance of cows at suitable intervals of time. Although milk recording at long intervals introduces some sampling errors for estimation of lactation yield of individual cows, but when the records are pooled, as in the case of sire proving, the sampling error percentage is likely to be small. The accuracy of prediction of lactation milk yield on the basis of recordings at short intervals is expected to be higher as compared to the accuracy of predictions of lactation milk yields on the basis of recordings at longer intervals. Most of the research work on milk recording schemes has been conducted on purebred cattle. Since in India crossbreeding of cattle has been taken up in several parts of country, therefore, it is necessary to examine the accuracy of prediction of lactation milk yield of cows and breeding value of bulls on the basis of various periodical recording schemes. The review of literature, therefore, has been made to know about the work already done about relative accuracy

of various milk recording systems in various breeds of dairy animals, especially cattle and buffaloes.

2.1.1 FORTNIGHTLY RECORDING

Davey and Alexander (1955) reported that the average error as 2.5 per cent of actual yield from test day yields taken at fortnightly intervals in Jersey cows.

Amble *et al.* (1959) and Amble and Rajagopalan (1960) estimated the lactation milk yield from test yield recorded at different intervals by simple random sampling and systematic sampling in cattle and buffaloes in India. Recording every two weeks provided an estimate of lactation yield of a single animal with a standard error of about two per cent. They reported that systematic sampling was better than simple random sampling method for estimation of lactation yield from test day records. On the basis of average error of estimate and their standard deviation, they recommended fortnightly recording to get reliable estimates of lactation yield of an individual animal.

Youssef *et al.* (1961) obtained the errors due to estimation as 1.56 per cent for recording at two weeks interval in Egyptian buffaloes. The frequency of errors of more than ± 5 per cent was one in 168 for recording at two weekly interval.

Agarwala (1962) found that irrespective of level of production the value of correlation increased as the interval between the recordings decreased. Recording of milk production after every 10 days for predicting the lactation yields was found to be most reliable.

Ivanov *et al.* (1969) estimated that the difference between observed milk yield (OMY) and predicted milk yield (PMY) under fortnightly milk recording was 66 kg in pure bred cattle and 36 kg in Danish Red crossbred cows in Bulgaria. The correlation

between OMY and PMY estimates was 0.800 and 0.860 in pure breeds and crossbreeds, respectively.

Kooner and Pal (1971) studied milk recording of 157 lactations of 166 Murrah buffaloes twice monthly and found it to be the most accurate; the correlation between estimated and actual lactation yields being 0.966.

Rao (1977) reported that the average error in the estimation of lactation milk yield from test day yields recorded at two weekly intervals ranged from -1.52 to 0.63 per cent in Sahiwal and its crosses and the percentage of average absolute error ranged from 2.01 to 3.62.

Kaura *et al.* (1983) found the estimate of phenotypic correlation between actual lactation milk yield and fortnightly predicted milk yield as 0.99. Fortnightly A.M. and P.M. milk recordings gave more accuracy than monthly and bimonthly sampling.

Murthy *et al.* (1984) used the 15th, 30th and 45th day to predict lactation milk yield by multiple regression equation in Ongole cattle. Correlation between 15th day milk yield and lactation milk yield was 0.64. Further predicting the lactation yield based on the records of day's milk yield taken at fixed days or at random from 25 to 35 and 40 to 50 days of lactation was highly reliable. The accuracy (R^2) of prediction was 97 and 91 per cent, respectively.

Anderson *et al.* (1986) obtained the significant differences among estimates of lactation yield on the basis of two weeks, one week or three day sampling intervals in 39 Holstein cows of seven herds of exotic cattle in U.S.A.

Agrawal *et al.* (1987) recorded daily milk yield in 77 Haryana cattle and 115 Murrah buffaloes at intervals of 7, 14, 28 or 56 days. There were no significant differences in the

accuracy of estimated milk yield on the basis of tests sampled at interval of 7, 14 or 28 days, but significantly higher estimates were obtained for cows sampled at 56 days interval.

Crosse *et al.* (1988) reported that most accurate method for estimating total lactation yield was based on one-day recording per week. The error increased as the interval between recordings increased. The majority of yields were within 5 per cent of the true yield when recording was frequent.

Dass (1991) observed that the accuracy under systematic and stratified random sampling was better with shorter testing intervals under fortnightly sampling; the per cent average error was lower under stratified random scheme. Variability in actual first lactation yield on drawing samples at fortnightly intervals could be explained to the extent of 98 per cent under systematic and stratified random sampling schemes.

2.1.2 MONTHLY RECORDING

Erb *et al.* (1952) observed that the calendar month method showed twice as much variation as the centering date method, but the former was not likely to be in error by more than +5 per cent for first calendar month in 25 per cent of records, not more than +12 per cent in one per cent of the records. Percentage error in estimating milk yield exceeding by 25 per cent of the records was 2.4 for 30 days testing interval. The accuracy of the different intervals of testing was grossly influenced by the stage of lactation in which cow was first tested.

Ashton (1956) reviewed the findings of various workers comparing different milk recording systems and reported that monthly recording could be used for obtaining a fairly reliable estimate of individual cow's lactation yield.

Amble and Rajagopalan (1960) obtained a standard error of 4 to 5 per cent in village herds of cows and buffaloes. There was

a correlation of 0.90 between monthly and total lactation yield rankings. To reach a rank correlation of 0.80, it was necessary to record over 55 per cent of the lactation duration.

Jaisorowski *et al.* (1966) found a correlation of 0.985 between milk yield estimated from monthly recording and actual lactation milk yield. The absolute mean error of the estimation was 87.6 litres. There was a correlation of 0.949 between yield at morning and total daily yield.

Poly and Poutous (1966) proposed that in order to reduce the cost of monthly recording each animal should be recorded every month at a single milking, alternating between morning and evening, daily milk yield being estimated by doubling the recorded yield. The accuracy of this type of recording was estimated by ratio method. This ratio estimate did not exceed actual yield by more than one per cent. They suggested that alternate monthly milk recording system was suitable for progeny testing programme.

Cunningham and Vial (1968) concluded that the conventional centering date method of calculating yields was more accurate than a method based on tests in the first four months of the lactation. It was also more accurate than multiple regression methods based on monthly test day yield, lactation length and calving date. The monthly testing was more accurate than bimonthly testing.

Everett *et al.* (1968) reported that the Dairy Herd Improvement Association (DHIA) method of testing in USA overestimated actual production by an average of 57.3 kg milk under monthly testing scheme. Adjusting production in the first and last test periods reduced the mean deviation from actual production upto 1.5 kg milk for monthly DHIA testing.

Ivanov *et al.* (1969) reported that the estimated lactation

yields, with 5, 10, 15 and 30 days recording intervals, were less than actual yield in dairy cattle in Denmark.

McDaniel (1969) reviewed sixty research reports dealing with the estimation of lactation yields in *Bos taurus* cattle from samples taken at various intervals. The average error in lactation yield was primarily a function of the length of the interval between tests. The variation in errors in milk yield (sd = 2.7%) from monthly testing for a 24 h period appeared to be lower than those for fat per cent (sd = 3.5%) or milk fat yield (sd = 5%) from the same testing scheme. Actual distribution of errors showed that at least 90 per cent of predicted milk yields were within ± 5 per cent of true production.

Ivanov *et al.* (1969) reported that the estimated lactation yield under monthly recording interval was 150 kg less in purebred and 154 kg less in crossbred cattle as compared to actual milk yields in Denmark.

Rai (1971) used 30 days sampling interval and three computing methods, viz. (1) no adjustment, (2) first test adjustment, and (3) first and last test adjustment of records. The average errors of estimate based on monthly samples by the three methods were 0.63, -0.02 and -0.13 per cent, respectively in Jersey and Friesian breeds of cattle.

Vachal and Berea (1971) revealed that the error of estimation of individual lactation milk yield from monthly recording was less than one per cent of actual yield in Holstein Friesian cows.

Radiiski (1973) found the average error per cent for 10 and 30 day recording intervals as 0.4 and 1.4 in Bulgarian Simmental cows and as -7.5 and -10.0 in Bulgarian Brown cows. Banis *et al.* (1974) reported that the averages of actual and estimated lactation yields from milk records made at 10 and 30 days interval were more or less similar.

Robertson and Speight (1974) found that 90 per cent of records obtained by the method practiced by the Scottish Milk Marketing Board were within 5 per cent of actual yields and 100 per cent within 10 per cent on adopting recording once every four weeks.

Lindstrom (1976) predicted lactation yield under monthly testing interval recording scheme in dairy cattle in Kenya. He found average error to be 1.34 to 1.52 per cent of actual milk yield.

Rao (1977) reported that the average error in the prediction of lactation milk yield in four weekly intervals ranged from -1.66 to 1.00 per cent and average absolute error ranged from 2.82 to 4.55 per cent in Sahiwal and its crosses with Brown Swiss. The average error ranged from 0.95 to 67.8 kg in weekly to 12 weekly sampling interval. Average absolute error showed a definite increasing trend as the interval of testing increased from one week (3.78 kg) to 12 week interval (8.07 kg).

Higgins (1979) obtained the range of error in estimating the lactation milk yield from monthly testing as -7.7 to 6.0 per cent of actual lactation yield. He also observed that in 95 per cent of the lactations, the error was less than 4.7 per cent and for 43.6 per cent of cows the error was less than one per cent.

Kaura *et al.* (1983) recommended the monthly recording of A.M. and P.M. milking under field conditions which was as accurate as fortnightly recording. They found mean differences of +60.2 to -39.6 kg between predicted and actual lactation yield. The error variance increased with increasing sampling interval.

Murthy *et al.* (1984) studied the efficacy of prediction of total lactation milk yield or 300 days milk yield based on single day milk yields of 15th, 30th and 45th day by multiple regression

equation. He observed 98 per cent of variation in prediction of 300 days milk yield under single test day milk recording on 15th, 30th and 45th day.

Chacko *et al.* (1984) reported that the method of estimation of lactation yield in Kerala was to have the sum of recordings multiplied with half of the recording interval before and after the respective recording.

Garcha and Dev (1985) reported that in Ludhiana the milk production was recorded at monthly intervals, that is one day in a month for 10 months on each cow. The first milk production record was generally obtained within a month of calving. Lactation milk yields for 305 days were computed from the monthly records and comparison of the bulls was made by using two methods (1) based on simple average of daughters and (2) based on least square means for each sire in which adjustment was made for the effects of years, month of calving, AI centre and type of farmer.

Lee (1985) found that 98.83 per cent production records under monthly test day recording fell within 5 per cent of actual value. The range in errors was 0.04 to 5.65 per cent. Correlations between individual monthly test day yields and actual 305 day yields ranged from 0.33 to 0.81; these were increasing from month one to month three and then decreasing.

Kulkarni *et al.* (1985) studied the effect of using test day yields at intervals of 28 ± 7 days for estimating lactation milk yield. The deviation of estimated yield from actual yield ranged from -88.5 to 132.6 kg (-7.83 to +11.9%) for buffaloes yielding less than average and from -140.9 to +166.75 kg (-7.95 to 11.9%) for those yielding more than average. Deviations of estimated yields from actual yields were -55.9 to +112.1 kg (-7.43 to 11.99%) for those yielding more than average. Deviations of estimated yields from actual yields were -55.9 to 112.1 kg (-7.43 to +11.99%) for buffaloes with lactations less than 251 days and from -140.9 to +166.8 kg (-7.95 to $\pm 11.90\%$) for those with

longer lactations. It was further found that among all the estimates, 81.67 per cent were within 5 per cent of the true yield. They considered method of calculation of yield with 28 ± 7 days interval for milk recording buffaloes under field conditions to be satisfactory.

Anderson *et al.* (1986) studied effect of length of sampling intervals on accuracy of estimating total lactation yield. They suggested 30 days sampling interval to give most accurate estimates of lactation yield.

Agrawal *et al.* (1987) concluded that interval of 28 days would be the most appropriate and that a complete day milk yield could be based on "an evening milking plus that from the morning milking the following day".

Khanna and Balaine (1988) studied the reliability of regular and irregular interval recording with variable centering date in estimating milk yield of crossbred cattle. They found that centering dates later than 30th day underestimated yield when sampling was carried out once or twice per month. Magnitude and direction of bias and sampling error were influenced by the day of lactation on which the first and last samples were taken.

Anderson *et al.* (1989) sampled daily milk yield using different frequencies and spacing of samples to investigate accuracy and precision of estimating total yield. Sampling methods differed significantly in ability to predict total yield accurately, and nearly all methods tended to overestimate actual yield. However, sample biases were insignificant for all equally spaced methods. The largest biases occurred when the post peak period was sampled infrequently. They suggested that the convenient and conventional 30-day equal interval sampling procedure should give acceptable estimates of total lactation milk yield in practice. Sampling emphasis on the post peak period was important in determining the magnitude of biases in non-linear procedure.

Gujar *et al.* (1989) investigated the efficiency of various milk recording systems for estimating lactation yield in Kankrej cattle and concluded that recording once per month on a fixed date would be satisfactory under practical conditions, and that the actual lactation duration of the individual cow should be used as the measurement of length of lactation.

Dass (1991) reported that the estimates of error, absolute error and standard deviation of error under monthly systematic and stratified sampling schemes in estimating 305 days or less milk yield using ratio method were 26.77, 68.56, 84.57 and 33.63, 74.15 and 89.64 kg, respectively. The systematic sampling was found to be better in monthly test day interval than the stratified random sampling scheme.

2.1.3 BIMONTHLY RECORDING

Erb *et al.* (1952) found that the daily variation among 62 lactation simulated records from daily yields of nine cows was such that bimonthly sampling would give an error of 3.4 per cent or more in one milk record out of four, the comparison of monthly and bimonthly estimates of milk and fat production of 306 DHIA cows indicated that differences between monthly and bimonthly estimates of milk yield to be around 7.2 per cent. The rank correlations between the yields of cows estimated by bimonthly and monthly recording within each herd-year indicated that 70 per cent of the correlations were 0.91 or greater. Repeatability estimates on 5,557 bimonthly lactations of 2,436 cows were 0.44 versus 0.49 for monthly (ignoring year differences) and 0.57 versus 0.61 for monthly recording eliminating years, the reliability of a single bimonthly lactation records in ranking a cow or producing ability was 96.6 per cent of that for a lactation based on monthly testing.

Amble and Rajagopalan (1960) analysed data of village herds of cows and buffaloes. Bimonthly recording provided standard error of about 10 per cent.

Cunningham and Vial (1968) found that bimonthly testing was little less accurate than monthly testing. They also reported that the use of bimonthly recording in combination with the conventional method of calculating yields would reduce the accuracy of progeny testing.

Everett *et al.* (1968) used modified centering date method of testing in USA. They modified the previous DHIA method to adjust production in the first and last periods according to the day of lactation. The previous method of testing overestimated actual production by an average of 80.8 and 80.8 kg of milk for bimonthly and trimonthly testing, respectively. Adjusting production in the first and last test periods reduced the mean deviation from actual production by 1.5 and -2.9 kg of milk in bimonthly and trimonthly recording, respectively. It was concluded that correcting test day production for the stage of lactation in the first and last test records merits consideration because of the more accurate estimate of actual production obtained and the reduction in the variance of the deviations of DHIA estimates from actual yield.

Lamb and young (1968) found that lactation total yields for milk and fat estimated from bimonthly tests by several different computational procedures generally had small positive biases (upto 2%).

McDanial (1969) reviewing the different reports on cattle observed that errors in milk yields computed from bimonthly samples were about 30 per cent greater than those based on monthly tests. He was of the opinion that accurate cow ranking and progeny testing could be based on samples taken as much as two months apart.

Rai (1971) designed experiment to investigate the possibilities of lengthening DHIA testing interval. He used three sampling intervals (1) 30 days, (2) 60 days, and (3) 90 days and three computing methods, viz. (1) unadjusted, (2) first test

adjusted and (3) first and last test adjusted to estimate the lactation milk yield. He found that the average errors were of the order of 0.84, 0.21 and -0.24 per cent for bimonthly and 0.84, 0.87 and -0.14 per cent for trimonthly recording scheme for no adjustment, first test adjustment and first and last test adjustment of computation method, respectively in both the schemes. The average errors of bimonthly first test adjusted and trimonthly first and last test adjusted estimates were closer to zero than that of monthly adjusted estimates. If the first test were delayed to about the tenth day of lactation, the trimonthly first and last test adjusted estimates could be an alternative to the monthly unadjusted estimates.

Rao (1977) inferred that average error in the estimation of lactation milk from test day yields recorded at 8 weekly intervals with first test commencing in different weeks, ranged from -4.41 to 2.61 per cent and absolute error ranged from 3.87 to 6.56 per cent in Sahiwal and its crosses. The standard deviations of error were larger in Sahiwal (306.93 to 397.50 kg) as compared to crossbreds (95.94 to 202.51 kg).

Lee (1985) obtained the estimates of 305 day yield from bimonthly test day records; he found that 89.22 per cent of estimates were within 5 per cent of actual values; the range in errors was 0.01 to 7.36 per cent; the mean error was 1.96 per cent and standard error of mean was ± 0.14 per cent. The ranking of cows culled on the basis of milk yield estimated from bimonthly recording would have been similar to that of cows culled on the basis of monthly recording.

Agrawal *et al.* (1987) found higher estimates of prediction for cows sampled at 56 days interval in Murrah buffaloes in field conditions.

Khanna and Balaine (1988) reported that the estimation from samples taken at bimonthly and trimonthly intervals over-estimated milk yield under regular and irregular interval

recording with variable centering date in estimating milk yield of crossbred cattle. The magnitude and direction of bias and sampling error was influenced by the days of lactation on which the first and last samples were taken.

Dass (1991) studied the efficacy of prediction of lactation yield in Murrah buffaloes based on bimonthly milk recording under systematic and stratified random sampling schemes using ratio method. The estimates of average error, per cent average error, average absolute error, per cent average absolute error and standard deviation of errors were 49.21 kg, 3.02 per cent, 120.97 kg, 7.44 per cent and 167.57 kg under systematic scheme respectively. In similar fashion, the estimates were 53.02 kg, 3.25 per cent, 120.04 kg, 7.33 per cent and 144.92 kg under stratified random sampling schemes. Stratified random sampling scheme became more efficient at bimonthly testing day interval as indicated by per cent average absolute error and standard deviation of error.

2.2 PART LACTATION STUDIES

Part lactation records could be used to reduce the time required for progeny testing of bulls and to have estimates of the productivity of cows soon after her first calving for the selective decisions. The rate of annual progress in improving additive genetic merit for lactation yield when selecting on part records could be improved by reduction in generation interval but may be reduced due to reduction in accuracy of estimation of breeding value of animals. The literature on inheritance of part lactation yield, their relationship with complete lactation yield, prediction of complete lactation yield from part yields and the value of part records in sire proving are reviewed in the following sections.

2.2.1 INHERITANCE OF PART LACTATIONS

The estimates of heritability of different parts of

Table 1. The heritability estimates of different parts of lactations

Sl. No.	Species/breed	Component of lactation	h^2	Author(s)
1.	Holstein cattle	First 120 days	0.34	Madden <i>et al.</i> (1955)
	-do-	First 274 days	0.63	-do-
2.	European breeds	First 70 days	0.36	Rendel <i>et al.</i> (1957)
3.	Jersey crossbred	1st month yield	0.19	Searle (1961)
		2nd "	0.10	-do-
		3rd "	0.14	-do-
		4th "	0.10	-do-
		5th "	0.08	-do-
		6th "	0.11	-do-
		7th "	0.07	-do-
		8th "	0.08	-do-
		9th "	0.08	-do-
		10th "	0.10	-do-
4.	Holstein	Early 90 days of first lactation	0.18	Smith and Legates (1962)
		Early 90 days of later lactation	0.38	-do-
5.	Ayrshire	5 months of first lactation	0.40	VanVleck (1964)
	Guernsey	-do-	0.03	-do-
	Jersey	-do-	0.20	-do-
	Brown Swiss	-do-	0.59	-do-
6.	Haryana cows	15 days milk yield	0.22	Singh <i>et al.</i> (1967)
		75 days "	0.39	-do-
		135 days "	0.63	-do-
		305 days "	0.32	-do-

contd.....

contd.... table 1

Sl. No.	Species/breed	Component of lactation	h^2	Author(s)
7.	Haryana cattle	3rd month to 8th month milk yield	0.12 to 0.33	Singh and Acharya (1969)
-do-		1st cumulative part to 8th cumulative part	0.16 to 0.43	-do-
8.	Murrah buffaloes	First month yield	0.76	Iqballuddin <i>et al.</i> (1970)
-do-		Cumulative 3 months yield	0.82	-do-
-do-		Cumulative 5 months yield	0.61	-do-
-do-		Cumulative 7 months yield	0.52	-do-
-do-		300 day milk yield	0.47	-do-
9.	Murrah buffaloes	Cumulative 9 months yield	0.30	Kushwaha <i>et al.</i> (1972)
-do-		Lactation milk yield	0.14	-do-
10.	Murrah buffaloes	1st to 8th cumulative monthly yield	0.21 to	Gokhale (1974)
-do-		1st month milk yield	0.272	-do-
-do-		2nd month "	0.157	-do-
-do-		3rd month "	0.198	-do-
-do-		4th month "	0.207	-do-
-do-		5th month "	0.233	-do-
-do-		6th month "	0.197	-do-
-do-		7th month "	0.190	-do-
-do-		8th month "	0.249	-do-
-do-		9th month "	0.121	-do-
-do-		10th month "	0.152	-do-
11.	Cattle	1st to 10th cumulative test day yield	0.18 to 0.25	Auran (1976)

contd.....

contd..... table 1

Sl. No.	Species/breed	Component of lactation	h^2	Author(s)
12.	Buffaloes	First 30 days yield	0.13	Rajendra Kumar (1978)
	-do-	First 60 days yield	0.17	-do-
	-do-	First 90 days yield	0.22	-do-
13.	Buffaloes	First 90 days yield	0.03 to 0.49	Reddy (1977)
	-do-	First 180 days yield	0.20 to 0.32	-do-
	-do-	First 270 days yield	0.41 to 0.50	-do-
	-do-	First 305 days yield	-0.08 to 0.27	-do-
14.	Haryana cattle	5th month yield	0.723	Sharma <i>et al.</i> (1980)
	-do-	6th month yield	0.875	-do-
15.	Karan Swiss	First 60 days yield	0.05	Mehta (1981)
	-do-	First 180 days yield	0.01	-do-
	-do-	First 210 days yield	0.03	-do-
	-do-	First 240 days yield	0.07	-do-
	-do-	First 270 days yield	0.01	-do-
	Karan Fries	First 60 days yield	0.88	-do-
	-do-	First 90 days yield	0.99	-do-
	-do-	First 120 days yield	0.95	-do-
	-do-	First 150 days yield	0.92	-do-
	-do-	First 180 days yield	0.79	-do-
	-do-	First 210 days yield	0.77	-do-
	-do-	First 240 days yield	0.74	-do-
	-do-	First 270 days yield	0.79	-do-
16.	Haryana cattle	4th month yield	0.34	Sharma <i>et al.</i> (1983)
	-do-	120 days cumulative milk yield	0.42	-do-
17.	Haryana cows	150 days milk yield	0.36	Singh and Tomar (1983)

contd.....

contd.... table 1

Sl. Species/breed No.	Component of lactation	h^2	Author(s)
18. Buffaloes	1st month yield	0.07	Singh and Yadav (1987)
	2nd "	0.11	-do-
	3rd "	0.08	-do-
	4th "	0.18	-do-
	5th "	0.07	-do-
	6th "	0.10	-do-
	7th "	0.08	-do-
	8th "	0.09	-do-
	9th "	0.10	-do-
	10th "	0.10	-do-
19. Sahiwal cattle	1st to 10th month yield	0.30 to 0.46	Srivastava and Khan (1987)
20. Gaolo cattle	2nd month yield	0.29	Pande (1988)
21. Sahiwal cattle	1st to 7th month yield of first lactation	0.16 to 0.52	Singh <i>et al.</i> (1988)
-do-	1st to 6th month yield of second lactation	0.14 to 0.78	-do-
22. Sahiwal cattle	First 30 days yield	0.684	Sushil Kumar (1990)
	First 60 days yield	0.136	-do-
	First 90 days yield	0.154	-do-
	First 120 days yield	0.164	-do-
	First 150 days yield	0.135	-do-
	First 180 days yield	0.182	-do-
	First 210 days yield	0.106	-do-
	First 240 days yield	0.219	-do-
	First 270 days yield	0.255	-do-
	First 300 days yield	0.276	-do-

lactations as reported in literature are summarised in Table 1. From the table it has emerged that 4th, 5th and 6th month part yields are generally more heritable than earlier or later month part yields. This suggests that selection based on 4th to 6th month part records may be almost as efficient as that based on whole records.

2.2.2 RELATIONSHIP BETWEEN PART AND COMPLETE LACTATION MILK YIELD

The relationship between predicted yield under sampling scheme and actual lactation yield are summarised in Table 2.

Rendel *et al.* (1957) observed that in six main dairy breeds of England and Wales, the average correlation between 70 days milk yield and 305 days milk yield was 0.80 in the first lactation, 0.775, 0.789 and 0.781 in the second, third and fourth lactations, respectively.

Pirchner (1961) observed phenotypic and genotypic correlations of part yields with whole lactations to be very high in Australian Brown and Oberinthal cattle and indicated that selection based on part records would be almost as efficient as that based on whole records.

Searle (1961a) reported that the genetic correlations between monthly yields and total milk yield were higher among early months of lactation than among later months and also higher than correlations between early and later months in Jersey and Jersey crossbreds. This may be due to higher temporary environmental effects in latter parts of lactation.

Smith and Legates (1962) estimated a genetic correlation of 0.92 in Holsteins between 90 days and 305 days milk yields. Searle (1963) found genetic correlations between monthly yields close to 1.0 from paternal half-sib analysis. VanVleck (1964) analysed data on Ayrshire, Guernsey, Holstein, Jersey and Brown Swiss to see the genetic relationship between 150 days and 305

Table 2. Relationship between predicted yield under sampling scheme and actual lactation yield

Sl. No.	Species/breed	Sampling schemes	Correlation between estimated yields and actual yields	Author(s)
1.	Black Pied low land cattle	3, 4, 6 and 8 weeks	0.978 to 0.999	Zorn and Gruhan (1943)
2.	Indian cows	Monthly	> 0.90	Amble and Rajagopalan (1960)
3.	Murrah buffaloes	Recommended 10 days test interval	Magnitude decrease with increase in test interval	Agarwala (1962)
4.	Dairy cattle	Monthly milk recording	0.985	Jasiorowski <i>et al.</i> (1966)
5.	Dairy cattle	Monthly, bimonthly and trimonthly	Ranged between 0.959 to 0.977 (monthly), 0.941 to 0.943 (bimonthly), and 0.917 to 0.947 (trimonthly)	Lamb and Young (1968)
6.	Murrah buffaloes	Fortnightly and monthly	0.996 to 0.992	Kooner and Pal (1970)
7.	Holstein Friesian and Brown Swiss	3, 4, 6 and 8 weeks	0.99, 0.99, 0.97 and 0.98	Steen and Buitrago (1977)
8.	Sahiwal and crossbred	10 records at 4 weeks intervals of 8th day of lactation	0.91 to 0.97	Amin (1983)
9.	Buffaloes	Fortnightly, monthly A.M. and/or P.M. and bimonthly recording	Ranged from 0.99 to 0.97	Kaura <i>et al.</i> (1983)
10.	Holstein Friesian X Ongole and Brown Swiss x Ongole	15, 30 and 45 days lactation of 1st and 2nd	0.98 and 0.99	Murthy <i>et al.</i> (1984)

days milk production. Genetic correlations in first and later lactations were 0.95 and 0.93, 0.66 and 0.68, 0.96 and 0.89 and 0.88, and 1.02 and 0.73 and for the five breeds, respectively.

Singh *et al.* (1967) estimated genetic correlations of 0.73, 0.96 and 0.98 for 15 days, 75 days and 135 days with 305 days milk yield in Haryana cattle. Singh and Acharya (1969) found genetic correlations of monthly and cumulative monthly yield with total production in first lactation Haryana cattle to be approaching unity.

Iqbaluddin *et al.* (1970) observed in Murrah buffaloes, a correlation of 0.71 between first month yield and first lactation yield. The correlation between first lactation yield and cumulative monthly yields increased with increase in cumulative months.

Khan and Ahmad (1972) estimated correlation between 305 days lactation milk yield and five successive four-week periods of lactation to be 0.81, 0.90, 0.91, 0.90 and 0.95, respectively in Sahiwal breed.

Kushwaha *et al.* (1972) estimated genetic correlations between different cumulative monthly yield and 300 days yield to be near unity in Murrah buffaloes.

Gokhale (1974) observed in Murrah buffaloes that genetic correlation of cumulative part lactation yield with total first lactation milk yield increased as lactation advanced; the genetic correlation was 0.79 for 30 days which increased to 0.97 for first 150 days and to 0.99 for 270 days; this rate of increase was negligible beyond first 150 days. The estimates of genetic and phenotypic correlations between monthly yields and total lactation milk yields were positive and high.

Auran (1976a) found mid-lactation test day yield to be having highest genetic and phenotypic correlation with 305 day

lactation yield in Norwegian Red breed. For fifth, sixth and seventh test days genetic correlation exceeded one. Cumulative test day yields had correlations ranging from 0.76 to 0.99 with ten cumulative test day yields. Last test day yields were closely related to total yield than cumulative test day yield.

Reddy (1977) found that the genetic correlations between 180 and 270 days milk yield and 270 and 305 days milk yield were 0.58 and 0.55, respectively.

Ipe (1979) found that the genetic correlations of part records with 300 days records were high and increased with progressive length of lactation (0.653 for 30 days and 0.991 for 270 days). The proportionate increase was found to be higher upto 150 days period ($r_G = 0.867$) than beyond it. Phenotypic correlations also showed the same trend of increase. Genetic correlations were observed to be slightly higher than corresponding phenotypic correlations. Sharma *et al.* (1980) reported that all monthly yields were correlated with 300 days yields (0.77 to 0.99).

Nagarckenkar and Basavaiah (1981) observed that correlation of lactation milk yield with 22 week yield ranged from 0.79 to 0.83. Koley *et al.* (1981) found that the genetic correlations of 100 days and 200 days milk yield with 300 days milk yield and total lactation yield were ranging from 0.69 ± 0.39 to 1.18 ± 0.44 .

Raheja (1982) reported that for Haryana cows genetic correlations between lactation yield and monthly yields after the first were all 0.90; in crossbreds the correlations tended to be highest for yield in the 3rd month, and decreased as lactation advanced for Brown Swiss x Haryana crossbreds, Jersey x Haryana and Holstein Friesian x Haryana crossbreds, respectively; genetic correlations between lactation yield and cumulative yields were greater than 0.9 for yields in two or more, three or more, and four or more months, respectively.

Zarnecki *et al.* (1982) found correlation of milk yields during first 30, 60, 90, 120, 150 and 180 days of first lactation milk yield with 305 days milk yield to be 0.70, 0.78, 0.83, 0.87, 0.90 and 0.93, respectively.

Sharma *et al.* (1983) reported the genetic and phenotypic correlation of each month with 300 days yield to be all high and positive indicating the advantage in use of part lactation production for early evaluation of sire and dam in Haryana cattle.

Tahir *et al.* (1983) also observed that the correlation between 305 days milk yield and that for 28, 56, 84 and 112 days part lactations were highly significant ($P < 0.01$) and increased with addition of subsequent monthly yield.

Singh and Tomar (1983) estimated that in the first lactation only, 90, 120 and 150 days milk yields were significantly correlated with 300 day yield (0.76 ± 0.25 , 0.78 ± 0.23 and 0.85 ± 0.15 , respectively).

Gurang and Taylor (1984) observed that all correlations were significant except for correlations of yield in first month with yield in fifth and later months and total yield. The highest correlations of monthly yield were in fourth and sixth month (0.84 and 0.89 respectively). Parmar *et al.* (1984) found the coefficient of correlation between first lactation yield with 90, 180 and 270 days yield to be positive and highly significant in cattle. These positive and highly significant correlations between part yields and first lactation yield followed an increasing trend as the number of days in milk increased.

The correlations of part lactation yields with 305 days yield within breed, showed that the 91 to 120 days (Karan Swiss) and 121 to 150 day part lactation yields (Karan Fries, Jersey x Tharparkar and overall) were highly correlated with 305 days yield (Mehta and Bhatnagar, 1986).

Jain and Dhillon (1986) observed that the genetic correlations between monthly yields and 300 days yield were 0.96 for yields in 91 to 150 days and greater than one for yields in 151 to 210 days; correlations between cumulative yields and lactation milk yield increased from 0.76 for yields in 31 to 60 days to 0.89 after 181 to 210 days. They concluded that selection for milk yield based on any of the first 5 months of lactation would be as effective as selection based on complete lactation yields. Murthy *et al.* (1986) reported that estimates of correlation coefficient of peak yield, first, second and third 60 days yield with 300 days lactation yield were 0.82 ± 0.03 , 0.84 ± 0.03 , 0.88 ± 0.02 and 0.85 ± 0.03 , respectively. All correlation estimates were highly significant, precise and homogenous, thereby, indicating their usefulness in selection programmes aiming to improve 300 days yield in Surti buffaloes.

Stipic (1986) reported that correlation of milk yield for 200 days with that for 300 days ranged from 0.74 to 0.84 and that of milk yield for 100 days with that for 300 days ranged from 0.46 to 0.70; all the estimates of correlations were statistically significant.

Singh and Yadav (1987) reported that the estimates of genetic correlations were 0.70 to 0.94 between yield in 2nd, 3rd, 4th and 5th months of lactation. So selection on the basis of part lactations may result in more genetic progress than on the basis of total milk yield. The estimate of heritability ranged from 0.11 to 0.18. Srivastava and Khan (1987) reported that there were significant genetic correlations of 0.62 to 0.97 between the yields in different months, except between yield in 10th month and yields in months 3 to 8.

Barbieri (1988) obtained the genetic correlation of monthly cumulative yield to day 30, 60, 90, 120, 150, 180, 210 and 240 with total yield as 0.06, 0.16, 0.17, 0.20, 0.31, 0.50, 0.72 and 0.91, respectively. Pandey (1988) reported that the genetic and phenotypic correlations between monthly milk yields were high and

significant for the first 5 months; values ranged from 0.91 ± 0.08 to 1.07 ± 0.06 for genetic correlations, and 0.44 ± 0.03 to 0.84 ± 0.92 for phenotypic correlations. Singh et al. (1988) found the genetic correlations between monthly and 300-day lactation yields to be generally high (range = 0.34 to 1.0).

Shrivastava and Khan (1989) observed that the yield for first 121 to 150 days of lactation showed the highest correlation with both 270 and 300 days lactation yields ($r = 0.982$ and 1.178 respectively). Part yields for first 61 to 90 days and 91 to 120 days were also quite closely correlated with 270 day lactation yields. Further, first 31 to 60 days and 61 to 90 days yields were quite closely correlated with 300 days lactation yield. It was concluded that the 61 to 90 day part lactation yields which has a relative efficiency only slightly lower than the 121 to 150 day yield, can be used for selection of animals for total lactation yield with a reasonable degree of accuracy. Cumulative part yield for first 90 days of lactation can also be used for this purpose.

Sushil Kumar (1990) found a genetic correlation of cumulative 60 and 90 days yield with lactation milk yield to be 0.198. After cumulative 90 days milk yield it gradually increased and approached unity in cumulative 210 days milk yield. The genetic correlations among cumulative 90 days to 180 days at 30 days interval were slightly higher giving an indication that middle months are perhaps more highly correlated genetically amongst themselves. The phenotypic correlations of part lactation milk yield with 300 days yield and among different part yields showed similar trend like that of genetic correlations in Sahiwal cattle.

2.3 PREDICTION OF COMPLETE LACTATION MILK YIELD FROM PART YIELD

Madden *et al.* (1959) developed ratio factors of the total to cumulative part production for Holstein cows. They felt that ratio method might underestimate total production of low producing cows and overestimated total production of high producing cows.

VanVleck and Henderson (1961a) were of the opinion that while constructing ratio factors for prediction of lactation yield in Holstein cattle, simultaneous consideration of age at first calving, season of calving and month of lactation should be given. VanVleck and Henderson (1961c) developed regression factors in Holsteins for extending part lactation milk records by a within-herd analysis of age at first calving and season of calving corrected data. The best single month for estimating a complete lactation were fourth, fifth and sixth months. A linear function of first five monthly test records was found to predict a complete second record as accurately as the total yield of first lactation. The linear function of first seven month records gave even more accurate predictions.

Dutt *et al.* (1965) predicted first lactation yield in Murrah buffaloes from 15, 75 and 135 days yield. Prediction equations for determining total lactation yield from part lactations were as follows:

$$Y = 1284 + 7.63 X_1$$

$$Y = 174 + 2.54 X_2$$

$$Y = -142 + 1.68 X_3$$

where, Y = predicted complete lactation milk yield, X₁, X₂ and X₃ were milk yields for 15, 75 and 135 days of lactation.

Iqbaluddin *et al.* (1970) studied monthly and cumulative yields of Murrah buffaloes and reported that the prediction of total first lactation yield (Y) based on first monthly yield (X₁), first 3-months yield (X₂), first 5-months yield (X₃) and age at first calving (X₄) was:

$$Y = 1826.02 + 12.53 X_1 + (-4.48) X_2 + 7.23 X_3 + 21.27 X_4$$

Khan and Ahmed (1972) reported on the basis of study of 212 Sahiwal cows that correlation values between 1st, 2nd, 3rd, 4th and 5th monthly yield with 305-days milk yield were 0.81, 0.90, 0.91 and 0.90 and 0.95, respectively. The multiple correlation was found to be 0.97.

Sidhar and Sundaresan (1973) made studies on records of 95 Nili-Ravi buffaloes and found that regression coefficients ranged from 2.65 to 6.44 and 1.09 to 2.90 for the single monthly and cumulative monthly averages, respectively. They also obtained seven equations for predicting 240 days milk yield from first seven cumulative monthly yields.

Auran and Mocquot (1974) compared the various methods of predicting the milk yield from part yields using data on Norewegian Red cattle and they were of the opinion that ratio method underestimated poor yields and overestimated good yields, but gave the estimate of variance close to the actual variance, whereas regression methods were more accurate as regards correlation between estimated and actual values but these were inferior as regards variance of estimates. Simple regression was easy to apply and was almost as accurate as multiple regression.

Gokhale (1974) studied the reliability of part lactations in estimating the total first lactation yield which revealed that amongst single monthly yields, 5th month's production showed the highest R^2 value (66.96%) followed closely by 6th month and 9th month production. The prediction equation based on 5-month's yield was:

$$Y = 437.09 + 7.74 X$$

where, Y = estimated first lactation milk yield, X = fifth month's milk yield

For earlier evaluation, 4th and 6th monthly combinations could conveniently be recommended to predict the total yield with

a fair degree of accuracy ($R^2 = 73.57\%$). The regression equation arrived at was:

$$Y = 222.57 + 4.10 X_1 + 4.692 X_2$$

where, X_1 and X_2 are the 4th and 6th monthly milk yields, respectively.

Abdel-Aziz *et al.* (1975) studied 2,832 lactation records of Egyptian buffaloes which were corrected for effects of farm, parity and season of calving and a least square analysis was used to calculate simple regression factors based on single month and cumulative monthly yields. Best single months for predicting 12 month yields were seventh and eighth with coefficients of determination of 0.36 and 0.38, respectively. Coefficient of determination for cumulative monthly records were 0.72 for second and 0.92 for seventh month.

Dommerholt (1976) found extrapolation of future yield, from yield at the last test, to be more accurate than linear regression of lactation milk yield on part lactation yield in Dutch Black Pied cows.

Rao (1977) reported that estimates of yields from lactation curve parameters obtained from weekly yield were less accurate compared to the yields estimated from weekly yields using systematic sampling method.

Reddy (1977) derived the prediction equations for 305 days yield from 90, 180, 270 and 305 days yields, using three methods of prediction (*viz.*, ratio factor method, regression method and modified regression method). The regression method was found to be the best, followed immediately by modified regression method, both of which were much superior to the ratio factor method.

Ipe (1979) investigated the estimation of lactation milk yield from part records by ratio, regression and modified regression methods. The average error in prediction by the three methods was almost zero. When absolute error and standard

deviation of error were calculated, the three methods did not differ in their efficiency especially in case of prediction based on 150 days and longer partial records; errors in estimates decreased with the increase in length of part lactation.

Chillar *et al.* (1980) fitted various regression coefficients of lactation yield on different part records, which were used to develop prediction equations. The earliest accurate prediction was from the 150 days record for which the correlations with lactation yield were ranging between 0.82 to 0.93 in Haryana, 0.76 to 0.89 in Half-Friesian and 0.79 to 0.90 in seventy five per cent Friesian.

Pilla *et al.* (1981) used the following equation to predict 305 days milk yield (Y_{305}): $Y_{305} = Y_x + \hat{Y}_r$, where Y_x is the known yield to day X of lactation and \hat{Y}_r is residual yield estimated as a linear function (corrected test record) which included the regression of daily yield on day of lactation (corrected for deviation between maximum recorded yield and the corresponding value for the group of which cow was a member). They used three other methods of estimation: multiple regression, the ratio method based on cumulative yield and the correlation between estimated and actual yields. The correlations for the new method were higher than those for other methods.

Saiganokar *et al.* (1981) reported in Sahiwal cattle that significant correlation was found for total lactation yield (52 weeks) with yield at 4, 8, 12 and 16 weeks and peak yield. They found that efficiency of predicting 52 weeks milk yield from 12 and 16 weeks record was 76 per cent, whereas it was less than 50 per cent when peak yield records were used.

Nagarcenkar and Basavaiah (1981) predicted 300 days milk yield from part yields by inverse polynomial, gamma function, ratio and regression methods. The result for ratio and regression methods for 22 weeks yield were considered useful in that correlations with actual 300 day yield were ranging from

0.79 to 0.83 and proportion of additional daughters required (1.35) was close to the minimal values.

Pathak *et al.* (1982) found the positive and significant correlation ($r = 0.726$) between 100 days milk production and 300 days yield. A linear regression of first 100-days production on 300 days production was fitted to predict 300 days milk yield from part yield (100 days yield) record. The prediction equation was $Y_1 = 249.59 + 2.035 X_2$, where Y_1 is the predicted or expected cumulative average milk yield for 300 days of i^{th} cow and X_1 is the first 100 days production of the same cow.

Tahir *et al.* (1983) found the best prediction regression equation on the basis of fourth month part lactation yield. The prediction equation was $Y = 126 + 2.123 X_4$, where X_4 is the 4th part lactation yield; this equation had the reliability of 72.42 per cent. The per cent contribution for the cumulative parts were in progressive order which shows that during first 28 days period only 10.25 per cent milk is produced, whereas 44.17 per cent of total milk production occurs during first 112 days. Sharma *et al.* (1983) reported that highest magnitude of correlation with milk yield was observed for first four month production. The records of fourth month may, therefore, be utilized for selecting cows.

Parmar *et al.* (1984) reported about the part lactation record of 90 days, 91 to 180, 181 to 270 and cumulative yield for 180 and 270 days of first lactation in Tharparkar cows. The maximum part yield was obtained at 91 to 180 days which shows that these animals reached peak production during this period. The prediction equation of total lactation yield (Y) on the basis of partial production records (X) was obtained as:

$$Y = 15.41 + 3.66 X$$

Agyemeng *et al.* (1985) suggested that in order to avoid the problems inherent in extending incomplete lactations to 305 days

for bull selection , milk yields in days 1 to 90, 91 to 180 and 181 to 270 or lactation trimester yield should be regarded as separate traits.

Batra and Lee (1985) made a study on 119,075 lactation records to calculate separate multiplicative extension factors and regression slope and intercepts for calculating 305 day lactation yield of milk and fat from cumulative part lactation yield and last test day yield of Holstein Friesian, Ayrshire, Guernesey and Jersey cows. They reported that the multiplicative and regression methods overestimated 305 day yields whereas the non-linear method underestimated the milk yield. The non-linear method was more accurate than the other methods in extending milk yield records from mid lactation but bias and standard errors of prediction increased as lactation advanced in contrast to the increasing accuracy of the other methods.

Do *et al.* (1986) analysed 3,740 records of Holstein Friesian cows. They observed that total lactation yield was best predicted by simple regression on monthly yields in months 5 and 6 ($R^2 = 0.87$) or on cumulative yields in lactation of 5 months and over ($R^2 = 0.92$ to 0.99). Multiple regression was applied, using cumulative yields, with R^2 of 0.91 for multiple regression on yields in months 1 to 4; prediction of remaining yield, by regression on last monthly yield, improved as the length of remaining lactation decreased but R^2 did not exceed 0.78.

Murthy *et al.* (1986) recommended that an index constructed on the basis of second 60 days (X3) and third 60 days (X4) part yield could be expected to bring up improvement in 300 days milk yield. The prediction equation constructed and thus recommended was of the form $Y = 114.88 + 2.93 X3 + 1.84 X4$ in Surti buffaloes.

Jain and Dhillon (1986) studied the usefulness of part lactation milk yield records for progeny testing of buffalo bulls by using first lactation records. The accuracy of the monthly

and cumulative monthly milk yields in ranking the buffalo bulls as compared to their ranking on the basis of first lactation milk yield was examined. They observed that all the sires selected on the basis of fourth or fifth month milk yield were common to those selected on the basis of first lactation milk yield.

Khoda and Trivedi (1987) developed the prediction equations for estimating 305 days yield of current lactation using single monthly, monthly cumulative, sequential monthly and three monthly sequential yields with varying number of preceding month's missing records. Although the sequential monthly equations were most accurate for predicting total yield, equations with single monthly records or cumulative records were only a little less accurate than the sequential monthly equations. For predicting total yields, the third, fourth, fifth and sixth month were best.

Khanna and Balaine (1989) simulated lactation milk yield from regular and irregular monthly, bimonthly and trimonthly records on the basis of individual daily milk weights of 1,296 lactations of crossbred dairy cattle. The simulation method-1 was defined as yields on test days, during a lactation, were summed up and then divided by number of test days to represent average one day yield over the lactation, which was then multiplied by lactation length to give simulated lactation milk yield. Simulation method-2 of lactation milk yield was done by the same procedure as in method-1, after correcting for the lactation curve during the first 60 days (for first test day yield) and the last 90 days (for the last test day yield) of lactation in case of irregular sampling method only. In method-3, simulation was done using test interval method with application of adjustment formulae for days from calving to first test days from last test to date dried and length of intervening test periods. Simulation method-1 was heavily biased, with larger variations in starting date (i.e. the day of first test). Simulation method-2 was clearly superior to method-1, but the latter was generally suitable. Simulation method-3, involving adjustment for the actual length of interval between consecutive

samples, resulted in the smallest error for regular monthly, bimonthly and irregular monthly intervals with the starting date between day 10 and 45.

Sebastian and George (1989) concluded that total milk yield in the first two lactations of Jersey and Brown Swiss crossbred cows could be predicted on the basis of peak yield, cumulative yield and lactation length with greater than 89 per cent accuracy.

Bhutta and Pandey (1989) found that the ratio of the first 30 days yield with total lactation yield predicted 300 days yield with almost the same accuracy as the ratio of the later yields. For the regression method, R^2 values were generally higher for 90 and 120 day yields (0.44 to 0.74 and 0.45 to 0.85 respectively) than for yields in earlier periods (0.14 to 0.78).

Roy and Katpatal (1989) used the regression method for predicting 300 day milk yield from cumulative monthly milk records. Among the single monthly milk yields used for predicting 300 day yield, the highest R^2 value (74%) was obtained for the 4th month followed by 5th (72%) and the 3rd (71%) months. The correlation of these three monthly records with 300 days milk yield were 0.86, 0.85 and 0.84, respectively. Among the different single cumulative monthly records used for prediction, the earliest month that had the maximum R^2 value was obtained for the first 5 month's yield ($R^2 = 83\%$) followed by the first four months yield ($R^2 = 78\%$). The results indicated that the 4th or 5th monthly or cumulative monthly records were the best for predicting 300 days milk yield. Among various multiple regression equations, those involving the first three, the first four and the first five months could be used with a high degree of accuracy for predicting 300 days yield.

Katoch et al. (1990) reported that the relative efficiency of selection based on fourth month production, first 120 days and 150 days milk yield as compared to first lactation milk yield was

high. The maximum correlated response was obtained for first lactation milk yield as a result of direct selection based on fourth month part or first 120 days and 150 days milk yield of first lactation.

Sushil Kumar (1990) concluded that ratio factor method generally gave overestimates whereas regression method gave underestimates of lactation yield. Cumulative 150 days and above yields gave the percentage average error less than one per cent by ratio factor method. Regression method was found to be inappropriate for prediction. It appears that part yields of 120 days to 150 days are adequate for predicting 300 days milk yield.

2.4 FACTORS AFFECTING PART LACTATION AND ESTIMATED TOTAL LACTATION MILK YIELD UNDER VARIOUS SAMPLING SCHEMES

Gokhale (1974) found in Murrah buffaloes that farm and period effects were highly significant in all monthly and cumulative monthly yields. The season effect was significant in case of third and fourth month of yield and 270 days yield. The age effect was significant in case of first and second monthly yields and cumulative monthly yield upto seven months.

Winnicki *et al.* (1974) estimated effects of months on different stages of lactation like first, second and third 100 days of production and found them to be significant.

Raheja and Balaine (1977) investigated the data pertaining to monthly and cumulative milk records in Haryana and its crosses with exotic breeds and observed that season of calving, year of calving, age and body weight at time of first calving had no significant effect on these traits.

Kumar *et al.* (1978) found the effects of farm, lactation order, year, season of calving and the interactions of farm x lactation order, season of calving x farm, season of calving x

lactation order, and season x year on cumulative monthly yields to be significant in Indian buffaloes.

Singh et al. (1979) found that period of calving had a significant effect on weekly milk yield in all weeks of production in Haryana cows. The farm effect was significant in all weeks except weeks 11 to 17 and 19. The month of calving had a significant effect in all weeks except 7-8 and 10-11, 13-15 and 42-44. Parity had a significant effect in weeks 2 to 28 with the exception of weeks 14 and 15.

Ipe (1979) reported that the effects of farms, periods and farm x period interactions were highly significant for cumulative monthly milk yields and 100 and 200 days yields when least squares analysis was conducted in buffaloes. Effect of season was not significant statistically. Regression on age at first calving was significant at one per cent level for cumulative monthly yields from 30 to 180 days and 100 to 200 days records, it was significant at 5 per cent level for 210 days; for other cumulative monthly yields, it was not significant.

Reddy and Mishra (1982) reported that season of calving influenced the part yield. They found that winter season calvers performed the best. Das and Balaine (1982) found that the season of calving affected lactation milk yield.

Nagarcenkar and Rao (1983) revealed that management level had significant influence on the lactation milk yield while the effect of other factors lacked significance. The age at first calving also was significantly influenced by both year effect and management level under the field conditions.

Srivastava et al. (1984) made a study on monthly milk records of Sahiwal cattle. They found that the monthly milk yield averages tended to be highest in cows calving in the rainy season. Season of calving significantly affected milk yields during months 6, 7 and 10 ($P < 0.01$) and during months 4, 5 and 9

($P < 0.05$). Rayalu *et al.* (1984) reported that year had a significant effect on all part lactation and 300 day yields in Friesian crossbred.

Chacko *et al.* (1984) found that the effects of AI centre, type of dam and sex of calf under the existing management practice contributed maximum to total variation. Other effects which significantly affected milk yield were year of calving, age of cow and sire. The effect of month of calving was found to be not significant in milk production of crossbred cattle.

Garcha and Dev (1985) reported that among the various non-genetic factors studied by them only AI centre and the type of farmer (land owners versus landless) contributed significantly to variation in lactation yield of progeny (9.29 and 1.64%); the effects of year and month of calving were non-significant in the field conditions.

Murthy *et al.* (1985) found that the significant variation due to period was observed on all the attributes of lactation yield studied except in the peak yield and second 60 days yield. Similarly, significant seasonal effects were observed on all the traits studied except the second 60 days yield in Surti buffaloes. For the 300 days cumulative yield, buffaloes that calved during the third season had significantly higher yield than buffaloes that calved during March-October season.

Rao and Sharma (1985) analysed weekly milk yield records of Murrah buffaloes by least squares. The milk yield was significantly affected by period of calving (three periods of three years each) in week 11-21, 30-32, 34 and 36 of lactation and by season of calving (summer, winter and rainy season) in week 24, 32, 37, 38, 40 and 42. It was concluded that the effects of period and season of calving vary with stage of lactation and these effects need to be corrected for further analysis of weekly milk yield.

Bhadauria *et al.* (1986) observed that most individual and cumulative monthly yields were significantly affected by farm, year and season of calving. Biswas *et al.* (1986) made a study of non-genetic factors on weekly milk yield records of Sahiwal cows. The weekly milk production for all the 43 weeks was significantly affected by parity. The effect of period of calving was significant for all the weekly yields indicating that the milk yield was sensitive to changes due to managerial and feeding conditions over periods. Season of calving influenced significantly the production during all weeks except for the last few weeks of lactation.

Singh and Yadav (1987) observed that the effects due to farm, period, season and age at first calving were non-significant, but weight at first calving had significant effect on all part and lactation milk yields. Period showed the maximum effect in negative direction for 90 days yield in Nili-Ravi buffaloes. The effect of season was non-significant for all cumulative part lactation yields.

2.5 SIRE EVALUATION

The need for evaluation of sires for their additive genetic or transmitting ability for milk production to its progeny has been recognised from time immemorial because a bull can produce large number of progeny and, therefore, few bulls are needed to breed a large population of cows. Thus, high selection intensity can be practiced among bulls. From the various investigations on relative contribution to genetic gain from various parent-offspring paths, it is evident that contribution of sires to produce daughters is more than that of dams to produce daughters. Therefore, accurate, efficient and early evaluation of breeding value of bulls is of prime importance. The annual genetic improvement in the population through sire selection depends on the accuracy of selection, selection intensity, genetic variability of the trait considered and generation interval.

Evaluation of dairy sires is done through progeny testing which has the superiority over pedigree evaluation. The idea of selecting breeding bulls by the progeny test is not new. Historically, livestock breeders like Robert Bakewell and Creuckshank are known to have hired out bulls and bringing them back into their own herds, if found superior as judged by their progeny performance (Goodale, 1927).

Lush (1931) emphasised the importance of adjusting for various non-genetic factors to obtain an unbiased estimate of animal's true breeding value. Lush (1933) was of the opinion that no index would give an infallible results. The source of error cannot be absolutely eliminated. All that can be done to minimise error as far as possible by new coming errors; still there will remain sampling errors intrinsic in the Mendelian nature of inheritance.

After World War II, many methods have been developed keeping in mind the spread of artificial insemination where they are particularly well suited. Significant contribution to the methodology of progeny testing had been made by Lush and Henderson in USA and by Alan Robertson in Great Britain.

2.5.1 DAUGHTER'S AVERAGE INDEX

Edward (1932) used daughter's average index ($I = \bar{D}$) to evaluate breeding value of sires within a herd. The index is simplest to compute but theoretically appropriate only for predicting the performance of progenies of sires born to cows of the same genetic group level as the dam of the daughter's under consideration and reared and tested under the same herd environment as the current daughters. The index would be biased if the levels of production of dams allotted to different sires are unequal.

Hansson (1913) proposed equal parent index $I = 2D - M$, where, D = average yield of daughters of the sire, and M =

average yield of dams mated to the sire. This index is also referred to as the Mount Hope Index after the name of a farm in Williamstown, Massachusetts, USA where it was first used. This index is based on the principle that the two parents contribute equally to the genetic make-up of the progeny.

2.5.2 CONTEMPORARY COMPARISON METHOD

The contemporary comparison method of dairy sire evaluation was evolved by Robertson and Rendel (1954) in an attempt to overcome the shortcomings of the daughter-dam comparison and simple daughter average method. The contemporary comparison method was adopted by milk marketing of 'England and Wales' for evaluating the bulls used in artificial insemination.

McArthur (1954) gave the details of the contemporary comparison method which is based on complete first lactation records of 200 days or more (upto 305 days) of daughters and their contemporary stable-mates, in each herd where the bull had daughters with records that could be compared to those of contemporaries, the average yield of the daughters (\bar{Y}) and the contemporaries (\bar{AY}) were calculated and the difference between the two averages weighted for the number of heifers in the groups. The weighting factor (W) was the harmonic mean $n_1 n_2 / n_1 + n_2$ of the number of daughters (n_1) and the number of contemporaries (n_2) in the herd. The weighted differences were added and the sum was divided by the sum of weights to obtain contemporary comparison (CC):

$$CC = \frac{EW (\bar{Y} - \bar{AY})}{EW}$$

where, $EW = \text{Effective number of daughters} = \sum_{i=1}^h \frac{n_{1i} n_{2i}}{n_{1i} + n_{2i}}$

where, h is number of herds.

The contemporary comparison value was adjusted for the number of daughters by multiplying with the factor 'b' (the

regression of the future daughters on those tested), where

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

The estimate of breeding value of the bull(s) was obtained as $S = 2b (CC) + \bar{A}$ in relation to all first calvers (\bar{A}) in herds where the test was made. For a comparison with the population as a whole, $0.2 (\bar{A} - \bar{P})$ was added where \bar{P} = the breed average for the first calvers assuming that the heritability of the inter-herd variation was 0.2

The relative breeding value (RBV) of the bull within breed was expressed as:

$$RBV = \frac{2b (CC) + 0.2 (\bar{A} - \bar{P}) + \bar{P} \times 100}{\bar{P}}$$

Robertson et al. (1956) pointed out that main advantages of contemporary method of progeny testing were:

(a) The age correlations were avoided since the daughters of the bull and their contemporary, on an average, start their first lactation at same time,

(b) Each daughter was compared to contemporaries in the same herd, i.e., on the same level of feeding and management.

However, this method had the disadvantage that in small herds there might not be any or sufficient number of contemporary daughters of other bulls to compare with.

2.5.3 LEAST SQUARE ANALYSIS METHOD

Robertson and Rendel (1954) used least square method for sire evaluation. Cunningham (1965) presented method for obtaining weighted least square estimates of sire effects from

non-orthogonal field data. Harvey (1966) gave practical application of the least square analysis of data with unequal subclass numbers.

In India, the least square (LS) method has been used commonly for analyses of animal breeding data. On the basis of a suggestion from the Jawahar Lal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, it has been mentioned 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 sire as fixed effects, and sire within genetic group and residual error both as random effects. However, it should be noted that fitting of herd-year-season effect as fixed is not feasible in our country because of small herds and that the LS method is not optimum and efficient method for evaluation of sires because it has several undesirable properties for evaluation of progeny testing data. In this method, the sires solutions are obtained assuming as if the sire effect is fixed. If this assumption is true then the basic aim of progeny testing will be at risk because we would not be able to predict the performance of future daughters of a sire on the basis of the performance of the presently available daughters at any point of time. To predict the performance of future progeny of a sire it is important that the sires under test should be assumed to be a random sample from a given population of sires.

2.5.4. BEST LINEAR UNBIASED PREDICTION (BLUP)

The herd-mate method of sire evaluation was implemented in USA in 1954. The herd mate comparison has been biased by incorrect adjustment for age at first calving, genetic trend, genetic differences and non-random sampling of mates within herd (Schmidt and VanVleck, 1974). The BLUP method for sire evaluation was developed at the Cornell University, USA taking care of the lacuna in the herd-mate method of sire evaluation. The Best Linear Unbiased Prediction (BLUP) of differences between sires can be obtained by use of the North-East artificial

insemination sire comparison method which eliminates biases due to genetic and environmental trend, differences between artificial insemination steps and non-random distribution of artificial insemination sires.

BLUP procedure is best (least error variance) method for prediction of breeding value of sires. This procedure has been described in detail by Henderson (1973). The most useful and important properties of the BLUP method are that (1) it maximizes the correlation between the predictor and the predictant and (2) under normality the expectation of the predictor is equal to the expectation of the predictant.

Harvey (1979) showed that the BLUP was only one to seven per cent more accurate than the Simplified Regressed Least Square (SRLS). However, the assumptions made for the SRLS method are contradictory because sires are first assumed to be fixed for estimating sire effects and then random for regressing the estimates of sire effects.

2.6 COMPARATIVE STUDY OF DIFFERENT SIRE EVALUATION METHODS

Politick *et al.* (1967) compared four methods of sire evaluation, viz., mean production of the daughters, daughter production corrected for the level of dams, contemporary comparison and dam-daughter comparison. They observed that the first two methods were unsuitable when the bulls in areas with different production levels were to be considered, whereas no valid conclusion could be drawn about the relative merit of two later methods because of the small number of daughters.

Miller *et al.* (1967) compared the ranking of sires by herd-mate comparison, least squares method and maximum likelihood method, which were in close agreement as measured by the Spearman rank correlation of sire effects.

Jain and Malhotra (1971) compared the relative efficiency of 11 models of sire evaluation. Two of these methods made use of information on daughter production only while in three other indices, records of daughters and their dams were utilized. The remaining six, however, used information on daughter and their contemporaries with or without records of their dams. They reported that relative efficiency of contemporary comparison method was better than daughter's average method.

Rao (1979) studied the rank correlation between sire evaluation methods like daughters average, contemporary comparison and least squares method. He reported that the rank correlation between daughter's average and least squares method were higher (0.91) as compared to that between contemporary comparison and daughter's average (0.77). He further reported that the rank correlation between contemporary comparison and least squares method was 0.75.

Gurnani and Nagarcenkar (1982) compared Henderson best linear unbiased prediction (BLUP) method with contemporary comparison method of Robertson for estimating breeding values of 28 Tharparkar sires each having a record of at least 10 daughters. The simple and rank correlation between the breeding values obtained by two methods were 0.824 and 0.915 respectively. Robertson's method was found to be 68.84 per cent as accurate as the Henderson's in ranking sires on the basis of their breeding value. They further reported that BLUP method is costly and gives higher errors of approximation in computer analysis when number of daughters are small. They recommended that Robertson's method may be adequate under Indian farm conditions where lack of computer facilities and large size of progeny per sire are limiting factor.

Dempfle and Hagger (1983) compared four models incorporating vectors for some or all of herd-year-season (h), sire group (g), sires (u) and residuals (e). The models were:

$$\text{BLUP 1} - Y = X_1 h + X_2 g + Zu + e$$

$$\text{BLUP 2} - Y = X_1 h + Zu + e$$

contemporary comparison (CC) - model and assumptions as for BLUP-2; least squares: $Y = X_1 H + Zu + e$. The u and e vectors were random for BLUP-1, BLUP-2 and CC, and e was random for least squares. The X_1 and X_2 are design matrices corresponding to fixed effects and Z is design matrix corresponding to random effects. The four models were tested for six distribution classes of daughters over herds: (1) only on a herd (a very large testing station), (2) random distribution, but each sire has only one daughter per herd, (3) clustering of daughters from pairs of sire groups, (4) clustering of daughters from the same group, (5) bulls of some groups competing heavily against each other and (6) bulls competing non-randomly as in class five with some bulls used mainly in top herds. Correlations between true and estimated breeding values and the square root of the correlation between repeat estimates are given. Where there were no genetic differences between sire groups, all procedures except BLUP-1 were equivalent; the latter being slightly inferior. For small genetic differences between groups and an unbalanced daughter distribution, BLUP-1 was best. For moderate and large genetic differences between sire groups, BLUP-1 was markedly superior to the other models. With small to moderate genetic differences, the correlation between true breeding value and its estimate was upto two per cent higher for BLUP-1 than for CC.

Hagger and Dempfle (1983) estimated breeding values of Brown Swiss and American Brown Swiss (ABS) x Swiss Brown (SB) bulls for first lactation milk yield by two variants of BLUP, by contemporary comparisons and by least squares. The bulls were grouped according to year of birth and percentage of ABS inheritance. For the four estimation methods, the square root of the correlation between estimates, calculated overall groups, was 0.913, 0.894, 0.869 and 0.874 respectively. Corresponding figures on a within group basis were 0.863, 0.863, 0.855 and 0.843. The correlation between repeat estimates for bulls with

similar numbers of daughters were 0.834, 0.800, 0.755 and 0.764 for the four methods when calculated over groups versus 0.744, 0.745, 0.731 and 0.710 within groups.

Bhasin and Rao (1983) sampled monthly milk yield according to six sampling plans, with test days falling on a fixed date in each month, irrespective of calving date. The sampling plan involved one-daily milk recording (A.M. or P.M.), two complete twice daily milk recordings (A.M. + P.M. and P.M. + A.M.), and twice daily milk recordings over two consecutive days (A.M. - P.M. and P.M. - A.M.). In each sampling plan, six estimated lactation yields were calculated. All sampling plans ranked the sires in similar order. The A.M. - P.M. plan and A.M. - A.M. sampling with adjustment for unequal milking intervals were the most reliable for evaluating breeding animals. The adjustments for length of first test period improved the accuracy of recording but adjustment for both first and last test periods were not superior to adjustment for first test period only.

Cordovi *et al.* (1984) compared the breeding value of milk yield of 20 Holstein-Friesian bulls by means of (1) contemporary comparison, (2) least squares analysis, (3) BLUP ignoring relationships among bulls, and (4) BLUP taking relationships among bulls into account. There were only slight differences in the ranking of the bulls using the four methods with correlations of 0.95 to 0.99 between them. The greatest differences between methods were between the contemporary comparison and other three methods.

Suzuki and Mitsumoto (1986) examined three models: the sire model using only first lactation records (SF model), the sire model utilising first to fifth lactations (SA model) and the model which incorporates sires and maternal-grand-sire (MGS model). Since an additive relationship was assumed among bulls, the proofs of the SF model were partitioned into daughter average yield and average adjustment for herd-year. The SA model included those of cow and parity effects. The MGS model included

those of the SF model and adjustment for sires' mates. The importance of the relationship matrix decreased as the number of daughters per sire increased. There was a negative correlation between the difference and the time of birth of sire. The evaluations by SF and MGS models with 100 daughters were highly significantly correlated (0.99) for milk and fat yield. It was concluded that imported bulls had been preferentially used regardless of their production ability.

Preisinger et al. (1986) estimated breeding values and variance components with models that represented herd-year-season effects in different ways. When a herd-year-season was replaced by herd-class-year-season, where herd class represented different milk yield or milk fat yield groups, estimates were biased because certain fixed effects were ignored. Also, estimates of additive variance were reduced. It was only useful to set up herd classes for herd-year-season group with less than two or three daughters from a single sire.

Gajbhiye and Dhanda (1987) conducted studies on sire evaluation and production performance of Gir cattle. Out of 12 sires evaluated using 5 sire indices, only one had a breeding value more than 20 per cent above the herd average. The rank correlation between sires by different methods were highly significant ($P < 0.01$). The five indices were:

$$I_1 = D$$

$$I_2 = A + \frac{2n}{n + 12} (\bar{D} - \bar{CD})$$

$$I_3 = A + \frac{1}{2} h^2 Q (\bar{D} - A)$$

$$I_4 = A + \frac{1}{2} h^2 Q (\bar{D} - \bar{CD})$$

$$I_5 = A + (\bar{D} - \bar{CD})$$

where, A = the herd average
 n = number of the daughters of the sire
 \bar{D} = average first lactation yield by daughters of the sire to be evaluated
 \overline{CD} = average of contemporary daughter of other bulls

$$Q = \frac{n}{1 + (n - 1) h^2/4}$$

Chauhan (1987) compared three models of sire evaluation using different environmental groupings. In model-1, the effect of herd-period-season was fixed; in model-2, the herd-period was fixed and herd-period-season was random; in model-3, herd was fixed and herd-period and herd-period-season were random. The overall effects of period and season of calving were regarded as fixed, and were removed by pre-correction. Compared with model-1, models-2 and -3 required approximately 80 and 67 per cent of the effective number of daughters respectively to give the equivalent variance of the estimates of sire effects. Using random effect models, the relative advantage, in terms of a smaller variance of sire effects, increased as the size of herd-period-season subclass decreased. In herd-period-season subclass fixed effects models subclasses with a single or few records or subclasses with all or almost all records of the same sire, contributed little or nothing to the progeny group comparisons. The random effects models could avoid these losses, and were considered to be useful especially where herds are small, provided sires can be assumed as randomly distributed over environmental subclasses.

Wiggans (1988) used an animal model to predict genetic merit for Ayrshire milk yield. The model included fixed herd-year-season and random herd-sire interaction, permanent environment, animal and residual effects.

Kuznetsov (1988) evaluated 161 bulls of Black Pied breeds on the basis of first lactation milk yield of their daughters. Each

bull had at least 15 daughters, and the average number of daughters per bull was 106. The evaluations were carried out using BLUP with and without taking into consideration genetic relationships among sires and with and without sire groups, and by four variants of the contemporary comparison method. Values of the two types of correlations between the BLUP and contemporary comparison methods were ranging from 0.869 to 0.957 and from 0.893 to 0.953 respectively. BLUP was more accurate than the contemporary comparison method by 4.5 to 6.5 per cent when contemporary comparison estimates were not corrected for genetic differences among herds and breed groups of bulls and 1.9 to 3.8 per cent when corrections were carried out.

Lee *et al.* (1988) estimated sire's breeding value by mixed model procedures. They analysed the data on milk yield of 618 Holstein offspring of 24 sires by BLUP procedures with models that included group effects (model-1) or did not include the group effects (model-2). Group effects were fitted by the country of origin of sires (model-2a and model-2b). The solutions for group effects indicated that USA sires ranked highest (PD = +1098.7 kg) and that Korean and Canadian sires were similar (PD = 0 and -15.8 kg respectively).

