GENETIC ARCHITECTURE OF GROWTH IN RELATION TO LACTATION PERFORMANCE IN SAHIWAL AND ITS CROSSES IN NORTHERN INDIA

Ph.D. THESIS

BY

Dyal Singh

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NATIONAL DAIRY RESEARCH INSTITUTE
KARNAL (HARYANA) INDIA

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THESIS
SUBMITTED TO THE PANJAB UNIVERSITY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE FACULTY OF DAIRYING, ANIMAL HUSBANDRY AND AGRICULTURE

BY
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KARNAL (HARYANA) INDIA
1977
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Division of Dairy Cattle Genetics
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I certify that the work reported in the thesis entitled "GENETIC ARCHITECTURE OF GROWTH IN RELATION TO LACTATION PERFORMANCE IN SAHIWAL AND ITS CROSSES IN NORTHERN INDIA" was carried out by Shri Dyel Singh, under my guidance for the requirement of Degree of Ph.D. in the Faculty of Dairying, Animal Husbandry and Agriculture of the Panjab University.

( R. R. Mishra )
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(Singh)

( Dyai Singh )
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<td>Su</td>
<td>Sahiwal</td>
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<tr>
<td>BS</td>
<td>Brown Swiss</td>
</tr>
<tr>
<td>HF</td>
<td>Holstein Friesian</td>
</tr>
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INTRODUCTION

Advances of international importance have been made in the production of food grains, the total wheat production alone rose from about 7.0 million tonnes in 1951 to about 27 million tonnes in 1973-74. In contrast to this, the progress in the area of animal production has not been substantial, the milk production in the country has gone up from 17.5 million tonnes in 1951 to only 23.20 million tonnes in 1973-74.

Milk and milk products are obviously the most widely accepted form of animal protein in India. Milk must be available to the general public, in adequate quantities, at reasonable prices. Furthermore, from nutritional point of view, the need to make-up the leeway between the present consumption level of milk (about 110 grams per capita per day) and the recommended level (284 grams) is imperative.

Dairying can not progress unless milk production becomes an economic proposition (Sundaresan, 1976). Milk production can be an economic proposition only under two conditions (i) supply of nutrients required for milk production as cheaply as possible - by feeding high quality greens; and (ii) higher levels
of production in dairy cows — by introduction of exotic germplasm in local cattle.

Considering the human population and their actual nutritional requirement of milk and milk products, National Commission of Agriculture and Animal Husbandry, INDIA (1976) indicated some projection to boost up milk production from present 23.2 million tonnes to 44.7 million tonnes by 1985 and 64.40 million tonnes by 2000 A.D. This projection demands, genetically faster gaining, early maturing and high producing cattle.

Systematic introduction of exotic inheritance into local stock has proved to be the best method of increasing milk production potential, however, adaptation of an animal to its environment is of primary importance. Foreign genetic strains cannot be introduced in a haphazard way into a given setting. With this objective in view the present project was taken to assess the genetic make-up of Sahiwal and its crosses in Northern India. The study was focussed on following four objectives (in brief):

(1) To assess the genetic architecture of growth parameters of Sahiwal and its crossbred cattle.

(2) Genetic study of first lactation components (initial, ascending, peak and descending yield) and 1st, 2nd and 3rd lactation yields.

(3) To estimate the genotypic and phenotypic correlations of growth parameters with first lactation performance.
(4) To construct the selection indexes with available economic values of selected traits.

Further, it was felt that the genetic knowledge of growth parameters and its direct quantitative effect on 1st lactation components, first, second and third lactation yield was inadequate, therefore, an investigation on genetic correlation between growth parameters and components of 1st lactation performance was taken-up in detail to ascertain the role of growth and body weights as a guide in construction of selection index combining milk production traits to suggest better genetic improvement of cattle in this region. The early selection of animal and an indication of better suited exotic germ plasm would avoid huge cost of rearing unprofitable producers.

The Sahiwal breed is most economic milk producing best dairy breed of the sub-continent. It has originated from Montgomery - Sahiwal district (Pakistan) but animals with high genetic architecture are available on various farms of Northern - Western India.

The Brown Swiss breed is officially selected for crossbreeding because of its qualities of heat tolerance, adaptability, feed conversion efficiency and draught power. The breed originated from Switzerland, but good milk strain has been developed by selective breeding in U.S.A. The Brown Swiss breed has been claimed to be a suitable donor in evolving multi-purpose cattle for economic milk production (NDRI, Karnal 1971-76).
The Holstein-Friesian is the breed of choice throughout the world as the best cattle breed for pure breeding as well as for crossing the local breeding stock. It is claimed to be most efficient for growth, production and draught. The breed was originated in Friesian Island (the Netherlands) but now good strains are available in all developed countries.
REVIEW OF LITERATURE

2.1. Body Weights

2.1.1. Birth weight

Birth weight is the first metric character which can be measured with reasonable accuracy. The influence of birth weight on survival, physiological and functional development in later life in form of growth and production traits was observed (Dawson et al., 1947; Yao et al., 1953; Singh and Desai, 1959 and Taneja and Bhat, 1970). It was also claimed by these and several other workers that calves born with heavier birth weight were found more vigorous and faster in growth than those born lighter (Prestin and Willis, 1970).

Factors Affecting Birth Weight

1. Breed: Variation in birth weight had been reported by several workers (Table 1). Exotic and exotic x zebu crossbred calves were observed with higher birth weight than zebu contemporaries (Naidu and Desai, 1961; Taneja and Bhat, 1970; Taneja, 1973; Mishra, 1973 and Hurty, 1974). Goswami and De (1963) and D'Souza (1972) could not find significant difference in birth weight of the groups of crossbred calves with varying amount of exotic inheritance.
Stanaker (1953) reported the heritability of birth weight as -0.09 from intrasire regression of daughter on dam. Legault and Touchberry (1962) estimated the heritability 0.38 by paternal half-sib correlation, 0.40 by intrasire regression of offspring on dam and 0.51 by full-sib correlation method of birth weight of five major breeds. The differences between the pooled estimates obtained by different methods might be due to sampling error, maternal effect, epistasis and dominance effect. Singh and Desai (1959) reported heritability 0.135 on birth weight of 277 Holstein-Friesian x Hariana halfbred calves, and Batra and Desai (1962) observed 0.23±0.15 on Sahiwal calves.

2. Season of Birth: Significant effect of season of birth on birth weight of Friesian x Zebu crosses (Roy and Goswami, 1960), of Gir, Ongole and Gujrati (Terres, 1961), of Sahiwal, Red Sindhi and Tharparkar (Modgil and Ray, 1965a,b), of Malvi breed (KrishnaRao, 1966) and of Sahiwal and Friesian x Sahiwal crosses (Taneja and Bhat, 1970; Taneja, 1973) was observed while Anantakrishnan and Lazarus (1953), Kohli et al. (1956) and Yadav (1964), Singh et al. (1966), Javeramkrishna et al. (1970) and Priya (1972) could not find significant effect of season on birth weight of some of the above and other breeds of cattle.

calves. Month of calving and weight of dam effect were found significant, while period of calving and calving sequence were statistically non-significant.

4. Sequence of Calving or Age of Dam—Roy and Geewami (1960) in Zebu x Holstein-Friesian crosses and Singh and Dutt (1961) in Sahiwal cattle reported that female calves were on an average 0.214 lb heavier at birth for each increase of one month in dam's age up to seven years. Yadav (1964) studied that birth weight of calf increased as the age of dam increased from 2.5 years to 7 years in Red Sindhi and their crosses with exotic breeds. Highly significant correlation between the age of dam and birth weight was observed by Junas and Kasir (1967) in purebred and crossbred Friesian calves and Venkateswarlu et al. (1972) in Ongole calves. Arora et al. (1971) observed that the mean birth weights of calves born to heifers and cows were 20.3 kg vs 22.8 kg (Haryana), 24.3 kg vs 25.9 kg (Holstein-Friesian x Sahiwal) and 23.6 kg vs 26.0 kg (Red Dane x Haryana) crosses bred respectively. Gurbachan Lal (1975) observed significant effect of parity on birth weight.

Non-significant effect of age of dam on birth weight was found by Kohli et al. (1956), Singh et al. (1968) and Jayaramkrishna et al. (1970).

5. Maternal Effect—Godley et al. (1960) and Dickerson (1960) stated that in crossbred cattle earlier characters were influenced by maternal environment and only mature characters were expressed according to genetic constitution of animal and environment. Geewami and De (1963) studied the birth weight and body weights of 3 groups
of crosses between Sahiwal and Red Sindhi with varying level of
Friesian blood and did not observe heterosis for average birth weight
but observe pronounced heterosis for the weight at 12 months' age.
They concluded that it could be likely that initial weight was
largely influenced by maternal effects which might hide the components
of genetic effect.

6. Farm Effect: Statistically significant effect of farm on
birth weight was claimed in Friesian x Sahiwal crossbreeds by Naidu
(1962), Taneja and Bhat (1970), Pandey (1971), Taneja (1973) and

7. Breed of Sire: Anantskrishnan and Lazarus (1953), Katpatal
(1970), Arora et al. (1971), Taneja and Bhat (1972), Taneja (1973)
and More et al. (1974) observed significant effect of breed of sire
on birth weight. Non-significant effect of breed of sire on
birth weight was observed by Kohli et al. (1958) in Mariana cattle.

Several workers studied the growth of crossbred calves
(McCuckin, 1937; Tandon, 1951; Ambie and Jain, 1967; Bhat and Khanna,
Their general observations were that crossbreds were heavier at
birth than zebu calves. Parija (1972) found that Gir x Holstein-
Friesian were 3.0 kg lower than Gir calves.

Taneja and Bhat (1972) reported that calves born to
crossbred dams having more than 50 percent Holstein inheritance mated
to Sahiwal sire were heavier at birth compared to those calves from
Holstein sire mated to dam having less than 50 percent inheritance.
The body weight and growth rate was reversed at 19 week and 12
months of age but not at 3 years.
<table>
<thead>
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<th>$h^2$ ± SE (PHC)</th>
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<tr>
<td><strong>Sahwal</strong></td>
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</tr>
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<td>19.0±3.10</td>
<td>17</td>
<td>-</td>
<td>Bhatnagar et al., 1974</td>
</tr>
<tr>
<td>19.6±0.13</td>
<td>342</td>
<td>0.14±0.14</td>
<td>Mishra, 1973</td>
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<td>19.7±0.32</td>
<td>224</td>
<td>-</td>
<td>Rao et al., 1974</td>
</tr>
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<td>20.7±0.20</td>
<td>557</td>
<td>0.23±0.15</td>
<td>Batra and Dass, 1962</td>
</tr>
<tr>
<td>20.9±0.16</td>
<td>491</td>
<td>0.39±0.16</td>
<td>Taneja and Bhat, 1971</td>
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<td>21.8</td>
<td>177</td>
<td>-</td>
<td>Kumar, 1947</td>
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<td>22.0</td>
<td>-</td>
<td>-</td>
<td>Sayer, 1936</td>
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**HF x SW crossbreeds**

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<tr>
<th>Crossbreed cattle with 12.5 percent Friesian inheritance</th>
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<tr>
<td>21.8±0.33</td>
<td>82</td>
</tr>
<tr>
<td>23.0±0.68</td>
<td>92</td>
</tr>
<tr>
<td>23.60</td>
<td>20N(1-3/32)</td>
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<tr>
<td>24.3±0.36</td>
<td>51N</td>
</tr>
<tr>
<td>24.9</td>
<td>20S(1-3/32)</td>
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<tr>
<td>26.4±0.45</td>
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**Crossbreed with 25% Friesian inheritance**

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<th>22.70±0.26</th>
<th>87</th>
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<tr>
<td>23.35±0.21</td>
<td>265</td>
</tr>
<tr>
<td>24.00±0.21</td>
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<tr>
<td>24.00±0.32</td>
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<tr>
<td>26.5±0.68</td>
<td>915</td>
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<td>27.27</td>
<td>96S(4-7/32)</td>
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References:
- Bhatnagar et al., 1974
- Mishra, 1973
- Rao et al., 1974
- Batra and Dass, 1962
- Taneja and Bhat, 1971
- Kumar, 1947
- Sayer, 1936
- Pandey, 1971
- Patil et al., 1974
- Gampule, 1971
- Naidu and Dass, 1965
- Gampule, 1971
- Naidu and Dass, 1965
- Pandey, 1971
- Murty, 1974
- Patil et al., 1974
- Naidu and Dass, 1965
- Naidu and Dass, 1965
- Gampule, 1971
<p>| Crossbred cattle with 37.5% Frisian inheritance |</p>
<table>
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<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.4±0.41</td>
<td>44</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>23.6±0.42</td>
<td>-</td>
<td>0.61±0.13(1/8-3/8)</td>
<td>Tanaka and Bhat, 1970</td>
</tr>
<tr>
<td>23.8±0.26</td>
<td>163</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>24.8±0.24</td>
<td>186</td>
<td>0.20±0.28</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>26.0±0.27</td>
<td>141N</td>
<td>0.29±0.21(1/8-3/8)</td>
<td>Naidu and Desai, 1965</td>
</tr>
<tr>
<td>26.5</td>
<td>32N(8-11/32)</td>
<td>-</td>
<td>Gampule, 1971</td>
</tr>
<tr>
<td>26.9±0.23</td>
<td>129S</td>
<td>0.01±0.17(1/8-3/8)</td>
<td>Naidu and Desai, 1965</td>
</tr>
<tr>
<td>28.4±0.31</td>
<td>37(8-11/32)</td>
<td>-</td>
<td>Gampule, 1971</td>
</tr>
</tbody>
</table>

<p>| Crossbred cattle with 50% Frisian inheritance |</p>
<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.1±0.19</td>
<td>298</td>
<td>0.36±0.27</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>24.6</td>
<td>-</td>
<td>0.62±0.19(1/2-3/4)</td>
<td>Tanaka and Bhat, 1970</td>
</tr>
<tr>
<td>24.7±0.52</td>
<td>82</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>25.6</td>
<td>57N</td>
<td>-</td>
<td>Gampule, 1971</td>
</tr>
<tr>
<td>25.7±0.86</td>
<td>16N</td>
<td>-</td>
<td>Naidu and Desai, 1965</td>
</tr>
<tr>
<td>26.3±0.37</td>
<td>70</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>28.6±0.13</td>
<td>55S</td>
<td>-</td>
<td>Naidu and Desai, 1965</td>
</tr>
</tbody>
</table>

<p>| Crossbred cattle with 62.5% Frisian inheritance |</p>
<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.1±0.47</td>
<td>55</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>23.6</td>
<td>18N(17-19/32)</td>
<td>-</td>
<td>Gampule, 1971</td>
</tr>
<tr>
<td>23.8±0.28</td>
<td>165</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>24.7±0.64</td>
<td>39N</td>
<td>-</td>
<td>Naidu and Desai, 1965</td>
</tr>
<tr>
<td>25.2±0.13</td>
<td>70B</td>
<td>0.17±0.11</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>27.4±0.68</td>
<td>26S</td>
<td>-</td>
<td>Naidu and Desai, 1965</td>
</tr>
</tbody>
</table>

..........contd.
<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs</th>
<th>h² ± SE</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(PHC)</td>
<td></td>
</tr>
</tbody>
</table>

**Crossbred cattle with 75% Friesian inheritance**

23.3±0.64  28  -  Pandey, 1971
24.0±0.30  110  -  Patil _et al._, 1974
25.4±0.13  511  0.26±0.17  Rusty, 1974
25.4±1.04  14N  -  Naidu and Dessai, 1965
25.6±      -  -  Taneja and Bhat, 1970
27.2±0.95  18S  -  Naidu and Dessai, 1965

**Crossbred cattle with 87.5% Friesian inheritance**

22.5±0.78  27  -  Patil _et al._, 1974
24.8±1.41  7N  -  Naidu and Dessai, 1965
26.1±0.15  451  0.32±0.41  Rusty, 1974
26.2n  35N(24-31/32)  -  Ganpule, 1971
27.4  35S(24-31/32)  -  -do-

**Brown Swiss x Sahiwal**

24.3±4.70  153  -  Bhatnagar _et al._, 1974
25.7±5.00  195  -  Bhatnagar _et al._, 1973

---

PHC = Paternal half-sib correlation
N = North zone, and
S = South zone of India
### 2.1.2. Body weight at 2 months/8 weeks age

Body weight at two months of age had been reported in Zebu and Zebu exotic crossbred cattle (Table 2). It is evident from the table that crossbreds are of higher body weight at two months age than their native indigenous cattle.

<table>
<thead>
<tr>
<th>Mean + SE</th>
<th>No. of obs.</th>
<th>h² ± SE</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Fraction of HF inheritance)</td>
<td>(PHC)</td>
<td></td>
</tr>
</tbody>
</table>

**Sahiwal**

| 36.2 ± 0.2 | 11 | - | Bhatnagar et al., 1974 |
| 42.3 ± 0.37 | 325 | - | Mishra, 1973 |
| 46.6 ± 0.42 | 458 | - | Taneja and Shat, 1971 |

**HF x Sw crossbreds**

<table>
<thead>
<tr>
<th>43.4 (12.8%)</th>
<th>47.7 (25.0%)</th>
<th>49.7 (37.5%)</th>
<th>52.6 ± 0.85</th>
<th>52.4 (50.0%)</th>
<th>48.6 (62.5%)</th>
<th>48.8 (75.0%)</th>
<th>48.9 (87.5%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.42 ± 0.11</td>
<td></td>
<td></td>
<td>0.75 ± 0.22</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>82 (80%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**BS x Sw crossbreds**

| 40.6 ± 0.6 | 113 | - | Bhatnagar et al., 1974 |
| 45.9 ± 7.7 | 146 | - | Bhatnagar et al., 1973 |
Rathore (1949) studied in detail the weight of Red Sindhi and its crosses with Jersey, Brown Swiss, Holstein and Guernsey at Allahabad Agricultural Institute and reported that average body weight of Sindhi female calves at two months age was significantly different from its crosses. The average weight of different grades with varying proportions of their inheritance was not significantly different at the same age.

Martin et al. (1962) found significant effect of breed of calf, sex, season of birth on birth weight and gain of weight to 8 weeks age. Parija (1972) analysed the record of 319 Gir and its 130 F₁ Holstein-Friesian crosses from military dairy farm, Maharashtra state. He observed significant effect of farm, period and breed group on 8 weeks body weight. The effect due to season was less and non-significant. Mishra (1973) studied the body weight of Sahiwal, Mariana, Tharparkar, Red Sindhi and Gir, and their Friesian crosses from military dairy farms. He observed that the body weights at 8 weeks age were significantly different among breed group and period studied. Differences due to season of birth on body weight at 2 months of age were non-significant.

Taneja (1973) studied the military dairy farm records and reported the significant effect of different level of Holstein-Friesian inheritance, farm and period of birth on two months body weight of Holstein-Friesian x Sahiwal crossbred calves and non-significant due to season of birth.

2.1.3 Body weight (kg) at 4 months/16 weeks of age

Body weight at 4 months age had been reported in Zebu and their exotic crossbred cattle (Table 3). The body weight
of crossbred was higher than indigenous cattle at 4 months age.

Table 3. Average body weight (kg) and heritability with
standard errors of female calves of Sahiwal
and its crosses at 4 months/16 weeks of age

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h²±SE</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(fraction of HF inheritance)</td>
<td>(PHC)</td>
<td></td>
</tr>
</tbody>
</table>

**Sahiwal**

- 61.5±7.30  12  -  Bhatnagar et al., 1974
- 67.9±0.67  322 -  Mishra, 1973
- 79.5±0.61  464 -  Tenaja and Bhat, 1971

**HF × SW crossbreds**

- 87.2±1.39  77(50%)  -  Mishra, 1973
- 97.6±4.30  9(62.5%)  -  Murty, 1974
- 90.8±3.80  17(75%)  -  —
- 94.3±2.30  30(87.5%) -  —

**BS × SW crossbreds**

- 69.3±11.2  106 -  Bhatnagar et al., 1974
- 81.1±15.6  150 -  Bhatnagar et al., 1973

Rathore (1949) observed non-significant differences
between mean weights of Sindhi and its crosses at 4 months age.
Parij (1972) observed significant differences in body weights at
four months age between Gir and Gir x Frisian crossbred cattle.
He classified the data into two seasons — wet salving (November
to April) and least calving (May to October) and observed significant effect due to farm. From the results of regression equation fitted to body weight against the age, he remarked that on the whole, growth in Gir and crossbred had linear trend from 0-52 weeks and observed highly significant differences in all cases with $R^2$ value of nearly 100 percent.

Rishra (1973) observed significant effect of period of birth in both Zebu and their Holstein crosses on 16th week body weight. The difference due to season of birth was significant for crossbreeds and not for Zebus. He observed significant variability due to breed in indigenous and non-significant in crossbred cattle.

Govindasah (1973) studied the 396 records of Marjane cattle and reported 0.60+0.22 heritability estimates by paternal half-sib correlation method, for 4 months body weight.

2.1.4. Body weight (kg) at 6 months age

Differences in body weight at six months of age were observed in Sahiwal and its exotic crosses (Table 4).

Stonaker (1953) reported heritability estimates for body weight at six month for Red Sindhi cattle as -0.05. Geewani and De (1963) observed significant differences between the means of body weight of three grades of Holstein-Friesian x Sahiwal crosses (7-8/16, 6/16 and 12-14/16), at six months age but he could not find significant differences at birth and at one month of age.

Singh and Desai (1971) estimated the heritability of body weight of Red Sindhi cattle at 6, 12, 18 and 24 months of age
on the basis of 99 half-sibs of 12 sires. The values were 0.49, 0.71, 0.69 and 0.52 respectively.

Pandey (1974) studied the performance of Holstein-Friesian x Sahiwal and Holstein-Friesian x Red Sindhi crossbred cattle with the variability of 1/16 Friesian inheritance in heavy rainfall area of military dairy farms controlled under the Eastern Command and observed significant differences in body weight at six months age due to farm, grades and between grades within farms. He estimated overall average weights of all grades 120.2±1.10, 123.0±2.32 and 110.5±1.74 for Holstein-Friesian x Sahiwal (at Namkun and Dehradun), HF x Sahiwal at Lucknow farm and HF x Red Sindhi at Allahabad farm respectively.

Ganpule (1971) estimated the body weights of Northern (Jullundur, Ambala, Lucknow, Meerut and Agra) and Southern (Kirkoe, Ahmednagar and Bangalore) farms at six month ages and he observed higher body weight for Southern farms for all grades except 24-31/32 grade.

Singh and Desai (1971) observed significant effect of farm and sire at 6 month body weight in Red Sindhi cattle. Pareja (1972) in his study on Gir and its Friesian crosses observed maximum growth rate in both groups during the period from 14th week to 26th week on the basis of absolute daily gain and regression coefficient. He suggested that 26th week body weight could be considered as the point of inflection in both genetic groups of cattle.
Table 4. Average body weight (kg) and heritability with standard errors of female calves of Sahiwal and its crosses at 6 months age

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>$h^2$ ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sahiwal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76.3±9.80</td>
<td>8</td>
<td>-</td>
<td>Bhatnagar et al., 1974</td>
</tr>
<tr>
<td>96.3±0.91</td>
<td>323</td>
<td>0.60±0.24</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>107.6±0.98</td>
<td>453</td>
<td>-</td>
<td>Tanaja and Bhat, 1971</td>
</tr>
</tbody>
</table>

**HF x SY Crossbreds**

**Crossbred cattle with 12.5% Friesian inheritance**

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>$h^2$ ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>99.3±2.17</td>
<td>80</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>110.8±2.08</td>
<td>80</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>114.4</td>
<td>20N(1-3/32)</td>
<td>-</td>
<td>Gangule, 1971</td>
</tr>
<tr>
<td>115.5</td>
<td>20S(1-3/32)</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

**Crossbred cattle with 25% Friesian inheritance**

<table>
<thead>
<tr>
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<th>No. of obs.</th>
<th>$h^2$ ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>109.5±4.06</td>
<td>204</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>110.2</td>
<td>40N(4-7/32)</td>
<td>-</td>
<td>Gangule, 1971</td>
</tr>
<tr>
<td>111.0±1.17</td>
<td>229</td>
<td>-</td>
<td>Ruty, 1974</td>
</tr>
<tr>
<td>114.1±2.25</td>
<td>67</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
</tbody>
</table>

**Crossbred cattle with 37.5% Friesian inheritance**

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>$h^2$ ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>115.5</td>
<td>18N(12-15/32)</td>
<td>-</td>
<td>Gangule, 1971</td>
</tr>
<tr>
<td>117.6±1.75</td>
<td>156</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>120.2</td>
<td>32N(8-11/32)</td>
<td>-</td>
<td>Gangule, 1971</td>
</tr>
<tr>
<td>123.0±1.59</td>
<td>152</td>
<td>-</td>
<td>Ruty, 1974</td>
</tr>
<tr>
<td>127.4</td>
<td>37S(8-11/32)</td>
<td>-</td>
<td>Gangule, 1971</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Mean±SE</th>
<th>No. of obs.</th>
<th>$h^2±SE$ (PHC)</th>
<th>References</th>
</tr>
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<tr>
<td>Crossbred cattle with 50% Frisian inheritance</td>
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<td></td>
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<tr>
<td>122.8±2.01</td>
<td>78</td>
<td>0.57±0.50</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>122.9±3.89</td>
<td>58</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>128.0±2.13</td>
<td>81</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>130.2</td>
<td>57</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>133.9±1.00</td>
<td>253</td>
<td>-</td>
<td>Rusty, 1974</td>
</tr>
<tr>
<td>Crossbred cattle with 62.5% Frisian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>116.0±1.84</td>
<td>106</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>124.1±2.05</td>
<td>52(9-10/16)</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>130.8</td>
<td>18N(17-19/32)</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>132.1</td>
<td>145(17-19/32)</td>
<td>-</td>
<td>-de-</td>
</tr>
<tr>
<td>135.9±1.50</td>
<td>553</td>
<td>-</td>
<td>Rusty, 1974</td>
</tr>
<tr>
<td>Crossbred cattle with 75% Frisian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>113.4±2.04</td>
<td>90</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>120.3</td>
<td>-</td>
<td>-</td>
<td>Taneja, 1973</td>
</tr>
<tr>
<td>124.3</td>
<td>70n(20-23/32)</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>126.1</td>
<td>70c(20-23/32)</td>
<td>-</td>
<td>-de-</td>
</tr>
<tr>
<td>131.4±0.95</td>
<td>354</td>
<td>-</td>
<td>Rusty, 1974</td>
</tr>
<tr>
<td>Crossbred cattle with 87.5% Frisian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>118.3±2.56</td>
<td>26</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>122.5</td>
<td>35n(24-31/32)</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>133.6±1.37</td>
<td>189</td>
<td>-</td>
<td>Rusty, 1974</td>
</tr>
</tbody>
</table>

**BS x SY Crossbreeds**

<table>
<thead>
<tr>
<th>Mean±SE</th>
<th>No. of obs.</th>
<th>-</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>92.6±4.6</td>
<td>82</td>
<td>-</td>
<td>Bhatnagar et al., 1974</td>
</tr>
<tr>
<td>193.8±22.1</td>
<td>134</td>
<td>-</td>
<td>Bhatnagar et al., 1973</td>
</tr>
</tbody>
</table>
Agarwal and Tomer (1972) studied the growth trend in Marana female calves and found maximum growth rate up to 6 months of age and thereafter, the general trend in growth declined. The effect due to season of birth was found non-significant. The average monthly growth rate up to 24 months age was not influenced by the birth of female calf.

Tanaja (1973) studied the body weights of Holstein-Friesian x Sahiwal with the fraction of 7/8 Holstein-Friesian inheritance in seven grades and observed significant differences due to grades, farms, periods and seasons. He estimated the heritability of body weights at six month 0.73±0.19, 0.62±0.14 and 0.64±0.20 respectively in Sahiwal, 4-30/64 and 36-63/64 Holstein-Friesian inheritance.

Rishekh (1973) observed significant difference due to breed and period of birth on average body weight of indigenous and their Friesian crosses. The difference due to season was also significant for crossbred but non-significant for indigenous cattle. The heritability estimates reported by paternal half-sib correlation method for six months body weights varied from zero to unity.

Hingane (1975) studied the growth and age at first calving in Gir and crossbred cattle from Government Cattle Breeding Farm, Kopargaon (Ahmednagar). The heritability estimate for six months body weight of Friesian x Gir crossbred was 0.24 by paternal half-sib correlation method.

2.1.5. Body weight at 9 months age

Indigenous cattle were of lower body weight at nine
months age than their exotic crosses (Table 5).

Table 5. Average body weight (kg) and heritability with standard errors of female calves of Sahiwal and its crosses at 9 months age

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs. (Fraction of HF inheritance)</th>
<th>K^2±SE</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>137.85±1.23</td>
<td>320</td>
<td>-</td>
<td>Risha, 1973</td>
</tr>
<tr>
<td>146.75±1.14</td>
<td>444</td>
<td>-</td>
<td>Taneja and Bhat, 1971</td>
</tr>
<tr>
<td>HF x Sw crossbreeds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>165.66±2.74</td>
<td>79(½)</td>
<td>-</td>
<td>Risha, 1973</td>
</tr>
<tr>
<td>145.18±1.44</td>
<td>240(¼)</td>
<td>-</td>
<td>Rusty, 1974</td>
</tr>
<tr>
<td>162.94±1.98</td>
<td>147(3/8)</td>
<td>-</td>
<td>-do-</td>
</tr>
<tr>
<td>177.42±1.72</td>
<td>229(½)</td>
<td>-</td>
<td>-do-</td>
</tr>
<tr>
<td>175.72±0.99</td>
<td>499(5/8)</td>
<td>-</td>
<td>-do-</td>
</tr>
<tr>
<td>171.06±1.29</td>
<td>304(3/4)</td>
<td>-</td>
<td>-do-</td>
</tr>
<tr>
<td>179.23±2.63</td>
<td>143(7/8)</td>
<td>-</td>
<td>-do-</td>
</tr>
</tbody>
</table>

Kasptal (1970) observed significant effect of breed of sire at 9 months body weight. Risha (1973) reported significantly higher body weights for crossbred than their Zebu mates. The variation in average body weight at nine month age were observed among indigenous breeds as well as among crossbred groups. Significant differences due to period and season of birth were observed in both Zebu and their Friesian crosses.
2.1.6. Body weight at 12 months age

Crossbred cattle with low and higher exotic inheritance
had lower body weights than halfbreds (Table 6).

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sahiwal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>115.0±10.9</td>
<td>9</td>
<td>-</td>
<td>Bhatnagar et al., 1974</td>
</tr>
<tr>
<td>155.2±20.1</td>
<td>34</td>
<td>-</td>
<td>Bhatnagar et al., 1973</td>
</tr>
<tr>
<td>176.3±1.59</td>
<td>268</td>
<td>0.62±0.28</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>182.5±1.60</td>
<td>349</td>
<td>1.05±0.25</td>
<td>Taneja and Bhat, 1971</td>
</tr>
</tbody>
</table>

HF x Sw crossbreds

Crossbred cattle with 12.5% Friesian inheritance

<table>
<thead>
<tr>
<th>Mean</th>
<th>No. of obs.</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>175.8</td>
<td>40M</td>
<td>Gampule, 1971</td>
</tr>
<tr>
<td>176.7±2.96</td>
<td>29</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>183.2±6.40</td>
<td>74</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>189.4</td>
<td>96S</td>
<td>Gampule, 1971</td>
</tr>
</tbody>
</table>

Crossbred cattle with 25% Friesian inheritance

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>180.1±1.77</td>
<td>232</td>
<td>0.80±0.39</td>
<td>Rusty, 1974</td>
</tr>
<tr>
<td>185.2</td>
<td>32</td>
<td>-</td>
<td>Gampule, 1971</td>
</tr>
<tr>
<td>186.7±3.79</td>
<td>67</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>188.7±2.61</td>
<td>183</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
</tbody>
</table>

......contd.
<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>$h^2 ± SE$ (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossbred cattle with 37.5% Frisian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>192.1±2.36</td>
<td>150</td>
<td>-0.01±0.21</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>197.9±5.21</td>
<td>44</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>202.4</td>
<td>18N</td>
<td>-</td>
<td>Gangula, 1971</td>
</tr>
<tr>
<td>208.3±2.65</td>
<td>145</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>Crossbred cattle with 50% Frisian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>203.4±3.70</td>
<td>82</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>204.4</td>
<td>97</td>
<td>-</td>
<td>Gangula, 1971</td>
</tr>
<tr>
<td>210.8±2.08</td>
<td>236</td>
<td>0.01±0.04</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>213.9±3.39</td>
<td>63</td>
<td>71.0</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>216.3±5.71</td>
<td>54</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>Crossbred cattle with 62.5% Frisian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>188.1±3.73</td>
<td>52</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>197.6±3.15</td>
<td>100</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>200.8</td>
<td>145</td>
<td>-</td>
<td>Gangula, 1971</td>
</tr>
<tr>
<td>201.8</td>
<td>18N</td>
<td>-</td>
<td>-de-</td>
</tr>
<tr>
<td>208.9±1.20</td>
<td>549</td>
<td>0.25±0.14</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>Crossbred cattle with 75% Frisian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>155.8</td>
<td>70N</td>
<td>-</td>
<td>Gangula, 1971</td>
</tr>
<tr>
<td>187.8±6.01</td>
<td>28</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>190.8±3.94</td>
<td>77</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>203.3±1.59</td>
<td>311</td>
<td>0.44±0.24</td>
<td>Murty, 1974</td>
</tr>
</tbody>
</table>

............contd.
<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of</th>
<th>N² ± SE</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>obs.</td>
<td>(PHC)</td>
<td></td>
</tr>
</tbody>
</table>

**Crossbred cattle with 87.5% Friesian inheritance**

| 185.4     | 35     | -        | Ganpule, 1971 |
| 187.7     | 35     | -        | -           |
| 193.6±6.60| 24     | -        | Patil et al., 1974 |
| 200.7±3.20| 99     | 0.18±0.51| Murty, 1974 |

**BS x SW crossbred cattle**

| 162.2±30.4 | 127 | -    | Bhatnagar et al., 1974 |
| 182.7±28.7 | 102 | -    | Bhatnagar et al., 1973 |

Naidu (1962) and Ganpule (1971) studied the suitability and performance of Holstein x Sahiwal crossbred animals in Northern and Southern farms of Military farms and observed significant differences in body weights between two regions. The crossbred cattle in general grow at faster rate in Southern than those in Northern regions. The crossbred animals lower than 25% Friesian inheritance had low body weight and growth rate as compared to their well adapted middle group. The heritability estimate for one year weight found to be 0.79±0.31 for Northern region. Ganpule (1971) obtained faster growth rate of Southern crossbred animal upto 12 month of age and thereafter the trend was reversed i.e. in favour of Northern crossbred cattle. He observed faster growth rate in 8-19/32 crossbred cattle in both the regions as compared to lower and higher Friesian level of inheritance upto 24 months of age.
McDowell et al. (1968) in six groups of two breed crosses of Ayrshire, Brown Swiss and Holstein found that effect of year and parity were only significant on weight upto 12 months but not thereafter.

