CHAPTER III

MATERIALS AND METHODS
MATERIALS AND METHODS

The data for the study were collected from ten military dairy farms on 1654 Murrah buffaloes. These ten farms were distributed in different parts of India as given below:

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of Farm</th>
<th>Number of animals on which records were collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ambala</td>
<td>370</td>
</tr>
<tr>
<td>2</td>
<td>Jullundur</td>
<td>64</td>
</tr>
<tr>
<td>3</td>
<td>Ferozepur</td>
<td>143</td>
</tr>
<tr>
<td>4</td>
<td>Lucknow</td>
<td>365</td>
</tr>
<tr>
<td>5</td>
<td>Allahabad</td>
<td>71</td>
</tr>
<tr>
<td>6</td>
<td>Jhansi</td>
<td>38</td>
</tr>
<tr>
<td>7</td>
<td>Jabalpur</td>
<td>107</td>
</tr>
<tr>
<td>8</td>
<td>Pimpri-Kirkee(Poona)</td>
<td>203</td>
</tr>
<tr>
<td>9</td>
<td>Bangalore</td>
<td>130</td>
</tr>
<tr>
<td>10</td>
<td>Secunderabad</td>
<td>163</td>
</tr>
</tbody>
</table>

Total: 1654

The geographical location and climatological features of the farms are as detailed in Table 3.1.
Table 3.1. Meteorological data of various military farms

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of Place</th>
<th>Location</th>
<th>Height above M.S.L. (Metres)</th>
<th>Mean Max. Temp. °C</th>
<th>Mean Min. Temp. °C</th>
<th>Av. Rainfall per year (mm)</th>
<th>Relative humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ambala</td>
<td>Lat. 30°23'N</td>
<td>Long. 76°46'E</td>
<td>272</td>
<td>40.8 (May)</td>
<td>6.8 (Jan.)</td>
<td>958.8 (Aug.)</td>
</tr>
<tr>
<td>2.</td>
<td>Jullundur</td>
<td>Lat. 30°56'N</td>
<td>Long. 75°52'E</td>
<td>247</td>
<td>41.2 (May)</td>
<td>5.8 (Jan.)</td>
<td>704.5 (Aug.)</td>
</tr>
<tr>
<td>(Ludhiana)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Ferozepur</td>
<td>Lat. 30°55'N</td>
<td>Long. 70°40'E</td>
<td>200</td>
<td>41.1 (June)</td>
<td>5.1 (Jan.)</td>
<td>536.6 (Aug.)</td>
</tr>
<tr>
<td>4.</td>
<td>Lucknow</td>
<td>Lat. 26°52'N</td>
<td>Long. 80°56'E</td>
<td>111</td>
<td>41.2 (July)</td>
<td>8.9 (Jan.)</td>
<td>992.4 (Aug.)</td>
</tr>
<tr>
<td>5.</td>
<td>Allahabad</td>
<td>Lat. 25°27'N</td>
<td>Long. 81°44'E</td>
<td>98</td>
<td>42.1 (May)</td>
<td>9.1 (Jan.)</td>
<td>1027.0 (Aug.)</td>
</tr>
<tr>
<td>6.</td>
<td>Jhansi</td>
<td>Lat. 25°27'N</td>
<td>Long. 78°55'E</td>
<td>251</td>
<td>42.6 (May)</td>
<td>9.2 (Jan.)</td>
<td>1000.1 (Aug.)</td>
</tr>
<tr>
<td>7.</td>
<td>Jabalpur</td>
<td>Lat. 23°10'N</td>
<td>Long. 79°57'E</td>
<td>393</td>
<td>41.9 (May)</td>
<td>9.0 (Dec.)</td>
<td>1447.5 (Aug.)</td>
</tr>
<tr>
<td>8.</td>
<td>Pimpri-Kirkee (Poona)</td>
<td>Lat. 18°32'N</td>
<td>Long. 73°51'E</td>
<td>559</td>
<td>37.9 (April)</td>
<td>12.0 (Dec.)</td>
<td>714.7 (Aug.)</td>
</tr>
<tr>
<td>9.</td>
<td>Bangalore</td>
<td>Lat. 12°58'N</td>
<td>Long. 77°35'E</td>
<td>921</td>
<td>33.4 (April)</td>
<td>15.0 (Jan.)</td>
<td>923.7 (July)</td>
</tr>
<tr>
<td>10.</td>
<td>Secunderabad</td>
<td>Lat. 17°27'N</td>
<td>Long. 78°28'E</td>
<td>545</td>
<td>44.6 (May)</td>
<td>13.4 (Dec.)</td>
<td>764.4 (Aug.)</td>
</tr>
</tbody>
</table>