Suzuki *et al.* (1989) studied joint evaluation of sires and cows using field data on the Holstein population of Hokkaido, Japan using a mixed linear model that included herd-year effects as fixed effects and additive genetic effects, non-additive genetic plus permanent environmental effects of cows and residual errors as random variables. An inverse of the numerator relationship matrix, computed by ignoring the relationships between females across herds, was used to obtain the BLUP solutions with the animal model. In this model, calculations were performed with successive absorption of non-additive genetic plus permanent environmental effects, herd-year effects and cow's additive genetic effects. Correlations between the estimated breeding values of sires by simultaneous evaluation with those from the official evaluation were 0.795 for milk yield and 0.757

for fat yield. For 81 sires with 1,000 daughters these correlations were 0.933 for milk yield and 0.866 for fat yield. Correlations between the breeding values of cows from joint evaluation with those of the intra-herd cow evaluation of Hokkaido Milk Recording Association (HMRA) were 0.959 and 0.941 for milk and fat yield respectively. Corresponding correlations for the 1462 elite cows that had the highest one per cent of the milk and fat proofs were 0.909 and 0.908, respectively.

Parekh and Singh (1989) analysed data on milk yield of 75 and 81 daughters from matings of Gir females with 5 Friesian and 7 Jersey sires by means of least squares, BLUP, simplified regressed least squares and least squares estimates adjusted for herd means of the sire and progeny. The rank correlations of breeding values of the sires estimated by the different methods were greater than 0.94.

Jovanovac (1989) reported that the correlation between breeding values determined by BLUP and contemporary comparison was 0.77 for milk yield, 0.69 for fat yield and 0.88 for fat percentage.

Lee *et al.* (1989) estimated the breeding values of 43 Holstein bulls from 1129 records using BLUP procedures. Breeding values ranged from -529.4 to 4459.0 kg and estimates of herd effects from 815.4 to 6240.0 kg.

Garcha *et al.* (1989) reported that repeatability by multi-trait BLUP breeding value was 12 to 15 per cent higher than the accuracy of single trait BLUP (first lactation only) and predicted error variances smaller by the same amount. Increasing the weighting factor on later lactations increased this superiority by about five per cent; 70 per cent of the superiority of multi-trait BLUP was due to the inclusion of greater than one trait, and improvement in data structure contributed 30 per cent bias in estimated breeding value due to embryo transfer schemes (caused by genetic changes in the cow

population); such bias could be removed by pre-correcting phenotypic values. For populations with small herds, the accuracy of single trait, multi-trait and repeatability BLUP models was similar. For populations with herd of 20 cows, the repeatability model was upto four per cent less accurate than the others.

Kumar and Bhatnagar (1989) evaluated sires of Karan Swiss cattle at NDRI, Karnal using 12 indices for estimating breeding values for milk yield. There were significant differences in index values between sires and between the different indices for milk yield. The best index on the basis of minimum variance was $I = A + n(D - \overline{CD}) / (n+12)$, where A = herd average milk yield, D = daughter average, \overline{CD} = average of contemporaries and n = number of daughter-dam pairs.

Ram and Yadav (1990) estimated the breeding values of Murrah buffalo sires at Haryana Agricultural University, Hisar by BLUP procedure. The breeding values ranged from -201.3 to 263.8 kg for milk yield, -141 to 226.4 kg for yield upto peak lactation and -0.073 to 0.082 kg for peak yield. The corresponding estimates for breeding values of females were -300.5 to 311.9, -130.4 to 305.9 and -0.084 to +0.120 kg.

Tajane and Rai (1990) compared five methods to estimate the breeding value of sires for milk yield: (1) the herd-mate comparison method, (2) an index corrected for auxillary traits (duration of lactation, dry period or calving interval in the 1st lactation), (3) least squares, (4) regressed least squares, and (5) BLUP. Rank correlations among breeding value estimates by the different methods were high and the correlation of the first four methods with BLUP was greater than 0.80. Repeatability of breeding values was highest for BLUP, and the bias due to small number of progeny per bull was least with BLUP and regressed least squares methods.

Anacker and Dieltz (1990) reported the advantages of BLUP over the contemporary comparison method for the prediction of breeding value of dairy bulls. Based on the performance of the daughters of 1361 bulls, the predicted breeding values for milk yield, milk fat yield and milk protein yield were 10.9, 9.6 and 12.5 per cent more accurate using BLUP than contemporary comparisons.

2.7 PART LACTATION YIELD AND SIRE EVALUATION

Observing the high positive correlation of 0.817 between milk yield during the first 90 days, and that of whole lactation in Piedmont cows, Dassat (1954) expressed the view that 90 days yield would be preferable for progeny testing bulls considering time, money and other factors.

O'Connor and Stewart (1958) compared the weighted difference of daughter yield and contemporary yield for 180 days and 305 days and found close correlation between the two. There was a good agreement in relative breeding value of the bulls calculated on 180 and 300 days yields.

Searle (1961b) analysed monthly records of artificially bred cows which indicated that records of about four to six months duration accumulated to a specified test day were suitable for progeny testing.

VanVleck and Henderson (1961a) presented a three-stage programme for evaluating sires used in artificial insemination. The first stage consisted of acceptance or rejection of sires based on the part lactation which was 5 months record of their daughters. The second stage would utilize both part records and complete records. The third and final stage would provide for evaluation, dependent on complete records alone. Selection index equations were presented for estimating the breeding value of sires for these combinations. VanVleck (1962) detailed the advantage of progeny test by part lactation. Genetic progress

would be proportional to the turn-over rate in testing bulls so that if interval was shortened by two per cent, the rate of genetic progress would be increased by 11 per cent. This would allow 10 per cent more bulls to be tested. Returning superior bulls to service a few months earlier, would increase the service life of these bulls.

Legates (1964) suggested use of part records in progeny testing seeing the high genetic correlation between part records and 305 days records.

Basovskii (1965) ranked four bulls on 30, 90 and 180 days milk yield and found that ranking was consistent. Compared with these results, the ranking of two bulls was reversed for evaluation on 300 days yield. The correlations between the three part lactations and 300 days yield were 0.650, 0.903 and 0.975, respectively.

Bar-Anan (1971) reported that the result of progeny test in Israel on 122 days yield was highly correlated with 305 days test ($r = 0.92$). So 122 days yield was decisive for the fate of most of the bulls. Due to this test, the best sires could be put in extensive service already at 4.5 years of age and three out of every four bulls was being sold after the test. The procedures of estimating the cumulative differences was to compare all sires to an initial genetic level. Lapushkova (1971) found high correlation in the progeny groups between 305 days yield and 150 and 200 days yields and found ranking of bulls to be similar.

Anisimov (1972) found rank correlation between progeny test based on 150 days yield and 300 days yield in three farms to be 1.00, 0.89 and 0.80, respectively and he concluded that the benefit of obtaining a sire proof by 150 to 210 days yield would over-weigh the slight loss of accuracy in the evaluation. Ruegsegger (1972) reported that correlation between breeding values based on 100 days tests and 305 days test was 0.85.

Kliment and Rybansky (1976) analysed the data on first to fourth lactation of Slovakian Pied bulls with adverse effect on milk production in four lactations and found that the differences in breeding values of bulls were identifiable after the 200 days first lactation.

Nagarcenkar and Basaviah (1981) analysed the daily milk yield records at weekly interval throughout lactation by inverse polynomial, gamma function, ratio and regression methods and the number of daughters' records required to achieve the same accuracy of sires' evaluation as that given by use of 300 days record in Murrah buffaloes. For the four methods, the correlation between predicted and actual 300 days milk yield ranged from 0.06 (based on 6 weeks yield) to 0.89 (26 weeks), -0.03 (14 weeks) to 0.94 (38 weeks); the proportional increase in number of daughters required to maintain accuracy of sire evaluation, ranged from 1.35 (26 weeks) to 382.06 (6 weeks), 1.29 (30 weeks) to very high (6 weeks), 1.31 (30 weeks) to 1.74 (38 weeks). Results of ratio and regression method for 22 weeks yield were considered useful. It was observed that 35 per cent more daughters were needed for extension of 22 weeks partial records by ratio and regression factors. This did not reduce as part lactation period was increased. This is also in conformity with reported finding that 150 days yield of first lactation had a high correlation with the first complete lactation milk production in Murrah buffaloes.

Danell (1982) developed a method of extending part lactations by using last test day yield with adjustment factors for effects of age at calving, month of calving and length of calving interval on test-day and total lactation yields. In comparison with herd-mate comparison, direct sire evaluation by best linear unbiased prediction gave a maximum of 13 per cent higher genetic merit within generations and 23 per cent higher merit across generations.

Tandon and Harvey (1984) studied first lactation data on 15,342 daughters of 666 bulls of cumulative milk yields in 150, 200, 250 and 305 days (corrected using Shook factors). Using the ratio of square root of variance of prediction errors to variance of breeding values as the criterion of accuracy, it was calculated that the accuracy of breeding value estimated using 305 day yields of 14 daughters can be obtained from estimates using 150 day yields of 18 daughters if relationships among bulls are taken into account or of 20 daughters, if they are ignored. However, expected genetic gain was approximately 11.8 per cent greater when 305 days yield were used than when 150 days yield were used. The effect on the accuracy of sire evaluation by considering additive genetic relationships among sires was greater when part lactation records were used than when 305 day records were used.

Jain and Dhillon (1986) used the part lactation milk yield for selecting buffalo bulls through progeny testing. The accuracy of the monthly and cumulative monthly milk yields in ranking the buffalo bulls as compared to their ranking on the basis of first lactation milk yield of their daughters were measured as Spearman's rank correlation coefficient using the least squares means for the sire progeny groups. The rank correlation for monthly milk yields for the first seven months of lactation were 0.657, 0.670, 0.756, 0.899, 0.899, 0.889 and 0.809 and for the six cumulative milk yields upto seven months of lactation, these were 0.755, 0.764, 0.795, 0.821, 0.856 and 0.902, respectively. Assuming that top 20 per cent of the buffalo bulls were to be selected through progeny testing, all the sires selected on the basis of fourth or fifth month milk yield were observed to be common to those selected on the basis of first lactation milk yield.

2.8 SIZE OF PROGENY GROUP REQUIRED TO PROVE THE SIRE

Lush (1933) was of the opinion that three daughters production was as accurate as full knowledge of both his sire and

dam. More than three daughters gave more information than that could possibly come from pedigree. Five daughters were considered as minimum number required in evaluating the sires' genetic merit.

Johanson and Robertson (1952) derived the formula for number of daughters needed to judge the sire on their performance which was:

$$\frac{4 - h^2}{1 - h^2}$$

where, h^2 is heritability. If h^2 was taken as 0.30, the number of daughters needed would be five. Robertson (1957) discussed the optimum group size in progeny testing. This involved testing ratio K , the ratio of the number of individuals which could be measured at each generation to the number of sires that were to be selected. $K = N/S$, where N was the total progeny measured, S was the number of sires selected. If n was the number of offspring per sire, $n = Kp$, where p was the proportion of sires selected. Wearden (1959) further modified Robertson's formula in determining adequate number of progeny per sire on a genetic experiment involving half sibs in various situations depending upon the heritability of the trait to reveal genetic differences between sires. If twenty-one sires were to be tested, fourteen daughters per sire would be required at heritability of 0.3 and ten daughters would be required at heritability of 0.4 to detect differences between sires at 5 per cent level of significance.

Searle (1961b) using genetic correlation of part and complete lactation milk yield and heritabilities of both, estimated that the number of daughters with part records required to give information equivalent to that of 30, 40 and 50 daughters with complete yield would be 40, 60 and 80.

VanVleck and Henderson (1961b) estimated the number of daughters with five month records required in place of 20, 30,

40, 50 and 100 daughters with complete records as 27, 44, 65, 92 and 476, respectively.

Ivanenko (1969) compared sire summaries for milk yield based on 5, 10, 15 and 20 and all daughters and found that first 10, 15 and 20 daughters did not have much adverse effect on sire ranking compared to all daughters.

Nazarenko (1970) analysed data on Red Steppler and Russian Simmental daughters. Correlations were calculated on the performance of all daughters with that of first 5, 10, 15, 20, 25, 30, 40 and 50 daughters. For milk yield, 15 to 20 daughters per sire were recommended.

Hunt *et al.* (1974) made simulation studies and inferred that when population size was small, genetic gain could be maximised by sampling maximum number of bulls with approximately 20 daughters.

Moller (1976) considered progeny tests with less than 20 daughters of little value and increasing group size above 40 as unnecessary.

Kretzechnar and Rose (1976) considered that standard deviation of breeding value would give a good measure of efficiency. Breeding values were computed on the basis of 10, 20, 30, 40, 50 and 60 daughters and found that with 30 daughters per group, breeding value could be estimated fairly accurately.

Basavaiah (1978) extended 22 weeks part yield by ratio and regression factors and showed that about 35 per cent more daughters were needed to evaluate the sires as accurately as their evaluation by use of actual 300 days lactation yield. In practice under field conditions, not all the daughters of the bulls can come to production simultaneously.

Ipe (1979) reported that the progeny group size needed in place of 10, 12, 15, 17, 20, 22 and 25 daughters with 300 days records, the number with 150 days record found necessary were 11, 14, 20, 24, 32, 39 and 52. For evaluation on the basis of 210 days yield, the corresponding daughter records needed were 11, 13, 17, 19, 23, 26 and 31.

CHAPTER - 3

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 SOURCE OF DATA

The data used in the present study were collected from the history sheets and daily milk record registers of Karan Swiss and Karan Fries breeds of cattle maintained at National Dairy Research Institute (NDRI), Karnal located in northern India. The data comprised of 2,96,496 daily records of 1044 cows in first lactation milk yield of Karan Swiss breed spread over a period of 17 years (from 1970 to 1987) and 2,38,810 daily records of 835 cows in first lactation milk yield of Karan Fries breed spread over a period of 15 years (from 1974 to 1988).

The fortnightly, monthly and bimonthly systematic and stratified random test day milk yields and part yields were generated for each cow using daily milk records. The cumulative part yield during first 30, 60, 90 days and so on at 30 days interval till 300 days were also generated for each cow using daily milk records in both breeds.

3.2 LOCATION AND CLIMATIC CONDITIONS

The NDRI, Karnal farm is situated in eastern zone of Haryana which is Trans-Gangetic Plain Region of India. Eastern zone of Haryana is also called as wet zone. The mean annual rainfall ranges from 500 mm to 1,000 mm. More than 70 per cent rains are received during July to September. Normal rainy days are more than 30 per annum. Intensity of monsoon rainfall varies from 20 to 30 mm per day and in winter cyclonic rainfall varies from 8 to 14 mm per day.

Temperatures vary greatly in this area during the year. May and June are hottest months and January and February are the coldest. Mean temperature more than 20°C prevails during 8 to 10 months of the year. During May and June, maximum temperature rises above 40°C and hot dry winds are common feature. In January, normal mean minimum temperature is 6 to 8°C. Frost for one/two days may also occur during winter months (Ghosh, 1991).

The farm is 250 metres above sea level at 29°43'N latitude and 70°59'E longitude. The average monthly values of weather norms for Karnal, for the period ranging from 1971 to 1982, as prepared by the Central Soil Salinity Research institute are given in Table 3.

3.3 MANAGEMENT PRACTICES

3.3.1 FEEDING

The nutritional requirements are met through a balanced ration of green and dry fodder along with concentrates. All the animals are stall-fed and colostrum from the dam was hand-fed to the calves. The calves are given mixture of whole and separated milk upto four months of age and separated milk upto six months of age only. Concentrates, minerals and roughages are made available to the calves from one month of age and fed according to body weights as per nutritional standards. During later age, feeding schedules/standards were laid down according to age group, considering the requirements for maintenance, growth and production. For adult cows, green fodders and other roughages are provided *ad libitum*. A 'let-down' ration of 0.5 kg of concentrate is provided at the time of milking and additional concentrate is provided to meet the requirement of high milk (greater than 8 kg) producers.

3.3.2 HOUSING

The calves were kept in covered calf pens upto six months.

Table 3. Average monthly values of weather norms (1971-1982)

Sl. No	Month	Temperature (°C)		Relative humidity (%)		Sun shine day (h)	Wind velocity (km/h)
		Max.	Min.	I	II		
1.	January	19.6	6.2	91	47	7.8	5.4
2.	February	21.8	7.9	88	46	8.3	6.0
3.	March	26.9	12.0	82	35	8.9	6.5
4.	April	35.3	17.8	61	20	10.5	7.1
5.	May	39.1	23.0	46	18	10.7	8.4
6.	June	37.8	24.5	64	38	9.1	9.0
7.	July	33.2	25.9	85	67	6.8	7.8
8.	August	32.5	25.2	88	71	7.4	5.6
9.	September	32.8	22.9	88	85	9.3	4.6
10.	October	31.9	16.9	87	42	9.6	3.5
11.	November	27.1	11.2	88	39	8.8	3.4
12.	December	21.7	6.7	91	38	8.0	4.0

Source : A climate of Karnal by Singh (1981), Division of Engineering, CSSRI, Karnal, ICAR Bulletin No. 8

The calves in the age group of six months to two years and heifers from two years to conception were kept in different open paddocks with sheds. The separate open paddocks with sheds under loose housing system were provided for dry, lactating and advanced pregnant cows.

3.3.3 MILKING

The milk recording of the cows was started from fifth day after calving till the date of drying. The cows were milked thrice a day, i.e. morning, noon and evening. The high yielding cows were milked by machine and low yielding cows by hand.

3.3.4 BREEDING POLICY

3.3.4.1 Development of Karan Swiss cattle

The crossbreeding of Sahiwal and few Red Sindhi cows with proven Brown Swiss bulls by import of semen from USA was taken up at the farm during 1963. The purpose of the project was to compare crossbreds of different generations of mating and level of exotic inheritance and evolve a strain of crossbred cattle suited to tropical climatic conditions. The American Brown Swiss was selected because of its comparatively high fat content among exotic breeds and high milk production. The colour of Brown Swiss also matched with that of Sahiwal and Red Sindhi. The project started in 1963 by importing frozen semen of nine bulls with progeny test averaging 5,400 kg (ranging from 5,045 to 6,543 kg). The aim was to have a herd of 200 Brown Swiss crossbred cows.

The comparative performance with respect to age at first calving and lactation milk production of various Brown Swiss crossbreds from 1966 to the period 1979-80 indicated that F₁ crossbreds were the best followed by 3/4 breeds, halfbreds (miscellaneous crosses like F₁ x F₂, F₂ x F₁ etc.) and F₂ were the poorest. The F₁ crossbreds had the lowest age at first



FIG. 1 KARAN SWISS CATTLE

calving of 30.8 months, first lactation production (305 days or less) of 2,933 kg and first calving interval of 421 days, the average of all lactation production (305 days or less) was 3,351 kg with average lactation length of 322 days and all lactations calving interval of 407 days. The next best crossbred group was 3/4 (Brown Swiss x Sahiwal) with average age at first calving of 31.3 months, first lactation (305 days or less) milk production of 2,687 kg and first calving interval of 408 days; the all lactation (305 days or less) production was 3,055 kg with average lactation length of 334 days and all calving interval of 411 days. The other genetic groups had performance lower than F₁ and 3/4-breds but all crossbred groups were better than indigenous breed groups. There was no significant evidence of non-additive genetic effects (heterosis) with respect to growth, milk production, age at maturity and reproduction efficiency. Therefore, in April 1980, the Breeding Committee of the Institute decided to merge all the genetic groups and to practice selective breeding for further genetic improvement of Brown Swiss x Zebu crossbreds (Karan Swiss) cattle to exploit additive genetic variability in the strain. The cows were selected on the basis of their own production performance and males selected on the basis of their pedigree performance. During April, 1980 when all the Brown Swiss crossbreds were merged to form 'Karan Swiss' (Fig. 1), the composition of Karan Swiss was: 86 per cent cows were halfbreds, 6.4 per cent cows had above 50 per cent of exotic inheritance, 4.8 per cent of cows were below 50 per cent of exotic inheritance and 2.8 per cent cows whose filial group was not known. Presently, most of the Karan Swiss cows are expected to have exotic inheritance level around 50 per cent (Gurnani *et al.*, 1986). The current breeding programme is to bring about improvement by selection of females on the basis of their own performance and selection of breeding males on the basis of their pedigree and progeny performance.

3.3.4.2 Development of Karan Fries cattle

For the purpose of eliciting information for the appropriate

choice of exotic breed and optimum level of exotic inheritance, the NDRI initiated a crossbreeding project in 1971. The Tharparkar (T) cows were mated with Holstein Friesian (H), Brown Swiss (B) and Jersey (J) to produce halfbreeds (HT, BT and JT). It was found that first generation HT crosses were the best.

The first generation HT crosses had average age at first calving of 28.2 months with first lactation yield of 3,471 kg in 305 days or less and all lactation average yield of 3,754 kg in 305 days or less. The first generation JT crosses had lowest performance.

These halfbreeds were further mated to Holstein Friesian to obtain crossbreeds with 75 per cent exotic inheritance consisting of 2-breed crosses ($3/4$ HT) and 3-breed crosses ($1/2$ H - $1/4$ B + $1/4$ T and $1/2$ H + $1/4$ J + $1/4$ T). It was found that 75 per cent crossbreeds were not showing any significant improvement over the first generation HT crosses. The average age at first calving among 75 per cent crossbreeds ranged from 33.70 to 35.50 months, the average first lactation 305 days or less milk yield ranged from 2,373 to 3,925 kg. The HS (Holstein x Sahiwal) crossbreeds at Indian Agricultural Research Institute, New Delhi were transferred to NDRI in 1976. The comparison of performance of 50 per cent HS crossbreeds with 75 per cent HS crossbreeds also indicated that there was no significant advantage of having exotic level of 75 per cent. Since performance of various two- and three- breed crosses indicated no evidence of any manifestation of heterosis for growth, production and reproduction performance, best possible improvement could be obtained by exploitation of additive genetic variance. The Breeding Committee of NDRI, therefore, decided that all the crossbred groups with 50 per cent or above inheritance of Holstein Friesian be grouped together and further improvement be brought about by mass selection. Approximately, half of the Friesian crossbreeds were having exotic inheritance level of 75 per cent Holstein Friesian and the rest were having 75 per cent exotic inheritance level from two exotic breeds ($1/2$ H + $1/4$ J + $3/4$ T or $1/2$ H +



FIG. 2 KARAN FRIES CATTLE

1/4 B + 1/4 T). The level of exotic inheritance was subsequently reduced to 62.5 per cent. For this purpose halfbred bulls of high breeding value from reputed organisations were procured and they were used to cover the crossbred cows with 75 per cent genetic inheritance. With the practice of mass selection on the basis of cows' own performance and judicious selection of bulls, a new strain of Friesian crossbred cattle named as 'Karan Fries' (Fig. 2) has been evolved. The NDRI has embarked upon a programme of proper initial selection of Karan Fries males on the basis of their pedigree performance, appropriate growth and body conformation for the purpose of judging their suitability towards fitness for production of good quality freezable semen. Semen of these bulls is being distributed to the different regions of the country for the purpose of their evaluation on the basis of progeny performance in different regions of country. This programme is expected to bring about consistent improvement in crossbred cattle of the farmers in the country (Gurnani⁶ et al., 1986).

3.4 COLLECTION AND STANDARDIZATION OF DATA

The available information for each animal was recorded from individual cow history sheets and daily milk record registers in following sequence: animal number, genetic group of animal, date of birth, sire number, genetic group of sire, dam number, genetic group of dam, date of first calving, milk yield (305 days or less), total milk yield, date of drying and daily milk yield (from 6th to 300th day or less milk yield).

A total of 85 Karan Swiss bulls and 101 Karan Fries bulls were used in the present data. However, only 51 Karan Swiss bulls and 54 Karan Fries bulls had five or more than five daughters with milk production record. The records of both breeds of cows of known pedigree with normal lactation were included in analysis. Lactation records shorter than 120 days were excluded from the study.

3.5 SAMPLING METHODS OF TEST RECORDS

The data of daily milk yields were sampled at fortnightly, monthly and bimonthly intervals under systematic sampling and stratified random sampling schemes upto 300 days of lactation or day of drying whichever was earlier.

3.5.1 SYSTEMATIC SAMPLING SCHEME

3.5.1.1 Fortnightly recording

A systematic sampling scheme was applied by selecting first test record (one day milk yield) at random from first fortnight and subsequent samples of test records were selected at exact interval of 15 days from the preceding date of test record till 300 days of lactation or date of drying whichever was earlier. The first test record was selected at random by the method of generation of random numbers by Power Residue Method (Grover, 1981).

3.5.1.2 Monthly recording

A systematic sampling scheme was applied by selecting first test record (one day milk yield) at random from first month and subsequent samples of test records were selected at exact intervals of 30 days from the preceding date of test records till 300 days of lactation or date of drying whichever was earlier.

3.5.1.3 Bimonthly recording

A systematic sampling scheme was applied by selecting first test record (one day milk yield) at random from first bimonth (60 days) and subsequent samples of test records were selected at exact intervals of 60 days from the preceding date of test records till 300 days of lactation or date of drying whichever was earlier.

3.5.2 STRATIFIED RANDOM SAMPLING SCHEME

3.5.2.1 Fortnightly recording

The lactation period of 300 days was divided into 20 strata at fortnightly (15 days) intervals. Then independent random samples of test records (one day milk yield) were drawn from each stratum during 1st, 2nd and so on upto 20th fortnightly strata or till date of drying whichever was earlier. Every test record from each stratum was selected as independent random sample by the method of generation of random numbers by power residue method (Grover, 1981).

3.5.2.2 Monthly recording

The lactation period of 300 days was divided into 10 strata at monthly (30 days) intervals. Then independent random samples of test records (one day milk yield) were drawn from each stratum during first, second and so on upto 10th monthly strata or till date of drying whichever was earlier. Every test record from each stratum was selected as independent random sample by the method of generation of random numbers by power residue method.

3.5.2.3 Bimonthly recording

The lactation period of 300 days was divided into 5 strata at bimonthly (60 days) intervals. Then independent random samples of test records (one day milk yield) were drawn from each stratum during 1st two, 2nd two, 3rd two, 4th two and 5th two months of strata of lactation or till date of drying whichever was earlier. Every test record from each stratum was selected as independent random sample by the method of generation of random numbers by power residue method.

3.6 PART LACTATION RECORDS

The part lactation milk yield was taken by addition of

observed daily milk yield during each fortnight, month and bimonth upto 300 days lactation or till date of drying. In the same way, cumulative part milk yield was obtained by summing up the relevant part lactation yields. The following sets of part lactation and cumulative lactation milk yields were generated:

1. Part lactation milk yield during 1st fortnight, 2nd fortnight and so on upto 20th fortnight.
2. Part lactation milk yield during first month, second month and so on till 10th month.
3. Part lactation milk yield during 1st two-months, 2nd two-months, 3rd two-months, 4th two-months and 5th two-months.
4. Cumulative part lactation milk yield during first 30, 60, 90 days and so on at 30 days interval till 300 days of lactation.

3.7 METHOD OF GENERATION OF RANDOM NUMBERS

According to the Power Residue Method (Grover, 1981), random numbers are formed by recursive relationship:

$$M_{n+1} = kM_n / \text{mod } p$$

where, M_n , M_{n+1} are successive numbers, while k and p are integer constants. The above equation implies that M_{n+1} is the remainder obtained after multiplying M_n by k and dividing by $\text{mod } p$. "mod" implies modulus. For instance, let $p = 11$, $k = 3$, $M_0 = 1$, then

$$M_1 = 3 \times 1/11 = 3$$

$$M_2 = 3 \times 3/11 = 9$$

$$M_3 = 3 \times 9/11 = 5$$

$$M_4 = 3 \times 5/11 = 4$$

This sequence repeats after some numbers. Attempt was made to make this repetition frequency minimum. This may be achieved by a suitable choice of k and p . The Computer Centre at this

Institute developed a computer programme to generate random numbers for fortnightly, monthly and bimonthly milk recording systems.

3.8 GENERATION OF TRAITS FOR STUDY

The first lactation records and daily milk yields were used to generate following traits for study:

3.8.1 PRODUCTION TRAITS

1. Observed first lactation milk yield (300 days or less) - OMY
2. Age at first calving (days) - AFC

3.8.2 SAMPLING SCHEMES

3.8.2.1 Systematic sampling schemes

- a) Predicted first lactation milk yield (300 days or less) under fortnightly systematic sampling scheme.
- b) Predicted first lactation milk yield (300 days or less) under monthly systematic sampling scheme.
- c) Predicted first lactation milk yield (300 days or less) under bimonthly systematic sampling scheme.

3.8.2.2 Stratified random sampling schemes

- a) Predicted first lactation milk yield (300 days or less) under fortnightly stratified random sampling scheme.
- b) Predicted first lactation milk yield (300 days or less) under monthly stratified random sampling scheme.

- c) Predicted first lactation milk yield (300 days or less) under bimonthly stratified random sampling scheme.

3.8.3 PART LACTATION RECORDS

- a) Fortnightly part lactation milk yields from 1st fortnight to 20th fortnight of the lactation.
- b) Monthly part lactation milk yields from 1st month to 10th month of lactation.
- c) Bimonthly part lactation milk yields from 1st bimonth to 5th bimonth of the lactation.
- d) Cumulative lactation milk yields at 30 days interval upto 300 days of lactation.

3.9 CLASSIFICATION OF DATA

The data were classified according to breed, genetic group of breed, season and period of calving.

3.9.1 GENETIC GROUPS WITHIN BREED

3.9.1.1 Karan Swiss breed

All the animals available in this breed were classified into four genetic groups on the basis of filial generation and level of exotic inheritance. The four genetic groups were assigned their code as shown in Table 4.

Table 4. Distribution of data according to genetic group and their codes for Karan Swiss cattle

Sl. No.	Genetic group	No. of cows	Code assigned
1.	I (F ₁)	211	6
2.	II (F ₂)	81	7
3.	III (62.5 to 75% exotic inheritance)	40	8
4.	IV (less than 62.5% exotic inheritance, <i>inter se</i> mated or filial group not known excepting F ₁ and F ₂)	712	9

3.9.1.2 Karan Fries breed

All the animals in this breed were classified into 5 genetic groups on the basis of their crosses of Holstein Friesian with Zebu cattle (Tharparkar and Sahiwal) and exotic cattle (Jersey and Brown Swiss). Five genetic groups were assigned the code numbers as under:

Table 5. Distribution of data according to genetic group and their codes for Karan Fries cattle

Sl. No.	Genetic group	No. of cows	Code assigned
1.	HT (Holstein x Tharparkar)	154	1
2.	KF (Karan Fries - inter se mated)	534	2
3.	HS (Holstein x Sahiwal)	71	3
4.	HJT [Holstein(50%) + Jersey(25%) + Tharparkar (25%)]	48	4
5.	HBT [Holstein(50%) + Brown Swiss(25%) + Tharparkar(25%)]	28	5

3.9.2 SEASON OF CALVING

A year was divided into five seasons as under:

Sl. No.	Name of season	Group of months	Code
1.	Winter	December to February	1
2.	Spring	March to April	2
3.	Summer	May to June	3
4.	Rainy	July to September	4
5.	Autumn	October to November	5

3.9.3 PERIOD OF CALVING

The data were spread over 18 years of first calving (1970 to 1987) for Karan Swiss breed and 15 years of calving (1974 to 1988) for Karan Fries breed. The data were classified into 8 periods of calving in case of Karan Swiss and 7 periods of calving in case of Karan Fries by merging the consecutive years as given below. The basic purpose was to have substantial number of observations in each period such that variation between periods was larger than within periods.

Table 6. Distribution of data according to periods for Karan Swiss cattle

Sl. No	Period of calving	Number of observations	Period code
1.	1970-71	66	1
2.	1972-73	112	2
3.	1974-75	146	3
4.	1976-77	211	4
5.	1978-79	180	5
6.	1980-81	114	6
7.	1982-83	117	7
8.	1984-87	104	8

Table 7. Distribution of data according to periods for Karan Fries cattle

Sl. No	Period of calving	Number of observations	Period code
1.	1974-75	62	3
2.	1976-77	102	4
3.	1978-79	99	5
4.	1980-81	140	6
5.	1982-83	141	7
6.	1984-85	164	8
8.	1986-88	148	9

3.10 STATISTICAL ANALYSIS

Statistical analyses were carried out separately for Karan Swiss and Karan Fries breeds with the help of HCL Horizon III computer system available at Computer Centre, National Dairy Research Institute, Karnal.

3.10.1 COW EVALUATION

3.10.1.1 Estimation of milk yield for every part of lactation under each of the above sampling schemes

Prediction of lactation milk yield (PMY) for 300 days or less under systematic and stratified random sampling schemes was made as under:

$$PMY = \sum_{i=1}^N (\text{space of sampling} \times \text{milk yield of sampled day})$$

$$+ \{[(\text{actual lactation length}) - (\text{space of sampling schemes} \times \text{number of samples})] \\ \times \text{milk yield of last sample yield}\}$$

where space of systematic and stratified random sampling schemes was as under:

1. Fortnightly = 15 days
2. Monthly = 30 days
3. Bimonthly = 60 days

3.10.1.2 Fitting of linear equations for prediction of first lactation milk yield under various sampling schemes, part lactation yield and cumulative part lactation milk yield

3.10.1.2.1 Ratio method

The ratio of 300 days lactation milk yield to part yield was calculated as under:

$$R_j = \frac{\sum_{i=1}^N Y_i}{\sum_{i=1}^N X_{ij}}$$

where, R_j = the ratio for extending j^{th} part record
 Y_i = the actual lactation yield of i^{th} animal

The estimated lactation yield of i^{th} animal from j^{th} part record:

$$Y_{ij} = R_j X_{ij}$$

The error of estimate was calculated as given below:

$$E_i = \hat{Y}_i - Y_i$$

where, E_i is the difference between estimated/predicted (\hat{Y}_i) and actual (Y_i) lactation yield of i^{th} cow

$$\text{Average error} = \frac{\sum_{i=1}^N E_i}{N}$$

where, N is the number of observations.

The per cent error (P) in the estimation of lactation yield from various sampling schemes, part yields and cumulative milk yields was calculated as shown below:

$$P = \frac{\sum_{i=1}^N E_i}{\sum_{i=1}^N Y_i} \times 100$$

The absolute error of estimation = $|E_i|$

$$\text{The average absolute error} = \frac{\sum_{i=1}^N |E_i|}{N}$$

$$\text{Average absolute error per cent} = \frac{\sum_{i=1}^N |E_i|}{\sum_{i=1}^N Y_i} \times 100$$

The variance of error was estimated as follows:

$$\text{Variance} = \frac{\sum_{i=1}^N E_i^2 - \frac{\left(\sum_{i=1}^N E_i \right)^2}{N}}{N - 1}$$

3.10.1.2.2 Prediction of lactation yield by regression method on the basis of observed part yields or estimated part yields under various sampling schemes

The linear regression of observed lactation milk yield (OMY) on part lactation milk yield was estimated by the model:

$$Y_i = a_j + b X_{ij}$$

where, Y_i = predicted milk yield (PMY) of i^{th} animal
 a_j = the constant for j^{th} part record
 b = the regression coefficient
 x_{ij} = the j^{th} part record of i^{th} animal

The coefficient of determination (R^2) of the regression model for the j^{th} part yield was estimated as described below:

$$R^2_j = \frac{b_j \sum_{i=1}^N X_{ij} Y_i - \frac{\sum_{i=1}^N X_{ij} \sum_{i=1}^N Y_i}{N}}{V(Y)} \times 100$$

where, $V(Y)$ = the variance of lactation milk yield (Y)
 b_j = the regression coefficient of Y_i on X_{ij}

X_{ij} = the j^{th} part lactation record of i^{th} animal
 N = number of observations

3.10.1.3 Effectiveness of prediction of lactation yield on the basis of observed part yields or estimated part yields under various sampling schemes

The multiple regression analysis was conducted to determine the effective contribution of different observed and estimated part yields to lactation milk yield (OMY). The milk yields of fortnightly, monthly, bimonthly and cumulative part lactations were taken as independent variables and OMY was regarded as dependent variable. The model used for this purpose was as follows:

$$Y = b_0 + b_1X_1 + b_2X_2 \dots\dots\dots b_nX_n$$

where, Y = observed lactation milk yield (OMY)

b_0 = a constant

b_1 = partial regression coefficient of Y on X_1

b_2 = partial regression coefficient of Y on X_2

b_n = partial regression coefficient of Y on X_n

$X_1, X_2 \dots\dots X_n$ are independent variables (part yields)

The estimates of the partial regression coefficients were obtained by solving the coefficient matrix derived from normal equations separately for each situation. The standard errors of partial regression coefficients were calculated according to Amble (1975) with the help of inverse elements of coefficient matrix. The significance of partial regression coefficients was tested by students' t-test.

-The analysis of variance was conducted as follows:

Source	d.f.	s.s.	m.s.	Variance ratio
Due to regression	n	SSr	MSr	$\frac{MSe}{MSr}$
Residual	(N-n-1)	SSe	MSe	
Total	(N-1)	SST		

where, n is the number of independent variables which varied from 5 to 20 in different cases.

The coefficient of determination (R^2) or accuracy of fitting the regression model was estimated as the ratio of sum of squares due to regression (SSr) to total corrected sum of squares (SST).

3.10.1.4 Selection of optimum number of test records for estimation of lactation yield by forward stepwise regression analysis

This is the improved version of the forward selection procedure. The improvement involves the reexamination at every stage of the regression of the variables incorporated into the model in previous stage. Any variable which provides a non-significant contribution is removed from the model. This process is continued until no more variables would be admitted to the equation and no more are rejected.

Step 1

The stepwise procedure started with the simple correlation matrix and entered into regression the part yield variable most

highly correlated with OMY. The highly correlated variable was entered as in the forward selection.

Step 2

Using the partial correlation coefficient as before, it again selected, as the next variable to enter regression, that independent variable whose partial correlation with the response (OMY) was highest. Then this 'entered independent variable' of part yield was analysed again by forward selection regression analysis.

Step 3

The regression equation was re-examined for the contribution of first variable which it would have made, if second variable had been entered first and first variable entered second (the forward selection did not do this). Since the value of the partial F was statistically tested for significance at $P < 0.05$, the first variable was retained when partial F was significant. The stepwise method selected the next variable to enter, the one most highly partially correlated with the response (OMY) (given that variable first and second were already in regression). This was taken as the third variable. The process was continued until a new variable did not give significant partial 'F' test (Draper and Smith, 1966).

3.10.2 EFFECT OF VARIOUS NON-GENETIC FACTORS ON OBSERVED AND PREDICTED LACTATION YIELDS BY METHOD OF LEAST SQUARE ANALYSIS

The effects of various non-genetic factors such as season of calving, period of calving and age at first calving on observed lactation yield and estimated lactation yields under different sampling schemes were studied in order to ascertain the contribution of these factors towards the variability in lactation yield. Since the number of observations in different

sub-classes were unequal and disproportionate, method of least squares analysis as described by Harvey (1966) was used to minimise the effect of non-orthogonality. The mathematical model used to study the effect of different non-genetic factors was as follows:

$$Y_{ijkl} = \mu + G_i + P_j + S_k + b(x_{ijkl} - \bar{X}) + e_{ijkl}$$

where, Y_{ijkl} = the record of i^{th} animal that calved in k^{th} season under the j^{th} period and i^{th} genetic group

μ = population mean

G_i = effect of i^{th} genetic group;

for Karan Fries (KF) ($i = 1, 2, 3, 4, 5$);

for Karan Swiss (KS) ($i = 6, 7, 8, 9$);

P_j = effect of j^{th} period of calving;

for Karan Swiss ($j = 1, 2, \dots, 8$);

for Karan Fries ($j = 3, 4, \dots, 9$);

S_k = effect of k^{th} season of calving;

for Karan Swiss and Karan Fries ($k = 1, 2, \dots, 5$);

b = partial regression of Y_{ijkl} on X_{ijkl} ;

X_{ijkl} = an independent continuous variable (age at first calving);

\bar{X} = breed average of age at first calving;

e_{ijkl} = random error associated with Y_{ijkl} and assumed to be normally and independently distributed with mean zero and constant variance σ_e^2 .

3.10.3 ADJUSTMENT OF DATA

The data were adjusted for genetic groups, season and period of calving and age at first calving to remove their differential effects. The adjusted records were used to estimate genetic parameters.

3.10.4 ESTIMATION OF GENETIC PARAMETERS

The adjusted records were used for estimation of genetic parameters. Only those progeny groups which had minimum of five daughters per sire were included in the estimation of genetic parameters.

3.10.4.1 Estimation of heritability (h^2)

The estimates of heritability of observed lactation milk yield, predicted lactation milk yield under different sampling schemes, part yields and cumulative yields were obtained by the method of paternal half-sib correlation (intra-sire correlation among daughters) method by least square analysis (Becker, 1975). The principle of the estimation is based on measuring resemblance among relatives (half sibs). The model used was

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

where, Y_{ij} = the performance of j^{th} progeny of i^{th} sire
 μ = the overall mean
 S_i = effect of i^{th} sire
 e_{ij} = random error associated with Y_{ij} and assumed to be NID ($0, \sigma_e^2$)

Analysis of variance table

Source of variation	d.f.	MSS	EMS
Among sires	S-1	MSs	$\frac{2}{e} + k \frac{2}{s}$
Progeny within sires	N-S	MSe	$\frac{2}{e}$
Total	N-1		

$$\sigma_s^2 = \frac{MSs - MSe}{k}$$

$$\sigma_e^2 = MSe$$

$$k = \frac{1}{s-1} \left[N - \frac{\sum_{i=1}^s n_i^2}{N} \right]$$

Hence, intra class correlation 't' among paternal half sibs was

$$t = \frac{\sigma_s^2}{\sigma_s^2 + \sigma_e^2}$$

Heritability was estimated as

$$h^2 = 4t = \frac{4\sigma_s^2}{\sigma_s^2 + \sigma_e^2}$$

where, σ_s^2 is the component of sire variance

σ_e^2 is the error variance

The standard error of h^2 was calculated by using the formula by Swiger *et al.* (1964):

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

where, N is the number of observations

S is the number of sires

K is the average number of progeny per sire (estimated by formula given above)

3.10.4.2 Genetic and phenotypic correlations

The genetic and phenotypic correlations among different traits, viz. observed lactation milk yield, predicted lactation milk yield under different sampling schemes, part and cumulative yields were estimated from the analysis of variance and covariance among sire groups as given by Becker (1975).

3.10.4.2.1 Genetic correlations (r_G)

The genetic correlation was estimated by using formula

$$r_G (XY) = \frac{[Cov_S (XY)]}{\sqrt{\left[\sigma_s^2 (X) \right] \left[\sigma_s^2 (Y) \right]}}$$

where, X and Y are two different traits for the same individual.

$Cov_S (XY)$ = sire component of covariance between traits X and Y

$\sigma_s^2 (X)$ and $\sigma_s^2 (Y)$ are the sire component of variance for

traits X and Y respectively

The standard error of genetic correlation was estimated by using the formula given by Robertson (1959):

$$SE(r_G) = \frac{1 - r_G^2}{\sqrt{2}} \sqrt{\frac{SE(h^2_X) \cdot SE(h^2_Y)}{h^2_X \cdot h^2_Y}}$$

where, h^2_X and h^2_Y are the heritability estimates of the traits X and Y.

3.10.4.2.2 Phenotypic correlation (r_p)

It was estimated as

$$r_p(XY) = \frac{Cov_s(XY) + Cov_e(XY)}{\sqrt{\left[\frac{\sigma_s^2(X)}{s} + \frac{\sigma_e^2(X)}{e} \right] \left[\frac{\sigma_s^2(Y)}{s} + \frac{\sigma_e^2(Y)}{e} \right]}}$$

where, $Cov_e(XY)$ is error component of covariance between traits X and Y

$\frac{\sigma_e^2(X)}{e}$ and $\frac{\sigma_e^2(Y)}{e}$ are the error components of variance for

traits X and Y, respectively.

The standard error of phenotypic correlations was obtained according to formula given by Panse and Sukhatme (1967).

$$SE(r_p) = \frac{1 - r_p^2(XY)}{\sqrt{N - 2}}$$

where, $r_p(XY)$ is the phenotypic correlation between X and Y traits in same individual and $N - 2$ is the degree of freedom.

The statistical significance of correlation coefficient was tested by Z-transformation and t-test as given by Snedecor and Cochran (1967).

3.10.5 SIRE EVALUATION

The breeding value of sires was estimated on the basis of observed lactation milk yield (OMY) and predicted lactation milk yield (PMY) on the basis of various sampling schemes and part lactation yields. The following methods of sire evaluation were used.

1. Simple daughter average indexd (I_1)

The sires were evaluated by simple daughter average using unadjusted data for various traits:

$$I_1 = \bar{D}$$

where, I_1 is the first sire index method for i^{th} sire

\bar{D} is daughter's average first lactation traits of the sire

2. Contemporary comparison method (I_2)

The simple daughter average method of sire evaluation is very easy to compute but has the several limitations, especially when the number of daughters per sire group are small and their spread is over longer period of time; then it provides biased estimates. Therefore, adjustment for time differences in daughters performance can be taken care of by contemporary comparison method. The contemporary of a cow was considered to be the daughters whose calving fell within two months before and two months after the date of calving of daughters of sires under evaluation. The formula used for estimating the sire index was as under:

$$I_2 = \mu + \frac{n_i}{\left(n_i + \frac{\sigma_e^2}{\sigma_s^2}\right)} (D - \overline{CAD})$$

where, I_2 = index of sire
 μ = population mean
 n_i = number of daughters of the sire
 σ_e^2 = component of error variance

σ_s^2 = component of sire variance
 \overline{CAD} = contemporary daughters average

This method not only adjusts records made at different periods but also takes into consideration the variation in number of daughters of sire under evaluation.

3. Least square analysis method (I₃)

For sire evaluation, the lactation milk yields, predicted milk yields, part yields, etc. were adjusted for the effects of genetic group, season and period of calving and age at first calving, using least square analysis method (Harvey, 1966) to minimise the effects of non-orthogonality. The mathematical model used to estimate the breeding value of sires was as follows:

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

where, Y_{ij} = j^{th} observation in i^{th} sire group (sire index value) adjusted for various non-genetic effects;
 μ = overall population mean;
 S_i = the effect of i^{th} sire expressed as a deviation from overall mean (μ);
 e_{ij} = random error associated with Y_{ij} and assumed to be NID $(0, \sigma_e^2)$.

4. Best Linear Unbiased Prediction (BLUP) (I₄)

Henderson (1975) proposed a modified maximum likelihood method using mixed model. It is called Best Linear Unbiased Prediction (BLUP). The procedure used was:

Let the linear mixed model be

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

where, Y is an n x 1 observation vector

X is known as n x p matrix of fixed effects (viz. period and season of calving, regression on age at calving, genetic group)

β is unknown fixed vector (p x 1)

Z is a known n x q matrix corresponding to random effects (sire effects)

u is a known random vector (q x 1)

u and e are non-observable random vectors with null means and

$$\text{Var} \begin{pmatrix} u \\ e \end{pmatrix} = \begin{pmatrix} G & D \\ D & R \end{pmatrix} \sigma^2$$

where, σ^2 is a scalar which is unknown and G and R are both non-singular

The analytical model used was

$$Y_{ijklmn} = \mu + G_i + P_j + S_k + B_l + b(X_{ijklmn} - \bar{X}) + e_{ijklmn}$$

where, Y_{ijklmn} = production of nth daughter of lth sire calved in kth season of jth period in ith genetic group

μ = population mean (fixed).

G_i = fixed effect of ith genetic group

P_j = fixed effect of jth period of calving

S_k = fixed effect of kth season of calving

B_l = random effect of lth sire with expectation zero and constant variance $\frac{\sigma^2}{s}$

b = partial regression of Y_{ijklmn} on X_{ijklmn}
 X_{ijklmn} = an independent continuous variable (age at first calving) corresponding to Y_{ijklmn}
 \bar{X} = breed average of age at first calving.

e_{ijklmn} = random error associated with Y_{ijklmn} and assumed to be normally and independently distributed with mean zero and constant variance σ_e^2

3.10.6 SPEARMAN RANK CORRELATION BETWEEN BREEDING VALUES BY DIFFERENT METHODS

The correlation between the rankings of the sires based on their breeding values estimated by various methods were tested by using Spearman rank correlation (Steel and Torrie, 1960) as

$$r(\text{rank}) = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

where, r = rank correlation
 n = number of sires under evaluation
 d_i = difference between the ranking of a sire by two methods

The significance of rank correlation was tested by

$$t = r \sqrt{\frac{n - 2}{1 - r^2}}$$

which has a student t-distribution with $n-2$ degree of freedom.

3.10.7 CRITERIA FOR JUDGING THE EFFECTIVENESS OF SIRE EVALUATION METHODS

The following criteria were used for judging the effectiveness of the various sire evaluation methods:

- i) Within-sire variance or error variance
- ii) Rank correlation of breeding values by a procedure with the breeding values by most efficient procedure.

3.10.8 NUMBER OF DAUGHTERS WITH PART RECORDS REQUIRED TO PROVE THE SIRE WITH THE SAME EFFICIENCY AS OBTAINED ON THE BASIS OF A GIVEN NUMBER OF TOTAL LACTATION RECORDS

Number of part records to prove the sire for lactation (300 days) yield with the same efficiency as that of given number of 300 days lactation milk records was estimated by the following two methods:

$$i) \quad n_i = \frac{\sigma_e^2 \sigma_g^2 A}{\sigma_{sg}^2 - \sigma_g^2 \sigma_s^2 A}$$

(Vanvleck and Henderson, 1961b)

$$\text{where, } A = \frac{\sigma_g^2}{\sigma_g^2 + \frac{\sigma_F^2}{n_i'}}$$

σ_e^2 = error component of variance of part records

σ_g^2 = sire component of variance of lactation (300 days) records

σ_{sg}^2 = covariance between S_i and g_i

σ_s^2 = sire component of variance of part records

$\frac{2}{F}$ = error component of variance of complete lactation

n_i = number of daughters with part records

n_i' = number of daughters with lactation (300 days) records

(ii) Searle (1961a) gave a method from which the number of daughters with part records required was estimated. On the basis of it, the following formula was used to determine the number of daughters with part records (n) required as against a fixed number of daughters with 300 days lactation records.

$$r \sqrt{\frac{n h_p^2}{4 + (n-1)h_p^2}} = \sqrt{\frac{N h^2}{4 + (N-1)h^2}}$$

where, r = genetic correlation between part and 300 days lactation yield;

n = number of daughters with part records;

N = number of daughters with 300 days yield;

h_p^2 = heritability of part lactation yield;

h^2 = heritability of 300 days yield.

$\sqrt{\frac{N h^2}{4 + (N-1)h^2}}$ was the accuracy of the sire proof for 300 days record. When 300 days records of 'N' daughters were used:

$\sqrt{\frac{N h_p^2}{4 + (n-1)h_p^2}}$ was the corresponding accuracy

for part lactation records. When part records of 'n' daughters were used, this factor, when multiplied by genetic correlation (r_G), would give the accuracy of sire proof for 300 days record when 'n' part records was used.

3.10.9 DETERMINATION OF OPTIMUM PROGENY GROUP SIZE

The breeding value of bulls with 15 or more daughters was considered as 'True Breeding Value' (TBV). For such set of bulls, the breeding value was estimated separately on the basis of first 5 daughters, first 8 daughters and first 12 daughters and 15 or more daughters. The correlations between breeding value of bulls on the basis of various progeny group sizes with 'True Breeding Value' were estimated. The minimum number of daughters in sire group which gave more than 80 per cent accuracy of prediction of TBV was considered as optimum.

3.10.10 COST OF FIELD RECORDING OF DAUGHTERS UNDER VARIOUS SAMPLING SCHEMES FOR SAME ACCURACY OF PROGENY TESTING OF BULLS WITH VARYING PROGENY GROUP SIZE

The number of progeny required per sire under various sampling schemes to obtain the same accuracy of evaluation of breeding value of sires as obtained for a given number of progeny size with complete first lactation yield was estimated by using the following formula (Cunningham and Vial, 1968):

$$n_{ik}' = n_i \left[1 + \frac{V(E_k)}{V(Y)} \right]$$

where, n_{ik}' = the number of daughters required for i^{th} sire under k^{th} sampling scheme,

n_i = the number of daughters available for the i^{th} sire with first lactation yield,

$V(E_k)$ = within sire error variance of prediction of lactation yield under k^{th} sampling, and

$V(Y)$ = variance of first lactation yield.

The cost of field recording for progeny testing a bull was obtained by considering the number of test records required under each sampling scheme for varying interval of recording multiplied by the cost of recording a cow on one day. The cost of recording a cow on a day was taken as Rs.6.

CHAPTER - 4

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The results of investigations on Karan Swiss and Karan Fries cattle have been presented and discussed as given below:

4.1 PERFORMANCE WITH RESPECT TO OBSERVED FIRST LACTATION MILK YIELD (OMY) AND PREDICTED LACTATION MILK YIELD (PMY) UNDER SYSTEMATIC AND STRATIFIED RANDOM SAMPLING SCHEMES

4.1.1 LEAST SQUARES MEANS AND STANDARD ERRORS FOR OBSERVED (OMY) AND PREDICTED (PMY) FIRST LACTATION MILK YIELD IN KARAN SWISS BREED

The least squares means with standard error for OMY and PMY under systematic and stratified random milk recording schemes for Karan Swiss cattle are shown in Table 8. It is seen from Table 8 that for Karan Swiss the overall least squares mean of observed first lactation milk yield (OMY) was 2639.98 ± 35.76 kg. The average predicted lactation milk yield on the basis of test day samples taken at fortnightly, monthly and bimonthly intervals under systematic sampling schemes were 2640.67 ± 35.84 kg, 2646.25 ± 36.39 kg and 2665.46 ± 37.00 kg, respectively and under stratified random sampling schemes were 2640.07 ± 35.84 kg, 2645.37 ± 36.00 kg and 2651.88 ± 36.37 kg, respectively. The estimates of average predicted lactation yields along with standard error were slightly higher as compared to average of OMY. Although there was a slightly increasing trend in PMY and its standard error with increase in testing interval, there was slight increase of 0.69 kg and 0.09 kg in average lactation milk yield in prediction as compared to OMY under fortnightly systematic and stratified random sampling schemes, respectively. However, under monthly systematic scheme there was increase of

Table 9. Least squares means for OMY and PMY under systematic and stratified random sampling scheme of Karan Swiss breed

(in kgs)

Effects	No. of obs.	OMY	Systematic sampling scheme			Stratified random sampling scheme		
			Fortnightly	Monthly	Bimonthly	Fortnightly	Monthly	Bimonthly
Population mean	1044	2639.98±35.76	2640.67±35.84	2646.25±36.39	2665.46± 37.00	2640.07±35.84	2645.37±36.00	2651.88±36.37
Genetic group**								
6	211	3017.66±47.49	3014.92±47.59	3025.57±48.21	3034.86± 49.14	3021.23±47.60	3021.21±47.81	3014.50±48.30
7	81	2482.44±75.58	2492.30±75.76	2493.37±76.74	2525.36± 78.22	2479.08±75.77	2486.62±76.10	2474.41±76.88
8	40	2571.49±96.86	2568.60±97.09	2578.15±98.35	2616.28±100.24	2568.12±97.10	2572.09±97.52	2604.63±98.53
9	712	2488.31±28.33	2486.88±28.40	2487.92±28.77	2485.34± 29.32	2491.82±28.41	2501.52±28.53	2513.97±28.82
Seasons**								
1	398	2643.34±40.79	2641.55±40.88	2651.03±41.42	2663.18± 42.21	2640.57±40.89	2644.96±41.07	2656.86±41.49
2	315	2459.64±43.20	2459.66±43.30	2460.49±43.86	2482.07± 44.70	2459.81±43.30	2460.29±43.49	2453.64±43.94
3	147	2633.13±56.89	2637.40±57.03	2633.53±57.77	2671.13± 58.88	2632.42±57.04	2630.95±57.28	2624.52±57.87
4	116	2604.80±62.01	2606.39±62.15	2616.73±62.97	2617.31± 64.17	2603.68±62.17	2619.06±62.43	2622.70±63.08
5	68	2858.97±78.19	2858.40±78.17	2869.47±79.39	2893.61± 80.91	2863.84±78.38	2871.55±78.72	2902.70±79.54
Periods**								
1	65	2674.31±79.58	2680.02±79.77	2675.98±80.81	2668.48± 82.36	2674.77±79.78	2697.57±80.12	2769.19±80.95
2	109	2862.59±62.02	2864.60±62.17	2860.29±62.98	2889.02± 64.18	2861.85±62.17	2890.11±62.44	2880.53±63.09
3	146	2667.96±58.53	2671.59±58.67	2671.21±59.43	2678.41± 60.57	2668.68±58.68	2668.04±58.93	2655.05±59.54
4	209	2452.86±54.84	2455.24±54.97	2466.00±55.69	2479.66± 56.76	2449.26±54.98	2458.00±55.22	2432.26±55.79
5	180	2331.80±54.75	2330.03±54.88	2325.82±55.60	2364.03± 56.66	2331.55±54.88	2331.07±55.13	2330.98±55.69
6	114	2493.54±71.45	2497.60±71.63	2513.98±72.56	2527.23± 73.95	2497.64±71.63	2494.50±71.94	2511.01±72.68
7	117	2561.20±71.93	2558.04±72.10	2576.97±73.04	2603.40± 74.43	2566.68±72.10	2561.39±72.42	2542.18±73.17
8	104	3075.58±72.90	3068.25±73.08	3079.77±74.03	3113.46± 75.45	3070.07±73.09	3062.21±73.40	3093.84±74.16

** Genetic group, season and period of calving significant (P < 0.01) under OMY and all six sampling schemes

6.27 kg for PMY and under monthly stratified random milk recording scheme there was increase of 5.37 kg as compared to OMY. Under bimonthly recording there was increase of 25.48 kg and 11.9 kg in average lactation milk yield under systematic and stratified random sampling schemes, respectively. The least square means of first lactation milk yield (305 days) of Karan Swiss cows were reported to be 2469.95 ± 697.77 kg by Kumar and Bhatnager (1989) and to be 2167 ± 116 kg by Kumar and Reddy (1989).

4.1.2 LEAST SQUARES MEANS AND STANDARD ERROR OF OBSERVED (OMY) AND PREDICTED (PMY) FIRST LACTATION MILK YIELD IN KARAN FRIES CATTLE

It is seen from Table 9 that the least squares mean of first lactation milk yield (OMY) was 2768.65 ± 55.02 kg. The average predicted lactation milk yield (PMY) on the basis of test records taken at fortnightly, monthly and bimonthly intervals were 2770.36 ± 55.20 kg, 2770.67 ± 55.61 kg and 2751.89 ± 56.88 kg under systematic sampling scheme, respectively and 2773.76 ± 55.16 kg, 2777.34 ± 55.04 kg and 2793.17 ± 56.31 kg under stratified random sampling scheme, respectively. The estimates of average predicted lactation milk yield and standard error showed a slightly increasing trend with increase in recording intervals for both sampling schemes. There was slight increase of 1.71 kg and 5.13 kg in average lactation milk yield in prediction as compared to OMY under fortnightly systematic and stratified random sampling schemes, respectively. However, under monthly systematic scheme, there was increase of 2.02 kg for PMY and under monthly stratified random milk recording scheme there was increase of 8.69 kg as compared to OMY. Under bimonthly systematic sampling scheme, the lactation milk yield was underestimated by -16.76 kg whereas under stratified sampling it was overestimated by 24.52 kg. The least square mean of first lactation milk yield (305 days) of Karan Fries cows was reported to be 2278 ± 178 kg by Kumar and Reddy (1989). The lactation milk yield (OMY) was reported to be 2909 kg in Holstein Friesian

Table 9. Least squares means for OMV and F¹⁰⁰ under systematic and stratified random sampling scheme of Karan Fries breed

(in kgs)

Effects	No. of obs.	OMV	Systematic sampling scheme			Stratified random sampling scheme		
			Fortnightly	Monthly	Bimonthly	Fortnightly	Monthly	Bimonthly
Population mean	835	2768.65± 55.02	2770.36± 55.20	2770.67± 55.60	2751.89± 56.88	2773.78± 55.16	2777.34± 55.04	2793.17± 56.31
Genetic groups ¹¹								
1	154	3239.72± 87.90	3251.19± 88.18	3246.63± 88.82	3215.03± 90.87	3250.73± 88.13	3238.60± 87.93	3293.43± 89.95
2	534	3134.52± 65.50	3133.18± 65.71	3138.04± 66.19	3149.44± 67.71	3131.74± 65.67	3150.18± 65.52	3138.12± 67.03
3	71	2708.54± 104.81	2712.82± 105.15	2724.51± 105.91	2688.00± 108.35	2717.73± 105.08	2967.32± 104.85	2717.16± 107.26
4	48	2324.14± 118.92	2321.62± 119.31	2319.44± 120.18	2280.45± 122.94	2334.36± 119.23	2350.44± 118.97	2329.81± 121.71
5	28	2436.29± 144.40	2432.98± 144.85	2424.71± 145.91	2426.51± 149.27	2434.35± 144.77	2450.15± 144.45	2487.31± 147.77
Seasons								
1	341	2841.62± 59.33	2816.59± 59.52	2820.62± 59.96	2800.84± 61.33	2819.24± 59.49	2824.41± 59.36	2839.33± 60.72
2	199	2649.83± 65.14	2654.11± 65.35	2643.27± 65.82	2621.85± 67.33	2655.77± 65.31	2651.28± 65.16	2636.17± 66.66
3	119	2767.87± 82.13	2769.86± 82.40	2779.42± 82.99	2746.06± 84.90	2769.23± 82.34	2766.94± 82.16	2812.36± 84.05
4	103	2744.43± 83.93	2740.17± 84.20	2746.22± 84.81	2730.02± 86.75	2742.55± 84.14	2763.63± 83.96	2764.91± 85.89
5	73	2866.47± 94.02	2871.07± 94.32	2863.80± 95.00	2860.66± 97.19	2882.14± 94.26	2880.48± 94.05	2913.06± 96.22
Periods ¹²								
3	62	2945.59± 107.16	2954.50± 107.50	2964.85± 108.29	2948.96± 110.70	2946.36± 107.44	2976.71± 107.20	2929.37± 109.66
4	100	3093.34± 85.86	3083.34± 86.14	3091.15± 86.76	3103.25± 88.76	3088.33± 86.08	3122.30± 85.89	3136.56± 87.86
5	99	2782.67± 74.74	2786.21± 74.98	2784.91± 75.53	2789.79± 77.26	2783.37± 74.93	2773.85± 74.77	2785.54± 76.49
6	130	2440.96± 92.11	2439.06± 92.40	2443.79± 93.07	2422.09± 95.22	2449.28± 92.35	2453.29± 92.14	2494.53± 94.26
7	134	2411.72± 121.39	2412.71± 121.78	2405.81± 122.66	2391.21± 125.49	2425.87± 121.71	2408.96± 121.44	2413.74± 124.23
8	164	2859.53± 115.52	2856.16± 115.09	2864.31± 116.74	2806.52± 119.42	2861.31± 115.82	2857.37± 115.57	2901.09± 118.22
9	146	2846.68± 118.55	2860.55± 118.93	2839.04± 119.79	2801.40± 122.55	2861.95± 118.86	2848.87± 118.60	2891.34± 121.32

¹ Season of calving had significant effect ($P < 0.05$) on monthly systematic and bimonthly systematic and stratified random sampling schemes

¹¹ Genetic group, season and period of calving significant ($P < 0.01$) under OMV and all six sampling schemes

x Sahiwal crossbreds with exotic inheritance of 3/8-5/8 and 2722.91 kg in crosses with Holstein Friesian inheritance of greater than 5/8 by Sharma *et al.* (1982). The estimated lactation milk yield was reported to be more than observed yield by Singh and Desai (1966), Pandey and Desai (1973), Taneja and Garg (1976), Basu and Ghai (1977), Bhat *et al.* (1978), Deshpande and Bonde (1982) and Kumar (1987) in Friesian x Sahiwal crossbreds, Rao (1977) in the crosses of Friesian with Zebu, Raheja and Balaine (1982) in crosses of Friesian with Haryana.

4.2 THE INFLUENCE OF VARIOUS FACTORS ON OBSERVED (OMY) AND PREDICTED (PMY) LACTATION MILK YIELD UNDER VARIOUS SAMPLING SCHEMES.

4.2.1 INFLUENCE OF SEASON, PERIOD OF CALVING, GENETIC GROUP AND AGE AT FIRST CALVING ON OBSERVED (OMY) AND PREDICTED (PMY) LACTATION MILK YIELD UNDER VARIOUS SAMPLING SCHEMES IN KARAN SWISS CATTLE

The least squares analysis of variance indicated that the effects of seasons, periods and genetic groups were statistically significant ($P < 0.01$) on observed lactation milk yield (OMY) as well as predicted lactation milk yield (PMY) under various sampling schemes as well as intervals of recording in Karan Swiss (Table 10). The regression of OMY as well as PMY's on age at first calving was statistically not significant. The least squares estimates of average effects of above factors under various sampling schemes are given in Table 8.

The OMY as well as PMY's under various sampling schemes were found to be highest in autumn and lowest in spring. It is thus seen that the sampling schemes did not generally alter the effect of season in prediction of milk yield. The effect of season was reported to be significant by Mehta and Bhatnagar (1986), Kakran (1987) and Datt and Joshi (1992) in Karan Swiss cattle on first lactation milk yield. Dass (1991) found significant effect of season on observed (OMY) and predicted (PMY) lactation milk yield

Table 10. Least square analysis of variance for effects of season and period of calving, genetic group and age at first calving on OMY and PMY's under systematic and stratified random sampling scheme of Karan Swiss cattle

(in kg²)

Source	d.f.	OMY	MEAN SUM OF SQUARES					
			Systematic sampling scheme			Stratified random sampling scheme		
			Fortnightly	Monthly	Bimonthly	Fortnightly	Monthly	Bimonthly
Season**	4	2823971.8	2815786.5	2978533.0	2956222.3	2834424.3	2939497.5	3481144.0
Period**	7	6708040.0	6619519.5	6680293.0	6755422.5	6648175.0	6693536.0	7368178.5
Genetic group**	3	12354604.0	12182967.0	12620449.0	12810945.0	12439684.0	12019440.0	11381083.0
Regression on AFC (days)	1	25846.1	42838.9	47726.4	41782.9	17292.7	38240.6	30.5
Error	1028	350287.6	351966.6	361156.6	375164.9	352035.8	355104.4	362460.4

** Significant (P < 0.01); * Significant (P < 0.05)

under fortnightly, monthly and bimonthly systematic and stratified random sampling scheme. On the other hand, the effect of month of calving was reported to be not significant in field condition in crossbred cattle by Chacko et al. (1984) and Garcha and Dev (1985).

Period of calving significantly ($P < 0.01$) affected OMY and PMY under fortnightly, monthly and bimonthly systematic and stratified random sampling schemes. Kakran (1987), Datt and Joshi (1992) in Karan Swiss cattle also reported significant effect of period of calving on observed first lactation milk yield. Dass (1991) reported that period of calving was found to have significant effect on PMY under three testing intervals of both sampling schemes in Murrah buffaloes. Panda and Sandhu (1983) in Jersey x Haryana crosses and Garcha and Dev (1985) in crossbred cows reported that period/ year of calving had statistically non-significant effect on first lactation milk yield.

Genetic groups had statistically highly significant effect ($P < 0.01$) on all traits. The highest OMY as well as PMY's under systematic sampling scheme were found to occur for genetic group F1 (3017.66 kg) and lowest for genetic group F2 (2482.44 kg). The highest PMY (3021.23 kg) occurred for genetic group F1 and the lowest PMY (2491.82 kg) occurred for genetic group *inter se* mated under stratified random sampling scheme (Table 8). The differences among mean yields for genetic groups F2 and *inter se* mated were, however, statistically not significant.

The published literature indicates that the statistically significant effect of genetic groups on first lactation milk yield was reported by Bhatnagar and Sharma (1976) in Brown Swiss x Sahiwal crosses and Raheja and Balaine (1982) in Brown Swiss x Haryana crosses. Kakran (1987) and Datt and Joshi (1992) found in Karan Swiss cattle that the effect of genetic group on first lactation milk yield was statistically non-significant.

Effect of age at first calving (AFC) on all traits was found to be statistically non-significant. Similar finding was reported by Raheja and Balaine (1977) in Haryana and its crosses and by Dass (1991) in Murrah buffaloes. Datt and Joshi (1992) found significant effect of AFC on first lactation milk yield in Karan Swiss cattle.

4.2.2 INFLUENCE OF SEASON, PERIOD, GENETIC GROUP AND AGE AT FIRST CALVING ON OBSERVED (OMY) AND PREDICTED (PMY) LACTATION MILK YIELD UNDER VARIOUS SAMPLING SCHEMES IN KARAN FRIES CATTLE

The least squares analysis of variance in Karan Fries indicated that the effects of period, genetic group and age at first calving was highly statistically significant on OMY as well as PMY's under various sampling schemes (Table 11). The effect of season of calving was not significant on OMY and PMY's under fortnightly systematic and stratified random sampling schemes but was significant ($P < 0.05$) on PMY under monthly and bimonthly recording. The least square means of OMY and PMY under various sampling schemes are given in Table 9.