Manassypova (1968) and Pilat (1972) studied the body weights of Kholmogor calves and Czechplied cattle respectively and indicated that calves from dams with high milk yield and heavy weights, were heavier at all ages than those with low milk yield. Pilat (1972) reported significantly higher body weights 3.5, 7.2, 5.8 to 6.0 kg respectively at 3, 6, 12 and 18 months of age in calves born to high milk producer and high body weight dams.

Katpatal (1970) studied 7 grades of Friesian x Sahiwal crossbred cattle from military dairy farm, Jabalpur with 7/8 Friesian inheritance and reported significant role of sire at 12 months body weight, but the effect of sire was negative on body weight upto 4 weeks of age, whereas Sahiwal had positive effect. The reversed effect was noticed after 4 weeks of age in these groups. Non-significant effect of breed of sire at an early age might be due to small number of observations. Katpatal observed significant effect associated with season and year of birth at 6, 9 and 1 year age.

The heritability value by paternal halfsib correlation from 600 unweaned Mariana calves for 3, 6, 9, 12 and 18 months body weights were 0.34±0.18, 0.40±0.21, 0.32±0.19, 0.21±0.18 and 0.90±0.43 respectively (Gokhale, 1970).

Pandey (1974) observed significant difference between grades of MF x Sahiwal crosses and non-significant effect of farms in heavy rainfall area.
Singh and Desai (1971) observed significant effect due to farm and sire on 12 months body weight of Red Sindhi cattle. They estimated 0.62 heritability for the trait by paternal halfsib method.

Arora (1972) estimated the heritability in Holstein-Friesian x Sahiwal crossbred by paternal halfsib correlation methods and values were 0.70 ± 0.20, 0.72 ± 0.20, 0.42 ± 0.25, 1.44 ± 0.25, 1.49 ± 0.25 and 0.59 ± 0.19 for body weights at 3, 6, 12, 24 and 36 months and weight at first calving respectively.

Taneja and Bhat (1972) and Taneja (1973) reported significant effect due to grade, farm, period, season and breed of sire on 12 months body weight. They indicated that the difference between farms and periods might be due to uncontrollable environmental differences. The heritability estimates for corrected data were 0.70 ± 0.18, 0.66 ± 0.14 and 0.64 ± 0.20 for Sahiwal, 4-30/64 and 36-63/64 crossbred cattle respectively (Taneja, 1973).

Parija (1972) observed significant effect of season of birth on 12 month body weight for Gir and its Holstein-Friesian crosses. The heritability estimates by paternal halfsib correlation for the trait were 0.89 ± 0.39 and 0.78 ± 0.56 for Gir and Holstein-Friesian x Gir crosses respectively.

Mishra (1973) reported significant effect of breed and period of birth in indigenous and non-significant effect of breed group in crossbred cattle for body weights at 12 months age. The effect associated with season of birth was significant in both indigenous and their crossbred cattle for the trait. The
heritability estimates were in the range of 0.07±0.17 to >1.0 by paternal half-sib correlation method in all indigenous and their Friesian crossbred cattle. Highly variable values of heritability with high standard errors might be due to small number of observations.

Murty (1974) estimated the heritability of each grade of Holstein-Friesian crossbreds by paternal half-sib correlation method and the estimates were in the range of -0.01±0.21 to 0.81±0.41.

Hingane (1975) reported 0.92 heritability estimate for twelve months body weight of Friesian x Gir crossbreds by paternal half-sib correlation method.

2.1.7. Body weight at 15 months age

It is evident from Table 7 that Sahiwal cattle had lower body weight at 15 months age than their exotic crossbreds.

<table>
<thead>
<tr>
<th>Table 7. Average body weight (kg) and heritability with standard errors of female calves of Sahiwal and its crosses at 15 months age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± S.E. (Fraction of Friesian inheritance)</td>
</tr>
<tr>
<td>Sahiwal</td>
</tr>
<tr>
<td>206.31±1.48</td>
</tr>
<tr>
<td>209.50±1.65</td>
</tr>
<tr>
<td>HF x Sx crossbreds</td>
</tr>
<tr>
<td>244.42±3.26</td>
</tr>
<tr>
<td>200.45±2.12</td>
</tr>
<tr>
<td>214.94±2.58</td>
</tr>
<tr>
<td>231.16±2.16</td>
</tr>
<tr>
<td>232.11±1.32</td>
</tr>
<tr>
<td>223.11±1.77</td>
</tr>
<tr>
<td>223.73±7.95</td>
</tr>
</tbody>
</table>
Mishra (1973) observed significant effect of breed in indigenous and non-significant in crossbred cattle on 15 months body weight. The effect due to period of birth was significant in both zebu and their exotic crossbred cattle. The difference due to season of birth was significant in zebu and non-significant in crossbred cattle.

Murty (1974) observed lower body weight at 15 months age for low Holstein-Friesian inheritance and highest for 5/8 grade.

2.1.8. Body weight at 18 months age

The crossbred cattle with low and higher exotic inheritance had lower body weights than half-bred cattle (Table 8).

Table 8. Average body weight (kg) and heritability with standard errors of female calves of Sahiwal and its crosses at 18 months age

<table>
<thead>
<tr>
<th>Mean ± SE (kg)</th>
<th>No. of obs.</th>
<th>H² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sahiwal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>232.6±1.51</td>
<td>441</td>
<td>-</td>
<td>Taneja and Bhat, 1971</td>
</tr>
<tr>
<td>235.9±1.76</td>
<td>317</td>
<td>-</td>
<td>Mishra, 1973</td>
</tr>
</tbody>
</table>

HF x SW crossbreds

Crossbred cattle with 12.5% Friesian inheritance

<table>
<thead>
<tr>
<th>Mean ± SE (kg)</th>
<th>No. of</th>
<th>H² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>214.7±4.16</td>
<td>65</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>216.3</td>
<td>40N</td>
<td>-</td>
<td>Gampala, 1971</td>
</tr>
<tr>
<td>217.7</td>
<td>465</td>
<td>-</td>
<td>-de-</td>
</tr>
</tbody>
</table>

.........contd.
<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossbred cattle with 25% Friesian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>222.4±2.40</td>
<td>207</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>222.9±4.54</td>
<td>63</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>246.3</td>
<td>32N</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>Crossbred cattle with 37.5% Friesian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>239.9±2.96</td>
<td>150</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>243.1±6.82</td>
<td>35</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>256.9</td>
<td>16N</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>264.1</td>
<td>40S</td>
<td>-</td>
<td>-do-</td>
</tr>
<tr>
<td>Crossbred cattle with 50% Friesian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>249.3±3.65</td>
<td>80</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>258.9</td>
<td>54N</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>265.1±2.02</td>
<td>224</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>275.0±3.90</td>
<td>67</td>
<td>-</td>
<td>Rishe, 1973</td>
</tr>
<tr>
<td>Crossbred cattle with 62.5% Friesian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>234.1±4.33</td>
<td>51</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>258.2</td>
<td>16N</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>256.9±1.50</td>
<td>533</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>Crossbred cattle with 75% Friesian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>235.8</td>
<td>70N</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>237.0</td>
<td>70S</td>
<td>-</td>
<td>-do-</td>
</tr>
<tr>
<td>239.8±6.79</td>
<td>28</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>250.8±1.96</td>
<td>298</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
</tbody>
</table>

......contd.
<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>H² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossbred cattle with 87.5% Friesian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>220.0</td>
<td>355</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>239.7</td>
<td></td>
<td>-</td>
<td>-de-</td>
</tr>
<tr>
<td>241.6±4.27</td>
<td>71</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
</tbody>
</table>

Pandey (1971) observed significant effect of breed group of Friesian and Sahiwal crosses and farm effect on 18th month body weight. Low body weights were detected in animals of lower exotic inheritance. He observed overall average body weight for heavy rainfall area 233.3±2.15 and for Lucknow 243.0±4.82 kg.

Singh and Desai (1971) reported highly significant effect of farm at 18 month body weight. The effect of sires on the weight of their progenies at various stages (6, 12 and 18 months) was found to be significant. Corresponding heritability estimates were of high order 0.71, 0.52 and 0.69 respectively. They suggested that sire groups continued to maintain high genetic variability all along the growth period.

Ganpule (1971) found slower growth trend at Southern farms on 18 month age. The growth rate at 18 month age was better at Northern farms than at Southern farms. Mishra (1973) calculated the body weight at 18 months age for zebu and their Friesian crossbred and worked out significant effect due to period and season of birth for the variability in their body weights.
Hingane (1975) observed highly significant difference in body weight of Gir and its Friesian crossbreds at 10 months of age. The heritability estimate of Friesian x Gir crossbreds was 0.64 by paternal half-sib correlation method.

2.1.9. Body weight at first fertile service

Rudgel and Ray (1965a,b) reported 288.74±1.07 kg body weight at first fertile service for Sahiwal cattle. Mishra (1973) reported the body weight at fertile service among ten genetic groups including the zebu and their Friesian crosses. He recorded highest average weight 345.34±4.17 kg for Mariana x Friesian and lowest 296.72±5.40 (Red Sindhi x Friesian). The trend of body weight at fertile service was almost similar in zebu and their Friesian crosses. He estimated the weight at first fertile service for 52 Friesian x Sahiwal crossbred animals (337.73±5.15 kg) and the heritability (h² = 0.44±0.46). The heritability estimates were 0.15±0.05, -0.62±0.52, -0.15±0.27, -0.24±0.35 for Friesian crossbreds of Mariana, Tharparker, Red Sindhi and Gir respectively. The h² estimates for Sahiwal, Mariana, Tharparker, Red Sindhi and Gir were 0.55±0.23, -0.37±0.08, >1.0, 0.47±0.27 and 0.48±0.33 respectively.

2.1.10. Body weight at first calving

Table 9 shows the average body weights of Sw and HF x Sw crossbred with 1/8 fraction of HF inheritance.

Gaines (1940) studying on Friesian cows found that weight was more important than age for lactation yield in young cows. Miller and McGilliard (1959) studied the relationship
between weight at first calving and first lactation milk production on 4677 Holstein, 1001 Guernsey and 501 Jersey cattle. They concluded from the independent influence of age and weight at first calving on milk production that delayed calving of heifers was economically disadvantageous and that heavier heifers possessed little or no advantage over lighter heifer of the similar age. Intraherd partial regression was about 75 lbs of milk per month of age and 200 lbs of milk per 100 lb weight at first calving.

Table 9. Average body weight (kg) and heritability with standard errors of Sahiwal and its crosses at first calving

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sahiwal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>269.2±31.5</td>
<td>33</td>
<td>-</td>
<td>Bhatnagar <em>et al.</em>, 1974</td>
</tr>
<tr>
<td>368.9±2.32</td>
<td>300</td>
<td>-0.06±0.11</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>380.2±31.0</td>
<td>-</td>
<td>-</td>
<td>Rudgal and Ray, 1965a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HF x Sx crossbreds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crossbred cattle with 12.5% Friesian inheritance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>345.1±4.50</td>
<td>56</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
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<td>Naidu and Desai, 1965</td>
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<td>Singh and Desai, 1967</td>
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<td>Pandey, 1971</td>
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<td>Naidu and Desai, 1965</td>
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<td>Singh and Desai, 1967</td>
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<td>400.0</td>
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<td>Khanna, 1968</td>
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<td>382.0</td>
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<td>Naidu and Desai, 1965</td>
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<td>415.0 ± 9.0</td>
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<td>Singh and Desai, 1967</td>
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<td>422.0</td>
<td>135</td>
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<td>Naidu and Desai, 1965</td>
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### Crossbred cattle with 87.5% Friesian inheritance

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### BS × SY crossbreds

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<th>References</th>
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<tbody>
<tr>
<td>299.2 ± 39.5</td>
<td>36 (pooled)</td>
<td>Bhatnagar et al., 1974</td>
</tr>
</tbody>
</table>

**BS × SY crossbreds**

- Rathore (1949) found that body weight of crossbred calves was significantly different at two year age for varying proportion of exotic inheritance. The differences due to breed of exotic cattle were not significant at 24 months but were significant at other ages. Low growth rate in crossbred cattle from birth to one month and between 6 and 12 months was observed. He showed that Guernsey x Red Sindhi crosses did not grow as well as others.

Among all exotic crosses, Holstein crossbred reached to the largest in size and Jersey crosses were almost similar to that of Sindhi
animals. He reported that crossbred female exceeded pure Red Sindhi by 12% body weight at two years age. Institute of Agricultural Statistics (1962) drew the conclusion on growth trend in crossbred cattle with different fraction of Holstein-Friesian inheritance that crossbred with 50 percent Friesian inheritance had higher growth rate than those of higher and lower fraction of Friesian inheritance and they are more adapted and adjustable to Indian conditions of climate and type of feeding.

Naidu and Desai (1965) observed significant differences between crossbred groups in North and approaching significance in South. It was observed that animals with more than 50 percent exotic inheritance at Northern Region attained lower weight at first calving than those with similar Friesian inheritance on Southern farms. The heritability for weight at first calving was 0.75±0.27 and 0.36±0.24 for Northern and Southern region for Holstein-Friesian crossbreeds of 4–15/32 grades respectively.

Rudgel and Ray (1965) could not find significant difference between weight at first conception and first calving in Sahiwal and Tharparkar heifers.

Naidu and Desai (1970) estimated heritability 0.75±0.33 by paternal half-sib correlation for Sahiwal cows. The heritability estimates 0.16±0.16 and 0.27±0.39 respectively for 1/4 and 1/2 grades of Holstein-Friesian x Sahiwal was reported by Bhat and Khanna (1970). They observed higher estimate of heritability for 1/8, 3/8, 5/8 and 3/4 Holstein grades.

Pandey (1971) observed significant differences between the mean weight at first calving, among grades and farms. The
overall average of body weight at calving was $350.8 \pm 2.62$, $382.0 \pm 6.05$ and $380.05 \pm 4.43$ for crossbreds at heavy rainfall areas (HRF), Lucknow (L) and Allahabad farms (RS\texttimes H) respectively.

Campbell (1971) studied the comparative performance of crossbred cattle in Northern and Southern parts of the country. He concluded from his findings that level of Friesian inheritance in crossbred heifers showed a significant effect in reducing the age of first calving up to 17-19/32, thereafter it was somewhat increased. Age at first calving was lower in crossbred of Northern region. This was due to the higher body weight at maturity compared to Southern region.

The contribution of weight at calving was greater than that of age at first calving (RajGopal, 1962; Singh and Desai, 1966, and Nagpal and Acharya, 1971). Chhabra et al. (1970) reported that age at first calving was more important than weight at calving for the variation in milk production in Mariana cows. The variation of 4 to 10 percent was observed in this breed due to age at first calving. This might be largely due to late age at first calving in Mariana cows. Nagpal and Acharya (1971) observed 1.3 percent variation in milk yield due to weight at first calving. The regression of 1st lactation production on weight at first calving was 0.64 kg per kg body weight.

The effects due to indigenous breeds and their Friesian crosses and variability due to period of birth on body weight at first calving were observed significantly by Misra (1973). The season of birth showed non-significant effect on this trait. He
suggested from his study that the breeds having higher average daily gain, had capacity to deliver calf at an early age. Holstein-Friesian x Red Sindhi showed highest daily gain and lower age at fertile service. The heritability estimates for all breeds and crosses ranged from 0 to >1.0 by paternal half-sib correlation method.

D'Souza (1972) estimated the heritability of weight at first calving 0.43±0.09, 0.86±0.12 and 0.89±0.29 for Red Sindhi, Gir and Friesian x Gir crossbred cattle respectively. These estimates were based on small number of progeny per sire.

Arora (1972) reported 0.59±0.19 heritability for halfbred Holstein-Friesian x Sahiwal and 0.60±0.34 above halfbred cattle by paternal half-sib correlation method.

Taneja (1973) observed significant effect due to grade, farm and period on weight at first calving whereas effect due to season was non-significant. The heritability estimates of body weights at first calving for Sahiwal, pooled 4-30/64 and pooled 36-63/64 genetic groups were 0.18±0.10, 0.21±0.08 and 0.21±0.10 respectively.

2.2. Growth Rate g/day

Several workers reported growth rate g/day for Sw and its crosses (Table 10).

Brody (1945) and Campbell and Lasley (1969) pointed the inflection period of growth of cattle. The maximum velocity of the growth was in general during first five months of life. Rathore (1949) reported higher growth rate for crossbred cattle
than Red Sindhi at all ages except between birth to one month and between 6 and 12 months. Among all crosses the growth rate of Holstein-Friesian crosses was better and Guernsey crosses was worst. The fastest growth was observed in 50 percent European inheritance. The influence of maternal environment was strong at birth but was diminished as animal grew older.

Raju (1983) from his study on Kangayam reported that the increase in body weight was greatest at four months of age by 8 lb more as against 6 months to 12 months of age.

<table>
<thead>
<tr>
<th>Gain per day (g)</th>
<th>Age interval (month)</th>
<th>References</th>
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<tr>
<td>Sahiwal</td>
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</tr>
<tr>
<td>293.8</td>
<td>0-2/2</td>
<td>Rudgal and Ray, 1965a,b</td>
</tr>
<tr>
<td>407.0</td>
<td>2/2-6</td>
<td>-do-</td>
</tr>
<tr>
<td>185.5±4.7</td>
<td>0-6</td>
<td>Kumar, 1969</td>
</tr>
<tr>
<td>197.0±3.2</td>
<td>0-6</td>
<td>-do-</td>
</tr>
<tr>
<td>390.0</td>
<td>0-6</td>
<td>Bhatnager et al., 1966</td>
</tr>
<tr>
<td>398</td>
<td>6-12</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>330</td>
<td>12-18</td>
<td>-do-</td>
</tr>
<tr>
<td>HF × Sw crossbreds</td>
<td></td>
<td></td>
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<tr>
<td>525±4</td>
<td>0-6</td>
<td>-do-</td>
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<tr>
<td>436</td>
<td>6-12</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>329</td>
<td>12-18</td>
<td>Mishra, 1973</td>
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<td>BS × Sw crossbreds</td>
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</tr>
<tr>
<td>510</td>
<td>0-6</td>
<td>Bhatnager et al., 1966</td>
</tr>
</tbody>
</table>
Sundaresan (1956) based on crossbreeding work at Allahabad observed that crossbred attained early maturity, gaining more body weight over local breeds.

Holtz et al. (1961) studied the relationship between rate of gain from birth to six months of age and subsequent yield of dairy cows and indicated that faster gaining Holstein produced the highest FCM mature equivalent.

The Institute of Agricultural Research Statistics (1962) observed linear growth up to 20 months of age. About 97 percent of the variation was predicted due to linear regression. It was also reported that monthly gain in weight decreased with increase in Holstein inheritance and crossbred with 50 percent exotic inheritance was most suitable for growth being better adjusted to the Indian condition.

Naidu and Desai (1965) studied the effect of Holstein-Friesian inheritance on growth of their crossbred cattle from Northern and Southern part of India and concluded that animals with lower than 1/4 Holstein level had slackened in growth as compared to the well adapted halfbreds. Those with higher Friesian level had not only less body weight but showed wide variability between the grades indicating differential response to the local conditions.

Rudgel and Ray (1965) studied the growth from birth to 2 year age and reported that a great reduction in the growth rate was observed from 7th month to 12th month of age. Sahiwal and Tharparkar had similar growth trend and mature body weight.

Gokhale (1970) observed that in general the rate of gain from 0-1 year indicated a decreasing trend in Mariana calves. The
average monthly rate from one to 3 years for females was 4.4 kg.

Singh and Desai (1971) and Agarwal and Tomer (1972) reported that growth rate velocity increased to maximum by about 6 months of age, thereafter general trend in growth declined.

Tanuja and Bhat (1971) studied the body weight from birth to three years age in Sahiwal and their Friesian crosses from seven military dairy farms and concluded that largest gain per day was observed in Indian Holstein 15/16, 31/32, and 63/64 Holstein grade followed by 3/8 and 7/8 Friesian inheritance. The growth rate from birth to 19 weeks, 19 to 26 weeks and from 27 to 52 weeks were 0.458, 0.526 and 0.411 kg per day respectively. The growth rate was maximum between 19th week to 26th week in all Friesian grades.

Gapule (1971) revealed from his study on the comparative performance of crossbred cattle in India that crossbred gained at faster rate in Southern region than those in Northern region upto 12 months of age. Thereafter the trend was reversed and 8-19/32 crossbreds grew at faster rate in both the regions as compared to lower and higher Friesian levels of inheritance. After 24 months of age 20-31/32 tried to make up for the body weight by gaining at higher rate.

Pilat (1972) reported the higher daily gain of daughters from high producing cows from 0-3, 3-6, 6-12 and 12-18 months of age and the values were 653, 717, 688 and 591 g whereas in daughters from low yielding cows, it were 629, 676, 623 and 602 g respectively during the same period. The percentage of daughters used for herd replacement was 7-36% from high fat producing cows vs. 27-44% from low fat producing cows.
Rishra (1973) studied the growth rate per day in Zebu cattle and their Holstein-Friesian crosses from 6-12 and 12-18 months interval and observed highest average daily gain of 0.508 kg in Gir x Friesian crossbreds from 6-12 month periods. Whereas the lowest was observed 293 kg in Gir cattle within the same period. The highest and lowest growth rate per day between 12-18 months age were observed in Red Sindhi x Friesian crossbred (0.381 kg) and in Gir (0.207 kg). He suggested from his study that amongst the indigenous breed Gir and Hariana could be in one group with highest growth up to one year followed by Sahiwal, Tharparkar and Red Sindhi in another group. The Holstein-Friesian genna plasma could increase the gain and reduce the age at first calving in Zebu cattle.

Rana et al. (1974) observed significant effect of season of birth on weight gain in Sahiwal and HF x Sw crossbred calves.

Rathi et al. (1974) studied the absolute weight gain in body weight from the data on 282 Hariana, 87 Friesian x Hariana, 58 Brown Swiss x Hariana and 32 Jersey x Hariana female crossbreds from 1964-1972 period and the results were given at monthly intervals. They observed maximum gain in Hariana purebreds during first month (13.23 kg) and among crossbreds the maximum gains were observed 15.71, 16.07 and 14.88 kg during 3rd month in Friesian, Brown Swiss and Jersey crossbred calves respectively. The lowest gains 3.04, 4.73, 6.54, 5.44 kg were observed for Hariana, HF x H, 85 x H and Jersey x Hariana crossbred during 5th, 13th, 12th and 1st month of ages. They revealed from their observation that 1st month of life is mainly a period of adjustment for crossbred cattle calves.
The variation in birth weight resulted wide variation in weight of calves up to six months of age (Singh and Desai, 1959) in Mariana, (Singh and Desai, 1971) in Red Sindhi calves. After the calves grow up on their own genetic make up for the expression of their traits, the differences in weight at subsequent stages were reduced. The efficiency of growth rate was maximum in first six month and thereafter dropped to about 1/6th, 1/16th and 1/20th of the initial rate.

Hingane (1975) estimated the growth rate per day for Gir and its Friesian crossbreeds at three month interval after birth up to 24 months of age. The maximum growth per day in Gir was 315 g from birth to 3 month period and 402 g in crossbred from 3-6 month period. Lowest growth rate among periods studied were observed 110 g and 246 g in Gir and its crossbred at 18 to 21 months and 15 to 18 months of age respectively.

2.3.1. Average age at 1st calving

Several workers reported age at first calving for Zebu and their European crossbred (Table 11). The average age at first calving in Zebu cattle was higher than their crosses with exotic breeds. The lowest age 36.5 month and highest 46.3±2.28 month was observed by Kartha (1934) and Puri and Malik (1963) for Sahiwal cattle respectively. Age at first calving was studied by many breeders being highly related with milk production. Slow growth rate and late maturity made the animal uneconomical.
Table 11. Average age at first calving (months) and heritability with standard errors of Sahiwal and its exotic crosses

<table>
<thead>
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<th>h²±SE (PNC)</th>
<th>References</th>
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<td>38.1±0.39</td>
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<td>Singh and Dessi, 1967</td>
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<td>39.4±0.31</td>
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<td>0.46±0.18</td>
<td>Nagpal and Acharya, 1970</td>
</tr>
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<td>39.6±2.5</td>
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<td>0.37±0.19</td>
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<td>0.19±0.14</td>
<td>Kaul, 1968</td>
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<td>40.7</td>
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<td>Gurbachan Lal, 1975</td>
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<td>41.0</td>
<td>112(1951-55)</td>
<td>-</td>
<td>Sundaresan et al., 1965</td>
</tr>
<tr>
<td>42.0</td>
<td>114(1956-60)</td>
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<td>Sundaresan et al., 1965</td>
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<td>0.16±0.29(I.S.R.)</td>
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HF x SY crossbreds

Crossbred cattle with 12.5% Friesian inheritance

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<td>Gurbachan Lal, 1975</td>
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<td>Gopule, 1971</td>
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<td>36.9</td>
<td>604</td>
<td>Naidu and Dessi, 1965</td>
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<td>39.0±0.48</td>
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<td>Pendey, 1971</td>
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Crossbred cattle with 25% Friesian inheritance

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<td>Naidu and Dessi, 1965</td>
</tr>
<tr>
<td>36.3</td>
<td>514</td>
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<td>37.1±0.40</td>
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<td>Hurty, 1974</td>
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<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>39.2±0.31</td>
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<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>39.6±0.72</td>
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<tr>
<td>39.4±0.25</td>
<td>426</td>
<td>0.06±0.13</td>
<td>Kaul, 1968</td>
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</table>

**Crossbred cattle with 37.5% Friesian inheritance**

<table>
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<th>h² ± SE (PHC)</th>
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<td>0.09±0.22</td>
<td>Murty, 1974</td>
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<td>36.4</td>
<td>144</td>
<td>-</td>
<td>Naidu and Dossi, 1965</td>
</tr>
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<td>37.1±0.17</td>
<td>50N</td>
<td>-</td>
<td>Ganpule, 1971</td>
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<td>37.2±0.27</td>
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<td>Patil et al., 1974</td>
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<td>37.7±0.79</td>
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<td>-</td>
<td>Pandey, 1971</td>
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</table>

**Crossbred cattle with 50% Friesian inheritance**

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<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.2±0.30</td>
<td>205</td>
<td>0.32±0.31</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>33.4</td>
<td>595N</td>
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<td>Kartha, 1934</td>
</tr>
<tr>
<td>34.3±3.8</td>
<td>91</td>
<td>0.43±0.43</td>
<td>Rishra, 1973</td>
</tr>
<tr>
<td>35.2±0.52</td>
<td>84</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>36.1</td>
<td>17</td>
<td>-</td>
<td>Naidu and Dossi, 1965</td>
</tr>
<tr>
<td>37.6±0.44</td>
<td>115</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>37.6±0.31</td>
<td>-</td>
<td>0.24±0.31</td>
<td>Kaul, 1968</td>
</tr>
</tbody>
</table>

**Crossbred cattle with 62.5% Friesian inheritance**

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Ganpule, 1971</td>
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<td>33.4±0.2</td>
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<td>0.34±0.15</td>
<td>Murty, 1974</td>
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<tr>
<td>35.2</td>
<td>32</td>
<td>-</td>
<td>Singh and Dossi, 1967</td>
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*contd.*
<table>
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<tr>
<th>Mean ± S.E.</th>
<th>No. of obs.</th>
<th>$h^2$ ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>35.2</td>
<td>303</td>
<td>-</td>
<td>Gurbachan Lal, 1975</td>
</tr>
<tr>
<td>35.9</td>
<td>72</td>
<td>-</td>
<td>Amble and Jain, 1967</td>
</tr>
<tr>
<td>36.9</td>
<td>394</td>
<td>-</td>
<td>Naidu and Desai, 1965</td>
</tr>
<tr>
<td>37.2±2.35</td>
<td>197</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
</tbody>
</table>

**Crossbred cattle with 75% Frisian inheritance**

<table>
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<th>No. of obs.</th>
<th>$h^2$ ± SE</th>
<th>References</th>
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<tbody>
<tr>
<td>33.6</td>
<td>295</td>
<td>-</td>
<td>Singh and Desai, 1967</td>
</tr>
<tr>
<td>33.9±0.3</td>
<td>306</td>
<td>&gt;1 ±0.12</td>
<td>Rurty, 1974</td>
</tr>
<tr>
<td>35.6±0.3</td>
<td>88W</td>
<td>-</td>
<td>Campule, 1971</td>
</tr>
<tr>
<td>35.8</td>
<td>88</td>
<td>-</td>
<td>Gurbachan Lal, 1975</td>
</tr>
<tr>
<td>36.8±0.98</td>
<td>24</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>37.1±0.44</td>
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<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>37.6±0.40</td>
<td>-</td>
<td>0.22±0.31</td>
<td>Kaul, 1968</td>
</tr>
</tbody>
</table>

**Crossbred cattle with 87.5% Frisian inheritance**

<table>
<thead>
<tr>
<th>Mean ± S.E.</th>
<th>No. of obs.</th>
<th>$h^2$ ± SE</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>34.4±0.70</td>
<td>42</td>
<td>-</td>
<td>Campule, 1971</td>
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<tr>
<td>35.4±0.76</td>
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<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>36.3±0.80</td>
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<td>-</td>
<td>Rurty, 1974</td>
</tr>
<tr>
<td>38.2</td>
<td>7</td>
<td>-</td>
<td>Naidu and Desai, 1965</td>
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</table>

**BS x Sx crossbreed**

<table>
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<th>References</th>
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<tr>
<td>30.0</td>
<td>30(F₁)</td>
<td>-</td>
</tr>
<tr>
<td>30.0</td>
<td>11(3/8)</td>
<td>-</td>
</tr>
<tr>
<td>33.0</td>
<td>20(F₂)</td>
<td>-</td>
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</table>

**Frisian breeds**

<table>
<thead>
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<th>Mean ± S.E.</th>
<th>$h^2$ ± SE</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.0±3.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>28.5±0.32</td>
<td>933</td>
<td>-</td>
</tr>
<tr>
<td>28.9</td>
<td>993</td>
<td>-</td>
</tr>
<tr>
<td>27.3 to 33.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>36.8</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Kartha (1934) found 3-4 months lower age at first calving in HF x SI crossbreds than SI cattle. Sayer (1936) and Mahadevan (1953) concluded from their study that it could be possible to reduce the age at first calving in Indian cattle by improved feeding and management in early life.

Dickerson and Charman (1940) and Cashin (1950) found that early first calvers were more economical producers than late calvers, although their initial yield was low but it was compensated by longer production life.

Hansson (1941) defined that most suitable age at first calving for the cow could be when the cow's total milk and butter fat production divided by the total food intake give the largest quotient. He pointed out that the efficiency of life time food-butter fat conversion decreased with increased age at first calving.

Tandon (1951) found that age at first calving decreased at a diminishing rate with increasing Friesian level in Red Sindhi and Sahiwal breeds. Various proportion of Holstein inheritance affected the age at first calving in a curvilinear way. He concluded that genes responsible for early maturity seemed to be dominant to late maturity of Red Sindhi and Sahiwal cattle.

Stokes et al. (1953) observed that age at first calving was greatly reduced by the introduction of Jersey genes into Red Sindhi cattle. Greater the relationship with Jersey, earlier was the age at first calving. Half bred Jersey animals calved at the average age of 29 months as compared to 41 months in Red Sindhi.
Sundarasan et al. (1954) argued that the breed characteristics are responsible for late maturity in tropical breed. McDowell et al. (1959) studied the effect of varying degree of Sindhi inheritance on age at first calving and birth weight and concluded that upto 75% Sindhi inheritance may be used in combination with Jersey without delaying the age of first calving.

Bhote (1963) reported that low productivity was due to lack of fodder and poor management practices. He suggested that if age of maturity can be reduced subsequently there will be an increase of 60% of total milk yield.

Naidu and Desai (1965) and Ganpule (1971) reported decrease in age at first calving with the increase in Holstein inheritance upto 16-19/32. It was observed that as soon as Holstein level in crossbred increased beyond 19/32 the overall adaptability of the crossbred to the tropical condition gradually decreased, resulting the increased age at first calving. The age at first calving was lower in crossbred of Northern region and indicated by genetic superiority and adequate adaptability of higher grades in North.

Acharya (1966) and Dhillon et al. (1970) reported significant effect of month of calving within year, on age at first calving in Hariana cows, whereas Tandon (1951) and Nagpal and Acharya (1970) did not find significant influence of season of calving on age at first calving in Sahiwal, HF x SW, HF x AS crossbreds. Guna et al. (1968) pointed out that age at first calving was not affected by the season of birth but was significantly
affected by the year of birth of heifer calves.

Sundaresan et al. (1965) found significant variation among periods and years within period for age at first calving in Tharparkar herd. Dhillon et al. (1970) and Nagpal and Acharya (1970) reported significant effect of period of calving on age at first calving.

Kaul (1968) studied the effects due to various genetic and non-genetic factors (grade, farm, period, season and breed of sire) on age at first calving. All the five fixed factors showed significant effect.

Anderson (1970) estimated the heritability for age at first calving 0.269, 0.14 and 0.17 for Danish-Red Cattle, Danish Black pied and Jersey cattle respectively.

Nagpal and Acharya (1971) revealed that age at first calving was significantly influenced by farm, year of calving and weight of dam at calving but not by season of calving. They observed 0.07% variation in milk production was due to age at first calving and later had significant effect on farmer. Similar observations were made by Kushwaha and Mishra (1969), Batra and Desai (1964) and Singh and Desai (1967) in Sahiwal cows. Singh et al. (1964), Tiwana (1967) and Gill (1969) reported non-significant effect of age at first calving on first lactation yield.

Bolaine (1971) estimated the heritability of age at first calving in Mariana cattle by intrasire daughter dam regression, half-sib correlation and half-sib correlation from generation wise analysis the values were 0.044±0.11, 0.54±0.15 and 0.32±0.13 from 420, 538 and 538 observations respectively.
Dutt and Tamer (1972) did observe the significant effect of herd but non-significant of year on age at first calving in Marana cattle.

O'Souza (1972) found significant difference between various genetic groups except between the crosses of Red Sindhi with HF and Red Dane.

Rishra (1973) studied the zebu breeds and their Friesian crosses and found that crosses had higher average daily gain became capable of bearing the calf at an earlier age. The heritability estimates on the basis of paternal half-sib correlation method ranged from -0.18 to 0.25 to 1.0 in genetic groups studied. He observed non-significant effect due to period and season of birth on age at first calving.

Gangwar et al. (1973) reported from their study on 160 crossbreds of Holstein-Friesian grades (1/8, 1/4, 3/4 and 5/8) that tendency of earlier calving was dominant over late calving and maturity age is controlled both by intrinsic as well as extrinsic factors.

Bhatnagar et al. (1975) estimated for the age at first calving accounted for 2.27% of total variation due to period of calving amongst F1 Brown Swiss crossbred. They suggested that management practices during different phases of growth up to the age at first calving confounded the effect of period on the age at first calving. The effect due to genetic groups was highly significant. Sahiwal cows had significantly higher age at first calving.
2.3.2. First lactation yield

Several workers reported variability in first lactation yield of Zebu and their exotic crosses (Table 12).

