GROWTH PERFORMANCE OF THREE-BREED CROSSES OF HOLSTEIN FRIESIAN, BROWN SWISS AND HARIANA CATTLE *

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ABSTRACT
The growth performance of three-breed crosses of Holstein Friesian, Brown Swiss and Hariana breeds of cattle (FBH) maintained at Indian Veterinary Research Institute, Izatnagar from 1976 to 1996 was studied. The overall mean body weight increased from 26.50 ± 0.35 kg at birth to 306.33 ± 3.19 kg at 24 months of age. Their average body weights at first fertile service and first calving were 268.50 ± 2.60 kg and 305.64 ± 2.84 kg, respectively. The mean body weight at birth of parent crosses was significantly (p < 0.01) higher than that of inter-se crosses. But after the birth, the inter-se crosses showed better growth rate and achieved higher mean body weights at 24 months of age than the parent crosses. The season of calving showed a significant (p < 0.01) effect at 6 months of age on growth performance of FBH crosses. The growth among periods was significant (p<0.01) during birth to 24 months of age indicated the effects of differential managemental practices on the growth performance of these crosses. The parity of the dams had no effect on the growth performance of their daughters. Their body weight variations are best explained by the gamma type function, which can be considered as a representative model of growth performance of three-breed crosses of Holstein Friesian, Brown Swiss and Hariana cattle during birth to 24 months of age.

INTRODUCTION
The cross-breeding programme was initiated during 1970 in the country to generate two-breed and three-breed crosses of Holstein Friesian, Brown Swiss and Jersey cattle of exotic inheritance with indigenous cows to improve attributes like fast growth rate, early maturity, high milk production, small body size, efficient feed conversion efficiency and higher butter fat percentage. Their growth measured in terms of body weight and body measurements provides useful information for diagnosis of health problems and managemental decisions (Devir et al., 1995; Halachmi et al., 1997; Maltz et al., 1997). With the introduction of exotic inheritance in indigenous breeds of cattle, the importance of assessing the trend of growth rate of crossbred populations has increased (Bhat and Singh, 1978; Ghosh et al., 1979; Kulkarni et al., 1982; Srivastava et al., 1984; Pandey et al., 1986; Nautiyal and Bhat, 1989; Chopra, 1990). Therefore, the present study was undertaken to assess the growth performance of three-breed crosses of Holstein Friesian, Brown Swiss with indigenous cows of Hariana breed of a herd maintained at Indian Veterinary Research Institute, Izatnagar.

MATERIAL AND METHODS
To study the growth performance of crossbred heifers from birth to 24 months of age, the data maintained at Cattle and Buffalo farm of Indian Veterinary Research Institute, Izatnagar of three-breed crosses between Holstein Friesian, Brown Swiss and Hariana (½F ¼B ¼H) from 1976 to 1996 were used. The Hariana cows of foundation stock were inseminated with imported semen of progeny-tested bulls of Brown Swiss to produce BH half-bred. To further increase the exotic inheritance to 75 per cent, the BH half-breds were mated to Holstein Friesian to produce three-breed crosses, namely, FBH. The FBH-inter-se generations were produced by inter-se mating between males and females of FBH progenies.

The body weights at birth, 3, 6, 12, 18 and 24 months of age were recorded along with body weights at first fertile service (FFS) and first calving (FC). The data were classified according to generation, period, season and parity of the dams. The entire period of 21 years
was divided into five periods viz. 1976-79, 1980-83, 1984-87, 1988-91 and 1992-1996. The five seasons were formed on the basis of the month of calving viz. winter (December to February), spring (March and April), summer (May and June), monsoon (July to September) and autumn (October and November).

Performing least squares analysis for partitioning the total variance as per method put forward by Harvey (1966), the fixed effects of generation (G), season (S), period (P) and parity of dams (PD) were obtained using linear model as below.

\[ Y_{ijklm} = \bar{Y} + G_i + S_j + P_k + PD_l + \epsilon_{ijklm} \]

where \( \bar{Y} \) is general mean, \( Y_{ijklm} \) is the \( m \)th observation of \( l \)th parity in \( k \)th period, \( j \)th season of \( i \)th generation and \( \epsilon_{ijklm} \) is random error associated with \( Y_{ijklm} \) observation distributed normally with mean zero and variance \( \sigma^2 \).