The OMY as well as PMY's under various sampling schemes were found to be highest in autumn season and lowest in spring season. It is thus seen that sampling schemes did not generally alter the effect of season in prediction of milk yield. Khanna and Bhat (1972) and Taneja and Bhat (1974) and Kumar (1987) found that season of calving did not have significant effect on lactation milk yield in Friesian x Sahiwal crosses. Dass (1991) reported that season of calving had significant effect on PMY's under fortnightly, monthly and bimonthly systematic and stratified random sampling schemes in Murrah buffaloes. He also found that least square mean of OMY as well as PMY's under both sampling schemes was highest in March to April and lowest in July to September.

Table 11. Least square analysis of variance for effects of season and period of calving, genetic group and age at first calving on OMY and PMY's under systematic and stratified random sampling scheme of Karan Fries cattle

(in kg²)

Source	d.f.	OMY	MEAN SUM OF SQUARES					
			Systematic sampling scheme			Stratified random sampling scheme		
			Fortnightly	Monthly	Bimonthly	Fortnightly	Monthly	Bimonthly
Season	4	1002680.5	995706.3	1121774.0*	1189250.8*	1036855.4	1100006.3*	1587120.1*
Period**	6	5316070.5	5321380.5	5338076.5	4979472.0	5166965.0	5401476.5	5757486.0
Genetic group**	4	9303153.0	9536125.0	9453878.0	9645326.0	9323377.0	9077604.0	10006801.0
Regression on AFC (days)**	1	7968023.5	8033971.5	7147774.0	6840686.5	8458281.0	8017378.5	7942291.5
Error	819	462565.0	465539.0	472335.1	494345.7	464988.5	462926.2	484451.4

** Significant (P < 0.01); * Significant (P < 0.05)

The period of calving had significant effect on OMY as well as PMY's under various sampling schemes. The significant effect of year/period of calving on first lactation milk yield was also reported by Khanna and Bhat (1972) and Kumar (1987) in Friesian x Sahiwal crossbred and Kakran (1987) in Karan Fries cattle. Dass (1991) also found significant effect of period on OMY and PMY's under fortnightly, monthly and bimonthly systematic and stratified random sampling schemes in Murrah buffaloes.

The effect of genetic group on OMY and PMY's was found to be statistically significant ($P < 0.01$). The least squares means of OMY and PMY's under various sampling schemes were found to be highest in genetic group H x T crosses and lowest in genetic group H x JT crosses. It is thus seen that sampling schemes did not generally alter the effect of genetic group in prediction of milk yield. The effect of genetic group was also found to be significant as reported by Pandey and Desai (1973) and Tomar and Tomar (1982) in Friesian x Sahiwal crossbreds, Choudhary and Barhat (1979) in Friesian x Haryana crosses, Raheja and Balaine (1982) in Brown Swiss, Friesian, Jersey and Red Dane halfbreds with Haryana and Kumar (1987) in Friesian x Sahiwal crosses and Kakran (1987) in Karan Fries cattle.

In this breed, the regression of OMY and PMY under each sampling scheme on age at first calving was found to be highly significant ($P < 0.01$). Basu and Gupta (1976) in Indian cattle, Gupta *et al* (1978) in Holstein Friesian x Sahiwal crosses, Kumar (1987) in Friesian x Sahiwal crosses and Dass (1991) in Murrah buffaloes also reported significant effect of age at first calving on observed lactation milk yield.

From the above presentation, it is seen that estimates of average predicted lactation yield along with standard error were slightly higher as compared to average of OMY. Although there was a slightly increasing trend in PMY's and their standard error with increase in testing interval in Karan Swiss and Karan Fries cattle, the least squares analysis of variance in both breeds

revealed that period of calving and genetic groups had statistically significant ($P < 0.01$) effect on observed (OMY) and predicted (PMY) lactation milk yields under various sampling schemes as well as interval of recording. The effect of season of calving was found to be significant ($P < 0.01$) on OMY and PMY under each sampling scheme in Karan Swiss breed. The effect of season of calving was not significant on OMY and PMY under fortnightly systematic and stratified random sampling schemes, but was significant ($P < 0.05$) on PMY under monthly and bimonthly recording in Karan Fries breed. The regression of OMY and PMY under each sampling scheme on age at first calving was not significant in Karan Swiss cattle, but was found to be highly significant ($P < 0.01$) in Karan Fries cattle. The sampling schemes did not generally alter the effects of various factors, viz., season and period of calving, genetic group and age at first calving on OMY and PMY's in both breeds.

4.3 INFLUENCE OF SEASON AND PERIOD OF CALVING, GENETIC GROUP AND AGE AT FIRST CALVING ON OBSERVED FORTNIGHTLY, MONTHLY AND BIMONTHLY PART MILK YIELD

Least squares analysis to assess the effect of season and period of calving, genetic group and age at first calving was also carried out for fortnightly, monthly and bimonthly part milk yield in Karan Swiss and Karan Fries cattle. The analysis of variance is given in Tables 12 to 19.

4.3.1 FORTNIGHTLY PART LACTATION MILK YIELD

The analysis of variance for fortnightly milk yield in Karan Swiss cattle (Table 12) indicated that the effect of season and period of calving was highly significant on all 20 fortnightly part milk yields. The genetic group effects were also highly significant for all 20 fortnightly part yields, whereas regression on age at first calving was not significant in all fortnightly yields.

Table 12. Least square analysis of variance for effects of season and period of calving, genetic group and age at first calving on fortnightly part milk yield of Karan Swiss cattle

MEAN SUM OF SQUARES (kg ²)											
Source	D.F.	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Season**	4	10088.1	25967.9	41569.2	41320.8	38518.4	40164.2	38406.3	42952.8	44953.3	48094.4
Period**	7	17857.3	33343.7	42496.1	43667.8	41380.2	38953.1	34269.8	28042.3	26243.3	25899.7
Genetic group**	3	44050.7	44446.3	45697.3	48292.2	40969.9	36201.4	34552.5	26698.6	27129.7	25588.9
Regression on APC (days)	1	711.7	203.4	2003.1	3118.4	4976.6	4877.9	3762.9	2817.0	2202.7	2114.7
Error	1028	1624.5	1450.6	1300.5	1167.1	1098.5	1062.3	1017.0	959.5	885.2 (1027)	860.7 (1024)

MEAN SUM OF SQUARES (kg ²)											
Source	D.F.	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Season**	4	44422.6	37181.0	34575.3	20775.4	27140.8	29045.7	32332.9	33746.5	24899.5	24041.1
Period**	7	25633.1	22656.6	17440.9	17721.7	16332.2	14594.7	13701.4	11838.3	9003.2	8152.0
Genetic group**	3	22679.6	21661.3	20449.0	17931.3	17278.3	18077.0	18072.0	15797.0	14043.1	11485.2
Regression on APC (days)	1	322.7	113.7	8.3	195.4	154.6	43.2	1.2	32.4	125.4	153.8
Error		789.8 (1012)	813.4 (995)	763.1 (976)	769.5 (957)	741.4 (940)	759.5 (927)	718.3 (906)	707.0 (856)	740.6 (761)	710.6 (658)

** Significant (P < 0.01)

Table 13. Least square analysis of variance for effects of season and period of calving, genetic group and age at first calving on fortnightly part milk yield of Karan Fries cattle

MEAN SUM OF SQUARES (kg ²)											
Source	D.F.	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Season**	4	24531.8	49055.5	61801.9	66576.6	63288.1	53524.5	46857.5	44791.8	38623.9	37037.1
Period**	6	11021.4	18939.8	24997.1	28685.7	27976.7	25983.0	23560.5	21558.0	22511.5	21196.0
Genetic group**	4	12893.7	19140.4	22716.9	25034.8	26972.0	30183.4	28291.3	24844.2	24424.0	27183.0
Regression on APC (days)	1	46616.0	61307.2	52368.8	51400.3	49322.4	49733.5	48614.3	37870.1	27153.2	22590.8
Error	819	1718.2	1681.6	16055.0	1559.2	1531.9	1589.5	1527.0	1457.9 (819)	1308.1 (814)	1293.3 (813)

MEAN SUM OF SQUARES (kg ²)											
Source	D.F.	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Season**	4	32645.3	28994.4	30369.0	34720.4	37471.5	39791.3	48934.2	52404.3	43377.6	32273.1
Period**	6	22094.7	19898.2	17343.7	14457.9	11046.4	8438.6	7415.3	5338.2	5893.2	6706.3
Genetic group**	4	25134.5	25339.8	22665.4	20957.4	21237.7	19735.7	17155.0	16385.3	15074.9	14241.4
Regression on APC (days)	1	22791.8	21842.7	21771.5	17496.9	13219.9	7862.1	8474.5	9833.9	12602.0	7142.7
Error		1229.1 (806)	1208.3 (798)	1146.4 (787)	1086.0 (781)	1032.6 (773)	1051.4 (762)	1044.7 (755)	1067.9 (704)	1047.2 (603)	1079.9 (534)

** Significant (P < 0.01)

The analysis of variance for fortnightly part yields in Karan Fries cattle (Table 13) revealed that the effects of season and period of calving and genetic group were highly significant on all 20 fortnightly part yields. The regression on age at first calving was also found to be statistically significant ($P < 0.01$) in all 20 fortnightly yields.

From the above presentation, it is seen that the effects of season and period of calving and genetic group were found to be highly significant on all 20 fortnightly part yields in both breeds whereas regression on age at first calving was found to be statistically highly significant in all fortnightly part yields in Karan Fries breed only. Singh *et al.* (1979) found in Haryana breed that period of calving had a significant effect on weekly milk yield in all weeks of production. The month of calving had a significant effect in all weeks except 7-8 and 10-11, 13-15 and 42-44. Rao and Sharma (1985) reported that the effects of period and season of calving varied with stage of lactation in Murrah buffaloes. The weekly milk yield was significantly affected by period of calving in week 11-21, 30-32, 34 and 36 of lactation and by season of calving in week 24, 32, 37, 38, 40 and 42. Biswas *et al.* (1986) reported that season and period of calving had significant effect on all weekly yields in Sahiwal cattle.

4.3.2 MONTHLY PART LACTATION MILK YIELD

It is seen from Table 14 that the season and period of calving and genetic group had highly significant effect ($P < 0.01$) on all 10 month part lactation milk yields, but regression on age at first calving was not significant in all monthly part milk yields in Karan Swiss cattle.

The analysis of variance of monthly part lactation yield of Karan Fries breed (Table 15) indicated that the season and period of calving, genetic group and regression on age at first calving had statistically highly significant ($P < 0.01$) effect on part milk yield.

Table 14. Least square analysis of variance for effects of season and period of calving, genetic group and age at first calving on monthly part milk yield of Karan Swiss cattle

Source	D.F.	MEAN SUM OF SQUARES (kg ²)									
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Season**	4	63139.1	164804.6	155153.2	160257.5	185827.8	153991.6	119160.2	108479.1	128818.2	98731.6
Period**	7	99198.4	172029.3	160467.7	124145.0	103946.2	96048.5	70955.6	62372.0	50931.7	36256.1
Genetic group**	3	176964.8	187648.2	154051.4	121821.3	106719.2	85344.8	72437.9	70318.0	66725.0	44631.2
Regression on APC (days)	1	154.2	10125.2	18485.7	13103.4	8450.0	915.8	314.5	110.9	619.9	350.8
Error	1028	5815.2	4762.7	4188.8	3795.3	3320.5 (1024)	3044.8 (995)	2892.6 (957)	2862.9 (927)	2585.0 (856)	2602.4 (658)

** Significant (P < 0.01)

Table 15. Least square analysis of variance for effects of season and period of calving, genetic group and age at first calving on monthly part milk yield of Karan Fries cattle

Source	D.F.	MEAN SUM OF SQUARES (kg ²)									
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Season**	4	133374.8	253380.1	229822.1	179849.3	148773.1	115765.8	124315.5	148322.9	199932.8	138139.3
Period**	6	58257.5	107152.9	107467.9	90039.8	87579.1	83274.8	61597.7	38273.2	24410.2	26340.0
Genetic group**	4	62641.4	95325.0	113922.5	106058.3	103083.2	100883.3	87772.3	81614.0	67541.3	57560.7
Regression on APC (days)**	1	214962.2	207476.2	198081.1	172374.8	100652.1	95124.8	76745.0	40273.8	35281.0	39553.5
Error	819	6370.3	6248.4	6051.8	5787.6	5024.0 (813)	4665.8 (798)	4302.4 (781)	3977.9 (762)	3989.6 (704)	4000.3 (534)

** Significant (P < 0.01)

It is thus seen from Table 14 and 15 that the season and period of calving and genetic group had significant effect ($P < 0.01$) on all 10 monthly part yields in both breeds whereas the regression on age at first calving was non-significant in Karan Swiss and highly significant in Karan Fries breed. Gokhale (1974) reported that effect of period of calving was highly significant in Murrah buffaloes in all monthly part yields. The season effect was significant in case of third and fourth month of yields and 270 days' yields. The regression on age at first calving was found to be significant in case of first and second monthly yields. Srivastava *et al.* (1984) reported that the season of calving significantly affected milk yields during months 6, 7 and 10 ($P < 0.01$) and during months 4, 5 and 9 ($P < 0.05$) in Sahiwal cattle. Godara and Yadav (1992) also reported that the effect of season of calving was significant on all 10 monthly part yields of first lactation except monthly part yield during first, second and seventh month in Murrah buffaloes. The effects of period of calving were significant on all the monthly part yields of first lactation, except on monthly milk yield of sixth month.

4.3.3 BIMONTHLY PART LACTATION MILK YIELD

The least squares analysis of variance on bimonthly part yields for Karan Swiss breed has been presented in Table 16. It is seen that the effects of season and period of calving and genetic group were highly significant on all five bimonthly part milk yields. The regression of these traits on age at first calving was non-significant.

In case of Karan Fries, it is seen from Table 17 that the season and period of calving and genetic group had influenced all five bimonthly part yields significantly ($P < 0.01$). The regression on age at first calving was found to be highly significant ($P < 0.01$) for all bimonthly part yields in Karan Fries cattle.

Table 16. Least square analysis of variance for effects of season and period of calving, genetic group and age at first calving on bimonthly part milk yield for Karan Swiss cattle

Source	D.P.	MEAN SUM OF SQUARES (kg ²)				
		1st	2nd	3rd	4th	5th
Season**	4	402563.5	600609.5	598279.1	406224.0	400587.0
Period**	7	529194.8	564380.2	405909.2	269812.5	165387.6
Genetic group**	3	722757.9	549278.0	359905.8	291076.3	187003.7
Regression on AFC (days)	1	7758.9	62680.3	15200.9	783.9	2291.3
Error	1028	19669.3 (1028)	15068.2 (1028)	11680.3 (995)	10532.4 (927)	8997.2 (658)

** Significant (P < 0.01)

Table 17. Least square analysis of variance for effects of season and period of calving, genetic group and age at first calving on bimonthly part milk yield for Karan Fries cattle

Source	D.P.	MEAN SUM OF SQUARES (kg ²)				
		1st	2nd	3rd	4th	5th
Season**	4	681032.1	765641.0	463262.2	493734.8	552347.3
Period**	6	322473.8	393239.0	333727.9	190376.2	112582.1
Genetic group**	4	310902.7	439303.3	397227.5	333626.3	240373.2
Regression on APC** (days)	1	845289.4	740152.3	391639.1	234521.2	157399.3
Error	819	23297.3 (819)	22715.5 (819)	18251.8 (798)	15470.8 (762)	14168.8 (534)

** Significant (P < 0.01)

It is thus seen from Table 16 and 17 that the season and period of calving and genetic group were found to have significant ($P < 0.01$) effect on all five bimonthly part yields in both breeds whereas the regression on age at first calving was found to be non-significant in Karan Swiss and highly significant in Karan Fries breed.

Murthy *et al.* (1985) found the significant variation due to period on all the components of lactation yield except in the peak yield and second 60 days yield. Similarly, significant seasonal effects were observed on all the components of lactation yield except the second 60 days yield in Surti buffaloes.

4.4 EFFECT OF SEASON AND PERIOD OF CALVING, GENETIC GROUP AND AGE AT FIRST CALVING ON CUMULATIVE PART MILK YIELD

The analysis of variance of Karan Swiss breed (Table 18) indicated that the season, period of calving and genetic group effects were statistically significant ($P < 0.01$) for all cumulative part yields. The regression on age at first calving was found to be not significant for all traits.

For Karan Fries cattle, the analysis of variance of cumulative part yields (Table 19) indicates that the season and period of calving, genetic group and regression on age at first calving effects were found to be significant ($P < 0.01$) for all cumulative part yields.

It is thus seen from Tables 18 and 19 that the season and period of calving and genetic group had significant effect on all cumulative part yields in both breeds. The regression on age at first calving was non-significant in Karan Swiss and significant ($P < 0.01$) in Karan Fries breed of all cumulative part yields.

The significant effect of season of calving on lactation milk yield was also reported by Basu and Gupta (1974) in Indian dairy cattle, Reddy and Mishra (1982) in Murrah buffaloes,

Table 18. Least square analysis of variance for effect of season and period of calving, genetic group and age at first calving on monthly cumulative part yield of Karan Swiss cattle

Source	D.P.	MEAN SUM OF SQUARES (kg ²)								
		First 30 days	First 60 days	First 90 days	First 120 days	First 150 days	First 180 days	First 210 days	First 240 days	First 270 days
Season**	4	63139.1	402563.5	972260.1	1683608.9	2488060.8	2937688.5	3014405.8	2639088.3	1972775.6
Period**	7	99198.4	529194.8	1259853.4	2150932.8	3102719.3	4220032.5	5386357.5	6584846.5	7614399.0
Genetic group**	3	176964.8	722757.9	1538783.1	2525180.8	3616102.8	4457423.5	5087506.0	6478919.5	7241047.5
Regression on APC (days)	1	154.2	7758.9	502225.9	114371.7	152836.3	203950.5	214707.5	278122.6	649970.9
Error	1028	5815.2 (1028)	19669.3 (1028)	39036.0 (1028)	62668.0 (1028)	88658.4 (1028)	114314.3 (995)	141564.3 (957)	168881.9 (927)	190598.6 (856)

** Significant (P < 0.01)

Table 19. Least square analysis of variance for effect of season and period of calving, genetic group and age at first calving on monthly cumulative part yield of Karan Fries cattle

MEAN SUM OF SQUARES (kg ²)										
Source	D.F.	First 30 days	First 60 days	First 90 days	First 120 days	First 150 days	First 180 days	First 210 days	First 240 days	First 270 days
Season**	4	133374.8	681032.1	1549787.3	2381272.8	2909289.0	2975960.3	2261168.0	1805242.9	919818.8
Period**	6	58257.5	322473.8	800562.3	1423278.0	2268273.0	2996248.0	3716611.3	4221856.0	4500547.5
Genetic group**	4	62641.4	310902.7	799473.9	1484897.6	2370608.0	3477027.5	4451331.0	5572720.0	6516076.0
Regression on APC (days)**	1	214962.2	845289.4	181787.9	3167393.5	4589829.0	5958772.5	7536412.5	9038398.0	9397743.0
Error	819	6370.3 (819)	23297.3 (819)	49477.7 (819)	8731.9 (819)	122618.8 (813)	165935.9 (799)	211872.5 (781)	251448.6 (762)	289908.6 (704)

** Significant (P < 0.01)

Bhadauria *et al.* (1986) in Jersey cows and Sushil Kumar (1990) in Sahiwal cattle. Period of calving having significant effect on cumulative yields was also reported by Nagpal and Acharya (1971) in Sahiwal cattle, Taneja and Bhat (1974) in Sahiwal x Holstein Friesian crossbreds, Jain and Dhillon (1975) in Sahiwal purebred and Holstein Friesian x Sahiwal crossbreds, Bhat *et al.* (1978) in crossbreds, Parekh and Sandhu (1978) in Tharparkar x Holstein Friesian crossbreds, Ipe (1979) in crossbreds; Dangi (1979) in dairy cattle; Deshpande and Bonde (1982) in Holstein Friesian x Sahiwal cattle, Reddy (1983) in Sahiwal, Reddy and Basu (1985) in crossbred, Bhadauria *et al.* (1986) in Jersey; Kumar (1987) in crossbreds and Sushil Kumar (1990) in Sahiwal cattle. The age effect was significant on cumulative monthly yields upto seven months in buffaloes as reported by Gokhle (1974). Sushil Kumar (1990) also found the regression of cumulative 30 days, 60 days, 180 days, 210 days, 240 days, 270 days and 300 days milk yield on age at first calving to be statistically significant. Raheja and Balaine (1977) in Haryana and crossbred cattle and Singh and Yadav (1987) in buffaloes reported that age at first calving had no significant effect on cumulative milk yield.

4.5 PREDICTION OF FIRST LACTATION MILK YIELD ON THE BASIS OF FORTNIGHTLY, MONTHLY AND BIMONTHLY TEST RECORDS UNDER SYSTEMATIC AND STRATIFIED RANDOM SAMPLING SCHEMES AND PART YIELDS BY RATIO METHOD

4.5.1 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF FORTNIGHTLY SYSTEMATIC SAMPLED TEST RECORD

The multiplicative ratio factors were developed for each fortnight separately. Then lactation milk yield was predicted on the basis of each fortnight's milk yield multiplied by the corresponding factor. The multiplicative ratio factors developed for prediction of lactation yield alongwith the accuracy of prediction are given in Table 20 for Karan Swiss and Karan Fries breeds.

Table 20. Ratio factors and their accuracies for prediction of first lactation milk yield (OMY) under fortnightly systematic test record yields

Duration of sampled part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Multiplicative ratio factor	Accuracy (%)	Number of observations	Multiplicative ratio factor	Accuracy (%)
FORTNIGHTLY INTERVAL						
1st	674	17.21	44.12	550	17.74	32.19
2nd	674	16.12	58.06	550	16.58	50.09
3rd	674	16.48	63.22	550	16.68	58.87
4th	674	16.97	67.45	550	17.09	63.09
5th	674	17.65	67.80	550	17.77	61.04
6th	674	18.27	69.01	550	18.22	67.95
7th	674	18.85	70.72	550	19.08	67.17
8th	674	19.55	64.83	550	19.49	66.26
9th	674	20.13	70.46	550	20.03	67.84
10th	674	20.73	70.78	550	20.51	66.74
11th	674	21.33	68.37	550	21.13	67.84
12th	674	21.74	63.91	550	21.33	67.10
13th	674	21.88	62.54	550	21.60	65.15
14th	674	22.46	60.36	550	21.97	64.79
15th	674	22.81	56.09	550	22.25	54.43
16th	674	22.87	47.90	550	22.43	49.31
17th	674	22.89	46.42	550	22.48	47.32
18th	674	22.96	39.96	550	22.89	40.93
19th	674	22.79	33.32	550	22.80	39.52
20th	674	22.75	28.84	550	22.97	35.85

The multiplicative ratio factors developed on the basis of fortnightly systematic sampled test record for Karan Swiss cattle (Table 20) indicated that the minimum estimate (16.12) of ratio factor was observed at second fortnight and maximum estimate (22.96) at 18th fortnight. The magnitude of multiplicative factors decreased from first to second fortnight and subsequently increased with the advance in lactation. The accuracy of prediction of lactation yield on the basis of fortnightly systematic sampled test records in Karan Swiss breed (Table 20) indicated that the maximum accuracy (70.78%) for prediction of lactation milk yield was observed at mid lactation (around 10th fortnight) and minimum (28.84%) at last sample test record (20th fortnight).

In case of Karan Fries breed, the multiplicative ratio factors (Table 20) indicated that the minimum estimate (16.58) of ratio factor was found at second fortnight and maximum estimate (22.97) at 20th fortnight. The magnitude of multiplicative ratio factor decreased from first fortnight to second fortnight and subsequently increased with advance in lactation. The accuracy of prediction of lactation yield for the Karan Fries breed on the basis of fortnightly systematic sampled test records was minimum (32.19%) at initial point (first fortnight) and maximum (67.84%) during mid lactation (9th and 11th fortnight) (Table 20). The estimate of accuracy showed negligible variation (67.95 to 67.10%) from 6th fortnight to 12th fortnight of lactation.

It is thus seen from Table 20 that for the Karan Swiss and Karan Fries breeds a single test record could be taken during a fortnight around mid-lactation to predict lactation yield with fairly high accuracy.

4.5.2 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF FORTNIGHTLY STRATIFIED RANDOM SAMPLED TEST RECORD BY RATIO METHOD

The multiplicative ratio factors developed on the basis of fortnightly stratified random sampled test records for Karan Swiss cattle (Table 21) indicated that the minimum estimate (16.10) of ratio factor was observed at second fortnight and maximum estimate (23.03) at 18th fortnight. The magnitude of multiplicative factors decreased from first fortnight to second

Table 21. Ratio factors and their accuracies for prediction of first lactation milk yield (OMY) under fortnightly stratified random test record yields

Duration of sampled part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Multiplicative ratio factor	Accuracy (%)	Number of observations	Multiplicative ratio factor	Accuracy (%)
FORTNIGHTLY INTERVAL						
1st	674	17.21	43.35	550	17.70	33.34
2nd	674	16.10	59.34	550	16.71	47.87
3rd	674	16.53	63.42	550	16.57	57.11
4th	674	16.96	69.70	550	17.11	60.91
5th	674	17.58	69.67	550	17.80	56.02
6th	674	18.12	68.52	550	18.23	67.74
7th	674	18.84	69.14	550	18.91	64.71
8th	674	19.59	67.39	550	19.38	67.61
9th	674	20.19	70.13	550	19.99	65.32
10th	674	20.75	69.46	550	20.67	67.77
11th	674	21.28	66.04	550	21.12	67.29
12th	674	21.70	64.08	550	21.46	67.92
13th	674	21.99	62.56	550	21.71	63.89
14th	674	22.39	57.93	550	21.98	62.89
15th	674	22.74	56.45	550	22.14	59.53
16th	674	22.82	49.74	550	22.44	48.19
17th	674	22.85	47.70	550	22.41	49.56
18th	674	23.03	40.68	550	22.57	41.78
19th	674	22.88	34.25	550	22.78	38.78
20th	674	22.89	29.20	550	22.75	34.55

fortnight and subsequently increased with advance in lactation. It is found that the accuracy of prediction of lactation yield by ratio factors was highest (70.13%) during 9th fortnight (Table 21), followed by the accuracy during 8th and 16th fortnight. The minimum (29.20%) accuracy was found for last three fortnights and first fortnight.

The multiplicative ratio factors for Karan Fries breed (Table 21) indicated that the minimum estimate (16.57) of ratio factor was at third fortnight and maximum (22.78) at 19th fortnight. The magnitude of multiplicative ratio factors decreased from first fortnight to third fortnight and subsequently increased with advance in lactation. The accuracy of prediction of lactation yield on the basis of fortnightly stratified random sampled test records (Table 21) was minimum (33.34 to 34.55%) during initial and last phase of lactation and maximum (67.29%) during mid lactation (10th fortnight). The estimates of accuracy showed negligible variation (67.74 to 67.92%) from 6th to 12th fortnight of lactation.

It is thus seen from Table 21 on the basis of stratified random sampling method that for Karan Swiss and Karan Fries breeds a single test record could be taken during a fortnight around mid lactation to predict lactation yield with fairly high accuracy.

4.5.3 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF FORTNIGHTLY PART LACTATION MILK YIELD BY RATIO METHOD

The multiplicative ratio factors developed for prediction of lactation yield along with the accuracy of prediction are given in Table 22 for Karan Swiss and Karan Fries breeds.

It is seen from Table 22 that the minimum estimate (16.27) of ratio factor was observed at second fortnight and maximum estimate (26.22) at 20th fortnight in Karan Swiss breed. The

Table 22. Ratio factors and their accuracies for prediction of first lactation milk yield (OMY) under fortnightly part yields

Duration of sampled part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Multiplicative ratio factor	Accuracy (%)	Number of observations	Multiplicative ratio factor	Accuracy (%)
FORTNIGHTLY INTERVAL						
1st	674	17.34	27.47	550	17.78	26.78
2nd	674	16.27	38.71	550	16.64	38.68
3rd	674	16.62	44.99	550	16.70	47.50
4th	674	17.13	46.96	550	17.17	49.60
5th	674	17.78	49.05	550	17.61	50.52
6th	674	18.41	49.32	550	18.42	54.06
7th	674	19.00	50.74	550	19.16	55.65
8th	674	19.78	47.84	550	19.79	56.39
9th	674	20.35	48.71	548	20.55	59.95
10th	673	21.03	47.67	548	21.18	60.80
11th	671	21.71	45.25	544	21.61	62.50
12th	668	22.23	42.41	538	22.56	61.23
13th	662	22.67	35.81	532	23.11	60.20
14th	656	23.24	33.02	529	23.65	52.85
15th	654	23.63	29.12	524	24.16	50.51
16th	652	23.79	25.05	518	24.67	49.30
17th	645	23.93	21.11	513	24.94	46.44
18th	637	24.42	15.74	485	26.68	42.22
19th	609	25.13	10.72	425	30.10	38.20
20th	503	26.22	7.21	382	33.08	30.25

magnitude of multiplicative ratio factors decreased from first fortnight to second fortnight and subsequently increased with advance in lactation. The accuracy of 50.74 per cent for prediction of lactation yield on the basis of seventh fortnight was highest followed by accuracies of 49.32 per cent for sixth fortnight, 49.05 per cent for fifth fortnight, 48.71 per cent for ninth fortnight and 47.84 per cent for eighth fortnight. The accuracy of prediction on the basis of initial (1st fortnight) and terminating phase (20th fortnight) of lactation was found to be minimum (7.21 to 27.47%).

It is seen from Table 22 that the minimum estimate (16.64) of ratio factor was observed at second fortnight and maximum estimate (33.08) at 20th fortnight in Karan Fries breed. The magnitude of multiplicative ratio factors decreased from first fortnight to second fortnight, and subsequently increased with advance in lactation. The accuracy of 62.50 per cent for prediction of lactation yield on the basis of eleventh fortnight was highest followed by accuracies of 61.23 per cent for 11th fortnight, 60.80 per cent for 10th fortnight, 59.95 per cent for 9th fortnight and 56.39 per cent for 8th fortnight. The accuracy of prediction on the basis of initial (1st fortnight) and terminating phase (20th fortnight) of lactation was found to be minimum (26.78 to 30.25%).

It is thus seen from Table 22 for the Karan Swiss and Karan Fries breeds that a single test record could be taken during 5th to 12th fortnight to predict lactation yield with fairly high accuracy.

Prediction of lactation milk yield on the basis of fortnightly systematic sampled test records reveals that maximum (70.78%) accuracy of prediction was obtained during 10th fortnight and minimum (28.89%) accuracy at 20th fortnight for Karan Swiss breed. The prediction on the basis of same sampling scheme reveals that the maximum (67.84%) accuracy was obtained during 9th to 11th fortnight and minimum (32.19%) during first

fortnight for Karan Fries breed. In the similar way when lactation milk yield was predicted on the basis of fortnightly stratified random sampled test record in Karan Swiss and Karan Fries breeds, then the maximum (70.13%) accuracy for prediction was obtained with test records during 9th fortnight and minimum (29.20%) accuracy during 1st and 20th fortnight for Karan Swiss cattle whereas maximum (67.29%) accuracy for test records during 10th fortnight and minimum (33.34%) accuracy during 1st and 20th fortnight was obtained for prediction on the basis of fortnightly stratified random test records in Karan Fries breed. It seems that the accuracies of prediction of lactation milk yield on the basis of fortnightly systematic and stratified random sampled test records were almost similar in both breeds. The prediction of lactation yield on the basis of fortnightly part yields reveals that maximum (50.74%) accuracy was obtained for 7th fortnightly and minimum (7.21%) for 20th fortnightly part yield for Karan Swiss and maximum accuracy (62.50%) for 11th fortnight and minimum (26.78%) for 1st fortnight in Karan Fries breed.

VanVleck and Henderson (1961a) reported that the best period for drawing single test record for estimating complete lactation yield was 8th to 12th fortnight of lactation in Holstein cows. Saigaonkar et al (1981) found that accuracy of predicting 52 weeks record on the basis of 6th and 8th fortnight was 76 per cent in Sahiwal cattle. Nagarcenkar and Basavaiah (1981) found that the prediction of lactation milk yield on the basis of 22 weeks (11th fortnight) gave highest accuracy (68.89%).

The following conclusions may be drawn from above presentation:

(i) Prediction of lactation milk yield on the basis of fortnightly systematic and stratified random sampled test records and fortnightly part yields by ratio method reveals that a single test record could be taken during the fortnight around mid lactation to predict lactation yield with fairly high accuracy.

(ii) The accuracy of prediction of lactation milk yield on the basis of fortnightly systematic and stratified random sampled test records were similar in both breeds; whereas accuracy based on fortnightly part yield was lower than above two milk recording schemes.

4.5.4 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF MONTHLY SYSTEMATIC SAMPLED TEST RECORDS BY RATIO METHOD

The ratio factors for prediction of lactation milk yield were developed for each month separately. Then lactation milk yield was predicted by adding each month's yield multiplied by the factor. The multiplicative ratio factors developed for prediction of lactation yield with the corresponding accuracy are given in Table 23 for Karan Swiss and Karan Fries breeds.

In case of Karan Swiss it is seen from Table 19 that the minimum estimate (8.31) of ratio factor was observed for first month and maximum estimate (11.49) for 9th month. The magnitude of multiplicative factors increased from first month to ninth month then decreased for tenth month. The accuracy of 67.80% for prediction on the basis of fourth monthly systematic sampled test record ratio factor was highest followed by accuracies of 67.99% for sixth month, 67.75% for fifth month and 66.74% for third month ratio factors. The accuracy of prediction on the basis of initial and terminating monthly systematic sampled test records was found to be minimum as 50.61% and 32.63% respectively in Karan Swiss cattle (Table 23).

The multiplicative ratio factors for Karan Fries breed (Table 23) indicated that the minimum estimate (8.45) of ratio factor was found for second month and maximum estimate (11.48) for 10th month. The magnitude of multiplicative ratio factors decreased from first month to second month and subsequently increased with advance in lactation. The accuracies of prediction on the basis of sixth, fifth and fourth monthly systematic sampled test records were found to be 66.68%, 65.98%

Table 23. Ratio factors and their accuracy for prediction of lactation milk yield under monthly systematic test record yields

Duration of sampled part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Multiplicative ratio factor	Accuracy (%)	Number of observations	Multiplicative ratio factor	Accuracy (%)
MONTHLY INTERVAL						
1st	674	8.31	50.61	550	8.55	40.06
2nd	674	8.34	63.30	550	8.45	59.41
3rd	674	8.94	66.74	550	9.00	64.25
4th	674	9.62	67.80	550	9.64	65.38
5th	674	10.21	67.75	550	10.10	65.98
6th	674	10.74	67.80	550	10.66	66.98
7th	674	11.06	63.26	550	10.85	64.36
8th	674	11.32	54.92	550	11.20	53.51
9th	674	11.49	45.86	550	11.31	48.57
10th	674	11.42	32.63	550	11.48	37.46

and 65.38%, respectively (Table 23). When initial and terminating monthly sampled test records were considered to predict lactation milk yield then the accuracies were found to be 40.06% and 37.46%, respectively.

It is thus seen that for Karan Swiss and Karan Fries breeds, a single test record could be taken on a month during mid lactation (4th to 6th month) to predict lactation yield with fairly high accuracy.

4.5.5 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF MONTHLY STRATIFIED SAMPLED TEST RECORDS BY RATIO METHOD

The multiplicative ratio factors developed on the basis of monthly stratified random sampled test records for Karan Swiss cattle (Table 24) indicated that the maximum estimate (8.29) of ratio factor was observed for first month and maximum estimate (11.43) for 9th month. The magnitude of multiplicative factors increased from first month to ninth month then decreased at tenth month. The accuracy of 68.88 per cent for prediction on the basis of sixth month sampled test record was found to be maximum followed by the accuracies of third month (68.04%), fourth month (67.19%) and fifth month (64.65%), respectively; whereas prediction on the basis of initial and terminating monthly sampled test records were found to be 43.05 and 37.64 per cent, respectively.

The multiplicative ratio factors and accuracy of prediction for Karan Fries cattle (Table 24) revealed that the accuracy for prediction based on fifth, third, sixth and fourth monthly stratified random test records were 69.75, 66.07, 65.23 and 64.35 per cent, respectively. When initial (first month) and terminating (tenth month) monthly sampled test records were taken to predict lactation milk yield, then the accuracy of prediction was 52.41 and 31.41 per cent, respectively. The minimum estimate (8.33) of ratio factor was found for second month and maximum estimate (11.47) for 10th month. The magnitude of multiplicative

Table 24. Ratio factors and their accuracy for prediction of lactation milk yield under monthly stratified random test record yields

Duration of sampled part lactation	KARAN SWISS BREED			KARAN PRIES BREED		
	Number of observations	Multiplicative ratio factor	Accuracy (%)	Number of observations	Multiplicative ratio factor	Accuracy (%)
MONTHLY INTERVAL						
1st	674	8.29	43.51	550	8.53	52.41
2nd	674	8.36	57.49	550	8.33	64.34
3rd	674	8.90	68.04	550	8.92	66.07
4th	674	9.63	67.19	550	9.54	64.35
5th	674	10.28	64.65	550	10.17	69.75
6th	674	10.68	68.88	550	10.57	65.23
7th	674	11.18	63.58	550	10.97	63.17
8th	674	11.34	52.81	550	11.26	50.95
9th	674	11.43	45.94	550	11.39	43.66
10th	674	11.41	37.64	550	11.47	31.41

ratio factors decreased from first month to second month and subsequently increased with advance in lactation.

It is thus seen that for Karan Swiss and Karan Fries breeds that a single test record could be drawn a month during mid lactation (3rd to 6th month) to predict lactation yield with fairly high accuracy.

4.5.6 PREDICTION OF LACTATION MILK YIELD BASED ON MONTHLY PART YIELDS BY RATIO METHOD

The multiplicative ratio factors developed for prediction of lactation yield on the basis of monthly part yields along with the accuracy of prediction are given in Table 25 for Karan Swiss and Karan Fries breeds.

Table 25 indicates that the minimum estimate (8.32) of ratio factor was observed for first month and maximum estimate (11.45) for 9th month in Karan Swiss cattle. The magnitude of multiplicative factor increased from first month to ninth month then decreased at tenth month. The accuracy of prediction on the basis of fifth monthly part yield was observed to be maximum (78.5%) followed by accuracies for fourth month (78.04%), third month (77.30%) and sixth month (74.86%); whereas accuracies for prediction on the basis of first and tenth month were found to be 63.07 and 36.31 per cent, respectively.

It is further seen from Table 25 that the minimum estimate (8.42) of ratio factor was observed for second month and maximum estimate (11.47) for tenth month in Karan Fries breed. The magnitude of multiplicative ratio factors decreased from first month to second month and subsequently increased with advance in lactation. The accuracies of prediction of lactation milk yield based on mid phase lactation monthly part yields were found to be 77.49 per cent for sixth, 76.92 per cent for fifth, 74.57 per cent for fourth and 73.35 per cent for seventh monthly part yields, whereas accuracies for prediction based on initial (first

Table 25. Ratio factors and their accuracy for prediction of lactation milk yield under monthly part yields

Duration of sampled part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Multiplicative ratio factor	Accuracy (%)	Number of observations	Multiplicative ratio factor	Accuracy (%)
MONTHLY INTERVAL						
1st	674	8.32	63.07	550	8.59	51.82
2nd	674	8.35	74.50	550	8.42	66.75
3rd	674	8.94	77.30	550	8.97	72.70
4th	674	9.59	78.04	550	9.58	74.57
5th	674	10.22	78.50	550	10.16	76.92
6th	674	10.74	74.86	550	10.63	77.49
7th	674	11.10	71.75	550	10.90	73.35
8th	674	11.38	61.95	550	11.19	61.90
9th	674	11.45	51.12	550	11.32	51.27
10th	674	11.41	36.31	550	11.47	41.77

month) and terminating (10th month) were found to be 51.82 and 41.77 per cent, respectively.

It is thus seen for the Karan Swiss and Karan Fries breeds that a single record could be taken during month around mid lactation (4th to 6th month) to predict lactation yield with fairly high accuracy.

The estimate of multiplicative ratio factors on the basis of monthly systematic test records ranged from 8.31 to 11.49 for Karan Swiss and 8.45 to 11.48 for Karan Fries breeds. Similar estimates of multiplicative factors based on monthly stratified random sampled test records ranged from 8.29 to 11.43 for Karan Swiss and 8.33 to 11.47 for Karan Fries breed. In the same way, the estimates of ratio factors based on monthly part yields ranged from 8.32 to 11.45 for Karan Swiss and 8.42 to 11.47 for Karan Fries breed. The prediction of lactation milk yield on the basis of monthly systematic sampled test records reveals that the maximum (67.80%) accuracy for prediction was obtained during fourth month and minimum (32.63%) for 10th month for Karan Swiss cattle and maximum (66.68%) accuracy for prediction was obtained during sixth month and minimum (37.46%) during 10th month for Karan Fries breed. On the other hand, prediction of lactation milk yield based on monthly stratified random sampled test records reveals that the maximum (68.88%) accuracy for prediction was obtained during sixth month and minimum (37.64%) during 10th month for Karan Swiss breed and maximum (69.75%) accuracy was obtained during fifth month and minimum (31.41%) during 10th month for Karan Fries cattle. The maximum and minimum accuracies for prediction on the basis of stratified random sampled test records were slightly higher than systematic sampled test records in both breeds. The prediction of lactation yield on the basis of monthly part yield reveals that maximum (78.04%) accuracy for prediction was obtained during fifth month and minimum (36.31%) during 10th month for Karan Swiss and maximum (77.49%) during sixth month and minimum (41.77%) during 10th month for Karan Fries breed.

VanVleck and Henderson (1961c) reported that the best single month for estimating lactation milk yield by ratio method was fourth, fifth and sixth month in Holstein Friesian cows. Jain and Dhillon (1986) observed that all the sires selected on the basis of fourth or fifth month milk yield were same as those selected on the basis of first lactation milk yield in buffaloes. Bhutta and Pandey (1989) found that by ratio method the milk yield during the first month predicted 300 days lactation yield with almost same accuracy as the milk yields of later month yields.

The following conclusion may be drawn from the above presentation:

1. Prediction of lactation milk yield on the basis of monthly systematic sampled test records reveal that a single test record could be taken during mid lactation (4th to 6th month) to predict lactation yield with fairly high accuracy in both the breeds. On the other hand, prediction of lactation yield on the basis of monthly stratified random sampled test record and monthly part yield reveals that a single test record could be taken during third month to sixth month to predict lactation yield with high accuracy.

2. The accuracy for prediction of lactation milk yield on the basis of stratified random sampled test records was slightly higher than systematic sampled test records, whereas accuracy based on monthly part yields was higher than stratified random and systematic sampled test records in both breeds.

4.5.7 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF BIMONTHLY SYSTEMATIC SAMPLED TEST RECORD BY RATIO METHOD

The ratio factors were developed for each bimonthly test records and part yield separately. Then lactation milk yield was predicted on the basis of each bimonth's multiplicative factor. The multiplicative ratio factors developed for prediction of

Table 26. Ratio factors and their accuracy for prediction of lactation milk yield under bimonthly systematic test record yields

Duration of sampled part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Multiplicative ratio factor	Accuracy (%)	Number of observations	Multiplicative ratio factor	Accuracy (%)
BIMONTHLY INTERVAL						
1st two months	674	4.16	60.09	550	4.28	51.56
2nd two months	674	4.58	69.35	550	4.65	64.22
3rd two months	674	5.22	67.77	550	5.21	64.42
4th two months	674	5.63	57.81	550	5.50	57.24
5th two months	674	5.71	37.28	550	5.71	40.96

lactation yield along with the accuracy are given in Table 26 for Karan Swiss and Karan Fries breeds.

It is seen that the lowest estimate (4.16) of ratio factor was observed during second bimonth and highest estimate (5.71) during fifth bimonth for Karan Swiss breed. The magnitude of multiplicative factors decreased from first bimonthly to second bimonthly test record and increased subsequently with advance in lactation. The accuracy for prediction based on second bimonthly test record was observed to be maximum (69.35%) followed by accuracies for third bimonth (67.77%), first bimonth (60.09%), fourth bimonth (67.77%) and fifth bimonth (37.28%).

The Table 26 indicates that the lowest estimate (4.28) of ratio factor was observed during first bimonth and the highest estimate (5.71) during fifth bimonth for Karan Fries breed. The magnitude of multiplicative ratio factors increased from first bimonth to fifth bimonth. The accuracy of prediction based on third bimonthly systematic test record was observed to be maximum (64.42%) followed by the accuracies for second bimonth (64.22%), fourth bimonth (57.24%), first bimonth (51.56%) and fifth bimonth (40.96%).

It is thus seen from Table 26 for Karan Swiss and Karan Fries breeds that a single test record could be taken during a bimonth during 2nd to 3rd bimonth to predict lactation yield with fairly high accuracy.

4.5.8 PREDICTION OF LACTATION MILK YIELD BASED ON BIMONTHLY STRATIFIED RANDOM SAMPLED TEST RECORD BY RATIO METHOD

The results of accuracy for prediction of lactation milk yield and their ratio factors have been shown in Table 27 for Karan Swiss and Karan Fries breeds. The lowest estimate (4.17) of ratio factor was observed during first bimonth and highest estimate (5.77) during fifth bimonth for Karan Swiss cattle. The magnitude of multiplicative ratio factors increased from first

Table 27. Ratio factors and their accuracy for prediction of lactation milk yield under bimonthly stratified random test record yields

Duration of sampled part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Multiplicative ratio factor	Accuracy (%)	Number of observations	Multiplicative ratio factor	Accuracy (%)
BIMONTHLY INTERVAL						
1st two months	674	4.17	60.43	550	4.24	48.03
2nd two months	674	4.64	64.14	550	4.64	65.57
3rd two months	674	5.27	63.96	550	5.17	68.02
4th two months	674	5.66	57.16	550	5.55	58.94
5th two months	674	5.77	34.80	550	5.70	40.41

bimonth to fifth bimonth. The maximum (64.14%) accuracy of prediction was observed on the basis of second bimonth sampled test record followed by the accuracies for third bimonth (63.98%), first bimonth (60.43%), fourth bimonth (57.16%) and fifth bimonth (34.80%) (Table 27).

In case of Karan Fries breed, it is seen that the lowest estimate (4.24) of ratio factors was observed during first bimonth and the highest estimate (5.70) during fifth bimonth for Karan Fries. The magnitude of multiplicative ratio factors increased from first bimonth to fifth bimonth. The accuracy (68.02%) based on third bimonth was found to be highest followed by the accuracies for second bimonth (65.57%), fourth bimonth (58.94%), first bimonth (48.03%) and fifth bimonth (40.41%).

It is thus seen from Table 27 for Karan Swiss and Karan Fries that a single record could be taken during a bimonth around mid lactation (2nd and 3rd bimonth) to predict lactation yield with fairly high accuracy.

4.5.9 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF BIMONTHLY PART YIELD BY RATIO METHOD

The multiplicative ratio factors developed for prediction of lactation yield along with the corresponding accuracy are given in Table 28 for Karan Swiss and Karan Fries breeds.

It is seen from Table 28 that the minimum estimate (4.17) of ratio factor was observed during first bimonth and maximum estimate (5.72) during fifth bimonth for Karan Swiss cattle. The magnitude of multiplicative factors increased from first bimonth to fifth bimonth. The prediction on the basis of ratio factors of second, third, first, fourth and fifth bimonthly part yields determined 80.77, 80.57, 73.38, 71.58 and 46.13 per cent accuracy in descending order, respectively.

Table 28. Ratio factors and their accuracy for prediction of lactation milk yield under bimonthly part yields

Duration of sampled part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Multiplicative ratio factor	Accuracy (R ² ,%)	Number of observations	Multiplicative ratio factor	Accuracy (R ² ,%)
BIMONTHLY INTERVAL						
1st two months	674	4.17	73.38	550	4.25	64.39
2nd two months	674	4.63	80.77	550	4.63	76.35
3rd two months	674	5.24	80.57	550	5.19	81.16
4th two months	674	5.62	71.58	550	5.52	71.24
5th two months	674	5.72	46.13	550	5.70	49.33

The Table 28 indicates that the lowest estimate (4.25) of ratio factor was observed during first bimonth and the highest estimate (5.70) during fifth bimonth for Karan Fries breed. The magnitude of multiplicative factors increased from first bimonth to fifth bimonth. The accuracy for prediction of lactation milk yield on third bimonthly part yield was found to be maximum (81.16%) followed by second bimonth (76.35%), fourth bimonth (71.24%), first bimonth (64.39%) and fifth bimonth (49.33%).

It is thus seen that a single record could be taken during a bimonth around mid lactation (2nd to 3rd bimonth) to predict lactation yield with fairly high accuracy in both breeds.

The estimate of multiplicative ratio factors on the basis of bimonthly systematic test records ranged from 4.16 to 5.71 for Karan Swiss and 4.28 to 5.71 for Karan Fries breed. Similar estimates of multiplicative factors based on bimonthly stratified random test records ranged from 4.17 to 5.77 for Karan Swiss and 4.24 to 5.70 for Karan Fries breed. In the same way, the estimates of ratio factors based on bimonthly part yields ranged from 4.17 to 5.72 for Karan Swiss and 4.25 to 5.70 for Karan Fries breed. The prediction of lactation milk yield on the basis of bimonthly systematic sampled test records reveals that the maximum (69.35%) accuracy for prediction was obtained during second bimonth and minimum (37.28%) during fifth bimonth for Karan Swiss cattle and maximum (64.42%) accuracy for prediction was obtained during third bimonth and minimum (40.96%) accuracy during fifth bimonth for Karan Fries breed. Further, the prediction of lactation milk yield based on bimonthly stratified random test records reveals that the maximum (64.14%) accuracy was obtained during second bimonth and minimum (34.80%) accuracy during fifth bimonth for Karan Swiss cattle and maximum (68.02%) accuracy was obtained during third bimonth and minimum (40.41%) accuracy during fifth bimonth for Karan Fries breed. The highest and lowest accuracies for prediction on the basis of bimonthly systematic sampled test records were higher than stratified random test records in Karan Swiss breed, whereas the highest and

The Table 28 indicates that the lowest estimate (4.25) of ratio factor was observed during first bimonth and the highest estimate (5.70) during fifth bimonth for Karan Fries breed. The magnitude of multiplicative factors increased from first bimonth to fifth bimonth. The accuracy for prediction of lactation milk yield on third bimonthly part yield was found to be maximum (81.16%) followed by second bimonth (76.35%), fourth bimonth (71.24%), first bimonth (64.39%) and fifth bimonth (49.33%).

It is thus seen that a single record could be taken during a bimonth around mid lactation (2nd to 3rd bimonth) to predict lactation yield with fairly high accuracy in both breeds.

The estimate of multiplicative ratio factors on the basis of bimonthly systematic test records ranged from 4.16 to 5.71 for Karan Swiss and 4.28 to 5.71 for Karan Fries breed. Similar estimates of multiplicative factors based on bimonthly stratified random test records ranged from 4.17 to 5.77 for Karan Swiss and 4.24 to 5.70 for Karan Fries breed. In the same way, the estimates of ratio factors based on bimonthly part yields ranged from 4.17 to 5.72 for Karan Swiss and 4.25 to 5.70 for Karan Fries breed. The prediction of lactation milk yield on the basis of bimonthly systematic sampled test records reveals that the maximum (69.35%) accuracy for prediction was obtained during second bimonth and minimum (37.28%) during fifth bimonth for Karan Swiss cattle and maximum (64.42%) accuracy for prediction was obtained during third bimonth and minimum (40.96%) accuracy during fifth bimonth for Karan Fries breed. Further, the prediction of lactation milk yield based on bimonthly stratified random test records reveals that the maximum (64.14%) accuracy was obtained during second bimonth and minimum (34.80%) accuracy during fifth bimonth for Karan Swiss cattle and maximum (68.02%) accuracy was obtained during third bimonth and minimum (40.41%) accuracy during fifth bimonth for Karan Fries breed. The highest and lowest accuracies for prediction on the basis of bimonthly systematic sampled test records were higher than stratified random test records in Karan Swiss breed, whereas the highest and

Table 29. Ratio factors and their accuracy for prediction of lactation milk yield from monthly cumulative part yields

Duration of sampled part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Multiplicative ratio factor	Accuracy (%)	Number of observations	Multiplicative ratio factor	Accuracy (%)
First 30 days	674	8.32	63.07	550	8.59	51.82
First 60 days	674	4.17	73.38	550	4.25	64.39
First 90 days	674	2.84	79.29	550	2.89	72.25
First 120 days	674	2.19	83.52	550	2.22	77.98
First 150 days	674	1.81	87.06	550	1.82	82.69
First 180 days	674	1.55	90.70	550	1.55	87.86
First 210 days	674	1.36	94.07	550	1.36	92.64
First 240 days	674	1.21	97.12	550	1.21	96.54
First 270 days	674	1.10	99.21	550	1.10	99.11

The multiplicative ratio factors, developed on the basis of monthly cumulative milk yield for Karan Swiss cattle (Table 29) indicated that the magnitude of multiplicative ratio factors increased with advancement of cumulative milk yield. The difference of ratio factors upto first 180 days cumulative yields was observed to be higher than subsequent cumulative yields. It is seen from Table 29 that the first 180 days cumulative yield was a reasonable predictor of lactation milk yield which gave sufficiently high (90.70%) accuracy for prediction of lactation milk yield in Karan Swiss cattle. When cumulative yield records for longer duration of lactation were considered for prediction, the accuracy increased but at slower rate.

The multiplicative ratio factors, developed on the basis of monthly cumulative milk yields for Karan Fries cattle (Table 29), also indicated that the magnitude of multiplicative ratio factor increased with advance of cumulative milk yield. The difference of ratio factors upto first 180 days cumulative yield was observed to be higher than subsequent cumulative yield. It is seen from Table 29 that first 180 days cumulative yield was a reasonable predictor of lactation milk yield which gave sufficiently high (87.86%) accuracy of prediction for Karan Fries breed. When cumulative yield records for longer duration of lactation were considered for prediction, the accuracy increased but at slower rate.

It is thus seen for Karan Swiss and Karan Fries breeds that first 180 days cumulative milk yield was a reasonable predictor of lactation milk yield.

Reddy and Mishra (1983) also reported that 180 days yield was a reasonable predictor of 305 days and total lactation yields in Murrah buffaloes. Parmar *et al.* (1984) reported that maximum part yield was obtained at 91 to 180 days of first lactation in Tharparkar cows which shows that these animals reached peak part lactation production during this period. Katoch *et al.* (1990) reported that the relative efficiency of selection based on first

120 days and 150 days cumulative yield as compared to first lactation milk yield was high in Jersey cattle. Sushil Kumar (1990) concluded that ratio factor method generally gave overestimates. The first 150 days and higher duration cumulative yield and above yields gave the percentage average error less than one per cent by ratio method in Sahiwal cattle.

It may be concluded from above presentation that first 180 day cumulative milk yield is a reasonable predictor of lactation milk yield in both the breeds.

4.6 PREDICTION OF FIRST LACTATION MILK ON THE BASIS OF FORTNIGHTLY, MONTHLY AND BIMONTHLY TEST RECORDS UNDER SYSTEMATIC AND STRATIFIED RANDOM SAMPLING SCHEMES AND PART YIELDS BY REGRESSION METHOD

4.6.1 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF FORTNIGHTLY SYSTEMATIC SAMPLED TEST RECORDS BY REGRESSION METHOD

The prediction equations and their accuracies are given in Table 30 for Karan Swiss and Karan Fries breeds.

It was seen for Karan Swiss breed that when only one test record was used for prediction of lactation milk yield, the 13th fortnight systematic sampled test record gave highest accuracies of fitting (67.33%) followed by accuracies of 67.17 per cent for 14th fortnight, 66.20 per cent for 11th fortnight, 65.35 per cent for 15th fortnight and 65.22 per cent for 12th fortnight. The accuracy of fitting on the basis of initial and terminating fortnightly test records was found to be the lowest as 37.65 and 24.42 per cent, respectively.

In the similar way for Karan Fries cattle, a linear regression model was fitted among 20 fortnightly test records to examine the highest accuracy for prediction of lactation milk yield. The 12th fortnight systematic sampled test record gave

Table 30. Regression equations and their accuracies for prediction of lactation milk yield under fortnightly systematic sampled test record yields

Duration of part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Regression equations	Accuracy (%)	Number of observations	Regression equations	Accuracy (%)
FORTNIGHT INTERVAL						
1st	1044	$Y = 1230.52 + 8.37 X_1$	37.65	835	$Y = 1592.88 + 7.99 X_1$	29.43
2nd	1044	$Y = 847.94 + 10.17 X_2$	50.28	835	$Y = 1121.75 + 9.93 X_2$	43.97
3rd	1044	$Y = 795.55 + 10.69 X_3$	53.09	835	$Y = 987.36 + 10.62 X_3$	52.35
4th	1044	$Y = 754.60 + 11.26 X_4$	59.77	835	$Y = 908.50 + 11.30 X_4$	55.75
5th	1044	$Y = 720.53 + 11.97 X_5$	60.90	835	$Y = 1032.90 + 11.06 X_5$	54.09
6th	1044	$Y = 750.75 + 12.11 X_6$	60.61	835	$Y = 995.43 + 11.54 X_6$	59.41
7th	1044	$Y = 689.92 + 12.96 X_7$	62.48	835	$Y = 1009.64 + 11.96 X_7$	58.70
8th	1044	$Y = 800.26 + 12.71 X_8$	59.65	835	$Y = 996.35 + 12.40 X_8$	62.12
9th	1044	$Y = 695.38 + 13.87 X_9$	64.34	831	$Y = 1011.25 + 12.76 X_9$	63.83
10th	1042	$Y = 742.38 + 13.97 X_{10}$	64.33	830	$Y = 1039.72 + 12.91 X_{10}$	66.21
11th	1035	$Y = 802.39 + 13.98 X_{11}$	66.20	826	$Y = 1029.48 + 13.50 X_{11}$	66.70
12th	1018	$Y = 960.43 + 13.15 X_{12}$	65.22	817	$Y = 1208.84 + 12.66 X_{12}$	68.02
13th	1002	$Y = 1018.59 + 13.02 X_{13}$	67.33	811	$Y = 1279.60 + 12.50 X_{13}$	67.56
14th	982	$Y = 1152.24 + 12.33 X_{14}$	67.17	799	$Y = 1339.52 + 12.48 X_{14}$	67.72
15th	968	$Y = 1213.13 + 12.12 X_{15}$	65.35	792	$Y = 1459.98 + 11.86 X_{15}$	62.85
16th	951	$Y = 1324.50 + 11.31 X_{16}$	61.24	784	$Y = 1573.90 + 11.26 X_{16}$	60.68
17th	936	$Y = 1431.27 + 10.59 X_{17}$	56.87	773	$Y = 1658.27 + 10.79 X_{17}$	58.65
18th	904	$Y = 1598.62 + 9.41 X_{18}$	48.63	750	$Y = 1953.04 + 8.96 X_{18}$	46.64
19th	822	$Y = 1881.89 + 7.09 X_{19}$	36.13	664	$Y = 2346.87 + 6.38 X_{19}$	32.16
20th	725	$Y = 2075.21 + 5.51 X_{20}$	24.42	584	$Y = 2538.01 + 5.10 X_{20}$	23.94

X_i = test record yield during i^{th} fortnight - kg
 Y = predicted first lactation milk yield (PMY) - kg

highest accuracy of fitting (68.02%) followed by accuracies of 67.72 per cent for 14th fortnight, 67.56 per cent for 13th fortnight, 66.70 per cent for 11th fortnight and 66.21 per cent for 10th fortnight. The prediction equations of initial and terminating fortnights gave minimum accuracy for prediction of lactation yield.

It is thus seen that a single test record could be taken during a fortnight in mid lactation (9th to 14th fortnight) to predict lactation yield with fairly high accuracy in both breeds.

4.6.2 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF FORTNIGHTLY STRATIFIED RANDOM SAMPLED TEST RECORDS BY REGRESSION METHOD.

Prediction equations and their accuracies based on fortnightly stratified random sampled test records are given in Table 31 for Karan Swiss and Karan Fries cattle.

A linear regression model was fitted among 20 fortnightly test records to examine the highest accuracy. For Karan Swiss cattle it was thus observed that 13th fortnight test record gave highest accuracy of fitting (68.12%) followed by accuracies of 66.97 per cent for 12th fortnight, 66.51 per cent for 14th fortnight, 66.09 per cent for 15th fortnight and 65.30 per cent for 10th and 11th fortnights. The minimum accuracy of fitting for prediction was observed during initial and terminating lactation.

For Karan Fries cattle, it was found that when a single test record was used to predict the lactation milk yield by regression method, the 12th fortnightly stratified random test record gave highest accuracy of fitting (68.48%) followed by accuracies of 68.21 per cent for 13th fortnight, 67.15 per cent for 10th fortnight, 67.03 per cent for 14th fortnight and 66.41 per cent for 11th fortnight. The prediction based on initial and

Table 31. Regression equations and their accuracies for prediction of lactation milk yield under fortnightly stratified random sampled test record yields

Duration of part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Regression equations	Accuracy (%)	Number of observations	Regression equations	Accuracy (%)
FORTNIGHT INTERVAL						
1st	1044	$Y = 1229.82 + 8.39 X_1$	37.75	835	$Y = 1567.15 + 8.17 X_1$	30.11
2nd	1044	$Y = 822.03 + 10.30 X_2$	50.89	835	$Y = 1121.45 + 9.97 X_2$	43.43
3rd	1044	$Y = 792.24 + 10.72 X_3$	53.90	835	$Y = 1019.43 + 10.41 X_3$	51.53
4th	1044	$Y = 741.58 + 11.35 X_4$	59.22	835	$Y = 894.86 + 11.42 X_4$	55.90
5th	1044	$Y = 647.58 + 12.39 X_5$	62.13	835	$Y = 1068.31 + 10.85 X_5$	52.28
6th	1044	$Y = 725.34 + 12.20 X_6$	60.53	835	$Y = 1057.81 + 11.18 X_6$	57.62
7th	1044	$Y = 720.05 + 12.73 X_7$	61.28	835	$Y = 1014.77 + 11.92 X_7$	58.65
8th	1044	$Y = 756.50 + 13.02 X_8$	60.05	835	$Y = 1006.98 + 12.28 X_8$	60.84
9th	1043	$Y = 725.46 + 13.68 X_9$	64.15	830	$Y = 1002.36 + 12.76 X_9$	63.80
10th	1040	$Y = 778.07 + 13.71 X_{10}$	65.29	829	$Y = 1003.68 + 13.24 X_{10}$	67.15
11th	1028	$Y = 836.19 + 13.68 X_{11}$	65.30	822	$Y = 1095.83 + 13.08 X_{11}$	66.41
12th	1011	$Y = 962.52 + 13.19 X_{12}$	66.97	814	$Y = 1192.99 + 12.80 X_{12}$	68.48
13th	992	$Y = 1044.48 + 12.86 X_{13}$	68.12	803	$Y = 1290.17 + 12.55 X_{13}$	68.21
14th	973	$Y = 1183.34 + 12.04 X_{14}$	66.51	797	$Y = 1401.28 + 12.11 X_{14}$	67.03
15th	956	$Y = 1234.10 + 11.95 X_{15}$	66.09	789	$Y = 1448.50 + 11.94 X_{15}$	65.07
16th	943	$Y = 1340.25 + 11.23 X_{16}$	62.22	778	$Y = 1608.35 + 11.01 X_{16}$	58.82
17th	922	$Y = 1444.94 + 10.50 X_{17}$	57.52	771	$Y = 1659.27 + 10.74 X_{17}$	76.32
18th	872	$Y = 1673.37 + 8.82 X_{18}$	46.36	720	$Y = 2079.15 + 8.04 X_{18}$	65.36
19th	777	$Y = 1936.88 + 6.64 X_{19}$	33.28	619	$Y = 2441.52 + 5.67 X_{19}$	27.91
20th	674	$Y = 2134.96 + 4.98 X_{20}$	21.16	550	$Y = 2600.80 + 4.56 X_{20}$	20.29

X_i = test record yield during i^{th} fortnight - kg
 Y = predicted first lactation milk yield (PMY) - kg

terminating fortnightly test records determined lowest accuracies of 30.11 per cent and 20.29 per cent, respectively.

It is thus seen from Table 31 for Karan Swiss and Karan Fries breeds that a single test record could be drawn during a fortnight around 10th fortnight to 15th fortnight to predict lactation yield with high accuracy.

4.6.3 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF FORTNIGHTLY PART YIELDS BY REGRESSION METHOD

The prediction equations and their accuracies based on fortnightly part yields are presented in Table 32 for Karan Swiss and Karan Fries breeds.

A linear regression model was fitted among 20 fortnightly part records to examine the highest accuracy of fitting the model. For Karan Swiss cattle, it was found that the 13th fortnightly part record gave highest accuracy of fitting (72.83%) followed by accuracies of 71.85 per cent for 12th fortnight, 71.56 per cent for 11th fortnight, 71.53 per cent for 14th fortnight and 71.18 per cent for 10th fortnight. The prediction based on 19th fortnight and 20th fortnight gave lowest accuracy of fitting as 34.33 per cent and 21.33 per cent, respectively.

In case of Karan Fries breed, a linear regression model was also fitted among 20 fortnightly part records to examine the highest accuracy of fitting. It was found that 12th fortnightly part record gave highest accuracy of fitting (74.31%) followed by accuracies of 73.61 per cent for 10th fortnight, 73.57 per cent for 11th fortnight, 73.50 per cent for 13th fortnight, 72.04 per cent for 14th fortnight and 69.95 per cent for 9th fortnight. The prediction based on 19th fortnight and 20th fortnight gave lowest accuracy of fitting as 28.80 and 20.91 per cent, respectively.

Table 32. Regression equations and their accuracies for prediction of lactation milk yield under fortnightly part milk yields

Duration of part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Regression equations	Accuracy (%)	Number of observations	Regression equations	Accuracy (%)
PORTNIGHT INTERVAL						
1st	1044	$Y = 967.88 + 10.08 X_1$	44.59	835	$Y = 1178.92 + 10.35 X_1$	37.54
2nd	1044	$Y = 651.37 + 11.37 X_2$	56.50	835	$Y = 885.79 + 11.15 X_2$	48.62
3rd	1044	$Y = 616.08 + 11.09 X_3$	60.31	835	$Y = 762.77 + 11.79 X_3$	57.40
4th	1044	$Y = 529.93 + 12.70 X_4$	65.35	835	$Y = 737.18 + 12.21 X_4$	60.77
5th	1044	$Y = 505.17 + 13.32 X_5$	67.50	835	$Y = 776.94 + 12.38 X_5$	61.32
6th	1044	$Y = 545.73 + 13.50 X_6$	66.93	835	$Y = 807.80 + 12.61 X_6$	64.06
7th	1044	$Y = 534.22 + 14.06 X_7$	68.79	835	$Y = 806.11 + 13.11 X_7$	65.65
8th	1044	$Y = 561.61 + 14.45 X_8$	67.70	835	$Y = 802.69 + 13.55 X_8$	66.38
9th	1042	$Y = 539.48 + 15.09 X_9$	70.19	830	$Y = 806.41 + 14.05 X_9$	69.95
10th	1039	$Y = 601.63 + 15.11 X_{10}$	71.18	829	$Y = 823.41 + 14.41 X_{10}$	73.61
11th	1027	$Y = 697.78 + 14.85 X_{11}$	71.56	822	$Y = 932.88 + 14.15 X_{11}$	73.57
12th	1010	$Y = 851.60 + 14.11 X_{12}$	71.85	814	$Y = 1047.86 + 13.84 X_{12}$	74.31
13th	991	$Y = 948.36 + 13.70 X_{13}$	72.83	803	$Y = 1169.35 + 13.38 X_{13}$	73.50
14th	972	$Y = 1076.26 + 13.03 X_{14}$	71.53	797	$Y = 1247.70 + 13.21 X_{14}$	72.05
15th	955	$Y = 1175.17 + 12.51 X_{15}$	69.20	789	$Y = 1365.71 + 12.65 X_{15}$	67.85
16th	942	$Y = 1270.52 + 11.87 X_{16}$	65.80	778	$Y = 1503.08 + 11.86 X_{16}$	64.51
17th	921	$Y = 1393.74 + 10.98 X_{17}$	60.22	771	$Y = 1600.90 + 11.27 X_{17}$	61.25
18th	871	$Y = 1643.65 + 9.10 X_{18}$	48.06	720	$Y = 2039.64 + 8.42 X_{18}$	44.31
19th	776	$Y = 1919.59 + 6.85 X_{19}$	34.33	619	$Y = 2427.00 + 5.84 X_{19}$	28.80
20th	673	$Y = 2129.10 + 5.04 X_{20}$	21.33	550	$Y = 2592.11 + 4.71 X_{20}$	20.91

X_i = test record yield during i^{th} month - kg
 Y = predicted first lactation milk yield (PMY) - kg

It is thus seen from Table 32 that a single test record could be taken during 9th fortnight to 14th fortnight to predict lactation yield with fairly high accuracy in both the breeds.

It is thus seen from above results that when a fortnightly systematic sampled test record was used to predict lactation yield, the 13th fortnight for Karan Swiss and 12th fortnight for Karan Fries breeds gave highest accuracies of fitting as 67.33 and 68.02 per cent, respectively. The prediction of lactation milk yield on the basis of fortnightly stratified random sampled test records reveals that 13th fortnight for Karan Swiss and 12th fortnight for Karan Fries gave highest accuracies of fitting as 68.12 per cent and 68.48 per cent, respectively. It seems that the highest accuracy of prediction of lactation milk yield on the basis of fortnightly systematic and stratified random sampled test records were almost similar in both breeds when a single fortnightly part yield record was used to predict lactation milk yield. However, prediction on the basis of part records indicated that the 13th fortnight for Karan Swiss and 12th fortnight part record for Karan Fries breeds gave highest accuracies of fitting as 72.83 and 74.31 per cent, respectively.