Table 12. Average first lactation milk yield (kg) and heritability with standard errors of Sahiwal and its crossbreeds

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sahiwal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1160</td>
<td>65</td>
<td>-</td>
<td>Sen <em>et al.</em>, 1953</td>
</tr>
<tr>
<td>1489</td>
<td>118</td>
<td>-</td>
<td>Singh and Choudhary, 1961</td>
</tr>
<tr>
<td>1596±21</td>
<td>456</td>
<td>0.15±0.14</td>
<td>Nagpal and Acharya, 1971</td>
</tr>
<tr>
<td>1610±19</td>
<td>655</td>
<td>0.48±0.15</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>1620±21</td>
<td>-</td>
<td>0.51±0.21</td>
<td>Khanna, 1968</td>
</tr>
<tr>
<td>1674</td>
<td>162</td>
<td>0.21±0.29</td>
<td>Singh and Dassi, 1967</td>
</tr>
<tr>
<td>1678±40</td>
<td>111</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1618±38</td>
<td>104</td>
<td>0.51±0.21</td>
<td>Khanna and Bhat, 1971</td>
</tr>
<tr>
<td>1588±33</td>
<td>188</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1753±3</td>
<td>901</td>
<td>-</td>
<td>Karthe, 1934</td>
</tr>
<tr>
<td>1772±3</td>
<td>118</td>
<td>-</td>
<td>Amble and Jain, 1966</td>
</tr>
<tr>
<td>2148</td>
<td>172</td>
<td>-</td>
<td>Bhatnagar <em>et al.</em>, 1975</td>
</tr>
<tr>
<td>2218</td>
<td>114</td>
<td>-</td>
<td>Sundaresan <em>et al.</em>, 1965</td>
</tr>
<tr>
<td>2236±33</td>
<td>298</td>
<td>-</td>
<td>Gopal and Bhatnagar, 1973</td>
</tr>
</tbody>
</table>

HF x SW crossbreeds

Crossbred cattle with 12.5% Friesian inheritance

<table>
<thead>
<tr>
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<th>No. of obs.</th>
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<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1650±88</td>
<td>179</td>
<td>-</td>
<td>Ganpula, 1971</td>
</tr>
<tr>
<td>1732±74</td>
<td>50</td>
<td>0.56±0.41</td>
<td>Khanna, 1968</td>
</tr>
</tbody>
</table>

...........contd.
<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>$h^2 ± SE$ (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1609±42</td>
<td>113</td>
<td>-</td>
<td>Tashan, 1973</td>
</tr>
<tr>
<td>1871±60</td>
<td>62</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>2207</td>
<td>192</td>
<td>-</td>
<td>Choudhry et al., 1974</td>
</tr>
</tbody>
</table>

**CROSSBRED CATTLE WITH 25% FRIESIAN INHERITANCE**

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>$h^2 ± SE$ (PHC)</th>
<th>References</th>
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</thead>
<tbody>
<tr>
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<td>56</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>1713±31</td>
<td>78S</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>1773±21</td>
<td>304</td>
<td>-</td>
<td>Kaul, 1968</td>
</tr>
<tr>
<td>1824±35</td>
<td>86</td>
<td>0.13±0.17</td>
<td>Khanna, 1968</td>
</tr>
<tr>
<td>1848±33</td>
<td>292</td>
<td>-</td>
<td>Tashan, 1973</td>
</tr>
<tr>
<td>2246</td>
<td>290</td>
<td>-</td>
<td>Choudhry et al., 1974</td>
</tr>
<tr>
<td>2381</td>
<td>225</td>
<td>-</td>
<td>McGucken, 1937</td>
</tr>
</tbody>
</table>

**CROSSBRED CATTLE WITH 37.5% FRIESIAN INHERITANCE**

<table>
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<tr>
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<th>No. of obs.</th>
<th>$h^2 ± SE$ (PHC)</th>
<th>References</th>
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</thead>
<tbody>
<tr>
<td>1780±54</td>
<td>85</td>
<td>-</td>
<td>Naidu and Dessi, 1965</td>
</tr>
<tr>
<td>1887±67</td>
<td>40</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>1995±36</td>
<td>259</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>2242</td>
<td>192</td>
<td>-</td>
<td>Choudhry et al., 1974</td>
</tr>
<tr>
<td>2420±47</td>
<td>140</td>
<td>0.48±0.44</td>
<td>Rusty, 1974</td>
</tr>
<tr>
<td>2448±169</td>
<td>24</td>
<td>-</td>
<td>Ambile and Jain, 1966</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.67±0.26</td>
<td>Khanna, 1968</td>
</tr>
</tbody>
</table>

**CROSSBRED CATTLE WITH 50% FRIESIAN INHERITANCE**

<table>
<thead>
<tr>
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<th>No. of obs.</th>
<th>$h^2 ± SE$ (PHC)</th>
<th>References</th>
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<td>Khanna, 1968</td>
</tr>
<tr>
<td>1934±48</td>
<td>170</td>
<td>-</td>
<td>Kaul, 1968</td>
</tr>
<tr>
<td>2063</td>
<td>17W</td>
<td>-</td>
<td>Singh and Dessi, 1967</td>
</tr>
<tr>
<td>2175±61</td>
<td>79</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
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<table>
<thead>
<tr>
<th>Mean ± S.E.</th>
<th>No. of obs.</th>
<th>h²±SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>2191±55</td>
<td>122</td>
<td>-</td>
<td>Tamhan, 1973</td>
</tr>
<tr>
<td>2241±64</td>
<td>64N</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>2422</td>
<td>169</td>
<td>-</td>
<td>Choudhry et al., 1974</td>
</tr>
<tr>
<td>2776±69</td>
<td>124</td>
<td>-0.33±0.09</td>
<td>Hurty, 1974</td>
</tr>
<tr>
<td>2760±36</td>
<td>595</td>
<td>-</td>
<td>Kartha, 1934</td>
</tr>
<tr>
<td>3122</td>
<td>572</td>
<td>-</td>
<td>McGuicken, 1937</td>
</tr>
<tr>
<td>3329±88</td>
<td>10</td>
<td>-</td>
<td>Bhasin and Dass, 1967</td>
</tr>
</tbody>
</table>

**Crossbred cattle with 62.5% Friesian inheritance**

| 2058       | 32N        | -           | Singh and Dass, 1967 |
| 2109±102   | 26N        | -           | Naidu and Dass, 1965 |
| 2334±47    | 199        | -           | Patil et al., 1974 |
| 2376       | 125        | -           | Choudhry et al., 1974 |
| 2412±87    | 43         | -           | Pandey, 1971 |
| 2757±39    | 307        | 0.58±0.25   | Hurty, 1974 |
| 3277       | 86         | -           | McGuicken, 1937 |

**Crossbred cattle with 75% Friesian inheritance**

| 1974±113   | 65S        | -           | Ganpule, 1971 |
| 2035±94    | 22         | -           | Pandey, 1971 |
| 2147±45    | 143        | -           | Koul, 1968 |
| 2174±105   | 32         | 0.97±0.63   | Khanna, 1968 |
| 2194±76    | 71         | -           | Ambre and Jain, 1966 |
| 2207±51    | 143        | -           | Tamhan, 1973 |
| 2430       | 76         | -           | Choudhry et al., 1974 |
| 2574±42    | 210        | 0.72±0.35   | Hurty, 1974 |
| 2948       | 290        | -           | McGuicken, 1937 |

*********contd.*
### Crossbred cattle with 87.5% Friesian inheritance

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024</td>
<td>315</td>
<td>–</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>2282±13</td>
<td>36</td>
<td>–</td>
<td>Tamhan, 1973</td>
</tr>
<tr>
<td>2341</td>
<td>42</td>
<td>–</td>
<td>Chaudhry et al., 1974</td>
</tr>
<tr>
<td>2475</td>
<td>27K</td>
<td>–</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>2567±105</td>
<td>31</td>
<td>–</td>
<td>Rurty, 1974</td>
</tr>
</tbody>
</table>

### BS x SY crossbreds

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3440</td>
<td>140(F₁)</td>
<td>–</td>
<td>Bhatnagar et al., 1975</td>
</tr>
<tr>
<td>2526</td>
<td>75(F₂)</td>
<td>–</td>
<td>–de–</td>
</tr>
</tbody>
</table>

### HF (India)

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2396±67</td>
<td>55</td>
<td>–</td>
<td>Khanna, 1968</td>
</tr>
<tr>
<td>2512±150</td>
<td>37</td>
<td>–</td>
<td>Rurty, 1974</td>
</tr>
</tbody>
</table>

Naidu and Desai (1968) observed highest yield in halfbred followed by 3/4 crossbred in Southern region. They could not detect significant difference in first lactation yield due to variation in Friesian blood level 4/32 to 15/32 in crossbred. The heritability estimates for 4–15/32 Friesian inheritance for Northern and Southern region were 0.18±0.19 and 0.50±0.27 by paternal halfsib correlation method. Naidu (1962) estimated 0.07 and 0.19 heritability value for Northern and Southern region for pooled grade (4–15/32).

Kushwaha and Misra (1969) reported that Sahiwal cows calving at 42–48 month of age gave greatest quantity of milk.
(1543.8±713.9 kg) and with the longest lactation length (306±65 days). Lee and Henderson (1969) revealed that variation in lactation yield was due to additive genetic variance and contribution of non-additive genetic variance was not far from zero.

Salaine et al. (1970) found that period of calving significantly affected the trait in Mariana cattle. Singh and Pandey (1970) studied the effect of season and year of calving from 10 years records of Mariana cows in Bihar and reported significant differences in calving percentages occurring in winter, spring, summer and rainy season. Effect of season of calving and year of calving for milk yield was significant.

Khanna and Bhat (1971) observed non-significant effect of farm on first, second and third lactation yield. Nagpal and Acharya (1971) studied the effect of non-genetic factor for Sahiwal herd and found that period of calving and weight at calving significantly affected the milk yield of first lactation. Season of calving and farm had no significant effect. Lactation number did not affect milk production significantly. The effect of herd and lactation period on first lactation milk production were highly significant but for year they were significant at 5 percent level. Age at calving was non-significant for milk production (Gaule et al., 1968; Tomar, 1969 and Bhasin, 1969). Anderson (1970) estimated the heritability for first lactation yield 0.39, 0.31 and 0.35 for Danish Red cattle, Danish Black Pied and Jersey cattle respectively.

Balaine (1974) estimated the heritability by intrasire daughter-dam regression, half-sib correlation and half-sib correlation from generation wise analysis. The values were 0.37±0.12, 0.40±0.16
and 0.58±0.17 from 302, 424 and 424 observations respectively.

Tomes et al. (1974) worked out some environmental factors affecting first lactation milk yield in 292 Mariana cows spread over 5 years (1963-67) and 6 farms. They observed significant effect due to year and farm on milk yield (least square technique). The cows around 35 month of age were significantly low producer than their older counterpart. Lactation period of 300 days affected the production adversely while longer lactation period was found to be favourable.

Ganpule (1971) noticed that milk yield increases with Frisian inheritance up to 20-23/32 grades in Northern region and 17-19/32 grades in Southern region. In North, crossbred produced more milk compared to South. This information was contrary to that reported by Naidu and Dasal (1965). The sire used in Northern region were found to be genetically superior as compared to Southern region.

Pandey (1971) calculated the overall average of first lactation milk yield of all grades of Frisian x Sahiwal and Frisian x Red Sindhi crosses as 2009±32.3 and 1936±56.6 kg for heavy rain fall area. He observed significant difference between the mean of each breed group and between farms.

Gupta (1974) estimated the heritability for each grade (HF x Sw) by regression of adjusted records of daughters on the adjusted records of dams. The pooled heritability estimates were of the order 0.22±0.11, 0.12±0.12 and 0.53±0.13 for 1st, 2nd and 3rd lactation respectively.
Hissa (1973) in his study of genetic analysis of production and reproduction traits in purebred (Sahiwal, Red Sindhi, Gir, Tharparker and Mariana) and their crosses with Friesian reported heritability for first lactation yield. The values were $0.48 \pm 0.15$, $0.36 \pm 0.21$, $0.02 \pm 0.12$, $0.15 \pm 0.43$, $0.40 \pm 0.35$ for purebreds and $0.65 \pm 0.63$, $0.44 \pm 0.78$, $>1.0$, $>1.0$ and $>1.0$ for their crosses respectively.

Abraham (1973) studied 14 years data of the local Kerala breed and its Jersey crossbred and grades with Red Sindhi located in heavy rainfall areas of Kerala. He classified the data into six genetic groups, five periods and two seasons. He observed negative deviation for local and 1/4 Jersey crossbreds from mean. Period and season of calving were found to be significant. The heritability estimates were $0.70 \pm 0.54$ and $-0.53 \pm 0.26$ for halfbred Jersey crosses and halfbred Red Sindhi blood respectively.

Taneja (1973) reported significant effect due to grade, farm and period and non-significant due to season on first lactation yield. He observed that halfbred and more than halfbred exotic blood grades had positive mean deviation and lower grade had negative mean deviation from overall least square mean value of first lactation yield. He estimated significant effect due to sire on first lactation yield for Sahiwal and 4-30/64 grades and non-significant for 36-63/64 group. For first lactation yield, additive variance due to sire was lowest for 4-30/64 genetic group followed by Sahiwal and 36-63/64 genetic group. The heritability estimates for first 300 days lactation yield were $0.41 \pm 0.14$, $0.17 \pm 0.07$ and $0.07 \pm 0.08$ for Sahiwal, 4-30/64 and 36-63/64 genetic groups.
Choudhry et al. (1974) reported significant effects due to farms, periods and genetic grades for milk yield. They explained the differences due to farms and periods might have occurred due to differences in the genetic composition of the herd and age group of animals. The non-significant effects due to parity of calving on milk yield indicated that animals attained adult body weight by the age at first calving. The effects due to age at first calving, 12 months body weight, peak yield on milk yield were found to be statistically significant. They observed that the performance of the 3/4 Friesian x Sahiwal crossbred was better than the 1/2 with respect to milk yield but halfbreeds were more suitable for better adaptability.

Patil et al. (1974) studied on various grades of Friesian x Sahiwal crossbred cattle and revealed that average lactation yield increased from 1/8 to 5/8 genetic group and after which there was a decline. The different values of genetic groups were statistically significant.

2.3.3. First Lactation Components

2.3.3.1. Average peak yield of 1st lactation (kg)

Naidu (1962) estimated the heritability of peak yield of 7/8-3/8 Friesian inheritance in first lactation, 0.39 for Northern region and 0.23 for Southern region. He reported highest peak yield 27 lbs for 3/4 at Southern farm and 26 lbs for 1/2 grade at Northern farms respectively. Further, he observed lowest peak yield for lower grade, 19 lbs for Northern region and 21 lbs for Southern region for 7/8 genetic group.
Pandey (1974) estimated average peak yield of different grades (pooled) of Friesian x Sahiwal (9.84 ± 0.14 kg) and for HF x RS crosses (9.16 ± 0.22 kg). He observed significant difference between grades but non-significant between farms.

Gill et al. (1971) estimated 0.49 ± 0.10 heritability for 463 Marana cattle for the peak yield of first lactation. Naidu and Desai (1970) reported 0.39 ± 0.25 heritability for the peak yield of 220 Sahiwal cows.

Pandey (1974) estimated peak yield of first lactation for Friesian x Sahiwal and Friesian x Red Sindhi for different grades and reported overall average as 9.84 ± 0.14 for 299 HF x Sw and 9.16 ± 0.23 for 78 HF x RS cows.

Choudhry et al. (1974) observed significant effect due to farms, periods, season of calving, parity of cow, and genetic grades for the peak yield. The effect due to age at first calving on peak yield was statistically significant. The least square means for the genetic grades indicate that the halfbreds were ranked superior for peak yield. The 1/2, 5/8, and 7/8 crosses were similar for peak yield. They suggested that maximum 26.38 percent improvement in peak yield was achieved by raising Friesian inheritance from 1/8 to 1/2 levels.

Chauhan et al. (1974) studied the peak yield and days to attain peak yield from 146 F₁ and 60 F₂ Brown Swiss crossbred cows and reported the significant difference in peak yield between two filial groups (F₁ and F₂), between season of calving within
filial groups. They observed significant effect due to order of lactation and non-significant effect due to season of calving on peak yield in $F_2$ crossbred cows. The average peak yield in the $F_1$ Brown Swiss crossbred cows calving in the cold season (December to February) was the highest and those calving in hot humid (June to August) was lowest.

Chauhan et al. (1976) observed $10.1\pm0.2$, $9.0\pm0.2$ and $9.9\pm0.4$ kg average peak yield of first lactation for $S_u$, Tharparker and Red Sindi cattle. The effect due to season of calving was significant for $S_u$ and Tharparker but non-significant for Red Sindi. They also indicated that highest peak yield of Sahiwal and Tharparker was found in the season when most of the cows calved (December to February).

### 2.3.3.2. Average yield (kg) of first lactation

Nagarckar (1966) reported $4.75\pm0.61$ and $6.77\pm0.54$ kg milking average for first lactation for Tharparker and Jersey cattle. Raut and Singh (1971) reported $2.61\pm0.25$ average milk yield of first lactation for 40 Marana cows. Gill and Allaire (1974) estimated average milk yield $13.63$ kg per day during first lactation for Frisian cattle.

Gurbachan Lal (1975) revealed average daily milk yield $5.15\pm1.05$, $7.60\pm0.85$, $8.74\pm0.91$, $7.65\pm0.79$, $9.35\pm1.94$ kg for Sahiwal, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{8}$ and $\frac{3}{4}$ Frisian inheritance grades.

### 2.3.4. First lactation length (days)

High variability of lactation length in Zebu breeds and their exotic crossbreeds was observed (Table 13).
Table 13. Average lactation length (days) and heritability
with standard errors of Sahiwal and its crossbreds

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>H² ± SE (PHC)</th>
<th>References</th>
</tr>
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<tr>
<td>Sahiwal</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>247</td>
<td>65</td>
<td>-</td>
<td>Sen et al., 1983</td>
</tr>
<tr>
<td>274</td>
<td>413</td>
<td>0.32±0.20</td>
<td>Sandhu, 1968</td>
</tr>
<tr>
<td>278</td>
<td>655</td>
<td>0.45±0.14</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>281</td>
<td>429</td>
<td>-</td>
<td>McGucken, 1937</td>
</tr>
<tr>
<td>296</td>
<td>160</td>
<td>-</td>
<td>Batra and Dass, 1964</td>
</tr>
<tr>
<td>300</td>
<td>403</td>
<td>-</td>
<td>Koul, 1968</td>
</tr>
<tr>
<td>300±4</td>
<td>180</td>
<td>-</td>
<td>Gurbachan Lal, 1975</td>
</tr>
<tr>
<td>321±9</td>
<td>80</td>
<td>-</td>
<td>Joke and Taylor, 1973</td>
</tr>
<tr>
<td>352</td>
<td>172</td>
<td>-</td>
<td>Bhatnagar et al., 1975</td>
</tr>
</tbody>
</table>

HF x SW crossbreds

Crossbred cattle with 12.5% Friesian inheritance

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>H² ± SE (PHC)</th>
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<td>278</td>
<td>10W</td>
<td>-</td>
<td>Ganguly, 1971</td>
</tr>
<tr>
<td>289</td>
<td>175</td>
<td>-</td>
<td>-do-</td>
</tr>
<tr>
<td>290±5</td>
<td>113</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>297±6</td>
<td>58</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
</tbody>
</table>

Crossbred cattle with 25% Friesian inheritance

<table>
<thead>
<tr>
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<th>H² ± SE (PHC)</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td>274</td>
<td>245</td>
<td>-</td>
<td>Naidu and Dass, 1966</td>
</tr>
<tr>
<td>280</td>
<td>396</td>
<td>-0.14±0.13</td>
<td>Sandhu, 1968</td>
</tr>
<tr>
<td>286</td>
<td>44W</td>
<td>-</td>
<td>Naidu and Dass, 1966</td>
</tr>
<tr>
<td>288±7</td>
<td>52</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>289</td>
<td>290</td>
<td>-</td>
<td>Tashen, 1973</td>
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<tbody>
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<td>292±3</td>
<td>240</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>295±3</td>
<td>313</td>
<td>-</td>
<td>Gurbachan Lal, 1975</td>
</tr>
<tr>
<td>300</td>
<td>394</td>
<td>-</td>
<td>Koul, 1968</td>
</tr>
<tr>
<td>318</td>
<td>225</td>
<td>-</td>
<td>McGuicken, 1937</td>
</tr>
</tbody>
</table>

**Crossbred cattle with 37.5% Friesian inheritance**

<table>
<thead>
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<th>$H^2 ± SE$ (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>266</td>
<td>17N</td>
<td>Naidu, 1962</td>
</tr>
<tr>
<td>284±3</td>
<td>259</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>287</td>
<td>39</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>299±4</td>
<td>141</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>302</td>
<td>38N</td>
<td>Ganpule, 1971</td>
</tr>
</tbody>
</table>

**Crossbred cattle with 50% Friesian inheritance**

<table>
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<th>$H^2 ± SE$ (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>265</td>
<td>17N</td>
<td>Naidu and Dassi, 1966</td>
</tr>
<tr>
<td>276</td>
<td>170</td>
<td>-0.16±0.24</td>
</tr>
<tr>
<td>287±4 (pooled all grade)</td>
<td>763</td>
<td>0.16±0.7</td>
</tr>
<tr>
<td>291</td>
<td>64</td>
<td>-</td>
</tr>
<tr>
<td>294±5</td>
<td>64</td>
<td>1.0</td>
</tr>
<tr>
<td>300</td>
<td>170</td>
<td>-</td>
</tr>
<tr>
<td>305±6</td>
<td>124</td>
<td>-</td>
</tr>
<tr>
<td>308</td>
<td>117</td>
<td>-</td>
</tr>
<tr>
<td>318</td>
<td>572</td>
<td>-</td>
</tr>
<tr>
<td>321</td>
<td>469</td>
<td>-</td>
</tr>
</tbody>
</table>

**Crossbred cattle with 62.5% Friesian inheritance**

<table>
<thead>
<tr>
<th>No.</th>
<th>$H^2 ± SE$ (PHC)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>270</td>
<td>33S</td>
<td>-</td>
</tr>
<tr>
<td>289</td>
<td>184</td>
<td>-</td>
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<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>$h^2$ ± SE</th>
<th>References</th>
</tr>
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<tbody>
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<td>292</td>
<td>72</td>
<td>-</td>
<td>Ambler and Jain, 1966</td>
</tr>
<tr>
<td>299</td>
<td>29</td>
<td>-</td>
<td>Verma et al., 1973</td>
</tr>
<tr>
<td>300±3</td>
<td>199</td>
<td>-</td>
<td>Patil et al., 1974</td>
</tr>
<tr>
<td>303±4</td>
<td>609</td>
<td>-</td>
<td>Gurbachan Lal, 1975</td>
</tr>
<tr>
<td>305±3</td>
<td>307</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>326</td>
<td>86</td>
<td>-</td>
<td>McGuicken, 1937</td>
</tr>
</tbody>
</table>

**Crossbred cattle with 75% Friesian inheritance**

<table>
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<tr>
<th>Mean ± SE</th>
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<th>$h^2$ ± SE</th>
<th>References</th>
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<tbody>
<tr>
<td>280</td>
<td>335</td>
<td>-</td>
<td>Naidu and Desai, 1966</td>
</tr>
<tr>
<td>290</td>
<td>146</td>
<td>0.36±0.39</td>
<td>Sandhu, 1968</td>
</tr>
<tr>
<td>296±4</td>
<td>143</td>
<td>-</td>
<td>Tamhan, 1973</td>
</tr>
<tr>
<td>297±3</td>
<td>210</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>300</td>
<td>143</td>
<td>-</td>
<td>Koul, 1968</td>
</tr>
<tr>
<td>304</td>
<td>49N</td>
<td>-</td>
<td>Ganpule, 1971</td>
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<tr>
<td>318</td>
<td>290</td>
<td>-</td>
<td>McGuicken, 1937</td>
</tr>
</tbody>
</table>

**Crossbred cattle with 87.5% Friesian inheritance**

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>$h^2$ ± SE</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>288</td>
<td>21N</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>296±5</td>
<td>31</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>303±11</td>
<td>36</td>
<td>-</td>
<td>Tamhan, 1973</td>
</tr>
<tr>
<td>316±168</td>
<td>-</td>
<td>-</td>
<td>Taneja, 1973</td>
</tr>
<tr>
<td>331</td>
<td>16N</td>
<td>-</td>
<td>Naidu, 1962</td>
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</tbody>
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**BS x SW crossbreds**

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>$h^2$ ± SE</th>
<th>References</th>
</tr>
</thead>
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<td>75 $F_2$</td>
<td>-</td>
<td>Bhathnagar et al., 1975</td>
</tr>
<tr>
<td>336</td>
<td>140 $F_1$</td>
<td>-</td>
<td>-de-</td>
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</table>

**Friesian**

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>$h^2$ ± SE</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>330</td>
<td>933</td>
<td>-</td>
<td>Gill and Allaire, 1974</td>
</tr>
</tbody>
</table>
Mehadevan (1955) reported that among unimproved Zebu breeds as many as 25% of the lactation ended before 200 days and among improved Zebu 60% of the lactation ended before 300 days. Introduction of Sahiwal genes into the small East African Zebu cows increased the lactation length from 239 to 283 days (Mehadevan et al., 1962).

Naidu and Desai (1966) indicated that animals in 16-23/32 Friesian grades produced milk for longest period which was measured to the optimum level of 300 days lactation period. The heritability coefficients for lactation period of Mariana cows were estimated, 0.32±0.03 by intramare regression of daughters on dam, 0.83±0.29 and 0.10±0.09 by halfsib correlation methods (Singh and Desai, 1961). Singh and Prasad (1966) obtained the heritability estimates 0.58±0.14, 0.44±0.25 and 0.38±0.18 by daughter dam regression, daughter dam correlation and paternal halfsib correlation methods respectively. Gill and Balsema (1971) estimated h² = 0.26±0.10 in Mariana while Soof and Singh (1970), Shukla and Prasad (1970) and Tomer et al. (1972) reported 0.06±0.01, in Mariana; -0.54±0.07, in Gir; and -0.03±0.07 in Mariana respectively.

Pandey (1971) reported overall average of lactation length for all grades of HF x Sw and HF x R5 as 297±3 and 296±5 days respectively for heavy rainfall area. He observed significant differences between grades and farms.

Tomer et al. (1972) found non-significant effect of age at first calving and year effect on first lactation length but lactation period was significantly affected by herds.
D'Souza (1972) reported average 284±8 and 282±7 days lactation length of HF x RS and HF x Gir crossbreeds. Duncan's multiple range test did not reveal significant difference in lactation length between Friesian x Red Sindhi and Friesian x Gir cattle.

Sandhu et al. (1973) studied the various genetic and non-genetic factors on lactation length. Effects due to farm, period and lactation numbers were significant, while that due to grades, season of calving and breed of sire were non-significant.

Misra (1973) reported average lowest and highest lactation length 243±5 and 281±3 days for Mariana and Red Sindhi cattle and among crossbred 279±7 and 336±7 days for HF x RS and HF x Mariana cattle. The heritability estimates for indigenous ranged from -0.002±0.12 (Gir) to 0.45±0.14 (Sahiwal) and for crossbred 0.44±0.78 (HF x Red Sindhi) to > 1.0 (HF x Mariana).

First lactation length was significantly affected due to grade of HF genes, farms, periods and non-significant due to season (Tanaja, 1973). He estimated significant effect due to sire for Sahiwal and 36-63/64 grades and nonsignificant for 4-30/64 Friesian inheritance. The additive variance due to sire was lowest for 4-30/64 genetic groups followed by Sahiwal and 36-63/64 genetic group. The heritability estimates for the traits were 0.16±0.10, 0.08±0.06 and 0.15±0.09 for Sahiwal, 4-30/64 and 36-63/64 Friesian grades.

Gurbachan Lal (1975) revealed significant effect of level of Friesian inheritance on lactation length for Friesian x Sahiwal crossbred cattle from Military Farm record.
2.3.5. First dry period (days)

The dry period in general was more in indigenous breeds than European cattle. Zebu x exotic crossbred had low dry period (Table 14). The average dry period was 90, 100 and 107 days in halfbred (HF x Sw), Ferozepur Sahiwal and ordinary Sahiwal in Northern region and 92 and 84 in halfbred (Red Sindhi x HF) and Red Sindhi respectively in Southern region (Kertha, 1954).

Table 14. Average first dry period (days) and heritability with standard error of Sahiwal and its crossbreds

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>h² ± SE (PHC)</th>
<th>References</th>
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<td>-</td>
<td>Gurbachan Lal, 1975</td>
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<td>158±4</td>
<td>503</td>
<td>-</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>196±98</td>
<td>245</td>
<td>-</td>
<td>Kushwaha and Mishra, 1969</td>
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<tr>
<td>232</td>
<td>85</td>
<td>-</td>
<td>Sen et al., 1953</td>
</tr>
<tr>
<td>296±5</td>
<td>-</td>
<td>-</td>
<td>Batra and Dass, 1968</td>
</tr>
</tbody>
</table>

HF x Sw crossbreds

Crossbred cattle with 12.5% Frisian inheritance

<table>
<thead>
<tr>
<th></th>
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<td>99</td>
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<td>-0.33(1-3/8)</td>
<td>Naidu, 1962</td>
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<td>Pandey, 1971</td>
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<td>Tamhan, 1973</td>
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<td>177</td>
<td>155</td>
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<td>119±4</td>
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<td>142±5</td>
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<th>Crossbred cattle with 37.5% Friesian inheritance</th>
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<td>113±4</td>
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<td>116</td>
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<td>124</td>
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<td>130±5</td>
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<table>
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<tbody>
<tr>
<td>Mean ± SE</td>
</tr>
<tr>
<td>94±3</td>
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<td>116</td>
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<td>129±7</td>
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<td>130</td>
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<td>141±15</td>
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<tbody>
<tr>
<td>Mean ± SE</td>
</tr>
<tr>
<td>92±4</td>
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<tr>
<td>103±6</td>
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<td>116±5</td>
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<tr>
<td>124</td>
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<td>127</td>
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<th>h² ± SE</th>
<th>References</th>
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<tr>
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**Crossbred cattle with 75% Friesian inheritance**

<p>| | | | |</p>
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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>101±56</td>
<td>146</td>
<td>0.03±0.12</td>
<td>Basu and Ghai, 1975</td>
</tr>
<tr>
<td>109±7</td>
<td>82</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>123±5</td>
<td>139</td>
<td>-</td>
<td>Tamhane, 1973</td>
</tr>
<tr>
<td>134</td>
<td>515</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>144</td>
<td>324</td>
<td>-</td>
<td>Naidu, 1962</td>
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**Crossbred cattle with 87.5% Friesian inheritance**

<p>| | | | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>113</td>
<td>219</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
<tr>
<td>114</td>
<td>204</td>
<td>-</td>
<td>-do-</td>
</tr>
<tr>
<td>139</td>
<td>475</td>
<td>-</td>
<td>Naidu, 1962</td>
</tr>
<tr>
<td>152±17</td>
<td>34</td>
<td>-</td>
<td>Tamhane, 1973</td>
</tr>
<tr>
<td>179</td>
<td>33N</td>
<td>-</td>
<td>Naidu, 1962</td>
</tr>
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**BS x EW crossbreds**

<p>| | | | |</p>
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</thead>
<tbody>
<tr>
<td></td>
<td>F₁</td>
<td>Bhatnagat et al., 1975</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F₂</td>
<td>-do-</td>
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**Friesian**

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<table>
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</thead>
<tbody>
<tr>
<td>62</td>
<td>933</td>
<td>-</td>
<td>Gill and Allaire, 1974</td>
</tr>
</tbody>
</table>

---

Klein and Woodward (1948) studied the influence of length of dry period upon the quantity of milk produced in the subsequent lactation and revealed that both long and short dry periods were associated with loss of production. With long dry period more milk will be lost in a current lactation than that gained in the subsequent lactation, similarly with short dry
period more milk will be lost in the subsequent lactation than that should be gained in the current lactation.

Sen et al. (1983) concluded from their study on Ayrshire crosses with Red Sindhi, Sahiwal and Mariana cattle and Friesian x Red Sindhi that dry period was found lowest in half-bred ranging from 73 (HF x R5) to 95 (Ayrshire x Mariana) days, in 3/4 grades 79 (Ayrshire x Mariana) to 92 days (Ayrshire x Red Sindhi). Whereas 1/4 crossbred had higher average dry period than both the genetic groups. In Zebu cattle the average dry period ranged from 178 to 272 days.

Tandon (1961) observed significant difference between the mean dry period (134±6 Vs 94±3 days) of Red Sindhi and Jersind cattle.

Naidu and Desai (1966) pointed out significant difference in dry period between the Holstein grades in Northern and nonsignificant in Southern region. The dry period decreased from 8/32 to 11/32 Holstein grade and observed to be constant upto 19/32 Holstein and then increased with the increase in Holstein inheritance.

Dadlani and Prabhu (1968), and Soof and Singh (1969) in Mariana and Abraham (1973) in Jersey x Local (Kerala) crosses observed moderate heritability for first dry period. The values ranged from 0.32±0.32 (Mariana) to 0.44±0.82 (Jersey x Local). Basu and Ghai (1975) reported low (0.03±0.12) heritability in pooled HF x Sw crossbreds.

Pandey (1971) estimated the overall average of pooled dry period of all grades 116±2 for HF x Sw and 132±7 in
Holstein-Friesian x Red Sindhi. The effects due to farm and grades were observed significant.

Salmae (1977) estimated the heritability for first dry period by intrasire daughter dam regression, halfsib correlation and halfsib correlation from generation wise as $0.08 \pm 0.12$, $0.60 \pm 0.20$ and $0.02 \pm 0.15$ respectively in Mariana cattle.

Tanaka (1975) observed significant effect due to grade and farms on first dry period whereas the effects due to period and season were nonsignificant. The highest and lowest least square mean of dry period was observed for 1/4 and 5/8 grade of Friesian inheritance respectively. Effects due to sires were significant for Sahiwal, 4-30/64 and 36-63/64 Friesian grades. The heritability estimates for first dry period were $0.17 \pm 0.11$, $0.11 \pm 0.07$ and $0.24 \pm 0.12$ for Sahiwal, 4-30/64 and 36-63/64 grades respectively.

2.3.6. Second and third lactation yield (kg)

Variation in second and third lactation for Sahiwal breed at different farms and among Friesian x Sahiwal crossbred had been reported by several workers (Table 15a and 15b).

Johnson and Carley (1961) estimated the heritability 0.42 in first lactation, -0.10 in the second lactation and 0.11 in the third lactation in Brown Swiss cattle. VanVleck and Bradford (1966) showed a decreasing trend in heritability values in Holstein cows from first to second, third and fifth lactation. The estimates of genetic correlation between first and second lactation yield were 0.87 and second and third lactation yield 0.91 and these correlations were not away from unity.
Table 15(a). Average second lactation yield (kg) and heritability with standard errors of Sahiwal and its crossbreds.