The following statistical models were fitted to overall least squares means of body weights at birth, 3, 6, 12, 18 and 24 months of age and monthly weight gains as: birth to 3 months, 3 to 6 months, 6 to 12 months, 12 to 18 months, 18 to 24 months and as: birth to 3 months, birth to 6 months, birth to 12 months, birth to 18 months and birth to 24 months to know the best-fitted model explaining their total variation during birth to 24 months of age.

1. Exponential growth function (Snedecor and Cochran, 1967):
\[ Y_t = a \cdot (b \cdot t) \text{ or } Y_t = a \cdot e^{ct} \]

2. Parabollic or quadratic function (Snedecor and Cochran, 1967):
\[ Y_t = a + b \cdot t + c \cdot t^2 \]

3. Parabollic exponential function (Sikka, 1950):
\[ Y_t = a \cdot e^{kt+c} \]

4. Inverse polynomial function (Nelder, 1966):
\[ Y_t = t / (a + b \cdot t + c \cdot t^2) \]

5. Gamma type function (Wood, 1976):
\[ Y_t = a \cdot t^b \cdot e^{ct} \]

6. Product of two exponential functions (Prasad and Singh, 2001):
\[ Y_t = a \cdot e^{(b \cdot t + c/t)} \]

where \( a, b, c \) are the parameters to be estimated from the data. The goodness of fit of these models was tested by three measures viz. coefficient of determination \( R^2 \), mean absolute error (MAE) and mean square error (MSE) given as below:

\[ R^2 = 1 - \frac{\sum_{i=1}^{n} (Y_{oi} - Y_{ei})^2}{\sum_{i=1}^{n} (Y_{oi} - Y_{m})^2} \]

\[ MAE = \frac{1}{n} \sum_{i=1}^{n} |Y_{oi} - Y_{ei}| \]

\[ MSE = \frac{1}{n - p} \sum_{i=1}^{n} (Y_{oi} - Y_{m})^2 \]

where \( Y_{oi} \) and \( Y_{ei} \) are observed and estimated values respectively of trait at \( i \)th stage of age, \( Y_{m} \) is mean of observed data, \( n \) is the time points during age of animal and \( p \) is the number of parameters in the model. Higher value of \( R^2 \) and smaller values of MAE and MSE showed better fit for the data. The ranks were allotted to these measures for different mathematical functions and their average rank was calculated for the choice of suitable function describing the growth performance of the crossbred heifers.

**RESULTS AND DISCUSSION**

The least squares means of body weights at six time points during birth to 24 months of age along with body weights at first fertile service and first calving are presented in Table 1. The overall mean body weight increased from 26.50 ± 0.35 to 306.33 ± 3.19 kg from birth to 24 months of age. The overall mean body weights at first fertile service and first calving of FBH crosses were 268.50 ± 2.60 kg and 305.64 ± 2.84 kg, respectively. These results are in conformity with the studies of...
### TABLE 1. Least squares means for various body weights (kg) of $\frac{1}{4}$ $\times$ $\frac{1}{4}$ and their inter- se crosses

<table>
<thead>
<tr>
<th>Source</th>
<th>Birth</th>
<th>3-month</th>
<th>6-month</th>
<th>12-month</th>
<th>18-month</th>
<th>24-month</th>
<th>Wt. at FFS</th>
<th>Wt at FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>26.50</td>
<td>67.28</td>
<td>96.58</td>
<td>151.70</td>
<td>226.46</td>
<td>306.33</td>
<td>268.50</td>
<td>305.64</td>
</tr>
<tr>
<td>±0.35</td>
<td>±0.73</td>
<td>±1.01</td>
<td>±1.79</td>
<td>±2.53</td>
<td>±3.19</td>
<td>±6.00</td>
<td>±2.84</td>
<td></td>
</tr>
<tr>
<td>(431)</td>
<td>(430)</td>
<td>(429)</td>
<td>(430)</td>
<td>(417)</td>
<td>(386)</td>
<td>(361)</td>
<td>(357)</td>
<td></td>
</tr>
</tbody>
</table>

**Generation groups**

- **FBH**
  - 27.95 \(\mu\) 69.13 \(\mu\) 96.64 \(\mu\) 147.71 \(c\) 216.11 \(bc\) 293.57 \(bc\) 246.13 \(ac\) 303.00 \(b\)
  - ±0.40 ±0.83 ±1.16 ±2.01 ±2.89 ±3.65 ±4.96 ±5.34
  - (189) (189) (188) (188) (186) (186) (162) (139)