Source: Climatological tables of observatories in India (1931-1960), Indian Meteorological Department, Government of India.
Management Practices

Military dairy farms which are in existence since decades have developed scientific norms of feeding and animal management. Instructions about the management practices to be adopted are given to all the farms by the Military Farms Directorate. A uniform management practice is thus being followed in these farms.

Feeding

The feeding is on scientific lines and considers the requirements for each category of animals. All the calves are weaned at birth and hand-fed. The schedule of feeding of calves from birth to six months of age is given in Table 3.2.

Buffaloes over six months of age are fed for growth, body maintenance and production. The concentrate mixture used for feeding is a balanced ration containing minimum of 16 percent DCP and 75 percent of TDN. 1.5 kg of concentrates is given as maintenance ration and additional allowance of 1.5 kg in advanced pregnancy. For lactating cows, one kg of concentrate is given for every 2 kg milk production.

The roughages are given *ad libitum*. Each farm has adequate land to grow sufficient fodders for the lactating animals maintained. During harvesting seasons, green fodder is fed. The surplus green fodder is converted into silage or hay depending on the facilities available.
<table>
<thead>
<tr>
<th>Days</th>
<th>No. of times</th>
<th>Fodder concentration to be fed per day</th>
<th>Calf starter (Kg)</th>
<th>Dam's Milk (litres)</th>
<th>Colostrum (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-3</td>
<td>Ad libitum preferably by grazing</td>
<td>2.6</td>
<td>0.050</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4-7</td>
<td>Ad libitum preferably by grazing</td>
<td>3.5</td>
<td>0.100</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8-14</td>
<td>Ad libitum preferably by grazing</td>
<td>2.6</td>
<td>0.150</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15-21</td>
<td>Ad libitum preferably by grazing</td>
<td>2.6</td>
<td>0.400</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>22-28</td>
<td>Ad libitum preferably by grazing</td>
<td>3.1</td>
<td>0.700</td>
<td></td>
</tr>
<tr>
<td>6-7</td>
<td>29-35</td>
<td>Ad libitum preferably by grazing</td>
<td>3.1</td>
<td>0.900</td>
<td>0.450</td>
</tr>
<tr>
<td>8</td>
<td>50-56</td>
<td>Ad libitum preferably by grazing</td>
<td>1.3</td>
<td>0.400</td>
<td>0.900</td>
</tr>
<tr>
<td>9</td>
<td>57-63</td>
<td>Ad libitum preferably by grazing</td>
<td>1.3</td>
<td>0.450</td>
<td>0.900</td>
</tr>
<tr>
<td>10</td>
<td>64-70</td>
<td>Ad libitum preferably by grazing</td>
<td>0.9</td>
<td>0.230</td>
<td>0.900</td>
</tr>
<tr>
<td>11-12</td>
<td>71-84</td>
<td>Ad libitum preferably by grazing</td>
<td>2.6</td>
<td>1.350</td>
<td>1.350</td>
</tr>
<tr>
<td>13-14</td>
<td>85-112</td>
<td>Ad libitum preferably by grazing</td>
<td>1.3</td>
<td>1.350</td>
<td>1.350</td>
</tr>
<tr>
<td>15-16</td>
<td>113-140</td>
<td>Ad libitum preferably by grazing</td>
<td>2.2</td>
<td>1.350</td>
<td>1.350</td>
</tr>
<tr>
<td>17-18</td>
<td>141-168</td>
<td>Ad libitum preferably by grazing</td>
<td>1.8</td>
<td>1.350</td>
<td>1.350</td>
</tr>
<tr>
<td>19-20</td>
<td>169-182</td>
<td>Ad libitum preferably by grazing</td>
<td>0.9</td>
<td>0.900</td>
<td>1.500</td>
</tr>
</tbody>
</table>
During off seasons, the roughages are supplemented by hill grass hay or wheat straw to meet the bulk requirements of animals.