<table>
<thead>
<tr>
<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>H² ± SE (PHC)</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td><strong>Sahiwal</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1693</td>
<td>42</td>
<td>-</td>
<td>Campule, 1971</td>
</tr>
<tr>
<td>1879 ± 26</td>
<td>456</td>
<td>0.46 ± 0.21</td>
<td>Acharya and Nagpal, 1971</td>
</tr>
<tr>
<td>1920 ± 52</td>
<td>106</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1827 ± 68</td>
<td>77</td>
<td>0.56 ± 0.27</td>
<td>Khanna and Bhat, 1971</td>
</tr>
<tr>
<td>1845 ± 52</td>
<td>118</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1889 ± 26</td>
<td>506</td>
<td>0.49 ± 0.17</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>2086</td>
<td>114</td>
<td>-</td>
<td>Bhatnagar et al., 1975</td>
</tr>
</tbody>
</table>

**MF x SW crossbreds**

Crossbred cattle with 12.5% Frisian inheritance

<table>
<thead>
<tr>
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<th>-</th>
<th>References</th>
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<tbody>
<tr>
<td>1981 ± 85</td>
<td>49</td>
<td>-</td>
<td>Pandey, 1971</td>
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<tr>
<td>2284</td>
<td>52(4-7/32)</td>
<td>-</td>
<td>Campule, 1971</td>
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</table>

Crossbred cattle with 25% Frisian inheritance

<table>
<thead>
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<th>Mean ± SE</th>
<th>No. of obs.</th>
<th>-</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976 ± 67</td>
<td>47</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>2319 ± 44</td>
<td>210</td>
<td>-</td>
<td>Aurty, 1974</td>
</tr>
<tr>
<td>2356</td>
<td>53</td>
<td>-</td>
<td>Campule, 1971</td>
</tr>
</tbody>
</table>

Crossbred cattle with 37.5% Frisian inheritance

<table>
<thead>
<tr>
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<th>References</th>
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<tbody>
<tr>
<td>2131 ± 101</td>
<td>35</td>
<td>-</td>
<td>Pandey, 1971</td>
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<tr>
<td>2453</td>
<td>136</td>
<td>-</td>
<td>Campule, 1971</td>
</tr>
<tr>
<td>2456 ± 68</td>
<td>102</td>
<td>-</td>
<td>Aurty, 1974</td>
</tr>
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<table>
<thead>
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<td>46</td>
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<td>2620±147</td>
<td>31</td>
<td>-</td>
<td>Misra, 1973</td>
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<td>2705±14</td>
<td>47</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>2776</td>
<td>33</td>
<td>-</td>
<td>Ganpule, 1971</td>
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<td>Crossbred cattle with 62.5% Friesian inheritance</td>
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<td>2657±67</td>
<td>140</td>
<td>-</td>
<td>Murty, 1974</td>
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<td>2670±121</td>
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<td>Pandey, 1971</td>
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<td>20</td>
<td>-</td>
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<td>2547±229</td>
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<td>2602±64</td>
<td>139</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
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<td>2949</td>
<td>46</td>
<td>-</td>
<td>Ganpule, 1971</td>
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<td>Crossbred cattle with 87.5% Friesian inheritance</td>
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<tr>
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<td>48</td>
<td>-</td>
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**BS x Sw crossbreds**

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<td>2855</td>
<td>42</td>
<td>(F₂)</td>
<td>-do-</td>
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<tr>
<td>3341</td>
<td>25(3/4)</td>
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<td>-do-</td>
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</table>
Table 15(b). Average third lactation yield (kg) and heritability with standard error of Sahiwal and its crossbreeds.

<table>
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<th>h² ± SE (PMC)</th>
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<td>1757</td>
<td>27</td>
<td>-</td>
<td>Gandule, 1971</td>
</tr>
<tr>
<td>1973±35</td>
<td>456</td>
<td>0.29±0.23</td>
<td>Acharya and Nagpal, 1971</td>
</tr>
<tr>
<td>2002±57</td>
<td>98</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1896±62</td>
<td>53</td>
<td>0.93±0.37</td>
<td>Khanna and Bhat, 1971</td>
</tr>
<tr>
<td>1872±63</td>
<td>86</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2016±31</td>
<td>306</td>
<td>0.66±0.22</td>
<td>Mishra, 1973</td>
</tr>
<tr>
<td>2359</td>
<td>64</td>
<td>-</td>
<td>Bhatnagar et al., 1975</td>
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**HF x Sw crossbreeds**

Crossbred cattle with 25% Frisian inheritance

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<td>1923±87</td>
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<tr>
<td>2392</td>
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<td>-</td>
</tr>
<tr>
<td>2704±56</td>
<td>140</td>
<td>-</td>
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</table>

Crossbred cattle with 37.5% Frisian inheritance

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<th>No. of obs.</th>
<th>References</th>
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</thead>
<tbody>
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<td>2267±95</td>
<td>33</td>
<td>-</td>
</tr>
<tr>
<td>2327</td>
<td>32</td>
<td>-</td>
</tr>
<tr>
<td>2756±77</td>
<td>71</td>
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</tbody>
</table>

Crossbred cattle with 50% Frisian inheritance

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<th>References</th>
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<td>-</td>
</tr>
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<td>2631</td>
<td>26</td>
<td>-</td>
</tr>
<tr>
<td>2963±215</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td>3013±205</td>
<td>22</td>
<td>-</td>
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</table>

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<tr>
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<th>$h^2$ ± SE (PHC)</th>
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<td>12</td>
<td>-</td>
<td>Pandey, 1971</td>
</tr>
<tr>
<td>3190±90</td>
<td>90</td>
<td>-</td>
<td>Murty, 1974</td>
</tr>
<tr>
<td>3368</td>
<td>15</td>
<td>-</td>
<td>Ganpule, 1971</td>
</tr>
</tbody>
</table>

| **Crossbred cattle with 75% Frisian inheritance** | | | |
| 2586±224 | 12 | - | Pandey, 1971 |
| 2621 | 28 | - | Ganpule, 1971 |
| 3140±105 | 107 | - | Murty, 1974 |

| **Crossbred cattle with 87.5% Frisian inheritance** | | | |
| 2993±209 | 11 | - | Murty, 1974 |
| 3137 | 44 | - | Ganpule, 1971 |

| **BS x SW crossbreds** | | | |
| 3356 | 27 | - | Bhatnagar et al., 1975 |
| 3546 | 6 | - | -de- |
| 3729 | 96 | - | -de- |

Ganpule (1971) observed increasing trend in milk yield from first to third lactation in Mariana and Sahiwal cattle and in all grades of HF x SW crossbred in Northern region of India.

Khanna and Patil (1971) studied the genetic architecture of Sahiwal cattle and revealed in their study that lactation yield increased from first to fourth lactation suggesting that lactational maturity was attained for these animals in the fourth lactation.
Pandey (1974) calculated the overall average of second and third lactation yield for various grades of Friesian x Sahiwal as 2236±44.8 and 2268±38.6 kg respectively. He observed significant difference between mean of grades but non-significant between farms.

Riera (1973) reported increasing trend in milk yield from first to third lactation in Sahiwal, Red Sindhi, Gir, Tharparker and Mariana cows and their Friesian crosses. The heritability estimates for second lactation ranged from -0.04±0.46 to 0.64±0.30 in Zebu cattle, and the heritability estimates for third lactation yield were 0.46±0.22, 0.40±0.29, -0.04±0.14, 0.76±0.76 and 0.40±0.55 for Sahiwal, Red Sindhi, Gir, Tharparker and Mariana cattle respectively.

2.4. Genetic and Phenotypic Correlations

2.4.1. Genetic and phenotypic correlation among body weight and other traits

Stonaker et al. (1953) estimated correlation 0.316, 0.261 and 0.327 respectively between birth weight and 6 month weight, birth weight and mature weight, and 6 month weight and mature weight of Jersey x Sindhi crossbred cattle. Anantakrishnan and Lazarus (1963) reported significant correlation of birth weight with weight at calving and non-significant correlation between birth weight and age at calving. Martin (1956) observed positive correlation between birth weight and weight increase from birth to 6 months and from 6 months to 12 months age to subsequent milk yield but association was not very close.
Singh and Desai (1959) reported negative but significant phenotypic association between birth weight and age at first calving (-0.42). The correlation of birth weight with first lactation yield was -0.166 (NS).

Swiger (1961) reported correlation of birth weight with weaning weight, first period of gain and final weight on 793 Hereford half-sibs belong to 23 sires. The values for genetic correlations were 0.69, 0.94 and 0.98, phenotypic correlations 0.31, 0.14 and 0.69 and environmental correlations 0.19, -0.05 and 0.47 respectively. The genetic and phenotypic correlations were highly significant. They concluded that genes which were responsible for early weight were also affecting body weight largely in later part of life. Hence a due importance should be given in selection by giving importance to birth weight and weight at earlier body weight. Lesley et al. (1961) supported this with their findings.

Natra and Desai (1962) revealed phenotypic correlation 0.0177 between birth weight and age at first calving in Sahiwal cattle and genetic correlation of birth weight with weight at 19 week and age at first calving were -1.222 and -1.562 respectively. Martin et al. (1962) reported the correlation of birth weight with weight gain were all less than 0.40. Early rate of gain had little or no effect on later gain, age at calving and milk production of dairy cattle.

Maidu (1962) reported phenotypic correlation of birth weight with weight at 19 week, at 1 year, at calving and age at calving for 4-15/32, HF x Su grades. For Northern region
the values were 0.1158, -0.0431, 0.0297 and -0.0245, and for Southern region the values were 0.2758, 0.000, 0.359 and -0.1618 respectively. The genetic correlation of birth weight with weight at 19 week, weight at first calving and age at first calving were -0.631, -0.572 and -0.203 respectively for 4-15/32 grade in Northern region. The genetic correlation between weight at first calving and age at first calving was 0.275, environmental correlation 0.426 and phenotypic correlation 0.272 in 4-15/32 grade respectively.

Positive correlation between birth weight and weight at 4 months and negative correlation between birth weight and weight at 12 months was reported by Ragub and Abd,El-Aziz (1961) in Frisian cattle. Forrest (1964) reported that no correlation existed between birth weight and rate of gain at any time after the animal had attained 200 lbs live weight in Shorthorn and Frisian calves.

Rappan (1965) reported the correlation coefficient between birth weight and body weight at 6 months of age was 0.22 and birth weight and 12 months age body weight was 0.33 in 1556 Black Pied cattle.

Singh and Choudhry (1961), and Kushwaha and Miera (1969) reported high phenotypic correlation between age at first calving and first lactation length.

Koul (1968) reported that phenotypic and genetic correlation of age at first calving with birth weight in Sahiwal cattle were -0.09 and -0.03 respectively and genetic correlation in halfsib HF x Su cattle was -0.12.
Averdunk (1968) estimated genetic correlation, 0.69 between weight at 364 and 500 days of age and 0.54 between weight at 1 year and gain from 1 year until 500 days of age. He reported that selection on weight at 1 year age would favour in picking up early maturing cows.

Naidu and Deasi (1970) reported correlation between weight at 19 weeks of age with weight at first calving (0.214), age at first calving (-0.214), first lactation 300 day milk yield (-0.494), first lactation milk yield with weight at first calving (0.236). Genetic correlation of age at first calving with birth weight, weight at 19 week, and weight at first calving were -0.203±0.372, -0.190±0.328 and 0.275±0.259 respectively. Batra and Deasi (1962) reported correlation of birth weight with weight at 19 weeks, weight at first calving, age at first calving and first milk yield as 0.370, 0.306 and 0.908 respectively while genetic correlation with weight at 19th week, weight and age at first calving were 0.963, 0.710 and -0.222 respectively.

Singh and Deasi (1971) suggested from their study on 110 Red Sindhi cews (Allahabad and Bangalore Military Farms) that to assure high milk production and high breeding efficiency it would be necessary to put selection pressure on those animals having high body weight and early first calving.

Tanaja and Bhat (1971) studied genetic correlation of birth weight with body weight at various ages in Sahiwal cattle. The values were small and negative except with weight at 36th month (0.81). They claimed that growth could be predicted with accuracy from birth weight. Genetic correlations of weight at 19th
week with weight at 52 weeks, 36 months and that of 52 weeks with 36 months were high. Age at first calving was negatively correlated with body weight at various ages.

Taylor and Fitzhugh (1971) estimated that the heritability for time taken to mature in body weight ranged from 0.22 at birth to 0.42 at 18 months of age. The genetic correlation between time taken to mature and mature weight were 0.34, 0.41, 0.39 and 0.38 at birth and 0.6 at 18 months of age respectively. They suggested that within a breed animal genetically heavier at maturity tended to take a longer time to reach mature body weight. Estimates of the genetic regression of time taken to mature on mature weight were 0.23, 0.33, 0.28 and 0.26 at birth and at 6, 12, 18 months of age respectively.

Paria (1972) estimated genetic correlation of age at first calving with birth weight, weight at 19 weeks, weight at 52 weeks, weight at 24 months, weight at 30 months and weight at 36 months -0.086, -0.347, -0.413, 0.554, 0.437 and -0.451 and their respective phenotypic values were -1.296, -0.373, -1.522, -1.631, -1.22, -0.927 in Gir cattle. Arora (1972) conducted study on HF x SW crossbred cattle and estimated the genetic and phenotypic correlation among body weights for half bred cattle, as given below. He also determined that selection could be effective at an early age of three to six month of age, as early traits had high positive genetic and phenotypic association with later traits.
<table>
<thead>
<tr>
<th></th>
<th>Birth wt.</th>
<th>Wt. at 3 mths</th>
<th>Wt. at 6 mths</th>
<th>Wt. at 12 mths</th>
<th>Wt. at 24 mths</th>
<th>Wt. at 1st calving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight</td>
<td>-</td>
<td>0.51</td>
<td>0.39</td>
<td>0.26</td>
<td>0.43</td>
<td>0.40</td>
</tr>
<tr>
<td>Weight at 3 mths age</td>
<td>0.34</td>
<td>-</td>
<td>0.29</td>
<td>0.84</td>
<td>0.71</td>
<td>0.24</td>
</tr>
<tr>
<td>Weight at 6 mths age</td>
<td>0.29</td>
<td>0.72</td>
<td>-</td>
<td>0.97</td>
<td>0.84</td>
<td>0.49</td>
</tr>
<tr>
<td>Weight at 12 mths age</td>
<td>0.22</td>
<td>0.57</td>
<td>0.74</td>
<td>-</td>
<td>0.81</td>
<td>0.55</td>
</tr>
<tr>
<td>Weight at 24 mths age</td>
<td>0.20</td>
<td>0.44</td>
<td>0.59</td>
<td>0.71</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Weight at 1st calving</td>
<td>0.12</td>
<td>0.49</td>
<td>0.31</td>
<td>0.40</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

O'Souza (1972) estimated that phenotypic correlation between birth weight and age at first calving was positive (0.22 and 0.043) in Red Sindhi x Friesian and Friesian x Gir and genetic correlation was 0.25 in Friesian x Gir crossbreds.

Tamer and Arora (1972) estimated significant negative association -0.552 between birth weight and age at first calving but small association with weight at first calving (0.10). The effect of sire on age at first calving of their daughters was highly significant and accounted for 23.3% of the total variation in age at first calving. From correlation they concluded that there was a decrease of age at first calving with corresponding increase in birth weight.

Willis et al. (1972) estimated the heritability for birth weight 0.39±0.3, 0.25±0.6, 0.09±0.1 and 0.62±0.4 respectively for Senta, Gertrudis, Charolaais, Holstein x Zebu and Brown Swiss x
Zebu and heritability for body weight at 90 days was $0.11 \pm 0.11$, $0.21 \pm 0.2$, $0.44 \pm 0.8$, $0.16 \pm 0.2$ and $0.08 \pm 0.1$ respectively in tropical environment. Phenotypic correlation between birth weight and 90 days weight ranged from 0.16 (Zebu) to 1.00 (BS x Zebu). The genetic correlations were $1.00$, $0.40$, $0.36$ for Charoleais, Zebu and Santa Gertrudis, $-0.46$ and $-0.23$ for BS x Zebu and Holstein x Zebu. Since the dams of the crossbreds were generally poor milk producers, it was suggested that these negative genetic correlation might reflect a genetic capacity for gain than was realized.

Govindasah (1973) estimated the phenotypic and genetic correlations of body weight on the basis of sire component of variance and covariance from 639 Hariana calves. He found that genotypically and phenotypically 4 months body weight was significantly correlated with 18 months and 24 months of body weight which indicates that genes which were influencing for early growth did affect advance age of body weights or it may be due to the pleiotropic effect of the genes affecting both the characters. Hence 4 months body weight was a better indicator for early maturity and rapid gain at later part of the life. From negative environmental correlations, he suggested that it would accelerate the genetic progress since selection for one trait would partially compensate for the effects of environmental differences on the other traits.

Taneja (1973) estimated the genetic ($r_g$) and phenotypic ($r_p$) correlation of birth weight with weight at 8, 26
and 52 weeks, weight at first calving, age at first calving, first lactation yield and first lactation length in Sahiwal, 4-30/64 and 36-63/64 Frissian inheritance. Genetic and phenotypic correlations of birth weight with body weights and other traits are given below:

<table>
<thead>
<tr>
<th>Traits</th>
<th>Sahiwal</th>
<th>4-30/64</th>
<th>36-63/64</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F_G</td>
<td>F_P</td>
<td>F_G</td>
</tr>
<tr>
<td>Weight at 8 week</td>
<td>.62±.16</td>
<td>.38±.04</td>
<td>.56±.11</td>
</tr>
<tr>
<td>Weight at 26 week</td>
<td>.45±.20</td>
<td>.14±.04</td>
<td>.46±.12</td>
</tr>
<tr>
<td>Weight at 52 weeks</td>
<td>.48±.19</td>
<td>.13±.04</td>
<td>.48±.12</td>
</tr>
<tr>
<td>Weight at 1st calving</td>
<td>&gt;4.0</td>
<td>.10±.04</td>
<td>.41±.16</td>
</tr>
<tr>
<td>Age at 1st calving</td>
<td>-.04±.32</td>
<td>-.09±.04</td>
<td>-.11±.22</td>
</tr>
<tr>
<td>First lact.</td>
<td>.33±.25</td>
<td>.00±.04</td>
<td>-.28±.19</td>
</tr>
<tr>
<td>First lact. yield</td>
<td>.54±.27</td>
<td>.01±.04</td>
<td>-.30±.20</td>
</tr>
</tbody>
</table>

Murty (1974) reported negative and significant correlation of age at first calving with body weight at 6, 12, 18 and 24 months of age and low and non-significant with birth weight in HF x 5w crossbred grades. The correlations for body weight at birth, 6, 12 and 18 months with first lactation yield were low and nonsignificant except in halfbred Jersey x 5w where the positive correlation was significant (0.26). Among Frissian
crosses the correlation between body weight at 24 months and first lactation yield were significant.

Hore et al. (1974) estimated correlation coefficients between the birth weight and weight gain per day up to six and twelve months of age for Sahiwal and HF x Sw crossbred female calves, the values were 0.656, 0.651 and 0.615 & 0.624 respectively.

Hingane (1975) reported low and nonsignificant phenotypic correlation of birth weight with weight at 6 months, weight at 12 months, 18 months and age at first calving as 0.24, 0.11, -0.06 and 0.17 for Gir and 0.029, 0.028, 0.024 and 0.090 for Holstein x Gir crossbreds respectively.

2.4.2. Genetic and phenotypic correlation among components of first lactation, first, second and third lactation yields, age at first calving and first lactation length

Waidu (1962) estimated genetic, phenotypic and environmental correlations of first lactation peak yield with first lactation milk yield in 4-15/32 Friesian x Sahiwal grades for Northern region. The values were 1.088, 0.743 and 0.715 respectively.

VanVleck and Bradford (1966) reported high genetic correlation about unity (0.97) between first and second lactation and \( r_G = 0.91 \) between second and third lactation yield of Holstein cows. Similarly high correlation \( r_G = 0.85 \) and \( r_G = 0.95 \) between first & second and second & third lactations respectively were reported (Barber and Robertson, 1966).
Singh and Prasad (1969) reported nonsignificant phenotypic correlation between age at first calving and first lactation yield in Bashaur cattle. Balsina et al. (1970) estimated peak month's yield 46.63±19.74 kg, lactation length 263±66 days and lactation yield 761±315 kg in 524 Mariana cattle. Heritability estimates by paternal half-sib correlation were 0.49, 0.21 and 0.40 respectively. The phenotypic correlation of peak month's yield with total lactation yield was 0.77±0.03 and between lactation length and lactation yield was 0.58±0.04.

Haider and Dessi (1970) reported phenotypic correlation (0.716) for 4-15/32 Friesian x Sahiwal grades between milk yield and peak yield and genetic correlation 0.420±0.824, 0.246±0.465 of age at first calving with 300 days yield and peak yield and environmental correlation 0.077 and -0.0022 respectively. Genetic correlation of 300 days yield with lactation length was 0.531. They suggested that 19th week weight and peak yield can be used as indicator for early maturity and higher milk production in crossbreds.

Holl (1970) studied the relationship between initial milk production and completed lactation yield of 660 lactations of 284 Czech Pied cows. Milk recording was carried out at either 7 days or 10 days intervals. At 7 days interval the maximum daily yield 20.8 kg was recorded in 5th week (10.4 days on an average) and at 10 days interval the maximum daily yield (19.9 kg) was recorded in the 4th ten day period (39.8 days on an average). The total milk yield was significantly correlated with maximum
yield recorded at 7 day interval (0.812) the 10th day interval (0.810) and the average maximum yield from 2 recording (0.840). Calculations were also presented for different lactation and calving seasons.

Köniczek (1970) estimated the correlation between the yield recorded for 1, 2, 3, 4, 5 or 6 days and that for the total lactation were 0.672, 0.765, 0.805, 0.859, 0.890 and 0.910 respectively in 1578 heifers.

Acharya and Nagpal (1971) estimated phenotypic ($r_p$ 0.53 and 0.47) and genotypic ($r_e$ 1.69×0.35 and 0.49×0.26) correlations of first lactation milk yield with second and third lactation yields and second lactation yield with third lactation yields were 0.35 and 0.62×0.17 respectively. Though lactation production was highly correlated ($r_e$ = 0.94×0.02) with lifetime production, but due to its low heritability it could not be considered for selection gain.

Gill et al. (1971) estimated $0.77×0.03$ phenotypic and $0.57×0.16$ genotypic correlation between milk yield and peak yield in Mariana cattle. The heritability of first lactation and peak yield was 0.49 and 0.40 respectively.

Ohri and Singh (1971) reported that first lactation yield was significantly correlated with lactation length $r = 0.74$ and peak yield $r = 0.27$ in Rathi cattle. They observed lactation milk yield increased with parity up to 4th lactation.

Gandolfi and Ruesc (1971) studied the lactation curve in 135 Canadian Frisian cows. The average first day milk
yield was 10.58±3.21 kg, in ascending phase 21.99±4.64 kg and peak daily yield 25.81±5.47 kg. The total production for a 305 days lactation was 4810±11.61 kg. The correlations between total milk yield and average daily production in the ascending phase, maximum daily production and average daily production in the first 9 weeks were 0.78, 0.82 and 0.82 respectively.

Stoyanov (1972) worked out significant correlation between maximum yield and total first lactation yield 0.77 and between first lactation yield and peak yield 0.63 from 1028 Bulgarian Brown Swiss cows. Anderson and Peterson (1972) estimated the heritability 0.17 and 0.15 respectively for first and second lactation yield in Danish Red cattle and 0.20 and 0.14 respectively in Danish Black Pied cattle.

Gravert and Baptist (1973) revealed from 20358 heifers record that correlation between initial yield and total yield was 0.76. The heritability for initial yield was 0.24 and for complete lactation it was 0.19. They explained that 305 days lactation was a function of initial yield and yield decreased per day, which were genetically negatively correlated. The heritability of yield per day was 0.16. Cannon et al. (1942) and Kennedy and Seath (1942) in Holstein and Jersey heifers respectively observed that part lactation yields were correlated with 305 days yield. Significant and high correlations between part lactation records and total yield were reported by O'Conner and Stewart (1958), Hickman (1960) in Friesian cattle. VanVlack and Henderson (1961a,b) studied the importance of part lactation yield in Holstein cows from corrected data for age and season of calving. They
reported 0.50 correlation value of a single test day record from 4th, 5th and 6th month of lactation with total lactation yield. A linear function of first five monthly test records was observed to predict a complete second record as accurately as the total yield of the first lactation.

Khan and Ahmed (1972) estimated correlation 0.81, 0.90, 0.91, 0.90 and 0.95 of first, second, third, fourth and fifth monthly yield with 305 days yield in 242 Sahiwal cows. The multiple correlation was found to be 0.97. Significant effect of age at first calving, season of calving and months of lactation on a part lactation and total milk production were observed by Lamb and McMillard (1960) in Holstein, Guernsey, Jersey and Brown Swiss cattle and VanVleck and Henderson (1961) in Holstein cows. High genetic correlations approaching unity between part, cumulative and total milk yield were reported by Maddan (1955) for 599 lactation records of Frisian cows, VanVleck and Henderson (1961a) in Holstein breed, Hickman (1960) in Ayrshire, Holstein and Jersey cattle. Singh et al. (1967) estimated the heritability 0.22±0.19, 0.39±0.22, 0.63±0.27 and 0.32±0.21 for 15, 75, 135 and 305 days lactation yields respectively, and reported high genetic correlation among these traits. Singh and Acharya (1969) reported heritability estimates of monthly milk yield ranging from zero to 0.46±0.13 by dam-daughter regression method and 0.12±0.12 to 0.33±0.15 by paternal halfsib method. They observed high genetic correlations of monthly and cumulative monthly production with total production.
2.4.3. Genetic and phenotypic correlation of body weight, growth rate and age at first calving with first lactation yield and its components, second and third lactation yield

Sundaresan et al. (1954) in Red Sindhi and Batra and Desai (1964) in Sahiwal reported moderate positive phenotypic correlation between age at first calving and first lactation yield. Puri and Sharma (1965) worked out high negative phenotypic correlation in Sahiwal between age at first calving and first lactation yield.

Sundaresan (1956) estimated 0.074 and 0.120 correlation between age at first calving and first lactation yield in halfbred Brown Swiss x Red Sindhi and 1/4 to 3/4 BS x Red Sindhi respectively. Blackmore et al. (1958) estimated positive relationship between birth weight and production traits in dairy cattle.

Singh and Desai (1969) studied inheritance of birth weight in Mariana cattle and observed phenotypic correlation of birth weight with age at first calving and first lactation yield which were -0.42 (highly significant) and -0.166 (NS) respectively.

Riller and McGilliard (1959) reported genetic correlation 0.30 between weight at first calving and first lactation production. The heritability based on paternal-sister correlation ranged from 0.4 to 0.8 for weights and from 0.3 to 0.6 for production in first lactation. Selection for increased milk production might result in large size, correcting production for weight should be based only on the environmental parts of the
relationship between weight and production to avoid in removing some genetic variation in production.

Ahmed (1981) indicated genetic and phenotypic correlation between age at first calving and first lactation yield as -0.29 and 0.18 respectively. The heritability for the traits was 0.38±0.07 by daughter dam regression and 0.02±0.10 by paternal half sib correlation.

Naidu (1962) estimated phenotypic and genetic correlation in 4-15/32 HF×5w grades of Northern region. The phenotypic correlations of first lactation milk yield with birth weight, weight at first calving, age at first calving, peak yield and lactation period were -0.138, 0.558, 0.107, 0.713 and 0.463 respectively and genetic correlations for these traits were 0.348, 0.185, 0.419, 1.088 and -0.565 and environmental correlations were -0.259, 0.468, 0.076, 0.715 and 0.592 respectively.

Several workers observed the significant curvilinear regression of milk yield on body weight (McDaniel and Legates, 1965, and Miller and Weaven, 1969) and they observed inconsistent values of genetic correlations between these traits. Peterskin (1964) studied the relationship between milk production and body weight in 13310 Simmental cows and found that average milk yield increased from 2540 kg for cows of less than 500 kg to 4583 kg for those weighing 700 kg or more and observed that highest milk yield occurred at intermediate body weight (551-600 kg).

Harville and Henderson (1966) in Jersey, Friesian and Guernsey breeds observed genotypic and phenotypic correlation not far from zero between age at first calving and first lactation yield.
Singh and Singh (1967) studied the relative efficiency of milk production in 86 cows of Melestein x Red Sindhi crossbred and showed that milk yield per unit of body weight at first calving increased from 3986 lbs at body weight of up to 750 lbs to a maximum of 5205 lbs at 851-950 lbs body weights. The partial regression of milk yield on body weight for constant age at first calving were -1.89, 0.36, 12.25 and 5.89 for body weight at first calving less than 751, 751-850, 851-950 and >950 lbs, respectively and they observed that body weight at first calving had more effect on milk yield than age at first calving in crossbred cows.

Singh et al. (1969) estimated the genetic and phenotypic correlation of birth weight and weight at first calving with age at first calving, first lactation yield and first dry period and between birth weight and weight at first calving. The phenotypic correlation values were low in order than genotypic correlations. Age at first calving was genetically associated with first lactation milk yield and first dry period $-0.481 \pm 0.167$ and $-0.165 \pm 0.308$ and phenotypically $0.049 \pm 0.044$ and $0.086 \pm 0.051$ respectively. Khushwaha and Mira (1969) reported significant ($r_p = 0.70$) correlation between age at first calving with first lactation length and $r_p = 0.03$ (NS) with first lactation yield in Sahiwal cows. Kavikar et al. (1969) estimated significant correlation ($r_p = 0.20$) of lactation yield with age at first calving. Bhasin (1969) reported that age at first calving was not correlated with first lactation yield. The correlation between lactation yield and lactation length was 0.658.
Stepanov (1970) reported that the milk yield of cows with body weights of 450-500, 550-600, 650-700 and 700-750 kg averaged 2993, 3364, 3817 and 4099 kg respectively and fat percent 3.99, 4.08, 4.10 and 4.23 respectively. The milk protein content also increased as body weight increased.

Shukle and Prasad (1970) reported the phenotypic correlation between lactation length and lactation yield (0.58) in Gir cattle and intraherd regression of lactation yield on lactation length was 8.98 lbs.

Nagpal and Acharya (1970) calculated phenotypic and genetic correlation of age at first calving with first lactation milk yield ($r_p = -0.01+0.05$ and $r_g = 0.58+0.12$) in Sahiwal cows. Juma and Eliya (1970) observed significant correlation between age at first calving and 305 days lactation yield in locally born Friesian cows (Iraq) which varied from 0.649-0.702 to 0.823-0.877 for 32 to 120 days yield, respectively. A significant correlation ($r_p = 0.56$) between age at first calving and overall milk production was observed in 857 records of 245 Maryana cattle (Mishra and Khushwaha, 1970).

Bairamov (1970) reported that phenotypic correlations between milk production and live weight in 37 Russian Simental, 38 Latvian Brown and 23 Russian Simental x Latvian Brown cows were 0.88, 0.95 and 0.77 respectively. Milk production per 100 kg live weight increased up to 501-551 and 451-500 kg in the 3 types respectively and decreased at higher weight.

Patil and Prasad (1970) reported high significant phenotypic correlations 0.67, 0.56 and 0.56 between lactation length
and lactation yield for cows on 3 farms. Naidu and Desai (1970) reported significant phenotypic correlation 0.236 between weight at first calving and 300 days milk yield. Hall (1971) estimated 0.252, 0.343, 0.302 and 0.310 phenotypic correlation of FCM milk yield of first lactation with body weight at 2 year, at first calving, daily gain from 1 to 2 year and with 6 month to 2 year age respectively.

The records of first calving in the Latvian cows revealed that 11.9, 39.5, 17.4, 31.2 percent of females calved at <25, 25-29, 30-32 or >32 months of age respectively (Tsalitis, 1971). The average first lactation milk yield was 3030 kg. The yield of females calving <18 months, 19-21, 25-27, 34-36 or >36 months amounted to 84.0, 95.4, 99.9, 100.6 and 102.2 percent of the average yield. Body weight in the 5 age groups averaged 386, 413, 413, 433 and 446 kg respectively.

Reddy and Behnager (1971) reported genetic and phenotypic correlation between age at first calving and first lactation yield -0.765±0.15 and 0.028±0.43 respectively.

Balaine (1971) estimated that the phenotypic and genetic correlations of 1st lactation yield with age at 1st calving in Hereford cattle were -0.027±0.05 and -0.33±0.52 respectively from gross phenotypic correlation and from intra sire daughter-dam regression. He concluded that age at first calving could be used as selection criterion for milk production, since this trait was highly heritable and had high negative genetic association with first lactation yield. He ignored genetic correlation as it had low reliability and high sampling error.
Significant positive phenotypic and genotypic association between body weights at 6, 12, 18 and 24 months of age with 1st lactation yield was observed by Singh and Desai (1971) in Red Sindhi cattle. They suggested that selection for higher body weight could reliably be done at 6 months body weight.

Khanna et al. (1972) while studying the genetic architecture of 945 cows of Frisian x Sahiwal crosses, reported that phenotypically birth weight was negatively correlated with first lactation yield in 3/8 and 5/8 grade and values were -0.045, -0.025 whereas in other grade (1/8, 1/4, 1/2 and 3/4) it had positive but low value ranging from 0.064 to 0.178. The genetic correlations of birth weight with first lactation yield were 0.303, 0.543 and 0.102 for 1/8, 1/4 and 3/8 grades of Frisian inheritance, respectively.

Khanna and Bhat (1972) studied 388 Sahiwal cows record and reported phenotypic correlation of first lactation milk yield with birth weight, weight at 19 weeks and weight at first calving as -0.052, -0.035 and 0.146 and their respective genotypic correlations were -0.490, -0.365 and 0.077. They reported negative genetic correlation of birth weight with second and third lactation yield (-0.54 and -0.61).

Dutt and Tamer (1972) estimated heritability 0.08±0.10 and 0.27±0.18 for uncorrected and corrected data of Mariana cows based on paternal half-sib correlation. The genetic correlation of age at first calving with milk yield, lactation length and daily milk production were -0.94±0.32, -0.89±0.15 and -0.45±0.24 respectively.
Parija (1972) reported the genetic association of first lactation yield with weight at birth, 19 weeks, 52 weeks, 24 months, 30 months and 36 months as 0.007±0.482, 0.007±0.22, -0.296±0.201, -0.033±0.218, -0.222±0.211 and -0.332±0.205, and their respective phenotypic correlations were 0.147, 0.010, 0.091, 0.216, 0.023 and -0.138 in Gir cattle. The genetic and phenotypic correlation of birth weight with first lactation yield were 0.15±0.635 and 0.447 respectively in Friesian x Gir crossbred cattle.