Amble et al. (1959) and Amble and Rajagopalan (1960) estimated the lactation milk yield from test day yields recorded at fortnightly intervals by simple random sampling and systematic sampling in cattle and buffaloes in India. They reported that systematic sampling was better than simple random sampling method for estimation of lactation yield from test day records. Agarwala (1962) reported that recording milk production after every 10 days for predicting the lactation yields was found to be most reliable. Dutt et al. (1965) predicted first lactation yield in Murrah buffaloes from 15 days yield. The prediction equation for determining total lactation yield from part yield was $Y = 1284 + 7.63 X_1$, where Y = predicted complete lactation milk yield, X_1 was milk yield for 15 days of lactation. Ivanov et al (1969) reported that the estimated lactation yields with 5, 10 and 15 days recording intervals were less than actual yield in

dairy cattle in Denmark. Nagarcenkar and Basavaiah (1981) predicted 300 days milk yield from part yields by regression method. They reported that 22 week yield (11th fortnight) was a reasonable predictor by regression method. Agrawal *et al.* (1987) recorded daily milk yield in 77 Haryana cattle and 115 Murrah buffaloes at intervals of 7, 14, 28 or 56 days. There were no significant differences in the accuracy of estimated milk yield on the basis of tests sampled at interval of 7, 14 or 28 days. Dass (1991) observed that the accuracy under systematic and stratified random sampling was better with shorter testing intervals in Murrah buffaloes.

It may be concluded from above presentation that the prediction of lactation milk yield on the basis of fortnightly systematic and stratified random sampled test records and fortnightly part yields by regression method reveals that a single test record could be taken a fortnight during 9th to 14th fortnight to predict lactation yield with fairly high accuracy in both breeds. The accuracy for prediction of lactation milk yield on the basis of fortnightly systematic and stratified random sampled test records by regression method were similar in both breeds, whereas accuracy based on fortnightly part yields was similar in Karan Swiss and Karan Fries as compared to above two milk recording schemes.

4.6.4 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF MONTHLY SYSTEMATIC SAMPLED TEST RECORDS BY REGRESSION METHOD

A linear regression model was fitted among all 10 monthly systematic sampled test records in both breeds. The prediction equations and their accuracies are given in Table 33 for Karan Swiss and Karan Fries breeds.

For Karan Swiss cattle, when a single test record was considered, it could be seen from Table 33 that the 7th monthly test record under systematic sampling scheme gave highest accuracy (68.91%) of fitting followed by accuracies of 67.85% for

Table 33. Regression equations and their accuracies for prediction of lactation milk yield under monthly systematic sampled test record yields

Duration of part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Regression equations	Accuracy (%)	Number of observations	Regression equations	Accuracy (%)
MONTHLY INTERVAL						
1st	1044	$Y = 1067.86 + 4.56 X_1$	42.32	835	$Y = 1165.03 + 4.46 X_1$	36.12
2nd	1044	$Y = 754.77 + 5.55 X_2$	55.92	835	$Y = 905.65 + 5.60 X_2$	53.90
3rd	1044	$Y = 733.95 + 6.02 X_3$	60.66	835	$Y = 1000.43 + 5.68 X_3$	56.59
4th	1044	$Y = 817.27 + 6.15 X_4$	59.04	835	$Y = 1046.20 + 5.96 X_4$	58.03
5th	1044	$Y = 765.34 + 6.79 X_5$	63.64	831	$Y = 1019.05 + 6.43 X_5$	65.20
6th	1024	$Y = 887.61 + 6.75 X_6$	67.85	819	$Y = 1156.25 + 6.47 X_6$	67.54
7th	995	$Y = 1063.10 + 6.43 X_7$	68.91	804	$Y = 1335.99 + 6.14 X_7$	60.16
8th	957	$Y = 1276.40 + 5.81 X_8$	64.91	787	$Y = 1521.30 + 5.78 X_8$	63.08
9th	925	$Y = 1507.56 + 5.06 X_9$	54.65	763	$Y = 1791.59 + 5.00 X_9$	55.17
10th	776	$Y = 1998.03 + 3.12 X_{10}$	29.32	619	$Y = 2473.19 + 2.78 X_{10}$	26.80

X_i = test record yield during i^{th} month - kg
 Y = predicted first lactation milk yield (PMLY) - kg

6th month, 64.91 per cent for 8th month, 63.64 per cent for 5th month and 60.66 per cent for 3rd month. The initial and terminating monthly test records were found to give lowest accuracy of prediction as 42.32 and 29.32 per cent, respectively.

Similarly for Karan Fries cattle when a single test record was used to draw the sample, it was found (Table 33) that the 7th monthly test record under systematic sampling scheme gave highest accuracy (68.16%) of prediction followed by accuracies of 67.54 per cent for 6th month, 65.20 per cent for 5th month, 63.08 per cent for 3rd month and 58.03 per cent for 4th month. However, initial and terminating monthly test records were observed to give minimum accuracy of fitting as 36.12 and 26.80 per cent, respectively.

It is thus seen from above presentation that a single systematically sampled test record could be taken during seventh month of lactation to predict lactation yield with fairly high accuracy in both breeds.

4.6.5 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF MONTHLY STRATIFIED RANDOM SAMPLED TEST RECORDS BY REGRESSION METHOD

Prediction equations and their accuracies of fitting based on monthly stratified random test records are given in Table 34 for Karan Swiss and Karan Fries breeds.

For Karan Swiss cattle when a single monthly test record was considered to predict lactation yield, the 7th monthly test record under stratified random sampling scheme was found to give highest accuracy (69.06%) of fitting followed by accuracies of 66.42 per cent for 6th month, 63.87 per cent for 5th month, 63.85 per cent for 8th month and 58.94 per cent for 3rd month. The initial and terminating monthly test records determined lowest accuracy as 44.78 and 21.51 per cent, respectively.

Table 34. Regression equations and their accuracies for prediction of lactation milk yield under monthly stratified random sampled test record yields

Duration of part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Regression equations	Accuracy (%)	Number of observations	Regression equations	Accuracy (%)
MONTHLY INTERVAL						
1st	1044	$Y = 1027.90 + 4.65 X_1$	44.78	835	$Y = 1275.40 + 4.73 X_1$	38.14
2nd	1044	$Y = 807.05 + 5.39 X_2$	54.04	835	$Y = 935.24 + 5.48 X_2$	54.38
3rd	1044	$Y = 703.24 + 6.09 X_3$	58.94	835	$Y = 937.81 + 5.84 X_3$	60.37
4th	1044	$Y = 775.47 + 6.34 X_4$	58.47	835	$Y = 960.43 + 6.17 X_4$	60.42
5th	1040	$Y = 787.53 + 6.74 X_5$	63.87	829	$Y = 1031.42 + 6.40 X_5$	62.36
6th	1011	$Y = 977.21 + 6.40 X_6$	66.43	814	$Y = 1186.12 + 6.30 X_6$	67.73
7th	973	$Y = 1130.54 + 6.23 X_7$	69.06	797	$Y = 1341.75 + 6.19 X_7$	66.56
8th	943	$Y = 1319.80 + 5.65 X_8$	63.85	778	$Y = 1591.48 + 5.56 X_8$	60.51
9th	872	$Y = 1653.70 + 4.44 X_9$	48.39	720	$Y = 2048.19 + 4.16 X_9$	43.81
10th	674	$Y = 2130.07 + 2.51 X_{10}$	21.51	550	$Y = 2593.18 + 2.34 X_{10}$	20.99

X_i = test record yield during i^{th} month - kg
 Y = predicted first lactation milk yield (PMY) - kg

Similarly for Karan Fries cattle, it was seen (Table 34) that when a single monthly test record was used to predict lactation milk yield by regression method, the 6th monthly stratified random sampled test record was found to give highest accuracy (67.73%) of fitting followed by accuracies of 66.56% for 7th month, 62.36 per cent for 5th month, 60.51 per cent for 8th month and 60.42 per cent for 4th month. The initial and terminating monthly test records gave minimum accuracy of prediction as 38.14 and 20.99 per cent respectively.

It is thus seen from above presentation (Table 34) for Karan Swiss and Karan Fries breeds that a single monthly test record under stratified random sampling scheme could be taken during 6th to 7th month of lactation to predict lactation yield with fairly high accuracy in both breeds.

4.6.6 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF MONTHLY PART RECORDS BY REGRESSION METHOD

Prediction equations and their accuracies of fitting based on monthly part records are given in Table 35 for Karan Swiss and Karan Fries breeds.

For Karan Swiss cattle, when a single monthly part record was considered to predict lactation yield, the 6th month part record was found to give highest accuracy (73.71%) of fitting followed by accuracies of 73.53 per cent for 7th month, 72.42 per cent for 5th month, 70.18 per cent for 4th month and 68.68 per cent for 3rd month. The initial and terminating monthly part records determined lowest accuracy as 52.97 and 22.09 per cent, respectively.

Similarly for Karan Fries cattle, it was seen (Table 35) that when a single monthly part record was used to predict lactation milk yield by regression method, the 6th monthly part record was found to give highest accuracy (75.48%) of fitting followed by accuracies of 74.10 per cent for 7th month, 73.61 per

Table 35. Regression equations and their accuracies for prediction of lactation milk yield under monthly part yields

Duration of part lactation	KARAN SWISS BREED			KARAN PRIES BREED		
	Number of observations	Regression equations	Accuracy (R ² , %)	Number of observations	Regression equations	Accuracy (R ² , %)
1st month	1044	Y = 725.49 + 5.64 X ₁	52.97	835	Y = 898.04 + 5.74 X ₁	40.59
2nd month	1044	Y = 527.72 + 6.26 X ₂	64.25	835	Y = 699.67 + 6.13 X ₂	60.37
3rd month	1044	Y = 482.00 + 6.85 X ₃	68.68	835	Y = 738.73 + 6.39 X ₃	64.18
4th month	1044	Y = 492.29 + 7.33 X ₄	70.18	835	Y = 750.73 + 6.82 X ₄	67.61
5th month	1044	Y = 536.19 + 7.69 X ₅	72.42	831	Y = 770.08 + 7.26 X ₅	73.59
6th month	1024	Y = 797.95 + 7.18 X ₆	73.71	819	Y = 994.33 + 7.01 X ₆	75.48
7th month	995	Y = 1035.78 + 6.62 X ₇	73.53	804	Y = 1202.40 + 6.68 X ₇	74.10
8th month	957	Y = 1236.20 + 6.06 X ₈	68.00	787	Y = 1459.74 + 6.07 X ₈	66.56
9th month	925	Y = 1611.25 + 4.68 X ₉	50.56	763	Y = 2011.63 + 4.29 X ₉	45.76
10th month	776	Y = 2120.77 + 2.58 X ₁₀	22.09	619	Y = 2584.47 + 2.38 X ₁₀	21.49

X_i = part yield during ith month - kg
Y = predicted first lactation milk yield (PMY) - kg

cent for 5th month, 67.61 per cent for 4th month and 66.56 per cent for 8th month. The initial and terminating monthly part records gave lowest accuracy of prediction as 40.59 and 21.49 per cent, respectively.

It is thus seen from above presentation (Table 35) for Karan Swiss and Karan Fries breeds that a single monthly part record could be taken during 6th month of lactation to predict lactation yield with fairly high accuracy.

VanVleck and Henderson (1961c) developed regression factors in Holsteins for extending part lactation milk records by a "within herd analysis" of age at first calving and season of calving corrected data. A linear function of first five monthly test records was found to predict a complete second record as accurately as the total yield of first lactation. The linear function of first seven monthly records gave even more accurate predictions. Sidhar and Sundaresan (1973) made studies on Nili-Ravi buffaloes and found that regression coefficients ranged from 2.64 to 6.44 for single monthly milk yields. Gokhale (1974) studied the reliability of part lactations in estimating the total first lactation yield which revealed that amongst single monthly yields, 5th month's production showed highest accuracy (66.96%) followed closely by 6th month and 9th month. The prediction equation based on fifth month's yield was $Y = 437.09 + 7.74 X$, where Y = estimated first lactation milk yield, X = fifth month's milk yield. Abdel-Aziz *et al.* (1975) used least square analysis method to calculate simple regression factors based on single month yield. They found that the best single month yield for prediction of lactation yield was seventh and eighth with coefficient of determination of 0.36 and 0.38, respectively in Egyptian buffaloes. Tahir *et al.* (1983) found the best prediction regression equation on the basis of fourth monthly part lactation yield which was $Y = 126 + 2.123 X_4$, where X_4 is the 4th monthly part lactation yield; this had the reliability of 72.42 per cent. Do *et al.* (1986) reported that total lactation yield was best predicted by simple regression on monthly yields

in months five to six ($R^2 = 0.87$). Khoda and Trivedi (1987) reported that the best predictors of 305 days milk yield by regression method were third, fourth, fifth and sixth month's yield.

Roy and Katpatal (1989) used the regression method for predicting 300 days milk yield based on single monthly yields. The 4th monthly yield was found to give highest accuracy (74%) of prediction followed by 5th month (72%) and 3rd month (71%).

4.6.7 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF BIMONTHLY SYSTEMATIC SAMPLED TEST RECORDS BY REGRESSION METHOD

The prediction equations and their accuracy for prediction on the basis of bimonthly systematic sampled test records are shown in Table 36 for Karan Swiss and Karan Fries breeds.

When a single bimonthly test record was considered, it is seen from Table 36 that for Karan Swiss cattle, the 4th bimonthly test record under systematic sampling scheme was found to give the highest accuracy (66.21%) of fitting followed by accuracies of 65.68 per cent for 3rd bimonth, 62.43 per cent for 2nd bimonth, 49.98 per cent for first bimonth and 38.92 per cent for 5th bimonth.

For Karan Fries breed, prediction of lactation yield on the basis of 3rd bimonthly test record under systematic sampling scheme was found to give highest accuracy (66.05%) of fitting followed by 64.74 per cent for 4th bimonth, 56.16 per cent for 2nd bimonth, 46.77 per cent for 1st bimonth and 35.80 per cent for 5th bimonth.

It is thus seen from above presentation that a single bimonthly test record under this sampling scheme could be drawn during 3rd and 4th bimonthly lactation period to predict lactation milk yield with fairly high accuracy.

Table 36. Regression equations and their accuracies for prediction of lactation milk yield under bimonthly systematic sampled test record yields

Duration of part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Regression equations	Accuracy (%)	Number of observations	Regression equations	Accuracy (%)
BIMONTHLY INTERVAL						
1st two months	1044	$Y = 885.72 + 2.56 X_1$	49.98	835	$Y = 1158.31 + 2.50 X_1$	46.77
2nd two months	1044	$Y = 757.40 + 3.05 X_2$	62.43	835	$Y = 1079.57 + 2.81 X_2$	56.16
3rd two months	1036	$Y = 834.60 + 3.38 X_3$	65.68	828	$Y = 1089.71 + 3.24 X_3$	66.05
4th two months	978	$Y = 1195.53 + 3.03 X_4$	66.21	796	$Y = 1451.13 + 2.95 X_4$	64.74
5th two months	848	$Y = 1831.64 + 1.92 X_5$	38.92	692	$Y = 2272.03 + 1.76 X_5$	35.80

X_i = test record yield during i^{th} bimonth - kg
 Y = predicted first lactation milk yield (PHY) - kg

4.6.8 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF BIMONTHLY STRATIFIED RANDOM SAMPLED TEST RECORDS BY REGRESSION METHOD

The prediction equations and their accuracies based on bimonthly test records are given in Table 37 for Karan Swiss and Karan Fries breeds.

A linear regression model of lactation milk yield was fitted on five bimonthly test records to examine the highest accuracy. It was thus observed that for Karan Swiss cattle 4th bimonthly test record under stratified random sampling scheme gave highest accuracy (66.21%) of fitting followed by accuracies of 64.21 per cent for 3rd bimonth, 58.26 per cent for 2nd bimonth, 51.32 per cent for 1st bimonth and 22.08 per cent for 5th bimonth.

For Karan Fries cattle it was found that when a single record was used to predict lactation milk yield by regression method, the 3rd bimonthly stratified random test record gave highest accuracy (67.97%) of fitting followed by accuracies of 64.29 per cent for 4th bimonth, 58.79 per cent for 2nd bimonth, 44.53 per cent for 1st bimonth and 21.61 per cent for 5th bimonth.

It is thus seen from above presentation (Table 37) that a single bimonthly test record under stratified random sampling scheme could be taken during 4th bimonth in Karan Swiss and 3rd bimonth in Karan Fries breeds to predict lactation milk yield with fairly high accuracy.

4.6.9 PREDICTION OF LACTATION MILK YIELD ON THE BASIS OF BIMONTHLY PART YIELD BY REGRESSION METHOD

The prediction equations and their accuracies based on bimonthly part milk yields are given in Table 38 for Karan Swiss and Karan Fries breeds.

Table 37. Regression equations and their accuracies for prediction of lactation milk yield under bimonthly stratified random sampled test record yields

Duration of part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Regression equations	Accuracy (R ² , %)	Number of observations	Regression equations	Accuracy (R ² , %)
BIMONTHLY INTERVAL						
1st two months	1044	Y = 903.67 + 2.54 X ₁	51.32	835	Y = 1190.30 + 2.45 X ₁	44.53
2nd two months	1044	Y = 822.42 + 2.96 X ₂	58.26	835	Y = 993.62 + 2.94 X ₂	58.79
3rd two months	1011	Y = 951.67 + 3.19 X ₃	64.95	814	Y = 1205.74 + 3.04 X ₃	67.97
4th two months	943	Y = 1290.87 + 2.86 X ₄	66.21	778	Y = 1537.36 + 2.83 X ₄	64.29
5th two months	674	Y = 2123.27 + 1.29 X ₅	22.08	550	Y = 2586.63 + 1.18 X ₅	21.61

X_i = test record yield during ith bimonth - kg
Y = predicted first lactation milk yield (PNY) - kg

Table 38. Regression equations and their accuracies for prediction of lactation milk yield under bimonthly part yields

Duration of part lactation	KARAN SWISS BREED			KARAN FRIES BREED		
	Number of observations	Regression equations	Accuracy (R ² , %)	Number of observations	Regression equations	Accuracy (R ² , %)
1st two months	1044	$Y = 506.87 + 3.16 X_1$	62.19	835	$Y = 616.53 + 3.21 X_1$	57.32
2nd two months	1044	$Y = 401.12 + 3.69 X_2$	72.35	835	$Y = 659.11 + 3.42 X_2$	68.31
3rd two months	1011	$Y = 731.97 + 3.63 X_3$	75.89	814	$Y = 911.33 + 3.54 X_3$	77.49
4th two months	943	$Y = 1177.51 + 3.12 X_4$	72.13	778	$Y = 1374.70 + 3.14 X_4$	71.27
5th two months	674	$Y = 2104.53 + 1.34 X_5$	23.70	550	$Y = 2569.68 + 1.23 X_5$	22.67

X_i = part yield during i^{th} bimonth - kg
 Y = predicted first lactation milk yield (PMY) - kg

For Karan Swiss cattle when a single bimonthly test record was considered to predict lactation milk yield, the 3rd bimonthly part yield was found to give highest accuracy (75.89%) of fitting followed by accuracies of 72.35 per cent for 2nd bimonth, 72.13 per cent for 4th bimonth, 62.19 per cent for 1st bimonth and 23.70 per cent for 5th bimonth.

Similarly, for Karan Fries cattle, a linear model of lactation yield was fitted on five bimonthly part yields to examine the maximum accuracy of prediction. It was found that the 3rd bimonthly part yield determined highest accuracy (77.49%) of fitting followed by 71.27 per cent for 4th bimonth, 68.31 per cent for 2nd bimonth, 57.32 per cent for 1st and 22.67 per cent for 5th bimonth.

It is thus seen from above presentation (Table 38) that a single bimonthly record could be drawn during 3rd bimonth's lactation period to predict lactation yield with fairly high accuracy in both the breeds. The prediction based on bimonthly part yield determined higher accuracy than bimonthly systematic and stratified random sampled test records in both the breeds.

The prediction of lactation milk yield on the basis of bimonthly systematic test records reveals that the maximum (66.21%) accuracy of fitting was obtained during 4th bimonth and minimum (38.92%) during 5th bimonth for Karan Swiss cattle and maximum (66.05%) accuracy of fitting was obtained during 3rd bimonth and minimum (35.80%) during 5th bimonth for Karan Fries breed, whereas prediction of lactation milk yield based on bimonthly stratified random test records reveals that the maximum (66.21%) accuracy of fitting was obtained during 4th bimonth and minimum (22.08%) accuracy during 5th bimonth for Karan Swiss cattle and maximum (67.97%) accuracy of fitting during 3rd bimonth and minimum (21.61%) accuracy during 5th bimonth in Karan Fries cattle. The highest accuracies for prediction on the basis of bimonthly systematic and stratified random sampled test records were similar but lowest accuracy was higher under

systematic sampling scheme as compared to stratified random sampling scheme in Karan Swiss breed. The maximum accuracy was slightly higher under stratified random sampling scheme than that under systematic sampling milk recording in Karan Fries breed.

The prediction based on bimonthly part yields reveals that maximum (75.89%) accuracy of fitting was obtained during 3rd bimonth and minimum (23.70%) accuracy during 5th bimonth in Karan Swiss breed and maximum (77.49%) accuracy of fitting during 3rd bimonth and minimum (22.67%) during 5th bimonth in Karan Fries breed. It is thus found that the accuracy of prediction of lactation milk yield on the basis of bimonthly part yield was higher than that obtained under systematic and stratified random sampled test records in both breeds.

Lamb and Young (1968) found that lactation totals for milk and fat estimated from bimonthly tests by several different computational procedures generally had small positive biases (upto 2%). McDaniel (1969), reviewing different reports on cattle, observed that errors in milk yields computed from bimonthly samples were about 30 per cent greater than those based on monthly tests. He was of the opinion that accurate cow ranking and progeny testing of bulls could be based on samples taken as much as two months apart.

A comparison of accuracy for prediction of lactation milk yield on the basis of bimonthly part yield with the two sampling schemes reveals that the higher difference of 9.68 per cent of accuracy was observed with systematic test records for Karan Swiss and 11.44 per cent of accuracy for Karan Fries breed whereas the higher difference of 9.68 per cent of accuracy was observed with stratified random sampled test records for Karan Swiss and 10.52 per cent of accuracy for Karan Fries breed. It may be concluded from above results that the prediction of lactation milk yield on the basis of bimonthly test records by regression method, that a single test record under systematic

sampling could be taken during 3rd bimonth's period of lactation in both breeds.

4.7 OPTIMUM COMBINATIONS OF TEST RECORDS AND MULTIPLE LINEAR REGRESSION EQUATIONS FOR PREDICTION OF LACTATION MILK YIELD

4.7.1 BEST PREDICTION EQUATIONS FOR ESTIMATION OF LACTATION MILK YIELD ON THE BASIS OF FORTNIGHTLY SYSTEMATIC SAMPLED TEST RECORDS

Simple linear and multiple linear regression equations were fitted to predict the lactation milk yield considering the various combinations of test records drawn under fortnightly systematic sampling scheme. The prediction equations which required minimum number of test records and gave sufficiently high (above 90%) accuracy of fitting the multiple regression model was considered to be the optimum. The forward selection stepwise regression analysis models were fitted to get the best combination of test records. The prediction equations fitted alongwith their accuracy for both the breeds are presented in Table 39.

In case of Karan Swiss cattle, it was found that when only one test record was used for prediction of lactation yield, the 13th fortnight systematic sampled test record gave highest accuracy (67.33%) of fitting. When two test records were used for prediction of lactation yield, it was found that the test record during 4th and 13th fortnight gave the highest accuracy (85.33%). Further when three samples were chosen, the highest accuracy (92.37%) of fitting the multiple regression model was obtained for test records drawn during 4th, 13th and 17th fortnight. When more number of test records were chosen for prediction, the accuracy of fitting the multiple regression models increased at slower rate. When all the 20 fortnightly test records were considered, the accuracy (99.23%) of fitting the prediction equations was obtained in Karan Swiss breed (Table 39).

Table 39. Prediction equations and their accuracy for estimation of lactation milk yield under fortnightly systematic sampling scheme with "best" combination of test records

Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS	1	$Y = 1018.59 + 13.02X_{13}$	67.33
KF		$Y = 1208.84 + 12.66X_{12}$	68.01
Both		$Y = 1069.42 + 13.28X_{13}$	69.56
KS	2	$Y = 347.34 + 7.10X_4 + 9.22X_{13}$	85.33
KF		$Y = 403.81 + 6.48X_3 + 9.60X_{12}$	83.59
Both		$Y = 325.19 + 7.29X_4 + 9.35X_{13}$	87.33
KS	3	$Y = 278.74 + 7.08X_4 + 5.31X_{13} + 5.08X_{17}$	92.37
KF		$Y = 279.39 + 6.32X_3 + 5.88X_{12} + 5.45X_{17}$	92.41
Both		$Y = 261.95 + 7.25X_4 + 5.31X_{13} + 5.12X_{17}$	93.02
KS	4	$Y = 203.31 + 4.85X_4 + 3.76X_7 + 4.22X_{13} + 5.26X_{17}$	94.04
KF		$Y = 234.19 + 4.08X_3 + 3.56X_6 + 4.60X_{12} + 5.71X_{17}$	94.23
Both		$Y = 203.99 + 5.55X_4 + 3.75X_9 + 3.58X_{13} + 5.37X_{17}$	94.66
KS	5	$Y = 184.16 + 4.55X_4 + 4.25X_7 + 4.25X_{13} + 3.40X_{17} + 2.12X_{19}$	95.62
KF		$Y = 209.99 + 3.84X_3 + 3.99X_6 + 4.68X_{12} + 3.87X_{17} + 2.04X_{19}$	95.98
Both		$Y = 178.17 + 5.35X_4 + 4.28X_9 + 3.49X_{13} + 3.55X_{17} + 2.10X_{19}$	96.10
KS	6	$Y = 112.31 + 2.20X_2 + 2.98X_4 + 3.87X_7 + 4.54X_{13} + 3.28X_{17} + 1.95X_{19}$	96.46
KF		$Y = 193.30 + 3.60X_3 + 3.07X_6 + 2.74X_{10} + 3.29X_{12} + 3.79X_{17} + 2.15X_{19}$	96.80
Both		$Y = 91.21 + 2.45X_2 + 3.38X_4 + 4.17X_9 + 3.77X_{13} + 3.41X_{17} + 1.93X_{19}$	97.04
KS	7	$Y = 75.16 + 2.31X_2 + 2.61X_4 + 3.11X_7 + 2.95X_{11} + 3.04X_{13} + 3.11X_{17} + 2.06X_{19}$	97.34
KF		$Y = 174.08 + 2.05X_2 + 3.58X_3 + 3.14X_6 + 2.72X_{10} + 2.40X_{12} + 2.49X_{17} + 2.10X_{19}$	97.35
Both		$Y = 87.42 + 2.21X_2 + 2.23X_4 + 2.36X_6 + 3.29X_9 + 3.65X_{13} + 3.39X_{17} + 2.02X_{19}$	97.54
KS	8	$Y = 77.18 + 2.35X_2 + 2.59X_4 + 3.13X_7 + 2.70X_{11} + 2.05X_{13} + 2.25X_{15} + 2.09X_{17} + 2.03X_{19}$	97.78
KF		$Y = 116.83 + 1.90X_2 + 2.14X_3 + 2.83X_6 + 2.82X_{10} + 2.47X_{12} + 2.46X_{15} + 2.45X_{17} + 1.97X_{19}$	97.77
Both		$Y = 66.64 + 2.29X_2 + 2.09X_4 + 2.24X_6 + 2.38X_9 + 2.30X_{11} + 2.71X_{13} + 3.26X_{17} + 2.08X_{19}$	97.96
KS	9	$Y = 66.69 + 2.34X_2 + 2.34X_4 + 2.32X_7 + 1.98X_9 + 2.02X_{11} + 1.90X_{13} + 2.23X_{15} + 2.10X_{17} + 2.11X_{19}$	98.06
KF		$Y = 106.58 + 1.89X_2 + 1.99X_3 + 2.03X_6 + 1.88X_8 + 2.18X_{10} + 2.12X_{12} + 2.63X_{15} + 2.42X_{17} + 2.42X_{19}$	98.05
Both		$Y = 62.43 + 2.32X_2 + 2.11X_4 + 2.18X_6 + 2.43X_9 + 2.13X_{11} + 1.77X_{13} + 2.09X_{15} + 2.32X_{17} + 2.04X_{19}$	98.31
KS	10	$Y = 60.08 + 2.18X_2 + 1.70X_4 + 1.54X_5 + 1.78X_7 + 1.87X_9 + 1.97X_{11} + 1.90X_{13} + 2.28X_{15} + 2.06X_{17} + 2.10X_{19}$	98.27
KF		$Y = 87.34 + 1.94X_2 + 1.90X_3 + 2.04X_6 + 1.76X_8 + 1.66X_{10} + 1.69X_{11} + 1.36X_{12} + 2.52X_{15} + 2.37X_{17} + 2.06X_{19}$	98.26
Both		$Y = 59.27 + 2.31X_2 + 2.18X_4 + 2.24X_6 + 2.38X_9 + 2.20X_{11} + 1.80X_{13} + 2.10X_{15} + 2.29X_{17} + 1.19X_{19} + 0.91X_{20}$	98.48

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Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS		$Y = 53.11 + 2.18X_2 + 1.67X_4 + 1.55X_5 + 1.81X_7 + 1.83X_9 + 2.04X_{11} + 1.87X_{13} + 2.33X_{15} + 2.06X_{17} + 1.29X_{19} + 0.88X_{20}$	98.46
KF	11	$Y = 98.47 + 1.91X_2 + 1.89X_3 + 2.06X_6 + 1.77X_8 + 1.67X_{10} + 1.76X_{11} + 1.36X_{12} + 2.53X_{15} + 2.32X_{17} + 1.19X_{19} + 0.94X_{20}$	98.47
Both		$Y = 55.96 + 2.27X_2 + 1.97X_4 + 1.80X_6 + 1.52X_8 + 1.62X_9 + 2.05X_{11} + 1.69X_{13} + 2.23X_{15} + 2.25X_{17} + 1.21X_{19} + 0.92X_{20}$	98.64
KS		$Y = 40.70 + 0.86X_1 + 1.50X_2 + 1.61X_4 + 1.54X_5 + 1.82X_7 + 1.88X_9 + 2.03X_{11} + 1.93X_{13} + 2.26X_{15} + 2.02X_{17} + 1.32X_{19} + 0.86X_{20}$	98.60
KF	12	$Y = 75.29 + 1.63X_2 + 1.34X_3 + 1.50X_4 + 1.57X_6 + 1.62X_8 + 1.73X_{10} + 1.69X_{11} + 1.34X_{12} + 2.54X_{15} + 2.35X_{17} + 1.17X_{19} + 0.95X_{20}$	98.63
Both		$Y = 35.76 + 0.97X_1 + 1.51X_2 + 1.91X_4 + 1.83X_7 + 1.56X_8 + 1.62X_9 + 2.03X_{11} + 1.77X_{13} + 2.16X_{15} + 2.20X_{17} + 1.23X_{19} + 0.90X_{20}$	98.81
KS		$Y = 40.81 + 0.83X_1 + 1.48X_2 + 1.63X_4 + 1.61X_5 + 1.74X_7 + 1.94X_9 + 1.99X_{11} + 1.87X_{13} + 1.57X_{15} + 1.28X_{16} + 1.54X_{17} + 1.29X_{19} + 0.85X_{20}$	98.71
KF	13	$Y = 47.77 + 0.84X_1 + 1.05X_2 + 1.18X_3 + 1.55X_4 + 1.64X_6 + 1.67X_8 + 1.66X_{10} + 1.71X_{11} + 1.41X_{12} + 2.51X_{15} + 2.29X_{17} + 1.16X_{19} + 0.94X_{20}$	98.78
Both		$Y = 33.99 + 0.96X_1 + 1.55X_2 + 1.89X_4 + 1.74X_6 + 1.42X_8 + 1.15X_9 + 1.27X_{10} + 1.60X_{11} + 1.67X_{13} + 2.15X_{15} + 2.20X_{17} + 1.22X_{19} + 0.91X_{20}$	98.91
KS		$Y = 40.39 + 0.86X_1 + 1.46X_2 + 1.64X_4 + 1.64X_5 + 1.71X_7 + 1.88X_9 + 1.40X_{11} + 1.17X_{12} + 1.42X_{13} + 1.55X_{15} + 1.24X_{16} + 1.55X_{17} + 1.27X_{19} + 0.87X_{20}$	98.81
KF	14	$Y = 45.77 + 0.89X_1 + 1.05X_2 + 1.19X_3 + 1.58X_4 + 1.61X_6 + 1.64X_8 + 1.54X_{10} + 1.61X_{11} + 1.06X_{12} + 1.53X_{14} + 1.75X_{15} + 2.07X_{17} + 1.16X_{19} + 0.93X_{20}$	98.93
Both		$Y = 31.49 + 0.93X_1 + 1.56X_2 + 1.82X_4 + 1.77X_6 + 1.46X_8 + 1.16X_9 + 1.27X_{10} + 1.62X_{11} + 1.68X_{13} + 1.207X_{15} + 1.61X_{17} + 0.98X_{18} + 0.91X_{19} + 0.90X_{20}$	98.99
KS		$Y = 36.78 + 0.85X_1 + 1.45X_2 + 1.60X_4 + 1.66X_5 + 1.69X_7 + 1.95X_9 + 1.40X_{11} + 1.20X_{12} + 1.41X_{13} + 1.50X_{15} + 1.22X_{16} + 0.92X_{17} + 1.05X_{18} + 0.98X_{19} + 0.81X_{20}$	98.90
KF	15	$Y = 38.67 + 0.91X_1 + 1.08X_2 + 1.14X_3 + 1.60X_4 + 1.48X_6 + 1.27X_8 + 1.17X_9 + 1.09X_{10} + 1.48X_{11} + 0.97X_{12} + 1.52X_{14} + 1.72X_{15} + 2.10X_{17} + 1.20X_{19} + 0.89X_{20}$	99.03
Both		$Y = 27.13 + 0.94X_1 + 1.47X_2 + 1.44X_4 + 1.07X_5 + 1.34X_6 + 1.37X_8 + 1.12X_9 + 1.25X_{10} + 1.58X_{11} + 1.70X_{13} + 2.07X_{16} + 1.58X_{17} + 1.08X_{18} + 0.94X_{19} + 0.88X_{20}$	99.07

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Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS	16	$Y = 35.04 + 0.86X_1 + 1.40X_2 + 1.41X_4 + 1.25X_5 + 1.11X_6 + 1.33X_7 + 1.89X_9 + 1.36X_{11} + 1.19X_{12} + 1.45X_{13} + 1.46X_{15} + 1.11X_{16} + 1.00X_{17} + 1.09X_{18} + 0.97X_{19} + 0.82X_{20}$	98.99
KF		$Y = 34.34 + 0.92X_1 + 1.05X_2 + 1.12X_3 + 1.51X_4 + 1.16X_6 + 0.98X_7 + 0.94X_8 + 1.06X_{10} + 1.45X_{11} + 0.94X_{12} + 1.55X_{14} + 1.73X_{15} + 2.10X_{17} + 1.22X_{19} + 0.89X_{20}$	99.10
Both		$Y = 29.25 + 0.96X_1 + 1.48X_2 + 1.45X_4 + 1.10X_5 + 1.29X_6 + 1.35X_8 + 1.15X_9 + 1.18X_{10} + 1.51X_{11} + 1.26X_{13} + 1.15X_{14} + 1.56X_{15} + 1.50X_{17} + 0.99X_{18} + 0.94X_{19} + 0.88X_{20}$	99.14
KS	17	$Y = 32.69 + 0.89X_1 + 1.38X_2 + 1.42X_4 + 1.19X_5 + 1.05X_6 + 0.97X_7 + 1.05X_8 + 1.40X_9 + 1.31X_{11} + 1.17X_{12} + 1.40X_{13} + 1.54X_{15} + 1.06X_{16} + 0.99X_{17} + 1.12X_{18} + 0.97X_{19} + 0.81X_{20}$	99.07
KF		$Y = 32.74 + 0.89X_1 + 1.07X_2 + 1.12X_3 + 1.42X_4 + 1.19X_6 + 1.00X_7 + 0.98X_8 + 1.06X_9 + 1.04X_{10} + 1.51X_{11} + 0.93X_{12} + 1.54X_{14} + 1.65X_{15} + 1.64X_{17} + 0.79X_{18} + 0.93X_{19} + 0.92X_{20}$	99.16
Both		$Y = 26.84 + 0.90X_1 + 1.18X_2 + 0.84X_3 + 1.16X_4 + 0.97X_5 + 1.23X_6 + 1.35X_8 + 1.14X_9 + 1.15X_{10} + 1.51X_{11} + 1.27X_{13} + 1.17X_{14} + 1.56X_{15} + 1.48X_{17} + 0.99X_{18} + 0.96X_{19} + 0.86X_{20}$	99.20
KS	18	$Y = 26.18 + 0.91X_1 + 1.42X_2 + 1.38X_4 + 1.12X_5 + 1.04X_6 + 0.91X_7 + 1.03X_8 + 1.05X_9 + 1.04X_{10} + 0.95X_{11} + 1.08X_{12} + 1.33X_{13} + 1.52X_{15} + 1.06X_{16} + 0.99X_{17} + 1.16X_{18} + 0.96X_{19} + 0.80X_{20}$	99.13
KF		$Y = 32.35 + 0.90X_1 + 1.04X_2 + 1.15X_3 + 1.42X_4 + 1.23X_6 + 1.02X_7 + 0.97X_8 + 1.07X_9 + 1.02X_{10} + 1.48X_{11} + 0.90X_{12} + 1.43X_{14} + 1.30X_{15} + 0.95X_{16} + 1.24X_{17} + 0.73X_{18} + 0.92X_{19} + 0.93X_{20}$	92.22
Both		$Y = 26.48 + 0.89X_1 + 1.16X_2 + 0.86X_3 + 1.18X_4 + 1.00X_5 + 1.20X_6 + 1.33X_8 + 1.17X_9 + 1.14X_{10} + 1.49X_{11} + 1.27X_{13} + 1.06X_{14} + 1.14X_{15} + 0.98X_{16} + 1.10X_{17} + 0.95X_{18} + 0.95X_{19} + 0.86X_{20}$	99.25
KS	19	$Y = 29.43 + 0.92X_1 + 1.43X_2 + 1.38X_4 + 1.13X_5 + 1.00X_6 + 0.94X_7 + 1.00X_8 + 1.08X_9 + 1.00X_{10} + 0.92X_{11} + 1.02X_{12} + 1.03X_{13} + 0.90X_{14} + 1.12X_{15} + 0.98X_{16} + 0.99X_{17} + 1.14X_{18} + 0.96X_{19} + 0.82X_{20}$	99.18
KF		$Y = 30.85 + 0.91X_1 + 1.02X_2 + 1.19X_3 + 1.41X_4 + 1.25X_6 + 0.99X_7 + 0.97X_8 + 1.01X_9 + 1.02X_{10} + 1.38X_{11} + 0.66X_{12} + 0.90X_{13} + 1.06X_{14} + 1.17X_{15} + 0.96X_{16} + 1.20X_{17} + 0.75X_{18} + 0.87X_{19} + 0.97X_{20}$	99.27
Both		$Y = 23.24 + 0.89X_1 + 1.13X_2 + 0.86X_3 + 1.13X_4 + 0.89X_5 + 0.94X_6 + 0.94X_7 + 1.04X_8 + 1.04X_9 + 1.09X_{10} + 1.48X_{11} + 1.22X_{13} + 1.09X_{14} + 1.15X_{15} + 0.98X_{16} + 1.10X_{17} + 0.95X_{18} + 0.96X_{19} + 0.87X_{20}$	99.30
KS	20	$Y = 23.87 + 0.88X_1 + 1.17X_2 + 0.78X_3 + 1.10X_4 + 1.03X_5 + 0.90X_6 + 0.93X_7 + 1.01X_8 + 1.08X_9 + 0.98X_{10} + 0.90X_{11} + 1.05X_{12} + 0.99X_{13} + 0.94X_{14} + 1.14X_{15} + 0.99X_{16} + 0.95X_{17} + 1.16X_{18} + 0.99X_{19} + 0.79X_{20}$	99.23
KF		$Y = 27.29 + 0.93X_1 + 1.02X_2 + 1.05X_3 + 1.17X_4 + 0.76X_5 + 1.01X_6 + 0.89X_7 + 0.97X_8 + 0.98X_9 + 1.05X_{10} + 1.33X_{11} + 0.66X_{12} + 0.92X_{13} + 1.09X_{14} + 1.12X_{15} + 0.94X_{16} + 1.21X_{17} + 0.78X_{18} + 0.91X_{19} + 0.95X_{20}$	99.32
Both		$Y = 24.23 + 0.91X_1 + 1.12X_2 + 0.89X_3 + 1.12X_4 + 0.91X_5 + 0.94X_6 + 0.92X_7 + 1.06X_8 + 1.01X_9 + 1.01X_{10} + 1.14X_{11} + 0.83X_{12} + 0.95X_{13} + 1.02X_{14} + 1.12X_{15} + 0.95X_{16} + 1.12X_{17} + 0.94X_{18} + 0.95X_{19} + 0.87X_{20}$	99.35

X_i = test record yield during i^{th} fortnight ($i = 1, \dots, 20$) - kg
 Y = predicted lactation milk yield (PMY) - kg

In case of Karan Fries cattle, it was found that when a single test record was used for prediction of lactation yield, the 12th fortnight systematic sampled test record gave highest accuracy (68.01%) of fitting the regression model. When two test records were used for prediction, it was found that the test records during 3rd and 12th fortnight gave highest accuracy (83.59%) of fitting. Further, when three samples (test records) were chosen, the highest accuracy (92.41%) of fitting the multiple regression model was obtained for test records drawn during 3rd, 12th and 17th fortnight. When more number of test records were chosen for prediction, the accuracy of fitting the multiple regression models increased at slower rate. When all 20 fortnightly test records were considered, the highest accuracy (99.32%) of fitting prediction equations was found in Karan Fries breed (Table 39).

It is thus seen from Table 39 that two records taken randomly during 4th and 13th fortnight or three records taken during 4th, 13th and 17th fortnight for Karan Swiss and two records taken randomly during 3rd and 12th fortnight or three records taken during 3rd, 12th and 17th fortnight for Karan Fries would be adequate for prediction of first lactation yield.

4.7.2 BEST PREDICTION EQUATIONS FOR ESTIMATION OF LACTATION MILK YIELD ON THE BASIS OF FORTNIGHTLY STRATIFIED RANDOM SAMPLED TEST RECORDS

The forward selection stepwise regression analysis models were fitted to predict the lactation milk yield considering the various combinations of test records drawn under fortnightly stratified random sampling scheme. The prediction equations which required minimum number of test records and gave sufficiently high (above 90%) accuracy of fitting the multiple regression model was considered to be optimum. The prediction equations fitted alongwith their accuracy for Karan Swiss and Karan Fries breeds are presented in Table 40.

Table 40. Prediction equations and their accuracy for prediction of lactation milk yield under fortnightly stratified random sampling scheme

Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS	1	$Y = 1044.48 + 12.86T13$	68.12
KF		$Y = 1192.99 + 12.80T12$	68.47
Both		$Y = 999.23 + 13.51T12$	70.05
KS	2	$Y = 360.82 + 7.07T4 + 9.18T13$	85.55
KF		$Y = 395.26 + 6.37T3 + 9.82T12$	84.02
Both		$Y = 344.88 + 6.99T4 + 9.39T12$	84.74
KS	3	$Y = 303.72 + 6.93T4 + 6.61T13 + 3.90T18$	91.77
KF		$Y = 302.96 + 6.10T3 + 7.66T12 + 3.86T19$	91.65
Both		$Y = 261.93 + 6.77T4 + 5.52T12 + 5.40T17$	93.11
KS	4	$Y = 212.05 + 4.25T4 + 4.38T7 + 5.41T13 + 4.22T18$	94.18
KF		$Y = 230.28 + 4.37T3 + 3.94T8 + 5.65T12 + 4.24T18$	93.93
Both		$Y = 211.25 + 4.68T4 + 3.49T7 + 4.32T12 + 5.69T17$	94.50
KS	5	$Y = 210.54 + 4.37T4 + 4.16T7 + 3.35T13 + 3.24T15 + 3.20T18$	95.38
KF		$Y = 193.03 + 4.47T3 + 3.90T8 + 3.39T12 + 3.85T15 + 2.87T18$	95.88
Both		$Y = 183.45 + 4.49T4 + 3.82T7 + 4.47T12 + 4.02T17 + 1.90T19$	95.99
KS	6	$Y = 133.83 + 2.42T2 + 2.64T4 + 3.81T7 + 3.52T13 + 3.20T16 + 3.01T19$	96.37
KF		$Y = 180.00 + 4.42T3 + 4.05T8 + 3.52T12 + 3.67T15 + 1.60T18 + 1.47T19$	96.63
Both		$Y = 102.59 + 2.28T2 + 2.80T4 + 3.60T7 + 4.62T12 + 3.90T17 + 1.85T19$	96.78
KS	7	$Y = 108.43 + 2.38T2 + 2.53T4 + 2.67T8 + 2.55T11 + 2.57T13 + 3.12T15 + 3.09T18$	97.04
KF		$Y = 148.61 + 3.28T3 + 2.21T5 + 3.20T8 + 3.37T12 + 3.71T15 + 1.64T18 + 1.51T19$	97.24
Both		$Y = 92.64 + 2.48T2 + 2.72T4 + 3.49T7 + 3.06T12 + 2.82T14 + 2.74T17 + 1.79T19$	97.50
KS	8	$Y = 100.06 + 2.36T3 + 2.47T5 + 2.73T8 + 2.72T10 + 2.52T13 + 3.07T16 + 1.73T18 + 1.52T19$	97.65
KF		$Y = 88.51 + 1.16T1 + 2.57T3 + 2.12T5 + 3.27T8 + 3.43T12 + 3.67T15 + 1.61T18 + 1.45T19$	97.58
Both		$Y = 75.20 + 2.49T2 + 2.42T4 + 2.48T7 + 2.28T9 + 2.42T12 + 2.58T14 + 2.72T17 + 1.89T19$	97.96
KS	9	$Y = 87.76 + 2.37T2 + 2.29T4 + 2.20T7 + 1.84T9 + 1.91T10 + 2.30T13 + 3.01T15 + 1.80T18 + 1.54T20$	97.90
KF		$Y = 84.04 + 1.17T1 + 2.48T3 + 1.98T5 + 2.50T8 + 1.90T10 + 2.64T12 + 3.62T15 + 1.62T18 + 1.44T19$	97.90
Both		$Y = 74.26 + 2.46T2 + 2.44T4 + 2.48T7 + 2.26T9 + 2.23T12 + 1.65T14 + 1.85T15 + 2.09T17 + 1.85T19$	98.18
KS	10	$Y = 83.38 + 2.38T3 + 2.33T4 + 2.11T7 + 1.79T9 + 1.40T10 + 1.62T12 + 1.46T13 + 2.86T15 + 1.85T18 + 1.50T19$	98.10
KF		$Y = 74.03 + 1.20T1 + 2.46T3 + 1.99T5 + 2.56T8 + 1.91T10 + 2.43T12 + 2.52T15 + 1.64T16 + 1.29T18 + 1.43T19$	98.14
Both		$Y = 69.99 + 2.45T2 + 2.41T4 + 2.21T7 + 1.55T9 + 1.62T10 + 1.72T12 + 1.56T14 + 1.87T15 + 2.10T17 + 1.86T19$	98.35

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Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS		$Y = 82.81 + 2.38T2 + 2.34T4 + 2.12T7 + 1.65T9 + 1.49T10 + 1.67T12 + 1.35T13 + 2.19T15 + 1.39T17 + 1.28T18 + 1.45T19$	98.30
KP	11	$Y = 78.23 + 1.19T1 + 2.16T3 + 1.36T5 + 1.62T6 + 1.94T8 + 1.83T10 + 2.37T12 + 2.45T15 + 1.71T16 + 1.33T18 + 1.44T19$	98.30
Both		$Y = 71.49 + 2.31T2 + 2.04T4 + 1.36T6 + 1.58T7 + 1.38T9 + 1.51T10 + 1.71T12 + 1.54T14 + 1.90T15 + 2.10T17 + 1.89T19$	98.49
KS		$Y = 75.60 + 2.17T2 + 1.64T4 + 1.58T5 + 1.74T7 + 1.48T9 + 1.34T10 + 1.71T12 + 1.32T13 + 2.19T15 + 1.35T17 + 1.34T18 + 1.41T19$	98.47
KP	12	$Y = 75.28 + 1.24T1 + 2.18T3 + 1.34T5 + 1.59T6 + 1.94T8 + 1.65T10 + 1.74T12 + 1.43T13 + 1.98T15 + 1.58T16 + 1.29T18 + 1.44T19$	98.54
Both		$Y = 72.16 + 2.24T2 + 2.03T4 + 1.42T6 + 1.54T7 + 1.48T9 + 1.47T10 + 1.75T12 + 1.49T14 + 1.81T15 + 1.57T17 + 1.06T18 + 1.48T19$	98.64
KS		$Y = 61.64 + 0.91T1 + 1.49T2 + 1.56T4 + 1.58T5 + 1.70T7 + 1.45T9 + 1.43T10 + 1.67T12 + 1.43T13 + 2.15T15 + 1.28T18 + 1.42T19$	98.65
KP	13	$Y = 72.39 + 1.19T1 + 2.21T3 + 1.37T5 + 1.59T6 + 1.87T8 + 1.79T10 + 1.71T12 + 1.41T13 + 1.97T15 + 1.59T16 + 1.24T18 + 0.89T19 + 0.65T20$	98.66
Both		$Y = 54.51 + 0.85T1 + 1.63T2 + 1.95T4 + 1.44T6 + 1.52T7 + 1.45T9 + 1.50T10 + 1.80T12 + 1.48T14 + 1.81T15 + 1.52T17 + 1.06T18 + 1.45T19$	98.77
KS		$Y = 57.72 + 0.90T1 + 1.48T2 + 1.54T4 + 1.59T5 + 1.71T9 + 1.47T10 + 1.71T12 + 1.40T13 + 2.18T15 + 1.29T17 + 1.24T18 + 0.95T19 + 0.59T20$	98.75
KP	14	$Y = 58.25 + 0.34T1 + 0.91T2 + 1.76T3 + 1.22T5 + 1.52T6 + 1.91T8 + 1.85T10 + 1.65T12 + 1.49T13 + 2.01T15 + 1.53T16 + 1.19T18 + 0.94T19 + 0.63T20$	98.74
Both		$Y = 54.31 + 0.78T1 + 1.22T2 + 1.16T3 + 1.42T4 + 1.35T6 + 1.43T7 + 1.45T9 + 1.47T10 + 1.82T12 + 1.54T14 + 1.83T15 + 1.47T17 + 1.08T18 + 1.44T19$	98.87
KS		$Y = 52.40 + 0.84T1 + 1.08T2 + 1.13T3 + 1.10T4 + 1.46T5 + 1.60T7 + 1.46T9 + 1.48T10 + 1.66T12 + 1.44T13 + 2.21T15 + 1.29T17 + 1.25T18 + 0.92T19 + 0.60T20$	98.86
KP	15	$Y = 60.04 + 0.89T1 + 0.96T2 + 1.69T3 + 1.24T5 + 1.55T6 + 1.91T8 + 1.85T10 + 1.61T12 + 1.48T13 + 1.81T15 + 1.02T16 + 0.98T18 + 0.93T19 + 0.61T20$	98.81
Both		$Y = 52.23 + 0.76T1 + 1.19T2 + 1.20T3 + 1.41T4 + 1.34T6 + 1.41T7 + 1.46T9 + 1.55T10 + 1.82T12 + 1.54T14 + 1.85T15 + 1.43T17 + 1.03T18 + 0.92T19 + 0.63T20$	98.97

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Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS	16	$Y = 52.96 + 0.81T_1 + 1.12T_2 + 1.20T_3 + 1.09T_4 + 1.44T_5 + 1.62T_7 + 1.39T_9 + 1.45T_{10} + 1.52T_{12} + 0.99T_{13} + 1.21T_{14} + 1.71T_{15} + 1.21T_{17} + 1.20T_{18} + 0.97T_{19} + 0.64T_{20}$	98.96
		$Y = 54.84 + 0.68T_1 + 1.03T_2 + 1.56T_3 + 1.10T_5 + 1.23T_6 + 1.07T_7 + 1.49T_8 + 1.74T_{10} + 1.57T_{12} + 1.52T_{13} + 1.81T_{15} + 0.99T_{16} + 1.10T_{17} + 0.91T_{18} + 0.95T_{19} + 0.60T_{20}$	
		$Y = 49.63 + 0.79T_1 + 1.26T_2 + 1.26T_3 + 1.36T_4 + 1.35T_5 + 1.43T_7 + 1.42T_9 + 1.47T_{10} + 1.43T_{12} + 1.08T_{13} + 1.13T_{14} + 1.69T_{15} + 1.42T_{17} + 1.02T_{18} + 0.93T_{19} + 0.62T_{20}$	
KS	17	$Y = 47.15 + 0.78T_1 + 1.16T_2 + 1.19T_3 + 1.03T_4 + 1.40T_5 + 1.19T_7 + 1.08T_9 + 1.33T_{10} + 1.47T_{12} + 1.01T_{13} + 1.17T_{14} + 1.72T_{15} + 1.26T_{17} + 1.18T_{18} + 0.94T_{19} + 0.61T_{20}$	99.04
		$Y = 50.80 + 0.87T_1 + 1.06T_2 + 1.59T_3 + 1.03T_5 + 1.17T_6 + 1.03T_7 + 1.13T_8 + 1.01T_9 + 1.37T_{10} + 1.49T_{12} + 1.51T_{13} + 1.73T_{15} + 0.97T_{16} + 1.14T_{17} + 0.92T_{18} + 0.95T_{19} + 0.61T_{20}$	
		$Y = 46.89 + 0.78T_1 + 1.22T_2 + 1.19T_3 + 1.12T_4 + 1.21T_5 + 1.06T_7 + 1.05T_8 + 1.08T_9 + 1.34T_{10} + 1.39T_{12} + 1.10T_{13} + 1.11T_{14} + 1.70T_{15} + 1.43T_{17} + 1.04T_{18} + 0.96T_{19} + 0.59T_{20}$	
Both	18	$Y = 41.03 + 0.79T_1 + 1.15T_2 + 1.04T_4 + 1.15T_7 + 1.12T_8 + 0.91T_9 + 0.87T_{10} + 1.12T_{11} + 1.04T_{12} + 0.97T_{13} + 1.12T_{14} + 1.70T_{15} + 1.27T_{17} + 1.16T_{18} + 0.97T_{19} + 0.63T_{20}$	99.12
		$Y = 45.10 + 0.85T_1 + 1.00T_2 + 1.16T_3 + 1.07T_4 + 0.74T_5 + 1.07T_6 + 0.99T_7 + 1.09T_8 + 1.01T_9 + 1.37T_{10} + 1.49T_{12} + 1.45T_{13} + 1.71T_{15} + 0.95T_{16} + 1.22T_{17} + 0.91T_{18} + 0.93T_{19} + 0.62T_{20}$	
		$Y = 44.14 + 0.80T_1 + 1.13T_2 + 1.14T_3 + 1.01T_4 + 0.90T_5 + 0.94T_6 + 0.96T_7 + 1.05T_8 + 1.01T_9 + 1.31T_{10} + 1.41T_{12} + 1.09T_{13} + 1.10T_{14} + 1.72T_{15} + 1.41T_{17} + 1.05T_{18} + 0.95T_{19} + 0.60T_{20}$	
KS	19	$Y = 40.91 + 0.76T_1 + 1.18T_2 + 1.19T_3 + 1.04T_4 + 1.40T_5 + 1.18T_7 + 1.14T_8 + 0.85T_9 + 0.86T_{10} + 1.18T_{11} + 1.00T_{12} + 0.93T_{13} + 1.04T_{14} + 1.31T_{15} + 0.99T_{16} + 0.90T_{17} + 1.06T_{18} + 0.96T_{19} + 0.64T_{20}$	99.18
		$Y = 45.42 + 0.84T_1 + 1.06T_2 + 1.16T_3 + 1.02T_4 + 0.74T_5 + 1.05T_6 + 0.99T_7 + 1.09T_8 + 1.00T_9 + 1.38T_{10} + 1.34T_{12} + 1.11T_{13} + 0.97T_{14} + 1.39T_{15} + 0.88T_{16} + 1.14T_{17} + 0.92T_{18} + 0.94T_{19} + 0.59T_{20}$	
		$Y = 39.44 + 0.79T_1 + 1.11T_2 + 1.16T_3 + 1.00T_4 + 0.90T_5 + 0.95T_7 + 1.04T_8 + 0.92T_9 + 0.99T_{10} + 0.94T_{11} + 1.04T_{12} + 1.03T_{13} + 1.07T_{14} + 1.69T_{15} + 1.41T_{17} + 1.06T_{18} + 0.96T_{19} + 0.60T_{20}$	
Both	20	$Y = 40.41 + 0.76T_1 + 1.17T_2 + 1.15T_3 + 0.98T_4 + 1.09T_5 + 0.82T_6 + 0.92T_7 + 1.06T_8 + 0.94T_9 + 0.78T_{10} + 1.19T_{11} + 0.97T_{12} + 0.95T_{13} + 1.03T_{14} + 1.33T_{15} + 0.99T_{16} + 0.89T_{17} + 1.05T_{18} + 0.98T_{19} + 0.64T_{20}$	99.23
		$Y = 42.75 + 0.83T_1 + 1.04T_2 + 1.19T_3 + 1.01T_4 + 0.73T_5 + 1.08T_6 + 0.95T_7 + 1.05T_8 + 0.91T_9 + 1.16T_{10} + 0.77T_{11} + 1.03T_{12} + 1.04T_{13} + 0.95T_{14} + 1.36T_{15} + 0.85T_{16} + 1.15T_{17} + 0.94T_{18} + 0.94T_{19} + 0.60T_{20}$	
		$Y = 37.72 + 0.80T_1 + 1.09T_2 + 1.18T_3 + 1.00T_4 + 0.90T_5 + 0.97T_6 + 0.93T_7 + 1.07T_8 + 0.89T_9 + 1.00T_{10} + 0.95T_{11} + 1.01T_{12} + 1.80T_{13} + 0.99T_{14} + 1.35T_{15} + 0.90T_{16} + 1.04T_{17} + 0.99T_{18} + 0.96T_{19} + 0.62T_{20}$	

T_i = test record yield during ith fortnight (i = 1, ..., 20) - kg
 Y = predicted lactation milk yield (PMY) - kg

For Karan Swiss it was found that when a single test record was used for prediction of lactation milk yield, the 13th fortnight's stratified random sampled test record gave highest accuracy (68.12%) of fitting. When two test records were used for prediction of lactation yield, it was found that the 4th and 13th fortnight's test records gave highest accuracy (85.55%) of prediction. These two best combinations of test records gave higher (17.35%) accuracy than single test record sampled. Further when three samples were chosen, the highest accuracy (91.37%) of fitting the multiple regression model was obtained for test records drawn randomly during 4th, 13th and 18th fortnight. These three sample test records combination gave 6.22 per cent higher estimate of coefficient of determination than two test record combinations. When more number of test records were chosen for prediction, the accuracy of fitting the multiple regression models increased but at slower rate. When all 20 fortnightly test records were considered, the highest accuracy (99.23%) of fitting the prediction equations was observed in Karan Swiss breed.

In case of Karan Fries cattle, it was found that when a single test record was used for prediction of lactation yield, the 12th fortnight's systematic sampled test record gave highest accuracy (68.47%) of fitting the regression model. When two test records were used for prediction, it was found that the test records during 3rd and 12th fortnight gave highest accuracy (84.02%) of fitting. Further when three samples were chosen, the highest accuracy (91.65%) of fitting the multiple regression model was obtained for test records drawn randomly during 3rd, 12th and 19th fortnight. When more number of test records were chosen for prediction, the accuracy of fitting the multiple regression models increased but at slower rate. When all 20 fortnightly test records were considered, the highest accuracy (99.14%) of fitting prediction equations was found in Karan Fries breed (Table 40).

It is thus seen from Table 40 that two records drawn at random during 4th and 13th fortnight or three records taken during 4th, 13th and 18th fortnight for Karan Swiss breed and in the same way two records taken at random during 3rd and 12th fortnight or three records taken during 3rd, 12th and 19th fortnight for Karan Fries breed would be adequate for prediction of first lactation milk yield based on fortnightly stratified random sample test records.

4.7.3 BEST PREDICTION EQUATIONS FOR ESTIMATION OF LACTATION MILK YIELD ON THE BASIS OF FORTNIGHTLY PART LACTATION YIELDS

The forward selection stepwise regression analysis models were fitted to predict the lactation milk yield considering the various combinations of fortnightly part lactation yields. The prediction equation which required minimum number of fortnightly part yield records and gave sufficiently high (above 90%) accuracy of fitting the multiple regression model was considered to be optimum. The prediction equations fitted alongwith their accuracy for Karan Swiss and Karan Fries breeds are given in Table 41.

It was found that when only one fortnightly part yield record was used for prediction of lactation milk yield in Karan Swiss, the 13th fortnightly part yield gave highest accuracy (72.83%) of fitting. When two fortnightly part yield records were used for prediction of lactation yield, it was found that 4th and 13th fortnightly part yield gave highest accuracy (90.61%) of fitting. Further when three samples were chosen, the highest accuracy (95.71%) of fitting the regression model was obtained during 4th, 13th and 17th fortnightly part yields in Karan Swiss breed. When more number of lactation records were chosen for prediction, the accuracy of fitting the multiple regression models increased but at slower rate. When all 20 fortnightly part yields were considered, the highest accuracy (99.91%) of fitting the prediction equation was observed in Karan Swiss breed.