- **FBH-I**
  - 26.80 \(\mu\) 68.78 \(\mu\) 100.03 \(a\) 154.68 \(ab\) 230.09 \(ab\) 307.60 \(a\) 265.86 \(b\) 319.76 \(a\)
  - ±0.38 ±0.79 ±1.11 ±1.95 ±2.77 ±3.49 ±4.82 ±5.10
  - (136) (135) (135) (136) (132) (127) (126) (123)

- **FBH-1**
  - 26.17 \(\mu\) 69.34 \(\mu\) 99.55 \(\mu\) 146.19 \(bc\) 231.37 \(a\) 313.77 \(a\) 243.23 \(bc\) 302.13 \(b\)
  - ±0.73 ±1.51 ±2.10 ±3.71 ±5.25 ±6.25 ±5.06 ±5.52

- **FBH-1**
  - 25.44 \(\mu\) 67.59 \(\mu\) 97.98 \(\mu\) 158.94 \(\mu\) 233.08 \(\mu\) 314.69 \(\mu\) 288.99 \(\mu\) 313.31 \(\mu\)
  - ±0.60 ±1.23 ±1.71 ±3.02 ±4.43 ±5.41 ±4.44 ±4.85
  - (54) (54) (54) (54) (47) (45) (44) (44)

**Season of birth**

- **Winter**
  - 26.87 68.47 98.39 \(\mu\) 150.97 227.90 305.58 271.56 305.28
  - ±0.44 ±0.90 ±1.25 ±2.20 ±3.14 ±3.97 ±3.22 ±3.51
  - (146) (145) (145) (146) (139) (125) (119) (119)

- **Spring**
  - 26.79 68.20 96.45 \(\mu\) 153.18 227.30 305.31 270.30 306.18
  - ±0.48 ±0.98 ±1.36 ±2.41 ±3.46 ±4.31 ±3.54 ±3.90
  - (87) (87) (87) (87) (83) (75) (70) (67)

- **Summer**
  - 26.32 66.87 96.73 \(\mu\) 152.32 233.25 310.01 268.87 310.37
  - ±0.66 ±1.35 ±1.88 ±3.32 ±4.69 ±5.66 ±4.65 ±5.08
  - (41) (41) (41) (41) (40) (38) (38) (38)

- **Monsoon**
  - 25.62 66.58 93.72 \(\mu\) 149.23 223.02 301.51 264.91 304.20
  - ±0.52 ±1.06 ±1.48 ±2.61 ±3.70 ±4.59 ±3.85 ±4.22
  - (85) (85) (85) (85) (84) (78) (70) (69)

- **Autumn**
  - 26.90 66.27 97.58 \(\mu\) 152.80 220.84 309.26 266.89 302.18
  - ±0.52 ±1.06 ±1.48 ±2.62 ±3.71 ±4.50 ±3.71 ±4.04
  - (72) (72) (71) (71) (70) (68) (64) (64)

**Period of birth**

- **1976-79**
  - 25.90 \(\mu\) 62.10 \(\mu\) 88.73 \(\mu\) 141.47 \(\mu\) 193.56 \(\mu\) 266.68 \(\mu\) 262.42 279.65 \(d\)
  - ±0.55 ±1.12 ±1.57 ±2.27 ±3.12 ±4.91 ±4.13 ±4.58
  - (131) (131) (130) (130) (128) (105) (82) (79)

- **1980-83**
  - 26.14 \(\mu\) 67.35 \(\mu\) 94.00 \(\mu\) 146.55 \(\mu\) 214.07 \(\mu\) 314.25 \(\mu\) 269.79 295.21 \(c\)
  - ±0.66 ±1.36 ±1.90 ±3.33 ±4.71 ±5.79 ±4.72 ±5.51
  - (49) (48) (48) (49) (49) (44) (43) (43)

- **1984-87**
  - 28.97 \(\mu\) 69.88 \(\mu\) 102.67 \(\mu\) 166.82 \(\mu\) 246.60 \(\mu\) 319.64 \(\mu\) 272.91 311.97 \(b\)
  - ±0.59 ±1.21 ±1.68 ±2.96 ±4.27 ±5.16 ±4.19 ±4.58
  - (63) (63) (63) (63) (60) (59) (59) (59)

- **1988-91**
  - 27.37 \(\mu\) 69.24 \(\mu\) 101.36 \(\mu\) 155.27 \(\mu\) 243.02 \(\mu\) 316.90 \(\mu\) 268.38 313.14
  - ±0.52 ±1.06 ±1.48 ±2.61 ±3.72 ±4.53 ±3.63 ±3.97
  - (70) (70) (70) (70) (67) (65) (66) (65)