**Housing**

The animals are stall fed. They are housed in sheds throughout the day except when the sheds have to be cleaned when they are left out in the paddocks. The sheds are different for young stock, dry animals, animals in advanced stage of pregnancy and lactating animals. The young stock are housed according to their age groups. Young stock from birth to six months, six months to two years, and heifers from two years to conception are kept in different sheds.

**Breeding**

Breeding of buffaloes in military farms is by natural service. Bulls are used by rotation every third day. Vasectomized bulls are also used to detect animals in heat. Experienced attendants also parade teaser bulls to locate animals in oestrus.

**Data collection**

The following particulars of the buffaloes which completed their first lactation in the herd were collected from the records and history and pedigree sheets.

1. Animal number
2. Sire number
3. Age at first calving in months
(4) First service period in days.
(5) Month and year of calving
(6) Yield in 300 days in kg in first lactation
(7) Complete lactation yield in kg in first lactation.
(8) Lactation length in days
(9) Initial milk yield - Milk yield on the 4th day of calving was taken as the initial milk yield as the colostrum was mostly fed to the calves.
(10) Milk yield of the day at weekly intervals starting from 4th day of initial milk yield till the end of the lactation or 300 days whichever was earlier.
(11) Peak yield in kg (maximum milk yield on a single day during the lactation).
(12) Ascending phase in days (Number of days required to reach the peak yield).
(13) Total milk yield in the ascending phase in kg.

The average lactation length was observed to be 297 days with a S.D. of 66 days. All the lactations which had less than 297-3x66 days i.e. 100 days were considered as abnormal lactations and hence were omitted from the scope of the study. Similarly, all the lactations terminating in abortions, drying due to sickness and such other abnormalities were also excluded. In some of the cases, the milk records for more than two months during the course of the lactation were not available. Such animals were also omitted from the scope
of the study. Finally the records of 1474 buffaloes were available for the present investigation.

Analytical methods

The mean, SD, SE and CV were calculated for the various parameters studied.

Least Squares Analysis

The influence of farm, period, season and the age at first calving of various traits were studied by using the least squares technique of analysis for non-orthogonal data as described by Harvey (1975). The following model was used for the purpose:

\[ Y_{ijkl} = \alpha + F_i + P_j + S_k + b(X_{ijkl}) + e_{ijkl} \]

Where,

- \( Y_{ijkl} \) = the \( i^{th} \) observation in the \( k^{th} \) season, \( j^{th} \) period in \( i^{th} \) farm.
- \( \alpha = (u - b\bar{X}) \), \( u \) being population mean, \( \bar{X} \) the average age at first calving.
- \( F_i \) = the effect of \( i^{th} \) farm (\( i = 1, \ldots, 10 \))
- \( P_j \) = the effect of \( j^{th} \) period (\( j = 1, \ldots, 4 \))
- \( S_k \) = the effect of \( k^{th} \) season (\( k = 1, 2 \))
- \( b \) = partial regression coefficient of \( Y_{ijkl} \) on age at calving.
- \( X_{ijkl} \) = age at first calving corresponding to \( Y_{ijkl} \)
- \( e_{ijkl} \) = random error which is assumed to follow normal distribution \( N(0, \sigma^2) \).
The following restrictions were imposed to estimate the least square constants of the main effects:

\[ \sum_i \alpha_i = \sum_j \beta_j = \sum_k \delta_k = 0 \]

The individual observations were corrected for the factors which affected the traits significantly for further analysis.

The data collected were spread over a period of thirteen years from 1963-1975. The thirteen years were grouped into four periods as follow:

1st period = 1963 to 1966 (4 years)
2nd period = 1967 to 1969 (3 years)
3rd period = 1970 to 1972 (3 years)
4th period = 1973 to 1975 (3 years)

The basis of classification of the year into seasons was the frequency of calving in different months. The Table 3.3 gives the distribution of calvings monthwise.

As could be seen from the table, 86 percent of the calvings occurred during July to December, while only 14 percent calvings occurred between January and June. The year was, therefore, divided into two seasons, namely, season one - least calving season, i.e., January to June; season two - maximum calving season, i.e., July to December.