Table 41. Prediction equations and their accuracy for estimation of lactation milk yield under fortnightly part lactation milk yield

Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS KF Both	1	Y = 948.36 + 13.70P13 Y = 1047.87 + 13.85P12 Y = 876.50 + 14.46P12	72.83 74.30 75.06
KS KF Both	2	Y = 211.15 + 7.80P4 + 9.50P13 Y = 237.68 + 6.83P3 + 10.36P12 Y = 192.10 + 6.98P3 + 10.31P12	90.61 88.82 89.21
KS KF Both	3	Y = 171.99 + 7.81P4 + 5.61P13 + 4.72P17 Y = 149.92 + 6.83P3 + 6.38P12 + 5.19P17 Y = 137.17 + 6.84P3 + 6.28P12 + 5.33P17	95.92 93.71 96.19
KS KF Both	4	Y = 123.40 + 5.80P4 + 3.57P8 + 4.20P13 + 5.13P17 Y = 113.84 + 5.09P3 + 3.62P8 + 4.30P12 + 5.77P17 Y = 103.08 + 5.09P3 + 3.70P8 + 4.29P12 + 5.75P17	97.02 96.95 97.32
KS KF Both	5	Y = 106.57 + 5.56P4 + 3.97P8 + 4.36P13 + 1.82P19 Y = 91.23 + 4.81P3 + 4.19P8 + 4.47P12 + 3.94P17 + 1.85P19 Y = 80.35 + 4.85P3 + 4.18P8 + 4.45P12 + 3.99P17 + 1.84P19	98.19 98.51 98.53
KS KF Both	6	Y = 55.39 + 1.61P1 + 4.17P4 + 4.16P8 + 4.51P13 + 1.79P19 Y = 82.56 + 4.93P3 + 4.21P8 + 2.81P12 + 2.65P14 + 2.90P17 + 1.83P19 Y = 77.73 + 4.97P3 + 4.14P8 + 2.77P12 + 2.71P14 + 2.88P17 + 1.84P19	98.67 98.87 98.92
KS KF Both	7	Y = 31.15 + 1.81P1 + 3.85P4 + 2.68P8 + 2.82P10 + 3.40P13 + 3.26P17 + 1.86P19 Y = 24.02 + 1.34P1 + 3.86P3 + 4.38P8 + 2.87P12 + 2.69P14 + 2.76P17 + 1.79P19 Y = 77.09 + 3.60P3 + 2.32P5 + 3.19P8 + 2.76P12 + 2.61P14 + 2.95P17 + 1.86P19	99.08 99.12 99.14
KS KF Both	8	Y = 34.68 + 1.76P1 + 3.96P4 + 2.69P8 + 2.75P10 + 2.22P13 + 2.19P15 + 2.20P17 + 2.90P19 Y = 20.04 + 1.44P1 + 2.42P3 + 2.26P5 + 3.47P8 + 2.81P12 + 2.64P14 + 2.87P17 + 1.84P19 Y = 32.34 + 1.41P1 + 2.30P3 + 2.52P5 + 3.28P8 + 2.86P12 + 2.62P14 + 2.80P17 + 1.84P19	99.35 99.33 99.39
KS KF Both	9	Y = 32.23 + 1.83P1 + 2.91P4 + 1.87P6 + 1.92P8 + 2.61P10 + 2.30P13 + 2.10P15 + 2.21P17 + 1.94P19 Y = 21.58 + 1.43P1 + 2.40P3 + 2.27P5 + 2.43P8 + 1.88P10 + 2.03P12 + 2.61P14 + 2.90P17 + 1.83P19 Y = 24.69 + 1.46P1 + 2.30P3 + 2.37P5 + 2.30P8 + 2.05P10 + 1.97P12 + 2.56P14 + 2.84P17 + 1.86P19	99.49 99.49 99.55
KS KF Both	10	Y = 28.53 + 1.81P1 + 2.91P4 + 1.89P6 + 1.91P8 + 2.62P10 + 2.34P13 + 2.10P15 + 2.21P17 + 1.44P19 + 0.54P20 Y = 21.87 + 1.42P1 + 2.30P3 + 2.34P5 + 2.42P8 + 1.93P10 + 2.04P12 + 2.61P14 + 2.29P17 + 0.92P18 + 1.51P19 Y = 24.62 + 1.44P1 + 2.25P3 + 2.41P5 + 2.33P8 + 2.05P10 + 1.99P12 + 2.57P14 + 2.25P17 + 0.90P18 + 1.52P19	99.57 99.59 99.62

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Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS	11	$Y = 23.51 + 1.06P1 + 1.42P2 + 2.17P4 + 1.90P6 + 1.88P8 + 2.63P10 + 2.36P13 + 2.17P15 + 2.16P17 + 1.43P19 + 0.54P20$	99.64
KF		$Y = 26.93 + 1.36P1 + 2.36P3 + 2.34P5 + 2.34P8 + 2.05P10 + 2.05P12 + 2.56P14 + 2.27P17 + 0.94P18 + 0.98P19 + 0.58P20$	99.67
Both		$Y = 22.80 + 1.41P1 + 2.26P3 + 2.43P5 + 2.29P8 + 2.12P10 + 1.99P12 + 2.57P14 + 2.24P17 + 0.91P18 + 1.01P19 + 0.56P20$	99.69
KS	12	$Y = 20.63 + 1.00P1 + 1.48P2 + 2.16P4 + 1.94P6 + 1.92P8 + 1.51P10 + 1.49P11 + 1.96P13 + 2.15P15 + 2.17P17 + 1.41P19 + 0.75P20$	99.71
KF		$Y = 14.29 + 1.41P1 + 2.29P3 + 2.37P5 + 2.38P8 + 2.09P10 + 2.02P12 + 1.54P14 + 1.48P15 + 1.82P17 + 0.90P18 + 1.00P19 + 0.57P20$	99.74
Both		$Y = 28.78 + 1.41P1 + 2.24P3 + 2.45P5 + 2.32P8 + 2.14P10 + 1.96P12 + 1.50P14 + 1.53P15 + 1.78P17 + 0.90P18 + 1.03P19 + 0.56P20$	99.76
KS	13	$Y = 20.17 + 0.99P1 + 1.47P2 + 2.09P4 + 2.01P6 + 1.96P8 + 1.48P10 + 1.48P11 + 1.98P13 + 2.17P15 + 1.65P17 + 0.82P18 + 1.09P19 + 0.58P20$	99.77
KF		$Y = 17.26 + 1.43P1 + 2.26P3 + 1.92P5 + 1.43P7 + 1.42P8 + 2.07P10 + 2.00P12 + 1.59P14 + 1.46P15 + 1.81P17 + 0.92P18 + 0.99P19 + 0.57P20$	99.78
Both		$Y = 21.89 + 1.43P1 + 2.22P3 + 1.98P5 + 1.40P7 + 1.43P8 + 2.09P10 + 1.95P12 + 1.57P14 + 1.47P16 + 1.76P17 + 0.92P18 + 1.04P19 + 0.56P20$	99.80
KS	14	$Y = 20.31 + 0.98P1 + 1.52P2 + 2.07P4 + 1.99P6 + 1.96P8 + 1.47P8 + 1.50P11 + 1.52P13 + 0.99P14 + 1.64P15 + 1.65P17 + 0.81P18 + 1.10P19 + 0.58P20$	99.79
KF		$Y = 16.08 + 1.47P1 + 2.21P3 + 1.96P5 + 1.38P7 + 1.45P8 + 2.06P10 + 1.60P12 + 1.06P13 + 0.89P14 + 1.52P15 + 1.79P17 + 0.91P18 + 1.02P19 + 0.57P20$	99.81
Both		$Y = 18.70 + 1.07P1 + 0.89P2 + 1.66P3 + 1.97P5 + 1.42P7 + 1.40P8 + 2.12P10 + 1.93P12 + 1.62P14 + 1.47P15 + 1.76P17 + 0.91P18 + 1.03P19 + 0.56P20$	99.82
KS	15	$Y = 21.00 + 1.00P1 + 1.49P2 + 2.09P4 + 2.00P6 + 1.90P8 + 1.52P10 + 0.98P11 + 0.97P12 + 1.00P13 + 1.05P14 + 1.61P15 + 1.66P17 + 0.82P18 + 1.11P19 + 0.57P20$	99.82
KF		$Y = 13.40 + 1.47P1 + 2.24P3 + 1.92P5 + 1.37P7 + 1.50P8 + 1.56P10 + 1.00P11 + 1.04P12 + 1.17P13 + 0.82P14 + 1.50P15 + 1.78P17 + 0.92P18 + 1.02P19 + 0.58P20$	99.83
Both		$Y = 18.70 + 1.04P1 + 0.91P2 + 1.64P3 + 1.99P5 + 1.43P7 + 1.39P8 + 2.10P10 + 1.92P12 + 1.65P14 + 0.93P15 + 0.91P16 + 1.34P17 + 0.92P18 + 1.03P19 + 0.56P20$	99.84

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Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS	16	$Y = 21.40 + 1.07P_1 + 0.94P_2 + 1.07P_3 + 1.49P_4 + 1.98P_6 + 1.91P_8 + 1.55P_{10} + 0.97P_{11} + 0.99P_{12} + 0.93P_{13} + 1.08P_{14} + 1.61P_{15} + 1.68P_{17} + 0.85P_{18} + 1.10P_{19} + 0.56P_{20}$	99.85
KF		$Y = 11.82 + 1.11P_1 + 0.86P_2 + 1.68P_3 + 1.92P_5 + 1.40P_7 + 1.46P_8 + 1.64P_{10} + 0.99P_{11} + 1.03P_{12} + 1.11P_{13} + 0.91P_{14} + 1.48P_{15} + 1.81P_{17} + 0.92P_{18} + 1.02P_{19} + 0.58P_{20}$	99.85
Both		$Y = 17.02 + 1.03P_1 + 0.94P_2 + 1.65P_3 + 1.97P_5 + 1.43P_7 + 1.44P_8 + 1.60P_{10} + 0.94P_{11} + 1.48P_{12} + 1.66P_{14} + 0.91P_{15} + 0.93P_{16} + 1.34P_{17} + 0.92P_{18} + 1.03P_{19} + 0.58P_{20}$	99.86
KS	17	$Y = 21.60 + 1.05P_1 + 0.98P_2 + 1.02P_3 + 1.57P_4 + 1.94P_6 + 1.93P_8 + 1.53P_{10} + 0.99P_{11} + 0.99P_{12} + 0.94P_{13} + 1.09P_{14} + 1.06P_{15} + 0.89P_{16} + 1.31P_{17} + 0.85P_{18} + 1.09P_{19} + 0.56P_{20}$	99.86
KF		$Y = 9.77 + 1.12P_1 + 0.85P_2 + 1.69P_3 + 1.92P_5 + 1.42P_7 + 1.06P_8 + 0.89P_9 + 1.11P_{10} + 1.03P_{11} + 1.02P_{12} + 1.07P_{13} + 0.94P_{14} + 1.44P_{15} + 1.82P_{17} + 0.92P_{18} + 1.01P_{19} + 0.59P_{20}$	99.87
Both		$Y = 16.32 + 1.05P_1 + 0.93P_2 + 1.61P_3 + 2.03P_5 + 1.37P_7 + 1.48P_8 + 1.56P_{10} + 1.00P_{11} + 1.02P_{12} + 0.94P_{13} + 1.12P_{14} + 0.96P_{15} + 0.92P_{16} + 1.33P_{17} + 0.91P_{18} + 1.03P_{19} + 0.57P_{20}$	99.88
KS	18	$Y = 20.87 + 1.04P_1 + 0.99P_2 + 1.03P_3 + 1.84P_4 + 1.13P_5 + 1.33P_6 + 1.96P_8 + 1.49P_{10} + 1.00P_{11} + 0.99P_{12} + 0.98P_{13} + 1.05P_{14} + 1.02P_{15} + 0.95P_{16} + 1.30P_{17} + 0.87P_{18} + 1.07P_{19} + 0.57P_{20}$	99.89
KF		$Y = 10.01 + 1.10P_1 + 0.86P_2 + 1.69P_3 + 1.93P_5 + 1.44P_7 + 1.01P_8 + 0.96P_9 + 1.06P_{10} + 1.05P_{11} + 1.01P_{12} + 1.01P_{13} + 1.04P_{14} + 0.97P_{15} + 0.84P_{16} + 1.39P_{17} + 0.93P_{18} + 1.01P_{19} + 0.59P_{20}$	99.89
Both		$Y = 14.84 + 1.05P_1 + 0.94P_2 + 1.61P_3 + 2.02P_5 + 1.41P_7 + 1.02P_8 + 0.90P_9 + 1.08P_{10} + 1.03P_{11} + 1.00P_{12} + 0.93P_{13} + 1.12P_{14} + 0.92P_{15} + 0.96P_{16} + 1.29P_{17} + 0.92P_{18} + 1.03P_{19} + 0.58P_{20}$	99.80
KS	19	$Y = 22.18 + 1.02P_1 + 1.00P_2 + 1.04P_3 + 0.99P_4 + 1.13P_5 + 0.93P_6 + 0.90P_7 + 1.52P_8 + 1.46P_{10} + 0.99P_{12} + 0.92P_{13} + 1.14P_{14} + 0.96P_{15} + 0.98P_{16} + 1.27P_{17} + 0.87P_{18} + 1.08P_{19} + 0.57P_{20}$	99.90
KF		$Y = 9.00 + 1.14P_1 + 0.90P_2 + 1.08P_3 + 1.00P_4 + 1.49P_5 + 1.44P_7 + 1.00P_8 + 0.98P_9 + 1.05P_{10} + 1.00P_{11} + 1.02P_{12} + 1.01P_{13} + 1.01P_{14} + 0.90P_{16} + 1.36P_{17} + 0.92P_{18} + 1.02P_{19} + 0.58P_{20}$	99.90
Both		$Y = 14.67 + 1.06P_1 + 0.95P_2 + 1.08P_3 + 0.96P_4 + 1.57P_5 + 1.40P_7 + 1.01P_8 + 0.91P_9 + 1.07P_{10} + 1.07P_{11} + 1.01P_{12} + 0.94P_{13} + 1.10P_{14} + 0.92P_{15} + 1.00P_{16} + 1.28P_{17} + 0.91P_{18} + 1.04P_{19} + 0.58P_{20}$	99.91
KS	20	$Y = 21.43 + 1.01P_1 + 1.03P_2 + 1.04P_3 + 0.99P_4 + 1.08P_5 + 0.93P_6 + 0.95P_7 + 1.05P_8 + 0.85P_9 + 1.05P_{10} + 1.02P_{11} + 1.01P_{12} + 0.94P_{13} + 1.12P_{14} + 0.97P_{15} + 1.01P_{16} + 1.22P_{17} + 0.90P_{18} + 1.08P_{19} + 0.57P_{20}$	99.91
KF		$Y = 11.31 + 1.12P_1 + 0.93P_2 + 1.04P_3 + 1.05P_4 + 1.07P_5 + 0.85P_6 + 0.98P_7 + 1.00P_8 + 0.99P_9 + 1.03P_{10} + 1.06P_{11} + 1.01P_{12} + 0.95P_{13} + 1.02P_{14} + 0.97P_{15} + 0.96P_{16} + 1.33P_{17} + 0.91P_{18} + 1.05P_{19} + 0.57P_{20}$	99.92
Both		$Y = 15.33 + 1.07P_1 + 0.97P_2 + 1.05P_3 + 1.02P_4 + 1.07P_5 + 0.91P_6 + 0.94P_7 + 1.04P_8 + 0.92P_9 + 1.05P_{10} + 1.04P_{11} + 1.00P_{12} + 0.93P_{13} + 1.08P_{14} + 0.95P_{15} + 0.99P_{16} + 1.27P_{17} + 0.90P_{18} + 1.05P_{19} + 0.58P_{20}$	99.92

P_i = part yield during i^{th} fortnight ($i = 1, \dots, 20$) - kg
 Y = predicted lactation milk yield (PMY) - kg

In case of Karan Fries when a single fortnightly part yield record was used for prediction, the 12th fortnightly part yield provided highest accuracy (74.33%) of prediction. When two fortnightly part yields were used for prediction, it was found that the part yield records during 3rd and 12th fortnight gave highest accuracy (88.82%) of fitting. Further when three fortnightly part records were considered, the best equations involved 3rd, 12th and 17th fortnightly part yields which gave highest accuracy (95.71%) of estimation of lactation yield. When more number of part yields were considered as independent variables, there was increase in accuracy of prediction but at slower rate. When all 20 fortnightly part yields were considered, the highest accuracy (99.92%) of fitting the prediction equation was found in Karan Fries breed.

It is thus seen from Table 41 that two part records taken during 4th and 13th fortnight or three part records taken at randomly during 4th, 13th and 17th fortnight for Karan Swiss breed; and two part records taken at randomly during 3rd and 12th fortnight or three part records taken during 3rd, 12th and 17th fortnightly part yield for Karan Fries breed would be adequate for prediction of first lactation milk yield based on fortnightly part yields.

Discussion on optimum combination of fortnightly test records

When a single record was considered, it was found that 13th fortnightly test record under systematic sampling and 12th fortnightly test record under stratified sampling and 12th fortnightly part milk yield were found to give highest accuracy (R^2) of prediction (69.56, 70.50 and 75.06%, respectively). When two fortnightly test records and fortnightly part yields were taken, the best multiple regression equations were found to be those utilising 4th and 13th fortnightly record under systematic sampling, 4th and 12th fortnightly record under stratified random sampling and 3rd and 12th fortnightly part yield; the accuracy of prediction being 87.10, 84.74 and 89.21 per cent, respectively.

When three test records were considered, the best equations involved 4th, 13th and 17th fortnightly yields under systematic sampling, 4th, 12th and 17th fortnightly record under stratified and 3rd, 12th and 17th fortnightly part yields; their accuracies of prediction being 93.02, 93.11 and 96.11 per cent, respectively. When more number of test records or part records were considered as independent variables there was increase in accuracy of prediction but at slower rate.

Saigaonkar *et al.* (1981) found that the two records during 6th and 8th fortnight gave highest accuracy (76%) of prediction of 26 fortnights' milk yield in Sahiwal cattle. Nagarcenkar and Basavaih (1981) reported that a single part record during 11th fortnight was best predictor for lactation milk yield in Murrah buffaloes.

It may be concluded on the basis of present investigations that in order to estimate first lactation milk yield, two records taken randomly during 4th fortnight and 12th or 13th fortnight or three records taken during 4th, 12th or 13th and 17th fortnight would be adequate for prediction of first lactation milk yield in field conditions in crossbred cattle.

4.7.4 BEST PREDICTION EQUATIONS FOR ESTIMATION OF LACTATION MILK YIELD ON THE BASIS OF MONTHLY SYSTEMATIC SAMPLED TEST RECORDS

Forward selection stepwise regression models were fitted to predict the lactation milk yield considering the various combinations of test records drawn under monthly systematic sampling scheme. The prediction equation which required minimum number of test records and gave sufficiently (above 90%) accuracy of fitting the multiple regression model was considered to be optimum. The prediction equations fitted alongwith their accuracy for Karan Swiss and Karan Fries breeds are given in Table 42.

Table 42. Prediction equations and their accuracy for estimation of lactation milk yield under monthly systematic sampling scheme

Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS KF Both	1	Y = 1063.10 + 6.42X7 Y = 1335.99 + 6.14X7 Y = 1121.53 + 6.54X7	68.93 68.16 70.43
KS KF Both	2	Y = 327.14 + 3.48X2 + 4.49X7 Y = 367.58 + 3.62X2 + 4.68X7 Y = 310.04 + 3.62X2 + 4.78X7	86.54 86.86 88.07
KS KF Both	3	Y = 283.81 + 3.48X2 + 3.11X7 + 2.13X9 Y = 314.75 + 3.59X2 + 3.08X7 + 2.04X9 Y = 272.48 + 3.59X2 + 3.11X7 + 2.10X9	91.50 91.40 92.34
KS KF Both	4	Y = 186.21 + 2.72X2 + 2.17X5 + 1.97X7 + 2.37X9 Y = 241.77 + 2.73X2 + 2.12X5 + 1.92X7 + 2.26X9 Y = 197.97 + 2.75X2 + 2.16X5 + 1.92X7 + 2.32X9	94.05 94.22 94.78
KS KF Both	5	Y = 110.36 + 1.13X1 + 1.86X2 + 2.15X5 + 1.97X7 + 2.27X9 Y = 218.52 + 2.70X2 + 2.29X5 + 1.94X7 + 1.50X9 + 0.82X10 Y = 110.77 + 1.14X1 + 1.88X2 + 2.16X5 + 2.02X7 + 2.19X9	95.27 95.47 95.85
KS KF Both	6	Y = 101.12 + 1.11X1 + 1.81X2 + 2.26X5 + 2.04X7 + 1.63X9 + 0.70X10 Y = 114.61 + 1.07X1 + 1.91X2 + 2.31X5 + 2.08X7 + 1.39X9 + 0.77X10 Y = 97.07 + 1.09X1 + 1.87X2 + 2.29X5 + 2.06X7 + 1.52X9 + 0.73X10	96.03 96.50 96.67
KS KF Both	7	Y = 82.75 + 1.05X1 + 1.36X2 + 1.33X4 + 1.56X5 + 1.96X7 + 1.64X9 + 0.75X10 Y = 103.61 + 0.98X1 + 1.11X2 + 1.34X3 + 1.87X5 + 2.02X7 + 1.42X9 + 0.83X10 Y = 86.97 + 0.98X1 + 1.14X2 + 1.32X3 + 1.88X5 + 1.99X7 + 1.51X9 + 0.79X10	97.87 97.29 97.37
KS KF Both	8	Y = 84.17 + 1.00X1 + 1.44X2 + 1.32X4 + 1.51X5 + 1.27X7 + 1.32X8 + 1.02X9 + 0.76X10 Y = 94.28 + 0.97X1 + 1.11X2 + 1.38X3 + 1.85X5 + 1.48X7 + 1.03X8 + 0.98X9 + 0.84X10 Y = 82.94 + 0.95X1 + 1.20X2 + 1.29X3 + 1.86X5 + 1.41X7 + 1.12X8 + 1.01X9 + 0.79X10	97.49 97.65 97.75
KS KF Both	9	Y = 77.70 + 1.01X1 + 1.43X2 + 1.20X4 + 1.14X5 + 0.98X6 + 0.86X7 + 1.24X8 + 1.04X9 + 0.76X10 Y = 81.51 + 1.02X1 + 1.09X2 + 1.33X3 + 1.45X5 + 0.91X6 + 1.12X7 + 0.95X8 + 0.85X10 Y = 71.56 + 0.98X1 + 1.17X2 + 1.25X3 + 1.42X5 + 1.00X6 + 1.00X7 + 1.03X8 + 1.01X9 + 0.81X10	97.82 81.51 98.06
KS KF Both	10	Y = 72.01 + 0.94X1 + 1.10X2 + 0.83X3 + 0.92X4 + 1.04X5 + 0.98X6 + 0.87X7 + 1.16X8 + 1.06X9 + 0.77X10 Y = 76.34 + 1.01X1 + 0.98X2 + 1.06X3 + 0.75X4 + 1.15X5 + 0.86X6 + 1.08X7 + 0.95X8 + 0.99X9 + 0.86X10 Y = 65.66 + 0.98X1 + 1.04X2 + 0.95X3 + 0.85X4 + 1.10X5 + 0.91X6 + 0.98X7 + 1.05X8 + 1.03X9 + 0.82X10	98.10 98.13 98.30

X_i = test record yield during i^{th} month ($i = 1, \dots, 10$) - kg
 Y = predicted lactation milk yield (PMY) - kg

In case of Karan Swiss cattle, it was found that when only one test record was used for prediction of lactation yield, the 7th month systematic sampled test record gave highest accuracy (68.93%) of fitting. When two test records were used for prediction of lactation yield, it was found that the test record during 2nd and 7th month determined highest accuracy (85.33%). Further when three samples were taken, the highest accuracy (91.50%) of fitting the regression model was obtained for test records drawn during 2nd, 7th and 9th month. When more number of test records were considered as independent variables, there was increase in accuracy of prediction but at slower rate. When all 10 monthly test records were considered, the highest accuracy (98.10%) of fitting the prediction equations was obtained (Table 42).

In case of Karan Fries cattle, it was found that when one test record was taken as independent variable, the 7th month test record under systematic sampling scheme gave highest accuracy (68.13%) of prediction. When two test records were used for prediction, it was found that the test records during 2nd and 7th month gave highest accuracy (86.86%) of fitting. Further, when three samples were chosen, the highest accuracy (91.40%) of fitting the regression model was obtained for test records drawn during 2nd, 7th and 9th month. When more number of records were considered as independent variables, there was increase in accuracy of prediction but at slower rate. When all 10 monthly systematic test records were considered, the highest accuracy (98.13%) of fitting the prediction equations was found (Table 42).

It is thus seen from Table 42 that two records drawn randomly during 2nd and 7th month or three records drawn during 2nd, 7th and 9th month for Karan Swiss and Karan Fries breeds would be adequate for prediction of first lactation milk yield.

4.7.5 BEST PREDICTION EQUATIONS FOR ESTIMATION OF LACTATION MILK YIELD ON THE BASIS OF MONTHLY STRATIFIED RANDOM SAMPLED TEST RECORDS

The forward selection stepwise regression analysis models were fitted to predict the lactation milk yield considering the various combinations of test records drawn under stratified random sampling scheme. The prediction equations which required minimum number of test records and gave sufficiently high (above 90%) accuracy of fitting the multiple regression model was considered to be optimum. The prediction equation alongwith their accuracy for Karan Swiss and Karan Fries breeds are presented in Table 43

In case of Karan Fries, it was found that when a single test record was used to predict the lactation yield, the 7th month stratified random sampled test record gave highest accuracy (69.05%) of fitting. When two test records were taken as independent variables, it was found that the best equation involved 2nd and 7th month test record and gave highest accuracy (87.37%) of prediction of lactation milk yield. Further, when three test records were taken as independent variables, the highest accuracy (90.82%) of fitting the multiple regression model was obtained during 2nd, 7th and 8th month. When more number of test records were considered as independent variables, there was increase in accuracy of prediction but at slower rate. When all 10 monthly stratified random sampled test records were considered, the highest accuracy (97.79%) of fitting the prediction equations was observed (Table 43).

In the same way, in case of Karan Fries when a single test record was used for prediction of lactation yield, the 6th month stratified random sampled test record determined highest accuracy (67.72%) of fitting. When two test records were considered as independent variables, it was found that 2nd and 6th month test records gave highest accuracy (81.13%) of prediction. Further, when three samples were chosen for prediction, the highest

Table 43. Prediction equations and their accuracy for estimation of lactation milk yield under monthly stratified random sampling schemes

Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS	1	$Y = 1130.54 + 6.23T_1$	69.05
KF		$Y = 1186.11 + 6.31T_1$	67.72
Both		$Y = 1121.53 + 6.53T_1$	70.43
KS	2	$Y = 364.63 + 3.45T_2 + 4.76T_1$	87.37
KF		$Y = 468.29 + 3.17T_2 + 4.62T_1$	81.13
Both		$Y = 310.05 + 3.62T_2 + 4.78T_1$	88.07
KS	3	$Y = 336.94 + 3.40T_2 + 2.75T_1 + 2.32T_3$	90.82
KF		$Y = 331.47 + 3.05T_2 + 3.48T_1 + 2.19T_3$	90.85
Both		$Y = 272.48 + 3.59T_2 + 3.11T_1 + 2.10T_3$	92.34
KS	4	$Y = 238.18 + 2.76T_2 + 1.93T_1 + 1.79T_3 + 2.40T_4$	93.07
KF		$Y = 277.10 + 1.55T_2 + 2.18T_1 + 2.85T_3 + 2.32T_4$	93.14
Both		$Y = 197.96 + 2.75T_2 + 2.16T_1 + 1.92T_3 + 2.32T_4$	94.78
KS	5	$Y = 200.88 + 2.67T_2 + 2.22T_1 + 1.70T_3 + 1.85T_4 + 0.84T_{10}$	94.88
KF		$Y = 244.54 + 1.61T_2 + 2.20T_1 + 1.99T_3 + 1.71T_4 + 1.52T_9$	94.90
Both		$Y = 110.77 + 1.14T_1 + 1.88T_2 + 2.16T_3 + 2.02T_4 + 2.19T_9$	95.85
KS	6	$Y = 141.29 + 1.08T_1 + 1.84T_2 + 2.18T_3 + 1.71T_4 + 1.79T_8 + 0.81T_{10}$	95.88
KF		$Y = 229.32 + 1.63T_2 + 2.22T_1 + 2.05T_3 + 1.65T_4 + 1.05T_9 + 0.59T_{10}$	95.68
Both		$Y = 97.07 + 1.09T_1 + 1.87T_2 + 2.29T_3 + 2.06T_4 + 1.52T_9 + 0.73T_{10}$	96.66
KS	7	$Y = 109.26 + 0.96T_1 + 1.22T_2 + 1.32T_3 + 1.71T_4 + 1.63T_7 + 1.86T_8 + 0.81T_{10}$	96.65
KF		$Y = 190.78 + 1.51T_2 + 1.39T_1 + 1.41T_4 + 1.67T_6 + 1.66T_8 + 1.07T_9 + 0.64T_{10}$	96.45
Both		$Y = 86.97 + 0.98T_1 + 1.14T_2 + 1.32T_3 + 1.88T_4 + 1.99T_7 + 1.51T_9 + 0.79T_{10}$	97.75
KS	8	$Y = 110.09 + 0.91T_1 + 1.18T_2 + 1.36T_3 + 1.76T_4 + 1.52T_7 + 1.42T_8 + 0.79T_9 + 0.58T_{10}$	97.16
KF		$Y = 115.12 + 0.76T_1 + 1.13T_2 + 1.20T_3 + 1.42T_4 + 1.72T_6 + 1.69T_8 + 1.01T_9 + 0.60T_{10}$	96.94
Both		$Y = 82.94 + 0.95T_1 + 1.20T_2 + 1.29T_3 + 1.86T_4 + 1.41T_7 + 1.12T_8 + 1.01T_9 + 0.79T_{10}$	97.75
KS	9	$Y = 104.11 + 0.90T_1 + 1.17T_2 + 1.33T_3 + 1.30T_4 + 1.03T_6 + 1.07T_7 + 1.33T_8 + 0.83T_9 + 0.59T_{10}$	97.60
KF		$Y = 102.89 + 0.78T_1 + 1.20T_2 + 1.14T_3 + 1.35T_4 + 1.30T_6 + 1.02T_7 + 1.24T_8 + 0.95T_9 + 0.58T_{10}$	97.33
Both		$Y = 71.56 + 0.98T_1 + 1.17T_2 + 1.25T_3 + 1.42T_4 + 1.00T_6 + 1.00T_7 + 1.03T_8 + 1.01T_9 + 0.80T_{10}$	98.06
KS	10	$Y = 95.07 + 0.88T_1 + 1.09T_2 + 1.06T_3 + 0.70T_4 + 1.08T_5 + 0.96T_6 + 1.04T_7 + 1.34T_8 + 0.86T_9 + 0.59T_{10}$	97.79
KF		$Y = 91.47 + 0.78T_1 + 1.16T_2 + 1.10T_3 + 1.01T_4 + 0.77T_5 + 1.03T_6 + 0.99T_7 + 1.22T_8 + 0.97T_9 + 0.60T_{10}$	97.54
Both		$Y = 65.67 + 0.98T_1 + 1.04T_2 + 0.95T_3 + 0.85T_4 + 1.10T_5 + 0.92T_6 + 0.98T_7 + 1.05T_8 + 1.03T_9 + 0.82T_{10}$	98.31

T_i = test record yield during i^{th} month ($i = 1, \dots, 10$) - kg.
 Y = predicted lactation milk yield (PMY) - kg

accuracy (90.85%) of fitting the multiple regression model was obtained during 2nd, 6th and 9th month. When more number of test records were considered as independent variables, there was increase in accuracy of prediction but at slower rate. When all 10 monthly test records were considered, the highest accuracy (97.54%) of fitting prediction equations was found (Table 43).

It is thus seen from Table 43 that two records taken at random during 2nd and 7th month or three records taken at random during 2nd, 7th and 8th month for Karan Swiss, and two test records taken at random during 2nd and 6th month or three test records taken randomly during 2nd, 6th and 9th month for Karan Fries breed would be adequate for prediction of first lactation yield based on monthly stratified random sampled test records.

4.7.6 BEST PREDICTION EQUATIONS FOR ESTIMATION OF LACTATION MILK YIELD ON THE BASIS OF MONTHLY PART YIELDS

Linear and multiple linear regression equations were fitted to predict the lactation milk yield considering the various combinations of monthly part records. The prediction equation which required minimum number of monthly part records and gave sufficiently high (above 90%) accuracy of fitting the multiple regression model was considered to be optimum. The forward selection stepwise regression analysis models were fitted to get the best combinations of part yields. The prediction equations fitted alongwith their accuracy for Karan Swiss and Karan Fries breeds are presented in Table 44.

In case of Karan Swiss it was found that when only one part record was taken as independent variable, the 6th monthly part yield record gave highest accuracy (73.70%) of fitting. When two part records were considered as independent variables, it was found that part records during 2nd and 6th month gave the highest accuracy (87.33%). Further when three part records were chosen, the highest accuracy (96.11%) of fitting the multiple regression model was obtained for part records taken during 2nd, 6th and 8th

Table 44. Prediction equations and their accuracy for estimation of lactation milk yield under monthly part lactation yield

Breed	No. of test records	Best prediction regression equations	Accuracy (%)
KS	1	$Y = 797.96 + 7.19P_6$	73.70
KP		$Y = 754.78 + 7.01P_6$	75.47
Both		$Y = 825.42 + 7.33P_6$	76.55
KS	2	$Y = 202.77 + 3.55P_2 + 4.96P_6$	87.31
KP		$Y = 282.75 + 3.34P_2 + 5.10P_6$	87.77
Both		$Y = 211.95 + 3.50P_2 + 5.06P_6$	88.88
KS	3	$Y = 154.00 + 3.65P_2 + 2.20P_6 + 3.22P_8$	96.11
KP		$Y = 168.80 + 3.39P_2 + 3.74P_6 + 2.08P_9$	95.78
Both		$Y = 138.81 + 3.45P_2 + 3.63P_6 + 2.18P_9$	96.33
KS	4	$Y = 128.05 + 3.58P_2 + 2.49P_6 + 2.55P_8 + 0.77P_{10}$	97.56
KP		$Y = 143.94 + 3.53P_2 + 2.70P_6 + 1.82P_8 + 1.23P_9$	97.02
Both		$Y = 129.41 + 3.56P_2 + 2.60P_6 + 1.87P_8 + 1.27P_9$	97.56
KS	5	$Y = 96.81 + 2.67P_2 + 1.72P_4 + 1.76P_6 + 2.61P_8 + 0.84P_{10}$	98.33
KP		$Y = 123.28 + 2.53P_2 + 1.80P_4 + 1.79P_6 + 1.95P_8 + 1.37P_9$	97.96
Both		$Y = 108.30 + 2.57P_2 + 1.80P_4 + 1.76P_6 + 1.91P_8 + 1.41P_9$	98.35
KS	6	$Y = 92.55 + 2.55P_2 + 1.86P_4 + 1.80P_6 + 1.88P_8 + 0.97P_9 + 0.56P_{10}$	98.90
KP		$Y = 102.94 + 2.52P_2 + 1.89P_4 + 1.89P_6 + 1.85P_8 + 0.81P_9 + 0.67P_{10}$	98.83
Both		$Y = 92.03 + 2.54P_2 + 1.89P_4 + 1.84P_6 + 1.88P_8 + 0.89P_9 + 0.61P_{10}$	98.98
KS	7	$Y = 57.16 + 0.87P_1 + 1.67P_2 + 2.00P_4 + 1.88P_6 + 1.83P_8 + 0.94P_9 + 0.55P_{10}$	99.16
KP		$Y = 28.55 + 1.03P_1 + 1.55P_2 + 2.05P_4 + 1.96P_6 + 1.85P_8 + 0.77P_9 + 0.64P_{10}$	99.20
Both		$Y = 41.29 + 0.95P_1 + 1.61P_2 + 2.04P_4 + 1.92P_6 + 1.85P_8 + 0.85P_9 + 0.59P_{10}$	99.26
KS	8	$Y = 59.28 + 0.91P_1 + 1.67P_2 + 1.99P_4 + 1.34P_6 + 1.06P_7 + 1.25P_8 + 0.96P_9 + 0.54P_{10}$	99.35
KP		$Y = 26.29 + 1.07P_1 + 1.54P_2 + 2.06P_4 + 1.40P_6 + 1.05P_7 + 1.33P_8 + 0.79P_9 + 0.62P_{10}$	99.36
Both		$Y = 41.70 + 0.98P_1 + 1.60P_2 + 2.03P_4 + 1.37P_6 + 1.05P_7 + 1.29P_8 + 0.87P_9 + 0.59P_{10}$	97.42
KS	9	$Y = 46.27 + 0.96P_1 + 1.64P_2 + 1.47P_4 + 0.95P_5 + 0.92P_6 + 1.05P_7 + 1.27P_8 + 0.97P_9 + 0.55P_{10}$	99.46
KP		$Y = 21.53 + 1.07P_1 + 1.59P_2 + 1.40P_4 + 1.10P_5 + 0.94P_6 + 1.05P_7 + 1.34P_8 + 0.79P_9 + 0.63P_{10}$	99.51
Both		$Y = 32.33 + 1.01P_1 + 1.61P_2 + 1.44P_4 + 1.03P_5 + 0.93P_6 + 1.04P_7 + 1.30P_8 + 0.87P_9 + 0.59P_{10}$	99.54
KS	10	$Y = 43.11 + 1.06P_1 + 1.06P_2 + 0.98P_3 + 0.97P_4 + 0.95P_5 + 0.96P_6 + 1.02P_7 + 1.25P_8 + 0.97P_9 + 0.56P_{10}$	99.56
KP		$Y = 23.24 + 1.11P_1 + 1.11P_2 + 0.90P_3 + 0.85P_4 + 1.18P_5 + 0.92P_6 + 1.01P_7 + 1.35P_8 + 0.81P_9 + 0.63P_{10}$	99.58
Both		$Y = 31.60 + 1.08P_1 + 1.08P_2 + 0.95P_3 + 0.91P_4 + 1.07P_5 + 0.94P_6 + 1.01P_7 + 1.31P_8 + 0.88P_9 + 0.59P_{10}$	99.61

P_i = part lactation yield during i^{th} month ($i = 1, \dots, 10$) - kg
 Y = predicted lactation milk yield (PMY) - kg

month. When more number of part records were considered as independent variables, there was increase in accuracy of prediction but at slower rate. When all 10 monthly part yields were considered as independent variables, the highest accuracy (99.56%) of fitting the equations was obtained (Table 44).

In case of Karan Fries when a single part record was used for prediction, the 6th monthly part yield determined highest accuracy (75.47%) of prediction of lactation milk yield. When two monthly part records were considered as independent variables, it was found that the part records during 2nd and 6th month gave highest accuracy (87.77%) of fitting. Further when three monthly part yield records were considered as independent variables, the best equations involved 2nd, 6th and 9th monthly part yields which gave highest accuracy (95.78%) of estimation of lactation milk yield. When more number of part records were considered as independent variables, there was increase in accuracy for prediction of lactation milk yield but at slower rate. When all 10 monthly part yields were considered, the highest accuracy (99.58%) of fitting the equations was obtained (Table 44).

It is thus seen from Table 44 that two part records taken during 2nd and 6th month or three part records taken during 2nd, 6th and 8th month for Karan Swiss breed; and two part records taken during 2nd and 6th month or three part records taken during 2nd, 6th and 9th month for Karan Fries breed would be adequate for prediction of lactation milk yield.

Discussion on optimum combination of monthly records

In both breeds, it was found that when one record was taken as independent variable, the 7th month test record under systematic and stratified random sampling scheme and 6th month part milk yield were found to be best and gave accuracy of prediction of 70.43, 70.43 and 76.55 per cent, respectively. When two records were taken as independent variables, it was

found that the best equation used 2nd and 7th month under systematic and stratified random sampling schemes and 2nd and 6th month part milk yield, the accuracies of prediction being 88.07, 88.07 and 88.88 per cent, respectively. When three records were taken as independent variables, the best prediction equations utilised 2nd, 7th and 9th month test records under systematic and stratified random sampling schemes and 2nd, 6th and 9th month part milk yield; the accuracy (R^2) of prediction were 92.34, 92.34 and 96.33 per cent, respectively.

VanVleck and Henderson (1961c) reported that the best single month for estimating complete lactation yield were fourth, fifth and sixth months by regression method in Holstein Friesian cows. Gokhale (1974) studied the reliability of part lactations in estimating the total first lactation yield which revealed that amongst single monthly yields, 5th month's production showed highest accuracy (66.90%). He also found the best combination of two part records to be 4th and 6th monthly part yield which gave a fair degree of accuracy (73.57%) for prediction of the lactation milk yield in Murrah buffaloes. Abdel-Aziz et al. (1975) found that the best single months for predicting 12 months yield were seventh and eighth with coefficient of determinations of 0.36 and 0.38 respectively in Egyptian buffaloes. Tahir et al. (1983) found the best prediction regression equation to be the one which used fourth month part lactation yield which gave 72.42 per cent accuracy of fitting. Do et al. (1986) observed that total lactation yield was best predicted by simple regression on monthly yields in months five to six ($R^2 = 87\%$); when two records of monthly cumulative yields were taken during first and fourth month, there was high accuracy (91%) of fitting the multiple regression model in Holstein-Friesian cows. Butta and Pandey (1989) found that 90 days and 120 days yield gave generally higher accuracy of fitting the regression model. Roy and Katpatal (1989) used the regression method for predicting 300 days milk yield from monthly part records. Among the single monthly part yields used for predicting lactation yield, the highest accuracy (74%) was obtained for 4th month followed by 5th

month (72%). Sushil Kumar (1990) found the part yields of 120 days to 150 days to be adequate for predicting lactation yield in Sahiwal cattle.

The results reveal that two records drawn randomly during 2nd and 6th month or 7th month and three records drawn randomly during 2nd, 7th and 9th month would be adequate for estimation of first lactation milk yield in field conditions.

4.7.7 BEST PREDICTION EQUATIONS FOR ESTIMATION OF LACTATION MILK YIELD ON THE BASIS OF BIMONTHLY SYSTEMATIC SAMPLED TEST RECORDS

Forward selection stepwise regression models were fitted to predict the lactation milk yield considering the various combinations of test records drawn under bimonthly systematic sampling scheme. The prediction equation which required minimum number of test records and gave sufficiently (above 90%) accuracy of fitting the multiple regression model was considered to be optimum. The prediction equations fitted alongwith their accuracy for Karan Swiss and Karan Fries breeds are given in Table 45.

In case of Karan Swiss, it was found that when a single test record was used for prediction of lactation yield, the 4th bimonthly systematic sampled test record gave highest accuracy (66.21%) of fitting. When two test records were considered as independent variables, it was found that the test record during 1st and 4th bimonth determined highest accuracy (86.18%). Further, when three samples were chosen, the highest accuracy (90.40%) of fitting the regression model was obtained for test records drawn during 1st, 3rd and 4th bimonth. When four test records were considered as independent variables, there was increase in accuracy of prediction but at slower rate. When all five bimonthly test records were considered, the highest accuracy (94.61%) of fitting the prediction equations was obtained.

Table 45. Prediction equations and their accuracies for estimation of lactation milk yield under bimonthly systematic sampling scheme

Breed	No. of test records	Best prediction equations	Accuracy (%)
KS	1	$Y = 1195.54 + 3.03X_4$	66.21
KF		$Y = 1089.71 + 3.24X_3$	66.04
Both		$Y = 877.29 + 3.44X_3$	68.42
KS	2	$Y = 370.74 + 1.73X_1 + 2.40X_4$	86.81
KF		$Y = 910.50 + 2.75X_3 + 1.10X_5$	78.55
Both		$Y = 323.54 + 1.49X_1 + 2.58X_3$	80.18
KS	3	$Y = 226.63 + 1.42X_1 + 1.24X_3 + 1.76X_4$	90.40
KF		$Y = 347.25 + 1.30X_1 + 2.12X_3 + 1.01X_5$	88.47
Both		$Y = 225.41 + 1.45X_1 + 1.26X_3 + 1.75X_4$	91.11
KS	4	$Y = 210.53 + 1.35X_1 + 1.35X_3 + 1.26X_4 + 0.62X_5$	92.98
KF		$Y = 281.18 + 1.35X_1 + 1.40X_3 + 1.19X_4 + 0.60X_5$	92.53
Both		$Y = 207.15 + 1.38X_1 + 1.39X_3 + 1.24X_4 + 0.61X_5$	93.43
KS	5	$Y = 175.73 + 0.97X_1 + 0.85X_2 + 0.93X_3 + 1.20X_4 + 0.66X_5$	94.61
KF		$Y = 211.70 + 0.98X_1 + 0.89X_2 + 0.90X_3 + 1.20X_4 + 0.67X_5$	94.62
Both		$Y = 165.15 + 0.99X_1 + 0.89X_2 + 0.92X_3 + 1.21X_4 + 0.67X_5$	95.14

X_i = test record yield during i^{th} month ($i = 1, \dots, 5$) - kg
 Y = predicted lactation milk yield (PMY) - kg

In case of Karan Fries when only one test record was used to predict the lactation yield, the 3rd bimonthly systematic sampled test record gave highest accuracy (66.04%) of fitting the regression model. When two test records were considered as independent variables, it was found that the test records during 3rd and 5th bimonth determined highest accuracy (78.55%) of prediction. Further when three samples were chosen, the highest accuracy (88.47%) of fitting the regression model was obtained for test records drawn during 1st, 3rd and 5th bimonth. When four test records were used for prediction of the lactation yield, there was increase in accuracy but at slower rate. When all five bimonthly systematic test records were considered as independent variables, the highest accuracy (94.62%) of fitting the equations was obtained (Table 45).

It is thus seen from Table 45 that two test records taken at random during 1st and 4th bimonth or three test records taken randomly during 1st, 3rd and 4th bimonth for Karan Swiss breed and two test records taken during 3rd and 5th bimonth or three test records taken during 1st, 3rd and 5th bimonth for Karan Fries breed would be adequate for prediction of first lactation yield.

4.7.8 BEST PREDICTION EQUATIONS FOR ESTIMATION OF LACTATION MILK YIELD ON THE BASIS OF BIMONTHLY STRATIFIED RANDOM SAMPLED TEST RECORDS

Linear and multiple linear regression equations were fitted to predict the lactation milk yield considering the various combinations of test records drawn under stratified random sampling scheme. The prediction equation which required minimum number of test records and gave sufficiently high (above 90%) accuracy of fitting the multiple regression model was considered to be optimum. The forward selection stepwise regression analysis models were fitted to get the best combination of test records. The prediction equations along with their accuracy for Karan Swiss and Karan Fries breeds are presented in Table 46.

Table 46. Prediction equations and their accuracies for estimation of lactation milk yield under bimonthly stratified random sampling scheme

Breed	No. of test records	Best prediction equations	Accuracy (%)
KS	1	$Y = 1290.87 + 2.86T_4$	66.21
KF		$Y = 12057.41 + 3.04T_3$	67.97
Both		$Y = 1000.69 + 3.23T_3$	68.99
KS	2	$Y = 542.12 + 1.91T_2 + 2.06T_4$	85.29
KF		$Y = 1043.90 + 1.92T_2 + 1.58T_4$	78.55
Both		$Y = 883.65 + 1.97T_3 + 1.69T_4$	80.14
KS	3	$Y = 350.30 + 0.98T_1 + 1.24T_2 + 1.95T_4$	89.37
KF		$Y = 436.00 + 1.31T_1 + 1.28T_3 + 1.60T_4$	88.85
Both		$Y = 368.32 + 1.35T_1 + 1.28T_3 + 1.60T_4$	90.00
KS	4	$Y = 315.10 + 0.92T_1 + 1.33T_2 + 1.69T_4 + 0.44T_5$	91.47
KF		$Y = 403.08 + 1.30T_1 + 1.38T_3 + 1.25T_4 + 0.42T_5$	91.00
Both		$Y = 292.76 + 0.94T_1 + 0.91T_2 + 0.88T_3 + 1.60T_4$	92.01
KS	5	$Y = 254.42 + 0.89T_1 + 0.98T_2 + 0.90T_3 + 1.28T_4 + 0.47T_5$	93.57
KF		$Y = 292.65 + 0.81T_1 + 1.04T_2 + 0.95T_3 + 1.20T_4 + 0.50T_5$	93.80
Both		$Y = 250.52 + 0.87T_1 + 1.02T_2 + 0.93T_3 + 1.25T_4 + 0.48T_5$	94.35

T_i = test record yield during i^{th} month ($i = 1, \dots, 5$) - kg
 Y = predicted lactation milk yield (PMY) - kg

In case of Karan Swiss, it was found that when only one test record was taken as independent variable, the 4th bimonthly stratified random sampled test record gave maximum accuracy (66.21%) of fitting. When two test records were used to predict the lactation milk yield, it was found that test records during 2nd and 4th bimonth determined highest accuracy (85.29%) of fitting. Further when three samples were chosen, the highest accuracy (89.37%) of fitting the regression model was obtained for test records drawn during 1st, 2nd and 4th bimonth. When four test records were considered as independent variables, there was increase in accuracy for prediction but at slower rate. When all five bimonthly test records were considered, the highest accuracy (93.57%) of fitting the prediction equations was obtained.

In case of Karan Fries, when only one test record was used to predict the lactation yield, the 3rd bimonthly stratified random sampled test record gave highest accuracy (67.97%) of fitting the regression model. When two test records were considered as independent variables, it was found that the test records during 2nd and 4th bimonth gave highest accuracy (78.94%) of fitting the regression model. Further, when three samples were chosen, the highest accuracy (88.85%) of fitting the multiple regression models was obtained during 1st, 3rd and 4th bimonth. When four test records were used for prediction of the lactation yield, there was increase in accuracy but at slower rate. When all five bimonthly stratified random sampled test records were considered as independent variables, the highest accuracy (93.80%) of fitting the equations was obtained (Table 46).

It is thus seen from Table 46 that two test records taken at random during 2nd and 4th bimonth or three test records taken randomly during 1st, 2nd and 4th bimonth for Karan Swiss breed; and two test records taken randomly during 2nd and 4th bimonth or three test records taken randomly during 1st, 3rd and 4th bimonth

for Karan Fries breed would be adequate for prediction of first lactation yield.

4.7.9 BEST PREDICTION EQUATIONS FOR ESTIMATION OF LACTATION MILK YIELD ON THE BASIS OF BIMONTHLY PART LACTATION YIELDS

Linear and multiple linear regression equations were fitted to predict the lactation milk yield considering the various combinations of bimonthly part records drawn. The prediction equations fitted alongwith their accuracy for Karan Swiss and Karan Fries breeds are presented in Table 47.

In case of Karan Swiss cattle, it was found that when only one part record was used to predict the lactation yield, the 3rd bimonthly part record gave highest accuracy (75.89%) of fitting. When two part records were used as independent variables, it was found that the part records during 1st and 3rd bimonth gave highest accuracy (87.54%). Further when three part records were chosen, the highest accuracy (96.18%) of fitting the multiple regression model was obtained for part records taken during 1st, 3rd and 4th bimonth. When four part records were considered as independent variables, there was increase in accuracy of prediction but at slower rate. When all five bimonthly part yields were considered as independent variables, the highest accuracy (98.51%) of fitting the equation was obtained in Karan Swiss breed (Table 47).

In case of Karan Fries cattle, when a single part record was used for prediction, the 3rd bimonthly part yield determined highest accuracy (77.49%) of fitting. When two part records were considered for prediction, it was found that the part records during 1st and 3rd bimonth gave highest accuracy (87.46%) of fitting. Further when three part records were considered as independent variables, the best equations involved 1st, 3rd and 4th bimonthly part records which gave highest accuracy (96.04%) of estimation of lactation milk yield. When four part records were considered as independent variables, there was increase in

Table 47. Prediction equations and their accuracies for estimation of lactation milk yield under bimonthly part lactation yield

Breed	No. of test records	Best prediction equations	Accuracy (%)
KS	1	Y = 731.96 + 3.67P3	75.89
KF		Y = 911.33 + 3.55P3	77.49
Both		Y = 754.97 + 3.69P3	78.58
KS	2	Y = 166.10 + 1.69P1 + 2.59P3	87.54
KF		Y = 214.02 + 1.62P1 + 2.68P3	87.46
Both		Y = 157.72 + 1.68P1 + 2.65P3	88.84
KS	3	Y = 149.20 + 1.72P1 + 1.13P3 + 1.66P4	96.18
KF		Y = 100.22 + 1.78P1 + 1.14P3 + 1.72P4	96.04
Both		Y = 111.84 + 1.76P1 + 1.15P3 + 1.69P4	96.51
KS	4	Y = 125.65 + 1.67P1 + 1.30P3 + 1.31P4 + 0.40P5	97.72
KF		Y = 72.24 + 1.74P1 + 1.41P3 + 1.23P4 + 0.42P5	97.86
Both		Y = 87.58 + 1.72P1 + 1.36P3 + 1.28P4 + 0.41P5	98.00
KS	5	Y = 99.43 + 1.15P1 + 0.96P2 + 0.85P3 + 1.36P4 + 0.43P5	98.51
KF		Y = 69.47 + 1.21P1 + 0.93P2 + 0.89P3 + 1.35P4 + 0.46P5	98.66
Both		Y = 78.76 + 1.18P1 + 0.95P2 + 0.87P3 + 1.35P4 + 0.45P5	98.73

P_i = part lactation record yield during i^{th} month ($i = 1, \dots, 5$) - kg
 Y = predicted lactation milk yield (PMY) - kg

accuracy of prediction but at slower rate. When all five bimonthly part yields were considered, the highest accuracy (98.66%) of fitting the equations was obtained (Table 47).

It is thus seen from Table 47 that two part records taken during 1st and 3rd bimonth or three part records taken during 1st, 3rd and 4th bimonth for Karan Swiss and Karan Fries breeds would be adequate for prediction of lactation milk yield.

Discussion on optimum prediction equation under bimonthly sampling

In both the breeds, when a single record was considered, it was found that the 3rd bimonthly test record under systematic and stratified random sampling schemes and 3rd bimonthly part yield gave highest accuracy of prediction. The accuracy of prediction being 68.42, 68.99 and 78.58 per cent, respectively. When two bimonthly test records and bimonthly part yields were taken, the best multiple regression equations were found to be those utilising 1st and 3rd bimonthly test record under systematic sampling, 3rd and 4th bimonthly record under stratified random sampling and 1st and 3rd bimonthly part yield; the accuracy of prediction being 80.18, 80.14 and 88.84 per cent, respectively. When three test records were considered, the best equations involved 1st, 3rd and 4th bimonthly records under systematic and stratified random sampling schemes and 1st, 3rd and 4th bimonthly part yields; their accuracy of prediction being 91.11, 90.00 and 96.51 per cent, respectively. When more number of test records or part records were considered as independent variables, there was increase in accuracy of prediction but at slower rate.

Murthy *et al.* (1986) reported that a sire index including yields in days 61-120 and 121-180 explained 83.4 per cent of the variation in lactation yield and the same were recommended for selection purposes in Surti buffaloes. They further reported that the correlation coefficient of first bimonthly, second bimonthly and third bimonthly part yields with 300 or less

lactation yields were 0.84 ± 0.03 , 0.88 ± 0.02 and 0.85 ± 0.03 , respectively (all the correlation estimates were highly significant), thereby indicating their usefulness in selection programme aiming to improve 300 days yield. The prediction equation constructed and thus recommended was of the form $Y = 114.88 + 2.29 X_3 + 1.86 X_4$, where Y is 300-days lactation yield, X_3 and X_4 are third and fourth monthly yields, respectively. Gokhale (1974) reported that the R^2 value of 70.64 per cent was obtained in predicting lactation yield of Murrah buffaloes using 60 to 150 days part yield.

Since 80 to 90 per cent accuracy of prediction is considered to be adequate, the results reveal that two records drawn randomly during 1st and 3rd bimonth and three records drawn randomly during 1st, 3rd and 4th bimonth would be adequate for estimation of first lactation milk yield in field conditions.

The following conclusions may be drawn from the above presentation:

(a) Single test record used for prediction of lactation yield

1. Under fortnightly test recording, it was found that the 13th fortnightly test record under systematic sampling and 12th fortnightly test record under stratified random sampling and 12th fortnightly part yield gave highest accuracy of prediction; the accuracy of prediction being 69.56, 70.50 and 75.06 per cent, respectively.

2. Under monthly test recording, it was observed that the 7th month test record under systematic and stratified random sampling schemes and 6th month part milk yield were found to be best and gave highest accuracy of prediction of 70.43, 70.43 and 76.55 per cent, respectively.

3. Under bimonthly test recording, it was observed that the 3rd bimonthly test record under systematic and stratified random

sampling schemes and 3rd bimonthly part yield were found to be best and gave highest accuracy of prediction of 68.42, 68.99 and 78.58 per cent, respectively.

From the above sampling schemes, it may be concluded that when one test record is to be used for prediction of lactation yield, the test record drawn during 6th to 7th month of lactation will give highest accuracy of prediction. If the single test record is drawn during earlier part of lactation the accuracy of prediction will be lower.

(b) Two test records used for prediction of lactation yield

1. Under fortnightly test recording, it was found that the 4th and 13th fortnightly records under systematic sampling, 4th and 12th fortnightly records under stratified random sampling and 3rd and 12th fortnightly part yields gave highest accuracy of prediction (being 87.10, 84.74 and 89.21 per cent, respectively).

2. Under monthly test recording, it was observed that the 2nd and 7th month under systematic and stratified random sampling schemes and 2nd and 6th month part milk yield to be best and gave highest accuracy of prediction of 88.07, 88.07 and 88.88 per cent, respectively.

3. Under bimonthly test recording, it was observed that the 1st and 3rd bimonthly test records under systematic and 3rd and 4th bimonthly records under stratified random sampling and 1st and 3rd bimonthly part yields gave highest accuracy of prediction of 80.18, 80.14 and 88.84 per cent, respectively.

From the above sampling schemes, the results reveal that two test records drawn randomly during 2nd and 6th month or 7th month would be adequate for estimation of first lactation milk yield in field conditions.

(c) Three test records used for prediction of lactation yield

1. Under fortnightly recording, it was found that 4th, 13th and 17th fortnightly test yields under systematic, 4th, 13th and 17th fortnightly records under stratified and 3rd, 12th and 17th fortnightly part yields determined highest accuracy of prediction of 93.02, 93.11 and 96.11 per cent, respectively.

2. Under monthly test recording, it was observed that 2nd, 7th and 9th month test records under systematic and stratified random sampling schemes and 2nd, 6th and 9th month part milk yields gave highest accuracy of prediction of 92.34, 92.34 and 96.33 per cent, respectively.

3. Under bimonthly test recording, it was observed that the 1st, 3rd and 4th bimonthly test records under systematic sampling, stratified random sampling scheme and bimonthly part milk yields were the best predictors which gave highest accuracy of prediction of 91.11, 90.00 and 96.50 per cent, respectively.

The above results on sampling schemes reveal that three test records drawn randomly during 2nd, 6th or 7th and 9th month would be adequate for estimation of first lactation milk yield under field conditions.

4.8 ERRORS IN PREDICTION OF LACTATION MILK YIELD UNDER VARIOUS SAMPLING SCHEMES

The five measures of errors in prediction of lactation milk yield under two sampling schemes and three testing intervals were used. These were (i) average error, (ii) per cent average error, (iii) average absolute error, (iv) per cent average absolute error, and (vi) variance of error. These are presented in Tables 48 and 49 for Karan Swiss and Karan Fries breeds, respectively.

Table 48. Errors of estimation of first lactation milk yield under various sampling schemes in Karan Swiss breed

Name of sampling scheme	Average error		Average absolute error		Variance of error (kg ²)	Relative efficiency (%)
	(kg)	(%)	(kg)	(%)		
A. Systematic sampling scheme						
I. Fortnightly interval	-1.648	-0.065	43.367	1.726	3241.56	100.00
II. Monthly interval	1.429	0.056	68.487	2.726	7921.61	40.92
III. Bimonthly interval	5.815	0.231	110.059	4.382	20704.90	15.65
B. Stratified sampling scheme						
I. Fortnightly interval	1.453	0.057	44.409	1.768	3333.82	100.00
II. Monthly interval	6.265	0.249	73.810	2.938	9040.47	36.87
III. Bimonthly interval	3.856	0.153	126.168	5.023	27449.00	12.14

Table 49. Errors of estimation of first lactation milk yield under various sampling schemes in Karan Fries breed

Name of sampling scheme	Average error		Average absolute error		Variance of error (kg ²)	Relative efficiency (%)
	(kg)	(%)	(kg)	(%)		
<u>A. Systematic sampling scheme</u>						
I. Fortnightly interval	1.416	-0.046	46.863	1.551	3612.87	100.00
II. Monthly interval	3.368	0.112	77.602	2.569	9491.87	38.06
III. Bimonthly interval	-5.993	-0.198	126.180	4.177	26003.30	13.89
<u>B. Stratified sampling scheme</u>						
I. Fortnightly interval	2.053	0.068	52.359	1.733	4538.99	100.00
II. Monthly interval	7.438	0.246	84.993	2.813	11710.10	38.76
III. Bimonthly interval	14.642	0.484	141.103	4.671	32614.20	13.91

4.8.1 ERRORS IN PREDICTION OF LACTATION MILK YIELD UNDER FORTNIGHTLY INTERVAL OF MILK RECORDING

The measures of average error, per cent average error, average absolute error, and per cent absolute error in predicted lactation milk yield (PMY) under fortnightly systematic sampling scheme were found to be -1.648 kg, -0.065 per cent, 43.367 kg and 17.26 per cent for Karan Swiss, respectively and 1.416 kg, -0.046 per cent, 46.863 kg and 1.551 per cent for Karan Fries breed, respectively. The variance of error in PMY was 3241.56 kg² for Karan Swiss and 3612.87 kg² for Karan Fries breeds. Further the corresponding measures of error in PMY under stratified random sampling scheme were found to be 1.453 kg, 0.057 per cent, 44.409 kg and 1.768 per cent for Karan Swiss and 2.053 kg, 0.068 per cent, 52.359 kg and 1.733 per cent for Karan Fries breeds, the variance of error in PMY was 3333.82 kg² for Karan Swiss and 4538.99 kg² for Karan Fries breeds. It was seen that the fortnightly systematic sampling scheme slightly underestimated lactation milk yield, while fortnightly stratified random sampling scheme slightly overestimated lactation milk yield.

Davey and Alexander (1955) reported the average error as 2.5 kg of actual yield from test day yields taken at fortnightly intervals in Jersey cows.

Amble *et al.* (1959) and Amble and Rajagopalan (1960) estimated the lactation milk yield from test day yield recorded at different intervals by simple random sampling and systematic sampling in cattle and buffaloes in India. Recording every two weeks provided an estimate of lactation yield of a single animal with a standard error of about two per cent. They reported that systematic sampling was better than simple random sampling method for estimation of lactation yield from test records. On the basis of average error of estimates and their standard error, they suggested fortnightly recording to get reliable estimates of lactation yield of an individual animal. Youssef *et al.* (1961)

obtained the errors due to estimation as 1.56 per cent for recording at two weeks interval in Egyptian buffaloes.

Agarwala (1962) found that irrespective of level of production the value of correlation increased as the interval between the recordings decreased. Recording of milk production at interval of 10 days for predicting the lactation yields was found to be most reliable.

Kooner and Pal (1971) studied milk recording of 157 lactations of 66 Murrah buffaloes twice monthly and found it to be most accurate.

Rao (1977) reported that the average error in the estimation of lactation milk yield from test day yields recorded at two weekly intervals ranged from -1.52 per cent to 0.63 per cent in Sahiwal and its crosses and the percentage of average absolute error ranged from 2.01 to 3.63 per cent.

Kaura *et al.* (1983) found the estimate of phenotypic correlation between actual lactation milk yield and fortnightly predicted milk yield as 0.99. Fortnightly AM and PM milk recording gave more accuracy than monthly and bimonthly sampling.

Agrawal *et al.* (1987) recorded daily milk yield in 77 Haryana cattle and 115 Murrah buffaloes at intervals of 7, 14, 28 or 56 days. There were no significant differences in the accuracy of estimated milk yield on the basis of test samples at interval of 7, 14 or 28 days but significantly higher estimates were obtained for cows sampled at 56 days.

Crosse *et al.* (1988) reported that the error increased as the interval between recordings increased. They found that the most accurate method for estimating total lactation yield was based on one day's recording per week.

Dass (1991) observed that the accuracy under systematic and stratified random sampling was better with shorter testing intervals. Further, under fortnightly sampling, per cent average error was lower under stratified random sampling scheme. Variability in actual first lactation yield on drawing samples at fortnightly interval could be explained to the extent of 98 per cent under systematic and stratified random sampling schemes.

It was seen from above results that the accuracy of prediction was generally better when the interval of recording is smaller under both the sampling schemes.

4.8.2 ERRORS IN PREDICTION OF LACTATION MILK YIELD UNDER MONTHLY INTERVAL OF MILK RECORDING

The measures of average error, per cent average error, average absolute error and per cent average absolute error in predicted lactation milk yield (PMY) under monthly systematic sampling scheme were found to be 1.429 kg, 0.056 per cent, 68.487 kg and 2.728 per cent for Karan Swiss and 3.368 kg, 0.112 per cent, 77.602 kg, 2.569 per cent for Karan Fries breeds respectively. The variance of error in PMY was 7921.61 kg² for Karan Swiss and 9491.87 kg² for Karan Fries breed. Further, the corresponding measures in PMY under stratified random sampling scheme were found to be 6.265 kg, 0.249 per cent, 73.810 kg and 2.938 per cent for Karan Swiss and 2.053 kg, 0.068 per cent, 52.359 kg and 1.733 per cent for Karan Fries breeds. The variance of error in PMY was 9040.47 kg² for Karan Swiss and 11,710.10 kg² for Karan Fries breeds. It was seen that the average error, per cent average error, average absolute error, per cent average absolute error and variance of errors under monthly intervals were higher than those obtained under fortnightly intervals. The comparison of error variances for same test interval under two sampling schemes indicated that the systematic sampling scheme was more efficient as compared to stratified random sampling scheme.

Ashton (1956) reviewed the findings of various workers comparing different milk recording systems and reported that monthly recording could be used for obtaining a fairly reliable estimate of individual cows' lactation yield.

Amble and Rajagopalan (1960) obtained an standard error of 4 to 5 per cent in village herds of cows and buffaloes under monthly recording scheme. Jasiorowski *et al.* (1966) found the absolute mean error of estimation to be 87.6 litres.

Poly and Poutous (1966) proposed that in order to reduce the cost of monthly recording, each animal should be recorded every month at a single milking alternating between morning and evening; the daily milk yield being estimated by doubling the recorded yield. The accuracy of this type of recording was estimated by ratio method. This prediction by ratio method did not exceed more than one per cent. They suggested that alternate monthly milk recording system was suitable for progeny testing programme. Cunningham and Vial (1968) concluded that the conventional centering date method of calculating yields was more accurate than a method based on tests in the first four months of the lactation. The monthly testing was more accurate than bimonthly testing.

Everett *et al.* (1968) reported that the Dairy Herd Improvement method of testing in USA overestimated actual production by an average of 57.3 kg milk under monthly testing scheme.

McDaniel (1969) reviewed sixty research reports dealing with the estimation of lactation yields in *Bos taurus* cattle from samples taken at various intervals. The variation in errors in milk yield (Sd = 2.7%) from monthly testing for a 24 h period appeared to be lower than those for fat per cent (Sd = 3.5%).

Ivanov *et al.* (1969) reported that the estimated lactation yield under monthly recording interval was 150 kg less in

purebred and 154 kg less in crossbred cattle as compared to actual milk yields in Denmark.

Rai (1971) used 30 days sampling interval and three computing methods, viz. (1) no adjustment, (2) first test adjustment, and (3) first and last test adjustment of records. The average errors of estimates based on monthly samples by three methods were 0.63, -0.02 and -0.13 per cent, respectively in Jersey and Friesian breeds of cattle.

Vachal and Berea (1971) revealed that the error of estimation of individual lactation milk yield from monthly recording to be less than one per cent of actual yield in Holstein Friesian cows.

Kadiiski (1973) found average error per cent for 10 and 30 day recording intervals as 0.4 and 1.4 per cent in Bulgarian Simmental cows and as -7.5 and -10.0 per cent in Bulgarian Brown cows.

Lindstorm (1976) predicted lactation yield under monthly testing interval recording scheme in dairy cattle in Kenya. He found average error to be 1.34 to 1.52 per cent of actual milk yield.

Rao (1977) reported that the average error in the prediction of lactation milk yield in four weekly intervals ranged from -1.66 to 1.00 per cent and average absolute error ranged from 2.82 to 4.55 per cent in Sahiwal and its crosses with Brown Swiss. The average error ranged from 0.95 to 67.8 kg in weekly to 12 weekly sampling intervals. Average absolute error showed a definite increasing trend as the interval of testing increased from one week (3.78 kg) to 12 week interval (8.07 kg). Basavaiah and Nagarcenkar (1978) reported that in order to have economy of milk recording for estimation of milk production of daughters of buffalo-bulls for their ranking, monthly periodical testing was considered most suitable in buffaloes.

Higgins (1979) obtained the range of error in estimating the lactation milk yield from monthly testing as -7.7 to 6.0 per cent of actual lactation yield.

Kaura *et al.* (1983) recommended the monthly recording AM and PM milking under field conditions which was so accurate as fortnightly recording. They found the mean differences to be +60.20 to -39.60 kg between predicted and actual lactation yield. The error variances increased with increasing sampling interval.

Lee (1985) found that the range of average error per cent varied from 0.04 to 5.65 per cent.

Kulkarni *et al.* (1985) found that the deviation of estimated yield from actual yield ranged from -88.5 to 132.6 kg (-7.83 to 11.9%) for buffaloes yielding less than average and from -140.9 to 166.75 kg (-7.95 to 11.9%) for those yielding more than average. Deviations of estimated yields from actual yields were -55.9 to 112.1 kg (-7.43 to 11.99%) for buffaloes with lactations less than 251 days and from -140.9 to 166.8 kg (-7.95 to 11.90%) for those with longer lactations. They considered recording test day yields at 28 + 7 days interval to be satisfactory procedure for milk recording buffaloes in field conditions.

Anderson *et al.* (1986) suggested 30 day sampling interval to give most accurate estimates of lactation yield.

Agrawal (1987) concluded that interval of 28 days would be the most appropriate and that a complete day milk yield could be based on evening milking plus that from the morning milking the following day.

Khanna and Balaine (1988) studied the reliability of regular and irregular interval recording with variable centering date in estimating milk yield of crossbred cattle. They found that centering dates later than 30 days underestimated yield when sampling was carried out once or twice per month.

Anderson *et al.* (1989) suggested that convenient and conventional 30 day equal interval sampling procedure should give acceptable estimates of total lactation milk yield in practice. Sampling emphasis on the post peak period was important in determining the magnitude of biases in non-linear procedure.

Gujar (1989) investigated the efficiency of various milk recording systems for estimating lactation yield in Kankrej cattle and concluded that recording once per month on a fixed date would be satisfactory under practical conditions and that the actual lactation duration of the individual cow should be used as the measure of length of lactation.

Dass (1991) reported that the estimates of error, absolute error and standard deviation of error under monthly systematic and stratified random sampling schemes in estimating 305 days or less milk yield using ratio method were 26.63, 74.15, 89.64, respectively. The systematic sampling was found to be better in monthly test day interval than stratified random sampling scheme.

In case of both breeds in the present investigation, it was seen from above results that the monthly periodical recording gave higher measures of error variances in prediction of lactation milk yield as compared to fortnightly recording. It was also found that the monthly systematic sampling scheme was more efficient as compared to stratified sampling scheme.

4.8.3 ERRORS IN PREDICTION OF LACTATION MILK YIELD UNDER BIMONTHLY INTERVALS OF RECORDING

The measures of average error, per cent average error, average absolute error, per cent absolute error in predicted milk yield (PMY) under bimonthly systematic sampling scheme were found to be 5.815 kg, 0.231 per cent, 110.059 kg and 4.382 per cent for Karan Swiss and -5.993 kg, -0.198 per cent, 126.180 kg and 4.177 per cent for Karan Fries breeds, respectively. The variance of error was 20704.90 kg² for Karan Swiss and 26003.30 kg² for Karan...

Fries breeds. Further the corresponding measures of error in PMY under stratified random sampling scheme were found to be 3.856 kg, 0.153 per cent, 126.168 kg and 5.023 per cent for Karan Swiss and 14.642 kg, 0.484 per cent, 141.103 kg and 4.671 per cent for Karan Fries breed. It was seen that all five measures under bimonthly periodical recording were higher than fortnightly as well as monthly intervals' recording schemes in both breeds. The bimonthly systematic sampling overestimated the lactation milk yield in Karan Swiss breed, but underestimated in Karan Fries breed. The comparison of error variances for the same test interval indicated that systematic sampling scheme was more efficient than stratified random sampling scheme.

Erb *et al.* (1952) found that the daily variation among 62 lactation simulated records from daily yields of nine cows was such that bimonthly sampling would give an error of 3.4 per cent, the comparison of monthly and bimonthly estimates of milk and fat production of 306 cows indicated that differences between monthly and bimonthly estimates of milk yield to be around 7.2 per cent.

Amble and Rajagopalan (1960) analysed data of village herds of cows and buffaloes. Recording bimonthly provided standard error of about 10 per cent.

Lamb and Young (1968) found that lactation totals for milk and fat estimated from bimonthly tests by several different computational procedures generally had small positive biases (upto 2%). Cunningham and Vial (1968) found that bimonthly testing was little less accurate than monthly testing. Everett *et al.* (1968) reported that correcting test day production for the stage of lactation in first and last records under bimonthly and trimonthly milk recording schemes gave more accurate estimate of actual production and reduced the variance of deviations of DHIA estimates from actual yield.

McDanial (1969) reviewing the different reports on cattle, observed that errors in milk yields computed from bimonthly

samples were about 30 per cent greater than those based on monthly tests.

Rai (1971) studied three computing methods, viz. (1) undadjusted, (2) first test adjusted and (3) first and last test adjusted under bimonthly recording scheme to estimate the lactation milk yield. He found that the average errors were of the order of 0.84, 0.21 and -0.24 per cent for bimonthly recording, respectively. Rathore (1972) found four and three per cent errors for milk and fat yields estimates in Jersey by bimonthly recording.

Rao (1977) inferred that average error in the estimation of lactation milk from test day yields recorded at 8 weekly intervals with first test commencing in different weeks, ranged from -4.41 to 2.61 per cent and absolute error ranged from 3.87 to 6.56 per cent in Sahiwal and its crosses. The standard deviations of error were larger in Sahiwal (306.93 to 397.50 kg) as compared to crossbreds (95.94 to 202.51 kg).

Lee (1985) obtained the estimates of 305 day yield from bimonthly test records; he found that 89.22 per cent of estimates to be within 5 per cent of actual values; the range in errors was 0.01 to 7.36 per cent; the mean error was 1.96 per cent and standard error of mean was ± 0.14 per cent.

Agrawal *et al.* (1987) found higher estimates of prediction for cows sampled at 56 days intervals in Murrah buffaloes in field conditions.

Khanna and Balaine (1988) reported that the estimation from samples taken at bimonthly and trimonthly intervals over-estimated milk yield under regular and irregular intervals of recording with variable centering date in estimating milk yield of crossbred cattle. The magnitude and direction of bias and sampling error was influenced by the days of lactation on which the first and last samples were taken.

Dass (1991) studied the efficacy of prediction of lactation yield in Murrah buffaloes based on bimonthly milk recording under systematic and stratified random sampling schemes using ratio method. The estimates of average error, per cent average error, average absolute error, per cent absolute error, and standard deviation of errors were 49.21 kg, 3.02 per cent, 120.97 kg, 7.44 per cent and 167.57 kg, respectively under systematic sampling scheme. In similar fashion, the estimates were 53.02 kg, 3.25 per cent, 120.04 kg, 7.33 per cent and 144.92 kg respectively under stratified random sampling scheme; the latter became more efficient at bimonthly testing day interval as indicated by per cent average absolute error and standard deviation of error.

It is seen from above presentation that the measures of error variance in predicted milk yield under bimonthly recording were higher than fortnightly as well as monthly interval of recording schemes in both breeds. This indicated that recording of milk at shorter interval gave better precision for the observed lactation yield.

The following conclusions may be drawn from above results and discussion:

1. The accuracy of prediction was better at shorter interval of milk recording under systematic and stratified random sampling schemes in both breeds. It was observed that the variance of error in predicted lactation milk yield increased gradually when the interval of test recording was increased.
2. Systematic sampling scheme gave better precision under all the three test day intervals of recording as compared to stratified random sampling scheme.
3. The per cent average error was found to be less than one per cent in all cases.