Gangwar et al. (1973) estimated correlation of maturity age (age at calving) from 160 crossbred cows with first lactation yield -0.30, 0.35, -0.95, -0.95 and with first lactation period -0.98, -0.95, -0.015 and 0.034 for 1/8, 1/4, 3/4 and 5/8 Friesian x Red Sindhi crossbred cattle. Abraham (1973) reported that the phenotypic correlation of age at first calving with first lactation yield, first lactation length and first dry period for 1/2 Jersey + 1/2 Local (Kerala) were 0.221±0.103, 0.061±0.124 and -0.169±0.165 and genetic correlations were more than unity with all the above traits respectively. The phenotypic correlation and genetic correlation between first lactation yield and first lactation length were 0.713±0.037 and >1.0 for Jersey x Local halfbreds.

Murty (1974) estimated correlation of body weights at birth, 6, 12 and 18 months of age with first lactation milk yield in Friesian x Sahiwal crossbred grade wise and found that the values were low and non-significant except between 24 months body weight where values for phenotypic correlation were 0.196 for 3/8, 0.221 for 5/8 and 0.272 for 3/4 grades of Friesian inheritance. He revealed with his findings that the trend in
phenotypic and genetic correlation for body weight at birth, 12 and 24 months of age with first lactation yield indicated that there existed either a low positive or no genetic antagonism between body weight and milk yield.

Bhatnagar et al. (1975) reported correlation between age at first calving and 305 days first lactation production ($r_p = 0.64$) amongst $F_1$ Brown Swiss crossbreds. They observed that $F_1$ and 75% Brown Swiss crossbred cows calving at higher age for the first time produced more milk. Basu and Ghai (1975) estimated genetic and phenotypic correlation -0.145 and 0.085 respectively from 409 Frissian x Sahiwal crossbred cattle from Ambala Farm.

2.5. Selection Index

The application of the selection index to animal improvement was taken up by Hazel (1943). Index was developed from heritabilities, genetic and phenotypic correlations (or from variances, covariances and standard deviations of each trait) and relative economic values of traits. For the genetic improvement of Swine herd of the Iowa station, he used four variates, pigs' own 160 days weight ($x_1$), Pigs' own market score ($x_2$), productivity of dam ($x_3$) and the average weight and score of the litter of which each pig was a member ($x_4$). The selection index was constructed by incorporating weight at
180 days of age and market score. These traits were available before breeding age.

\[ I = 0.137W - 0.268S. \]

Further the index was developed by using the productivity of the dam as a measure of each pig's productivity in the index.

\[ I_2 = 0.136W - 0.232S + 0.164P. \]

The third index was designed to incorporate information about the average weight and score of the litter in which each pig was born. The amount of genetic progress expected where a given index was used in making selection was proportional to the correlation of index and aggregate genotype \( R_{IH} \). He compared the three constructed indexes. The second and third indexes were 8.8 and 11.3 percent more efficient than that of first. The maximum genetic progress might be achieved by using 3rd selection index though it need time and economy in maintaining records.

Hazel and Lush (1942), Young (1961), Syrstad (1968) and Simon (1969) compared the effectiveness of selection indexes with independent culling level and Tandem method and showed its superiority over latter two. The superiority of the index increased as the number of traits with equal relative values were increased.

The selection indexes for the genetic improvement in milk and fat yield were constructed by Legates and Lush (1954), Farthing and Legates (1957), Mason and Touchberry (1970), Syrstad (1968) and Tainberg (1968) for Jersey, Holstein, Norwegian, Red and White and Russian breeds of cattle respectively.
The greater emphasis was given to control the traits of age at first calving, lactation period, service period and dry period.

Osborne (1957), Jardine (1958), Young (1961) and Searle (1963) discussed the relative efficiencies for different combinations of weighting factors on individuals and its ancestors.

Searle (1965) studied the efficiency of the indirect selection in relation to direct selection of a trait. He reported that (a) the selection for the basic trait on the basis of an alternative trait was preferable if the coefficient of genetic correlation between the alternative trait and the basic trait was more than the coefficient of correlation between the phenotypic and the genotypic values of the basic traits. (b) The selection of a basic trait would be preferable only when the heritability value of the alternative trait exceeded the heritability value of the basic trait. (c) Combining an alternative trait or trait along with the basic trait in a selection index would always be better than using basic trait or the alternative trait alone.

Heidhaus and Henderson (1962) compared three selection methods incorporating several traits simultaneously. The methods were: (1) the basic index which weighted the phenotypic observations according to their relative economic values, (2) the heritabilities index, in which breeding value of each individual was estimated. By using heritability estimates and breeding value the individual was weighted according to their economic values, (3) the estimated index which was the classical selection index except that estimated parameters instead of true
population parameters were used. None of the described methods could achieve as much genetic progress as would be expected under optimal conditions. They suggested that the heritability index or the basic index could be used with certain limitation in small populations.

Lush (1961) elaborated certain aspects of selection index for increasing the rate of improvement and making selection more effective. He indicated that characters which might have negative genetic correlations between them, when included in the selection index improved the general efficiency of the index.

Ahmed (1961) developed three selection indexes of Hariana cattle of Indian Veterinary Research Institute, incorporating (1) Age at first calving, first calving interval, first lactation yield, body weight on first calving and butter fat percentage. (2) Involving four traits except butter fat percent, and (3) including three traits, age at first calving, first calving interval and first lactation yield. He reported the superiority of last index over the first two indexes.

Williams (1962) concluded from a theoretical problem that if the required variance and covariances were very poorly estimated it might be advisable to use a base index in which the weighting factors could simply be relative economic values.

Tallis (1962) discussed the idea of imposing certain restrictions on the general index procedures. But these views would be limited since the normal restrictions of optimum change or zero change could be introduced to the index as soon as the population approached the optimum level for a particular trait.
The restricted selection index was applied when it was desired to hold a character constant at a particular level and other traits were allowed to be varied. Similar work was also reported by Kempthorne and Marske (1959).

Henderson (1963) suggested to construct sub-indexes when variable economic weighting happened for various traits used for selection index. A series of such sub-indexes from the traits were obtained. A super index for each animal was then calculated by weighing each of his sub-indexes by the relative economic value of that trait.

\[ I = w_1 I_1 + w_2 I_2 + \ldots + w_n I_n \]

Where, \( I_n \) and \( w_n \) were sub-index and relative economic values.

Acharya (1966) constructed the selection index for the Marwana cattle of Government Livestock Farm, Hissar, involving age at first calving, first lactation milk yield and first calving interval. The efficiency of index was 0.86 \( R_{IM} \).

Wilton and VanVleck (1967) discussed the construction of a selection index for two traits when the economic value of one trait dependent on the level of the other traits.

Pease et al. (1967) investigated the inaccuracy in the economic weights for an index incorporating the aggregate genotype of seven traits. They found ±50% and ±100% errors in the economic value of any trait reduced the efficiency of the index by less than 2% and up to 4% respectively. If two of the traits were exceptional in that error of ±100% caused a
10% reduction in efficiency. They suggested that the efficiency of the index method did not suffer very much if economic weights were not accurate.

Roan (1968) suggested that if suitable data could be available and particularly where many traits were involved a better procedure was to compare the relative economic values as partial regression coefficients of the net value of the individual on the separate component traits.

Gurnani (1968) developed a number of restricted and unrestricted selection indexes in Tharparkar cattle and obtained optimum index value involving the traits, first lactation milk yield ($X_1$), age at first calving ($X_3$) and first calving interval ($X_4$). The index value was:

$$I = 0.78X_1 - 2.11X_3 + 0.66X_4$$

He concluded that restriction on first calving interval affected the genetic gain in the total genetic score more than did the restriction on age at first calving.

Singh et al. (1969) studied the genetics of the six economic traits and calculated the method of estimating their relative economic values. The traits on Marana cattle were birth weight ($X_1$), weight at first calving ($X_2$), age at first calving ($X_3$), milk yield in first lactation ($X_4$), first service period ($X_5$) and first dry period ($X_6$). He developed different selection indexes for the genetic improvement in Marana cattle. The selection index for six traits was:

$$I = (-30.185)X_1 + (-0.098)X_2 - 46.048X_3$$
$$+ 1.680X_4 - 7.370X_5 + 1.788X_6$$
The correlation between I and H was 0.909. On comparing the indexes they concluded that selection based on an index including only age at first calving and milk yield had greater genetic improvement simultaneously in age at first calving, in first lactation milk yield and first service period.

Chhina (1975) constructed twenty-eight selection indexes involving various traits in Gir cattle. He recommended the index for adoption which involved the traits, $X_1$ = age at first calving, $X_2$ = first lactation milk yield, and $X_4$ = first lactation length:

$$ I = -0.7073X_1 + 0.1988X_2 - 0.5093X_4 $$
with $R_{IH} = 0.4464$.

The expected genetic gain per generation from this index would be 81.94 kg higher milk yield of first lactation and about 1 month and 7 days reduction in age at first calving and first lactation length respectively.

Toomer (1969), Kaul (1973), Mangurkar (1973) and Gokhale (1974) developed selection indexes for buffaloes in India, incorporating age at first calving, first milk production and including a part of the lactation yield to bring improvement in the aggregate breeding value of animals.
CHAPTER III

MATERIAL AND METHODS
MATERIAL AND METHODS

3.1. Generation Information about data

   a. Source and type of data

      The breeding records incorporated in this present investigation comprised of 689 Sahiwal, 639 Brown Swiss x Sahiwal and 3892 Holstein-Friesian x Sahiwal crossbred females, extended over a period of 15 years from 1961-1975. These data were collected from National Dairy Research Institute, Karnal and six Military Dairy Farms of Northern India (Ambala, Bareilly, Birkhentuuri, Jullundur, Lucknow and Meerut). The record of Sahiwal and its exotic crossbred females available on the farms were obtained from pedigrees and history sheets and the components of first lactation yield were noted from milk record registers.

   b. Brief history of the herds

      Sahiwal and its Brown Swiss and Holstein-Friesian crossbred cattle included in this study were farm born. Brown Swiss x Sahiwal crossbreeding started at N.D.R.I. farm in 1963. The exotic blood of Ayrshire, Shorthorn, Jersey and Holstein-Friesian was introduced for upgrading the indigenous cattle.
(Red Sindhi, Sahiwal, Mariana and Tharparker) at Military Dairy Farms round about the beginning of the present century. Friesians were used extensively for crossbreeding at Military Farms due to its superiority in milk production and adaptability (Forman, 1927; McGuckin, 1937; Prasad, 1951).

c. Breeding Policy

The breeding policy at NDRI Farm continued to maintain purebred Zebu stock and crossbreeding them with exotic bulls to get 50 and 75 percent exotic blood and further to evolve a breed by inter se matings (well adapted and economic milk producers). At Military Dairy Farm the attempt was made to maintain exotic germ plasm close to half or 5/8 level, but a range of exotic inheritance (1/64 to 63/64) was produced with forward and backward crossings. The animals recorded at different farms are given in Table 16.

The sires of females with half or above exotic inheritance were Friesian or Brown Swiss, and with low exotic inheritance were Sahiwal purebreds (Scheme-I).

Scheme-I. Breeding Plan at Military Dairy Farms of North-Western India (Diagramatic)

![Diagram of Breeding Plan]
d. Climatic conditions

All the seven farms considered in this study are situated in North-Western India. The climatic conditions of all the farms are almost similar, therefore, these farms were grouped under one belt of dry Northern region of the country.

e. Managerial Practices

The standard feeding under loose housing system with uniform managerial practices are almost similar at these Military Farms, because they follow common instructions given by Central Directorate of Military Farms, New Delhi. Weaning was practiced at birth and cows were milked by hand. Most of the cows were milked twice a day but animals giving more than 12 kg were milked thrice a day. A few high yielding cows (18 kg) were milked four times a day. Animals that were born at one farm but were shifted to another farms during early growth and completed their production at other farm were considered to be part of such herds. Milk yield was recorded at each milking for each animal. The animals with breeding troubles, low production or female calves failed to meet the rearing standard (growth rate) were culled from time to time. Birth weight of the calf was recorded within eight hours of birth, weekly weights were recorded for each female calves up to one year and thereafter monthly weights were recorded up to first calving. The Friesian crosses were bred at the age of 21-24 months or at body weight of 340 kg. The corresponding figures for indigenous animals were 24-27 months or 320 kg body weight. Recently it was modified to 15 months age or 260 kg
Table 16. Animals recorded at different farms

<table>
<thead>
<tr>
<th>Farms</th>
<th>Exotic inheritance groups</th>
<th>Zebu</th>
<th>1/8</th>
<th>2/8</th>
<th>3/8</th>
<th>4/8</th>
<th>5/8</th>
<th>6/8</th>
<th>7/8</th>
<th>F₂ &amp; F₃</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) N.O.R.I.,Karnal</td>
<td>Sahiwal</td>
<td>Brown Swiss x Sahiwal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle Farm</td>
<td>477</td>
<td>-</td>
<td>12</td>
<td>16</td>
<td>238</td>
<td>-</td>
<td>90</td>
<td>-</td>
<td>283</td>
<td>1116</td>
<td></td>
</tr>
<tr>
<td>(B) Military Farms</td>
<td>Sahiwal</td>
<td>Friesian x Sahiwal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Ambala</td>
<td>-</td>
<td>87</td>
<td>162</td>
<td>15</td>
<td>69</td>
<td>370</td>
<td>81</td>
<td>56</td>
<td>-</td>
<td>840</td>
<td></td>
</tr>
<tr>
<td>(2) Bareilly</td>
<td>-</td>
<td>75</td>
<td>64</td>
<td>56</td>
<td>82</td>
<td>138</td>
<td>52</td>
<td>13</td>
<td>-</td>
<td>480</td>
<td></td>
</tr>
<tr>
<td>(3) Birdhantouri</td>
<td>-</td>
<td>5</td>
<td>39</td>
<td>39</td>
<td>35</td>
<td>142</td>
<td>86</td>
<td>78</td>
<td>-</td>
<td>424</td>
<td></td>
</tr>
<tr>
<td>(4) Jullundur</td>
<td>-</td>
<td>82</td>
<td>57</td>
<td>92</td>
<td>71</td>
<td>185</td>
<td>55</td>
<td>114</td>
<td>-</td>
<td>656</td>
<td></td>
</tr>
<tr>
<td>(5) Lucknow</td>
<td>-</td>
<td>14</td>
<td>22</td>
<td>30</td>
<td>146</td>
<td>68</td>
<td>139</td>
<td>36</td>
<td>-</td>
<td>455</td>
<td></td>
</tr>
<tr>
<td>(6) Meerut</td>
<td>212</td>
<td>45</td>
<td>53</td>
<td>132</td>
<td>183</td>
<td>203</td>
<td>216</td>
<td>115</td>
<td>-</td>
<td>1159</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>689</td>
<td>308</td>
<td>409</td>
<td>380</td>
<td>824</td>
<td>1106</td>
<td>719</td>
<td>412</td>
<td>283</td>
<td>5130</td>
<td></td>
</tr>
</tbody>
</table>
body weight (which over the earlier) for all breeds.

f. Feeding

The standard feeding schedule as prescribed by Directorate of Military Farms is based on body weight, genetic group and considering the maintenance, growth, production, pregnancy and climatic conditions. The young stock is housed and reared separately in following groups:

1. Birth to 6 months
2. Six months to one year
3. One year to two year
4. Two year to mating

g. Recording of observations

The available observations were recorded from history cum pedigree sheets and milk record registers of females for the following traits:

A. Body weights at different ages (kg)

1. Weight at birth
2. Weight at two months
3. Weight at four months
4. Weight at six months
5. Weight at nine months
6. Weight at twelve months
7. Weight at fifteen months
8. Weight at eighteen months
9. Weight at first fertile service
10. Weight at first calving
The growth rates at different intervals of age were worked out from the above information.

11. Growth rate from birth to 2 months of age
12. Growth rate from 2 to 4 months age
13. Growth rate from 4 to 6 months age
14. Growth rate from 6 to 9 months age
15. Growth rate from 9 to 12 months age
16. Growth rate from 12 to 15 months age
17. Growth rate from 15 to 18 months age

8. Production Traits

18. Age at first calving (months)
19. First lactation length (days)
20. First lactation yield (kg)
21. First, second and third 300 days or less, as standard yield (kg)
22. First dry period (days)
23. The components of first lactation yield as:

   (a) Initial yield (kg): Average daily yield from 2 days production after colostrum period.

   (b) Ascending yield: Average daily yield from 16th and 17th days production after calving.

   (c) Peak Yield: Average one day yield from maximum yield of two consecutive days.

   (d) Descending yield: The average daily yield from 120th and 121st days production after calving.

   (e) Milking daily average yield: Complete lactation production divided by days in milk.
3.2. Classification of Data

The data of Sahiwal, BS x 5W and Friesian x Sahiwal were classified according to the farm, genetic groups, parity, season and periods for all the traits.

a. Farms

Although standard managerial practices were followed at all the farms but variation from farm to farm existed due to availability of green fodder, housing, land, irrigation, climate, genetic composition of the herd and other uncontrollable conditions.

b. Genetic Groups

The Friesian x Sahiwal crosses were grouped in seven classes with an interval of 12.5% level of exotic inheritance (1/8, 2/8, 3/8, 4/8, 5/8, 6/8 and 7/8). Exotic inheritance less than 12.5% fraction was clubbed with nearest level of blood group. Sahiwal animals were considered as one genetic group. Brown Swiss x Sahiwal females were grouped in five classes (6/8, 4/8, 3/8, 2/8 and $F_2-F_3$).

c. Parity of Birth

Parity of birth could have significant effect on birth weight and weight at subsequent months. The data classified in four parity groups: (1) First (2) Second (3) Third, and fourth (4) Fifth and above sequence of calving.
d. Season of birth/calving

The year was divided into four seasons based on climate: (i) November - January (Winter) (ii) February - April (Spring) (iii) May - July (Summer) (iv) August - October (Monsoon).

e. Period of birth/calving

The data collected for 15 years in case of Sahiwal and Friesian x Sahiwal crosses and 12 years in case of Brown Swiss x Sahiwal crosses were divided into 5 and 4 periods of 3 years each.

<table>
<thead>
<tr>
<th>Years</th>
<th>Sahiwal, HF x Sw - Sw x HF</th>
<th>BS x Sw</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961-1963</td>
<td>Period I</td>
<td>-</td>
</tr>
<tr>
<td>1964-1966</td>
<td>Period II</td>
<td>Period I</td>
</tr>
<tr>
<td>1967-1969</td>
<td>Period III</td>
<td>Period II</td>
</tr>
<tr>
<td>1970-1972</td>
<td>Period IV</td>
<td>Period III</td>
</tr>
<tr>
<td>1973-1975</td>
<td>Period V</td>
<td>Period IV</td>
</tr>
</tbody>
</table>

3.3. Statistical Methods

The analysis was done on IBM 1620 (Institute of Agricultural Research Statistics, New Delhi) and 360 (Delhi University Computer Centre), Electronic Computers. In order to study the genetic architecture of growth and production traits, the non-genetic factors affecting the traits were neutralized. As the breeding data was non-orthogonal with disproportionate
sub-class numbers the least square technique was used to overcome these difficulties (Harvey, 1966). Statistical methods were employed according to the type of data for calculating required estimates. The processing of the data was done accordingly.

1. Purebred Sahiwal
2. Brown Swiss x Sahiwal crosses
3. Holstein-Friesian x Sahiwal crosses
   (a) Friesian x Sahiwal crosses (4/8 to 7/8) sired by Friesian bulls.
   (b) Sahiwal x Friesian crosses (1/8 to 3/8) sired by Sahiwal bulls.

#### 3.3.1. Mathematical Estimates

**a. The average daily gain (g/day)**

The absolute gain in weight per unit time was worked out from different intervals of time as:

\[
\text{Average daily gain} = \frac{W_2 - W_1}{T_2 - T_1}
\]

Where, \( W_1 \) and \( W_2 \) are initial and final weights at \( T_1 \) and \( T_2 \), initial and final age of animals.

**b. Least square mean**

The Model-I of Eisenhart was used for least square analysis (Harvey, 1966). Five way and four way classification with fixed effect without interaction was used for body weights,
growth rates, milk components of first lactation yield and first, second and third lactation yields.

\[ Y_{ijklmn} = u + a_i + b_j + c_k + d_l + f_m + \varepsilon_{ijklmn} \]

Where,

\[ Y_{ijklmn} = \text{The observations on nth animal of m season,} \]

1 period, k parity, j genetic group and i farm.

\[ u = \text{overall mean when equal sub-class number exist.} \]

\[ a_i = \text{effect of the ith farm (1-6)} \]

\[ b_j = \text{effect of the jth genetic group (1-7)} \]

\[ c_k = \text{effect of the kth parity of birth (1-4)} \]

\[ d_l = \text{effect of the lth period of birth (1-5)} \]

\[ f_m = \text{effect of the mth season (1-4)} \]

\[ \varepsilon_{ijklmn} = \text{random error} \]

To study the least square means of first lactation components, first lactation yield and first, second and third lactation yield the parity of birth was eliminated. The restriction was imposed that \( \sum a_i = \sum b_j = 0 \). The coefficients of one effect was subtracted from other coefficients of within the effect by columns and rows. Thus reduced least square equations were produced. Then from the inverse matrix of the reduced equation, the constant estimates were obtained. In the Model the \( a_i \) are expressed as deviations from \( u \). Therefore, it is logical to assume that \( \sum a_i = 0 \) and obtained the constant estimates as deviation from \( u \). Reduced least square equation was obtained after subtracting one coefficient of the effect from
column and rows within the effect and symmetrical set of
equations were solved for the inversion of the variance -
covariance matrix and constants were worked out from the inverse
elements and RHA's of the equations.

Standard error

The standard error of \( u \) was worked out from the
inverse matrix

\[
SE\ u = \sqrt{(C_{ii}) e^2}
\]

Where,

\( u \) = population mean when equal frequencies exist
among the classes.

\( C_{ii} \) = corresponding diagonal inverse element for
that constant

\( e^2 \) = error mean square

c. Estimation of variance components

The sum of squares for each effect was obtained in
the general way as shown below:

\[
S_e, S_q, = B' Z^{-1} B,
\]

Where \( B' \) is a row vector of constant estimates for a given
set (such as \( s_i \)); \( Z^{-1} \) is the inverse of the segment of the
inverse of the variance - covariance matrix, corresponding,
by row and column, to this set of constants; and \( B \) is a column
vector of the set of constants.

The analysis of variance model in general was
followed for various traits under study (Harvey, 1966).
d. Test of all comparisons among means

In a group of more than two means F test will not
give any clue as to how many differences were significant at
known probability, therefore to overcome this difficulty, Tukey's
test (1953) was applied to test the difference among all means.

\[ D = q \overline{sx} \]

\[ \overline{sx} = \sqrt{\frac{\text{Error mean square}}{n_2}} \]

\( q = \) Table value at \( n_1 \) and \( n_2 \) degree of freedom,
\( n_1 = \) number of subclass means used.
\( n_2 = \) error degree of freedom.

The differences between two means are greater or equal to
\( D \) value, indicate the significance at 5 or 1\% level of probability.

e. Correction of the data for genetic study

Various non-genetic factors (farm, parity, season
and period) and genetic groups affecting the traits were worked
out by analysis of variance. The constants of all levels of all
the factors affecting the traits were obtained and individual
observations were corrected for the significant effect of non-
genetic factors. The adjusted body weight, growth rate and
production traits were obtained as given below:

\[ Y_{ijkmn} = Y_{ijkmn} - (a_i + b_j + c_k + d_l + f_m) \]
Where,

\[ Y_{ijklmn} = \text{The actual body weight record of the animal at given age.} \]

\[ a_i = \text{farm constant} \]

\[ b_j = \text{genetic group constant} \]

\[ c_k = \text{parity of birth constant} \]

\[ d_l = \text{period of birth constant} \]

\[ f_m = \text{constant for season of birth} \]

--- Regression Analysis ---

The adjusted data was used for the regression analysis. Various regression models were used to estimate the first total lactation production from growth rate and body weights (premanifested traits), lactation length and first lactation components.

(a) Linear regression model with one trait

\[ Y = a + bx + e \]

(b) Multiple linear regression model, taking two or more than two traits:

\[ Y = a + b_1x_1 + b_2x_2 + \ldots + b_nx_n + e \]

(c) Quadratic or curvilinear regression model with one, two or more than two traits:

\[ Y = a + b_1x_1 + b_1x_1^2 + b_2x_2 + b_2x_2^2 + \ldots + b_nx_n + b_nx_n^2 \]

Where,

\[ a = \text{intercept value} \]

\[ y = \text{dependent traits} \]
\[ b_1 - b_n = \text{coefficient of linear regression} \]

\[ x_1 \text{ to } x_n = \text{independent traits} \]

\[ e = \text{residual error} \]

(c) \( F \) test

The significant test for the regression was estimated as:

\[ F = \frac{\text{Regression mean square}}{\text{Residual mean square}} \text{ at } n_1 \text{ (degree of freedom of regression)} \text{ and } n_2 \text{ (degree of freedom of error) degrees of freedom.} \]

(a) The coefficient of determination \((R^2)\) value was calculated:

\[ R^2 = \frac{\text{Sum of square due to regression}}{\text{Total sum of square}} \]

g. Age (mths) and first lactation production (kg) relationship

To study the effect of age at first calving, on first lactation yield and first lactation length, the 4 sets (1. Sahiwal, 2. BS x Sw, 3. HF x Sw sired by Frisian sires, and 4. Sw x HF sired by Sahiwal sires) of corrected data were classified into eight classes with three months interval of age at first calving. The classes were 1. \( \leq 27.0 \) 2. 27-30.0 3. 30-33.0 4. 33-36.0 5. 36-39.0 6. 39-42.0 7. 42-45.0 and 8. \( \geq 45\) months of age.
h. Body weight (at first calving) and first lactation yield relationship

The body weights at first calving were grouped into seven classes with 40 kg class difference. 1. ≤ 250 2. 251-290 3. 291-330 4. 331-370 5. 371-410 6. 411-450 and 7. ≥ 451 kg body weight to find the effect of body weight (at first calving) on first lactation yield. The four sets of corrected data were used for the study.

't' test

To test the significance differences between means from non paired data, 't' test was used:

\[ t = \frac{\bar{X} - \bar{Y}}{SE(\bar{X} - \bar{Y})} \text{ with } (N_1 + N_2 - 2) \text{ degree of freedom} \]

3.3.2. Genetic Estimates

Genetic study was made on all the corrected records of body weights, growth rates and production performance traits.

Sires with five or more than five daughters were included in this study. Heritability, genetic and phenotypic correlations were worked out by paternal half-sib unbalanced design (Becker, 1975).

a. Heritability \((h^2)\) estimates

The model used is given below:

\[ Y_{ik} = u + s_i + e_{ik} \]

Where, \( Y_{ik} \) = \( k^{th} \) animal records of \( i^{th} \) sire
\[ u = \text{common mean to all animals} \]
\[ S_i = \text{effect of } i^{th} \text{ sire common to all its daughters} \]
\[ e_{ik} = \text{uncontrolled environmental and genetic deviations attributable to individuals within sire groups.} \]

**Analysis of variance**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>d.f.</th>
<th>SS</th>
<th>MS</th>
<th>( \text{EMS} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between sires</td>
<td>( S - 1 )</td>
<td>( S )</td>
<td>( S )</td>
<td>( S )</td>
</tr>
<tr>
<td>Progeny within sires</td>
<td>( S(n-1) )</td>
<td>( S )</td>
<td>( S )</td>
<td>( S )</td>
</tr>
</tbody>
</table>

Where,

\[ S = \text{number of sires} \]
\[ n = \text{number of individuals within the } i^{th} \text{ sire.} \]
\[ k = \text{weighted average, number of progeny under each sire} \]
\[ V_S = \text{the variance due to sire which contains } 1/4, \text{ the genetic variance plus a small fraction of epistatic variance} \]
\[ V_W = \text{variance attributed within sires, which includes all the environmental variance plus } 3/4 \text{ the genetic variance, all of dominance and a major part of epistatic variance} \]

\[ V_S = \frac{MS - MS}{k} \]

\[ h^2 = \frac{V_S}{V_W + V_S} \times 4 \]
\[ \bar{K} = \frac{1}{s-1} \left( n_s - \frac{n_i^2}{n_s} \right) \]

Where,

\( s = \text{number of sires} \)
\( n_s = \text{Total number of individuals under all sires} \)
\( n_i^2 = \text{Sum of squares of the progeny per sire.} \)

**Standard error of \( h^2 \)**

The standard error of \( h^2 \) for unequal number of progeny per sire was estimated by **Swiger et al. (1964)** method:

\[ SE \; h^2 = \frac{4}{\sqrt{V(t)}} \]

Where,

\[ V(t) = 4 \sqrt{\frac{2(n-1)(1-t)^2 \left[ 1 + (\bar{K}-1) t \right]^2}{\bar{K}^2 (n-s)(s-1)}} \]

Where,

\( t = \text{intra class correlation} \)
\[ t = \frac{VS}{VS + VH} \]
\( n = \text{Total number of progeny} \)
\( \bar{K} = \text{weighted number of daughters' under each sire} \)

**Estimation of correlations**

The components of covariance between two traits were calculated by **Becker (1975)** method for the estimation of genetic and phenotypic correlations.
Analysis of Covariance

---

Source of variation | d.f. | Mean cross product (MCP) | Expected mean cross product (EMCP)
--- | --- | --- | ---
Between sires | $s-1$ | MCP$_s$ | COV$_w$ + \( \overline{K} \) COV$_w$
Progeny within sires | $n_1-1$ | MCP$_w$ | COV$_w$
---

\( \overline{K} \) was estimated as in heritability estimate for unequal number of progeny per sire in the analysis of variance.

The components of variance were derived as before in $h^2$ estimate.

Estimating covariance components

\[
\text{COV}_w = \text{MCP}_w
\]

\[
\text{COV}_s = \frac{\text{MCP}_s + \text{MCP}_w}{\overline{K}}
\]

b. Genetic correlation ($r_G$)

\[
\text{COV}_s(x,y)
\]

\[
r_G = \frac{\text{COV}_s(x,y)}{\sqrt{VS(x) \cdot VS(y)}}
\]

Where, $x$ and $y$ represents two characters in the same individual.

\[
\text{COV}_s(x,y) = \text{Covariance between two traits } x \text{ and } y \text{ due to sires.}
\]

\[
VS(x) = \text{Variance of } x \text{ trait due to sires}
\]

\[
VS(y) = \text{Variance of } y \text{ trait due to sires}
\]

In an analysis of half-sib families the component of covariance between sire estimate 1/4 additive genetic covariance, 1/16 Cov AA and 1/64 Cov AAA (Becker, 1975).
Standard error (SE) of genetic correlation ($r_G$)

Standard error of the genetic correlation was estimated by Reeve (1955) and Robertson (1959) method:

$$\text{SE. } r_G = \sqrt{\frac{1 - r_G^2}{2}} \div \sqrt{\frac{\text{SE.}(h_1^2) \cdot \text{SE.}(h_2^2)}{h_1 \cdot h_2}}$$

Where, $h_1^2$ and $h_2^2$ were the heritabilities of x and y traits used for $r_G$.

c. Phenotypic correlation ($r_p$)

Phenotypic correlation coefficient was estimated as outlined by Searle (1961) and Becker (1975):

$$r_p = \frac{\text{COV}_S(xy) + \text{COV}_W(xy)}{\sqrt{\text{VS}(x) + \text{WV}(x) \cdot \text{VS}(y) + \text{WV}(y)}}$$

Where,

$\text{COV}_W(xy) = $ Covariance between x and y traits within sires.

$\text{COV}_S(xy) = $ The additive genetic covariance for x and y traits between sires.

$\text{VS}(x) = $ Sire component of variance for x trait

$\text{VS}(y) = $ Sire component of variance for y trait

$\text{WV}(x) = $ Environmental component of variance for x trait

$\text{WV}(y) = $ Environmental component of variance for y trait.
Standard error (SE) of phenotypic correlation

Standard error of phenotypic correlation was estimated as given by Penaec and Sukatma (1967):

\[
SE r_p = \frac{1 - r_p^2(xy)}{n-2}
\]

Where,

\( r_p(xy) \) = phenotypic correlation coefficient between x and y character in the same individual.

\( n-2 \) = degree of freedom

3.3.3. Construction of Selection Index

From the adjusted data the following estimates were derived to construct selection indexes by Hazel (1943) method and assumptions.

Genetic estimates

The following genetic estimates were calculated by paternal half-sib correlation method:

(a) Heritability of each trait.

(b) Genetic correlation between traits.

Phenotypic estimates

(a) Phenotypic correlations.

(b) Phenotypic standard deviation of traits.

Relative economic value for each trait

In the present study the economic value reported by Kuber Ram and Kulwant Singh (1975) were used to work out
relative economic value for each trait.

The cost of body weight at six, 12 months and weight at first calving will be same as for age at respective intervals. The economic values of the traits for Friesian crossbreds were considered equal to Brown Swiss crossbred animals. The sale price of milk @ Rs. 1.40 per kg with 3.5% fat was taken. It was corrected on the basis of fat content produced by the cows (Chauka and Miahra, 1976).

Relative economic values of some traits of Sw, BS x Sw, HF x Sw and Sw x HF cattle are given below:

<table>
<thead>
<tr>
<th>Traits</th>
<th>Sw</th>
<th>BS x Sw</th>
<th>HF x Sw</th>
<th>Sw x HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight at 6 month</td>
<td>0.459</td>
<td>0.360</td>
<td>0.416</td>
<td>0.436</td>
</tr>
<tr>
<td>age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body weight at 12 month</td>
<td>0.464</td>
<td>0.352</td>
<td>0.398</td>
<td>0.412</td>
</tr>
<tr>
<td>age at first calving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(months)</td>
<td>0.654</td>
<td>0.399</td>
<td>0.480</td>
<td>0.560</td>
</tr>
<tr>
<td>Age at 1st calving</td>
<td>5.606</td>
<td>4.332</td>
<td>4.628</td>
<td>5.128</td>
</tr>
<tr>
<td>Average peak yield (kg)</td>
<td>1.429</td>
<td>1.491</td>
<td>1.437</td>
<td>1.420</td>
</tr>
<tr>
<td>First milking average (kg)</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>
Index equations (Hazel, 1943)

1. \[ b_1 x_1 x_1 + b_2 x_1 x_2 + \ldots + b_n x_n x_n = r_{x_1 H} = \gamma_{G} x_1 (d_{1} \gamma_{G} G_1 + d_{2} \gamma_{G} G_2 + \ldots + d_{n} \gamma_{G} G_n) \]

2. \[ b_1 x_2 x_1 + b_2 x_2 x_2 + \ldots + b_n x_n x_n = r_{x_2 H} = \gamma_{G} x_2 (d_{1} \gamma_{G} G_1 + d_{2} \gamma_{G} G_2 + \ldots + d_{n} \gamma_{G} G_n) \]

\[ \vdots \]

n. \[ b_1 x_n x_1 + b_2 x_n x_2 + \ldots + b_n x_n x_n = r_{x_n H} = \gamma_{G} x_n (d_{1} \gamma_{G} G_1 + d_{2} \gamma_{G} G_2 + \ldots + d_{n} \gamma_{G} G_n) \]

Where,

- \( b_n \) are the regression coefficients calculated to maximize the correlation between
- \( r_{x_n x_n} \) = Phenotypic correlation between two traits.
- \( \gamma_{G} G_n \) = Genotypic correlation between two traits.
- \( \sigma_{G_n} \) = Genetic standard deviation \((\sigma_{G}) = \sqrt{h^2 \times \sigma^{2}_{G}} \) of each trait.