Lactation curve studies

To study the shape of the lactation curve, the following mathematical models were tried. Weekly milk yield data on the individual animals were used to estimate the
Table 3.3. Frequency distribution of calvings

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Month</th>
<th>Frequency of calvings</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>January</td>
<td>67</td>
</tr>
<tr>
<td>(2)</td>
<td>February</td>
<td>50</td>
</tr>
<tr>
<td>(3)</td>
<td>March</td>
<td>40</td>
</tr>
<tr>
<td>(4)</td>
<td>April</td>
<td>21</td>
</tr>
<tr>
<td>(5)</td>
<td>May</td>
<td>19</td>
</tr>
<tr>
<td>(6)</td>
<td>June</td>
<td>29</td>
</tr>
<tr>
<td>(7)</td>
<td>July</td>
<td>109</td>
</tr>
<tr>
<td>(8)</td>
<td>August</td>
<td>484</td>
</tr>
<tr>
<td>(9)</td>
<td>September</td>
<td>389</td>
</tr>
<tr>
<td>(10)</td>
<td>October</td>
<td>205</td>
</tr>
<tr>
<td>(11)</td>
<td>November</td>
<td>115</td>
</tr>
<tr>
<td>(12)</td>
<td>December</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1598</td>
</tr>
</tbody>
</table>
parameters of the mathematical model selected for investigation:

(i) **Inverse polynomial** (Nelder, 1966)

\[ \frac{X}{Y} = b_0 + b_1 X + b_2 X^2 \]

Where,

\[ Y = \text{Days' yield in the } x^{th} \text{ week.} \]

\[ X = \text{Week number after parturition (ranging from 1 to 43)} \]

\[ b_0, b_1, \text{ and } b_2 \text{ are the parameters of the mathematical model.} \]

(ii) **Exponential parabola** (Sikka, 1950)

The exponential parabola was used in fitting the individual lactation curves.

\[ Y_t = A e^{bt} + ct^2 \]

Where,

\[ Y_t = \text{Yield in the } t^{th} \text{ week.} \]

\[ t = \text{Week number after parturition (ranging from 1 to 43).} \]

\[ e = \text{base of natural logarithms.} \]

\[ A, b \text{ and } c \text{ are constants.} \]

This function was transformed into a quadratic function by logarithmic transformation for estimation of the parameters \( A, b \text{ and } c. \)

\[ \log Y_t = \log A + bt + ct^2 \]
(iii) Gamma function (Wood, 1967)

Gamma function was used in fitting the lactation curve function.

\[ Y_n = A n^b e^{-cn} \]

Where,

- \( Y_n \) = Days' milk yield in the \( n^{th} \) week.
- \( n \) = Week number after parturition (ranging from 1 to 43).
- \( e \) = base of natural logarithms
- \( A, b \) and \( c \) are the parameters.

The above function was transformed into a linear one by logarithmic transformation for the estimation of parameters.

\[ \log_e Y_n = \log_e A + b \log_e n - cn \]

The daily yield in the early lactation increases till \( n^{th} \) week, where \( b \log_e n = cn \) and \( \log_e Y_n = a \). Therefore, \( 'a' \) represents log of peak yield.

The number of weeks after parturition required to attain the peak yield is given by:

\[ n_p = \frac{b}{c} \] (Wood, 1967)

Method of least squares was employed to estimate the parameters of the above mathematical models.

The mathematical models which precisely described the lactation curve as determined by the coefficient of determination \( (R^2) \) were selected for further study.

The mathematical models finally selected were fitted to individual animals' lactation yield in the first lactation.
The environmental effects like farm, period, season and age at first calving were estimated by using Harvey's technique of least squares analysis of non-orthogonal data as described earlier.

**Estimation of persistency**

A number of measures of persistency were studied. In the estimation of the measures of persistency, cumulative part yields were estimated by making use of weekly milk yield data. In some of the cases, weekly milk yield records for a part of the period were not available. When more than eight continuous weekly milk recordings were missing, the data of that animal was not considered for the estimation of persistency. When less than eight observations were missing, the missing observations were estimated as follows:

(a) When the observations were missing at the beginning itself, the first observation available was reckoned as the observation for the missing weeks.

(b) When the observations were missing in the middle of the lactation, the average of the preceding and succeeding observations of the missing values was reckoned as the value of the missing observations.