4.9 GENETIC AND PHENOTYPIC PARAMETERS OF KARAN SWISS AND KARAN FRIES BREEDS

The purpose of this investigation is to examine different sire evaluation procedures on the basis of test records obtained under various sampling schemes and part lactation yields. Therefore, the estimation of genetic parameters of relevant traits was made. The measures of heritability of various economic traits and their phenotypic and genetic correlations are the parameters which reflect upon genetic composition of a population. Their estimates express the extent of genetic variability and covariability of various traits measured on individuals constituting the population. The heritability of a trait gives an idea of the proportion of genetic variance to the total phenotypic variance in a given population for a particular trait during a specified time period. It also measures the regression of additive genetic value of animal on its phenotypic value. The knowledge of these parameters is required in formulation of appropriate evaluation and selection criteria for bringing about genetic improvement.

The heritability estimates were obtained for observed part lactation yield, cumulative part lactation yield and observed lactation milk yields and predicted lactation milk yields under systematic and stratified random sampling schemes from data adjusted with least squares constants for differential effects of season and period of calving, genetic group and regression on age at first calving.

4.9.1 HERITABILITY (h^2) ESTIMATES OF FORTNIGHTLY PART YIELDS

The heritability estimates (h^2) of fortnightly part yields are given on diagonal of Table 50 for Karan Swiss and Table 51 for Karan Fries breeds.

In case of Karan Swiss breed, it is seen from Table 50 that the h^2 estimate of fortnightly part yield showed an increasing

Table 50. Estimates of heritability, genetic and phenotypic correlations of observed lactation milk yield (OMY) and fortnightly part lactation yield of Karan Swiss breed

Traits	No. of obs.	OMY	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
OMY	969	0.343 +0.101	0.806 +0.085	0.952 +0.020	0.989 +0.005	0.974 +0.011	1.040 NE	1.017 +0.008	0.964 +0.016	1.006 NE	0.980 +0.007	0.943 +0.021	0.950 +0.020	0.961 +0.016	1.009 NE	0.990 +0.004	0.921 +0.035	0.905 +0.042	0.935 +0.028	0.789 +0.103	0.562 +0.249	0.519 +0.233
P1	969	0.630 +0.024	0.190 +0.076	0.951 +0.024	0.915 +0.044	0.878 +0.061	0.732 +0.149	0.753 +0.119	0.604 +0.172	0.728 +0.117	0.744 +0.107	0.761 +0.097	0.786 +0.091	0.771 +0.099	0.869 +0.062	0.685 +0.136	0.511 +0.195	0.659 +0.144	0.653 +0.139	0.581 +0.193	0.207 +0.361	0.319 +0.325
P2	969	0.723 +0.022	0.889 +0.014	0.254 +0.087	1.002 NE	0.978 +0.001	0.931 +0.039	0.952 +0.023	0.823 +0.080	0.895 +0.045	0.899 +0.042	0.918 +0.033	0.965 +0.015	0.963 +0.016	1.045 NE	0.866 +0.062	0.730 +0.120	0.722 +0.122	0.718 +0.118	0.555 +0.200	0.225 +0.374	0.315 +0.330
P3	969	0.752 +0.021	0.792 +0.019	0.925 +0.012	0.225 +0.082	1.003 NE	0.948 +0.030	0.981 +0.009	0.866 +0.064	0.962 +0.017	0.977 +0.010	0.959 +0.017	0.992 +0.003	1.007 NE	1.090 NE	0.973 +0.014	0.854 +0.076	0.839 +0.084	0.846 +0.077	0.713 +0.157	0.472 +0.346	0.565 +0.274
P4	969	0.796 +0.019	0.725 +0.022	0.855 +0.016	0.929 +0.011	0.241 +0.085	0.939 +0.035	0.977 +0.011	0.894 +0.050	0.998 +0.001	0.998 +0.001	0.986 +0.005	1.006 NE	1.028 NE	1.059 NE	0.953 +0.024	0.864 +0.070	0.875 +0.066	0.889 +0.058	0.725 +0.162	0.601 +0.302	0.697 +0.228
P5	969	0.799 +0.019	0.645 +0.024	0.769 +0.020	0.842 +0.017	0.915 +0.012	0.128 +0.066	0.951 +0.029	1.063 NE	1.031 NE	1.024 NE	1.012 NE	1.066 NE	1.120 NE	1.218 NE	1.198 NE	1.057 NE	1.134 NE	1.486 NE	1.120 NE	0.676 +0.432	0.920 +0.143
P6	969	0.812 +0.018	0.596 +0.025	0.725 +0.022	0.798 +0.019	0.866 +0.016	0.928 +0.011	0.215 +0.080	0.959 +0.020	1.036 NE	1.026 NE	1.023 NE	1.014 NE	1.020 NE	1.028 NE	0.943 +0.028	0.864 +0.068	0.783 +0.108	0.715 +0.136	0.564 +0.236	0.480 +0.355	0.461 +0.033
P7	969	0.807 +0.018	0.564 +0.026	0.679 +0.023	0.747 +0.021	0.814 +0.018	0.874 +0.015	0.914 +0.012	0.227 +0.083	0.942 +0.026	0.932 +0.029	0.943 +0.023	0.947 +0.024	0.950 +0.023	1.016 NE	0.982 +0.009	0.883 +0.061	0.815 +0.100	0.652 +0.182	0.643 +0.283	0.815 +0.277	0.637 +0.443
P8	969	0.812 +0.018	0.532 +0.027	0.642 +0.024	0.696 +0.023	0.757 +0.020	0.789 +0.019	0.844 +0.017	0.915 +0.012	0.304 +0.095	1.020 NE	1.029 NE	1.045 NE	1.051 NE	1.033 NE	1.010 NE	0.928 +0.034	0.869 +0.064	0.843 +0.076	0.673 +0.194	0.638 +0.259	0.486 +0.307
P9	968	0.828 +0.018	0.510 +0.027	0.616 +0.025	0.660 +0.023	0.732 +0.021	0.764 +0.020	0.808 +0.018	0.858 +0.016	0.925 +0.012	0.361 +0.103	0.999 NE	1.007 NE	1.021 NE	0.985 +0.006	0.968 +0.013	0.894 +0.045	0.856 +0.063	0.836 +0.068	0.677 +0.151	0.599 +0.217	0.459 +0.249
P10	965	0.834 +0.017	0.488 +0.028	0.588 +0.026	0.635 +0.024	0.702 +0.022	0.735 +0.021	0.779 +0.020	0.813 +0.018	0.849 +0.016	0.920 +0.012	0.397 +0.109	0.993 +0.002	1.013 NE	0.937 +0.027	0.897 +0.043	0.832 +0.069	0.764 +0.095	0.747 +0.097	0.579 +0.180	0.423 +0.289	0.403 +0.285

contd.....

contd..... table 50

Traits	No. of obs.	ONY	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
P11	953	0.827 +0.018	0.480 +0.028	0.568 +0.026	0.603 +0.025	0.664 +0.024	0.699 +0.023	0.742 +0.217	0.772 +0.020	0.790 +0.019	0.851 +0.017	0.922 +0.012	0.345 +0.102	1.015 NE	1.004 NE	0.975 +0.010	0.942 +0.025	0.897 +0.045	0.834 +0.068	0.716 +0.136	0.613 +0.225	0.534 +0.238
P12	938	0.823 +0.018	0.454 +0.029	0.533 +0.027	0.567 +0.026	0.620 +0.025	0.648 +0.024	0.695 +0.023	0.734 +0.022	0.759 +0.021	0.796 +0.019	0.848 +0.017	0.917 +0.012	0.343 +0.102	0.984 +0.007	0.967 +0.014	0.963 +0.016	0.909 +0.040	0.794 +0.083	0.755 +0.120	0.661 +0.207	0.513 +0.246
P13	916	0.837 +0.018	0.438 +0.029	0.505 +0.028	0.539 +0.027	0.590 +0.026	0.622 +0.025	0.672 +0.024	0.716 +0.023	0.733 +0.022	0.758 +0.021	0.793 +0.019	0.847 +0.017	0.919 +0.012	0.299 +0.096	0.997 +0.001	0.979 +0.009	0.936 +0.028	0.888 +0.047	0.853 +0.076	0.777 +0.150	0.670 +0.191
P14	896	0.815 +0.019	0.423 +0.030	0.474 +0.029	0.493 +0.029	0.551 +0.027	0.578 +0.027	0.619 +0.026	0.658 +0.025	0.676 +0.024	0.706 +0.023	0.732 +0.022	0.776 +0.021	0.823 +0.018	0.906 +0.014	0.322 +0.101	0.972 +0.012	0.965 +0.016	0.930 +0.030	0.923 +0.041	0.853 +0.104	0.833 +0.108
P15	882	0.798 +0.020	0.413 +0.030	0.445 +0.030	0.459 +0.029	0.508 +0.029	0.535 +0.028	0.572 +0.027	0.604 +0.027	0.612 +0.026	0.642 +0.025	0.680 +0.024	0.721 +0.023	0.761 +0.021	0.830 +0.018	0.910 +0.013	0.303 +0.099	0.981 +0.008	0.854 +0.061	0.939 +0.032	0.916 +0.065	0.833 +0.112
P16	867	0.793 +0.020	0.427 +0.003	0.452 +0.030	0.452 +0.030	0.483 +0.029	0.494 +0.029	0.534 +0.028	0.551 +0.028	0.572 +0.027	0.597 +0.027	0.634 +0.026	0.672 +0.025	0.701 +0.024	0.764 +0.021	0.836 +0.018	0.919 +0.013	0.313 +0.101	0.917 +0.034	0.993 +0.003	0.959 +0.027	0.816 +0.105
P17	844	0.780 +0.021	0.428 +0.031	0.458 +0.030	0.450 +0.030	0.481 +0.030	0.467 +0.030	0.496 +0.029	0.504 +0.029	0.525 +0.029	0.566 +0.028	0.600 +0.027	0.620 +0.026	0.645 +0.026	0.698 +0.024	0.762 +0.022	0.809 +0.020	0.898 +0.015	0.337 +0.122	0.826 +0.073	0.678 +0.161	0.616 +0.167
P18	744	0.736 +0.024	0.421 +0.032	0.459 +0.031	0.448 +0.031	0.466 +0.031	0.446 +0.031	0.446 +0.031	0.439 +0.032	0.451 +0.031	0.496 +0.030	0.531 +0.030	0.543 +0.029	0.554 +0.029	0.606 +0.028	0.670 +0.026	0.725 +0.024	0.793 +0.021	0.858 +0.018	0.266 +0.099	0.990 +0.006	0.904 +0.056
P19	657	0.648 +0.028	0.396 +0.034	0.415 +0.034	0.403 +0.034	0.409 +0.034	0.374 +0.035	0.363 +0.035	0.342 +0.035	0.359 +0.035	0.396 +0.034	0.420 +0.034	0.437 +0.034	0.457 +0.033	0.514 +0.032	0.574 +0.031	0.631 +0.029	0.705 +0.026	0.737 +0.025	0.897 +0.016	0.155 +0.085	0.953 +0.029
P20	697	0.607 +0.032	0.405 +0.037	0.415 +0.036	0.404 +0.037	0.415 +0.036	0.374 +0.037	0.371 +0.037	0.327 +0.038	0.329 +0.038	0.357 +0.037	0.391 +0.037	0.401 +0.037	0.409 +0.037	0.456 +0.036	0.529 +0.034	0.596 +0.032	0.670 +0.030	0.691 +0.029	0.817 +0.023	0.897 +0.017	0.234 +0.107

Diagonal values are estimates of heritability. The upper diagonal values are genetic correlations and lower diagonal values are the phenotypic correlations.

ONY = Observed lactation milk yield; P_i = Part lactation yield during ith fortnight

Table 51. Estimates of heritability, genetic and phenotypic correlations of observed lactation milk yield (OMY) and fortnightly part lactation yield of Karan Fries breed

Traits	No. of obs.	OMY	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
OMY	731	0.294 +0.106	0.769 +0.105	0.753 +0.110	0.838 +0.074	0.880 +0.056	0.906 +0.048	0.996 +0.001	0.992 +0.003	0.985 +0.007	0.998 +0.000	1.035 NE	1.018 +0.008	0.984 +0.007	1.002 +0.001	0.996 NE	1.025 NE	0.986 +0.007	0.961 +0.023	0.931 +0.040	0.854 +0.085	0.910 +0.056
F1	731	0.608 +0.029	0.286 +0.105	0.969 +0.015	0.970 +0.014	0.943 +0.028	0.979 +0.010	0.863 +0.066	0.737 +0.123	0.706 +0.137	0.797 +0.099	0.803 +0.095	0.825 +0.083	0.731 +0.119	0.824 +0.081	0.807 +0.097	0.867 +0.074	0.854 +0.087	0.853 +0.091	0.835 +0.102	0.719 +0.166	0.779 +0.148
F2	731	0.698 +0.026	0.870 +0.018	0.300 +0.107	0.996 +0.001	0.981 +0.009	0.982 +0.009	0.877 +0.059	0.763 +0.110	0.699 +0.138	0.763 +0.111	0.719 +0.127	0.713 +0.124	0.629 +0.151	0.703 +0.124	0.705 +0.135	0.756 +0.126	0.740 +0.145	0.699 +0.166	0.706 +0.160	0.589 +0.204	0.763 +0.147
F3	731	0.771 +0.023	0.762 +0.023	0.911 +0.015	0.308 +0.108	0.993 +0.003	0.996 +0.001	0.905 +0.045	0.821 +0.085	0.769 +0.109	0.831 +0.081	0.809 +0.089	0.803 +0.088	0.710 +0.122	0.780 +0.094	0.778 +0.105	0.845 +0.082	0.818 +0.104	0.769 +0.129	0.743 +0.140	0.610 +0.197	0.754 +0.154
F4	731	0.793 +0.022	0.696 +0.026	0.844 +0.019	0.943 +0.012	0.309 +0.108	0.998 +0.000	0.947 +0.026	0.877 +0.060	0.838 +0.079	0.890 +0.054	0.841 +0.076	0.813 +0.085	0.742 +0.111	0.817 +0.080	0.815 +0.089	0.872 +0.069	0.832 +0.097	0.811 +0.109	0.780 +0.162	0.677 +0.176	0.765 +0.150
F5	731	0.794 +0.022	0.644 +0.028	0.780 +0.023	0.874 +0.017	0.928 +0.013	0.242 +0.099	0.932 +0.035	0.880 +0.063	0.845 +0.082	0.882 +0.067	0.848 +0.078	0.841 +0.079	0.795 +0.099	0.900 +0.049	0.914 +0.048	0.967 +0.021	0.910 +0.059	0.840 +0.105	0.752 +0.157	0.561 +0.258	0.842 +0.125
F6	731	0.795 +0.022	0.601 +0.029	0.731 +0.025	0.822 +0.021	0.869 +0.018	0.938 +0.012	0.281 +0.104	0.999 NE	0.985 +0.007	1.010 NE	0.992 +0.003	0.975 +0.012	0.944 +0.027	1.032 NE	1.023 NE	1.048 NE	1.066 NE	1.032 NE	0.902 +0.061	0.772 +0.138	0.958 +0.033
F7	731	0.804 +0.021	0.560 +0.030	0.685 +0.026	0.775 +0.023	0.825 +0.020	0.884 +0.017	0.943 +0.012	0.255 +0.101	0.999 NE	1.002 NE	0.969 +0.015	0.944 +0.027	0.935 +0.031	1.020 NE	1.011 NE	1.053 NE	1.080 NE	1.084 NE	1.012 NE	0.923 +0.055	0.976 +0.019
F8	731	0.805 +0.021	0.531 +0.031	0.651 +0.028	0.735 +0.025	0.785 +0.022	0.837 +0.020	0.885 +0.017	0.933 +0.012	0.241 +0.099	0.976 +0.012	0.938 +0.032	0.915 +0.042	0.930 +0.034	1.011 NE	0.971 +0.015	1.018 NE	1.067 NE	1.111 NE	1.067 NE	0.929 +0.049	1.006 NE
F9	727	0.823 +0.021	0.520 +0.031	0.634 +0.028	0.718 +0.025	0.767 +0.023	0.809 +0.021	0.854 +0.019	0.890 +0.016	0.933 +0.013	0.265 +0.102	0.988 +0.006	0.963 +0.018	0.969 +0.015	1.043 NE	1.031 NE	1.094 NE	1.121 NE	1.133 NE	1.033 NE	0.891 +0.072	0.965 +0.026
F10	726	0.852 +0.019	0.519 +0.031	0.612 +0.029	0.705 +0.026	0.751 +0.024	0.786 +0.022	0.820 +0.021	0.850 +0.019	0.881 +0.017	0.927 +0.013	0.277 +0.104	0.989 +0.005	0.987 +0.006	1.070 NE	1.070 NE	1.139 NE	1.160 NE	1.167 NE	1.055 NE	0.845 +0.099	0.950 +0.036

contd.....

contd.,..... table 51

Traits No. of obs.	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	
F11	0.848 +0.019	0.486 +0.032	0.555 +0.030	0.641 +0.028	0.699 +0.026	0.729 +0.025	0.755 +0.024	0.786 +0.023	0.812 +0.021	0.843 +0.020	0.917 +0.014	0.297 +0.108	1.023 NE	1.065 NE	1.077 NE	1.166 NE	1.177 NE	1.196 NE	1.140 NE	0.968 +0.021	1.006 NE
F12	0.851 +0.019	0.456 +0.033	0.526 +0.031	0.604 +0.029	0.661 +0.028	0.690 +0.027	0.724 +0.025	0.747 +0.024	0.775 +0.023	0.805 +0.022	0.867 +0.018	0.930 +0.013	0.310 +0.110	1.017 NE	1.034 NE	1.105 NE	1.117 NE	1.125 NE	1.088 NE	1.046 NE	1.120 NE
F13	0.858 +0.019	0.443 +0.033	0.507 +0.032	0.585 +0.030	0.633 +0.029	0.672 +0.028	0.707 +0.026	0.727 +0.025	0.747 +0.025	0.783 +0.023	0.830 +0.021	0.870 +0.018	0.930 +0.013	0.346 +0.116	1.016 NE	1.048 NE	1.036 NE	1.086 NE	1.011 NE	0.964 +0.023	1.001 NE
F14	0.845 +0.020	0.448 +0.034	0.491 +0.033	0.564 +0.031	0.602 +0.030	0.632 +0.029	0.654 +0.028	0.675 +0.028	0.695 +0.027	0.729 +0.026	0.772 +0.024	0.818 +0.021	0.861 +0.019	0.919 +0.014	0.264 +0.105	1.029 NE	1.043 NE	1.028 NE	0.983 +0.011	1.054 NE	0.983 +0.012
F15	0.827 +0.021	0.418 +0.034	0.456 +0.034	0.532 +0.032	0.556 +0.031	0.573 +0.031	0.588 +0.030	0.608 +0.030	0.616 +0.030	0.654 +0.028	0.705 +0.027	0.761 +0.024	0.797 +0.023	0.854 +0.019	0.922 +0.014	0.208 +0.097	1.033 NE	1.049 NE	1.058 NE	1.085 NE	1.029 NE
F16	0.813 +0.022	0.430 +0.034	0.459 +0.034	0.523 +0.032	0.541 +0.032	0.541 +0.032	0.550 +0.032	0.579 +0.031	0.583 +0.031	0.611 +0.030	0.674 +0.028	0.721 +0.026	0.755 +0.025	0.805 +0.022	0.853 +0.020	0.927 +0.014	0.169 +0.092	0.993 +0.005	1.020 +0.017	1.965 +0.029	0.962 +0.030
F17	0.813 +0.022	0.443 +0.034	0.476 +0.034	0.538 +0.032	0.538 +0.032	0.531 +0.032	0.535 +0.032	0.556 +0.032	0.563 +0.031	0.588 +0.031	0.645 +0.029	0.682 +0.028	0.711 +0.027	0.758 +0.025	0.808 +0.022	0.867 +0.019	0.933 +0.013	0.164 +0.092	1.039 NE	0.927 +0.053	0.851 +0.106
F18	0.783 +0.024	0.443 +0.035	0.478 +0.035	0.521 +0.034	0.522 +0.034	0.514 +0.034	0.510 +0.034	0.510 +0.034	0.511 +0.034	0.542 +0.033	0.602 +0.031	0.627 +0.031	0.655 +0.030	0.691 +0.028	0.734 +0.027	0.795 +0.024	0.855 +0.020	0.929 +0.014	0.173 +0.057	0.926 +0.051	0.865 +0.093
F19	0.734 +0.029	0.428 +0.039	0.468 +0.038	0.500 +0.038	0.495 +0.038	0.481 +0.038	0.456 +0.038	0.464 +0.038	0.466 +0.038	0.493 +0.038	0.553 +0.036	0.577 +0.035	0.594 +0.035	0.615 +0.034	0.669 +0.032	0.723 +0.030	0.766 +0.028	0.832 +0.024	0.907 +0.019	0.216 +0.116	0.990 +0.007
F20	0.674 +0.034	0.460 +0.041	0.484 +0.040	0.501 +0.040	0.478 +0.041	0.465 +0.041	0.459 +0.041	0.440 +0.042	0.427 +0.042	0.434 +0.042	0.478 +0.041	0.490 +0.041	0.497 +0.040	0.508 +0.040	0.551 +0.039	0.610 +0.037	0.644 +0.036	0.725 +0.032	0.786 +0.029	0.915 +0.018	0.227 +0.128

Diagonal values are estimates of heritability. The upper diagonal values are genetic correlations and lower diagonal values are the phenotypic correlations.

ONY = Observed lactation milk yield; F_i = Part lactation yield during ith fortnight

trend from 1st fortnight to 4th fortnight and declined during 5th fortnight and subsequently increased from 6th fortnight to 10th fortnight, and thereafter decreased from 11th to 15th fortnight. Further, h^2 estimate increased from 16th fortnight to 17th fortnight and decreased thereafter. The h^2 was highest (0.397) for 10th fortnight and lowest (0.190) for first fortnight. The estimates of h^2 of 9th to 12th fortnight part yields were found to be higher than that of observed lactation milk yield (OMY).

In case of Karan Fries breed, it was seen (Table 51) that the h^2 estimate of fortnightly part yield showed an increasing trend from 1st fortnight to 4th fortnight and decreased from 5th fortnight to 8th fortnight and subsequently increased from 9th fortnight to 13th fortnight and decreased thereafter. The h^2 estimate was highest (0.346) for 13th fortnightly part yield. The h^2 estimates of 2nd to 4th fortnight and 11th to 13th fortnightly part yields were found to be higher than that of OMY.

It is thus seen from above presentation (Tables 50 and 51) for Karan Swiss and Karan Fries breeds that the higher estimates of heritability were observed around mid lactation's fortnight part yield. Only few reports were available on heritability estimates of fortnightly part yields. Singh et al. (1967) reported that the h^2 estimate of first fortnightly part yield was 0.22 in Haryana cattle.

4.9.2 HERITABILITY (h^2) ESTIMATES OF MONTHLY PART YIELDS

The h^2 estimates of monthly part yields are given on diagonal of Table 52 for Karan Swiss and Table 53 for Karan Fries breeds.

For Karan Swiss breed, it is seen from Table 52 that the h^2 estimate of monthly part milk yield showed an increasing trend from 1st month to 2nd month and declined during 3rd month. Further it showed an increasing trend from 4th month to 5th month and decreased subsequently from 6th month to 10th month. The h^2

Table 52. Estimates of heritability, genetic and phenotypic correlations of observed lactation milk yield (OMY) and monthly part lactation milk yield of Karan Swiss breed

Traits --->	No. of observations	OMY	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
OMY	1044	0.343 +0.101	0.892 +0.047	0.981 +0.008	1.034 NE	1.004 NE	0.960 +0.015	0.952 +0.019	1.011 NE	0.907 +0.042	0.812 +0.092	0.564 +0.214
M1	1044	0.694 +0.023	0.228 +0.083	0.955 +0.021	0.906 +0.047	0.829 +0.075	0.841 +0.064	0.900 +0.044	0.899 +0.048	0.673 +0.139	0.610 +0.177	0.420 +0.290
M2	1044	0.787 +0.019	0.862 +0.016	0.241 +0.085	1.001 NE	0.974 +0.011	0.977 +0.009	1.027 NE	1.061 NE	0.857 +0.075	0.769 +0.131	0.706 +0.204
M3	1044	0.823 +0.018	0.718 +0.022	0.889 +0.014	0.195 +0.077	1.041 NE	1.040 NE	1.070 NE	1.049 NE	0.872 +0.073	0.743 +0.173	0.625 +0.281
M4	1044	0.830 +0.017	0.636 +0.024	0.786 +0.019	0.890 +0.014	0.294 +0.093	1.013 NE	1.026 NE	1.013 NE	0.864 +0.066	0.685 +0.181	0.544 +0.286
M5	1044	0.848 +0.017	0.580 +0.026	0.711 +0.022	0.883 +0.019	0.900 +0.014	0.405 +0.110	1.006 NE	0.952 +0.021	0.824 +0.075	0.671 +0.148	0.478 +0.248
M6	1024	0.845 +0.017	0.532 +0.027	0.634 +0.025	0.724 +0.022	0.793 +0.019	0.890 +0.014	0.358 +0.104	0.982 +0.007	0.926 +0.033	0.776 +0.107	0.570 +0.217
M7	995	0.848 +0.017	0.481 +0.029	0.563 +0.027	0.650 +0.025	0.729 +0.022	0.782 +0.020	0.881 +0.015	0.307 +0.099	0.965 +0.015	0.922 +0.040	0.785 +0.130
M8	957	0.809 +0.019	0.453 +0.030	0.488 +0.029	0.552 +0.028	0.607 +0.026	0.660 +0.025	0.742 +0.022	0.873 +0.016	0.294 +0.098	0.957 +0.022	0.875 +0.078
M9	925	0.780 +0.022	0.480 +0.031	0.496 +0.030	0.497 +0.030	0.509 +0.030	0.577 +0.029	0.624 +0.027	0.717 +0.024	0.852 +0.018	0.276 +0.100	0.936 +0.037
M10	776	0.647 +0.030	0.444 +0.036	0.436 +0.036	0.402 +0.037	0.369 +0.037	0.419 +0.036	0.453 +0.036	0.551 +0.033	0.697 +0.029	0.858 +0.020	0.244 +0.100

Diagonal values are estimates of heritability. The upper diagonal values are genetic correlations and lower diagonal values are the phenotypic correlations.

where, M_i = part milk yield during i^{th} month
 NE = not estimable

Table 53. Estimates of heritability, genetic and phenotypic correlations of observed lactation milk yield (OMY) and monthly part lactation milk yield of Karan Fries breed

Traits	No. of observations	OMY	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
OMY	835	0.294 +0.010	0.744 +0.113	0.860 +0.064	0.969 +0.015	0.989 +0.005	1.022 NE	0.992 +0.003	0.992 +0.003	0.993 +0.003	0.937 +0.036	0.930 +0.043
M1	835	0.666 +0.027	0.302 +0.107	0.974 +0.012	0.935 +0.033	0.789 +0.131	0.751 +0.114	0.691 +0.132	0.716 +0.122	0.790 +0.115	0.770 +0.130	0.812 +0.119
M2	835	0.793 +0.022	0.837 +0.020	0.316 +0.109	0.978 +0.011	0.828 +0.082	0.846 +0.072	0.752 +0.106	0.774 +0.097	0.834 +0.090	0.765 +0.129	0.788 +0.133
M3	835	0.807 +0.021	0.720 +0.025	0.899 +0.016	0.261 +0.101	0.947 +0.028	0.957 +0.022	0.895 +0.051	0.963 +0.018	1.012 NE	0.882 +0.076	0.955 +0.036
M4	835	0.818 +0.021	0.634 +0.028	0.803 +0.022	0.916 +0.014	0.256 +0.101	0.974 +0.013	0.921 +0.038	0.984 +0.007	1.049 NE	1.052 NE	1.025 NE
M5	831	0.854 +0.019	0.596 +0.029	0.758 +0.024	0.846 +0.019	0.918 +0.014	0.279 +0.104	0.973 +0.012	1.047 NE	1.127 NE	1.063 NE	1.003 NE
M6	819	0.867 +0.018	0.531 +0.031	0.674 +0.027	0.751 +0.024	0.807 +0.022	0.891 +0.017	0.307 +0.110	1.034 NE	1.130 NE	1.008 NE	1.082 NE
M7	804	0.875 +0.018	0.493 +0.033	0.617 +0.029	0.692 +0.027	0.737 +0.025	0.811 +0.022	0.906 +0.016	0.341 +0.116	1.033 NE	0.985 +0.009	1.014 NE
M8	787	0.833 +0.021	0.456 +0.034	0.552 +0.032	0.580 +0.031	0.615 +0.030	0.684 +0.028	0.785 +0.023	0.894 +0.017	0.196 +0.096	1.015 NE	0.968 +0.024
M9	763	0.811 +0.023	0.483 +0.035	0.546 +0.033	0.542 +0.033	0.548 +0.033	0.612 +0.031	0.692 +0.028	0.778 +0.025	0.893 +0.018	0.178 +0.098	0.874 +0.086
M10	619	0.719 +0.032	0.498 +0.040	0.518 +0.040	0.496 +0.040	0.474 +0.041	0.518 +0.040	0.548 +0.039	0.604 +0.037	0.704 +0.033	0.839 +0.025	0.235 +0.121

Diagonal values are estimates of heritability. The upper diagonal values are genetic correlations and lower diagonal values are the phenotypic correlations.

where, M_i = part milk yield during i^{th} month
 NE = not estimable

was highest (0.405) for 5th month and lowest (0.195) for 3rd month. The h^2 estimates of 5th and 6th month part yields were found to be higher than that of observed lactation milk yield (OMY) in Karan Swiss cattle.

In case of Karan Fries breed, it was found that the h^2 estimate of monthly part yield also showed an increasing trend from 1st month to 2nd month and declined during 3rd month. Further, it increased from 4th month to 7th month and decreased thereafter from 8th month to 10th month. The estimate of h^2 was found to be highest (0.341) during 7th month and lowest for 8th month milk yield. The higher estimates of heritability could be seen from 1st, 2nd, 6th and 7th month as compared to OMY.

It is thus seen from above presentation (Tables 52 and 53) that 5th and 6th month for Karan Swiss and 1st, 2nd, 6th and 7th month part yields for Karan Fries cattle were more heritable than OMY; whereas lower estimate of h^2 was observed during 3rd month part yield in both breeds.

VanVleck (1964) reported that the estimate of h^2 for 5th month of first lactation was found to be 0.40 for Ayresshire, 0.03 for Guernsey, 0.27 for Holstein, 0.20 for Jersey and 0.59 for Brown Swiss breeds.

Singh and Acharya (1969) gave a range of heritability from 0.12 to 0.33 for 3rd month to 8th month part yield in Haryana cattle.

Gokhale (1974) reported that the h^2 estimates for ten month part yields beginning with first month were 0.272, 0.157, 0.198, 0.207, 0.233, 0.197, 0.190, 0.249, 0.121 and 0.152 in Murrah buffaloes. Further, it was seen that 1st month and 5th month part yields were more heritable.

Sharma *et al.* (1980) observed that the h^2 estimate was 0.723 for 5th month and 0.875 for 6th month in Haryana cattle. Sharma *et al.* (1983) reported that the h^2 estimate was 0.34 for 4th month part yield in Haryana cattle.

Srivastava and Khan (1987) gave a range of h^2 from 0.30 to 0.46 for 1st month to 10th month part yields in Sahiwal cattle. Singh *et al.* (1988) reported a range of heritability estimates from 0.16 to 0.52 for 1st month to 7th month part yield of first lactation in Sahiwal breed. Pande (1988) found h^2 for 2nd month part yield to be 0.29 in Gaolao cattle. Singh *et al.* (1988) gave a range of heritability as 0.14 to 0.78 for 1st to 6th month part yield of second lactation in Sahiwal.

Singh and Yadav (1987) reported that the h^2 estimates for 10th month part yields beginning with first month were 0.07, 0.11, 0.08, 0.18, 0.07, 0.10, 0.08, 0.09, 0.10 and 0.10 in buffaloes. It was seen that the 4th month part yield was most heritable.

4.9.3 HERITABILITY (h^2) ESTIMATES OF BIMONTHLY PART YIELDS

The h^2 estimates of bimonthly part milk yields are given on diagonal of Table 54 for Karan Swiss and Table 55 for Karan Fries breeds.

For Karan Swiss, it is seen from Table 54 that the h^2 estimate of bimonthly part yield showed an increasing trend from 1st bimonthly to 3rd bimonthly part yield and declined thereafter. The h^2 estimate was highest (0.388) for 3rd bimonth yield and lowest (0.245) for 1st bimonth yield. The heritability of 3rd bimonth yield was higher than OMY.

In case of Karan Fries breed, it was found that the h^2 estimate of bimonthly part yield showed a decreasing trend from 1st bimonth yield to 2nd bimonth yield and increased during 3rd bimonth and declined thereafter. The h^2 was highest (0.337) for

Table 54. Estimates of heritability, genetic and phenotypic correlations of observed (OMY) and bimonthly part lactation yield in Karan Swiss breed.

Traits	No.of obs.	OMY	B1	B2	B3	B4	B5
OMY	969	0.343 ±0.101	0.945 ±0.023	1.007 NE	0.949 ±0.020	0.957 ±0.019	0.619 ±0.185
B1	969	0.765 ±0.020	0.245 ±0.085	0.924 ±0.035	0.958 ±0.018	0.865 ±0.065	0.614 ±0.217
B2	969	0.850 ±0.016	0.803 ±0.019	0.260 ±0.088	1.020 NE	0.936 ±0.033	0.637 ±0.235
B3	939	0.869 ±0.016	0.653 ±0.024	0.849 ±0.017	0.388 ±0.109	0.926 ±0.032	0.623 ±0.184
B4	852	0.852 ±0.017	0.527 ±0.028	0.669 ±0.025	0.811 ±0.019	0.310 ±0.101	0.881 ±0.071
B5	607	0.721 ±0.028	0.499 ±0.035	0.468 ±0.035	0.541 ±0.034	0.740 ±0.027	0.285 ±0.115

Diagonal values are estimates of heritability. The upper diagonal values are genetic correlations and lower diagonal values are the phenotypic correlations.

where, B_i = Bimonthly part lactation yield of i^{th} part, NE = Not estimable

Table 55. Estimates of heritability, genetic and phenotypic correlations of observed (OMY) and bimonthly part lactation yield in Karan Fries breed.

Traits	No.of obs.	OMY	B1	B2	B3	B4	B5
OMY	969	0.294 ±0.106	0.819 ±0.080	0.992 ±0.003	1.009 NE	0.974 ±0.012	0.998 ±0.001
B1	969	0.764 ±0.023	0.337 ±0.112	0.888 ±0.053	0.795 ±0.087	0.782 ±0.100	0.906 ±0.060
B2	969	0.830 ±0.020	0.815 ±0.021	0.262 ±0.102	0.959 ±0.019	0.994 ±0.002	1.040 NE
B3	969	0.889 ±0.017	0.692 ±0.027	0.873 ±0.018	0.327 ±0.112	1.073 NE	1.034 NE
B4	867	0.875 ±0.018	0.563 ±0.031	0.683 ±0.281	0.839 ±0.020	0.282 ±0.109	1.020 NE
B5	607	0.791 ±0.028	0.561 ±0.039	0.553 ±0.039	0.619 ±0.037	0.785 ±0.029	0.247 ±0.131

Diagonal values are estimates of heritability. The upper diagonal values are genetic correlations and lower diagonal values are the phenotypic correlations.

where, B_i = part milk yield during i^{th} bimonth
NE = Not estimable

1st bimonth yield and lowest (0.247) for 5th bimonth yield. The h^2 estimate of 1st bimonth and 3rd bimonth part yields were found to be higher than that of OMY.

It is thus seen from above results that the 3rd bimonthly part yield was most heritable in both breeds.

Mehta (1981) reported that the h^2 of first bimonthly part yield was 0.05 for Karan Swiss and 0.88 for Karan Fries breed. Sushil Kumar (1990) reported that the estimate of h^2 was 0.136 for 1st bimonth yield for Sahiwal cattle.

4.9.4 HERITABILITY (h^2) ESTIMATES OF CUMULATIVE PART YIELDS

The h^2 estimates for 10 monthly cumulative part yields are given on diagonal of Table 56 for Karan Swiss and Table 57 for Karan Fries breeds.

For Karan Swiss breed, it is seen from Table 56 that the h^2 estimates of monthly cumulative part yields showed an increasing trend from first 30 days part yield to first 180 days part yield and decreased thereafter. The h^2 estimate was highest (0.328) for first 180 days part yield. In general, there was more consistency and uniformity in the estimates based on cumulative part lactation yields. The h^2 estimates ranged from 0.246 to 0.328 for monthly cumulative part yields.

In case of Karan Fries breed, it was found that the estimate of h^2 of monthly cumulative part yields showed an increasing trend from first 30 days part yield to first 60 days part yield and decreased from first 90 days to first 120 days part yield. Further it showed an upward trend from first 150 days to first 210 days part yield and decreased thereafter. The h^2 was highest (0.363) for first 210 days part yield. The h^2 estimates ranged from 0.309 to 0.363 for monthly cumulative part yields. All the estimates of h^2 for cumulative part yields were more heritable than that of OMY.

Table 56. Estimates of heritability, genetic and phenotypic correlations of observed lactation milk yield (CMY) and cumulative lactation milk yield of Karan Swiss cattle

Traits	No. of observations	CMY	CMY-30	CMY-60	CMY-90	CMY-120	CMY-150	CMY-180	CMY-210	CMY-240	CMY-270
CMY	970	0.343 +0.101	0.892 +0.047	0.945 +0.023	0.978 +0.009	0.993 +0.002	0.980 +0.008	0.963 +0.015	0.962 +0.017	0.963 +0.017	0.911 +0.047
CMY-30	970	0.694 +0.023	0.228 +0.083	0.989 +0.005	0.973 +0.013	0.944 +0.026	0.977 +0.032	0.930 +0.032	0.912 +0.041	0.900 +0.047	0.842 +0.084
CMY-60	970	0.765 +0.020	0.969 +0.007	0.245 +0.065	0.996 +0.001	0.983 +0.008	0.972 +0.012	0.979 +0.009	0.978 +0.010	0.958 +0.020	0.897 +0.058
CMY-90	970	0.814 +0.018	0.925 +0.012	0.983 +0.005	0.244 +0.085	0.997 +0.001	0.982 +0.003	0.997 +0.001	1.000 NE	0.987 +0.006	0.931 +0.041
CMY-120	970	0.847 +0.017	0.887 +0.014	0.956 +0.009	0.989 +0.004	0.269 +0.089	0.999 NE	0.999 NE	1.000 NE	0.993 +0.003	0.949 +0.031
CMY-150	966	0.881 +0.015	0.857 +0.016	0.931 +0.011	0.972 +0.007	0.993 +0.003	0.322 +0.092	0.999 NE	0.997 +0.001	0.990 +0.004	0.950 +0.029
CMY-180	940	0.920 +0.013	0.832 +0.018	0.907 +0.013	0.952 +0.009	0.979 +0.006	0.993 +0.003	0.328 +0.100	0.997 +0.001	0.993 +0.003	0.963 +0.020
CMY-210	898	0.939 +0.011	0.808 +0.019	0.885 +0.015	0.931 +0.012	0.963 +0.008	0.901 +0.006	0.994 +0.003	0.317 +0.100	0.996 +0.001	0.984 +0.008
CMY-240	868	0.960 +0.009	0.791 +0.020	0.886 +0.017	0.911 +0.013	0.945 +0.011	0.966 +0.008	0.983 +0.006	0.994 +0.003	0.309 +0.101	0.985 +0.008
CMY-270	787	0.976 +0.007	0.770 +0.022	0.846 +0.019	0.894 +0.015	0.928 +0.013	0.951 +0.010	0.970 +0.008	0.984 +0.006	0.994 +0.003	0.246 +0.095

Diagonal values are estimates of heritability. The upper diagonal values are genetic correlations and lower diagonal values are the phenotypic correlations.

where, CMY_i = cumulative lactation milk yield of i^{th} days
 NE = not estimable

Table 57. Estimates of heritability, genetic and phenotypic correlations of observed lactation milk yield (OMY) and cumulative lactation milk yield of Karan Fries

Traits	No. of observations	OMY	CMY-30	CMY-60	CMY-90	CMY-120	CMY-150	CMY-180	CMY-210	CMY-240	CMY-270
OMY	731	0.294 +0.106	0.771 +0.102	0.819 +0.080	0.871 +0.059	0.925 +0.036	0.967 +0.015	0.990 +0.004	0.992 +0.003	0.984 +0.007	0.974 +0.012
CMY-30	731	0.673 +0.027	0.309 +0.108	0.996 +0.001	0.988 +0.005	0.957 +0.020	0.938 +0.029	0.913 +0.040	0.889 +0.051	0.868 +0.061	0.843 +0.073
CMY-60	731	0.764 +0.023	0.960 +0.010	0.337 +0.112	0.996 +0.001	0.975 +0.011	0.960 +0.019	0.938 +0.027	0.912 +0.039	0.890 +0.050	0.876 +0.057
CMY-90	731	0.836 +0.021	0.913 +0.015	0.982 +0.006	0.328 +0.111	0.991 +0.004	0.982 +0.008	0.967 +0.015	0.950 +0.230	0.930 +0.032	0.917 +0.039
CMY-120	731	0.836 +0.020	0.870 +0.018	0.953 +0.011	0.989 +0.005	0.311 +0.109	0.997 +0.001	0.989 +0.005	0.979 +0.009	0.963 +0.017	0.956 +0.021
CMY-150	726	0.868 +0.018	0.839 +0.020	0.929 +0.013	0.973 +0.008	0.993 +0.004	0.312 +0.109	0.995 +0.001	0.990 +0.004	0.978 +0.010	0.974 +0.012
CMY-180	712	0.911 +0.015	0.813 +0.021	0.906 +0.015	0.955 +0.011	0.981 +0.007	0.994 +0.003	0.348 +0.115	0.998 NE	0.992 +0.003	0.992 +0.003
CMY-210	693	0.948 +0.012	0.789 +0.023	0.882 +0.017	0.935 +0.013	0.965 +0.009	0.983 +0.006	0.995 +0.003	0.363 +0.119	0.996 +0.001	0.996 +0.001
CMY-240	674	0.963 +0.010	0.763 +0.024	0.861 +0.019	0.914 +0.015	0.945 +0.012	0.966 +0.009	0.984 +0.006	0.995 +0.003	0.362 +0.120	0.999 NE
CMY-270	625	0.979 +0.008	0.754 +0.026	0.846 +0.021	0.898 +0.017	0.929 +0.014	0.951 +0.012	0.971 +0.009	0.986 +0.006	0.995 +0.003	0.355 +0.124

Diagonal values are estimates of heritability. The upper diagonal values are genetic correlations and lower diagonal values are the phenotypic correlations.

where, CMY_i = cumulative lactation milk yield of i^{th} days
 NE = not estimable

It is thus seen from above results that first 180 days part yield for Karan Swiss and first 210 days part yield for Karan Fries were most heritable.

Madden *et al.* (1955) reported the estimates of h^2 to be 0.34 for first 120 days and 0.63 for first 274 days part yield in Holstein cattle. Smith and Legates (1962) reported h^2 of first 90 days part yield of first lactation and first 90 days part yield of later lactations to be 0.18 and 0.38 in Holstein cattle respectively.

Singh *et al.* (1967) reported the estimates of h^2 to be 0.39 for first 75 days and 0.63 for first 135 days part yield in Haryana cows. Singh and Acharya (1969) gave a range of h^2 from 0.16 to 0.43 for 1st monthly cumulative part yield to 8th monthly cumulative yield in Haryana cattle. Singh and Tomar (1983) reported h^2 of first 150 days part yield to be 0.36 in Haryana cattle.

Auran (1976) gave a range of h^2 from 0.18 to 0.25 for first to tenth month cumulative part yield in cattle. Sharma *et al.* (1983) reported h^2 of first 120 days cumulative yield to be 0.42 in Haryana cattle.

Mehta (1981) found lower estimates of h^2 for monthly cumulative yield in Karan Swiss and higher estimate of monthly cumulative yield in Karan Fries breeds.

Sushil Kumar (1990) reported higher estimate of h^2 for first 30 days yield and lower estimates of h^2 from first 60 days yield to first 270 days part yield in Sahiwal cattle.

Thus estimates of part lactation milk yield as reported by different workers showed divergent trend.

4.9.5 HERITABILITY ESTIMATES OF OBSERVED LACTATION MILK YIELD (OMY) AND PREDICTED LACTATION MILK YIELD (PMY) UNDER SYSTEMATIC AND STRATIFIED RANDOM SAMPLING SCHEMES

The h^2 estimates of OMY and PMY's under fortnightly, monthly and bimonthly systematic and stratified random sampling schemes are given on diagonal of Table 58 for Karan Swiss and Table 59 for Karan Fries breeds.

For Karan Swiss cattle, it is seen (Table 58) that the h^2 estimates for OMY and PMY under fortnightly, monthly and bimonthly systematic and stratified random sampling schemes were 0.343 ± 0.102 , 0.341 ± 0.101 , 0.356 ± 0.103 , 0.354 ± 0.103 , 0.354 ± 0.103 , 0.341 ± 0.101 and 0.398 ± 0.109 in Karan Swiss cattle, respectively. The difference of h^2 of PMY under various sampling schemes as compared to the estimate of OMY were found to be -0.2 per cent for fortnightly, 1.3 per cent for monthly and 1.1 per cent for bimonthly systematic schemes and 1.1 per cent for fortnightly, -0.2 per cent for monthly and 5.5 per cent for bimonthly stratified random sampling schemes.

In case of Karan Fries breed, it is seen (Table 59) that the h^2 estimates were 0.294 ± 0.103 for OMY, 0.278 ± 0.104 for fortnightly, 0.285 ± 0.105 for monthly and 0.269 ± 0.103 for bimonthly systematic predicted lactation milk yield and 0.275 ± 0.104 for fortnightly, 0.243 ± 0.093 for monthly and 0.258 ± 0.101 for bimonthly stratified random sampled predicted lactation milk yield. The differences of h^2 of PMY under three testing intervals of both sampling schemes as compared to the estimate of OMY were -1.6 per cent for fortnightly, -3.0 per cent for monthly and -2.5 per cent for bimonthly systematic PMY and -1.9 per cent for fortnightly, -5.1 per cent for monthly and -3.6 per cent for bimonthly stratified random sampled PMY.

It is thus seen from above results that the h^2 estimates of PMY under various sampling schemes varied from 1 to 5 per cent as compared to estimate of OMY in both breeds. The h^2 estimates of

Table 58. Estimates of heritability, genetic and phenotypic correlations of observed (OMY) and predicted (PMY) lactation milk yield under various sampling schemes for Karan Swiss cattle

Traits	OMY	S1	S2	S3	S4	S5	S6
OMY	0.343 +0.102	1.001 NE	1.002 NE	1.004 NE	1.000 NE	1.001 NE	0.948 NE
S1	0.995 +0.003	0.341 +0.101	1.004 NE	1.005 NE	1.002 NE	1.002 NE	0.949 +0.004
S2	0.989 +0.005	0.986 +0.005	0.356 +0.103	1.002 NE	1.004 NE	1.001 NE	0.950 NE
S3	0.971 +0.008	0.973 +0.008	0.971 +0.009	0.354 +0.103	1.007 NE	1.000 NE	0.950 NE
S4	0.995 +0.003	0.990 +0.004	0.984 +0.006	0.968 +0.009	0.354 +0.103	1.000 +0.002	0.942 NE
S5	0.988 +0.005	0.983 +0.006	0.977 +0.008	0.960 +0.010	0.983 +0.007	0.341 +0.101	0.955 NE
S6	0.950 +0.009	0.946 +0.010	0.937 +0.010	0.922 +0.012	0.945 +0.010	0.942 +0.014	0.398 +0.109

Diagonal values are estimates of heritability. The upper diagonal values are genetic correlations and lower diagonal values are the phenotypic correlations.

where, NE = Not estimable

Table 59. Estimates of heritability, genetic and phenotypic correlations of observed (OMY) and predicted (PMY) lactation milk yield under various sampling schemes for Karan Fries cattle

Traits	OMY	S1	S2	S3	S4	S5	S6
OMY	0.294 +0.103	1.000 NE	1.002 NE	1.007 NE	0.999 NE	0.998 NE	1.004 NE
S1	0.996 +0.003	0.278 +0.104	1.001 NE	1.007 NE	0.999 NE	1.000 NE	0.991 +0.004
S2	0.989 +0.005	0.988 +0.005	0.285 +0.105	1.002 NE	1.003 NE	1.006 NE	1.012 NE
S3	0.972 +0.008	0.973 +0.008	0.969 +0.009	0.269 +0.103	1.002 NE	0.998 NE	1.001 NE
S4	0.995 +0.003	0.991 +0.004	0.984 +0.006	0.965 +0.009	0.275 +0.104	0.996 +0.002	1.008 NE
S5	0.987 +0.005	0.982 +0.006	0.976 +0.008	0.961 +0.010	0.981 +0.007	0.243 +0.993	1.001 NE
S6	0.964 +0.009	0.961 +0.010	0.957 +0.010	0.940 +0.012	0.959 +0.010	0.951 +0.014	0.258 +0.101

Diagonal values are estimates of heritability. The upper diagonal values are genetic correlations and lower diagonal values are the phenotypic correlations.

where, NE = Not estimable

OMY and PMY were higher in Karan Swiss breed as compared to Karan Fries breed.

Bhatnagar *et al.* (1983) reported estimate of h^2 of milk yield in Sahiwal cattle to be 0.25 ± 0.12 . Chand and Narain (1984) found that the h^2 of first lactation milk yield was 0.42 ± 0.27 in Sahiwal cattle.

Taneja and Bhatnagar (1985) reported the h^2 of lactation milk yield to be 0.35 ± 0.18 in Tharparkar cattle. Senger *et al.* (1987) found the h^2 of 300 day milk yield to be 0.23 ± 0.26 in Tharparkar cattle. Khan *et al.* (1988) gave a range of h^2 of Sahiwal and crossbreds to be from 0.20 to 0.76.

Kumar and Bhatnagar (1989) reported the h^2 of milk yield to be 0.78 ± 0.21 in Karan Swiss breed.

Arora and Sharma (1983) found the h^2 of first lactation milk yield to be 0.31 ± 0.10 in Holstein Friesian cattle.

Singh *et al.* (1986) reported the estimate of h^2 to be 0.34 in Friesian x Sahiwal cattle. Nishimura (1988) observed that the h^2 was 0.26 ± 0.08 for lactation milk yield in Holstein Friesian cows.

Carabana *et al.* (1989) reported the h^2 estimate to be 0.16 in Holstein Friesian. Werf *et al.* (1989) observed the h^2 of OMY to be 0.38 for crossbreds. Welper *et al.* (1989) observed that h^2 estimate for lactation milk yield was 0.22 in Holstein cows.

Dass (1991) reported that h^2 estimate for observed milk yield (OMY) was 0.132 ± 0.138 and that of predicted lactation milk yield (PMY) under systematic sampling scheme to be 0.411 ± 0.181 for fortnightly, 0.343 ± 0.171 for monthly and 0.459 ± 0.188 for bimonthly sampled test records. In similar way, h^2 of PMY under stratified random sampling scheme were found to be

0.122 \pm 0.137 for fortnightly, 0.063 \pm 0.126 for monthly and 0.140 \pm 0.139 for bimonthly test records in Murrah buffaloes.

4.9.6 GENETIC AND PHENOTYPIC CORRELATIONS OF OBSERVED LACTATION MILK YIELD (OMY) WITH PREDICTED LACTATION MILK YIELD (PMY) UNDER VARIOUS SAMPLING SCHEMES

The estimates of genetic and phenotypic correlations of observed (OMY) with predicted (PMY) lactation milk yield on the basis of test records drawn under fortnightly, monthly and bimonthly systematic and stratified random sampling schemes are given in Table 58 for Karan Swiss and Table 59 for Karan Fries breed. It is seen from these tables that the estimates of genetic correlations between OMY with PMY under various sampling schemes were very high being greater than 0.948 for Karan Swiss and to be near unity in Karan Fries breed. Similarly, the estimates of phenotypic correlations were also very high (ranging from 0.950 to 0.989) in Karan Swiss and (ranging from 0.964 to 0.989) in Karan Fries breed. All the estimates of phenotypic and genetic correlations were statistically significant ($P < 0.01$) in both breeds. These results suggest that the predicted lactation milk yield under various sampling schemes would give high phenotypic and genetic accuracy of selection for lactation milk yield.

These results agree with the findings of Pirchner (1961), Smith and Legetes (1962), Kushwaha (1972), Gokhale (1974) and Sharma *et al.* (1983). Dass (1991) reported that the genetic and phenotypic correlations between OMY and PMY under fortnightly, monthly and bimonthly systematic and stratified random test records were highly significant. Most of the genetic correlations were closer or approaching unity in Murrah buffaloes.

4.10 EVALUATION OF BREEDING VALUE OF SIRES ON THE BASIS OF OBSERVED LACTATION MILK YIELD (OMY) AND PREDICTED LACTATION MILK YIELD (PMY) OF THEIR DAUGHTERS UNDER VARIOUS SAMPLING SCHEMES AND PART LACTATIONS

The purpose of evaluating breeding value of bulls on the basis of observed lactation milk performance and predicted performance of daughters was to examine whether the sampling methods, viz., systematic and stratified random, under three testing intervals had any impact on the accuracy and efficiency of sire evaluation. Further, it is of interest to examine the effectiveness of various prevalent sire evaluation methods under different sampling schemes. For this purpose, four methods of sire evaluation were used. These were:

- i) Daughter's average (I_1),
- ii) Contemporary comparison method (I_2),
- iii) Least squares method (I_3) and
- iv) Best linear unbiased prediction (BLUP) method (I_4).

4.10.1 SIRE EVALUATION BY DIFFERENT METHODS ON THE BASIS OF OBSERVED LACTATION MILK YIELD FOR KARAN SWISS AND KARAN FRIES CATTLE

The breeding values of Karan Swiss and Karan Fries bulls estimated on the basis of their daughter's observed lactation milk yield (OMY) along with their ranks are presented in Table 60. All these sires had at least five daughters with first lactation milk yield.

It was found for Karan Swiss breed that by index method I_1 , there were 29 sires which had index above the average breeding value, whereas 22 sires had index below the average. The average breeding value of sires was 2493.63 kg. The highest estimate of breeding value was 3105.75 kg (24.54% above average) of sire No.1617. The lowest index was 1669.57 kg (33.04% below average)

Table 60. Sire indices and their ranking based on observed lactation milk yield (OMY) by different methods

KARAN SWISS BREED										KARAN FRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1	24	3036.58	5	2981.93	7	2612.58	29	2619.77	29	2	24	2938.29	38	2707.23	49	2657.63	38	2710.23	43
3	79	2711.59	18	3136.71	2	2759.14	19	2744.72	13	3	11	3473.45	9	3220.34	17	3095.18	8	2931.72	8
6	6	2713.33	17	2181.89	40	2825.67	12	2705.11	17	4	18	2692.22	47	2812.96	44	2493.11	50	2627.15	51
9	6	2744.17	14	2665.76	22	2830.33	11	2706.86	16	6	7	2854.14	42	2665.66	51	2374.86	51	2658.11	49
12	23	2466.17	27	2753.92	19	2637.96	27	2637.42	27	15	5	3001.60	33	3111.19	25	2583.00	47	2743.55	37
14	5	2306.60	35	2291.36	35	2100.80	50	2463.37	48	18	10	2990.10	35	3279.84	11	3026.60	14	2896.02	12
16	5	2626.00	21	2578.16	25	2779.20	17	2682.38	21	20	24	2762.58	43	2790.59	46	2676.54	36	2722.21	41
17	27	3031.11	7	3073.93	4	2782.11	16	2741.35	14	24	8	3342.13	16	3165.47	21	2779.00	27	2793.41	27
22	11	2777.82	12	2895.99	8	2850.09	10	2745.70	12	34	5	3203.00	21	2968.80	33	2656.20	39	2763.04	31
28	14	2404.79	30	2140.96	41	2554.43	33	2589.50	33	40	7	3649.00	6	3483.77	5	3217.71	5	2941.49	6
36	49	3097.24	3	3118.22	3	2806.06	14	2776.07	9	45	10	2675.40	48	2942.68	37	2617.20	44	2724.26	40
40	8	2310.25	34	2016.43	45	2314.00	45	2496.84	19	74	6	3664.50	5	3228.63	16	3018.83	15	2867.33	18
41	15	3037.00	4	2783.56	37	2751.33	20	2703.98	18	104	7	4110.29	1	3542.05	3	3437.43	2	3015.35	2
56	24	2566.25	23	2890.65	9	2642.04	26	2640.26	26	147	7	2652.29	49	2961.82	36	2635.71	42	2745.81	34
60	5	2067.20	43	2003.49	48	2112.00	49	2467.02	46	148	16	3217.19	20	3521.35	4	2983.31	18	2899.07	11
73	30	2212.80	39	1902.71	50	2412.80	40	2470.70	43	185	11	2140.73	54	2454.30	54	2120.91	54	2499.89	54
75	15	2500.13	25	2367.24	32	2526.33	35	2571.55	35	194	8	2356.25	53	2712.49	48	2224.00	52	2589.84	52
104	13	2601.62	22	2698.19	20	2908.85	6	2787.09	8	223	7	3772.57	4	3345.91	9	3221.14	4	2942.66	5
147	9	2448.89	29	2596.59	24	2760.33	18	2693.52	20	233	14	3170.29	24	3093.62	26	2751.07	30	2776.17	30
172	18	2041.22	46	2011.80	46	2314.39	44	2432.80	50	281	26	3042.38	29	2841.08	43	2741.00	31	2762.08	32
186	77	2044.58	45	1831.56	51	2470.62	36	2490.50	40	311	13	2941.31	37	3308.41	10	2917.15	21	2857.60	21
193	45	2207.62	40	2235.22	37	2531.82	34	2551.56	36	314	11	2900.00	40	2939.15	38	2575.18	48	2701.27	45
316	23	1960.00	49	2011.47	47	2387.83	41	2465.60	47	340	46	3031.80	31	2633.24	53	2612.87	45	2656.47	50
340	18	2108.44	42	2267.34	36	2598.28	31	2612.25	32	364	23	3344.17	15	3138.66	24	2904.91	22	2866.17	20
347	8	2378.75	31	2568.46	26	2690.38	24	2659.64	24	385	36	3430.31	10	3377.12	8	2972.39	20	2924.98	9
435	19	2000.42	48	2091.84	43	2460.26	38	2522.87	38	687	10	3581.00	7	3206.83	18	3158.90	6	2951.61	4
478	28	2329.00	32	2568.10	27	2741.00	21	2712.47	15	746	16	3491.69	8	3228.13	15	3055.38	10	2937.71	7
481	14	1812.86	50	1915.45	49	2367.36	42	2482.52	42	821	5	2921.40	39	2804.45	45	2535.00	49	2730.73	38
835	6	2050.83	44	2349.36	34	2468.83	37	2575.36	34	2507	48	2640.63	50	2782.27	47	2671.23	37	2700.43	46
848	16	2158.75	41	2400.80	30	2459.81	39	2529.66	37	2981	12	2721.83	46	3016.29	31	2676.58	35	2743.57	36
851	13	2234.38	38	2364.36	33	2602.54	30	2617.57	30	3005	8	3191.38	22	3379.41	7	3097.13	7	2909.95	10
947	25	2326.60	33	2668.50	21	2615.96	28	2621.97	28	3026	14	2740.50	44	3037.31	30	2686.64	33	2743.80	35

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KARAN SWISS BREED										KARAN FRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1039	5	2244.00	37	2212.67	39	2120.40	47	2469.70	44	3041	13	2876.85	41	3089.42	28	2867.46	25	2833.55	24
1063	23	2801.48	11	2785.71	16	2808.39	13	2754.48	11	3107	8	3389.25	14	3474.78	6	3053.00	11	2893.85	13
1065	16	2040.75	47	2118.48	42	2332.25	43	2452.71	49	3143	8	3912.50	2	3813.81	1	3576.38	1	3085.67	1
1085	7	1669.57	51	2057.58	44	2018.86	51	2389.17	51	3168	9	3123.22	25	3249.54	13	2696.22	32	2760.09	33
1089	12	2813.42	10	2886.42	10	3019.42	2	2840.68	2	3217	6	3175.17	23	3252.29	12	3085.33	9	2887.53	15
1206	23	2497.52	26	2386.93	31	2668.78	25	2658.60	25	3222	20	2724.85	45	2963.10	35	2676.65	34	2727.71	39
1216	10	2817.80	9	2773.79	18	2990.20	3	2808.98	5	3231	8	3036.00	30	3163.50	22	2888.63	24	2833.51	25
1258	25	2737.48	15	3158.88	1	2913.48	5	2811.53	3	3256	7	3830.71	3	3591.30	2	3329.43	3	2979.08	3
1361	16	3035.88	6	2837.70	14	3104.81	1	2919.18	1	3298	5	3106.00	26	3146.35	23	3052.40	12	2868.30	17
1416	10	2748.30	13	2436.32	28	2590.00	32	2613.68	31	4012	11	3417.91	13	3085.81	29	2990.27	17	2885.20	16
1561	28	2926.18	8	2222.06	38	2695.86	22	2679.64	22	4021	6	3230.67	19	2923.95	39	2753.00	29	2786.89	28
1617	11	3105.73	1	2876.15	12	2937.27	4	2790.29	7	4051	9	3426.89	11	3180.99	20	3030.56	13	2891.99	14
1621	25	2715.24	16	3066.63	5	2873.80	9	2803.58	6	4066	8	3238.63	18	2923.60	41	2890.38	23	2834.20	23
1622	31	2685.10	19	3042.85	6	2884.97	7	2822.14	4	4069	7	3102.14	27	2965.97	34	2841.29	26	2814.93	26
1626	12	2659.67	20	2869.07	13	2883.42	8	2768.05	10	4075	12	3005.75	32	2999.11	32	2598.33	46	2707.11	44
1627	21	2554.67	24	2878.16	11	2692.38	23	2673.76	23	4081	15	2999.00	34	2842.43	42	2648.80	40	2721.01	42
1655	7	3098.14	2	2800.24	15	2799.71	15	2701.66	19	4093	20	2964.70	36	2923.73	40	2623.50	43	2696.26	47
3232	5	2459.20	28	2643.23	23	2169.00	46	2485.37	41	4101	5	3421.80	12	3243.82	14	3003.80	16	2855.34	22
3310	5	2252.40	36	2402.63	29	2116.60	48	2468.42	45	4102	8	3314.13	17	3091.86	27	2977.75	19	2866.20	19
										4121	17	3099.06	28	3183.30	19	2768.06	28	2783.10	29
										4226	8	2524.25	52	2637.43	52	2152.50	53	2563.62	53
										9815	44	2588.39	51	2704.92	50	2640.77	41	2679.25	48

where, R = Rank of the sire; I₁ = Daughter's average method; I₂ = Contemporary comparison method; I₃ = Least square analysis method
I₄ = BLUP method

of sire No. 1085. The difference between the highest and lowest index was 1436.16 kg.

The estimates of sire index by method I_2 showed that there were 27 Karan Swiss sires which had index above the average breeding value, whereas 24 sires had index below the average. The average breeding value of sires was 2525.98 kg. The highest index was 3158.88 kg (25.05% above average) of sire No. 1258. The lowest index was 1831.56 kg (27.49% below average) of sire No. 186. The difference between the highest and lowest index was 1327.32 kg.

Further by method I_3 , there were 22 Karan Swiss sires which had index above the average breeding value, whereas 29 sires had index below the average. The average breeding value of sires was 2613.62 kg. The highest index was 3104.81 kg (18.79% above average) of sire No. 1361. The lowest index was 2018.86 kg (22.75% below average) of sire No. 1085. The difference between the highest and lowest index was 1085.95 kg.

The evaluation of breeding value by index method I_4 indicated that there were 23 sires which had indices above the average breeding value; whereas 28 sires had index below the average. The average breeding value of sires was 2636.26 kg. The highest index was 2919.18 kg (10.73% above average) of sire No. 1361. The lowest index was 2389.10 kg (9.3% below average) of sire No. 1085. The difference between the highest and lowest indices was 530.18 kg.

In case of Karan Fries breed, it was found that by index method I_1 , there were 25 sires which had index above the average breeding value; whereas 29 sires had index below average. The average breeding value of all sires was 3114.48 kg. The highest index was 4110.29 kg (31.99% above average) of sire No. 104. The lowest index was 2558.39 kg (17.85% below average) of sire No. 185. The difference between highest and lowest index was 1551.9 kg.

Evaluation by index method I_2 revealed that 29 sires had index above the average breeding value, whereas 25 sires had index below average. The average breeding value of sires was 3076.87 kg. The highest index was 3813.81 kg (23.95% above average) of sire No. 3143. The lowest index was 2454.30 kg (20.23% below average) of sire No. 185. The difference between highest and lowest index was 1359.51 kg.

Further, it was found that by index method I_3 , there were 26 sires which had index above the average breeding value, whereas 28 sires had index below average. The average breeding value was 2820.67 kg (26.79% above average) of sire No. 3143. The lowest index was 2120.91 kg (24.80% below average) of sire No. 185. The difference between the highest and lowest index was 1455.47 kg.

On evaluation by index method I_4 , it was seen that 26 sires had index above the average breeding value and 28 sires had index below the average. The average breeding value of sires was 2801.63 kg. The highest index was 3085.67 kg (10.13% above average) of sire No. 3143. The lowest index was 2499.89 kg (10.77% below average) of sire No. 185. The difference between highest and lowest index was 585.78 kg.

4.10.2 SIRE EVALUATION BY DIFFERENT METHODS ON THE BASIS OF PREDICTED LACTATION MILK YIELD (PMY) UNDER FORTNIGHTLY SYSTEMATIC SAMPLING SCHEME FOR KARAN SWISS AND KARAN FRIES BREEDS

The breeding values of Karan Swiss and Karan Fries bulls estimated on the basis of their daughter's observed lactation milk yield (OMY) alongwith their ranks are presented in Table 61.