The efficiency of selection index was measured in terms of \( r_{x_n H} \) (Hazel, 1943)
CHAPTER IV

RESULTS
RESULTS

4.1. Body Weights

Body weights at birth and at different intervals of chronological ages were analyzed (T₁, T₂, T₃, Fig. 1 and Appendix T₁, T₂, T₃).

4.1.1. Birth weight:—The least square means of body weight at birth for Sw, BS x Sw and HF x Sw = Sw x HF female calves were 21.03±0.13, 25.51±0.22 and 23.45±0.07 kg respectively. The mean birth weight of Sahiwal female calves was significantly (P<0.01) lower than its BS and HF crosses. There was significant difference between the mean birth weight of BS x Sw and HF x Sw female calves.

Among genetic grades of BS inheritance, the highest mean birth weight was of 6/8 group (27.30 kg) followed by 3/8 (26.44 kg) and the lowest mean birth weight was of 2/8 (22.86 kg) which was significantly lower than 6/8, 3/8 and F₂-F₃. Difference among genetic groups was statistically significant.
Among genetic grades of HF inheritance, the highest average weight at birth was found for 5/8 (23.74 kg) and lowest for 2/8 (23.07 kg), significant differences of mean birth weight of 1/8 and 2/8 from 5/8 and 7/8 genetic groups were observed (Tukey's test).

4.1.2. Weight at 2 months age

The least square means were found to be 43.67±0.34, 46.84±1.03 and 53.99±0.20 kg for Sw, B5 x Sw and HF x Sw - Sw x HF respectively. These means were significantly (P< 0.01) different from each other.

The highest least square mean was found for 6/8 of B5 x Sw (49.66 kg) and lowest for 3/8 (43.83 kg). These values differed significantly (P<0.05). There was no significant difference among other genetic groups of B5 x Sw crossbreeds (Tukey's test).

The highest and lowest average body weights at 2 months age were observed for 7/8 (55.77 kg) and for 1/8(51.19 kg) grades of HF x Sw, respectively. Tukey's test indicated that 1/8 genetic group had significantly lower body weight from 7/8, 6/8, 5/8, 4/8 and 3/8 grades while 2/8 and 3/8 genetic groups from 7/8, 6/8, 5/8 and 4/8 grades respectively. Among other genetic groups no significant difference was observed.

4.1.3. Body weight at 4 months age - The average weight at four months age by least square technique was found to be 70.24±0.61, 74.80±1.79 and 86.36±0.47 kg for Sw, B5 x Sw and
HF x Sw - Sw x HF breed groups respectively. These means differed
significantly \((P\leq 0.01)\) from each other.

Among genetic groups of BS inheritance 6/8 and 4/8 were
positively and 3/8, 2/8 and \(F_2\text{-}F_3\) were negatively deviated from
their common least square mean. Body weight of 3/8 was significantly
lower from other means at four months age. In other genetic groups
difference was nonsignificant. The highest and lowest mean values
were 78.18 and 69.31 kg for 4/8 and 3/8 genetic groups respectively.

Among genetic groups of HF inheritance, 7/8, 6/8, 5/8
and 4/8 were positively and 3/8, 2/8 and 1/8 were negatively
deviated from their common least square mean. Tukey's test revealed
that means of lower grades (3/8, 2/8 and 1/8) were significantly
lower from higher grades. The highest and lowest mean values were
90.84 kg and 81.28 kg for 6/8 and 1/8 genetic groups respectively.

4.1.4. Body weight at 6 months age: The least square means
for Sw, BS x Sw and HF x Sw - Sw x HF were observed as 97.20±0.75,
107.62±2.43 and 119.28±0.42 kg respectively. These values were
highly significant \((P\leq 0.01)\) from one another.

The genetic groups 6/8 and 4/8 of BS inheritance were
positively and 3/8, 2/8 and \(F_2\text{-}F_3\) were negatively deviated from
their common least square mean. The highest and lowest mean
values were 112.96 and 103.04 kg for 4/8 and 3/8 genetic groups
respectively. The mean of 3/8 was significantly lower than 4/8
grade but these were nonsignificant from others.

The higher grades of HF inheritance were positively
and lower grades were negatively deviated from their common mean.
The highest and lowest least square means were 123.95 and 112.19 kg of 6/8 and 1/8 grades respectively. The grade of 1/8 HF had significantly (P < 0.05) lower body weight at six month age from other genetic groups except 2/8. The mean body weights of 3/8 and 2/8 grades were significantly lower than 7/8, 6/8, 5/8 and 4/8 grades (Tukey's test).

4.1.5. Body weight at 9 months age: The least square means of three breed groups studied were 128.52±1.49, 136.28±2.49 and 158.71±0.64 kg for Sw, 85xSw and HFxSw-SwHF respectively. These means were highly significant (P < 0.01).

The mean effect of 6/8 and 4/8 grades of 85 inheritance were positively and 3/8, 2/8 and F2-F3 were negatively deviated from their overall mean. The highest weighted average was 143.65 kg of 4/8 and lowest was 129.81 kg of 2/8 genetic group. The mean difference test did not reveal differences among the averages of these genetic grades.

The highest and lowest least square means were 163.66 and 149.86 kg of 5/8 and 1/8 grades of HF inheritance respectively. The average body weight of 1/8 grade was significantly lower than all other grades except 2/8, while 3/8 had lower weight than 6/8, 5/8 and 4/8 grades (Tukey's test).

4.1.6. Body weight at 12 months age: Weighted means for Sw, 85xSw and HFxSw-SwHF were 159.54±1.78, 171.16±2.96 and 193.36±0.61 kg respectively and these means differed significantly (P < 0.01).

The genetic groups of 6/8, 4/8 and 3/8 with 85 inheritance were positively and 2/8, F2-F3 were negatively deviated from their least square mean. The highest least square mean was
175.37 kg of 4/8 and lowest 163.92 kg of \( F_2-F_3 \) genetic groups. There was no significant \( (P \leq 0.05) \) difference among means of all genetic groups.

The genetic groups of 6/8, 5/8, 4/8 and 3/8 with HF inheritance were positively and 7/8, 2/8 and 1/8 were negatively deviated from their population mean. Half-bred found to be highest (200.59 kg) and 1/8 lowest (183.67 kg) in average body weight. Test of comparison revealed that 1/8 and 2/8 had significantly lower average weight than higher grades of HF; 7/8 had significantly lower than 5/8 and 4/8; 3/8 and 6/8 had lower than halfbred females at 12 months body weight.

4.1.7. Body weight at 15 months age—The least square means were found to be 189.97±2.23, 204.49±3.39 and 224.95±0.78 kg for \( S_w \), \( B_5 \times S_w \) and \( H F \times S_w \) crossbred females respectively. The difference among three breed groups was found to be highly significant \( (P \leq 0.01) \).

The highest and lowest means were found to be 213.43 and 191.18 kg of 6/8 and 2/8 genetic groups respectively. Non-significant difference among means of various \( B_5 \times S_w \) grades was observed.

The genetic groups of 6/8, 5/8, 4/8 and 3/8 grades of HF were positively and 7/8, 2/8 and 1/8 were negatively deviated from their overall least square mean. The halfbreds were ranked superior and 1/8 inferior in weight at 15 months age. The least square means of 1/8 was significantly lower than all grades, 2/8 was lower than 5/8, 4/8 and 3/8; 7/8 was lower than 5/8 and 4/8, and 3/8 was lower from halfbreds (Tukey's test).
Table 17. Least square means (u) with standard errors and constants for genetic groups of B5 x S4 crosses bred.

<table>
<thead>
<tr>
<th>Traits</th>
<th>Constants for genetic groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6/0</td>
</tr>
<tr>
<td></td>
<td>a</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td></td>
</tr>
<tr>
<td>Wt. at birth</td>
<td>25.51±0.22(639)</td>
</tr>
<tr>
<td>Wt. at 2 months</td>
<td>46.84±1.03(592)</td>
</tr>
<tr>
<td>Wt. at 4 months</td>
<td>74.80±1.79(579)</td>
</tr>
<tr>
<td>Wt. at 6 months</td>
<td>107.82±2.43(544)</td>
</tr>
<tr>
<td>Wt. at 9 months</td>
<td>136.28±2.49(422)</td>
</tr>
<tr>
<td>Wt. at 12 months</td>
<td>171.16±2.96(395)</td>
</tr>
<tr>
<td>Wt. at 15 months</td>
<td>204.49±3.39(359)</td>
</tr>
<tr>
<td>Wt. at 18 months</td>
<td>231.65±3.26(325)</td>
</tr>
<tr>
<td>Wt. at 1st fertile service</td>
<td>274.76±9.13(248)</td>
</tr>
<tr>
<td>Wt. at 1st calving</td>
<td>347.48±6.88(229)</td>
</tr>
<tr>
<td>Growth rate g/day</td>
<td></td>
</tr>
<tr>
<td>Birth to 2 months</td>
<td>375.8±14.9(592)</td>
</tr>
<tr>
<td>2 to 4 months</td>
<td>455.7±18.8(577)</td>
</tr>
<tr>
<td>4 to 6 months</td>
<td>531.0±20.7(541)</td>
</tr>
<tr>
<td>6 to 9 months</td>
<td>335.0±14.7(422)</td>
</tr>
</tbody>
</table>

...cont'd.
<table>
<thead>
<tr>
<th>Traits</th>
<th>u</th>
<th>Constants for genetic groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6/8</td>
</tr>
<tr>
<td>9 to 12 months</td>
<td>362.8±17.5 (395)</td>
<td>abc⁺</td>
</tr>
<tr>
<td>12 to 15 months</td>
<td>367.9±21.0 (360)</td>
<td>abc⁺</td>
</tr>
<tr>
<td>15 to 18 months</td>
<td>314.6±22.5 (321)</td>
<td>ab⁻</td>
</tr>
<tr>
<td>Production Traits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age at 1st calving (mths)</td>
<td>30.4±0.97 (287)</td>
<td>a⁻</td>
</tr>
<tr>
<td>First lact. yield (kg)</td>
<td>328.95±133.20 (211)</td>
<td>207.23 (110)</td>
</tr>
<tr>
<td>Initial yield (kg)</td>
<td>10.4±0.46 (276)</td>
<td>a⁻</td>
</tr>
<tr>
<td>Ascending yield (kg)</td>
<td>12.1±0.46 (275)</td>
<td>a⁻</td>
</tr>
<tr>
<td>Peak yield (kg)</td>
<td>14.5±0.45 (269)</td>
<td>a⁻</td>
</tr>
<tr>
<td>Descending yield (kg)</td>
<td>10.4±0.39 (225)</td>
<td>a⁻</td>
</tr>
<tr>
<td>Milking Average (kg)</td>
<td>9.98±0.28 (211)</td>
<td>a⁻</td>
</tr>
<tr>
<td>1st Lact. length (days)</td>
<td>336.4±10.10 (211)</td>
<td>a⁻</td>
</tr>
<tr>
<td>1st dry period (days)</td>
<td>74.4±6.00 (180)</td>
<td>a⁻</td>
</tr>
<tr>
<td>First 170-305 days</td>
<td>290.27±3.86 (211)</td>
<td>a⁻</td>
</tr>
<tr>
<td>lact. length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First 170-305 days</td>
<td>2888.89±92.43 (211)</td>
<td>a⁻</td>
</tr>
<tr>
<td>lact. yield (kg)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figures in parentheses indicate number of observations.
The constants superscripted by an alphabet with asterisk(*) are significantly (P<.05)
higher than those constants which are superscripted by the same alphabet.
Table 18. Least square means (μ) with standard errors and constants for genetic groups of HF x Sw crossbreds

<table>
<thead>
<tr>
<th>Traits</th>
<th>7/8</th>
<th>6/8</th>
<th>5/8</th>
<th>4/8</th>
<th>3/8</th>
<th>2/8</th>
<th>1/8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weights (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wt. at birth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23.45±0.07(3802)</td>
<td>b*</td>
<td>a*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wt. at 2 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53.99±0.20(3736)</td>
<td>b*</td>
<td>a*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wt. at 4 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>86.36±0.47(3718)</td>
<td>b*</td>
<td>a*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wt. at 6 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>119.28±0.42(3698)</td>
<td>b*</td>
<td>a*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wt. at 9 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>158.71±0.64(3622)</td>
<td>b*</td>
<td>a*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wt. at 12 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>350.67±4.99(1387)</td>
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Growth rate g/day

| Birth to 2 months       | a*b      | b*     | abd*    | ac*     | abcde*   | abcd*   | abcdef* |
| 505.2±3.1(3728)         |          |        |         |         |          |         |          |
| 2 to 4 months           | a*b      | b*     | abd*    | ac*     | abcde*   | abcd*   | abcdef* |
| 633.8±3.6(3714)         |          |        |         |         |          |         |          |
| 4 to 6 months           | a*b      | b*     | abd*    | ac*     | abcde*   | abcd*   | abcdef* |
| 541.6±3.9(3692)         |          |        |         |         |          |         |          |
| 6 to 9 months           | a*b      | b*     | abd*    | ac*     | abcde*   | abcd*   | abcdef* |
| 437.0±3.6(3615)         |          |        |         |         |          |         |          |

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<td>15 to 18 months</td>
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<td>4.2(934)</td>
<td>8.4(319)</td>
<td>6.0(279)</td>
<td>-0.3(333)</td>
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**Production traits**

| Age at first calving (mths) | 36.36±0.25(2693) | 0.04(242) | -0.23(353) | -0.89(803) | -0.98(454) | 0.51(216) | 0.33(327) | 1.22(298) |
| First lact. milk yield (kg) | 184.24(151) | 305.48(250) | 240.03(618) | 304.10(341) | -267.87(159) | -423.69(276) | -342.30(267) |
| Initial yield (kg)          | 8.49±0.17(2655) | 0.74(242) | 0.74(351) | 0.86(375) | 0.65(453) | -0.56(211) | -1.01(321) | -1.37(282) |
| Ascending yield (kg)        | 9.97±0.12(2648) | 1.02(241) | 1.18(350) | 0.95(375) | 0.71(449) | -0.99(210) | -1.30(321) | -1.87(282) |
| Peak yield (kg)             | 11.55±0.16(2640) | 0.75(239) | 1.03(347) | 1.11(791) | 0.85(441) | -0.95(206) | -1.34(232) | -1.83(294) |
| Descending yield (kg)       | 8.68±0.13(2577) | 0.54(231) | 0.70(333) | 0.94(791) | 1.02(436) | -0.90(201) | -1.18(319) | -1.99(277) |
| Milking Ave. (kg)           | 8.35±0.11(2062) | 0.43(150) | 0.62(249) | 0.76(621) | 0.90(341) | -0.60(157) | -1.01(277) | -1.09(267) |
| 1st lact. length (days)     | 309.52±2.94(2069) | 3.63(181) | 14.06(250) | 2.56(621) | 1.82(341) | -6.77(58) | -12.56(278) | -2.75(270) |
| First dry period (days)     | 124.78±3.75(1763) | 5.60(119) | 0.12(193) | -4.85(538) | -8.63(312) | 4.11(132) | -1.89(226) | 5.54(243) |
| First 170-305 days lact. length | 284.14±1.16(2042) | 1.99(155) | 4.36(252) | 0.44(621) | 1.60(342) | -0.87(158) | -5.10(253) | -2.38(261) |
| First 170-305 days lact. yield (kg) | 2352.57±33.67(2042) | 176.12(155) | 210.77(252) | 235.72(621) | 299.07(342) | -193.05(158) | -377.68(253) | -350.97(261) |

Figures in parentheses indicate the number of observations. The constants superscripted by an alphabet with an asterisk (*) are significantly (P<.05) higher than those constants which are superscripted by the same alphabet.
4.1.8. Body weight at 18 months age—The least square means of three breed groups studied for body weight at 18 months age, ranked the Friesian crossbred at the top followed by Brown Swiss crosses and Sahiwal females (Fig.1). Their respective values were 256.13±0.93, 231.65±3.26 and 219.95±2.32 kg, which varied significantly (P<0.01).

The constant effects derived from least square technique for 6/8 and halfbreds of BS were positive and for 3/8, 2/8 and F2-F3 were negative. Least square means ranked halfbreds superior in body weight at 18 months age and 2/8 grade inferior among five genetic groups studied. The respective body weights for halfbreds and 2/8 grade were 245.86 and 219.14 kg and was found to be significant (P<0.05)(Table 17).

The least square constants of 7/8, 2/8 and 1/8 genetic groups were negative and constants for 6/8, 5/8, 4/8 and 3/8 of HF inheritance were positive. The least square means for the genetic grades revealed the superiority of halfbred and inferiority of 1/8 grades for weight at 18 months age. The genetic grade of 1/8 was significantly lower in body weight than all higher grades. Genetic group of 2/8 was significantly lower in weight than 5/8 and 4/8; 7/8 lower than halfbreds, whereas 6/8 grade was significantly lower than halfbred females (Table 19).

4.1.9. Body weight at first fertile service—The body weight at first fertile service was 288.91±2.75, 274.76±9.13 and 317.13±1.75kg
for $S_w$, $85 \times S_w$, and $Hf \times S_w-S_wxHF$ crossbreds respectively. The
difference among means of three breeds was found to be significant
($P<.05$).

The least square means of $6/8$, $4/8$, $3/8$ and $F_2-F_3$
genetic groups of $85$ inheritance were higher than overall mean of
$85 \times S_w$ crossbreds. The female of $6/8 85$ inheritance attained
higher weight at fertile service followed by $F_2-F_3$ group. The
lowest weight ($255.68$ kg) was observed for $2/8$ genetic group.
The means of five grades did not differ significantly (Tukey's test).

The least square constants for genetic groups of
$6/8$, $5/8$, $4/8$ and $3/8$ were positive, and for $7/8$, $2/8$ and $1/8$ were
negative. The halfbreds had highest body weight at fertile service
and $1/8$ had lowest among seven genetic groups of $HF$ inheritance
(Table 18). The test of comparison revealed that $1/8$ grade had
significantly lower body weight from $6/8$, $5/8$, $4/8$ and $3/8$ while
$2/8$ had lower than $1/2$ and $3/8$. There was non-significant
difference among other means.

4.1.10. Body weight at first calving— The least square means
for $S_w$, $85 \times S_w$, and $Hf \times S_w-S_wxHF$ were $331.65\pm2.18$, $347.48\pm6.88$
and $350.67\pm4.99$ kg respectively (Fig. 1). The least square mean
of body weight of $S_w$ cows was significantly ($P<.01$) lower than its
exotic crosses. There was non-significant difference between
$85 \times S_w$ and $Hf \times S_w-S_wxHF$ group averages.

The least square constants for $6/8$, $4/8$ and $2/8$ were
positive whereas for $3/8$ and $F_2-F_3$ genetic groups of $85$ inheritance
were negative. The genetic group of $6/8$ was observed to be highest
in body weight at first calving ($355.98$ kg) and the lowest body
FIG. 1 CHANGE IN BODY WEIGHT (Kg) OF FEMALE CALVES WITH INCREASING AGE IN MONTHS.
weight (339.64 kg) was found for F₂-F₃ crossbred females. There was non-significant difference among weights at first calving in all five genetic groups studied.

The least square constants of the genetic grades of 7/8, 6/8 and 1/8 were negatively and 5/8, 4/8, 3/8 and 2/8 were positively deviated from their common mean. The halfbred females were found highest in body weight (360.56 kg) and 1/8 lowest (342.69 kg) among seven genetic groups studied. Non-significant difference among means of all grades except between 1/8 and 1/2; 6/8 and 4/8 grades were observed.

4.2. Growth rates (g/day)

The growth rate was calculated from different age intervals as average gain in body weight (g) per day.

4.2.1. Growth rate from birth to 2 months of age: The least square mean of growth rate (g/day) from birth to 2 months of age was observed to be 375.9±5.5, 375.8±14.9 and 505.2±3.1 g of Sw, B₅x₅w and Hf₅x₅w-SwxF crossbred females (Appendix T₃). The growth rate of Hf₅x₅w was significantly higher (P<0.01) than other two breed groups. The difference between Sw and B₅x₅w female calves was non-significant.

The highest growth rate in B₅ crossbred was found for halfbred (385.2 g) and lowest for 2/8 (371.2 g)(Table 17 and Fig.2a). The growth rate of halfbreds was significantly (P<0.05) higher than other genetic groups of B₅ crosses (Tukey’s test).

In HF grades, constant effects derived from least square mean had positive value for halfbreds and higher grades
but negative values for lower grades. The highest growth rate per day (531.4 g) and lowest (462.4 g) were observed for 7/8 and 1/8 grade. Tukey's test ranked 7/8 and 6/8 grades significantly superior in growth rate from 5/8, 3/8, 2/8 and 1/8 grades while halfbreds and 5/8 were better from 3/8, 2/8 and 1/8 grades (Table 18).

4.2.2. Growth rate from 2-4 months age: The growth rate of Sw, BSxSw and HFxSw-SwxHF crossbred females were 436.4±6.5, 455.7±18.0, and 533.8±3.6 g respectively by least square technique. Among three breed groups, HFxSw females were significantly higher in growth rate from Sw and BSxSw females while later two did not attain the statistical level of significant difference.

The least square constants for 6/8 and 3/8 were negative and 4/8, 2/8 and F_{2}-F_{3} were positive from their common mean. Halfbreds were significantly higher in growth rate from 6/8, 3/8 and F_{2}-F_{3} genetic groups whereas 2/8 from 3/8 and 6/8 (Table 17 and Fig. 2a). The inter AA group (F_{2}-F_{3}) was higher from 6/8 and 3/8 genetic groups.

Among HF inheritance, higher grades (7/8, 6/8, 5/8 and 4/8) were positively and lower grades (3/8, 2/8 and 1/8) were negatively deviated from their common least square mean. The means difference test revealed the superiority of 6/8 over all other HF grades. Higher grades were significantly different from lower grades. The genetic group 2/8 was found lower in growth rate from all other grades (Table 18 and Fig. 2b).

4.2.3. Growth rate from 4-6 months age: The least square means for Sw, BS x Sw and HFxSw-SwxHF crossbred females were
451.8±7.1, 531.0±20.7 and 541.6±3.9 g respectively. The 5w females had significantly (P<0.01) lower growth rate than their exotic crosses. There was non-significant difference among crossbred of two exotic breeds (Appendix T1,2,3).

The genetic group 3/8 of BS inheritance had significantly highest growth rate (579.9 g) from all other grades. The mean difference was found significant among all grades except between 6/8 and F2-F3 groups (Table 17 and Fig. 2a).

Among seven genetic groups of Friesian inheritance, the significant differences were observed except between 6/8 and 5/8, and 7/8 and 5/8 genetic groups. Least square means ranked 6/8 grade higher (563.0g) and 1/8 lower (513.8g) in average gain (g/day)(Table 18 and Fig. 2b).

4.2.4. Growth rate from 6 to 9 months age— Sahiwal, BSx5w and HFx5w-5wxF female calves gained at an average rate of 352.6±10.4, 335.0±14.7 and 437.0±3.6 g per day.(Appendix T1,2,3).

The BS inheritance genetic groups of 6/8, 4/8 and 3/8 were positively while 2/8 and F2-F3 were negatively deviated from their common least square mean. Tukey's test indicated significant differences among least square means of all genetic groups except between 2/8 and F2-F3. The lowest and highest growth rate was 378.8 and 264.8 g for halfbreds and 2/8 genetic groups respectively.

The least square constants of HF inheritance for 7/8, 6/8, 2/8 and 1/8 were negative and other were positive from their weighted mean. Their least square means were significantly different from one another except between 6/8 and 2/8 grades. The
highest growth rate per day was 468.5g and the lowest was 414.9g for halfbreeds and 7/8 grades respectively (Table 18 and Fig. 2b).

4.2.5. Growth rate from 9 to 12 months age:— The weighted means for 5w, B5x5w and Hf5x5w-SwHF were 339.7±16.8, 362.8±17.5 and 393.5±4.1g per day respectively. Their comparative means were highly significant (P<.01). The 5w female had lowest growth rate gram per day (Appendix T1,2,3).

Among BS inheritance grades, halfbreeds and 3/8 showed significantly higher growth rate per day than 6/8, 2/8 and F2-F3 groups and 6/8 and 2/8 showed higher than F2-F3 groups. Halfbreeds expressed their superiority (388.9g/day) in growth rate over other genetic groups. The Inter es (F2-F3) groups showed poorest growth (318.7g/day)(Table 17).

The highest growth per day in HF inheritance was found in 3/8 grade (421.0g) and lowest in 7/8 (362.2g). Tukey’s test indicated significant difference among least square means of all grades except between 6/8 and 1/8 grades (Table 18).

4.2.6. Growth rate from 12 to 15 months age:— The least square means for Sahiwal, BSx5w and Hf5x5w-SwHF were 333.9±14.3, 367.9±21.0 and 349.7±4.9g respectively. The growth rate of BSx5w was significantly (P<.01) higher.

Among BS crossbred, 6/8, 4/8 and 3/8 had higher while 2/8 and F2-F3 had lower weights from their common least square mean. Significant difference was observed except between 3/8 and 4/8 grades. The highest growth rate was observed in halfbred females (Table 17 and Fig. 2a).
Among HF crossbreds, 7/8, 6/8, 4/8, 2/8 and 1/8 had lower and 5/8 and 3/8 had higher weights from their common least square mean. The highest positive deviation was observed for 3/8 and negative for 1/8 grade. The least square means of all grades were significantly different from each other except between halfbreds, 2/8 and 7/8; between 6/8 and 7/8; and between 7/8 and 2/8 grades (Table 18 and Fig.2b).

4.2.7. Growth rate from 15 to 18 months: age—Sahiwal.

BSxS and HFxS—SxHF crossbred females had 330±14.8, 314.6±22.5 and 343±44.6 g least square means for their velocity of growth rate per day. Sahiwal females had significantly (P<0.01) higher growth rate per day from their BS crosses but it was not significantly different from their Frissian crosses. The difference between the means of BSxS and HFxS crosses was not significant.

The effects due to genetic groups of 6/8, 4/8 and 2/8 were positively while F2—F3 and 3/8 grade of BS were negatively deviated from their least square mean. The lowest (215.3g) and highest (386.7g) growth rate was observed in 3/8 and halfbred grades respectively. Tukey's test revealed significant difference among least square means of all grades except between F2-F3, 6/8 and 2/8 grades (Table 17 and Fig.2a).

The constant effects due to genetic groups in HF inheritance were found to be positive for 6/8, 5/8, 4/8 and 3/8, and negative for 7/8, 2/8 and 1/8 grades from their common least square mean. The halfbred had higher growth rate (351.4g) and 1/8 had lower (329.7g) per day among seven genetic groups studied. Tukey's test indicated significant difference among least square
FIG. 2(a) GROWTH RATE (g/day) AT DIFFERENT INTERVALS OF AGE FOR FEMALE CALVES (SW & BSXSW GENETIC GROUPS.)
FIG. 2(b) GROWTH RATE (g/day) AT DIFFERENT INTERVALS OF AGE FOR FEMALE CALVES (HFXSW GENETIC GROUPS).
means of all grades except between 5/8 and 6/8, between 6/8 and 2/8, and between 4/8 and 3/8 grades.

Comparative growth rate (g/day) of BSxSw and HFxSw genetic groups

(a) The different genetic groups of BS inheritance possessed higher gain per day during 4-6 months of age (Table 17 and Fig.2a). Among genetic groups, halfbreeds gained weight (g/day) at higher rate at different intervals of age except 5 1/2 to 7 months of age where 3/8 genetic group was found superior in gain. Filial groups (F₂-F₃) was lowest in gain per day from 6 month to 18 months of age interval than other genetic groups of BS inheritance. This might be due to loss of heterotic gene action.

(b) Maximum velocity of weight gain per day was observed during 4-6 months of age in all grades of HFxSw crosses (Table 18 and Fig.2b). Among grades the 6/8 showed higher rate of gain per day from 2 to 7 months of age but halfbreed registered their superiority from 7 to 10 1/2 month of age and further 3/8 group gained at higher rate upto 17 1/2 months age. This indicates the shifting nature of various grades for growth rate (g/day) at different intervals of age. This might be due to genetic variability and environmental influences that elicit a favourable response in some groups and not in others. The continued fall in growth rate of 7/8 grade could be due to the dampening effect of environment on higher exotic germ plasm in sub-tropical climate.

A very peculiar and interesting impression of the figures No.2a and 2b are a steep fall of growth rate (g/day) in all genetic groups at age interval of 6-9 months. Several reasons
for this particular phenomenon can be propounded based on genetical, managemental and environmental variability and their joint effects.

4.3. Production Traits

Age at first calving, first lactation yield and its components, first lactation length and first dry period were considered for this study.

4.3.1. Age at first calving (mths)!- The least square means for S_w, B_SxS_w and H_FxS_w-S_wxH_F were 38.65±2.69, 30.41±0.57 and 36.36±0.25 months respectively. These means differed significantly from each other.

The least square constants for genetic groups of BS inheritance indicated that 6/8 and F_2-F_3 groups were positively and 4/8 and 3/8 were negatively deviated from their common mean. The lowest age at first calving was found to be 28.77 months for halfbreds followed by 3/8 grade (28.90 months). The highest age at first calving was 32.74 months for F_2-F_3 group. Tukey's test revealed that average mean of F_2-F_3 was significantly higher from halfbred and 3/8, and 6/8 from halfbreds (Table 17).

The least square constants for 6/8, 5/8 and 4/8 genetic groups of HF inheritance were negatively and 7/8, 3/8, 2/8 and 1/8 were positively deviated from their common least square mean. The lowest average age (35.38 months) for halfbreds and highest (37.58 months) for 1/8 genetic group was observed. It was observed that halfbreds and higher grades had significantly low age at first calving than 1/8 grade, while 5/8 and 4/8 from 2/8 and 3/8 grades (Table 18 and Fig.4a,b).
4.3.2. First lactation yield (kg): The least square mean of first lactation yield for S5, BSxS5 and HFXS5-SuxHF were 2022.11±38.87, 3288.95±133.20 and 2495.94±39.81 kg respectively. These means were statistically significant (P<0.05) (Appendix T1,2,3).

Among BS grades, 3/8 produced highest quantity of milk (4006.21 kg) and F2-F3 groups produced the lowest (2688.44 kg). Mean test indicated that 3/8 produced significantly (P<0.05) more milk than 6/8, F2-F3 where halfbreds produced significantly higher than F2-F3 (Table 17) (Fig.3a,b).

Among HF grades, 7/8, 6/8, 5/8 and 4/8 grades yielded milk 2679.58, 2800.82, 2735.37 and 2799.44 kg respectively which was significantly higher from lower grades (3/8, 2/8 and 1/8).

Among higher grades 7/8 produced significantly low milk than 6/8 and 4/8 grades (Table 18 and Fig.4a,b).

4.3.3. First lactation components (kg): The least square means for S5, BSxS5 and HFXS5-SuxHF crossbred cattle were observed as 5.81±0.10, 10.40±0.46, 8.49±0.17 kg per day for initial yield, 7.54±0.12, 12.10±0.46 and 9.97±0.12 kg per day for ascending yield, 8.96±0.04, 14.58±0.46 and 11.35±0.16 kg per day for maximum (peak) yield, 6.65±0.10, 10.40±0.39 and 8.68±0.13 kg per day for descending yield, and 6.36±0.07, 9.98±0.28 and 8.35±0.11 kg for milking average respectively. The differences between breeds were significant for initial, ascending, peak, descending and first milking average.

Among BS grades, 3/8 produced significantly (P<0.05) higher initial (13.15 kg), ascending (14.90 kg) and peak yield (18.02 kg) from 6/8 and F2-F3 groups whereas halfbred (F4) produced more than F2-F3. Genetic group 3/8 and 4/8 respectively
produced 11.93 and 11.16 kg descending yield per day which was significantly higher than F₂⁻F₃ groups. Milking average per day of lactation yield of 3/8 (11.83 kg) was found significantly (P≤0.05) superior over 6/8 (9.17 kg) and F₂⁻F₃ (8.56 kg) genetic groups. Halfbreeds (F₁) produced significantly (P≤0.05) higher milking average (10.37 kg) from F₂⁻F₃ crossbreeds (Table 17).

Higher grades of HF inheritance (7/8, 6/8, 5/8 and 4/8) produced significantly (P≤0.05) higher initial, ascending, peak, descending and milking average of first lactation from lower grades (3/8, 2/8 and 1/8). The grades varied widely for these traits and no definite trend was maintained by any of the higher grades (Table 18).

4.3.4. First lactation length (days) - Sahiwal, BSxSU and HFxSU-SuxHF had 321.98±4.50, 336.40±10.10 and 309.51±2.94 days of lactation period. The least square means of three breed groups were significantly (P≤0.05) different from each other (Appendix T₁,2,3).

The genetic groups of 6/8, and F₂⁻F₃ of BS inheritance were negatively while 3/8 and 4/8 were positively deviated from their least square mean of 336.40 days. The genetic group 3/8 produced milk for a longer time whereas F₂⁻F₃ produced for a comparatively shorter time. Non-significant differences among their least square means were observed (Table 17).

Among HF grades, 3/8, 2/8 and 1/8 produced milk for a shorter period than higher grades. Test of comparison revealed that 6/8 grade produced milk for a longer period (P≤0.05)
from 1/8, 2/8 and 3/8 grades whereas, 2/8 grade for a shorter period (Table 18).

4.3.5. First dry period: Least square means for $S_w$, $S_5xS_w$

and $H_FxS_w - S_wxHF$ were 134.6+4.90, 74.40+6.00 and 124.8+3.75 days respectively. These means differed significantly ($P<.05$).

Among $S_5$ inheritance grades, the lowest dry period 60.65 days for 4/8 and highest 82.02 days for 3/8 was observed (Fig. 3a,b). The mean test revealed nonsignificant difference among four genetic groups (Table 17).

Among $H_F$ inheritance grades, the lowest dry period was 116.15 days and highest 130.38 days for halfbred and 7/8 grades respectively. The genetic groups were not significantly different from their dry periods (Table 18).

4.3.6. First 170-305 days lactation length: The least square means for $S_w$, $S_5xS_w$ and $H_FxS_w - S_wxHF$ were 282.62+1.90, 290.27+3.86 and 284.14+1.16 days respectively. These means were significantly different from each other ($P<.05$).

Among genetic groups of $S_5$ inheritance, 6/8 and 4/8 produced milk significantly for longer period than $F_2-F_3$ group. Likewise, the genetic groups 7/8, 6/8 and 4/8 of $H_F$ inheritance produced milk for significantly longer period than 2/8, whereas 1/8 grade produced for significantly shorter period than 6/8 grades.