(c) When the observations were missing at the end of the lactation, the last available observation was assumed to be the milk yield during the end of the lactation.

(d) When 300\(^\text{days}\) milk yield of an animal was not available, the same was calculated from the weekly milk yield data.
The following measures of persistency were studied:

(1) **Rate of increase**

Rate of increase in daily milk yield from initial yield to peak yield per day (kg) was estimated as follows:

\[
\text{Rate of increase} = \frac{\text{Peak yield} - \text{Initial yield}}{\text{Duration of ascending phase}}
\]

(2) **Average daily yield in ascending phase**

\[
\text{Average daily yield in ascending phase} = \frac{\text{Yield in ascending phase}}{\text{Duration of ascending phase}}
\]

(3) **Ludwick-Petersen method** - The general formula suggested by Ludwick-Petersen (1943) for estimating persistency measure was used.

The lactation length was divided into four periods:

- **Period 1** = 1 - 10 weeks
- **Period 2** = 11 - 20 weeks
- **Period 3** = 21 - 30 weeks
- **Period 4** = 31 - 40 weeks

When,

\[
p = \frac{4X_2}{X_1} + \frac{3X_3}{X_2} + \frac{2X_4}{X_3} + \frac{X_4}{X_3} - \left\{ \frac{(4-1)(4-2)}{2} \right\}
\]

Where, \(X_i\) is the total milk yield in the \(i\)th period.

(4) **Mahadevan's method** - A slight modification was made in the method suggested by Mahadevan (1951). Instead of taking first 180 days milk yield, total milk yield in the first 26 weeks (or
182 days) was taken for ease of calculation.

$$p = \frac{A - B}{B}$$

Where,

$P$ = the persistency index,

$A$ = milk yield in the first 26 weeks of lactation, and

$B$ = milk yield in the first 10 weeks of lactation.

(5) Johansson and Hansson (1948) suggested the ratio of yields of second hundred days to first hundred days and third hundred days to first hundred days as two measures of persistency. To facilitate the computation of these two measures of persistency from the weekly milk yield data, the ratios of the milk yield of second fourteen weeks to first fourteen weeks and third fourteen weeks to first fourteen weeks were taken for estimating the measures of persistency.

(a) $P_{2:1} = \frac{p_2}{p_1}$

(b) $P_{3:1} = \frac{p_3}{p_1}$

Where, $P_1$, $P_2$ and $P_3$ are the first, second and third fourteen weeks milk yield totals respectively.

(6) The ratio of descending phase yield to the ascending phase yield was taken as another measure of persistency.

$$p = \frac{300 \text{ days milk yield} - \text{Yield in ascending phase}}{\text{Yield in ascending phase}}$$
Estimation of genetic parameters

The heritability and genetic correlations were estimated by paternal halfsib method. The sires which had a minimum of five daughters were only included for the estimation. The mathematical model to estimate heritability was

\[ Y_{ij} = U + S_i + e_{ij} \]

Where,

- \( Y_{ij} \) = \( j^{th} \) observation of \( i^{th} \) sire
- \( U \) = overall mean common to all observations.
- \( S_i \) = Random effect of \( i^{th} \) sire common to all its progeny.
- \( e_{ij} \) = random error assumed to follow \( N(0, \sigma^2) \).

The sire component of variance was estimated by the analysis of variance as follows:

Analysis of variance table

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>( \bar{M}S, S_s )</th>
<th>Component of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between sires</td>
<td>( S-1 )</td>
<td>( \bar{M}S_s )</td>
<td>( \sigma^2 + K \sigma_s^2 )</td>
</tr>
<tr>
<td>Within sires</td>
<td>( N-S )</td>
<td>( \bar{M}S_e )</td>
<td>( \sigma_e^2 )</td>
</tr>
<tr>
<td>Total</td>
<td>( N-1 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where, 

\[ K = \frac{1}{S-1}(N - \frac{\sum n_i^2}{N}) \]

Where, \( S \) is the number of sires,
\( N \) is the total number of progeny,
\( n_i \) is the number of progeny for each sire, and 
\( K \) is the average progeny per sire.

\[
\sigma_s^2 = \frac{MS_s - MS_e}{K^2}
\]

and

\[
h^2 = \frac{4 \times \sigma_s^2}{\sigma_e^2 + \sigma_s^2}
\]

Standard error of \( h^2 \) was estimated as per the formula given 
by Swiger et al. (1964).

\[
SE(h^2) = 4 \times \sqrt{\frac{2(N-1)(1-h^2/4)^2 \left\{1+(K-1)h^2/4\right\}^2}{K^2(N-S)(S-1)}}
\]

The genetic correlation values between various traits were 
estimated by analysis of covariance technique.