It was found for Karan Swiss breed that by index method I_1 there were 25 sires which had index above the average breeding value, whereas 26 sires had index below average. The average breeding value of sires was 2492.24 kg. The highest index was 3111.18 kg (24.83% above average) of sire No. 1617. The lowest

Table 61. Sire indices and their ranking based on PNY under fortnightly systematic sampling scheme by different methods

KARAN SWISS BREED										KARAN FRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1	24	3053.75	5	3006.83	7	2631.29	27	2632.99	27	2	24	2943.33	38	2709.07	48	2664.29	38	2714.85	44
3	79	2712.09	16	3139.89	1	2762.28	18	2747.28	13	3	11	3464.55	11	3210.99	18	3093.27	8	2935.29	8
6	6	2710.83	17	2189.21	40	2811.33	12	2699.47	17	4	18	2671.44	48	2787.01	46	2473.78	50	2615.21	51
9	6	2729.00	13	2654.97	21	2817.17	11	2701.60	16	6	7	2872.71	42	2671.05	51	2379.57	51	2659.27	50
12	23	2467.83	27	2756.61	8	2644.22	26	2641.86	26	15	5	2991.40	34	3108.82	25	2563.00	49	2739.60	38
14	5	2310.00	35	2292.13	35	2097.40	50	2465.35	48	18	10	2986.50	35	3280.85	12	3022.50	16	2898.34	14
16	5	2612.00	21	2566.52	26	2767.00	17	2678.40	23	20	24	2758.50	43	2787.17	45	2674.83	35	2721.63	41
17	27	3014.81	6	3043.27	6	2767.33	16	2730.28	14	24	8	3320.88	17	3155.57	23	2752.88	29	2785.79	28
22	11	2791.91	11	2906.61	8	2866.73	9	2753.26	11	34	5	3190.00	22	2961.58	34	2634.00	42	2758.89	33
28	14	2403.14	30	2147.21	41	2544.93	32	2584.86	33	40	7	3682.66	6	3511.11	6	3250.00	4	2958.06	4
36	49	3100.31	2	3118.65	1	2807.80	13	2777.11	9	45	10	2707.50	47	2973.86	33	2648.50	39	2738.37	39
40	8	2340.88	32	2040.71	45	2336.63	44	2508.65	39	74	6	3758.67	5	3282.06	11	3075.33	11	2889.03	16
41	15	3010.40	7	2752.81	19	2729.73	21	2691.00	19	104	7	4108.71	1	3547.87	3	3420.86	2	3016.76	2
56	24	2549.25	24	2863.32	13	2629.92	28	2632.14	28	147	7	2640.29	49	2954.61	38	2628.29	43	2744.69	36
60	5	2095.60	43	2020.32	46	2129.40	49	2475.53	46	148	16	3213.66	21	3527.23	4	2980.63	18	2900.83	13
73	30	2229.87	39	1940.10	49	2430.47	40	2484.81	42	185	11	2147.09	54	2455.70	54	2131.00	54	2501.32	54
75	15	2505.27	25	2373.73	32	2533.13	35	2576.44	35	194	8	2318.13	53	2679.05	50	2188.25	52	2574.62	52
104	13	2592.00	22	2683.14	20	2898.00	5	2780.03	8	223	7	3808.80	4	3368.96	8	3240.71	5	2954.95	6
147	9	2445.44	29	2589.48	24	2755.22	19	2690.94	20	233	14	3171.64	23	3095.93	28	2755.07	28	2779.67	30
172	18	2035.89	47	2805.77	48	2309.59	45	2431.67	50	281	26	3042.35	29	2847.78	42	2745.96	31	2766.18	31
186	77	2038.56	46	1821.11	51	2466.45	38	2487.31	41	311	13	2940.15	39	3307.73	10	2912.46	22	2858.22	22
193	45	2209.71	40	2240.21	37	2534.82	34	2553.84	36	314	11	2919.91	40	2959.40	37	2599.64	47	2712.61	45
316	23	1963.43	49	2019.48	47	2392.09	41	2469.84	47	340	46	3035.00	32	2646.11	52	2623.63	45	2664.67	49
340	18	2096.78	42	2255.18	36	2586.72	31	2605.42	31	364	23	3357.78	15	3162.45	22	2925.74	21	2881.46	17
347	8	2368.13	31	2556.93	27	2679.50	24	2655.07	25	385	36	3407.72	13	3348.05	9	2956.28	20	2915.39	10
435	19	1997.11	48	2091.13	43	2456.84	39	2521.75	38	687	10	3576.70	7	3206.74	19	3159.30	6	2956.75	5
478	28	2337.14	33	2583.53	25	2749.96	20	2718.64	15	746	16	3477.00	9	3221.82	16	3044.81	15	2935.75	7
481	14	1814.50	50	1925.58	50	2366.86	42	2483.91	43	821	5	2974.20	36	2835.46	43	2594.60	48	2748.17	34
835	6	2069.50	44	2365.48	33	2486.17	36	2582.83	34	2507	48	2637.21	50	2772.55	47	2670.23	37	2699.75	46
848	16	2163.69	41	2406.02	28	2466.50	37	2534.87	37	2981	12	2723.33	45	3025.36	31	2682.25	33	2747.19	35
851	13	2243.00	38	2365.26	34	2609.23	30	2621.81	29	3005	8	3222.50	20	3416.89	7	3133.13	7	2928.10	9
947	25	2321.68	34	2653.40	22	2613.92	29	2620.82	30	3026	14	2729.07	44	3030.53	30	2680.36	34	2741.52	37

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KARAN SWISS BREED										KARAN PRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1039	5	2261.20	36	2233.32	38	2134.20	48	2477.07	45	3041	13	2887.62	41	3106.46	27	2881.00	25	2842.67	24
1063	23	2788.96	12	2773.61	16	2802.78	14	2750.06	12	3107	8	3427.00	12	3513.99	5	3083.30	10	2909.49	12
1065	16	2044.88	45	2133.40	42	2340.69	43	2459.51	49	3143	8	3914.88	2	3835.06	1	3582.50	1	3096.11	1
1085	7	1665.28	51	2060.42	44	2017.71	51	2392.38	51	3168	9	3126.22	25	3251.62	15	2701.11	32	2763.56	32
1089	12	2823.00	9	2895.02	9	3033.42	2	2846.29	2	3217	6	3171.33	24	3256.83	14	3084.67	9	2891.87	15
1206	23	2491.00	26	2382.41	31	2667.96	25	2658.09	24	3222	20	2719.80	46	2961.07	35	2674.80	36	2727.24	40
1216	10	2813.60	10	2770.19	17	2991.20	3	2807.88	6	3231	8	3036.88	31	3168.51	21	2893.00	24	2838.22	25
1258	25	2715.60	15	3122.72	2	2895.56	7	2817.96	4	3256	7	3810.00	3	3584.95	2	3314.57	3	2980.22	3
1361	16	3059.56	3	2874.56	12	3135.31	1	2935.39	1	3298	5	3110.20	26	3155.26	24	3061.20	13	2875.09	20
1416	10	2689.00	19	2386.61	30	2542.10	33	2591.15	32	4012	11	3403.00	14	3063.54	29	2967.36	19	2878.55	18
1561	28	2917.68	8	2226.85	39	2697.75	23	2680.92	21	4021	6	3234.50	19	2920.95	40	2751.33	30	2788.77	27
1617	11	3111.18	1	2882.19	11	2945.45	4	2793.18	7	4051	9	3471.33	10	3214.83	17	3068.78	12	2911.35	11
1621	25	2722.12	14	3074.55	4	2883.20	8	2809.24	5	4066	8	3262.00	18	2935.34	39	2905.25	23	2842.79	23
1622	31	2693.45	18	3053.31	5	2897.19	6	2830.31	3	4069	7	3102.71	28	2959.85	36	2831.57	26	2814.42	26
1626	12	2636.92	20	2840.93	14	2862.67	10	2756.18	10	4075	12	3041.75	30	3022.98	32	2626.08	44	2720.76	42
1627	21	2559.95	23	2882.28	10	2701.86	22	2679.91	22	4081	15	3000.33	33	2828.17	44	2638.93	40	2717.42	43
1655	7	3059.43	4	2774.03	15	2773.57	15	2691.02	18	4093	20	2973.30	37	2914.36	41	2623.15	46	2696.29	47
3232	5	2459.40	28	2636.69	23	2180.80	46	2491.85	40	4101	5	3480.40	8	3275.00	13	3053.20	14	2872.86	21
3310	5	2258.60	37	2399.06	29	2134.40	47	2477.14	44	4102	8	3340.50	16	3107.30	26	2994.75	17	2876.19	19
										4121	17	3103.06	27	3171.03	20	2762.12	27	2781.20	29
										4226	8	2512.88	52	2612.80	53	2132.00	53	2553.61	53
										9815	44	2584.55	51	2691.39	49	2637.32	41	2676.56	48

where, R = Rank of the sire; I₁ = Daughter's average method; I₂ = Contemporary comparison method; I₃ = Least square analysis method
 I₄ = BLUP method

index was 1665.29 kg (33.18% below average) of sire No. 1085. The difference between the highest and lowest index was 1445.89 kg.

Index method I₂ showed that there were 24 sires which had index above the average breeding value whereas 27 sires had index below the average. The average breeding value of sires was 2525.03 kg. The highest index was 3139.89 kg (24.43% above average) of sire No. 3. The lowest index was 1821.11 kg (27.87% below average) of sire No. 186. The difference between highest and lowest index was 1318.18 kg.

Further, it was found that by index method I₃, there were 28 Karan Swiss sires which had index above the average breeding value of sires, whereas 23 sires had index below average. The average breeding value of sires was 2614.02 kg. The highest index was 3135.21 kg (19.93% above average) of sire No. 1361. The lowest index was 2017.71 (22.81% below average) of sire No. 1085. The difference between the highest and lowest breeding value was 1117.50 kg.

When breeding value of Karan Swiss sires was evaluated by index method I₄, there were 26 sires which had index above the average breeding value; whereas 25 sires had index below average. The average breeding value of sires was 2636.96 kg. The highest index was 2935.39 kg (11.31% above average) of sire No. 1361. The lowest index was 2392.38 kg (9.27% below average) of sire No. 1085. The difference between highest and lowest index was 543.01 kg.

Similarly, in case of Karan Fries breed, it was found that by index method I₁, there were 25 sires which had index above the average breeding value; whereas 29 sires had index below average. The average breeding value of sires was 3120.59 kg. The highest index was 4108.71 kg of sire No. 104 and lowest index was 2147.09 kg of sire No. 185. The difference between the highest and lowest indices was 1860.62 kg.

Evaluation of breeding value by index method I_2 showed that there were 28 sires which had index above the average breeding value, whereas 26 sires had index below average. The average breeding value of sires was 3081.49 kg. The highest index was 3835.06 kg (24.45% above average) of sire No. 3143. The lowest index was 2455.70 kg (20.30% below average) of sire No. 2455. The difference between highest and lowest index was 1379.36 kg.

It was found that by index method I_3 that there were 26 sires which had index above the average breeding value, whereas 28 sires had index below average. The average breeding value of sires was 2825.43 kg. The highest index was 3582.50 kg (26.79% above average) of sire No. 3143 and lowest index was 2131.00 kg (24.57% below average) of sire No. 185. The difference between highest and lowest index was 1451.50 kg.

Evaluation by index method I_4 showed that there were also 26 sires which had index above the average breeding value, whereas 28 sires had index below average. The average breeding value of sires was 2805.52 kg. The highest index was 3096.11 kg (10.35% above average) of sire No. 3143. The lowest index was 2501.32 kg (10.84% below average) of sire No. 185. The difference between highest and lowest index was 594.79 kg.

4.10.3 SIRE EVALUATION BY DIFFERENT METHODS ON THE BASIS OF PREDICTED LACTATION MILK YIELD (PMY) UNDER MONTHLY SYSTEMATIC SAMPLING SCHEME FOR KARAN SWISS AND KARAN FRIES BREEDS

The breeding value of Karan Swiss and Karan Fries breeds on the basis of their daughter's predicted lactation milk yield under monthly systematic sampling scheme alongwith their ranks is given in Table 62.

For Karan Swiss (KS) breed, it was found that by index method I_1 , there were 27 sires which had index above average breeding value, whereas 24 sires had index below average. The

Table 62. Sire indices and their ranking based on PMY under monthly systematic sampling scheme by different methods

KARAN SWISS BREED										KARAN FRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1	24	3053.38	5	3017.70	7	2636.96	29	2638.16	29	2	24	2967.96	36	2723.35	48	2672.54	37	2719.71	41
3	79	2706.76	18	3126.03	3	2758.84	20	2745.30	13	3	11	3484.73	9	3228.83	16	3102.36	8	2941.69	7
6	6	2749.00	14	2213.72	39	2862.50	11	2722.61	16	4	18	2650.67	48	2758.57	47	2448.78	50	2599.11	51
9	6	2708.33	17	2639.20	23	2797.50	14	2698.67	18	6	7	2875.00	42	2660.40	51	2364.00	51	2652.03	50
12	23	2480.65	27	2773.51	17	2658.96	26	2653.43	26	15	5	3052.20	30	3145.86	25	2605.40	46	2750.67	36
14	5	2246.00	36	2244.40	37	2038.20	50	2443.26	49	18	10	2985.70	34	3293.32	12	3018.40	16	2898.34	13
16	5	2632.60	21	2584.84	26	2792.40	16	2690.64	21	20	24	2751.38	43	2770.89	46	2667.29	38	2716.26	42
17	27	3025.63	6	3075.12	5	2784.30	17	2744.81	14	24	8	3391.25	14	3206.48	19	2812.13	27	2808.49	27
22	11	2791.45	12	2909.90	9	2864.73	10	2756.68	12	34	5	3223.60	22	2970.96	34	2650.20	40	2763.21	32
28	14	2368.64	31	2105.02	41	2522.71	34	2572.69	33	40	7	3691.43	6	3531.40	5	3252.86	4	2962.22	4
36	49	3105.94	1	3154.03	2	2821.98	12	2790.71	9	45	10	2650.00	49	2920.90	41	2588.70	47	2712.00	44
40	8	2322.50	34	2027.89	45	2333.00	43	2505.93	39	74	6	3734.67	5	3263.74	14	3038.67	13	2879.46	17
41	15	2979.27	7	2719.70	19	2704.93	22	2678.91	22	104	7	4159.14	1	3593.83	2	3464.00	2	3035.88	2
56	24	2572.17	23	2901.30	11	2654.54	27	2650.42	27	147	7	2661.43	47	2968.61	35	2646.86	41	2750.72	35
60	5	2070.20	43	2003.16	47	2120.80	48	2470.38	45	148	16	3240.81	20	3566.65	4	3004.06	17	2915.17	11
73	30	2237.50	38	1945.84	49	2447.07	38	2496.41	40	185	11	2137.91	54	2444.04	54	2122.27	54	2493.68	54
75	15	2466.47	28	2334.32	33	2507.13	35	2561.36	35	194	8	2315.00	53	2675.32	49	2195.75	52	2574.40	52
104	13	2604.77	22	2698.57	21	2915.92	5	2794.62	8	223	7	3766.00	4	3342.57	9	3191.86	5	2940.93	8
147	9	2456.11	29	2591.08	25	2761.56	19	2697.33	19	233	14	3188.93	23	3096.57	27	2768.43	29	2786.79	29
172	18	2046.39	44	2007.04	46	2321.06	44	2437.08	50	281	26	3021.19	33	2802.86	43	2725.04	32	2752.23	34
186	77	2038.81	45	1817.46	51	2473.88	36	2493.48	42	311	13	2937.54	38	3322.69	10	2916.23	24	2861.14	23
193	45	2210.71	39	2231.74	38	2538.58	33	2557.55	36	314	11	2934.27	39	2965.75	36	2608.00	45	2715.72	43
316	23	1943.13	49	1980.09	48	2375.22	42	2457.11	47	340	46	3043.65	31	2648.77	52	2620.67	44	2661.72	49
340	18	2107.50	42	2267.71	35	2606.83	30	2619.14	30	364	23	3366.22	15	3159.00	23	2923.57	22	2881.18	16
347	8	2371.38	30	2560.54	27	2680.50	24	2668.24	25	385	36	3456.81	10	3409.77	8	2994.06	18	2944.18	6
435	19	1976.00	48	2061.88	43	2441.21	40	2511.22	38	687	10	3557.40	7	3187.32	21	3133.20	7	2948.05	5
478	28	2357.07	33	2615.43	24	2774.36	18	2738.59	15	746	16	3487.88	8	3217.65	18	3045.94	10	2938.37	9
481	14	1807.71	50	1914.93	50	2375.86	41	2487.80	43	821	5	2906.20	40	2785.43	45	2508.60	49	2723.99	39
835	6	2030.17	46	2326.67	34	2444.83	39	2568.48	34	2507	48	2642.00	50	2787.02	44	2676.06	36	2703.93	45
848	16	2160.25	41	2384.79	31	2455.81	37	2527.98	37	2981	12	2737.75	45	3044.66	31	2698.50	33	2754.69	33
851	13	2238.31	37	2353.36	32	2598.08	31	2616.94	31	3005	8	3233.13	21	3435.57	7	3141.38	6	2933.69	10
947	25	2363.31	32	2716.88	20	2648.44	28	2646.25	28	3826	14	2745.64	44	3056.90	30	2693.86	34	2748.22	37

contd..... table 62

KARAN SWISS BREED										KARAN FRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1039	5	2195.60	40	2181.75	40	2083.40	49	2458.07	46	3041	13	2902.69	41	3129.93	26	2901.23	25	2853.73	24
1063	23	2804.13	11	2788.21	16	2816.43	13	2762.34	11	3107	8	3361.13	16	3469.19	6	3021.63	15	2888.11	15
1065	16	2028.31	47	2095.02	42	2317.56	45	2443.82	48	3143	8	3912.75	2	3851.24	1	3585.63	1	3102.31	1
1085	7	1657.71	51	2036.49	44	2005.00	51	2382.89	51	3168	9	3169.11	24	3296.17	11	2742.00	31	2780.03	30
1089	12	2840.08	9	2910.96	8	3044.17	2	2858.33	2	3217	6	3112.83	26	3221.21	17	3027.17	14	2875.90	18
1206	23	2507.13	25	2396.71	30	2676.91	25	2665.88	24	3222	20	2708.75	46	2947.55	37	2667.00	39	2722.08	40
1216	10	2817.10	10	2772.62	18	2985.70	3	2811.19	6	3231	8	3125.38	25	3235.03	15	2981.50	20	2872.85	20
1250	25	2733.68	15	3158.40	1	2913.08	7	2833.85	3	3256	7	3799.00	3	3593.42	3	3299.86	3	2978.54	3
1361	16	3054.63	4	2865.32	14	3126.25	1	2936.71	1	3298	5	3098.00	28	3153.47	24	3049.60	9	2873.71	19
1416	10	2720.10	16	2408.94	29	2570.60	32	2606.19	32	4012	11	3413.18	13	3071.54	29	2993.73	19	2891.98	14
1561	28	2936.07	8	2246.45	36	2715.71	21	2695.73	20	4021	6	3258.67	19	2929.24	40	2788.83	28	2800.85	28
1617	11	3102.00	2	2889.84	12	2941.18	4	2796.36	7	4051	9	3440.78	12	3193.11	20	3045.33	11	2903.85	12
1621	25	2750.60	13	3118.12	4	2910.72	8	2832.26	4	4066	8	3260.25	18	2934.67	39	2918.13	23	2848.81	25
1622	31	2686.48	20	3043.86	6	2890.65	9	2828.57	5	4069	7	3112.14	27	2974.17	33	2854.00	26	2823.04	26
1626	12	2691.67	19	2904.61	10	2914.25	6	2788.42	10	4075	12	2976.58	35	2978.93	32	2573.58	48	2694.86	47
1627	21	2551.95	24	2875.62	13	2691.14	23	2674.60	23	4081	15	3029.80	32	2878.92	42	2681.80	35	2739.81	38
1655	7	3085.86	3	2792.65	15	2794.00	15	2703.03	17	4093	20	2966.90	37	2940.38	38	2624.45	43	2696.25	46
3232	5	2481.00	26	2650.51	22	2199.80	46	2496.27	41	4101	5	3456.00	11	3279.61	13	3041.60	12	2871.48	21
3310	5	2269.60	35	2438.24	28	2147.60	47	2479.20	44	4102	8	3307.38	17	3091.18	28	2974.50	21	2870.19	22
										4121	17	3070.59	29	3172.21	22	2744.41	30	2771.31	31
										4226	8	2502.13	52	2620.95	53	2133.00	53	2550.61	53
										9815	44	2568.50	51	2664.36	50	2625.05	42	2666.50	48

where, R = Rank of the sire; I₁ = Daughter's average method; I₂ = Contemporary comparison method; I₃ = Least square analysis method
I₄ = REIND method

average breeding value of sires was 2492.98 kg. The highest index was 3105.94 kg (24.58% above average) of sire No. 36. The lowest index was 1657.71 kg (33.50% below average) of sire No. 1085. The difference between highest and lowest index was 1448.23 kg.

When Karan Swiss sires were evaluated by index method I₂, there were 27 sires which had index above the average breeding value, whereas 24 sires had index below average. The average breeding value of sires was 2527.02 kg. The highest index was 3158.40 kg (24.98% above average) of sire No. 1258. The lowest index was 1817.46 kg (28.07% below average) of sire No. 186. The difference between highest and lowest index was 1340.94 kg.

Evaluation by index method I₃ showed that there were 29 sires which had index above the average breeding value, whereas 22 sires had index below average. The average breeding value of Karan Swiss sires was 2616.91 kg. The highest index was 3126.05 kg (19.45% above average) of sire No. 1361. The lowest index was 2005.00 kg (23.38% below average) of sire 186. The difference between highest and lowest index was 1121.25 kg.

On evaluation by index method I₄, there were 28 Karan Swiss sires which had index above the average breeding value, whereas 23 sires had index below average. The average breeding value of all sires was 2640.89 kg. The highest index was 2967.47 kg (12.36% above average) of sire No. 1361. The lowest index was 2382.89 kg (9.7% below average) of sire No. 1085. The difference between highest and lowest index was 553.82 kg.

In case of Karan Fries breed, it was found that by index method I₁, there were 25 sires which had index above average breeding value, whereas 29 sires had index below average. The average breeding value of sires was 3121.29 kg. The highest index was 4159.14 kg (33.25% above average) of sire No. 104. The lowest index was 2137.91 kg (31.50% below average) of sire No.

185. The difference between the highest and lowest index was 1448.23 kg.

When Karan Fries sires were evaluated by index method I₂, there were 28 sires which had index above the average breeding value and 26 sires had index below the average. The average breeding value of sires was 3085.39 kg. The highest index was 3851.24 kg (24.82% above average) of sire No. 3143. The lowest index was 2444.04 kg (20.78% below average) of sire No. 185. The difference between highest and lowest index was 1407.20 kg.

Evaluation by index method I₃ showed that 26 sires had index above the average breeding value, whereas 28 sires had index below the average. The average breeding value of Karan Fries sires was 2825.43 kg. The highest index was 3585.63 kg (26.90% above average) of sire No. 3143. The lowest index was 2094.38 kg (25.87% below average) of sire No. 185. The difference between highest and lowest index was 1491.25 kg.

On evaluation by index method I₄, it was found that there were 27 Karan Fries sires which had index above the average breeding value, whereas 27 sires had index below average. The average breeding value of sires was 2806.38 kg. The highest index was 3102.31 kg (10.54% above average) of sire No. 3143. The lowest index was 2493.68 kg (11.14% below average) of sire No. 185. The difference between highest and lowest index was 553.82 kg.

4.10.4 SIRE EVALUATION BY DIFFERENT METHODS ON THE BASIS OF PREDICTED LACTATION MILK YIELD (PMY) UNDER BIMONTHLY SYSTEMATIC SAMPLING SCHEME FOR KARAN SWISS AND KARAN FRIES BREEDS

The breeding value of Karan Swiss and Karan Fries breeds on the basis of their daughter's predicted lactation milk yield (PMY) under bimonthly systematic sampling scheme alongwith their ranks is given in Table 63.

Table 63. Sire indices and their ranking based on PMY under bimonthly systematic sampling scheme by different methods

KARAN SWISS BREED										KARAN FRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1	24	3109.75	3	3085.99	4	2689.88	25	2680.09	24	2	24	2951.50	38	2736.08	48	2653.63	35	2701.58	42
3	79	2737.00	13	3193.10	1	2809.86	16	2792.29	11	3	11	3390.09	13	3127.10	21	3009.73	13	2884.33	11
6	6	2727.17	16	2142.24	39	2854.33	10	2729.91	18	4	18	2654.89	48	2761.44	46	2444.67	50	2592.50	51
9	6	2681.83	19	2617.91	24	2801.00	17	2710.33	19	6	7	2880.00	42	2675.61	50	2373.71	51	2646.68	49
12	23	2498.83	27	2792.64	17	2683.13	26	2675.18	26	15	5	3019.40	30	3093.56	27	2564.60	49	2726.31	36
14	5	2284.00	35	2286.10	35	2075.20	49	2466.85	48	18	10	2944.50	40	3238.96	15	2975.70	17	2864.81	17
16	5	2559.20	22	2535.43	27	2750.00	21	2687.65	22	20	24	2722.13	46	2742.55	47	2622.54	41	2681.90	46
17	27	3023.56	6	3077.88	6	2789.44	18	2752.97	13	24	8	3432.38	11	3227.12	16	2847.25	25	2807.61	25
22	11	2735.91	14	2852.29	13	2838.73	14	2751.11	14	34	5	3220.80	19	2969.58	34	2648.20	37	2748.50	31
28	14	2368.14	31	2127.21	40	2540.29	35	2589.84	34	40	7	3755.71	5	3552.63	3	3004.14	4	2959.19	5
36	49	3095.94	4	3120.97	3	2826.51	15	2797.16	9	45	10	2683.70	47	2954.53	38	2615.30	43	2713.70	39
40	8	2320.50	34	2028.69	45	2325.88	45	2512.28	40	74	6	3691.50	6	3206.95	18	2990.67	15	2846.94	19
41	15	2960.80	7	2687.68	22	2691.07	24	2677.43	25	104	7	4025.86	1	3477.63	5	3331.00	3	2968.10	3
56	24	2521.63	25	2819.94	16	2607.63	30	2622.49	31	147	7	2638.29	49	2955.19	37	2598.43	45	2722.13	38
60	5	2116.60	42	2037.64	44	2150.60	47	2491.51	43	148	16	3198.38	21	3489.36	4	2947.38	20	2871.93	13
73	30	2174.37	40	1853.47	50	2418.63	40	2479.53	45	185	11	2191.36	54	2495.96	54	2147.73	52	2501.87	54
75	15	2464.53	29	2344.03	33	2522.80	36	2577.49	36	194	8	2258.25	53	2613.43	51	2111.50	53	2538.26	52
104	13	2618.77	21	2716.62	19	2953.92	5	2822.98	7	223	7	3758.86	4	3323.27	10	3188.29	6	2920.26	9
147	9	2519.44	26	2660.70	23	2850.44	11	2747.51	16	233	14	3183.93	22	3105.30	25	2742.79	28	2763.69	28
172	18	2043.89	47	2011.68	46	2346.06	44	2459.16	50	281	26	3027.35	29	2830.01	43	2723.04	29	2744.43	33
186	77	2048.71	46	1828.63	51	2500.26	37	2518.72	39	311	13	2947.23	39	3329.20	9	2909.15	21	2844.98	20
193	45	2219.98	37	2248.57	36	2572.00	33	2587.90	35	314	11	2961.18	37	2983.91	32	2615.73	42	2709.92	41
316	23	1951.30	49	1987.58	48	2398.22	41	2478.29	46	340	46	2989.09	32	2585.97	53	2575.72	47	2624.07	50
340	18	2083.39	44	2228.41	38	2590.78	32	2615.00	33	364	23	3289.61	17	3091.89	28	2857.61	23	2830.19	22
347	8	2422.75	30	2614.72	25	2756.00	20	2700.52	20	385	36	3401.56	12	3373.14	8	2949.08	19	2903.35	10
435	19	1981.58	48	2055.23	43	2461.11	39	2529.96	38	687	10	3631.00	7	3264.43	12	3213.70	5	2964.60	4
478	28	2349.07	33	2586.73	26	2782.61	19	2748.96	15	746	16	3481.44	10	3241.30	14	3043.69	11	2923.48	6
481	14	1839.00	50	1933.54	49	2388.93	42	2502.56	42	821	5	2980.80	34	2843.05	42	2597.20	46	2734.95	34
835	6	2115.33	43	2398.98	30	2554.00	34	2619.34	32	2507	48	2522.58	50	2765.52	45	2646.04	38	2677.07	47
848	16	2148.31	41	2375.11	32	2463.06	38	2539.10	37	2981	12	2783.83	43	3066.83	30	2713.50	31	2751.73	30
851	13	2216.92	38	2326.60	34	2609.23	29	2630.48	29	3005	8	3280.13	18	3436.59	7	3161.50	7	2922.60	8
947	25	2350.44	32	2700.20	21	2655.40	28	2655.97	28	3026	14	2741.64	44	3022.53	31	2661.57	33	2722.81	37

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KARAN SWISS BREED										KARAN FRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1039	5	2279.00	36	2241.56	37	2140.00	48	2488.14	44	3041	13	2897.92	41	3094.51	26	2862.92	22	2822.56	23
1063	23	2828.74	11	2821.37	15	2848.22	12	2789.21	14	3107	8	3384.50	15	3464.65	6	3034.25	12	2876.11	12
1065	16	2050.75	45	2118.49	41	2352.19	43	2471.58	47	3143	8	3885.25	2	3783.21	1	3539.00	1	3060.93	1
1085	7	1619.43	51	2007.38	47	1983.57	51	2384.37	51	3168	9	3087.56	25	3210.99	17	3651.22	36	2732.18	35
1089	12	2336.67	9	2897.35	9	3053.00	2	2870.40	2	3217	6	3164.33	23	3250.63	13	3060.83	10	2868.10	15
1206	23	2524.83	24	2414.03	29	2708.96	22	2692.94	21	3222	20	2731.20	45	2966.18	35	2659.30	34	2710.66	40
1216	10	2834.90	10	2781.78	18	3019.10	4	2835.59	6	3231	8	2980.00	35	3119.74	23	2808.13	26	2793.32	26
1258	25	2746.56	12	3169.11	2	2937.40	6	2855.80	4	3256	7	3860.86	3	3617.48	2	3361.14	2	2978.24	2
1361	16	3083.69	5	2897.11	10	3166.75	1	2967.47	1	3298	5	3052.40	27	3116.04	24	2981.80	16	2837.01	21
1416	10	2728.90	15	2415.38	28	2591.80	31	2625.01	30	4012	11	3523.09	9	3198.56	19	3097.00	9	2922.94	7
1561	28	2883.39	8	2117.89	42	2671.39	27	2667.57	27	4021	6	3161.50	24	2886.01	41	2682.00	32	2753.74	29
1617	11	3194.45	1	2993.37	8	3039.00	3	2854.70	5	4051	9	3396.56	14	3151.44	20	2993.56	14	2867.00	16
1621	25	2718.16	17	3059.27	7	2888.92	9	2821.50	8	4066	8	3205.38	20	2898.41	40	2853.63	24	2809.91	24
1622	31	2712.61	18	3079.81	5	2932.52	7	2863.88	3	4069	7	3042.71	28	2918.54	39	2775.57	27	2781.63	27
1626	12	2664.75	20	2886.95	11	2913.08	8	2795.01	10	4075	12	2983.58	33	2974.53	33	2570.83	48	2685.44	45
1627	21	2543.48	23	2857.36	12	2698.76	23	2685.16	23	4081	15	2964.87	36	2802.82	44	2605.87	44	2691.73	44
1655	7	3122.27	2	2833.64	14	2839.14	13	2731.00	17	4093	20	2991.20	31	2965.22	36	2639.60	39	2699.03	43
3232	5	2481.60	28	2707.45	20	2208.20	46	2510.42	41	4101	5	3534.00	8	3296.21	11	3101.20	8	2868.64	14
3310	5	2186.60	39	2378.68	31	2071.20	50	2465.56	49	4102	8	3307.38	16	3088.91	29	2967.00	18	2851.44	18
										4121	17	3054.82	26	3124.74	22	2715.88	30	2746.74	32
										4226	8	2470.75	52	2592.87	52	2094.38	54	2531.95	53
										9815	44	2590.48	51	2728.35	49	2634.91	40	2670.85	48

where, R = Rank of the sire; I₁ = Daughter's average method; I₂ = Contemporary comparison method; I₃ = Least square analysis method
 I₄ = BLUP method

For Karan Swiss breed, it was found that by index method I_1 , there were 26 sires which had index above the average breeding value, whereas 25 sires had index below the average. The average breeding value of sires was 2496.66 kg. The highest index was 3194.45 kg (27.94% above average) of sire No. 1617. The lowest index was 1619.43 kg (35.13% below average) of sire No. 1085. The difference between highest and lowest index was 1575.02 kg.

When Karan Swiss sires were evaluated by index method I_2 , there were 26 sires which had index above the average breeding value, whereas 25 sires had index below the average. The average breeding value of sires was 2528.50 kg. The highest index was 3193.10 kg (26.28% above average) of sire No. 1617. The lowest index was 1828.50 kg (27.68% below average) of sire No. 186. The difference between highest and lowest index was 1364.47 kg.

Evaluation by index method I_3 showed that there were 28 sires which had index above the average breeding value, whereas 23 sires had index below the average. The average breeding value of Karan Swiss sires was 2633.72 kg. The highest index was 3166.75 kg (20.23% above average) of sire No. 1361. The lowest index was 1983.57 kg (24.68% below average) of sire No. 1085. The difference between highest and lowest index was 1183.18 kg.

When sires were evaluated by index method I_4 , then 26 Karan Swiss sires had index above the average breeding value and 25 sires had index below the average. The average breeding value of sires was 2657.36 kg. The highest index was 2967.47 kg (11.66% above average) of sire No. 1361. The lowest index was 2384.37 kg (10.27% below average) of sire No. 1085. The difference between highest and lowest index was 583.10 kg.

In case of Karan Fries breed, it was found that by index method I_1 , there were 24 sires which had index above the average breeding value, whereas 30 sires had index below the average. The average breeding value of sires was 3111.45 kg. The highest index was 4025.86 kg (29.38% above average) of sire No. 104. The

lowest index was 2191.36 kg (29.57% below average) of sire No.185. The difference between highest and lowest index was 1834.50 kg.

Evaluation by index method I_2 revealed that 29 sires had index above the average breeding value, whereas 25 sires had index below average. The average breeding value of sires was 3070.93 kg. The highest index was 3783.21 kg (23.19% above average) of sire No. 3143. The lowest index was 2495.96 kg (18.72% below average) of sire No. 185. The difference between highest and lowest index was 1287.25 kg.

On evaluation by index method I_3 , it was seen that there were 26 Karan Fries sires which had index above the average breeding value, whereas 28 sires had index below the average. The average breeding value of sires was 2805.05 kg. The highest index was 3539.00 kg (26.16% above average) of sire No. 3143. The lowest index was 2094.38 kg (25.33% below average) of sire No. 1085. The difference between highest and lowest index was 1444.62 kg.

It was found by index method I_4 that there were 26 Karan Fries sires which had index above the average breeding value, whereas 28 sires had index below average. The average breeding value of sires was 2784.71 kg. The highest index was 3060.48 kg (9.9% above average) of sire No. 3143. The lowest index was 2501.87 kg (10.51% below average) of sire No. 185. The difference between highest and lowest breeding value of sires was 608.63 kg.

4.10.5 SIRE EVALUATION BY DIFFERENT METHODS ON THE BASIS OF PREDICTED MILK YIELD UNDER FORTNIGHTLY STRATIFIED RANDOM SAMPLING SCHEME FOR KARAN SWISS AND KARAN FRIES BREEDS

The breeding values of Karan Swiss (KS) and Karan Fries (KF) breeds on the basis of their daughter's predicted lactation milk yield (PMY) under fortnightly stratified random sampling scheme are given in Table 64.

Table 64. Sire indices and their ranking based on PMY under fortnightly stratified random sampling scheme by different methods

KARAN SWISS BREED

KARAN FRIES BREED

Sire No.	I ₁		I ₂		I ₃		I ₄		Sire No. of daughters per sire	I ₁		I ₂		I ₃		I ₄		
	R	R	R	R	R	R	R	R		R	R	R	R	R	R	R	R	R
1	24	3059.63	4	3020.14	7	2633.92	27	2634.31	27	2	2922.79	39	2676.33	50	2646.21	40	2704.54	44
3	79	2710.73	18	3136.32	2	2756.82	17	2742.82	11	3	3508.91	9	3259.31	14	3133.18	7	2953.60	6
6	6	2736.17	15	2196.87	39	2850.00	10	2714.30	16	4	2702.44	48	2815.44	43	2501.89	50	2633.20	51
9	6	2751.67	13	2678.96	22	2835.83	12	2709.07	17	6	2886.86	42	2839.58	52	2353.43	51	2652.98	50
12	23	2465.61	27	2752.87	17	2633.04	28	2631.69	28	15	3024.60	31	3116.15	25	2613.20	45	2755.36	35
14	5	2293.00	35	2279.11	35	2000.00	50	2456.65	40	18	2997.90	31	3205.21	11	3031.00	14	2902.66	12
16	5	2601.80	21	2569.22	26	2757.80	10	2673.77	22	20	2740.67	43	2766.94	47	2663.81	37	2715.84	42
17	27	3026.15	6	3069.69	4	2774.85	16	2736.33	14	24	3325.25	16	3148.43	23	2769.88	29	2793.81	29
22	11	2768.64	12	2892.35	10	2838.64	11	2740.38	12	34	3185.00	22	2956.86	38	2646.20	41	2764.30	32
28	14	2394.00	30	2126.72	41	2544.07	33	2582.81	33	40	3640.00	6	3482.12	5	3212.43	4	2945.68	7
36	49	3093.16	3	3095.19	3	2800.12	14	2771.43	10	45	2705.30	47	2971.17	34	2648.90	39	2740.45	38
40	8	2321.63	34	2023.01	45	2327.25	44	2500.77	39	74	3742.17	4	3260.41	13	3072.17	10	2888.97	15
41	15	3018.27	7	2743.39	19	2731.33	21	2692.24	19	104	4158.71	1	3582.11	3	3483.71	2	3038.00	2
56	24	2576.04	23	2908.09	9	2649.67	26	2645.50	26	147	2670.57	49	2968.24	36	2654.43	38	2755.56	34
60	5	2049.40	45	1987.83	48	2099.40	47	2460.36	44	148	3227.88	20	3335.78	4	2996.31	16	2909.90	11
73	30	2222.67	38	1915.24	50	2419.93	40	2475.09	43	185	2168.45	54	2467.00	54	2148.82	54	2512.61	54
75	15	2511.80	25	2380.92	33	2534.07	35	2575.34	35	194	2343.50	53	2691.87	49	2207.00	52	2584.79	52
104	13	2589.15	22	2690.79	21	2897.54	6	2781.63	8	223	3743.00	5	3326.00	9	3191.86	5	2930.70	8
147	9	2436.78	29	2582.89	25	2742.67	20	2685.42	20	233	3166.50	23	3090.69	26	2753.29	30	2780.10	30
172	18	2037.67	47	2009.77	46	2311.11	45	2429.21	50	281	3036.58	30	2852.76	42	2738.65	31	2762.37	33
186	77	2052.97	44	1850.00	51	2478.19	36	2496.82	40	311	2947.62	37	3312.90	10	2925.62	22	2865.51	19
193	45	2212.73	39	2244.89	37	2536.91	34	2555.26	36	314	2918.73	40	2959.37	37	2603.36	47	2716.18	41
316	23	1953.48	49	2000.32	47	2381.78	41	2460.26	45	340	3015.63	32	2623.69	53	2608.11	46	2653.54	49
340	18	2101.11	42	2256.68	36	2591.78	31	2607.73	32	364	3361.61	15	3177.35	22	2933.78	21	2887.09	16
347	8	2364.00	31	2557.01	27	2676.50	24	2653.36	25	385	3414.14	11	3358.29	8	2966.86	18	2923.35	9
435	19	1989.63	48	2073.42	43	2446.21	39	2512.70	38	687	3588.70	7	3218.43	19	3177.60	6	2964.89	5
478	28	2339.11	33	2585.68	24	2747.82	19	2717.59	15	746	3529.81	8	3278.11	12	3102.94	8	2967.59	4
481	14	1820.21	50	1919.67	49	2377.21	42	2486.67	41	821	2925.00	38	2806.58	45	2551.40	49	2738.78	39
835	6	2061.00	43	2352.82	34	2472.33	37	2575.36	34	2507	2643.65	50	2777.35	46	2673.90	36	2703.38	45
848	16	2168.25	41	2405.29	29	2463.19	38	2530.67	37	2981	2713.17	46	3026.46	31	2687.92	35	2751.47	36
851	13	2265.00	36	2398.36	30	2626.62	29	2630.52	29	3005	3185.13	21	3377.50	7	3092.50	9	2913.44	10
947	25	2343.16	32	2691.51	20	2625.72	30	2628.57	30	3026	2748.64	44	3038.88	29	2696.50	33	2751.27	37

contd..... table 64

KARAN SWISS BREED										KARAN FRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1039	5	2212.40	40	2178.05	40	2091.00	49	2457.65	47	3041	13	2869.85	41	3066.83	28	2858.00	25	2832.43	25
1063	23	2779.35	11	2750.68	18	2784.83	15	2738.56	13	3107	8	3384.50	13	3476.99	6	3049.00	13	2897.35	13
1065	16	2049.19	46	2123.07	42	2334.44	43	2452.36	49	3143	8	3912.75	2	3826.06	1	3574.00	1	3092.30	1
1085	7	1644.29	51	2024.15	44	1986.43	51	2372.96	51	3168	9	3126.00	26	3254.43	15	2699.44	32	2764.53	31
1089	12	2810.42	10	2879.93	12	3009.75	2	2836.80	2	3217	6	3145.17	24	3240.02	17	3057.17	11	2884.31	17
1206	23	2506.39	26	2395.68	32	2672.52	25	2661.03	24	3222	20	2740.85	45	2974.94	33	2691.90	34	2738.75	40
1216	10	2828.50	9	2786.71	16	2995.10	3	2812.60	6	3231	8	3070.50	29	3186.06	20	2921.75	23	2850.14	23
1258	25	2729.60	16	3149.65	1	2904.36	5	2825.79	4	3256	7	3858.14	3	3623.94	2	3360.29	3	2995.96	3
1361	16	3055.31	5	2868.02	14	3121.19	1	2930.90	1	3298	5	3105.00	28	3148.32	24	3055.00	12	2874.49	18
1416	10	2736.50	14	2424.76	28	2580.70	32	2608.50	31	4012	11	3363.45	14	3036.12	30	2934.91	20	2864.81	20
1561	28	2925.46	8	2223.24	38	2698.14	22	2681.24	21	4021	6	3254.33	18	2940.83	40	2776.33	28	2798.17	28
1617	11	3158.64	1	2927.73	8	2989.27	4	2818.08	5	4051	9	3421.78	10	3179.23	21	3028.44	15	2895.90	14
1621	25	2715.28	17	3069.38	5	2870.32	9	2801.77	7	4066	8	3252.13	19	2941.41	39	2904.75	24	2843.80	24
1622	31	2691.58	19	3059.19	6	2891.48	8	2827.55	3	4069	7	3112.14	27	2970.49	35	2852.86	26	2823.20	26
1626	12	2666.17	20	2885.39	11	2892.50	7	2773.60	9	4075	12	2987.08	34	2976.50	32	2580.50	48	2701.08	46
1627	21	2546.33	24	2869.47	13	2682.43	23	2666.98	23	4081	15	2975.27	35	2809.65	44	2623.13	43	2710.86	43
1655	7	3107.14	2	2826.25	15	2814.29	13	2707.77	18	4093	20	2958.10	36	2908.95	41	2619.10	44	2695.37	47
3232	5	2438.40	28	2648.67	23	2148.20	46	2476.29	42	4101	5	3412.80	12	3244.47	16	2992.00	17	2857.51	22
3310	5	2229.20	37	2396.24	31	2095.00	48	2458.89	46	4102	8	3293.88	17	3080.31	27	2958.88	19	2863.92	21
										4121	17	3139.53	25	3235.45	18	2808.06	27	2807.92	27
										4226	8	2560.63	52	2659.06	51	2190.00	53	2578.43	53
										9815	44	2592.98	51	2701.74	48	2644.36	42	2682.82	48

where, R = Rank of the sire; I₁ = Daughter's average method; I₂ = Contemporary comparison method; I₃ = Least square analysis method
I₄ = BLUP method

In case of Karan Swiss breed, it was found that by index method I_1 , there were 26 sires which had index above the average breeding value, whereas 25 sires had index below the average. The average breeding value of sires was 2493.46 kg. The highest index was 3158.64 kg (26.67% above average) of sire No. 1617. The lowest index was 1644.29 kg (34.05% below average) of sire No. 1085. The difference between two extreme breeding values of indices was 1514.35 kg.

Evaluation by index method I_2 showed that 27 sires had index above the average breeding value and 24 sires had index below the average. The average breeding value of KS sires was 2527.08 kg. The highest index was 3149.65 kg (24.63% above average) of sire No. 1258. The lowest index was 1850.00 kg (26.79% below average) of sire No. 186. The difference between highest and lowest index was 1299.65 kg.

Evaluation by index method I_3 revealed that there were 30 Karan Swiss sires which had index above the average breeding value, whereas 21 sires had index below average. The average breeding value of sires was 2611.90 kg. The highest index was 3121.09 kg (19.49% above average) of sire No. 1361. The lowest index was 1986.43 kg (23.94% below average) of sire No. 1085. The difference between the two extreme breeding values of sires was 1134.76 kg.

It was found by index method I_4 that there were 26 KS sires which had index above the average breeding value, whereas 25 sires had index below average. The average breeding value of sires was 2635.41 kg. The highest index was 2930.90 kg (11.21% above average) of sire No. 1361. The lowest index was 2372.96 kg (9.95% below average) of sire No. 1085. The difference between highest and lowest indexes was 557.94 kg.

In case of Karan Fries breed, it was found that by index method I_1 , there were 26 sires which had index above the average breeding value, whereas 28 sires had index below the average.

In case of Karan Swiss breed, it was found that by index method I_1 , there were 26 sires which had index above the average breeding value, whereas 25 sires had index below the average. The average breeding value of sires was 2493.46 kg. The highest index was 3158.64 kg (26.67% above average) of sire No. 1617. The lowest index was 1644.29 kg (34.05% below average) of sire No. 1085. The difference between two extreme breeding values of indices was 1514.35 kg.

Evaluation by index method I_2 showed that 27 sires had index above the average breeding value and 24 sires had index below the average. The average breeding value of KS sires was 2527.08 kg. The highest index was 3149.65 kg (24.63% above average) of sire No. 1258. The lowest index was 1850.00 kg (26.79% below average) of sire No. 186. The difference between highest and lowest index was 1299.65 kg.

Evaluation by index method I_3 revealed that there were 30 Karan Swiss sires which had index above the average breeding value, whereas 21 sires had index below average. The average breeding value of sires was 2611.90 kg. The highest index was 3121.09 kg (19.49% above average) of sire No. 1361. The lowest index was 1986.43 kg (23.94% below average) of sire No. 1085. The difference between the two extreme breeding values of sires was 1134.76 kg.

It was found by index method I_4 that there were 26 KS sires which had index above the average breeding value, whereas 25 sires had index below average. The average breeding value of sires was 2635.41 kg. The highest index was 2930.90 kg (11.21% above average) of sire No. 1361. The lowest index was 2372.96 kg (9.95% below average) of sire No. 1085. The difference between highest and lowest indexes was 557.94 kg.

In case of Karan Fries breed, it was found that by index method I_1 , there were 26 sires which had index above the average breeding value, whereas 28 sires had index below the average.

bulls on the basis of their daughter's lactation milk yield under monthly stratified random sampling scheme are given in Table 65.

In case of Karan Swiss breed, it was found that by index method I_1 , there were 25 sires which had index above the average breeding value, whereas 26 sires had index below the average. The average breeding value of sires was 2501.09 kg. The highest index was 3117.86 kg (24.66% above average) of sire No. 1655. The lowest index was 1642.86 kg (34.31% below average) of sire No. 1085. The difference between highest and lowest index was 1475.00 kg.

Evaluation by index method I_2 showed that 27 sires had index above the average breeding value and 24 sires had index below the average. The average breeding value of sires was 2533.76 kg. The highest index was 3157.60 kg (24.62% above average) of sire No. 1258. The lowest index was 1840.65 kg (27.35% below average) of sire No. 186. The difference between highest and lowest breeding value of sires was 1316.95 kg.

It was found by index method I_3 that there were 28 KS sires which had index above the average breeding value of sires, whereas 23 sires had index below the average. The average breeding value of sires was 2620.29 kg. The highest index was 3119.19 kg (18.73% above average) of sire No. 1361. The lowest index was 1993.29 kg (23.92% below average) of sire No. 1085. The difference between highest and lowest index was 1117.90 kg.

When sires were evaluated by index method I_4 , then there were 26 sires which had index above the average breeding value and 25 sires had index below the average. The average breeding value of KS sires was 2642.52 kg. The highest index was 2923.21 kg (10.62% above average) of sire No. 1361. The lowest index was 2385.91 kg (9.71% below average) of sire No. 1085. The difference between highest and lowest indexes was 537.30 kg.

Table 65. Sire indices and their ranking based on PNY under monthly stratified random sampling scheme by different methods

KARAN SWISS BREED										KARAN FRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1	24	3042.38	5	2971.26	7	2600.46	31	2613.42	32	2	24	2956.42	38	2740.24	49	2675.79	37	2727.25	43
3	79	2706.94	18	3120.54	3	2757.96	20	2744.20	13	3	11	3482.27	9	3209.56	16	3102.55	10	2929.88	7
6	6	2680.50	20	2140.17	41	2777.50	17	2690.92	21	4	18	2708.89	46	2842.51	45	2515.83	50	2650.20	51
9	6	2719.67	17	2647.81	23	2805.00	15	2700.84	19	6	7	2838.43	42	2679.18	52	2348.57	51	2664.01	50
12	23	2455.30	28	2738.16	19	2630.65	27	2634.47	28	15	5	2991.60	34	3104.31	27	2556.80	48	2745.80	37
14	5	2302.40	36	2280.60	35	2081.80	50	2464.00	49	18	10	2960.60	36	3235.74	12	3011.80	14	2887.45	14
16	5	2689.00	19	2623.85	24	2843.40	11	2706.37	18	20	24	2785.00	43	2822.06	46	2701.96	32	2743.11	38
17	27	3018.48	7	3047.46	6	2762.48	18	2728.42	14	24	8	3169.38	14	3177.82	21	2799.25	28	2804.29	28
27	11	2780.45	12	2892.35	10	2853.00	10	2749.21	12	34	5	3225.40	20	2983.47	34	2660.20	40	2771.09	31
28	14	2443.50	30	2202.42	40	2585.71	33	2610.39	33	40	7	3630.29	5	3487.23	5	3202.43	5	2930.20	6
36	49	3117.04	2	3127.14	2	2811.27	14	2780.94	7	45	10	2663.90	48	2938.83	36	2616.40	45	2732.07	40
40	8	2355.50	32	2065.81	44	2339.75	44	2513.08	39	74	6	3615.83	6	3164.29	23	2927.50	22	2840.71	24
41	15	3080.93	3	2829.06	15	2788.93	16	2728.00	15	104	7	4146.86	1	3531.39	3	3459.29	2	3010.25	2
56	24	2591.54	22	2923.42	9	2672.96	25	2663.55	25	147	7	2572.29	51	2913.12	39	2553.14	49	2727.80	42
60	5	2123.00	42	2051.77	45	2152.80	48	2486.61	45	148	16	3241.81	18	3522.66	4	3007.56	15	2908.97	12
73	30	2233.33	38	1939.14	49	2431.30	40	2486.88	44	185	11	2163.45	54	2510.73	54	2145.82	54	2532.00	54
75	15	2514.07	25	2390.30	29	2532.07	34	2577.95	35	194	8	2354.00	53	2736.29	50	2227.00	52	2609.23	52
104	13	2568.38	23	2657.22	22	2874.92	3	2769.93	9	223	7	3794.29	4	3332.92	9	3226.57	4	2937.79	4
147	9	2449.67	29	2596.56	25	2759.00	19	2695.73	20	233	14	3237.71	19	3160.47	24	2808.71	26	2807.81	26
172	18	2048.89	46	2022.68	48	2318.28	45	2439.25	50	281	26	3044.19	31	2844.25	44	2748.77	30	2770.52	32
186	77	2050.42	45	1840.65	51	2475.00	36	2495.45	42	311	13	2949.85	39	3304.95	10	2939.69	21	2867.57	18
193	45	2205.49	40	2232.20	38	2528.00	35	2550.03	36	314	11	2919.27	40	2956.85	35	2586.45	47	2715.26	45
316	23	1969.70	49	2028.24	47	2396.87	41	2474.98	46	340	46	3060.46	30	2704.46	51	2647.63	42	2687.69	49
340	18	2118.83	43	2282.47	36	2609.22	30	2661.59	30	364	23	3348.26	16	3134.67	25	2914.52	23	2871.34	17
347	8	2390.88	31	2574.30	26	2695.88	24	2665.36	24	385	36	3442.69	11	3379.71	7	2990.00	17	2935.04	5
435	19	2008.53	48	2109.03	43	2468.95	37	2531.50	37	687	10	3537.90	7	3165.86	22	3118.60	7	2929.42	8
478	28	2331.46	33	2572.90	27	2742.14	21	2714.61	17	746	16	3474.44	10	3201.30	18	3040.38	12	2925.83	9
481	14	1806.93	50	1921.31	50	2369.07	42	2487.47	43	821	5	2967.00	35	2855.93	43	2590.40	46	2754.05	35
835	6	2046.83	47	2354.53	33	2466.50	38	2579.24	34	2507	48	2656.58	49	2811.95	47	2684.21	35	2714.06	46
848	16	2137.44	41	2374.01	31	2438.50	39	2520.25	38	2981	12	2703.83	47	2994.16	33	2657.42	41	2741.52	39
851	13	2236.00	37	2362.46	32	2600.31	32	2619.39	31	3005	8	3211.63	21	3366.56	8	3114.25	8	2911.78	11
947	25	2327.08	34	2666.46	21	2615.20	29	2623.40	29	3036	14	2772.79	44	3074.25	29	2717.86	31	2764.59	33

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KARAN SWISS BREED										KARAN PRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1039	5	2315.20	35	2260.59	37	2184.80	47	2496.88	41	3041	13	2904.08	41	3116.33	26	2901.46	24	2850.19	23
1063	23	2811.30	11	2802.72	17	2826.65	13	2768.11	10	3107	8	3349.63	15	3416.70	6	3034.25	13	2884.48	15
1065	16	2054.06	44	2139.24	42	2346.56	43	2465.32	48	3143	8	3809.88	3	3679.45	1	3476.75	1	3035.46	1
1085	7	1642.86	51	2046.72	46	1993.29	51	2385.91	51	3168	9	3122.89	27	3235.21	13	2686.22	33	2762.46	34
1089	12	2864.67	9	2947.00	8	3071.42	2	2869.18	2	3217	6	3160.50	24	3233.43	14	3082.17	11	2883.92	16
1206	23	2473.30	27	2348.57	34	2646.22	26	2644.99	26	3222	20	2711.75	45	2938.17	37	2666.85	38	2727.98	41
1216	10	2827.50	10	2782.09	18	2999.70	3	2814.92	6	3231	8	3185.38	28	3209.13	17	2961.88	19	2859.77	21
1258	25	2737.76	14	3157.60	1	2918.28	5	2835.57	4	3256	7	3829.43	2	3560.86	2	3331.71	3	2970.58	3
1361	16	3036.69	6	2831.56	14	3111.19	1	2923.21	1	3298	5	3207.20	22	3191.45	19	3160.60	6	2893.42	13
1416	10	2772.90	13	2467.57	28	2627.20	28	2635.15	27	4012	11	3378.18	13	3058.50	30	2952.18	20	2867.37	19
1561	28	2915.18	8	2206.14	39	2697.82	23	2682.59	23	4021	6	3166.33	23	2907.93	40	2685.33	34	2772.95	30
1617	11	3070.55	4	2818.18	16	2899.55	6	2772.68	8	4051	9	3382.33	8	3239.53	11	3185.33	9	2916.73	10
1621	25	2728.40	15	3083.34	5	2890.52	7	2816.15	5	4066	8	3153.63	25	2872.15	42	2887.13	27	2807.03	27
1622	31	2723.03	15	3098.29	4	2925.68	4	2853.02	3	4069	7	3142.43	26	2996.83	32	2886.57	25	2831.81	25
1626	12	2651.17	21	2854.06	12	2872.92	9	2764.20	11	4075	12	3029.67	33	3032.98	31	2620.83	43	2725.57	44
1627	21	2563.43	24	2887.24	11	2704.29	22	2683.46	22	4081	15	3035.47	32	2895.80	41	2683.67	36	2746.25	36
1655	7	3117.86	1	2832.99	13	2836.14	12	2719.05	16	4093	20	2960.05	37	2929.97	38	2619.85	44	2701.42	47
3232	5	2477.80	26	2679.39	20	2196.20	46	2500.52	40	4101	5	3414.00	12	3225.05	15	2991.20	16	2851.99	22
3310	5	2221.40	39	2382.26	30	2101.60	49	2470.33	47	4102	8	3317.00	17	3180.18	28	2983.75	18	2867.28	20
										4121	17	3096.88	29	3185.21	20	2767.00	29	2785.97	29
										4226	8	2521.13	52	2663.83	53	2191.63	53	2583.37	53
										9815	44	2611.02	50	2752.55	48	2664.32	39	2701.41	48

where, R = Rank of the sire; I₁ = Daughter's average method; I₂ = Contemporary comparison method; I₃ = Least square analysis method
 I₄ = BLUP method

In case of Karan Fries breed, it was found that by index method I₁, there were 27 sires which had index above the average breeding value, whereas same number of sires had index below average. The average breeding value of sires was 3117.70 kg. The highest index was 4146.86 kg (33.01% above average) of sire No. 104. The lowest index was 2163.45 kg (30.60% below average) of sire No. 185. The difference between highest and lowest index was 1983.41 kg.

Sire evaluation by index method I₂ revealed that there were 28 sires which had index above the average breeding value of sires, whereas 26 sires had index below the average. The average breeding value of sires was 3079.06 kg. The highest index was 3679.45 kg (19.49% above average) of sire No. 3143. The lowest index was 2704.46 kg (12.16% below average) of sire No. 185. The difference between highest and lowest index was 974.99 kg.

It was found by index method I₃ that there were 25 sires which had index above the average breeding value of KF sires, whereas 29 sires had index below the average. The average breeding value of sires was 2824.41 kg. The highest index was 3476.75 kg (23.09% above average) of sire No. 3143. The lowest index was 2348.57 kg (16.84% below average) of sire No. 185. The difference between highest and lowest index was 1128.18 kg.

When sires were evaluated by index method I₄, then there were 27 sires which had index above the average breeding value of sires, whereas same number of sires had index below average. The average breeding value of KF sires was 2806.96 kg. The highest index was 3035.46 kg (8.14% above average) of sire No. 3143. The lowest index was 2650.20 kg (5.58% below average) of sire No. 185. The difference between highest and lowest indexes was 385.26 kg.

4.10.7 SIRE EVALUATION BY DIFFERENT METHODS ON THE BASIS OF PREDICTED LACTATION YIELD UNDER BIMONTHLY STRATIFIED RANDOM SAMPLING SCHEME FOR KARAN SWISS AND KARAN FRIES BREEDS

The breeding values of sires for Karan Swiss (KS) and Karan Fries (KF) breeds on the basis of their daughter's predicted lactation milk yield under bimonthly stratified random sampling scheme are given in Table 66.

Table 66. Sire indices and their ranking based on PMY under bimonthly stratified random sampling scheme by different methods

KARAN SWISS BREED										KARAN FRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1	24	3015.88	3	2981.01	7	2517.88	33	2542.27	33	2	24	2923.71	37	2679.21	51	2657.79	41	2718.53	44
3	79	2757.76	11	3261.80	1	2819.87	11	2798.02	6	3	11	3424.18	12	3150.42	22	3059.73	11	2922.70	11
6	6	2688.67	18	2028.40	45	2374.83	42	2514.43	35	4	18	2712.22	47	2841.48	42	2542.56	48	2665.91	51
9	6	2702.00	16	2665.29	21	2809.17	13	2687.62	19	6	7	2853.43	40	2682.06	50	2374.00	51	2674.10	48
12	23	2455.91	30	2750.25	16	2640.78	26	2631.26	26	15	5	3007.80	33	3117.36	26	2606.60	44	2764.48	36
14	5	2352.00	33	2280.47	35	1927.20	49	2364.92	48	18	10	2886.20	39	3172.73	20	2935.40	20	2866.35	19
16	5	2676.00	19	2637.91	23	2849.20	9	2693.31	16	20	24	2763.54	44	2798.00	46	2696.88	38	2742.88	39
17	27	3011.93	4	3063.63	5	2718.93	20	2690.88	17	24	8	3395.13	13	3210.90	17	2816.13	29	2817.89	29
22	11	2713.45	15	2866.79	12	2812.18	12	2719.66	12	34	5	3110.40	28	2934.82	39	2565.40	47	2753.98	37
28	14	2511.29	27	2214.81	38	2418.07	37	2492.18	38	40	7	3733.57	5	3494.80	5	3283.57	4	2970.01	6
36	49	3156.33	2	3199.86	2	2746.37	16	2724.71	10	45	10	2632.30	50	2910.96	40	2579.90	45	2721.43	43
40	8	2374.75	32	2003.94	47	2108.25	47	2372.90	47	74	6	3750.50	4	3258.39	14	3056.17	13	2828.27	15
41	15	3011.53	5	2768.43	15	2712.80	22	2673.07	21	104	7	4205.00	1	3580.21	3	3523.57	2	3047.99	2
56	24	2583.25	23	2941.54	9	2668.83	25	2651.96	25	147	7	2715.43	46	3008.78	33	2697.14	37	2779.28	33
60	5	2223.80	38	2041.46	44	1922.80	50	2363.42	49	148	16	3263.50	19	3552.31	4	3015.19	16	2921.79	12
73	30	2189.37	41	1837.62	50	2399.37	39	2447.45	43	185	11	2192.36	54	2517.30	54	2207.00	53	2555.15	54
75	15	2601.87	22	2499.45	28	2621.27	27	2615.91	27	194	8	2429.13	53	2785.73	47	2345.75	52	2650.82	52
104	13	2543.15	25	2660.19	22	2865.46	8	2759.48	9	223	7	3730.57	6	3304.36	10	3196.86	5	2941.81	7
147	9	2468.67	29	2610.98	25	2768.78	14	2687.62	18	233	14	3239.71	21	3155.25	21	2786.64	30	2803.04	30
172	18	2033.06	45	1998.49	48	2306.61	43	2407.10	45	281	26	3016.04	31	2817.60	45	2746.42	31	2772.39	35
186	77	2032.64	46	1821.05	51	2472.10	34	2486.25	39	311	13	2924.85	36	3280.91	12	2890.23	25	2852.57	23
193	45	2197.84	40	2227.68	37	2541.22	31	2552.20	31	314	11	2927.64	35	2953.50	36	2575.18	46	2713.84	46
316	23	1961.83	49	2005.70	46	2395.13	40	2455.05	42	340	46	3033.24	30	2657.34	52	2623.76	43	2670.53	50
340	18	3064.00	44	2211.01	39	2523.39	32	2551.38	32	364	23	3319.70	16	3091.03	27	2890.30	24	2862.67	21
347	8	2429.63	31	2634.91	24	2715.25	21	2657.79	24	385	36	3483.42	10	3449.96	6	3032.17	15	2970.82	5
435	19	1996.32	47	2077.16	42	2443.53	35	2496.22	37	687	10	3498.50	8	3127.62	23	3082.80	8	2926.52	10
478	28	2311.79	34	2541.86	27	2723.32	19	2694.89	15	746	16	3552.69	7	3311.91	9	3113.56	7	2973.32	4
481	14	1773.57	50	1840.70	49	2130.93	46	2317.80	51	821	5	2805.60	42	2762.53	48	2414.20	50	2715.18	45
835	6	1967.00	48	2237.90	36	2381.67	41	2517.21	34	2507	48	2679.42	49	2838.01	44	2701.54	35	2728.71	42
848	16	3147.06	42	2352.68	32	2437.75	36	2498.85	36	2981	12	2730.25	45	3026.57	31	2718.33	34	2773.33	34
851	13	2238.62	37	2322.44	33	2595.00	29	2599.89	29	3005	8	3211.13	22	3391.28	8	3137.25	6	2931.95	8
947	25	2300.68	35	2600.52	26	2603.96	28	2604.81	28	3026	14	2774.86	43	3083.31	28	2742.64	32	2781.43	32

contd..... table 66

KARAN SWISS BREED										KARAN FRIES BREED									
Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R	Sire No.	No. of daughters per sire	I ₁	R	I ₂	R	I ₃	R	I ₄	R
1039	5	2209.20	39	2156.50	41	1919.40	51	2362.14	50	3041	13	2808.08	41	3032.77	30	2844.69	27	2831.05	27
1063	23	2746.83	13	2719.84	13	2765.17	15	2720.54	11	3107	8	3343.88	14	3431.42	7	2982.63	18	2877.04	17
1065	16	2080.19	43	2179.12	40	2407.06	38	2479.13	40	3143	8	3945.38	2	3847.30	1	3637.13	1	3109.59	1
1085	7	1735.57	51	2069.39	43	2107.71	48	2389.10	46	3168	9	3192.67	23	3298.91	11	2733.56	33	2786.18	31
1089	12	2841.25	9	2959.68	8	3067.42	2	2869.69	2	3217	6	3119.67	26	3216.65	15	3069.50	10	2892.12	14
1206	23	2486.70	28	2385.20	30	2678.26	24	2658.13	23	3222	20	2704.65	48	2946.25	37	2700.10	36	2750.03	38
1216	10	2762.30	10	2748.70	17	2955.20	3	2789.88	7	3231	8	3115.88	27	3214.89	16	3001.50	17	2883.73	16
1258	25	2698.56	17	3141.72	3	2899.24	5	2821.60	5	3256	7	3890.14	3	3634.06	2	3398.00	3	3007.29	3
1361	16	3001.69	6	2833.54	14	3082.50	1	2910.85	1	3298	5	3038.00	29	3125.81	24	3032.40	14	2873.53	18
1416	10	2757.20	12	2439.90	29	2588.00	30	2597.09	30	4012	11	3489.91	9	3125.24	25	3072.18	9	2928.11	9
1561	28	2975.86	7	2293.47	14	2731.43	18	2701.06	14	4021	6	3295.33	17	2954.99	35	2823.00	34	2820.06	28
1617	11	2964.00	8	2317.90	19	2736.18	17	2677.92	20	4051	9	3450.33	11	3201.17	18	3058.00	12	2910.34	13
1621	25	2738.44	14	3124.33	4	2903.88	4	2825.08	3	4066	8	3281.88	18	2937.86	38	2942.00	19	2862.69	20
1622	31	2654.97	20	3034.49	6	2886.13	7	2823.09	4	4069	7	3150.57	25	3012.13	32	2909.14	22	2848.24	24
1626	12	2647.50	21	2926.94	10	2896.92	6	2772.36	8	4075	12	2894.92	38	2887.13	41	2494.00	49	2671.84	49
1627	21	2537.48	26	2886.37	11	2695.86	23	2669.11	22	4081	15	2997.67	34	2841.27	43	2656.40	42	2736.32	40
1655	7	3180.29	1	2860.53	13	2844.71	10	2710.82	13	4093	20	3010.60	32	2990.07	34	2672.05	39	2733.75	41
3232	5	2543.20	24	2693.92	20	2223.80	44	2470.68	41	4101	5	3327.60	15	3181.32	19	2902.20	23	2840.21	26
3310	5	2286.80	36	2377.63	31	2140.40	45	2440.89	44	4102	8	3257.75	20	3055.62	29	2931.88	21	2858.96	22
										4121	17	3181.12	24	3278.68	13	2864.06	26	2843.26	25
										4226	8	2476.13	52	2627.01	53	2110.13	54	2567.08	53
										9815	44	2622.93	51	2754.45	49	2670.41	40	2707.27	47

where, R = Rank of the sire; I₁ = Daughter's average method; I₂ = Contemporary comparison method; I₃ = Least square analysis method
 I₄ = BLUP method

In case of Karan Swiss breed, it was found that by index method I_1 , there were 27 sires which had index above the average breeding value of sires, whereas 24 sires had index below the average. The average breeding value of sires was 2496.85 kg. The highest index was 3180.29 kg (27.27% above average) of sire No. 1685. The lowest index was 1735.57 kg (30.48% below average) of sire No. 1085. The difference between highest and lowest index was 1444.72 kg.

Sire evaluation by index method I_2 showed that 27 sires had index above the average breeding value and 24 sires had index below average. The average breeding value of sires was 2523.82 kg. The highest index was 3261.80 kg (29.24% above average) of sire No. 3. The lowest index was 1821.05 kg (27.84% below average) of sire No. 186. The difference between highest and lowest index was 1440.80 kg.

When sires were evaluated by index method I_3 , then there were 30 sires which had index above the average breeding value of sires; whereas 21 sires had index below the average. The average breeding value of KS sires was 2578.45 kg. The highest index was 3082.50 kg (19.54% above average) of sire No. 1361. The lowest index was 1919.40 kg (25.55% below average) of sire No. 1039. The difference between highest and lowest index was 1163.10 kg.

It was found by index method I_4 that there were 27 sires which had index above the average breeding value of sires, whereas 24 sires had index below the average. The average breeding value of KS sires was 2607.05 kg. The highest index was 2910.85 kg (11.65% above average) of sire No. 1361. The lowest index was 2317.80 kg (11.09% below average) of sire No. 481. The difference between highest and lowest index was 593.05 kg.

In case of Karan Fries breed, it was found that by index method I_1 , there were 25 sires which had index above the average breeding value of sires, whereas 29 sires had index below the average. The average breeding value of sires was 3120.76 kg.

The highest index was 4205.00 kg (34.74% above average) of sire No. 104. The lowest index was 2192.36 kg (29.74% below average) of sire No. 185. The difference between highest and lowest index was 2012.64 kg.

Sire evaluation by index method I_2 revealed that 27 sires had index above the average breeding value of sires and same number of sires had index below average. The average breeding value of sires was 3084.09 kg. The highest index was 3847.30 kg (24.74% above average) of sire No. 3143. The lowest index was 2517.30 kg (18.37% below average) of sire No. 185. The difference between highest and lowest index was 1330.00 kg.

When sires were evaluated by index method I_3 , then there were 27 sires which had index above the average breeding value, whereas same number of sires had index below the average. The average breeding value of KF sires was 2835.54 kg. The highest index was 3637.13 kg (28.26% above average) of sire No. 3143. The lowest index was 2110.13 kg (25.58% below average) of sire No. 4226. The difference between highest and lowest breeding values of sires was 1527.00 kg.

Further, it was found that by index method I_4 , there were 28 sires which had index above the average breeding value of sires, whereas 26 sires had index below average. The average breeding value of KF sires was 2818.85 kg. The highest index was 3109.59 kg (10.31% above average) of sire No. 3143. The lowest index was 2555.15 kg (9.35% below average) of sire No. 185. The difference between highest and lowest index was 554.44 kg.

Discussion on average breeding value of sires by different methods under various sampling schemes

In the above, the results of evaluation of breeding value of sires by four methods on the basis of daughter's observed first lactation milk yield (OMY) and first lactation milk yield predicted under six sampling schemes were presented. The average

breeding values of sires alongwith the range of breeding values are summarized in Table 67 for Karan Swiss and Karan Fries breeds.

It was found that for Karan Swiss, the highest average breeding value was obtained for the method I₄ (BLUP) under all sampling schemes and OMY; the lowest being for method I₁ (daughter's average) (Table 67). The range of breeding values for method I₄ was lowest and for method I₁ was highest for all the sampling schemes and OMY. This indicates that the sampling schemes did not have any effect on the relative effectiveness of the sire evaluation methods. The sampling scheme S₃, however, gave the highest average breeding value and range of breeding values for every method. Therefore, for Karan Swiss data it may be inferred that least discrimination among sires was obtained by BLUP method and maximum discrimination by daughter's average index method. The sampling scheme S₃ (bimonthly systematic sampling) provided the highest discrimination.

For Karan Fries cattle, the highest average breeding value was obtained for the method I₁ (daughter's average) under all sampling schemes and OMY, the lowest being for method I₄ (BLUP) (Table 67). The range of breeding values for method I₄ was lowest and for method I₁ was highest for all the sampling schemes and OMY. This indicates that the sampling schemes did not have any effect on the relative effectiveness of the sire evaluation methods. The sampling method S₂ (monthly systematic scheme) however, gave the highest average breeding value and range of breeding values. Therefore, for Karan Fries data, it may be inferred that least discrimination among sires was obtained by BLUP and maximum discrimination by daughter's average index method. The sampling scheme S₂ (monthly systematic sampling) provided highest discrimination.