4.3.7. First 170-305 days lactation yield: The least square means of 1853.61±33.32, 2888.89±92.43 and 2352.57±33.67 kg were
observed for S\(w\), BSxSw and HFxSw-SwxHF respectively. Their
means were significantly \((p<0.05)\) different from each other.

Halfbreds and 3/8 of BS inheritance produced 3206.29
and 3162.54 kg milk which was significantly higher from \(F_2-F_3\)
group. Among genetic groups of HF inheritance higher grades
7/\(8\), 6/\(8\), 5/\(8\) and 4/\(8\) produced significantly \((p<0.05)\) higher milk
than lower grades, whereas 3/\(8\) produced significantly higher milk
than 2/\(8\) grade. Halfbreds were superior (2651.64 kg) and 2/\(8\)
inferior (1974.68 kg) milk producers compared to other grades of
HF inheritance.

Relative performance of different genetic
groups of BS x Sw crossbreds and Sahiwal

A comparative picture of the six selected economic
traits (Body weight at 12 months age, body weight at first
calving, age at first calving, first total lactation yield, first
milking average and first dry period of five genetic groups of
\(F_2-F_3\), 2/\(8\), 3/\(8\), 4/\(8\)(\(F_1\)) and 6/\(8\) of BS inheritance are depicted
in Fig. 3a. All the traits for \(Sw\) were taken as unity and
relative performance of the BSxSw crossbreds with different
levels of BS inheritance were compared. It is evident from the
Fig.3a that among genetic group of BS inheritance, 3/\(8\) group
was found superior in yielding higher first total lactation
yield, first milking average while it was similar to halfbreds
in maintaining weight (kg) at 12 months age, and weight at first
calving and age at first calving (months). Halfbreds showed
their superiority having low first dry period than 3/\(8\) and
other groups. The superiority of 3/\(8\) grade might be due to
better genes combination and their interaction with environment.
A further comparison was made among genetic groups and Sahiwal cattle considering halfbreds as base for the relative performance of six traits (Fig.3b). It is evident from the figure that 3/8 genetic group was superior and 5w cows were inferior in first lactation yield and first milking average. Filial group \((F_2-F_3)\) showed larger gap for halfbreds than 6/8 genetic group.

Relative performance of different genetic groups of HFx5w crossbreds and Sahiwals

The relative performance of seven genetic grades of HF inheritance revealed the superiority of halfbred (Fig.4a). Halfbred produced higher first total lactation yield, first milking average, attained higher weight at 12 months age and at first calving and had low age at first calving and first dry period than other genetic groups. While comparing these grades from 5w it is evident that all seven genetic groups (with the fraction of 12.5 percent HF inheritance) were towards the desired direction. There was linear increase in first lactation milk yield and weight at 12 months age and at first calving with the increase of Friesian inheritance up to 50% level, after this the performance was diffusely decreased for various traits with the increase of exotic germ plasm. Figure 4b showed the relative performance of HFx5w genetic groups and 5w cattle comparing from halfbreds. Converging and diverging lines of six economic traits indicated the superiority of halfbreds.

(a) Non-genetic factors affecting body weight, growth rate and production traits:

Non-genetic factors such as farm, parity of birth,
season and period of birth, season and period of calving were analysed by least square technique to study their effect on body weight, growth rate and production traits of three breed groups $S_w$, $B_{5xS_w}$ and $H_{FxS_w-Sw\timesHF}$ (Appendix T_{4,5,6}).

1. Farm effect—The farm effects were studied by analysis of variance for $S_w$ and $H_{FxS_w}$ cattle. The effect due to farms was non-significant for the traits of weight at birth, growth rate from 12-15 months, 15-18 months of age, age at first calving and first lactation components (ascending, peak and descending yields) but farm effect was highly significant ($P<.01$) for other studied traits of Sahiwal cattle. The significant effect ($P<.05$) due to farms was observed for various traits of $H_{FxS_w}$ crossbred cattle (Appendix T_{4,5,6}).

2. Parity of birth—The effect due to parity of birth was studied for body weights and growth rate traits. It was found significant for weight at 9 months age and weight at first fertile service in Sahiwal cattle. The parity effect was found significant ($P<.05$) for weight at birth, 4 and 6 months age, growth rate 2-4 months, 12-15 months and weight at fertile service in $B_{5xS_w}$ cattle. The effect was non-significant ($P>.05$) for other traits in Sahiwal and $B_{5xS_w}$ cattle. Non-significant ($P>.05$) effect due to parity of birth was observed for the traits studied in $H_{FxS_w}$ crossbred female calves (Appendix T_{4,5,6}).

3. Season of birth/season of calving—The effect due to season was found significant ($P<.01$) in Sahiwal female calves for the traits of weight at 9 and 12 months age, growth rate from 6-9, 9-12, 12-15 and 15-18 months of age, age at first calving and descending yield
but non-significant for other traits. In BSxSw crossbred females, the effect due to season was significant ($P<0.05$) for the traits of weight at birth, 4, 6, 9, 12 and 15 months of age, weight at calving and for growth rate 2 to 4, 4 to 6, 6 to 9, 9 to 12, 12 to 15 and 15 to 18 months of age and descending yield. The effect was found non-significant ($P>0.05$) for other traits. In HFxSw, the effect due to season was highly significant ($P<0.01$) for all the traits except for weight at 15 months, weight at fertile service, weight at calving and first lactation yield (Appendix T4,5,6).

4. Period of birth/calving - Least squares analysis of variance indicated that effect due to period was non-significant for gain in body weight per day (from 4-6, 6-9, 9-12 and 12-15 months age), first lactation yield, descending yield, milking average and first dry period in Sahiwal females but was found highly significant ($P<0.01$) for other traits. In BSxSw crossbreds, highly significant ($P<0.01$) effect due to period was found for body weights at 2, 4, 6, 9, 12, 15 and 18 months of age, weight at fertile service, growth rate from birth to 2 month, 2-4, 4-6 and 9-12 months age interval, age at first calving, first 170-305 days lactation length and first dry period.

In HFxSw crossbreds, the effect due to period of birth was found significant for body weights, growth traits and production traits except 6-9 months growth rate g/day (Appendix T4,5,6).

(B). Effect due to Genetic Groups:

This study was done for 5 groups of BSxSw and 7 groups of HFxSw cattle. The effect due to genetic group was
non-significant for the traits of body weights at 2 months age, weight at fertile service, weight at calving, growth rate from birth to 2 months and 4-6 months age, first lactation length and first dry period of BSxSw genetic groups, but it was significant (P<0.05) for other traits. The effect due to genetic group was non-significant for growth 12-15, 15-18 months age and for first dry period of HFxSw genetic groups, whereas for other traits effect was significant (P<0.05) (Appendix T5,6).

(C) Relationship between body weights at first calving and first lactation
milk yield and milk average

The high frequency of calving was 31 percent (at body weight range 331-370 kg) in Sw and 37 percent (at body weight range 291-330 kg) in BSxSw crossbreds. They produced 1890.2±71.4 and 3051.8±140.5 kg total milk yield in their first lactation respectively. About 40 percent HFxSw and 35 percent SwxHF heifers calved at body weight range of 371-410 kg and produced average first lactation yield 2866.2±47.4 and 2111.4±40.4 kg respectively (Table 19). Significant (P<0.05) difference between average first lactation yield of heifers calving at different range of body weights are shown in Table 19.

From Fig. 5a it is evident that BSxSw, HFxSw, SwxHF crossbred heifers calved at lower body weight (250 kg or below) produced more milking average than those in next higher group of body weight (251-290 kg). With the further increase of body weight at first calving (from 291 kg onwards) there was a linear trend of increase in first lactation milking average except for Sw breed where only minor increase was noticed up to the
<table>
<thead>
<tr>
<th>Body weight group (kg)</th>
<th>250</th>
<th>251-290</th>
<th>291-330</th>
<th>331-370</th>
<th>371-410</th>
<th>411-450</th>
<th>&gt;451</th>
</tr>
</thead>
<tbody>
<tr>
<td>First lact. milk yield (kg)</td>
<td>2265.1</td>
<td>ab</td>
<td>1993.5</td>
<td>abed</td>
<td>ab</td>
<td>abed</td>
<td>1787.5</td>
</tr>
<tr>
<td></td>
<td>±59.5</td>
<td>±105.4</td>
<td>±104.6</td>
<td>±71.4</td>
<td>±90.8</td>
<td>±99.5</td>
<td>±299.1</td>
</tr>
<tr>
<td>First Milking average (kg)</td>
<td>6.24</td>
<td>6.06</td>
<td>6.26</td>
<td>6.36</td>
<td>6.58</td>
<td>6.15</td>
<td>6.06</td>
</tr>
<tr>
<td>Frequency of calving (%)</td>
<td>3.20</td>
<td>18.27</td>
<td>27.88</td>
<td>31.41</td>
<td>12.82</td>
<td>5.45</td>
<td>0.64</td>
</tr>
<tr>
<td>BSxS (Total number of observations = 297)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First lact. milk yield (kg)</td>
<td>3750.0</td>
<td>ab</td>
<td>2887.6</td>
<td>sc</td>
<td>3018.5</td>
<td>sc</td>
<td>2937.5</td>
</tr>
<tr>
<td></td>
<td>±129.6</td>
<td>±433.9</td>
<td>±140.5</td>
<td>±149.9</td>
<td>±137.0</td>
<td>±432.4</td>
<td></td>
</tr>
<tr>
<td>First Milking average (kg)</td>
<td>10.74</td>
<td>8.39</td>
<td>9.24</td>
<td>10.20</td>
<td>10.30</td>
<td>11.08</td>
<td>-</td>
</tr>
<tr>
<td>Frequency of calving (%)</td>
<td>1.72</td>
<td>6.90</td>
<td>36.63</td>
<td>33.16</td>
<td>17.24</td>
<td>4.31</td>
<td>-</td>
</tr>
<tr>
<td>HFxS (Total number of observations = 593)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First lact. milk yield (kg)</td>
<td>2963.7</td>
<td>b</td>
<td>2642.3</td>
<td>sc</td>
<td>2416.2</td>
<td>sc</td>
<td>2685.0</td>
</tr>
<tr>
<td></td>
<td>±32.2</td>
<td>±392.3</td>
<td>±90.2</td>
<td>±58.2</td>
<td>±47.4</td>
<td>±137.0</td>
<td>±176.6</td>
</tr>
<tr>
<td>First Milking average (kg)</td>
<td>9.12</td>
<td>7.16</td>
<td>7.37</td>
<td>8.50</td>
<td>8.90</td>
<td>9.48</td>
<td>10.02</td>
</tr>
<tr>
<td>Frequency of calving (%)</td>
<td>1.11</td>
<td>0.44</td>
<td>8.06</td>
<td>23.85</td>
<td>39.42</td>
<td>22.17</td>
<td>4.26</td>
</tr>
<tr>
<td>SxHF (Total number of observations = 486)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First lact. milk yield (kg)</td>
<td>2212.7</td>
<td>a</td>
<td>1826.8</td>
<td>ab</td>
<td>1985.4</td>
<td>ab</td>
<td>2093.0</td>
</tr>
<tr>
<td></td>
<td>±44.9</td>
<td>±185.6</td>
<td>±73.8</td>
<td>±61.4</td>
<td>±40.4</td>
<td>±81.15</td>
<td>±219.15</td>
</tr>
<tr>
<td>First Milking average (kg)</td>
<td>7.16</td>
<td>6.48</td>
<td>6.51</td>
<td>6.97</td>
<td>6.99</td>
<td>7.12</td>
<td>8.13</td>
</tr>
<tr>
<td>Frequency of calving (%)</td>
<td>1.23</td>
<td>1.85</td>
<td>12.55</td>
<td>26.34</td>
<td>35.19</td>
<td>19.55</td>
<td>19.02</td>
</tr>
</tbody>
</table>

Least square means superscripted by similar letters are significantly (P<0.05) different from each other.
body weight of 410 kg. Further it was observed that crossbred heifers which calved at the weight of 250 kg and below possessed higher proportion of exotic germ plasm (HF inheritance). These animals were also observed better in body weight gain at 12 months of age and their age at calving was also lower than other group averages. This indicates better dairy merit of this group in comparison to 251 to 290 kg body weight heifers. Further the regression analysis of this study revealed the curvilinear relationship between the first lactation milk yield and body weights (Appendix T7,8,9,10(I) and Fig. 5a).

(D) Relationship between age at first calving and first lactation milk yield and milking average

The data were arranged in seven age group range.
The maximum number was observed between 36.1 to 39.0 months (S_w - 23%), 27.1 to 30.0 months (B5xS_w - 35%), 33.1 to 36.0 months (H_FxS_w - 27%) and 36.1 to 39.0 months (S_wxH_F - 28%) with their respective average yield of 2014.9, 3199.2, 2924.7 and 2118.6 kg. The S_w, B5xS_w, H_FxS_w and S_wxH_F heifers respectively calving at 27.1-30.0, 32.1-45.0, 30.1-33.0 and 33.1-36.0 months of age produced higher lactation average. The significant difference of average milk yield between different age groups existed in four breed groups had no specific trend (Table 20 and Fig.5b).

Figure 5b explained the relationship of age at first calving and first milking average for four breed groups. First lactation milking average was less influenced by age at first calving but S_w heifers calving at low-or age produced lower milking average than calving at higher age. This might be due to
FIG. 3. RELATIVE PERFORMANCE OF FEMALES OF DIFFERENT GENETIC GROUPS (SW & BSXSW)
(a) CONSIDERING SW PERFORMANCE AS BASE.

(b) CONSIDERING BSXSW HALF-BRED PERFORMANCE AS BASE.

RELATIVE PERFORMANCE IN %

GENETIC GROUPS WITH BROWN SWISS INHERITANCE

- AGE AT FIRST CALVING (mths)
- BODY WEIGHT AT 12 mths AGE (kg)
- BODY WEIGHT AT FIRST CALVING (kg)
- FIRST DRY PERIOD (DAYS)
- MILKING AVERAGE (kg)
- FIRST TOTAL LACT. YIELD
Fig 4 Relative Performance of Females of Different Genetic Groups (SW&HFxSW)
(a) Considering SW Performance as Base.

Fig 4 Relative Performance of Females of Different Genetic Group (SW&HFxSW)
(b) Considering HFxSW Halfbred Performance as Base.
FIG. 5(a). RELATIONSHIP BETWEEN BODY WEIGHT (Kg) AT FIRST CALVING AND MILKING AVERAGE (Kg) OF FOUR BREED GROUPS.

FIG. 5(b). RELATIONSHIP BETWEEN AGE AT FIRST CALVING (Month) AND MILKING AVERAGE (Kg) OF FOUR BREED GROUPS.
Table 20. Relationship between age at first calving and first lactation milk yield and milking average

<table>
<thead>
<tr>
<th>Age groups</th>
<th>27.0</th>
<th>27.1-30.0</th>
<th>30.1-33.0</th>
<th>33.1-36.0</th>
<th>36.1-39.0</th>
<th>39.1-42.0</th>
<th>42.1-45.0</th>
<th>&gt;45.1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>First lact. yield (kg)</strong></td>
<td></td>
<td>a</td>
<td>ab</td>
<td>abc</td>
<td>abcd</td>
<td>abcde</td>
<td>abcdef</td>
<td>abdeg</td>
</tr>
<tr>
<td></td>
<td>1569.2</td>
<td>2451.9</td>
<td>2416.6</td>
<td>2004.4</td>
<td>2014.9</td>
<td>2099.7</td>
<td>2098.5</td>
<td>2172.4</td>
</tr>
<tr>
<td></td>
<td>±155.8</td>
<td>±239.6</td>
<td>±101.5</td>
<td>±68.8</td>
<td>±72.6</td>
<td>±90.6</td>
<td>±81.3</td>
<td>±101.2</td>
</tr>
<tr>
<td><strong>First milking average (kg)</strong></td>
<td>5.11</td>
<td>7.04</td>
<td>6.17</td>
<td>6.21</td>
<td>5.96</td>
<td>6.32</td>
<td>6.35</td>
<td>6.39</td>
</tr>
<tr>
<td><strong>Frequency of calving (%)</strong></td>
<td>1.25</td>
<td>5.03</td>
<td>9.42</td>
<td>16.98</td>
<td>23.02</td>
<td>15.89</td>
<td>13.17</td>
<td>15.27</td>
</tr>
<tr>
<td></td>
<td>a</td>
<td>ab</td>
<td>abc</td>
<td>abcd</td>
<td>abcde</td>
<td>abcdef</td>
<td>abdeg</td>
<td>abcdefg</td>
</tr>
<tr>
<td></td>
<td>3193.9</td>
<td>3199.2</td>
<td>3061.5</td>
<td>3126.3</td>
<td>2969.6</td>
<td>3156.0</td>
<td>4733.0</td>
<td>3470.0</td>
</tr>
<tr>
<td></td>
<td>±122.2</td>
<td>±125.2</td>
<td>±138.3</td>
<td>±291.4</td>
<td>±208.4</td>
<td>±992.0</td>
<td>±50.49</td>
<td></td>
</tr>
<tr>
<td><strong>First milking average (kg)</strong></td>
<td>9.51</td>
<td>9.61</td>
<td>9.94</td>
<td>9.83</td>
<td>9.22</td>
<td>10.42</td>
<td>8.98</td>
<td>10.33</td>
</tr>
<tr>
<td><strong>Frequency of calving (%)</strong></td>
<td>25.94</td>
<td>34.91</td>
<td>20.28</td>
<td>9.91</td>
<td>6.14</td>
<td>0.94</td>
<td>0.47</td>
<td>1.41</td>
</tr>
</tbody>
</table>

Least square means superscripted by similar letters are significant at 0.05 different from each other.
poor body development and growth for this breed. BSxSw crossbreeds calving at the age of 39.1 to 42.0 months and above 45 months of age produced significant (P<0.05) higher milking average than other groups calving at lower age.

(E) Regression analysis

This study was conducted on standardized data of four breed groups e.g. Sahiwal, BSxSw, HFxSw and SwxMF crossbreeds. Simple linear, multiple and quadratic regression models were fitted for the prediction of first lactation yield. The data was analyzed in two sets:

Set-I

In this part of study, the following traits were incorporated for the prediction of first lactation yield:

1. Birth weight (kg) - X₁
2. Weight at 6 months age (kg) - X₂
3. Weight at 12 months age (kg) - X₃
4. Weight at first calving (kg) - X₄
5. Maximum growth rate (g/day) 4-6 mths age - X₅
6. Age at first calving (mths) - X₆
7. First lactation length (days) - X₇
8. First lactation yield (kg) - Y

Set-II

The following traits were involved for the prediction of first lactation yield:

1. Initial yield (kg) - X₁
2. Ascending yield (kg) - X₂
3. Peak yield (kg) - X₃
4. Descending yield (kg) - X₄
5. First lactation yield (kg) - Y
Set-I

Prediction of first lactation yield on the basis of body weight, growth rate, age at first calving and first lactation length traits

Thirty four regression equations were developed with possible combination of independent traits for each breed group. The highest $R^2$ values were obtained from quadratic equation No. 18 where all the traits were fitted in the regression equation ($T_{7a}$).

The $R^2$ values in 18th equation were 58.76, 64.99, 46.02 and 45.30% for Sahiwal, B5x5w, HFx5w and SwxHF breed groups respectively. The lowest $R^2$ values in these breeds were observed in equation No.11 where independent trait was growth rate between 4 to 6 months age. The values were 0.38, 0.71, 0.03 and 0.00% respectively ($T_{7a,8a,9a,10a}$). The tables revealed that maximum variation in first lactation was explained by first lactation period alone e.g. 55.07% in Sahiwal, 55.82% in B5x5w, 34.29% in HFx5w and 40.43% in SwxHF crossbreds. The magnitude of $R^2$ values (from Set-I traits) for weight at first calving and age at first calving were greater than other independent traits (except lactation length) in four breed groups studied. The $R^2$ values from linear and quadratic equations were almost equal in HFx5w and SwxHF crossbred but in Sahiwal and B5x5w crossbreds values were different. Quadratic equations gave higher $R^2$ values for body weights than their linear equations which explained their curvilinear relationship with first lactation yield.

Non-significant estimates due to regressions were observed for 7, 8, 9, 11, 15 and 16 equations in Sahiwal; 8, 11, 16 and 28th equations in B5x5w; 11, 24 and 28th equations in HFx5w,
and 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 24, 26 and 29th
equations in $S_{xHF}$ crossbreds. Significant correlations ($P \leq 0.05$)
between observed and predicted values for dependent traits were
observed in all other regression equations fitted ($T_{7a,8a,9a,10b}$).

**Sat-II**

**Prediction of first lactation yield on the basis of initial, ascending, peak and descending yields**

Eighteen regression equations with different combina-
tion of independent traits and models were derived for each breed
group to predict first lactation yield from its components ($T_{7b,8b,9b,10b}$). This revealed that deviation due to regression (simple
linear, multiple and quadratic) fitted for the prediction of
first lactation yield from initial, ascending, peak and descending
yields were significant ($P \leq 0.05$) in four breed groups studied. The
$R^2$ values from linear and quadratic equations indicated that
relationship between first lactation yield and its components
were following same linear trend in four breed groups studied.

The highest magnitude of $R^2$ value from simple
linear regression was observed as 47.98, 38.56 and 34.23% from
descending yield in Sahiwal, $BSxS_w$ and $S_{xHF}$ crossbreds
respectively and 48.35% from peak yield in $HFxS_w$. Their respective
curvilinear $R^2$ values were 47.98, 38.56, 48.93 and 34.25 which
were not far away from their linear relationships. Among all
18 equations fitted, the highest values of $R^2$ were 55.55, 44.75,
55.02 and 42.10% for $S_w$, $BSxS_w$, $HFxS_w$ and $S_{xHF}$ crossbreds
respectively (from equation No.10 where all the traits were used).
Appendix $T_{7b,8b,9b,10b}$ suggested that maximum variation ($R^{2}$) in
the first lactation yield with minimum number of independent
traits could be expected from peak and descending yield by fitting
multiple regression equation.
### 4.4 Genetic Estimates

Number of sires and average number of progeny per sire used for the estimation of $h^2$, $r_g$ and $r_p$ are given in Table 21.

**Table 21.** Number of sires and average number of half-sibs per sire used for the estimation of heritability ($h^2$) genetic ($r_g$) and phenotypic ($r_p$) correlations.

<table>
<thead>
<tr>
<th>Breed groups</th>
<th>Traits</th>
<th>$S_m$ (No. of sires $\bar{K}$)</th>
<th>BSx$S_m$ (No. of sires $\bar{K}$)</th>
<th>HFx$S_m$ (No. of sires $\bar{K}$)</th>
<th>SxxMF (No. of sires $\bar{K}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
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<td>(9)</td>
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<tr>
<td>Body weight (kg)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Wt. at birth</td>
<td>33</td>
<td>13</td>
<td>31</td>
<td>18</td>
<td>40</td>
</tr>
<tr>
<td>Wt. at 2 mths</td>
<td>33</td>
<td>13</td>
<td>31</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>Wt. at 4 mths</td>
<td>32</td>
<td>13</td>
<td>31</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>Wt. at 6 mths</td>
<td>32</td>
<td>13</td>
<td>31</td>
<td>16</td>
<td>40</td>
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<tr>
<td>Wt. at 9 mths</td>
<td>25</td>
<td>11</td>
<td>25</td>
<td>15</td>
<td>35</td>
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<tr>
<td>Wt. at 12 mths</td>
<td>25</td>
<td>11</td>
<td>24</td>
<td>14</td>
<td>32</td>
</tr>
<tr>
<td>Wt. at 15 mths</td>
<td>25</td>
<td>10</td>
<td>24</td>
<td>14</td>
<td>32</td>
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<tr>
<td>Wt. at 18 mths</td>
<td>25</td>
<td>10</td>
<td>21</td>
<td>14</td>
<td>32</td>
</tr>
<tr>
<td>Wt. at 1st fertile service</td>
<td>25</td>
<td>10</td>
<td>17</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>Wt. at 1st calving</td>
<td>25</td>
<td>10</td>
<td>17</td>
<td>12</td>
<td>26</td>
</tr>
<tr>
<td>Growth rate g/day</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Birth to 2mth age</td>
<td>33</td>
<td>13</td>
<td>31</td>
<td>17</td>
<td>40</td>
</tr>
<tr>
<td>2 to 4mths age</td>
<td>32</td>
<td>13</td>
<td>31</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>4 to 6mths age</td>
<td>32</td>
<td>13</td>
<td>31</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>6 to 9mths age</td>
<td>25</td>
<td>11</td>
<td>25</td>
<td>14</td>
<td>35</td>
</tr>
<tr>
<td>9 to 12mths age</td>
<td>25</td>
<td>11</td>
<td>24</td>
<td>14</td>
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<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 to 15mths age</td>
<td>25</td>
<td>10</td>
<td>24</td>
<td>13</td>
<td>32</td>
<td>67</td>
<td>42</td>
<td>20</td>
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<tr>
<td>15 to 18mths age</td>
<td>25</td>
<td>10</td>
<td>21</td>
<td>14</td>
<td>32</td>
<td>64</td>
<td>42</td>
<td>20</td>
</tr>
</tbody>
</table>

**Production traits**

- **Age at 1st calving (mths)**: 34 11 19 13 29 57 40 17
- **First lact. yld (kg)**: 34 11 16 11 27 46 40 14
- **Initial yld (kg)**: 34 11 19 13 29 56 41 16
- **Ascending yld (kg)**: 34 11 19 13 29 56 41 16
- **Peak yld. (kg)**: 34 11 17 14 29 55 41 17
- **Descending yld (kg)**: 34 11 16 12 29 55 41 16
- **First Milking ev. (kg)**: 34 12 16 11 27 46 40 16
- **Lact. Length (days)**: 34 11 16 11 27 46 40 15
- **Dry period (days)**: 32 12 15 11 28 43 35 16
- **First 170-305 days lact. length**: 34 11 16 11 28 40 40 15
- **First 170-305 days lact. yield (kg)**: 34 11 16 11 28 40 40 14
- **Second lact. yld (kg)**: 305 days or below 28 9 10 10 26 26 32 14
- **Third lact. yield (kg)**: 305 days or below 24 8 8 8 21 16 31 11

---

K = Average number of half-sibs per sire

**4.4.1. Heritability estimates**

The heritability values from uncorrected data were found to be higher with higher standard errors for all the traits (Table 22) of HF x SW crossbreds. When the data was adjusted by fitting constants for the effects of farm, parity, season and period, the standard errors of the heritability values were reduced. On further standardization of data for
Table 22. Heritability estimates with standard errors of various traits of HF x S crossbred

<table>
<thead>
<tr>
<th>Traits</th>
<th>From unadjusted</th>
<th>From adjusted except genetic group</th>
<th>From adjusted for nongenetic and genetic group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weights (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wt. at birth</td>
<td>0.168±0.068</td>
<td>0.155±0.057</td>
<td>0.156±0.057</td>
</tr>
<tr>
<td>Wt. at 2 mths age</td>
<td>0.632±0.157</td>
<td>0.266±0.083</td>
<td>0.261±0.082</td>
</tr>
<tr>
<td>Wt. at 4 mths age</td>
<td>0.627±0.156</td>
<td>0.224±0.074</td>
<td>0.216±0.072</td>
</tr>
<tr>
<td>Wt. at 6 mths age</td>
<td>0.442±0.121</td>
<td>0.178±0.063</td>
<td>0.175±0.062</td>
</tr>
<tr>
<td>Wt. at 9 mths age</td>
<td>0.411±0.115</td>
<td>0.152±0.059</td>
<td>0.158±0.058</td>
</tr>
<tr>
<td>Wt. at 12mths age</td>
<td>0.545±0.141</td>
<td>0.202±0.094</td>
<td>0.205±0.087</td>
</tr>
<tr>
<td>Wt. at 15mths age</td>
<td>0.657±0.161</td>
<td>0.296±0.090</td>
<td>0.322±0.095</td>
</tr>
<tr>
<td>Wt. at 18mths age</td>
<td>0.715±0.171</td>
<td>0.320±0.093</td>
<td>0.340±0.099</td>
</tr>
<tr>
<td>Wt. at first fertile service</td>
<td>0.156±0.058</td>
<td>0.115±0.048</td>
<td>0.117±0.046</td>
</tr>
<tr>
<td>Wt. at 1st calving</td>
<td>0.336±0.120</td>
<td>0.195±0.087</td>
<td>0.192±0.085</td>
</tr>
<tr>
<td>Growth rate g/day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth to 2mths age</td>
<td>0.454±0.104</td>
<td>0.153±0.048</td>
<td>0.149±0.046</td>
</tr>
<tr>
<td>2 to 4mths age</td>
<td>0.218±0.072</td>
<td>0.063±0.035</td>
<td>0.063±0.035</td>
</tr>
<tr>
<td>4 to 6mths age</td>
<td>0.128±0.043</td>
<td>0.054±0.027</td>
<td>0.052±0.026</td>
</tr>
<tr>
<td>6 to 9mths age</td>
<td>0.099±0.039</td>
<td>0.045±0.030</td>
<td>0.046±0.031</td>
</tr>
<tr>
<td>9 to 12mths age</td>
<td>0.105±0.039</td>
<td>0.092±0.036</td>
<td>0.095±0.037</td>
</tr>
<tr>
<td>12 to 15mths age</td>
<td>0.100±0.039</td>
<td>0.025±0.021</td>
<td>0.038±0.024</td>
</tr>
<tr>
<td>15 to 18mths age</td>
<td>0.064±0.031</td>
<td>0.025±0.024</td>
<td>0.025±0.022</td>
</tr>
<tr>
<td>Production traits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age at first calving (mths)</td>
<td>0.481±0.129</td>
<td>0.451±0.122</td>
<td>0.454±0.123</td>
</tr>
<tr>
<td>1st Lact.yld(kg)</td>
<td>0.272±0.093</td>
<td>0.180±0.071</td>
<td>0.191±0.074</td>
</tr>
<tr>
<td>Initial yld(kg)</td>
<td>0.114±0.088</td>
<td>0.168±0.060</td>
<td>0.164±0.058</td>
</tr>
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</table>

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<table>
<thead>
<tr>
<th>Traits</th>
<th>From unadjusted</th>
<th>From adjusted except genetic group</th>
<th>From adjusted for nongenetic and genetic group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascending yield (kg)</td>
<td>0.162±0.064</td>
<td>0.104±0.045</td>
<td>0.101±0.044</td>
</tr>
<tr>
<td>Peak yield (kg)</td>
<td>0.376±0.129</td>
<td>0.396±0.132</td>
<td>0.391±0.131</td>
</tr>
<tr>
<td>Descending yield (kg)</td>
<td>0.352±0.123</td>
<td>0.291±0.109</td>
<td>0.301±0.112</td>
</tr>
<tr>
<td>1st Milking1st lact. (kg)</td>
<td>0.214±0.078</td>
<td>0.176±0.069</td>
<td>0.168±0.072</td>
</tr>
<tr>
<td>First lact. length (days)</td>
<td>0.126±0.058</td>
<td>0.079±0.045</td>
<td>0.074±0.044</td>
</tr>
<tr>
<td>First dry period (days)</td>
<td>0.105±0.057</td>
<td>0.025±0.046</td>
<td>0.007±0.030</td>
</tr>
<tr>
<td>First 170-305 days lact. length</td>
<td>0.083±0.051</td>
<td>0.045±0.042</td>
<td>0.026±0.037</td>
</tr>
<tr>
<td>First 170-305 days lact. yield (kg)</td>
<td>0.222±0.184</td>
<td>0.172±0.085</td>
<td>0.168±0.072</td>
</tr>
</tbody>
</table>

Genetic grades deviation from least square mean, the precision of heritability were found to be higher. Further genetic and phenotypic correlations were also found to be higher with higher precision (Table 22 and Fig.8a,b).

The h², r_g and r_p estimates on standardized data are only presented and discussed in detail for all breed groups (Figs.6, 7, 8a, 9).

4.4.1.1. Heritability estimates of body weights:— The heritability values were higher for all body weight traits of Sahiwal cattle except weights at 6, 9 and 15 months age. The highest h² value (0.593±0.191) was observed for weight at 2 months age and lowest (0.294±0.174) for weight at 9 months age (Fig.6).
The estimates for body weights of BSxSw crossbreds revealed high heritability (0.571±0.213) for weight at 15 months age and the low heritability (0.169±0.203) for weight at first calving (Fig. 7).

The highest estimate was found to be 0.340±0.099 for weight at 18 months age and lowest was 0.117±0.048 for weight at fertile service among all the body weight traits of HFxSw crossbreds (Fig. 8a).

The highest \( h^2 = 0.603±0.160 \) and lowest \( h^2 = 0.105±0.112 \) heritability values were observed for weight at 2 months age and weight at first calving respectively for SwxHF crossbreds (Fig. 9).

4.4.1.2. Heritability estimates for growth rate g/day:- In Sahiwal cattle the high heritability was observed for growth rate from birth to 2 months age \( h^2 = 0.616±0.192 \) whereas for other growth rate traits the estimates were low (Fig. 6).

The heritability estimates which ranged from 0.131±0.130 to 0.245±0.139 were observed for growth rate traits for BSxSw crossbred calves (Fig. 7).

The low heritability estimate ranging from 0.025±0.022 to 0.149±0.046 were observed for HFxSw crossbreds (Fig. 8a).

The heritability estimates for growth rate g/day at various intervals of age in SwxHF crossbred cattle were low except from birth to 2 months age, where it was found to be 0.444±0.126 (Fig. 9).
4.4.1.3. Heritability estimates for production traits

(a) Age at first calving (months): The high heritability values $0.745\pm0.205$, $0.482\pm0.223$, $0.454\pm0.123$ and $0.635\pm0.187$ were found for Sahiwal, B5x5w, Hfx5w and SwxHF crossbred cattle respectively (Figs. 7, 8a and 9).

(b) First lactation yield and its components: The heritability estimates of first lactation yields were $0.238\pm0.140$, $0.124\pm0.166$, $0.191\pm0.074$ and $0.062\pm0.076$ for $5w$, B5x5w, Hfx5w and SwxHF crossbred cattle respectively. The estimates of $h^2$ for initial ascending, peak and descending yield of first lactation of $5w$ and B5x5w crossbreds followed one trend and Hfx5w and SwxHF crossbreds followed another trend (Figs. 6, 7, 8a and 9). The heritability of peak yield was $0.553\pm0.192$, $0.290\pm0.110$, $0.391\pm0.131$ and $0.275\pm0.140$ for $5w$, B5x5w, Hfx5w and SwxHF crossbred breed groups respectively. These estimates were higher from other components of first lactation yield. The heritability of milking average ranged from $0.168\pm0.072$ (Hfx5w) to $0.454\pm0.176$ ($5w$).