### Analysis of covariance table

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>MCP</th>
<th>EMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between sires</td>
<td>( S-1 )</td>
<td>( MCP_{s(XY)} )</td>
<td>( \text{Cov}<em>{w(XY)} + K \text{Cov}</em>{s(XY)} )</td>
</tr>
<tr>
<td>Within sires</td>
<td>( N-S )</td>
<td>( MCP_{w(XY)} )</td>
<td>( \text{Cov}_{w(XY)} )</td>
</tr>
<tr>
<td>Total</td>
<td>( N-1 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where,
\( S = \) the number of sires
\( N = \) total number of observations
\( K = \) average number of progeny per sire
The sire component of covariance is given by
\[ \text{Cov}_s(XY) = \frac{\text{MCP}_s(XY) - \text{MCP}_u(XY)}{K} \]

Genetic correlation is given by
\[ r_G(XY) = \frac{\text{Cov}_s(XY)}{\sqrt{\sigma^2_s(X) \sigma^2_s(Y)}} \]

The approximate standard error of \( r_G(XY) \) was estimated according to the formula given by Robertson (1959).
\[ \text{S.E.} r_G(XY) = (1 - r^2_G(XY)) \left( \frac{S.E. h^2(X) \times S.E. h^2(Y)}{2(h^2(X) \times h^2(Y))} \right) \]

Estimates of phenotypic correlation

The phenotypic correlation between two traits was estimated by the product moment correlation coefficient.
\[ r_p(XY) = \frac{\sum XY - \frac{\sum X \times \sum Y}{n}}{\sqrt{\left( \sum X^2 - \frac{\left( \sum X \right)^2}{n} \right) \left( \sum Y^2 - \frac{\left( \sum Y \right)^2}{n} \right)}} \]

The standard error of phenotypic correlation was estimated as:
\[ \text{S.E.} r_p(XY) = \sqrt{1 - r^2 \frac{1}{n-2}} \]

Estimation of lactation yield from systematic sampling of daily milk records at different intervals

The weekly milk yield data of individual animals were used to estimate the total lactation yield during the first lactation. Different intervals of sampling were tried.
The milk yield at different intervals of sampling was generated from weekly systematic samples of milk yield. Various sampling intervals and starting of the first sample are given below:

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Testing interval</th>
<th>The first sample starting with</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Weekly</td>
<td>1st week</td>
</tr>
<tr>
<td>2.</td>
<td>Two</td>
<td>i) 1st</td>
</tr>
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<td></td>
<td></td>
<td>ii) 2nd</td>
</tr>
<tr>
<td>3.</td>
<td>Four</td>
<td>i) 1st</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii) 2nd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii) 3rd</td>
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<tr>
<td></td>
<td></td>
<td>iv) 4th</td>
</tr>
<tr>
<td>4.</td>
<td>Six</td>
<td>i) 1st</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii) 2nd</td>
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<tr>
<td></td>
<td></td>
<td>iii) 3rd</td>
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<td></td>
<td></td>
<td>iv) 4th</td>
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<td></td>
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<td>v) 5th</td>
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<tr>
<td></td>
<td></td>
<td>vi) 6th</td>
</tr>
<tr>
<td>5.</td>
<td>Eight</td>
<td>i) 1st</td>
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<td></td>
<td></td>
<td>ii) 2nd</td>
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<td></td>
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<td>iii) 3rd</td>
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<tr>
<td></td>
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<td>iv) 4th</td>
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<td></td>
<td>v) 5th</td>
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<td></td>
<td></td>
<td>vi) 6th</td>
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<tr>
<td></td>
<td></td>
<td>vii) 7th</td>
</tr>
<tr>
<td></td>
<td></td>
<td>viii) 8th</td>
</tr>
<tr>
<td>6.</td>
<td>Ten</td>
<td>i) 1st</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii) 2nd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii) 3rd</td>
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<td></td>
<td>iv) 4th</td>
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<td>vii) 7th</td>
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<td>viii) 8th</td>
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<td>ix) 9th</td>
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<td></td>
<td>x) 10th</td>
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<tr>
<td>7.</td>
<td>Twelve</td>
<td>i) 1st</td>
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<td>ii) 2nd</td>
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<td>iii) 3rd</td>
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<td>x) 10th</td>
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<td></td>
<td>xi) 11th</td>
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<tr>
<td></td>
<td></td>
<td>xii) 12th</td>
</tr>
</tbody>
</table>
for each systematic sample, the lactation milk yield was estimated as follows:

\[ Y_{ij} = \frac{\sum Y_{ijk} \times \text{Lactation length}}{n_{ij}} \]

Where,

- \( Y_{ij} \) is the estimated lactation yield in the \( j^{th} \) systematic sample of the \( i^{th} \) animal.
- \( Y_{ijk} \) is the \( k^{th} \) observation in the \( j^{th} \) systematic sample for the \( i^{th} \) animal.
- \( n_{ij} \) is the number of observations in the \( j^{th} \) systematic sample for the \( i^{th} \) animal.

**Estimation of Errors**

a. The sampling error in the estimated lactation yield for each animal was calculated by:

\[ E_{ij} = \hat{Y}_{ij} - Y_i \]

Where, \( E_{ij} \) is the sampling error.

- \( \hat{Y}_{ij} \) is the estimated lactation yield of the \( i^{th} \) animal in the \( j^{th} \) systematic sample.
- \( Y_i \) is the actual first lactation yield of the \( i^{th} \) animal.

b. The average sampling error was calculated by

\[ E_j = \frac{\sum E_{ij}}{N} \]

Where, \( E_j \) is the average sampling error, and \( N \) is the number of animals.
The standard deviation of the sampling error was calculated by

$$SDE_j = \sqrt{\frac{\sum_{i}^{N} (E_{ij} - \bar{E}_{ij})^2}{N}}$$

Average percentage error in the $j^{th}$ systematic sample was calculated by

$$\text{Percentage error} = \frac{\sum_{i}^{N} E_{ij}}{\sum_{i}^{N} Y_{i}} \times 100$$

Average absolute error was calculated by

$$\text{Av. absolute error} = \frac{\sum_{i}^{N} |E_{ij}|}{N}$$

Percentage absolute error was calculated by:

$$\text{Percentage absolute error} = \frac{\sum_{i}^{N} |E_{ij}|}{\sum_{i}^{N} Y_{i}} \times 100$$

Estimation of lactation yield from part lactations

The part lactation yields of 4 weeks, 6 weeks, etc at an increment of 2 weeks, up to 42 weeks were used to estimate the complete lactation yield of an animal. The part lactation yields were estimated from the weekly systematic yields.

$$X_{i} = \text{part lactation yield} = \sum_{j}^{42} X_{ij}$$

Where, $j$ varying from 4 to 42 weeks depending upon the period of part lactation.

$$Z_{ij} = j^{th} \text{ weekly yield per day of the } i^{th} \text{ animal,}$$

$$X_{i} = \text{the part lactation yield of } i^{th} \text{ animal.}$$
Ratio and regression methods were used to estimate the total (300 days) lactation yield.

a. **Ratio method**

\[ \hat{Y}_i = R \times X_i \]

Where, \( R = \frac{\sum Y_i}{\sum X_i} \)

Where, \( \hat{Y}_i \) = the estimated lactation yield of \( i^{th} \) animal
\( X_i \) = the estimated part lactation yield
\( Y_i \) = the actual 300 days yield.

b. **Regression method**

The linear regression model was used to predict the first lactation yield on the basis of part lactation yield. The model was:

\[ \hat{Y}_i = a + bX_i \]

Where, \( \hat{Y}_i \) is the estimated 300 days lactation yield of \( i^{th} \) animal
\( X_i \) is part lactation yield of \( i^{th} \) animal
and \( a \) and \( b \) are the intercept and the regression coefficient respectively.

Method of least squares was used to fit the regression equation.

The various types of error estimates as described in the previous section were also calculated for estimated lactation yield.