Table 67. A summary table of sire evaluation by different methods under various sampling schemes.

Trait	Method	KARAN SWISS BREED						KARAN PRYES BREED					
		Average of breeding value (kg)	No. of sires above average	No. of sires below average	Maximum breeding value (kg)	Minimum breeding value (kg)	Range of breeding value (kg)	Average of breeding value (kg)	No. of sires above average	No. of sires below average	Maximum breeding value (kg)	Minimum breeding value (kg)	Range of breeding value (kg)
OMY	I ₁	2494	29	22	3106(25%)	1670(33%)	1436	3114	25	29	4110(31%)	2558(18%)	1552
	I ₂	2526	27	24	3158(25%)	1832(27%)	1327	3077	29	25	3813(24%)	2454(20%)	1360
	I ₃	2613	22	29	3104(19%)	2018(23%)	1086	2820	26	28	3576(27%)	2121(24%)	1455
	I ₄	2636	23	28	2920(11%)	2389(9%)	530	2801	26	28	3085(10%)	2499(10%)	585
S ₁	I ₁	2492	25	26	3111(25%)	1665(33%)	1445	3121	25	29	4108(31%)	2584(17%)	1524
	I ₂	2525	27	24	3139(24%)	1821(28%)	1318	3081	28	26	3835(24%)	2456(20%)	1379
	I ₃	2614	28	23	3135(20%)	2018(23%)	1118	2825	26	28	3582(27%)	2131(25%)	1452
	I ₄	2637	26	25	2935(11%)	2392(9%)	543	2806	26	28	3096(10%)	2501(10%)	595
S ₂	I ₁	2493	27	24	3106(25%)	1658(34%)	1448	3121	25	29	4159(33%)	2138(32%)	2021
	I ₂	2527	27	24	3158(25%)	1817(28%)	1341	3085	28	26	3851(25%)	2444(21%)	1407
	I ₃	2617	29	22	3126(20%)	2005(24%)	1121	2825	26	28	3585(27%)	2094(26%)	1491
	I ₄	2641	28	23	2967(12%)	2383(9%)	553	2806	27	27	3102(11%)	2493(11%)	554
S ₃	I ₁	2497	26	25	3104(28%)	1619(35%)	1575	3111	24	30	4026(29%)	2191(30%)	1834
	I ₂	2528	26	25	3193(27%)	1828(28%)	1364	3070	29	25	3783(23%)	2496(19%)	1287
	I ₃	2634	28	23	3166(20%)	1984(25%)	1183	2805	26	28	3539(26%)	2094(25%)	1444
	I ₄	2657	26	25	2967(12%)	2384(10%)	583	2704	26	28	3060(10%)	2502(11%)	609

contd.....

contd..... table 67

Trait	Method	KARAN SWISS BREED					KARAN FRIES BREED						
		Average of breeding value (kg)	No. of sires above average	No. of sires below average	Maximum breeding value (kg)	Minimum breeding value (kg)	Range of breeding value (kg)	Average of breeding value (kg)	No. of sires above average	No. of sires below average	Maximum breeding value (kg)	Minimum breeding value (kg)	Range of breeding value (kg)
S ₄	I ₁	2494	26	25	3159(27%)	1644(34%)	1514	3118	26	28	4158(33%)	2168(30%)	1990
	I ₂	2527	27	24	3149(25%)	1850(27%)	1300	3080	27	27	3826(24%)	2467(20%)	1359
	I ₃	2612	30	21	3121(20%)	1986(24%)	1115	2827	26	28	3574(26%)	2148(24%)	1425
	I ₄	2635	26	25	2930(11%)	2373(10%)	557	2808	27	27	3092(10%)	2512(10%)	579
S ₅	I ₁	2501	25	26	3117(25%)	1643(34%)	1457	3110	27	27	4147(33%)	2163(30%)	1983
	I ₂	2534	27	24	3158(25%)	1840(27%)	1317	3079	28	26	3679(19%)	2704(12%)	975
	I ₃	2620	28	23	3111(19%)	1993(24%)	1118	2824	25	29	3476(23%)	2349(17%)	1128
	I ₄	2643	26	25	2923(11%)	2385(9%)	537	2806	27	27	3035(8%)	2650(6%)	385
S ₆	I ₁	2496	27	24	3180(27%)	1735(30%)	1444	3120	25	29	4205(35%)	2192(30%)	2012
	I ₂	2523	27	24	3262(29%)	1821(28%)	1440	3084	27	27	3847(25%)	2517(18%)	1330
	I ₃	2578	30	21	3082(20%)	1919(26%)	1163	2835	27	27	3637(28%)	2110(26%)	1527
	I ₄	2607	27	24	2910(12%)	2318(11%)	593	2818	28	26	3109(10%)	2555(9%)	554

4.11 EFFICIENCY OF VARIOUS SIRE EVALUATION METHODS ON THE BASIS OF OBSERVED (OMY) AND PREDICTED (PMY) LACTATION MILK YIELD UNDER SYSTEMATIC AND STRATIFIED RANDOM SAMPLING SCHEMES WITH THREE TESTING INTERVALS

An efficient method of sire evaluation should have a minimum error variance, i.e., within sire variance of the index values. The sire evaluation method which gives the lowest error variance was considered to be most efficient. The error variances of four sire evaluation methods on the basis of observed (OMY) and predicted (PMY) lactation milk yield under fortnightly, monthly and bimonthly systematic and stratified random sampling schemes are presented in Table 68 for Karan Swiss and Karan Fries breeds.

For Karan Swiss breed, it was found that contemporary comparison method I_2 had the lowest error variance for OMY as well as PMY's under all the six sampling schemes. This was followed by least square analysis method (I_3), BLUP method (I_4) and least efficient was daughter's average method (I_1) which had the highest error variance. Further for I_2 the lowest error variance was obtained when observed lactation milk yield (OMY) was considered as compared to PMY's under various sampling schemes. There was increase in error variance with the increase in interval of recording for both systematic and stratified random sampling schemes. For the same interval of recording the stratified sampling had lower error variance as compared to systematic sampling. The relative efficiency of method I_2 under all six sampling schemes with respect to I_2 of OMY ranged from 86 per cent (scheme S_4) to 100 per cent (scheme S_4) whereas relative efficiency of method I_3 under OMY and all six sampling schemes with respect to I_2 of OMY ranged from 55 per cent (scheme S_3) to 60 per cent (OMY). In the same way, the relative efficiency of method I_4 under OMY and various sampling schemes with respect to I_2 of OMY ranged from 52 per cent (scheme S_3) to 57 per cent (OMY) whereas for method I_1 , it ranged from 51 per cent (scheme S_3) to 56 per cent (OMY). The above results on Karan Swiss indicate that method I_3 (least square analysis method) under OMY

Table 68. Efficiency of various sire evaluation methods on the basis of observed (OMY) and predicted (PMY) lactation milk yield under various sampling schemes

Traits	Methods of sire evaluation	KARAN SWISS BREED			KARAN FRIES BREED		
		Error variance (kg ²)	Relative efficiency with respect to I ₂ (%)	Relative efficiency with respect to I ₂ of OMY	Error variance (kg ²)	Relative efficiency with respect to I ₂ (%)	Relative efficiency with respect to I ₂ of OMY
OMY	I ₁	324793	55.58	55.58	1788344	9.74	9.74
	I ₂	180528	100.00	100.00	174237	100.00	100.00
	I ₃	300121	60.15	60.15	419410	41.54	41.54
	I ₄	319105	56.57	56.57	456184	38.19	38.19
Fortnightly systematic (S1)	I ₁	327357	55.29	55.14	452796	39.47	38.48
	I ₂	180996	100.00	99.74	178750	100.00	97.47
	I ₃	302950	59.74	59.59	421381	42.42	41.34
	I ₄	321915	56.22	56.07	450616	38.97	37.99
Monthly systematic (S2)	I ₁	334369	56.48	53.99	457277	41.21	38.10
	I ₂	188067	100.00	95.58	188476	100.00	92.44
	I ₃	309817	60.96	58.26	426053	44.23	40.89
	I ₄	329545	57.31	54.78	463313	40.68	37.60
Bimonthly systematic (S3)	I ₁	348719	56.85	51.76	473534	38.12	36.79
	I ₂	198264	100.00	91.05	180535	100.00	96.51
	I ₃	323890	61.21	55.73	430893	41.13	39.69
	I ₄	344473	57.55	52.40	477425	37.81	36.49
Fortnightly stratified (S4)	I ₁	325771	54.44	55.41	454129	38.94	38.36
	I ₂	180615	100.00	99.95	176858	100.00	98.85
	I ₃	300562	60.09	60.06	422194	41.89	41.26
	I ₄	319965	56.44	56.42	459059	38.52	37.95
Monthly stratified (S5)	I ₁	332072	55.32	54.36	457740	35.71	38.06
	I ₂	183728	100.00	98.25	163486	100.00	106.57
	I ₃	306532	59.93	58.89	423690	38.58	41.12
	I ₄	325734	56.40	55.42	460783	35.48	37.81
Bimonthly stratified (S6)	I ₁	342388	60.08	52.72	1837608	10.02	9.48
	I ₂	208195	100.00	86.71	184237	100.00	94.57
	I ₃	315064	66.08	57.29	439767	41.89	39.62
	I ₄	335893	61.98	53.74	478248	38.52	36.43

and various sampling schemes had highest relative efficiency with the most efficient method of I_2 with OMY.

Further, it is noted that for Karan Swiss, the relative efficiency of method I_3 (least squares method) with respect to method I_2 ranged from 60 to 90 per cent for various sampling schemes. The relative efficiency of BLUP method I_4 with respect to method I_2 ranged from 56 to 68 per cent. In similar way, the relative efficiency of method I_1 with respect to most efficient method I_2 ranged from 55 to 60 per cent for OMY and PMY's under various sampling schemes.

In case of Karan Fries cattle, it was found that contemporary comparison method I_2 had the lowest error variance for OMY as well as PMY's under systematic and stratified random sampling schemes followed by least square method I_3 . Further, for I_2 the lowest error variance was obtained when monthly stratified random sampling scheme was considered. It is seen that fortnightly milk recording under both sampling schemes gave the lowest error variance. For same interval of recording the stratified sampling had lower error variance as compared to systematic sampling. The relative efficiency of I_2 method under all six sampling schemes with respect to I_2 of OMY ranged from 92 per cent (scheme S_2) to 106 per cent (scheme S_5); whereas relative efficiency of method I_3 under OMY and six sampling schemes ranged from 39 per cent (scheme S_6) to 41 per cent (OMY). In the same way the relative efficiency of method I_4 under OMY and PMY for various sampling schemes ranged from 36 per cent (scheme S_6) to 38 per cent (OMY), whereas relative efficiency of method I_1 ranged from 9 per cent (scheme S_6) to 38 per cent (scheme S_1). The above results on Karan Fries indicate that method I_3 (least square analysis) under OMY and PMY under various sampling schemes had highest relative efficiency with most efficient method I_2 with OMY.

Further, the relative efficiency of method I_1 with respect to most efficient method I_2 ranged from 10 to 41 per cent for OMY

and PMY under various sampling schemes, whereas efficiency of method I_3 ranged from 39 to 42 per cent for OMY and six sampling schemes. In the same way the relative efficiency of method I_4 with respect to method I_2 ranged from 35 to 41 per cent for OMY as well as PMY under six sampling schemes.

It is thus seen from the above results that contemporary comparison method I_2 was the most efficient method of sire evaluation for OMY as well as PMY's under different milk recording systems followed by least square method (I_3), BLUP (I_4) and daughter average index (I_1) for Karan Swiss and Karan Fries breeds.

Politick *et al.* (1967) compared four methods of sire evaluation, viz., mean production of the daughters, daughter production corrected for the level of dams, contemporary comparison and dam-daughter comparison. They observed that first two methods were unsuitable when the bull in areas with different production levels were to be considered, whereas no valid conclusions could be drawn about the relative merit of two later methods because of the small number of daughters.

Jain and Malhotra (1971) reported that the relative efficiency of contemporary comparison method (I_2) was better than daughter's average method (I_1) which was similar to the results of present study.

Gurnani and Nagarcenkar (1982) reported that BLUP method was more efficient than contemporary comparison method; the contemporary comparison method had 68.84 per cent accuracy as compared to BLUP method.

Dempfle and Hagger (1983) found that the BLUP procedure, where genetic group of sires and herd-year-seasons were also considered, had 2 per cent high correlation between true breeding value and its estimate as compared to contemporary comparison method.

4.12 ACCURACY OF VARIOUS SIRE EVALUATION METHODS WITH RESPECT TO MOST EFFICIENT METHOD ON THE BASIS OF OBSERVED (OMY) AND PREDICTED (PMY) LACTATION MILK YIELD UNDER THREE TESTING INTERVALS OF SYSTEMATIC AND STRATIFIED RANDOM SAMPLING SCHEMES

In the previous section, it was inferred that contemporary comparison method I_2 for sire evaluation was found to be most efficient. Accuracy of other methods with respect to most efficient method I_2 was estimated by determining rank correlation between index values on the basis of OMY and PMY's under various sampling schemes obtained by various methods with method I_2 . Such rank correlations are given in Table 69 for Karan Swiss and Karan Fries breeds and accuracy in Table 70 for Karan Swiss and Karan Fries breeds.

In case of Karan Swiss breed, the rank correlation for method I_1 , method I_3 and method I_4 with most efficient method I_2 ranged from 0.778 to 0.801, 0.742 to 0.762 and 0.805 to 0.821 for OMY and PMY's under various sampling schemes, respectively. These rank correlations were statistically significant ($P < 0.01$). This indicates that all methods tended to rank sires with fairly high accuracy.

Similarly, in case of Karan Fries breed, it was found that the rank correlations of methods I_1 , I_3 and I_4 with most efficient method I_2 ranged from 0.754 to 0.770, 0.850 to 0.870 and 0.889 to 0.904 for OMY and PMY's under various sampling schemes, respectively. These estimates of rank correlation were highly significant ($P < 0.01$). This revealed that all methods tended to rank sires with fairly high accuracy.

Rao (1979) reported that the rank correlation between daughter's average and least squares method was higher (0.91) as compared to that between contemporary comparison and daughter's average (0.77); the rank correlation between contemporary comparison and least squares method was 0.75.

Table 69. Rank correlation of different methods with most efficient sire evaluation method (I₂) for Karan Swiss and Karan Fries Breeds

Name of trait	KARAN SWISS BREED			KARAN FRIES BREED		
	Method I ₁	Method I ₃	Method I ₄	Method I ₁	Method I ₃	Method I ₄
OMY	0.782	0.746	0.805	0.754	0.855	0.891
S ₁	0.792	0.762	0.818	0.762	0.863	0.895
S ₂	0.792	0.748	0.813	0.763	0.851	0.889
S ₃	0.801	0.756	0.821	0.767	0.861	0.902
S ₄	0.778	0.754	0.806	0.758	0.870	0.904
S ₅	0.786	0.742	0.807	0.751	0.850	0.891
S ₆	0.781	0.775	0.818	0.770	0.850	0.886

All rank correlations are significant (P < 0.01)

Table 70. Observed accuracy of sire's breeding value estimated on the basis of different progeny group size as compared to breeding value on the basis of '15 or above' daughters under various sampling schemes

Sire evaluation method	Progeny group size	OMY	SYSTEMATIC SAMPLING SCHEMES			STRATIFIED RANDOM SAMPLING SCHEMES		
			Fortnightly (S ₁)	Monthly (S ₂)	Bimonthly (S ₃)	Fortnightly (S ₄)	Monthly (S ₅)	Bimonthly (S ₆)
----- Accuracy (%) -----								
KARAN SWISS BREED								
I ₁	5	63.20	62.80	50.67	61.46	63.04	61.30	67.70
	8	85.19	84.08	82.81	83.71	85.00	86.11	83.72
	12	96.23	96.04	95.45	95.84	96.23	96.43	95.84
I ₂	5	17.22	17.22	17.55	21.80	17.55	16.32	25.70
	8	73.10	73.27	68.55	77.61	71.74	72.59	69.72
	12	89.87	89.11	88.54	89.30	90.63	90.06	87.60
I ₃	5	27.66	28.09	22.27	26.83	25.60	23.71	30.47
	8	75.86	73.27	71.74	71.74	74.13	77.08	73.10
	12	87.04	86.67	85.00	85.74	87.04	87.98	85.74
I ₄	5	27.66	28.09	22.09	26.83	25.50	23.71	30.69
	8	39.94	73.27	71.74	71.74	74.99	77.08	73.10
	12	87.04	86.49	85.00	85.74	87.04	87.98	86.11

contd.....

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Sire evaluation method	Progeny group size	OMY	SYSTEMATIC SAMPLING SCHEMES			STRATIFIED RANDOM SAMPLING SCHEMES		
			Fortnightly (S ₁)	Monthly (S ₂)	Bimonthly (S ₃)	Fortnightly (S ₄)	Monthly (S ₅)	Bimonthly (S ₆)
----- Accuracy (%) -----								
KARAN FRIES BREED								
I ₁	5	42.64	44.35	50.97	39.94	44.35	40.57	43.56
	8	61.62	62.41	66.25	54.31	62.88	60.21	61.46
	12	86.86	86.86	87.98	86.67	86.49	87.42	86.30
I ₂	5	1.50	00.03	1.06	1.00	1.40	3.24	00.31
	8	17.38	25.50	27.24	20.70	21.16	17.80	14.13
	12	58.36	58.67	63.84	65.28	58.98	58.67	52.85
I ₃	5	37.45	41.47	43.95	35.04	42.51	34.10	42.25
	8	57.45	56.40	60.37	45.69	59.90	55.50	55.35
	12	78.85	78.32	79.74	78.49	78.49	78.67	75.16
I ₄	5	37.45	41.47	43.95	35.16	42.10	30.03	42.25
	8	57.45	56.25	60.37	45.69	59.29	55.50	55.35
	12	78.85	78.32	79.74	78.49	78.14	78.67	75.16

Bhasin and Rao (1983) reported that ranking of sires using actual and estimated yields showed that the top 25 per cent of the sires were ranked more or less in the same manner in all methods of estimations indicating that any of the sampling plans could be used for ranking of sires. They used six sampling schemes using different combinations of AM and PM.

Cordovi *et al.* (1984) found that there were slight differences in ranking of bulls by contemporary comparison, least squares and BLUP (including and excluding relationships) method.

Anacker and Dietl (1990) found that predicted breeding value for milk yield by BLUP method was 10.9 per cent more accurate than contemporary comparison.

Tajane and Rai (1990) found that the correlation of breeding values of Holstein Friesian x Sahiwal bulls by herd-mate comparison and least squares with BLUP were greater than 0.80.

Kuznetsov (1988) reported that the correlations between the BLUP, with and without consideration of relationship matrix, and contemporary comparison methods ranged from 0.869 to 0.957 and from 0.893 to 0.953 in Black cattle.

Parekh and Singh (1989) found in Holstein Friesian x Gir and Jersey x Gir crosses that least squares method was better than BLUP; however, the correlation between the two methods was 0.94.

Jovanovac (1989) reported that correlation between breeding values determined by BLUP and contemporary comparison was 0.77 for milk yield.

In the present investigation, however, the contemporary comparison method was found to be more efficient than least squares and BLUP methods. This indicates that the adjustment for year-season environmental effects was more effective in contemporary comparison as compared to the other methods.

However, the rank correlations of BLUP and least squares method with contemporary comparison were fairly high.

4.13 PROGENY GROUP SIZE REQUIRED ON THE BASIS OF PART LACTATION RECORDS TO GET THE SAME EFFICIENCY OF SIRE EVALUATION AS OBTAINED UNDER COMPLETE LACTATION YIELD

It is expected that the accuracy of breeding value of sires on the basis of part lactation records of their daughters would be lower than that obtained on the basis of complete lactation yield of daughters. This is because part lactation yields contain less information on the milk producing ability of cows as compared to complete lactation yield. Also part lactation records are expected to be subjected to larger influence of temporary environmental effects. These aspects are quantified by the estimates of heritability of part records versus complete lactation records. Further, the phenotypic and genetic correlations of part records with complete lactation records are less than one and so the accuracy of predictability of complete lactation yield on the basis of part records will be lower. Therefore, to get the same accuracy of evaluation of breeding value of sires on the basis of part records as compared to complete lactation yield, more daughters would be needed.

The progeny group size on the basis of part records for a given number of daughters with complete lactation yield to get same accuracy was determined by two methods as elaborated in Materials and Methods. These methods use the estimates of heritability of part records and complete records, and genetic correlation between them. Since all these estimates are subjected to sampling errors so it was found that for certain progeny numbers with complete lactation yield, the progeny number for part records was coming to be negative. Similar result was reported by Ipe (1979). Such numbers have been indicated by letter 'NE' in the Tables 71 to 75. The estimates of progeny group size with part records required to prove a sire with same accuracy of proof as based on fixed number of daughters with

Table 71. Progeny group size with fortnightly part yield records required to prove a sire with same accuracy of proof as based on fixed number of daughters with complete lactation yield (300 days) in Karan Swiss breed

Trait	1st		2nd		3rd		4th		5th		6th		7th		8th		9th		10th	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
5	19	19	8	8	8	8	8	8	14	13	8	8	9	9	6	6	5	5	5	4
10	58	58	16	16	16	16	16	16	28	24	17	15	18	18	11	10	10	10	11	10
15	180	180	27	26	25	25	25	25	43	35	25	23	28	28	17	17	16	15	17	15
20	NR	NR	38	38	34	34	34	34	57	46	33	30	39	38	23	22	21	20	25	20
25	NR	NR	50	50	42	42	44	43	71	55	41	37	51	51	29	27	27	27	34	26
30	NR	NR	65	64	52	52	55	54	85	65	50	44	64	64	34	33	33	33	44	32
35	NR	NR	81	80	61	61	66	65	99	73	58	50	70	78	40	38	40	38	57	39
40	NR	NR	99	99	70	70	77	77	113	81	66	57	94	93	46	43	47	43	72	46
45	NR	NR	122	121	80	80	90	89	127	89	74	63	111	109	51	48	54	48	91	54
50	NR	NR	148	146	90	90	103	101	142	96	83	69	130	128	57	53	61	53	115	62

Trait	11th		12th		13th		14th		15th		16th		17th		18th		19th		20th	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
5	6	6	7	8	6	10	6	11	7	17	8	24	5	22	14	NR	NR	NR	NR	NR
10	12	14	12	18	12	28	11	35	16	89	17	NR	10	NR	49	NR	NR	NR	NR	NR
15	19	24	18	35	17	64	17	118	27	NR	29	NR	16	NR	215	NR	NR	NR	NR	NR
20	28	36	26	62	23	NR	22	NR	41	NR	46	NR	23	NR	NR	NR	NR	NR	NR	NR
25	37	52	34	119	29	NR	29	NR	58	NR	70	NR	33	NR	NR	NR	NR	NR	NR	NR
30	47	73	42	303	35	NR	35	NR	82	NR	107	NR	44	NR	NR	NR	NR	NR	NR	NR
35	60	103	52	NR	41	NR	41	NR	114	NR	172	NR	50	NR	NR	NR	NR	NR	NR	NR
40	74	151	63	NR	46	NR	47	NR	164	NR	315	NR	76	NR	NR	NR	NR	NR	NR	NR
45	91	235	75	NR	52	NR	54	NR	248	NR	900	NR	100	NR	NR	NR	NR	NR	NR	NR
50	111	422	88	NR	58	NR	60	NR	419	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

NR = Not estimable

Table 72. Progeny group size with fortnightly part yield records required to prove a sire with name accuracy of proof as based on fixed number of daughters with complete lactation yield (300 days) in Karan Fries breed

Trait	1st		2nd		3rd		4th		5th		6th		7th		8th		9th		10th	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
5	12	12	12	12	8	8	7	7	8	8	5	5	6	6	6	6	6	5	5	5
10	38	39	43	NE	20	20	16	15	18	18	11	11	12	12	13	13	11	11	11	9
15	NE	NE	283	NE	41	40	28	28	30	30	16	16	18	18	20	19	17	16	16	13
20	NE	NE	NE	NE	82	83	46	45	46	46	21	21	24	24	27	27	23	21	21	17
25	NE	NE	NE	NE	212	NE	72	72	66	66	27	27	31	30	34	34	28	25	27	20
30	NR	NR	NR	NR	NR	NR	119	119	94	94	32	32	37	37	41	41	34	30	32	23
35	NR	NR	NR	NR	NR	NR	224	222	133	133	38	38	43	43	49	49	40	35	37	27
40	NE	NE	NE	NE	NE	NE	647	632	195	196	47	43	50	50	57	56	45	39	42	29
45	NE	NE	NE	NE	NE	NE	NE	NE	305	308	49	49	57	56	64	64	51	43	48	32
50	NE	NE	NE	NE	NE	NE	NE	NE	509	567	55	54	63	63	73	72	57	48	53	35

Trait	11th		12th		13th		14th		15th		16th		17th		18th		19th		20th	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
5	5	4	5	4	4	4	6	5	7	6	9	9	10	11	11	10	11	12	9	8
10	10	7	10	7	8	7	11	11	14	12	19	19	22	25	27	22	27	29	19	19
15	15	10	15	10	13	10	17	16	22	18	29	28	33	40	37	35	51	57	32	32
20	20	12	20	13	17	13	23	21	29	23	39	38	46	58	53	49	92	111	47	49
25	25	14	26	16	21	15	28	26	36	27	49	48	60	79	73	65	180	258	68	71
30	30	16	32	18	25	17	34	31	43	32	60	59	75	101	96	84	489	2072	94	100
35	35	18	38	20	29	20	40	36	50	36	70	69	91	135	123	105	NE	NE	132	143
40	40	20	44	22	34	22	46	41	58	40	81	80	109	174	158	130	NE	NE	186	209
45	45	21	50	24	38	24	51	46	65	44	93	90	128	224	201	160	NE	NE	276	328
50	49	22	56	25	41	25	57	51	72	47	104	101	149	291	259	194	NE	NE	450	602

NE = Not estimable

Table 73. Progeny group size with monthly part yield records required to prove a sire with same accuracy of proof as based on fixed number of daughters with complete lactation yield (300 days) in Karan Swiss breed

Trait	1st		2nd		3rd		4th		5th		6th		7th		8th		9th	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
5	11	11	8	8	9	8	6	6	5	4	6	8	6	12	8	25	13	NE
10	26	25	16	16	18	16	12	12	10	9	12	19	11	35	18	NE	37	NE
15	45	46	24	24	27	23	18	17	15	13	18	39	17	104	31	NE	105	NE
20	75	75	33	33	37	30	24	23	21	18	26	78	23	NE	48	NE	1245	NE
25	122	122	42	42	46	37	30	29	28	22	35	197	28	NE	72	NE	NE	NE
30	210	209	51	51	55	43	35	34	35	27	45	NE	34	NE	110	NE	NE	NE
35	434	430	61	61	64	49	41	40	44	32	56	NE	39	NE	172	NE	NE	NE
40	2136	2042	71	71	73	55	47	45	53	37	69	NR	45	NE	300	NR	NR	NR
45	NE	NE	82	82	82	60	45	51	63	42	84	NE	51	NE	717	NE	NE	NE
50	NE	NR	93	93	92	65	59	56	75	48	102	NE	56	NE	NE	NE	NE	NE

NR = Not estimable

Table 74. Progeny group size with monthly part yield records required to prove a sire with same accuracy of proof as based on fixed number of daughters with complete lactation yield (300 days) in Karan Fries breed

Trait	1st		2nd		3rd		4th		5th		6th		7th		8th		9th	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
5	13	13	7	7	6	6	6	6	5	5	5	4	4	4	8	8	10	10
10	48	48	17	17	13	13	12	12	10	9	9	7	9	8	16	16	22	21
15	654	626	32	32	20	20	18	18	15	13	15	10	13	13	24	24	35	33
20	NR	NR	56	56	27	27	25	25	19	17	20	13	18	17	32	32	50	46
25	NR	NR	103	102	35	35	31	31	23	21	25	15	22	21	40	48	67	60
30	NR	NR	231	224	43	43	38	38	28	25	30	17	27	25	48	48	87	77
35	NR	NR	1952	1543	52	52	44	44	32	28	36	19	32	29	57	56	110	95
40	NR	NR	NR	NR	61	61	51	51	36	32	41	21	36	33	65	64	138	116
45	NR	NR	NR	NR	71	71	58	58	40	35	46	23	41	37	74	73	173	140
50	NR	NR	NR	NR	81	81	65	65	43	38	52	24	46	41	82	81	216	167

NR = Not estimable

Table 75. Progeny group size with bi-monthly part yield records required to prove a sire with same accuracy of proof as based on fixed number of daughters with complete lactation yield (300 days) in Karan Swiss breed

Trait	KARAN SWISS BREED										KARAN FRIES BREED									
	1st		2nd		3rd		4th		5th		1st		2nd		3rd		4th		5th	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
5	9	9	7	7	5	7	6	18	7	NE	8	9	6	6	4	3	7	6	6	6
10	18	18	13	13	11	18	13	126	NE	NE	21	21	12	12	9	6	12	11	12	12
15	29	29	20	19	17	37	21	NE	NE	NE	46	47	18	18	13	9	18	18	18	19
20	42	41	27	26	24	75	29	NE	NE	NE	116	117	24	24	18	11	24	24	24	25
25	56	56	34	32	33	207	39	NR	NR	NE	1211	1294	30	30	22	13	31	31	30	31
30	73	72	40	38	42	NE	49	NE	NE	NE	NE	NE	36	36	27	15	38	37	37	38
35	93	92	47	44	53	NE	61	NE	NR	NR	NE	NE	42	42	31	17	45	45	43	44
40	117	115	54	50	66	NE	74	NE	NE	NE	NE	NE	48	48	36	18	53	52	49	51
45	146	144	61	56	82	NE	89	NE	NE	NE	NE	NE	55	55	40	20	61	61	55	58
50	183	180	67	62	109	NE	107	NE	NE	NE	NE	NE	61	61	45	21	70	68	61	65

NE = Not estimable

complete lactation yield under different intervals of part yields are given in Table 71 to 75.

It is seen from these tables that the part yield for which heritability was higher, less number of daughters were required as compared to part yield with higher heritability. For example, for fortnightly part yield of Karan Swiss, when there were 5 records with complete lactation, the number of daughters required under first fortnightly yield was 19 by both methods. This number reduced to 8 for 2nd to 4th fortnight. The number was generally higher than 5 for most of part records except for 10th fortnight for method 2. The number of progeny required was almost similar for part records during 9th or 10th fortnight (mid-lactation) as compared to number required for complete lactation yield. Keeping in view the sampling variation of the estimates used, it appears that number of part records around 9th fortnight was nearer or slightly higher than the number required for complete lactation yield. The mid lactation fortnightly part yield had the highest heritability. The later fortnightly part yields (17th to 18th) had low heritability. Therefore, for 17th to 18th fortnight, the number of daughters required with part records was not estimable as the denominator of the equation became negative.

In case of Karan Fries cattle, the number of daughters with mid-lactation's fortnightly part records (9th to 13th fortnight) required to give the information equivalent to that of different progeny group size with complete lactation yield, would be nearer or slightly higher than the number of daughters with complete lactation yield, due to higher heritable part of lactation. The initial and terminating fortnightly part yields required more number of additional daughters to give same accuracy of sire evaluation as compared to daughters with complete lactation milk yield (Table 72). A similar trend for the number of daughters with monthly and bimonthly part records was found to give the same accuracy for sire proof to that of progeny group size with complete lactation for both breeds (Tables 73 to 75). In the

present study, the number of daughters with part records required, for increasing accuracy to the same level as for complete lactation becomes comparatively large since the genetic correlation between part yield and complete lactation yield is lower. The difference between numbers becomes more pronounced with increase in the number of daughters with complete records after a certain stage. Such differences were pronounced beyond 15 daughters with complete records in case of fortnightly and monthly part yield and beyond 25 in case of bimonthly part yield. When part lactation records are used to estimate the breeding value of sires for complete lactation yield, there is a range of number of daughters when part lactation records can be equally efficient. This depends on the heritability of the part lactation and its genetic correlation with complete lactation yield. As the aim of sire evaluation is to rank the bulls on the basis of their daughters records as early as possible in order not to increase the generation interval, the use of daughters with part records can be useful. However, slightly more number of daughters would be needed.

Searle (1961b) reported that the number of daughters with part records required to give the information equivalent to that of 30, 40 and 50 daughters with complete yield would be 40, 60 and 80. VanVleck and Henderson (1961) estimated the number of daughters with five months records required in place of 20, 30, 40, 50 and 100 daughters with complete records as 27, 44, 65, 92 and 476 respectively.

Ipe (1979) reported that the progeny group size needed in place of 10, 12, 15, 17, 20, 22 and 25 daughters with 300 days yield, the number with 150 days yield found necessary were 11, 14, 20, 24, 32, 39 and 52. For evaluation on the basis of 210 days yield, the corresponding daughter records needed were 11, 13, 17, 19, 23, 26 and 31.

4.14 OPTIMUM PROGENY GROUP SIZE BY DIFFERENT METHODS OF SIRE EVALUATION UNDER OBSERVED LACTATION MILK YIELD (OMY) AND PREDICTED LACTATION MILK YIELD (PMY's) UNDER VARIOUS SAMPLING SCHEMES

The breeding values of sires were estimated separately on the basis of four progeny group sizes, viz. first 5, 8, 12 and "15 or above" daughters performance with respect to OMY and PMY's under various sampling schemes. Four methods of sire evaluation were applied, viz. daughter's average index method (I_1), contemporary comparison method (I_2), least squares method (I_3) and best linear unbiased prediction method (I_4). The lactation milk yields were predicted under fortnightly, monthly and bimonthly systematic and stratified random sampling schemes. The correlation between the breeding values of sires based on different number of progeny group sizes with the breeding value on the basis of "15 or above" daughters were estimated separately for Karan Swiss and Karan Fries breeds (Tables 76 and 77). Such correlations indicate the repeatability of sire evaluation.

It was found that the correlation between the index I_1 based on 5 daughters with that based on "15 or above" daughters ranged from 0.766 (scheme S_2) to 0.819 (scheme S_6). This indicates that accuracy of sire evaluation based on five daughter's ranged from 58 to 68 per cent. When 8 daughters per bull were available, the above estimate of correlation ranged from 0.910 (scheme S_2) to 0.928 (scheme S_5), which indicates that the accuracy of sire evaluation ranged from 82 to 86 per cent. When 12 daughters per sire were available, the correlation of breeding values with that based on "15 or above" daughters ranged from 0.977 (scheme S_2) to 0.982 (scheme S_5). This indicates that the accuracy of sire evaluation ranged from 95 to 96 per cent.

Further, it was observed that the correlation between the index I_2 based on 5 daughters with that based on "15 or above" daughters ranged from 0.404 (scheme S_5) to 0.507 (scheme S_6). This indicates that accuracy of sire evaluation ranged from 16 to

Table 76. Correlation between breeding value of bulls on the basis of different progeny group size with that based on "15 or above" daughters' breeding value under various sampling schemes in Karan Swiss breed

Sire evaluation method	Progeny group size	OMY	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆
Daughter average method (I ₁)	5	0.795*	0.793*	0.766*	0.784*	0.794*	0.783*	0.819*
	8	0.923**	0.917**	0.910**	0.912**	0.922**	0.928**	0.915**
	12	0.981**	0.980*	0.977**	0.979**	0.981**	0.982**	0.979**
Contemporary comparison method (I ₂)	5	0.415	0.415	0.419	0.467	0.419	0.404*	0.507
	8	0.855**	0.856**	0.828**	0.881**	0.847**	0.852**	0.835**
	12	0.948**	0.944**	0.941**	0.945**	0.952**	0.949**	0.936**
Least square method (I ₃)	5	0.526	0.530	0.472	0.518	0.506	0.487	0.552
	8	0.871**	0.856**	0.847**	0.847**	0.861**	0.878**	0.855**
	12	0.933**	0.931**	0.922**	0.926**	0.933**	0.938**	0.926**
BLUP method (I ₄)	5	0.526	0.530	0.470	0.518	0.505	0.487	0.554
	8	0.632*	0.856**	0.847**	0.847**	0.866**	0.878**	0.855**
	12	0.933**	0.930**	0.922**	0.926**	0.933**	0.938**	0.928**

* Significant (P < 0.05)

** Significant (P < 0.01)

Table 77. Correlation between breeding value of bulls on the basis of different progeny group size with that based on "15 or above" daughters' breeding value under various sampling schemes in Karan Fries breed

Sire evaluation method	Progeny group size	OMY	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆
Daughter average method (I ₁)	5	0.653	0.666	0.714	0.632	0.666	0.637	0.660
	8	0.785**	0.790**	0.814**	0.737**	0.793**	0.776**	0.784**
	12	0.932**	0.932**	0.938**	0.931**	0.930**	0.935**	0.929**
Contemporary comparison method (I ₂)	5	-0.124	-0.010	0.103	0.100	-0.119	-0.180*	0.056
	8	0.417	0.505	0.522	0.455	0.460	0.422**	0.376
	12	0.764**	0.766**	0.799**	0.808**	0.768**	0.766**	0.727**
Least square method (I ₃)	5	0.612	0.644	0.663	0.592	0.652	0.548	0.650
	8	0.758*	0.751*	0.777**	0.676**	0.774**	0.745*	0.744*
	12	0.888**	0.885**	0.893**	0.886**	0.886**	0.887**	0.867**
BLUP method (I ₄)	5	0.612	0.644	0.663	0.593	0.649	0.548	0.650
	8	0.758*	0.750*	0.777**	0.676**	0.770**	0.745*	0.744*
	12	0.888**	0.885**	0.893**	0.886**	0.884**	0.887**	0.867**

* Significant (P < 0.05)

** Significant (P < 0.01)

25 per cent. When 8 daughters per bull were available, the above estimates of correlation ranged from 0.828 (scheme S₂) to 0.881 (scheme S₃) which revealed that the accuracy of sire evaluation based on 8 daughters ranged from 69 to 78 per cent. When 12 daughters per sire were available, the correlation of breeding values with that based on "15 or above" daughters ranged from 0.941 (scheme S₂) to 0.952 (scheme S₄). This indicated that the accuracy of sire evaluation ranged from 89 to 91 per cent.

For index I₃, it was found that the correlation between index based on 5 daughters with that based on "15 or above" daughters ranged from 0.472 (scheme S₂) to 0.552 (scheme S₆). This indicates that the accuracy of sire evaluation based on five daughters ranged from 22 to 30 per cent. When 8 daughters per bull were available, the above estimates of correlation ranged from 0.847 (scheme S₂) to 0.861 (scheme S₄). This reveals that the accuracy of sire evaluation ranged from 72 to 74 per cent. When 12 daughters per sire were available, the correlation of breeding value with that based on "15 or above" daughters ranged from 0.922 (scheme S₂) to 0.938 (scheme S₄), which indicates that the accuracy of sire evaluation ranged from 85 to 87 per cent.

For index I₄, it was found that the correlation between index based on 5 daughters with that based on "15 or above" daughters ranged from 0.470 (scheme S₂) to 0.554 (scheme S₅) which indicates that the accuracy of sire evaluation ranged from 22 to 31 per cent. When 8 daughters per bull were available, the correlation between breeding values ranged from 0.632 (scheme S₁) to 0.878 (scheme S₅). This indicates that the accuracy of sire evaluation ranged from 39 to 77 per cent. When 12 daughters per sire were available, the correlation of breeding value with that based on "15 or above" daughters ranged from 0.922 (scheme S₂) to 0.938 (scheme S₅). This reveals that the accuracy of sire evaluation ranged from 85 to 88 per cent.

It is seen from Table 76 that the estimates of correlation between breeding values based on 8 and 12 daughters with that

based on "15 or above" daughters were statistically significant ($P < 0.01$) for all four methods of sire evaluation, whereas the estimates of correlation between breeding values based on five daughters were found to be not significant under indexes I_2 , I_3 , and I_4 of sire evaluation.

In case of Karan Fries breed, it was found that correlation between the index I_1 based on 5 daughters with that based on "15 or above" daughters ranged from 0.632 (scheme S_3) to 0.714 (scheme S_2). This indicates that accuracy of sire evaluation based on five daughters ranged from 40 to 51 per cent. When 8 daughters per bull were available, the above estimates of correlation ranged from 0.737 (scheme S_3) to 0.814 (scheme S_2), which reveals that the accuracy of sire evaluation ranged from 54 to 66 per cent. When 12 daughters per sire were available, the correlation of breeding value with that based on "15 or above" daughters ranged from 0.92 (scheme S_6) to 0.938 (scheme S_2). This indicates that the accuracy of sire evaluation ranged from 86 to 88 per cent.

In similar way, for index I_2 , it was observed that the correlation between index based on 5 daughters with that based on "15 daughters and above" ranged from -0.018 (scheme S_1) to 0.103 (scheme S_2) which indicates the range of accuracy of sire evaluation as 0.03 to 3 per cent. This is due to small size of progeny for their contemporary daughters in the data. When 8 daughters per bull were available, the estimates of correlation ranged from 0.376 (scheme S_6) to 0.505 (scheme S_1) which gave the range of accuracy of sire evaluation from 14 to 27 per cent. Further, when 12 daughters per sire were available, the correlation of breeding value with that based on "15 or above" daughters ranged from 0.727 (scheme S_6) to 0.808 (scheme S_3). This indicates that the accuracy of sire evaluation ranged from 53 to 64 per cent.

Similarly for index I_3 , it was found that the correlation between the index based on 5 daughters with that based on "15 or

based on "15 or above" daughters were statistically significant ($P < 0.01$) for all four methods of sire evaluation, whereas the estimates of correlation between breeding values based on five daughters were found to be not significant under indexes I_2 , I_3 , and I_4 of sire evaluation.

In case of Karan Fries breed, it was found that correlation between the index I_1 based on 5 daughters with that based on "15 or above" daughters ranged from 0.632 (scheme S_3) to 0.714 (scheme S_2). This indicates that accuracy of sire evaluation based on five daughters ranged from 40 to 51 per cent. When 8 daughters per bull were available, the above estimates of correlation ranged from 0.737 (scheme S_3) to 0.814 (scheme S_2), which reveals that the accuracy of sire evaluation ranged from 54 to 66 per cent. When 12 daughters per sire were available, the correlation of breeding value with that based on "15 or above" daughters ranged from 0.92 (scheme S_6) to 0.938 (scheme S_2). This indicates that the accuracy of sire evaluation ranged from 86 to 88 per cent.

In similar way, for index I_2 , it was observed that the correlation between index based on 5 daughters with that based on "15 daughters and above" ranged from -0.018 (scheme S_1) to 0.103 (scheme S_2) which indicates the range of accuracy of sire evaluation as 0.03 to 3 per cent. This is due to small size of progeny for their contemporary daughters in the data. When 8 daughters per bull were available, the estimates of correlation ranged from 0.376 (scheme S_6) to 0.505 (scheme S_1) which gave the range of accuracy of sire evaluation from 14 to 27 per cent. Further, when 12 daughters per sire were available, the correlation of breeding value with that based on "15 or above" daughters ranged from 0.727 (scheme S_6) to 0.808 (scheme S_3). This indicates that the accuracy of sire evaluation ranged from 53 to 64 per cent.

Similarly for index I_3 , it was found that the correlation between the index based on 5 daughters with that based on "15 or

In case of Karan Fries breed, it was found that when there were 5 daughters per bull, the method I_1 under fortnightly systematic and stratified random sampling schemes gave highest (44%) accuracy of sire evaluation. Further, when 8 daughters per bull were available, the method I_1 under monthly systematic sampling scheme gave highest (66%) accuracy of sire evaluation. In the same way, when 12 daughters per sire were available, the method I_1 under monthly systematic sampling scheme gave the highest (88%) accuracy.

It is, thus, seen that the breeding value estimates based on 12 daughters per sire using method I_1 (daughter average method) estimate had highest accuracy. However, the results on efficiency of sire evaluation methods indicated that contemporary comparison method was most efficient in this data. The contemporary comparison method had very low accuracy when the progeny group size was very small (5 to 8). When the progeny group size was 12, the accuracy of sire evaluation by contemporary comparison was comparable to daughter average method and other methods.

From the above results, it is also seen that when the progeny group size was increased there was increase in accuracy of sire evaluation in every case as theoretically expected.

Further, it is observed that the accuracy of sire evaluation on the basis of test records of daughters under the two sampling schemes and three intervals of recording were similar to the accuracy of sire evaluation based on observed lactation milk yield (OMY). This indicates that any of the sampling schemes could be employed. In field conditions, bimonthly recording under stratified random sampling scheme could be used. This system of sampling would not have any biases in practice as the farmer would not know, much in advance, as to the day on which his cow will be milk recorded.

Lush (1933) was of the opinion that a minimum of five daughters per bull were required in evaluating the sire's genetic merit.

Nazarenko (1970) determined optimum progeny group size of sires in Red Steppler and Russian Simmental cattle. Correlations were calculated on the performance of all daughters with that of first 5, 10, 15, 20, 25, 30, 40 and 50 daughters. For milk yield, 15 to 20 daughters per sire were recommended.

Mollar (1976) considered progeny tests with less than 20 daughters of little value and increasing group size above 40 as unnecessary.

Kretzechnar and Rose (1976) computed the breeding values based on 10, 20, 30, 40, 50 and 60 daughters and found that with 30 daughters per sire group, breeding value could be estimated fairly accurately.

Rao (1979) studied the repeatability of breeding value estimates based on daughter's average and contemporary comparison method of sire evaluation using first 5, 10 and 50 daughters. He reported that accuracies of breeding value estimates, based on 5, 10 and 50 daughters, were 0.42, 0.46 and 0.50 for daughter's average and 0.23, 0.25 and 0.49 for contemporary comparison method of sire evaluation.

Bhullar and Dev (1986) reported higher accuracy of breeding values based on daughter's average method of sire evaluation using 8 and 15 daughters, being 0.67 and 0.74.

Winkelman and Schaeffer (1988) studied the repeatability of breeding value estimates based on least squares method using three linear models. They observed that the accuracy of breeding value estimate based on 20 daughters ranged from 0.50 to 0.57 for three linear models. Tajane and Rai (1990) found the repeatability of breeding value estimates based on daughters with

Table 18. Cost of field recording of daughters under various sampling schemes for same accuracy of progeny testing of bulls with varying progeny group size

Number of daughters observed milk yield (TONY)	Portnightly systematic sampling (S ₁)		Monthly systematic sampling (S ₂)		Bimonthly systematic sampling (S ₃)		Portnightly stratified random sampling (S ₄)		Monthly stratified random sampling (S ₅)		Bimonthly stratified random sampling (S ₆)	
	No. of daughters test required	Cost of recording records (Rs) required	No. of daughters test required	Cost of recording records (Rs) required	No. of daughters test required	Cost of recording records (Rs) required	No. of daughters test required	Cost of recording records (Rs) required	No. of daughters test required	Cost of recording records (Rs) required	No. of daughters test required	Cost of recording records (Rs) required
5	5	100	5	50	5	300	5	150	5	100	5	300
10	10	200	10	100	11	600	10	300	10	200	11	600
15	15	300	15	150	16	900	15	480	15	300	16	900
20	20	400	20	200	21	1200	20	630	21	400	22	1260
25	25	500	26	260	27	1560	25	810	26	500	27	1560
30	30	600	31	310	32	1860	30	960	31	600	33	1860
35	35	700	36	360	37	2160	35	1110	36	700	38	2160
40	40	800	41	410	43	2460	40	1290	41	800	43	2460
45	45	900	46	460	48	2760	45	1440	46	900	49	2760
50	50	1000	51	510	53	3060	51	1590	51	1020	54	3060

* Cost of recording @ Rs.6 per test record

Note: The number of daughters required under various sampling schemes have been rounded to the nearest unit place

50 per cent exotic inheritance, using least squares method of sire evaluation, as 0.57 for Holstein sires and 0.62 for Sahiwal sires.

4.15 COST OF FIELD RECORDING OF DAUGHTERS UNDER VARIOUS SAMPLING SCHEMES FOR SAME ACCURACY OF PROGENY TESTING OF BULLS WITH VARYING PROGENY GROUP SIZE

The number of daughters required per crossbred sire under various sampling schemes and observed milk yield (OMY) for the same accuracy of sire evaluation were estimated (Table 78). It was found that the percentage of more daughters required under various sampling schemes as compared to OMY was 0.97 per cent for fortnightly systematic sampling schemes (S₁), 2.44 per cent for monthly systematic sampling scheme (S₂), 6.54 per cent for bimonthly systematic sampling schemes (S₃), 1.09 per cent for fortnightly random sampling (S₄), 2.90 per cent for monthly stratified random sampling (S₅) and 8.37 per cent for bimonthly stratified random sampling (S₆). The number of daughters required under stratified random sampling schemes would be slightly higher than those required under systematic sampling schemes. The number of daughters required was rounded to the nearest unit place (Table 78). It was found that for fortnightly sampling schemes, the number of daughters required was almost same as for OMY. For higher accuracy the number of daughters under monthly and bimonthly recording would be slightly higher than those required under fortnightly sampling scheme. The cost of recording milk yield on a day was taken as Rs.6.00 per test record. It was found that for same accuracy of sire evaluation the cost of recording was lowest for bimonthly recording. Further, the cost of systematic sampling was lower than that of bimonthly stratified random sampling. For example, when 50 daughters per sire are required for observed milk yield with complete recording of lactation, the number of daughters required under bimonthly systematic sampling (S₃) would be 53 and under bimonthly stratified random sampling would be 54. The cost of recording under S₃ would be Rs.1,590 and under S₆ would be Rs.1,620. Therefore, it may be concluded that bimonthly systematic sampling scheme is cheaper. As seen in the earlier section for getting unbiased test records in field conditions, the bimonthly stratified random scheme was desirable; this will require slightly more (about 4%) cost.

CHAPTER - 5

SUMMARY AND CONCLUSION

5. SUMMARY AND CONCLUSIONS

The present investigation was conducted on Karan Swiss (KS) and Karan Fries (KF) cattle maintained at National Dairy Research Institute, Karnal. The data comprised of 2,96,496 daily records of 1044 cows in first lactation milk yield of Karan Swiss breed spread over a period of 17 years (from 1970 to 1987) and 2,38,810 daily records of 835 cows in first lactation milk yield of Karan Fries breed spread over a period of 15 years (from 1974 to 1988). The number of sires were 51 for Karan Swiss and 54 for Karan Fries. The records of both breeds of cows of known pedigree with normal lactation were included in analysis. Lactation records shorter than 120 days were excluded from the study. The traits considered were: observed first lactation milk yield (OMY), age at first calving (AFC), predicted first lactation milk yield (PMY) under fortnightly (S₁), monthly (S₂) and bimonthly (S₃) systematic sampling schemes, fortnightly (S₄), monthly (S₅) and bimonthly (S₆) stratified random sampling schemes and fortnightly, monthly and bimonthly part lactation yield and monthly cumulative yields.

For Karan Swiss, the overall least squares mean of OMY was 2639.98 ± 35.76 kg. The average predicted lactation milk yield (PMY) on the basis of S₁, S₂ and S₃ were 2640.67 ± 35.84 kg, 2646.25 ± 36.39 kg and 2665.46 ± 37.00 kg, respectively and under S₄, S₅ and S₆ were 2640.07 ± 35.84 kg, 2645.37 ± 36.00 kg and 2651.88 ± 36.37 kg, respectively. In case of Karan Fries, the overall least squares mean of OMY was 2768.65 ± 55.02 kg. The average PMY's on the basis of S₁, S₂ and S₃ were 2770.36 ± 55.20 kg, 2770.67 ± 55.61 kg and 2751.89 ± 56.88 kg and under S₄, S₅ and S₆ were 2773.76 ± 55.16 kg, 2777.34 ± 55.04 kg and 2793.17 ± 56.31 kg, respectively.

The effects of periods and genetic groups were statistically significant ($P < 0.01$) on OMY as well as PMY's under various sampling schemes as well as intervals of recording in both breeds. The effect of season on OMY and PMY's under six sampling schemes was statistically significant in case of Karan Swiss and PMY's under monthly and bimonthly recording schemes for Karan Fries; however, it was not significant in case of fortnightly systematic sampling scheme in Karan Fries. The effect of age at first calving on OMY and PMY's under six sampling schemes was not significant in case of Karan Swiss but highly significant in case of Karan Fries. The OMY as well as PMY's under various sampling schemes were found to be highest in autumn and lowest in spring for both the breeds. In case of KS, the highest OMY as well as PMY's under systematic sampling schemes were found to occur for genetic group F1 (3017.66 kg) and lowest for genetic group F2 (2482.44 kg). In case of stratified random sampling scheme of KS, the highest PMY (3021.23 kg) occurred for genetic group F1 and lowest PMY (2491.82 kg) occurred for genetic group of *inter se* mated cows. The least squares means of OMY and PMY's under six sampling schemes for Karan Fries were found to be highest in genetic group H x T crosses and lowest in genetic group H x JT crosses.

The season and period of calving and genetic group had influenced all 20 fortnightly, 10 monthly and 5 bimonthly part lactation milk yields and cumulative milk yield in Karan Swiss and Karan Fries cattle; whereas regression on age at first calving was not significant in all fortnightly, monthly and bimonthly part lactation yields and cumulative milk yields in Karan Swiss breed, but in case of Karan Fries, it was found to be significant.

The prediction of lactation milk yield on the basis of fortnightly systematic sampled test records by ratio method reveals that maximum (70.78%) accuracy of prediction was obtained during 10th fortnight for Karan Swiss breed. The prediction on the basis of same sampling scheme revealed that the maximum

(67.84%) accuracy was obtained during 9th to 11th fortnight for Karan Fries breed. In the similar way, when the lactation milk yield was predicted on the basis of fortnightly stratified random sampled test records, the maximum (70.13%) accuracy for prediction was obtained with test records during 9th fortnight for Karan Swiss cattle, whereas maximum (67.29%) accuracy for test records occurred during 10th fortnight for Karan Fries cattle. The accuracies of prediction of lactation milk yield on the basis of fortnightly systematic and stratified random sampled test records by ratio method were almost similar in both breeds. The prediction of lactation milk yield on the basis of fortnightly part yields reveals that maximum (50.74%) accuracy was obtained for 7th fortnightly and minimum (7.21%) for 20th fortnightly part yield for Karan Swiss and maximum accuracy (62.50%) for 11th fortnight and minimum (26.78%) for 1st fortnight in Karan Fries breed.

The prediction of lactation milk yield on the basis of monthly systematic sampled test records by ratio method revealed that maximum (67.80%) accuracy for prediction was obtained during fourth month for Karan Swiss, whereas maximum (66.68%) accuracy for prediction was obtained during sixth month for Karan Fries cattle. On the other hand, prediction of lactation milk yield based on monthly stratified random sampled test records revealed that maximum (68.88%) accuracy for prediction was obtained during sixth month for Karan Swiss and maximum (69.75%) during fifth month for Karan Fries breed. The maximum accuracies for prediction on the basis of stratified random sampled test records were slightly higher than systematic sampled test records in both breeds, whereas the prediction of lactation yield on the basis of monthly part yield by ratio method revealed that maximum (78.04%) accuracy of prediction was obtained during fifth month for Karan Swiss and maximum (77.49%) during sixth month for Karan Fries cattle.

The prediction of lactation milk yield on the basis of bimonthly recording for both sampling schemes and part yields

revealed that the maximum accuracy (64 to 81%) of estimation was obtained during second bimonth for Karan Swiss and during third bimonth for Karan Swiss cattle.

For both the breeds, first 180 days cumulative milk yield was a reasonable predictor of lactation milk yield. For both the breeds, when a single test record was considered, it was found that 13th fortnightly test record under systematic sampling and 12th fortnightly test record under stratified sampling and 12th fortnightly part milk yield gave highest accuracy of prediction by regression method (69.56, 70.50 and 75.06%, respectively). When two fortnightly test records and fortnightly part yields were taken, the best multiple regression equations were found to be those utilising 4th and 13th fortnightly records under systematic sampling scheme, 4th and 12th fortnightly records under stratified random sampling and 3rd and 12th fortnightly part yields; the accuracies of prediction being 87.10, 84.74 and 89.21 per cent, respectively. When three test records were considered, the best equations involved 4th, 13th and 17th fortnightly yields under systematic sampling, 4th, 12th and 17th fortnightly records under stratified random sampling and 3rd, 12th and 17th fortnightly part yields; their accuracies of prediction being 93.02, 93.11 and 96.11 per cent, respectively. When more number of test records or part records were considered as independent variables, there was increase in accuracy of prediction but at slower rate.

In both the breeds, it was found that when one record was taken as independent variable, the 7th month test record under systematic and stratified random sampling scheme and 6th month part milk yield gave accuracy of prediction of 70.47, 70.43 and 76.55 per cent, respectively. When two records were taken as independent variables, it was found that the best equation used 2nd and 7th month yield under systematic and stratified random sampling schemes and 2nd and 6th month part milk yields, the accuracies of prediction being 88.07, 88.07 and 88.88 per cent, respectively. When three records were taken as independent

variables, the best prediction equations utilised 2nd, 7th and 9th month test records under systematic and stratified random sampling schemes and 2nd, 6th and 9th month part milk yields, the accuracies of prediction were 92.34, 92.34 and 96.33 per cent, respectively.

In both the breeds, when a single record was considered, it was found that the 3rd bimonthly test record under systematic and stratified random sampling schemes and 3rd bimonthly part yield gave highest accuracy of prediction; the accuracy of prediction being 68.42, 68.99 and 78.58 per cent, respectively. When two bimonthly test records and bimonthly part yields were taken, the best multiple regression equations were those utilising 1st and 3rd bimonthly test records under systematic sampling, 3rd and 4th bimonthly records under stratified random sampling and 1st and 3rd bimonthly part yields; the accuracies of prediction being 80.18, 80.14 and 88.84 per cent, respectively. When three test records were considered, the best equations involved 1st, 3rd and 4th bimonthly records under systematic and stratified random sampling schemes and 1st, 3rd and 4th bimonthly part yields; their accuracies of prediction being 91.11, 90.00 and 96.51 per cent, respectively. When more number of test records or part records were considered as independent variables, there was increase in accuracy of prediction but at slower rate.

The accuracy of prediction was better at shorter interval of milk recording under systematic and stratified random sampling schemes in both breeds. It was observed that the error variance in predicted lactation milk yield was increased gradually when the interval of test recording was increased. The systematic sampling scheme gave better precision under all the three test day intervals of recording as compared to stratified random sampling scheme. The per cent average error was found to be less than one per cent in all cases.

The heritabilities of different traits were estimated after adjusting the data for non-genetic factors (season and period of

calving, genetic group and age at first calving). The heritability (h^2) was highest (0.397) for 10th fortnight. The estimates of heritability of 9th to 12th fortnightly part yields were found to be higher than that of observed lactation milk yield (OMY) in Karan Swiss cattle. In case of Karan Fries breed, the h^2 estimate was highest (0.346) for 13th fortnightly part yield. The h^2 estimates of 2nd to 4th fortnightly and 11th to 13th fortnightly part yields were found to be higher than that of OMY. The h^2 estimate of monthly part yield was highest (0.405) for 5th month and h^2 estimates of 5th and 6th month part yields were found to be higher than observed lactation milk yield (OMY) in Karan Swiss cattle. The estimate of h^2 was found to be highest (0.341) during 7th month and h^2 estimates of 1st, 2nd, 6th and 7th month were found to be higher than that of OMY in Karan Fries breed. For Karan Swiss, the h^2 estimate was highest (0.388) for 3rd bimonth yield, whereas the h^2 was highest (0.337) for 1st bimonth yield and h^2 estimate of 1st bimonth and 3rd bimonth part yields were found to be higher than that of OMY in Karan Fries breed. The h^2 estimate of cumulative part yield was highest (0.328) for first 180 days part yield in Karan Swiss and highest (0.363) for first 210 days part yield in Karan Fries breeds.

The heritability estimates for OMY and PMY's under fortnightly, monthly and bimonthly systematic and stratified random sampling schemes were 0.343 ± 0.102 , 0.341 ± 0.101 , 0.356 ± 0.103 , 0.354 ± 0.103 , 0.354 ± 0.103 , 0.341 ± 0.101 and 0.398 ± 0.109 in Karan Swiss cattle, respectively. In case of Karan Fries breed, the h^2 estimates were 0.294 ± 0.103 for OMY, 0.278 ± 0.104 for fortnightly, 0.285 ± 0.105 for monthly and 0.269 ± 0.103 for bimonthly systematic predicted lactation milk yield and 0.275 ± 0.104 for fortnightly, 0.243 ± 0.093 for monthly and 0.258 ± 0.101 for bimonthly stratified random sampled predicted lactation milk yield. The h^2 estimates of PMY's under various sampling schemes varied from 1 to 5 per cent as compared to estimate of OMY in both breeds.

The estimates of genetic correlations between OMY with PMY's under various sampling schemes were very high being greater than 0.948 for Karan Swiss and to be near unity in Karan Fries breed. Similarly, the estimates of phenotypic correlations were also very high (ranging from 0.950 to 0.989) in Karan Swiss and (ranging from 0.964 to 0.989) in Karan Fries breed. All the estimates of phenotypic and genetic correlations were statistically significant ($P < 0.01$) in both breeds. These results suggest that the predicted lactation milk yield under various sampling schemes would give high phenotypic and genetic accuracy of selection for lactation milk yield.

It was found that for Karan Swiss, the highest average breeding value of sires was obtained for method I_4 (BLUP) under all sampling schemes and OMY; the lowest being for method I_1 (daughter's average). The range of breeding values of sires for method I_4 (BLUP) was lowest and for method I_1 was highest for all the sampling schemes and OMY. This indicates that sampling schemes did not have any effect on the relative effectiveness of the sire evaluation methods. The sampling scheme S_3 (bimonthly systematic sampling), however, gave the highest average breeding value and range of breeding values for every method. Therefore, for Karan Swiss data, least discrimination among sires was obtained by BLUP method and maximum discrimination by daughter's average index method. The sampling scheme S_3 provided the highest discrimination. For Karan Fries cattle, the highest average breeding value of sires was obtained for the method I_1 (daughter's average) under all sampling schemes and OMY, the lowest being for method I_4 (BLUP). The range of breeding values for method I_4 was lowest and for method I_1 was highest for all the samples schemes and OMY. This indicates that the sampling schemes did not have any effect on the relative effectiveness of the sire evaluation methods. The sampling method S_2 (monthly systematic scheme), however, gave the highest average breeding value and range of breeding values. Therefore, for Karan Fries data, least discrimination among sires was obtained by BLUP and maximum discrimination by daughter's average index method. The

sampling scheme S2 (monthly systematic sampling scheme) provided highest discrimination.

For Karan Swiss breed, it was found that contemporary comparison method (I₂) had the lowest error variance for OMY as well as PMY's under all six sampling schemes. This was followed by least square analysis method (I₃), BLUP method (I₄) and least efficient was average method (I₁) which had the highest error variance. Further, for method I₂ the lowest error variance was obtained when observed lactation milk yield (OMY) was considered as compared to PMY's under various sampling schemes. There was increase in error variance with increase in interval of recording for both systematic and stratified random sampling schemes. The method I₃ (least square analysis method) under OMY and various sampling schemes had highest relative efficiency with most efficient method I₂ with OMY. In case of Karan Fries cattle, it was found that contemporary comparison method I₂ had the lowest error variance for OMY as well as PMY's under systematic and stratified random sampling schemes followed by least square method I₃. Further, for method I₂ the lowest error variance was obtained when monthly stratified random sampling scheme was considered. It was observed that fortnightly milk recording under both sampling schemes gave lowest error variance. For same interval of recording, the stratified sampling had lower error variance as compared to systematic sampling. It was found that method I₃ (least square analysis) under OMY and PMY's under various sampling schemes had highest relative efficiency with most efficient method I₂ of OMY.

In case of Karan Swiss breed, the rank correlation for method I₁, method I₃ and method I₄ with most efficient method I₂ ranged from 0.778 to 0.801, 0.742 to 0.762 and 0.805 to 0.821 for OMY and PMY's under various sampling schemes, respectively. These rank correlations were statistically significant ($P < 0.01$). This indicates that all methods tended to rank sires with fairly high accuracy. Similarly, in case of Karan Fries cattle, it was found that the rank correlations of method I₁, I₃ and I₄

with most efficient method I_2 ranged from 0.754 to 0.770, 0.850 to 0.870 and 0.889 to 0.904 for OMY and PMY under various sampling schemes, respectively. These estimates of rank correlation were highly significant ($P < 0.01$). This also revealed that all methods tended to rank sire with fairly high accuracy.

It is concluded that contemporary comparison method I_2 was the most efficient method of sire evaluation for OMY as well as PMY's under different milk recording systems followed by least square method (I_3), BLUP (I_4) and daughter average index (I_1) for Karan Swiss and Karan Fries breeds.

The part yield for which heritability was higher, less number of daughters were required as compared to part yield with lower heritability. For fortnightly part yield of Karan Swiss, when there were 5 records with complete lactation, the number of daughters required under first fortnightly yield was 19 by both methods. This number reduced to 8 for 2nd to 4th fortnight. The number was generally higher than 5 for most part records except for 10th fortnight for method 2. The number of progeny required was almost similar for part records during 9th or 10th fortnight (mid lactation) as compared to number required for complete lactation yield. Keeping in view, the sampling variation of the estimator used, it appears that number of part records around 9th fortnight was nearer or slightly higher than number required for complete lactation yield. The later fortnightly part yields (17th to 18th) had low heritability. Therefore, for 17th to 18th fortnight, the number of daughters required with part records was not estimable as the denominator of the equation became negative.

In case of Karan Fries cattle, the number of daughters, with mid-lactation's fortnightly part records (9th to 13th fortnight) required to give the information equivalent to that of different progeny group size with complete lactation yield, would be nearer or slightly higher due to higher heritable part of lactation. The initial and terminating fortnightly part yields

required more number of additional daughters to give same accuracy of sire evaluation as compared to daughters with complete lactation milk yield. A similar trend for the number of daughters with monthly and bimonthly part records was found to give the same accuracy for sire proof to that of progeny group size with complete lactation for both breeds. In the present study, the number of daughters with part records required, for increasing accuracy to the same level as for complete lactation yield, becomes comparatively large since the genetic correlation between part yield and complete lactation yield is lower. There is a range of number of daughters when part lactation records can be equally efficient. This depends on the heritability of the part lactation and its genetic correlation with complete lactation yield. As the aim of sire evaluation is to rank the bulls on the basis of their daughters records as early as possible in order not to increase the generation interval, the use of daughters with part records can be useful. However, slightly more number of daughters would be needed.

The repeatability of breeding value estimates was obtained by determining the correlation of the breeding values of sires based on first 5, 8 and 12 daughters with "15 or above" daughters. It was found that there was increase in repeatability of breeding value estimates as the number of daughters per sire increased for OMY and PMY's under various sampling schemes for both breeds. For Karan Swiss breed, it was found that when there were 5 daughters per bull, the method I_1 under bimonthly stratified random sampling scheme S6 gave highest (68%) accuracy of sire evaluation. Further, when 8 daughters per bull were available, the method I_1 under monthly stratified random sampling scheme (S5) gave highest accuracy (86%) accuracy of sire evaluation. In the same way, when 12 daughters per bull were available, the method (I_1) under monthly stratified random sampling scheme (S5) gave highest accuracy (96%). In case of Karan Fries breed, it was found that when there were 5 daughters per bull, the method I_1 under fortnightly systematic and stratified random sampling schemes gave highest (44%) accuracy of

sire evaluation. Further, when 8 daughters per bull were available, the method I_1 under monthly systematic sampling scheme gave highest (66%) accuracy of sire evaluation. In the same way, when 12 daughters per sire were available, the method I_1 under monthly systematic sampling scheme gave the highest (88%) accuracy. It was thus observed that the breeding value estimates based on 12 daughters per sire using method I_1 (daughter average method) had highest accuracy. However, the results on efficiency of sire evaluation methods indicated that contemporary comparison method was most efficient in this data. The contemporary comparison method had very low accuracy when the progeny group size was very small (5 to 8). When the progeny group size was 12, the accuracy of sire evaluation by contemporary comparison was comparable to daughter average method and other methods.

It was observed that the accuracy of sire evaluation on the basis of test records of daughters under the two sampling schemes and three intervals of recording were similar to the accuracy of sire evaluation based on observed lactation milk yield (OMY). This indicates that any of the sampling schemes could be employed. In field conditions, bimonthly recording under stratified random sampling could be more useful. This system of sampling would not have any biases in practice as the farmer would not know, much in advance, as to the day on which his cow will be milk recorded.

In order to evaluate the possibility of reducing the cost of recording, the number of daughters required for fortnightly sampling scheme was almost same as for OMY. For higher accuracy, the number of daughters under monthly and bimonthly recording would be slightly higher than those required under fortnightly sampling scheme. It was found that for same accuracy of sire evaluation, the cost of recording was lowest for bimonthly recording. Further, the cost of bimonthly systematic sampling was slightly lower than that of bimonthly stratified random sampling. When 50 daughters per sire are required for observed milk yield with complete recording of lactation, the number of

daughters required under bimonthly systematic sampling (S3) would be 53 and under bimonthly stratified random sampling would be 54. The cost of recording under S3 would be Rs.1,590 and under S6 would be Rs.1,620. Therefore, systematic sampling scheme would be slightly cheaper. However, for getting unbiased test records in field conditions, the bimonthly stratified random scheme would be desirable. This will require slightly more (about 4%) cost.

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