- **1992-96**
  - 24.12 \(\mu\) 67.52 \(\mu\) 96.12 \(\mu\) 148.58 \(\mu\) 235.06 \(\mu\) 314.20 \(\mu\) 269.02 329.05 \(\mu\)
  - ±0.40 ±0.82 ±1.15 ±2.03 ±2.88 ±3.52 ±2.85 ±3.11
  - (118) (118) (118) (113) (113) (111) (111) (111)

* p< 0.01 * p< 0.01 * p< 0.01 * p< 0.01 * p< 0.01 * p< 0.01 * p< 0.01 * p< 0.01

The body weights differed significantly (p < 0.01) among the generations at birth, 3, 6, 12, 18 and 24 months of age for FBH crosses. The mean body weight at birth (27.95 ± 0.40 kg) of parent crosses (FBH) was significantly (p < 0.01) higher than that of the inter-se crosses. But, after the birth, the inter-se crosses had shown better growth rate than the parent crosses. The inter-se crosses FBH-I1, FBH-I2 and FBH-I3 achieved significantly (p < 0.01) higher mean body weights at 24 months of age than the parent crosses. The mean body weights at first fertile service of FBH-I3 (288.99 ± 4.44 kg) and FBH-I4 (298.31 ± 6.44 kg) were significantly (p < 0.01) higher than the other crosses. The mean body weights at first calving among the generations differed significant (p < 0.01) but no definite trend was observed with increase of generation order. The general trend of growth revealed that the growth rate after birth of parent crosses was slower than inter-se crosses during first 24 months of age from FBH crosses.

The season of calving showed a significant (p < 0.05) effect at 6 months of age on growth performance of FBH crosses contrary to reports of earlier workers (Rathi and Balaine, 1984; Khedekar et al., 1985; Nautiyal and Bhut, 1989). The monsoon-born calves had lower body weight in comparison to calves of other seasons indicating that humid stress after birth had adverse effect on growth performance of FBH crosses. However, the mean body weights at the first fertile service and first calving did not differ significantly among the seasons. The mean body weight differed significantly (p < 0.01) among periods indicating the effects of different managemental practices on the growth performance of FBH crosses, which is in conformity to findings of earlier workers (Misra, 1973, Koul, et al. 1985; Nautiyal and Bhat, 1989). The parity of dams had no effect on the growth performance of their daughters from FBH crosses.

The ranking based on three measures revealed that body weight variations were best explained by gamma type function (99.93%) followed by quadratic function (99.75%) during birth to 24 months of age for FBH crosses.
TABLE 2. Estimated parameters of different functions along with measures of their goodness-of-fit of three-breed crosses (FBH)