**Sire evaluation**

Two methods of sire evaluation were used. Only sires with a minimum of five daughters were included for
evaluation. It was assumed that the matings were at random in each herd.

(a) Simple daughters' average index (I₁)

In this method, the average 300 days lactation yield during the first lactation of the progeny of a sire was taken as an index of the sire.

\[ I₁ = \overline{d} \]

(b) Contemporary deviation method (I₂)

The following sire index was used to evaluate the sires:

\[ I₂ = u + \frac{2nh^2}{4+(n-1)h^2} (\overline{d} - \overline{d}_{AD}) \]

Where,

- \( u \) = herd average
- \( h^2 \) = the heritability of first lactation
- \( n \) = the number of daughters of the sire
- \( \overline{d} \) = the average of the daughters
- \( \overline{d}_{AD} \) = the contemporary average of daughters.

The variance of the two sire indices was calculated as below:

\[ V(I₁) = \frac{\sum_{i=1}^{n} D_i^2 - (\sum_{i=1}^{n} D_i)^2/n}{n(n-1)} \]

The variance of I₂ was calculated as follows:

\[ V(I₂) = V(Z \times A) = Z^2 V(A) + A^2 V(Z) \]

Where, \( Z = \frac{2nh^2}{4+(n-1)h^2} \)
Where, \( C_{AD} \) is the milk yield of the contemporaries,

\( N \) is the number of contemporaries.

\[ U(Z) = U(h^2) \left[ \frac{4n^2}{\{4+(n-1)h^2\}^2} - \frac{4n(n-1)}{\{4+(n-1)h^2\}^3} + \frac{4n^2(n-1)^2(h^2)^2}{\{4+(n-1)h^2\}^4} \right] \]

(Kempthorne, 1957)

The contemporary average was calculated by taking all the animals in the first lactation in the same year, in a particular herd, except the yield of the daughters' of the sire under evaluation.

The sire indices by the two methods were evaluated for each herd separately as the sires were exclusively used within a herd by natural service. For each herd, the sires were ranked on the basis of the two indices. To compare the ranking of the sires by the two methods, Spearman's rank correlation coefficient as per following formula was calculated:

\[ r = 1 - \frac{6 \sum d_i^2}{n(n^2-1)} \]
Where, $d_i$ is the difference between the rankings of the sire by the two methods.

$n$ is the number of sires under evaluation.

The product moment correlation as defined earlier was also calculated for the two indices.

**Sire evaluation by using systematic sampling of daily milk records**

The interval of systematic sampling of daily milk records (explained earlier) which gave least error variance were selected to evaluate the sires. The first lactation yield was estimated from the systematic samples of periodical daily milk yield data on each animal. The estimated first lactation yield was used to construct the sire indices. Sire index $I_1$ alone was considered for such studies.

The minimum interval for periodical sampling of daily milk records needed for the estimation of first lactation yield of daughters to evaluate the sires as precisely as on the basis of actual 300 days lactation records was determined.

The number of daughters per sire (to be brought under systematic sampling of daily milk records) to determine the breeding value as accurately as that of using actual 300 days lactation yield was also estimated.

$$n' = n(1 + \frac{V(E)}{V(Y)})$$  
(Rao, 1977)

Where, $n'$ is the number of daughters to be brought under systematic sampling plan,

$n$ is the number of daughters with actual 300 days lactation records,
U(£) is the variance of sampling error in systematic sample estimate, and
V(Y) is the variance in the actual 300 days first lactation yield.

Sire evaluation by using part lactation records

(i) The estimated 300 days first lactation yield, based on part lactation records described earlier (page 97) were used to evaluate the sires.

(ii) Besides the above, gamma function and inverse polynomial were fitted for the part lactation records. These functions were used to extrapolate the part yields to 300 days first lactation yield. This was also used in sire evaluation.

(iii) The part lactation yields estimated from the systematic sample itself were used to evaluate the sires.

(a) The period upto which the part lactation yield of a daughter is required to determine the breeding value of a sire as accurately as that based on actual 300 days lactation yield was also estimated.

(b) The number of daughters for which the part lactation records should be taken in (a) above was estimated as described earlier (page 96).

The product moment correlation and the rank correlations between the sire indices based on 300 days yield and systematic sample estimates/part lactation estimates were calculated as well.