<table>
<thead>
<tr>
<th>Parameters/Measures</th>
<th>Exponential function</th>
<th>Quadratic function</th>
<th>Parabolic exponential function</th>
<th>Inverse polynomial function</th>
<th>Gamma-type function</th>
<th>Product of two exponential functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight at birth, 3, 6, 12, 18 and 24 months of age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>42.3126</td>
<td>31.4114</td>
<td>32.0404</td>
<td>-0.0024</td>
<td>46.1118</td>
<td>61.6196</td>
</tr>
<tr>
<td>B</td>
<td>1.0955</td>
<td>9.4934</td>
<td>0.1862</td>
<td>0.0137</td>
<td>0.2454</td>
<td>0.0699</td>
</tr>
<tr>
<td>C</td>
<td>0.0912</td>
<td>0.0780</td>
<td>-0.0040</td>
<td>-0.0025</td>
<td>0.0475</td>
<td>-0.0852</td>
</tr>
<tr>
<td>R^2 (%)</td>
<td>89.40</td>
<td>99.75</td>
<td>96.53</td>
<td>99.05</td>
<td>99.93</td>
<td>99.43</td>
</tr>
<tr>
<td>MAE</td>
<td>25.97</td>
<td>4.34</td>
<td>16.17</td>
<td>41.59</td>
<td>3.21</td>
<td>8.98</td>
</tr>
<tr>
<td>MSE</td>
<td>2246.26</td>
<td>45.58</td>
<td>613.00</td>
<td>11019.67</td>
<td>37.46</td>
<td>2.5809</td>
</tr>
<tr>
<td>Av. Rank</td>
<td>1.33</td>
<td>5.00</td>
<td>2.67</td>
<td>2.00</td>
<td>6.00</td>
<td>4.00</td>
</tr>
<tr>
<td>Monthly weight gains: birth to 3 months, birth to 6 months, birth to 12 months, birth to 18 months and birth to 24 months of age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>10.9676</td>
<td>18.4440</td>
<td>20.7413</td>
<td>-0.1094</td>
<td>8.4650</td>
<td>3.1482</td>
</tr>
<tr>
<td>B</td>
<td>1.0085</td>
<td>-6.1640</td>
<td>-0.5377</td>
<td>0.2034</td>
<td>-1.1985</td>
<td>2.3673</td>
</tr>
<tr>
<td>C</td>
<td>0.0085</td>
<td>1.0400</td>
<td>0.0910</td>
<td>-0.0211</td>
<td>0.4773</td>
<td>1.2337</td>
</tr>
<tr>
<td>R^2 (%)</td>
<td>0.02</td>
<td>94.49</td>
<td>93.29</td>
<td>95.02</td>
<td>98.26</td>
<td>96.24</td>
</tr>
<tr>
<td>MAE</td>
<td>1.6177</td>
<td>0.3768</td>
<td>0.4165</td>
<td>0.2566</td>
<td>0.1790</td>
<td>0.2412</td>
</tr>
<tr>
<td>MSE</td>
<td>8.0598</td>
<td>0.4333</td>
<td>0.5146</td>
<td>0.2192</td>
<td>0.1067</td>
<td>0.2203</td>
</tr>
<tr>
<td>Av. Rank</td>
<td>1.00</td>
<td>3.00</td>
<td>2.00</td>
<td>4.33</td>
<td>6.00</td>
<td>4.67</td>
</tr>
<tr>
<td>Monthly weight gains: birth to 3 months, 3 to 6 months, 6 to 12 months, 12 to 18 months, 18 to 24 months of age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>10.8415</td>
<td>17.6280</td>
<td>19.3516</td>
<td>-0.1067</td>
<td>8.4606</td>
<td>3.2140</td>
</tr>
<tr>
<td>B</td>
<td>1.0203</td>
<td>-5.4451</td>
<td>-0.4766</td>
<td>0.2016</td>
<td>-1.3474</td>
<td>0.2424</td>
</tr>
<tr>
<td>C</td>
<td>0.0201</td>
<td>0.9429</td>
<td>0.0628</td>
<td>-0.0216</td>
<td>0.4689</td>
<td>1.2019</td>
</tr>
<tr>
<td>R^2 (%)</td>
<td>3.03</td>
<td>76.88</td>
<td>75.32</td>
<td>86.62</td>
<td>87.47</td>
<td>88.64</td>
</tr>
<tr>
<td>MAE</td>
<td>1.6812</td>
<td>0.7965</td>
<td>0.8404</td>
<td>0.5427</td>
<td>0.5045</td>
<td>0.4961</td>
</tr>
<tr>
<td>MSE</td>
<td>8.18</td>
<td>1.9318</td>
<td>2.19</td>
<td>1.098</td>
<td>1.1072</td>
<td>0.9190</td>
</tr>
<tr>
<td>Av. Rank</td>
<td>1.00</td>
<td>3.00</td>
<td>2.00</td>
<td>4.33</td>
<td>4.67</td>
<td>6.00</td>
</tr>
</tbody>
</table>

(Table 2). The monthly body weight gains from birth to 3 months, birth to 6 months, birth to 12 months, birth to 18 months, birth to 24 months of age were also well fitted to gamma type function (98.26%) followed by the product of two exponential functions (96.24%). However, the monthly weight gain during birth to 3 months, 3 to 6 months, 6 to 12 months, 12 to 18 months, 18 to 24 months of age showed their best fit to the product of two exponential functions (88.64 %) closely followed by gamma type function (87.47%). Therefore, gamma type function was adjudged as the best-suited model explaining the growth performance of three-breed crosses of Holstein Friesian, Brown Swiss and Hariana breeds of cattle.

CONCLUSION

The growth performance of three-breed crosses of Holstein Friesian, Brown Swiss and Hariana cattle showed significant (p < 0.01) effects of generations and periods during birth to 24 months of age. The season of calving except at 6 months and parity of dams did not influence the body weight changes during birth to 24 months of age. The growth performance was well explained by gamma type function during birth to 24 months of age.

REFERENCES