(c) First total lactation length and first 170-305 days lactation length

The $h^2$ values of $0.132\pm0.118$, $-0.051\pm0.111$, $0.074\pm0.044$ and $-0.096\pm0.045$ for first total lactation length were observed for $5w$, B5x5w, Hfx5w and SwxHF crossbreds. The values estimated from 170 to 305 days lactation length were $0.197\pm0.144$, $0.015\pm0.130$, $0.026\pm0.037$ and $-0.033\pm0.046$ respectively.

(d) First dry period: The $h^2$ values for first dry period were $-0.141\pm0.071$, $0.193\pm0.207$, $0.007\pm0.030$ and $0.272\pm0.157$ for $5w$, B5x5w, Hfx5w and SwxHF crossbreds respectively.
(a) First, second and third lactation yields (305 days or below) 

The heritability estimates for \( S_w, B_s x S_w, H_F x S_w \) and \( S_w \times H_F \) crossbreds were \( 0.476 \pm 0.259, 0.157 \pm 0.174, 0.169 \pm 0.072 \) and \( 0.152 \pm 0.131 \) for first standard lactation yield; \( 0.586 \pm 0.237, 0.091 \pm 0.032, 0.231 \pm 0.135 \) and \( 0.176 \pm 0.112 \) for second standard lactation yield and \( 0.256 \pm 0.219, -0.048 \pm 0.266, 0.245 \pm 0.138 \) and \( 0.356 \pm 0.169 \) for third standard lactation yield respectively.

4.4.2. Genetic and Phenotypic correlations: The genetic and phenotypic correlations among 10 body weight traits at various chronological age, 7 growth rate traits at different age intervals and 8 production traits were estimated for \( S_w, B_s x S_w, H_F x S_w \) and \( S_w \times H_F \) crossbred cattle.

4.4.2.1. Genetic and Phenotypic correlation of body weight traits

(i) Genetic correlations: Genetic correlations > 0.25 were observed among several body weight traits except 3 and 9 (0.16±0.37), 4 and 9 (0.23±0.44) traits in Sahiwal cattle. High genetic correlations were observed between 1 with 5; 2-3, 4-5, 6, 7, 8; 3-4, 5, 6, 7; 4-5, 6, 7, 8; 5-6, 7, 8, 9; 6-7, 8; 7 with 8 and 9 with 10 traits. Negative genetic correlation of weight at 2, 6, 15 and 18 months age with weight at first calving was observed (fig.6).

Genetic correlations > 0.25 were observed among all body weight traits except between 2 and 10 (0.19±0.25) in \( B_s x S_w \) crossbreds. High genetic correlations (> .70) between 2-3, 4-5, 6, 7, 9; 3-4, 5, 6, 9; 4-5, 6, 9; 5-6, 7, 8, 9; 6-7, 8, 9; 7-8, 9 and 8 with 9 were observed. Birth weight, weight at 9, 12, 15, 18 months age
and weight at first fertile service were negatively correlated with weight at first calving. These negative $r_G$ were low in order and ranged from $-0.04 \pm 0.24$ to $-0.19 \pm 0.18$ (Fig. 7).

Genetic correlations more than 0.25 were observed between all body weight traits of HF$x$S$_w$ crossbreed except 2 with 9 ($r_G = 0.17 \pm 0.24$). Genetic correlations more than 0.70 were found between 2-3, 4, 5; 3-4, 5, 6; 4-5, 6, 7, 8, 9, 10; 5-6, 7, 8, 10; 6-7, 8, 10; 7-8, 10; 8 with 10 and 9 with 10 traits (Fig. 8a).

In S$_w$xHF crossbreed, genetic correlation $\angle 0.25$ were observed for several body weight traits. Genetic correlations more than 0.70 between 2-3, 4, 5, 6, 7, 8; 3-4, 5, 6, 7, 8; 4-5, 6, 7, 8; 5-6, 7; 6-7, 8 and 7 with 8 traits were observed (Fig. 9). Negative $r_G$ between 5 with 10 and 9 with 2, 3, 4, 5 were observed.

(ii) Phenotypic correlations ($r_p$): Phenotypic correlations $\angle 0.25$ were observed for several body weight traits in Sahiwal. Phenotypic correlations more than 0.70 were observed between 2 with 3, 3 with 4, 4 with 5, 5 with 6, 6 with 7 and 7 with 8 traits. High and low $r_p$ were observed $0.99 \pm 0.01$ (between 3 and 4 traits) and $0.07 \pm 0.06$ (between 2 and 10 traits). (Fig. 6).

Phenotypic correlations $\angle 0.25$ were found between weight at calving with all body weight traits except with weight at first fertile service ($0.40 \pm 0.04$) and also between weight at fertile service with birth, 2 and 4 months weight. High $r_p$ were observed between 2 with 3, 3 with 4, 4 with 5, 5 with 6, 7; 6 with 7,8 and 7 with 8. (Fig. 7).

Less than 0.25 $r_p$ were observed among several body weight traits of HF$x$S$_w$ cattle. Correlation between birth weight
and weight at first calving was 0.10±0.03. Phenotypic correlations more than 0.70 were observed 3 with 5, 6 with 7 and 7 with 8 traits (Fig.8a). Body weights recorded at low age had poor associations (r_p) with weight at higher age (weight at first fertile service and weight at calving).

Phenotypic correlations < 0.25 were observed between several body weight traits in SxHF crossbreds. Phenotypic correlations more than 0.70 were observed 3 with 4, 4 with 5, 5-6, 7; 6 with 7 and 7 with 8 traits. Body weight at 4, 6 and 9 months age were negatively correlated with weight at first fertile service and their association was low in order.

4.4.2.2. Genetic and Phenotypic correlations of growth rate traits

(i) Genetic correlations: Genetic correlations more than 0.25 were estimated in all traits except between 11 and 14 (0.19±0.41) in Sahiwal breed. Positive genetic correlations more than 0.70 were found between 11-12, 16; 12-15, 16; 13-14, 15, 16, 17; 14-17; 15-16, 17 and 16 with 17 growth traits. Negative r_G were observed 11 with 17, 12 with 13, 14, 17 and 14 with 16 traits (Fig.6).

More than 0.25 r_G were observed between growth rate traits except 11 with 15 (0.07±0.60) and 14 with 17 (0.05±0.57) in BxS crossbreds. High positive r_G were observed 11 with 13, 13 with 15 and 15 with 16 traits. Negative r_G 11 with 14, 17; 12-14, 17; 13-14, 15, 17; 14 with 15, 15 with 17 and 16 with 17 were observed. These negative r_G were ranged from -0.05±0.44 to -0.19, 0 (Fig.7).

Genotypic correlations more than 0.25 were found
between several growth traits except between 12-16, 17; 13-14, 17 and 14 with 15 traits in HF x SW crossbreds. High \( r_g \) were observed 11 with 12 (0.86±0.07), 12 with 13 (0.96±0.03), 15 with 16 (>1.0) and 16 with 17 (>1.0). Negative \( r_g \) between 11-13, 14; 12 with 14, 13 with 16; 14-16, 17 were found and these values ranged from -0.04±0.46 to -0.42±0.36 (Fig. 8a).

More than 0.25 \( r_g \) between all growth rate traits were found except 11 with 16 (-0.12±0.57) in SW x HF crossbreds. High genetic correlations were estimated 11 with 14; 12-13, 14; 13 with 16 and 15 with 16 traits. Negative \( r_g \) were observed 11 with 16; 12-15, 16, 17; 13 with 15; 14-15, 16 and 15 with 17 traits.

(ii) Phenotypic correlations:

Phenotypic correlations ≤15±.06 were found between all growth traits of Sahiwal cattle. Low and negative \( r_p \) were observed between 11-14, 17; 12-13, 14, 16, 17; 13-15, 17; 14-15, 16 and 15 with 17 traits (Fig. 8).

The highest \( r_p \) 11 with 12 was found to be 0.27±0.03 whereas other correlations were low in order. Negative \( r_p \) of growth traits between 11-14, 17; 12-14, 17; 13-14, 15, 17; 14-15, 16, 17; 15-16, 17 and 16 with 17 traits were calculated in BS x SW crossbreds.

Less than 0.13±0.02 \( r_p \) were observed between all growth traits in HF x SW crossbreds. Low and negative \( r_p \) were estimated between 11-14, 17; 12-14, 15, 16; 13-15, 17; 14-16, 17; 15 with 17 and 16 with 17 traits which ranged from -0.01±0.02 to -0.14±0.38 (Fig. 8a).
Phenotypic correlations \(0.20 \pm 0.03\) were obtained between all growth traits of S\(\times\)HF crossbreds. The negative \(r_p\) were found between 11-14, 15, 17; 12-14, 15, 16, 17; 13-15, 17; 14-15, 16 and 15 with 17 traits but they were low in order.

4.4.2.3. Genetic and Phenotypic correlations of production traits

(i) Genetic correlations: Genetic correlations more than 0.25 were estimated for all production traits in Sahiwal cattle. Genetic correlations more than 0.70 were found between 18-23, 24; 19 with 20; 20-21, 22, 23, 24, 25; 21-22, 23; 22-23, 24, 25; 23-24, 25 and 24 with 25 traits (Fig.6).

In B\(\times\)S\(\times\) high \(r_G\) were observed between all traits except 18-19, 20, 25; 19-22, 23, 25; 20 with 21 and 23 with 25 production traits. Age at first calving was genetically negatively correlated with initial, ascending and peak yield, and lactation length with total milk yield, initial and descending yields (Fig.7).

In H\(\times\)S\(\times\) high positive \(r_G\) were observed among all production traits (Fig. 8a) except 19 with 21 (0.03\(\pm 0.35\)) and 19 with 22 (0.04\(\pm 0.45\)). Genetically age at first calving was negatively correlated with lactation length, first lactation yield and its components (initial, ascending, peak, descending and milking average).

More than 0.25 \(r_G\) were observed between several production traits except between 18-20, 25 and 19 with 24 traits in S\(\times\)HF crossbreds. High \(r_G\) 19 with 22; 20-22, 23, 24; 21-22, 23; 22-23, 24, 25 and 23 with 24 traits were observed. Negative \(r_G\)
<table>
<thead>
<tr>
<th>No.</th>
<th>Traits</th>
<th>Growth rate (g/day) traits</th>
<th>Production traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight at birth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td>Age at first calving (mths)</td>
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<td>First lactation yield (kg)</td>
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<td>25</td>
<td>First milking average (kg)</td>
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**FIG. 6** HERITABILITY, GENETIC AND PHENOTYPIC CORRELATIONS

WITH STANDARD ERRORS OF SW CATTLE

|     | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    | 15    | 16    | 17    | 18    | 19    | 20    | 21    | 22    | 23    | 24    | 25    |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|     | 533   | 49    | 39    | 37    | 77    | 68    | 51    | 48    | 39    | 26    | 21    | 18    | 16    | 43    | 38    | 36    | 34    | 24    | 28    | 01    | 06    | 07    | 06    | 07    | 06    |
| 1   | 153   | 154   | 155   | 156   | 157   | 158   | 159   | 1510  | 1511  | 1512  | 1513  | 1514  | 1515  | 1516  | 1517  | 1518  | 1519  | 1520  | 1521  | 1522  | 1523  | 1524  | 1525  | 1526  | 1527  | 1528  |
| 2   | 327   | 328   | 329   | 330   | 331   | 332   | 333   | 334   | 335   | 336   | 337   | 338   | 339   | 340   | 341   | 342   | 343   | 344   | 345   | 346   | 347   | 348   | 349   | 350   | 351   |
| 3   | 19    | 20    | 21    | 22    | 23    | 24    | 25    | 26    | 27    | 28    | 29    | 30    | 31    | 32    | 33    | 34    | 35    | 36    | 37    | 38    | 39    | 40    | 41    | 42    | 43    |
| 4   | 44    | 45    | 46    | 47    | 48    | 49    | 50    | 51    | 52    | 53    | 54    | 55    | 56    | 57    | 58    | 59    | 60    | 61    | 62    | 63    | 64    | 65    | 66    | 67    | 68    |
| 5   | 69    | 70    | 71    | 72    | 73    | 74    | 75    | 76    | 77    | 78    | 79    | 80    | 81    | 82    | 83    | 84    | 85    | 86    | 87    | 88    | 89    | 90    | 91    | 92    | 93    |

**GENETIC CORRELATIONS**

**PHENOTYPIC CORRELATIONS**

(The heritability values are given at diagonals)
### Fig. 8(a) Heritability, Genetic and Phenotypic Correlations

**With Standard Errors of HF x SW Crossbreds**

#### Genetic Correlations

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#### Phenotypic Correlations

(The heritability values are given at diagonals)

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**Note:** This document contains a table and a diagram with numerical data that describe heritability and genetic and phenotypic correlations between different traits in HF x SW crossbreds. The table includes standard errors for each correlation. The phenotypic correlations are indicated by the values on the diagonal, while the genetic correlations are presented in the off-diagonal elements. The data is presented in a structured format, with rows and columns representing different traits or genetic markers. The table helps in understanding the relationships and variability within the crossbred population.

FIG. 9 HERITABILITY, GENETIC AND PHENOTYPIC CORRELATIONS
WITH STANDARD ERRORS OF SW X HF CROSSBREEDS

GENETIC CORRELATIONS

\[
\begin{array}{ccccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\
\text{1} & 255.35 & 55.66 & 68.38 & 40.40 & 27.18 & -10 & 28.74 & -83.77 & -23.21 & 0.53 & -73.47 & 46.56 & \text{>106.36} & \text{-0.21} \\
\text{2} & 25 & 60.93 & 84.91 & 58.86 & 14.07 & -28.79 & 67.97 & -63.51 & 1.56 & -0.44 & 10.60 & -40.81 & -25.31 & \text{<165.04} & -0.08 \\
\text{3} & 15 & 66.32 & 97.15 & 73.13 & 54.80 & 87.69 & 93.31 & -87.31 & 0.15 & -0.10 & 0.86 & 0.51 & -0.01 & \text{-20.62} & \text{<115.10} \\
\text{4} & 15 & 50.84 & 27.94 & 10.02 & 0.36 & 0.02 & 0.10 & 0.66 & 92.86 & -87.50 & 25.37 & 0.05 & -28.43 & 47.65 & 62.22 & -42.16 \\
\text{5} & 12 & 35.65 & 80.22 & 99.98 & 56.77 & -0.07 & 0.03 & 0.75 & 10.72 & 86.49 & 63.22 & -12.40 & -80.85 & 54.79 & -27.43 & 15.22 \\
\text{6} & 42 & 38.47 & 60.73 & -30.35 & 0.98 & 0.68 & 0.79 & 99.99 & 62.63 & -19.30 & 46.48 & -83.54 & 54.24 & -0.04 & -54.62 & 21.03 \\
\text{7} & 15 & 28.47 & 60.71 & -78.73 & 96.37 & -14.87 & 0.90 & 38.10 & 10.91 & -85.43 & -10.30 & 74.73 & 16.04 \\
\text{8} & 15 & 22.49 & 59.59 & 33.64 & 84.84 & 39.90 & 0.66 & 70 & 10.69 & -42.81 & 21.15 & -20.84 & 32.08 & -0.10 & 30.12 & 13.44 \\
\text{9} & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 \\
\end{array}
\]

PHENOTYPIC CORRELATIONS
(THE HERITABILITY VALUES ARE GIVEN AT DIAGONALS)
were observed between 18-19, 21; 19-20, 21, 22, 25; 20 with 25 and 23 with 25 traits.

The genetic correlations of first standard lactation yield with second and third were \(0.99\pm0.01\) and \(0.56\pm0.33\) for \(S_w\); \(>1.0\) and \(>1.0\) in \(B_s\times S_w\); \(0.33\pm0.26\) and \(0.16\pm0.37\) for \(H_f\times S_w\) and \(0.48\pm0.52\) and \(0.24\pm0.43\) for \(S_w\times H_f\) crossbreds. The estimates of \(r_{G}\) between second and third lactation were \(0.71\pm0.35\) \((S_w)\), \(0.79\pm0.29\) \((B_s\times S_w)\), \(-0.21\pm0.39\) \((H_f\times S_w)\) and \(0.91\pm0.06\) \((S_w\times H_f)\) noticed. Genotypic correlations of first and second lactation yield with first dry period were \(-0.05\pm0.33\) and \(-0.45\pm0.27\) for \(S_w\); \(-0.82\pm0.28\) and \(-0.84\pm0.55\) for \(B_s\times S_w\); \(>1.0\) and \(-0.45\pm0.44\) for \(H_f\times S_w\) and \(0.04\pm0.76\) and \(0.06\pm0.44\) for \(S_w\times H_f\) crossbreds.

(ii) Phenotypic correlation: Phenotypic correlations more than 0.25 were observed between several production traits except age at first calving with all other production traits, 19-21, 25 in \(S_w\) cattle. High \(r_p\) \((0.77\pm0.01)\) was found between 19 and 20; and 0.88\pm0.01\) between 22 and 23 traits. Low negative \(r_p\) \((-0.01\pm0.05)\) between 18 and 19 was observed (Fig. 6).

In \(B_s\times S_w\) crossbreds, \(r_p\) more than 0.25 were observed between several productive traits except age at first calving with all other traits, 19 with 21, 22, 23, 24 and 25. High \(r_p\) values were found 19 with 20; 21-22, 23 and 22 with 23 traits. Negative \(r_p\) were found between age at first calving with lactation length and peak yield traits (Fig. 7).

Phenotypic correlations more than 0.25 were observed between several production traits except that of age at first calving with various production traits and lactation length with
21, 22, 23, 24 and 25 traits in HF x Sw crossbreds. Very low and negative r_p \((-0.01\pm0.03)\) were observed between 18 and 19 traits. Phenotypic correlations more than 0.70 between 22 with 23, 23-24, 25; 24 with 25 traits were observed (Fig.8a).

In Sw x HF crossbreds r_p more than 0.25 were estimated between several production traits except age at first calving with production traits and lactation length with 21, 22, 23, 24 and 25 traits. Negative r_p was observed between 19 and 25 traits (Fig.9).

The phenotypic correlations of first standard lactation yield with second and third and 2nd with 3rd lactation were respectively 0.65\(\pm0.02\), 0.48\(\pm0.04\) and 0.54\(\pm0.03\) for Sw; 0.56\(\pm0.04\), 0.51\(\pm0.06\) and 0.64\(\pm0.05\) for BS x Sw; 0.52\(\pm0.02\), 0.35\(\pm0.03\) and 0.49\(\pm0.03\) for HF x Sw and 0.47\(\pm0.02\), 0.46\(\pm0.03\) and 0.59\(\pm0.02\) for Sw x HF crossbreds. The phenotypic correlations of first and second lactation yield with first dry period were \(-0.15\pm0.06\), \(-0.04\pm0.06\) for Sw; \(-0.40\pm0.11\), \(-0.19\pm0.12\) for BS x Sw; \(-0.07\pm0.03\), 0.10\(\pm0.03\) for HF x Sw and \(-0.02\pm0.04\) and 0.05\(\pm0.04\) respectively.

4.4.2.4. Genetic and Phenotypic correlations between body weight and growth rate(g/day) traits

(i) Genetic correlation: In Sahiwal cattle r_G more than 0.25 were observed between many traits except between 1-11, 16; 3 with 13, 7 with 13; 9-11, 13 traits. Negative r_G were found between 1 with 13, 9 with 12, 10-11, 13, 15, 16, 17 traits (Fig.6).
In 85x5w crossbreds $r_G$ more than 0.25 were estimated between body weights and growth rate traits except 1-11, 17; 2-15, 16, 17; 3-16, 17; 5-16, 17; 6-16, 17; 9 with 14; 10-12, 13, 15, 17 traits. Negative $r_G$ were calculated between 1-13, 14, 16; 2 with 14; 3-14, 15; 4-14, 15, 16, 17; 5 with 14, 6 with 14, 7 with 14, 8 with 14, 9 with 16 and 10-11, 14 traits (Fig.7).

Genotypic correlations more than 0.25 were found between body weights and growth rate traits except between 1-12, 13, 17; 2 with 14, 3 with 14, 4 with 14, 7 with 14, 8 with 14, 9 with 11; 10-11, 16 traits. High genetic correlations were estimated between many traits in HFx5w crossbreds. Negative genotypic correlations were observed between 1 and 14 ($-0.04_{0.03}$), 2 and 13 ($-0.02_{0.07}$), 9 and 14 ($-0.13_{0.43}$) traits (Fig.8a).

In SuHF crossbreds $r_G$ more than 0.25 were estimated between several traits except 1-11, 17; 5 with 17; 9-12, 13 traits. High $r_G$ were estimated between 1-13, 14; 2-11, 14; 3-11, 12, 14, 16; 4-12, 13, 14; 5-11, 12, 13, 14; 6-11, 12, 14; 7-11, 12, 13, 14; 8-13, 14, 17; 10-11, 12, 14 traits. Negative $r_G$ were observed between many traits (Fig.9).

(ii) Phenotypic correlations— Phenotypic correlations more than 0.25 were found between 11-2, 3, 4, 5, 6, 7, 8; 12-3, 4, 5, 6; 13-4, 5, 6, 7, 8; 14-5, 6, 7, 8; 15-7, 8 traits. High $r_p$ was found between 2 and 11 ($0.85_{0.01}$) traits. Negative $r_p$ were found between 1-11, 12; 2-14, 3 with 14; 4-14, 15; 5 with 15 and 10 with 17 traits (Fig.6).

In 85x5w crossbreds, high $r_p$ was found to be $0.82_{0.01}$ between 2 and 11 traits. Phenotypic correlation values
more than 0.25 were observed between many traits. Negative \( r_p \) were found 3 with 14, 4 with 14, 5 with 16, 6 with 16, 9 with 15, and 10 with 14 traits (Fig. 7).

High \( r_p (0.85 \pm 0.01) \) was observed between 2 and 11 traits in HF \( \times S_w \) crossbreds. Phenotypic correlations more than 0.25 were found between many traits of body weight and growth rate. Negative \( r_p \) between 1–11, 15; 2–14, 17; 3 with 14; 3–15, 16; 4–14, 15; 5–15, 16, 17; 6–16, 17; 7 with 17 and 10 with 15 were found (Fig. 8a).

In \( S_w \times H F \) crossbreds high \( r_p (0.87 \pm 0.00) \) was found between 2 and 11 traits. Phenotypic correlations more than 0.25 were found between 11–2, 3, 4, 5, 6; 12–3, 4, 5, 6, 7; 13–4, 5, 6, 8; 14–5, 6; 15–6, 7, 8; 16–7, 8 and 17 with 8 traits. Negative \( r_p \) were found 1 with 14; 2–14, 17; 3–14, 17; 4–14, 17; 5 with 17, 6 with 17 and 10 with 17 traits.

4.4.2.5. Genetic and phenotypic correlations between body weight and production traits

(i) Genetic correlation- High positive \( r_G \) were observed between 5–24, 25; 10 with 25 traits and high negative between 5–19, 21, 22, 23 and 6 with 21 traits in Sahiwal breed. Age at first calving was negatively correlated with all body weight traits. Several negative correlations between lactation length, first total lactation yield, initial, ascending, peak, descending and milking average with body weight traits were noticed. Weight at first fertile service and weight at first calving were positively correlated with first lactation yield and its components (Fig. 6).
In BSxSw high $r_g$ were observed 7 with 19, 8 with 19 and 8 with 23 traits. Several negative $r_g$ between body weight traits and production traits were observed. Age at first calving was negatively correlated with birth weight, weight at 2, 6 and 15 months age. Weight at first calving was negatively correlated with first lactation yield and its components (Fig.7).

In HFxSw high $r_g$ between 4-21, 22; 5-21, 22; 6-21, 22, 23, 24; 7-21, 22, 23, 25; 8-21, 22, 23, 25; 9-20, 21, 22, 23, 24, 25 and 10-20, 21, 22, 23, 24 traits were observed. Age at first calving was negatively correlated with all body weight traits and six months weight with lactation length (Fig.8a).

High $r_g$ were observed 1 with 13 and 0 with 21 traits of SwxHF crossbreds. Age at first calving was negatively correlated with all body weight traits except with birth, 4 and 12 months age. Several negative correlations between body weight traits and production traits were noticed (Fig.9).

(ii) Phenotypic correlations: Phenotypic correlations $r_p \geq 0.25$ were observed between body weights and production traits in Sahiwal breed. Several negative $r_p$ were observed between these traits. Age at first calving was negatively correlated with all body weight traits except with weight at calving (Fig.6).

In BSxSw crossbreds $r_p \geq 0.25$ were observed between all correlations except 1 with 25 (0.45±0.07) and 10 with 18 (0.26±0.05) traits. Age at first calving was negatively correlated with body weight traits except with weight at first calving. Negative $r_p$ were also noticed 10 with 19, 6 with 21, 7 with 21, 6 with 22, 1 with 24, 2 with 24, 2 with 25 and 7 with 25 traits (Fig.7).
In HF x Sw crossbreds $r_p$ were more than 0.25 were observed between 9-18; 10-20, 23, 24, 25 traits. Age at first calving was negatively correlated with all body weight traits except body weight at first fertile service and weight at first calving. Negative $r_p$ were observed 6-19 and 10-19 traits (Fig.8a).

In Sw x HF crossbreds all $r_p$ were more than 0.25 except between 18-10 (0.26 + 0.04) traits. Age at first calving was negatively correlated with all body weight traits except with 4 and 9 months' age and weight at calving. Negative $r_p$ were observed between 2-19, 3-19, 10-19 and 2-20 traits (Fig.9).

4.2.6. Genetic and phenotypic correlations between growth rate (g/day) and production traits

(i) Genetic correlations: Age at first calving was negatively correlated with 12, 15 and 17 traits in Sw breed. High negative $r_G$ were estimated between 12-18, 21, 22, 23, 24; 13-19; 14-19, 21, 22, 23; and 17-18 traits. High positive $r_G$ were observed between 13-25; 14-18; 14-24, 25; 15-19, 20, 21, 23; 17-20, 23, 24, 25 traits (Fig.6).

In BS x Sw crossbreds age at first calving was negatively correlated with growth rate traits except with 17 trait. Several other high negative correlations between growth rate and production traits were noticed. High positive $r_G$ between 11-19, 22, 23, 24; 13-19, 22; 15-21, 22, 23; 16-19, 20, 24; 17-22, 23, 24, 25 traits were found (Fig.7).

Age at first calving was negatively correlated with growth traits of HF x Sw crossbreds. Negative $r_G$ were also observed between 11-19; 16-19 and 17-19 traits. High positive $r_G$ were
estimated between 12-21, 24; 14-19, 20, 24; 15-21, 22; 16-21, 22; 17-20, 21, 22, 23, 24, 25 traits (Fig. 8a).

In SwxHF crossbreds, age at first calving was negatively correlated with growth traits except with 11 and 12 traits. Several other negative $r_g$ were also noticed. High $r_g$ values were found between 12-21, 22; 14-21, 15-20, 22, 23, 25; 17-22 traits (Fig. 9).

(ii) Phenotypic correlations: Phenotypically age at first calving was negatively correlated with all growth traits of Sahiwal cattle and correlation ranged from $-0.03\pm0.07$ to $-0.16\pm0.06$. Less than 0.25 $r_p$ were observed between all traits. Several negative $r_p$ but low in order were observed between growth rate and production traits (Fig. 6).

In 85xSw crossbreds, age at first calving was negatively correlated with all growth rate traits and values ranged from $-0.01\pm0.08$ to $-0.18\pm0.09$. Correlations $\angle 0.25$ were noticed between growth rate and production traits and several $r_p$ were negative (Fig. 7).

In HFxSw crossbreds $r_p \angle 0.25$ were observed between all growth rate and production traits. Age at first calving was negatively correlated with all growth rate traits except with growth rate between 15 and 18 months' age. Negative $r_p$ were observed between 15-19 and 16-21 traits (Fig. 8a).

Phenotypically age at first calving was negatively correlated with all growth rate traits of SwxHF crossbreds and values ranged from $-0.03\pm0.04$ to $-0.11\pm0.04$. Less than 0.25 $r_p$ were observed between all traits. Low negative correlation between 11-19, 20; 14-21; 15-19; 17-19; 20-23 traits were estimated (Fig. 9).
4.5. Selection Indexes

The traits used in developing selection indexes were:

\[ X_1 = \text{Body weight at 6 months' age (kg)} \]
\[ X_2 = \text{Body weight at 12 months' age (kg)} \]
\[ X_3 = \text{Body weight at first calving (kg)} \]
\[ X_4 = \text{Age at 1st calving (mths)} \]
\[ X_5 = \text{Peak milk yield (kg)} \]
\[ X_6 = \text{Mmilking average (kg)} \]

Four selection indexes (Hazel, 1943) for each breed groups of SW, BSxSW, HFxSW and SWxF were constructed incorporating:

I. \( X_1 \) to \( X_6 \) traits
II. \( X_2, X_3 \) and \( X_6 \) traits
III. \( X_3, X_5 \) and \( X_6 \) traits
IV. \( X_4, X_5 \) and \( X_6 \) traits

The correlation between selection index and aggregate breeding value \( R_{IH} \), the expected genetic change of the trait (values in parentheses), value of each trait in the selection index (underlined) and total expected genetic gain in rupees \( (\Delta H) \) is given in Table 23 and Fig. 10a,b; 11a,b; 12a,b and 13a,b. It is evident from the table that higher \( R_{IH} \) values for Index IV were observed in four breed groups with low expected aggregate genetic gain \( (\Delta H) \) than Index I and II. Though Index II had low correlation between Index and aggregating breeding value \( R_{IH} \) but showed higher expected genetic gain \( \Delta H \) than Index III and IV.
Table 23. Selection Indexes using six end three traits

<table>
<thead>
<tr>
<th>Index No.</th>
<th>(\Delta M)</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[I]</td>
<td>245.65</td>
<td>91.24</td>
</tr>
<tr>
<td>(I = 0.078X_1 + 0.278X_2 + 0.460X_3 - 3.941X_4 + 3.348X_5 + 6.445X_6)</td>
<td>(.81)</td>
<td>(4.06)</td>
</tr>
<tr>
<td></td>
<td>12.13</td>
<td>.81</td>
</tr>
<tr>
<td></td>
<td>11.8</td>
<td>(-1.20)</td>
</tr>
<tr>
<td></td>
<td>14.2</td>
<td>(.86)</td>
</tr>
<tr>
<td></td>
<td>10.9</td>
<td>(.70)</td>
</tr>
<tr>
<td></td>
<td>10.8</td>
<td></td>
</tr>
<tr>
<td>[II]</td>
<td>172.62</td>
<td>88.98</td>
</tr>
<tr>
<td>(I = 0.435X_2 + 0.321X_3 + 7.291X_6)</td>
<td>(.84)</td>
<td>(.94)</td>
</tr>
<tr>
<td></td>
<td>12.12</td>
<td>(.94)</td>
</tr>
<tr>
<td></td>
<td>20.2</td>
<td>(.82)</td>
</tr>
<tr>
<td>[III]</td>
<td>95.96</td>
<td>78.28</td>
</tr>
<tr>
<td>(I = 0.309X_3 + 0.325X_5 + 7.003X_6)</td>
<td>(.74)</td>
<td>(.82)</td>
</tr>
<tr>
<td></td>
<td>7.47</td>
<td>(.94)</td>
</tr>
<tr>
<td></td>
<td>35.5</td>
<td>(.94)</td>
</tr>
<tr>
<td>[IV]</td>
<td>96.66</td>
<td>93.89</td>
</tr>
<tr>
<td>(I = -3.445X_4 + 7.507X_5 - 5.358X_6)</td>
<td>(-1.01)</td>
<td>(.78)</td>
</tr>
<tr>
<td></td>
<td>14.6</td>
<td>(.39)</td>
</tr>
<tr>
<td></td>
<td>16.1</td>
<td>(.39)</td>
</tr>
</tbody>
</table>

**BS x Sm crossbred**

<table>
<thead>
<tr>
<th>Index No.</th>
<th>(\Delta M)</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[I]</td>
<td>197.60</td>
<td>74.02</td>
</tr>
<tr>
<td>(I = 2.655X_1 - 2.146X_2 + 0.537X_3 - 1.316X_4 + 11.389X_5 + 10.547X_6)</td>
<td>(.11)</td>
<td>(3.45)</td>
</tr>
<tr>
<td></td>
<td>31.2</td>
<td>(.45)</td>
</tr>
<tr>
<td></td>
<td>2.61</td>
<td>(2.61)</td>
</tr>
<tr>
<td></td>
<td>48.5</td>
<td>(.39)</td>
</tr>
<tr>
<td></td>
<td>23.7</td>
<td>(1.15)</td>
</tr>
<tr>
<td></td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>[II]</td>
<td>134.97</td>
<td>70.42</td>
</tr>
<tr>
<td>(I = 0.114X_2 - 0.010X_3 + 2.457X_5)</td>
<td>(.49)</td>
<td>(.47)</td>
</tr>
<tr>
<td></td>
<td>17.7</td>
<td>(.90)</td>
</tr>
<tr>
<td></td>
<td>19.6</td>
<td>(.10)</td>
</tr>
<tr>
<td>[III]</td>
<td>18.87</td>
<td>71.05</td>
</tr>
<tr>
<td>(I = 0.041X_3 - 0.617X_5 + 0.155X_6)</td>
<td>(-.58)</td>
<td>(.74)</td>
</tr>
<tr>
<td></td>
<td>26.6</td>
<td>(.28)</td>
</tr>
<tr>
<td></td>
<td>28.4</td>
<td>(.19)</td>
</tr>
<tr>
<td></td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>[IV]</td>
<td>47.31</td>
<td>90.86</td>
</tr>
<tr>
<td>(I = -10.624X_4 - 16.672X_5 + 39.230X_6)</td>
<td>(-.62)</td>
<td>(-.46)</td>
</tr>
<tr>
<td></td>
<td>16.4</td>
<td>(.47)</td>
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<td></td>
<td>12.2</td>
<td>(.56)</td>
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<td>29.5</td>
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---contd. (Table 23)---

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<tr>
<th></th>
<th>( I )</th>
<th>( X_1 )</th>
<th>( X_2 )</th>
<th>( X_3 )</th>
<th>( X_4 )</th>
<th>( X_5 )</th>
<th>( X_6 )</th>
<th>( \Delta H )</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>( 0.09X_1 + 0.08X_2 + 0.08X_3 - 0.24X_4 + 0.20X_5 + 1.11X_6 )</td>
<td>239.95</td>
<td>58.21</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>( (2.22)2.1 )</td>
<td>( (15.74)3.03 )</td>
<td>( (9.89)13.4 )</td>
<td>( (2.12)3.0 )</td>
<td>( (1.59)22.3 )</td>
<td>( (1.81)27.8 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>( 0.39X_2 + 0.05X_3 + 0.96X_6 )</td>
<td>149.65</td>
<td>56.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( (11.83)24.0 )</td>
<td>( (10.16)3.4 )</td>
<td>( (0.76)26.7 )</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>III</td>
<td>( 0.13X_3 + 2.01X_4 - 0.99X_6 )</td>
<td>72.54</td>
<td>74.75</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>( (6.76)20.8 )</td>
<td>( (0.85)28.8 )</td>
<td>( (0.55)12.3 )</td>
<td></td>
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</tr>
<tr>
<td>IV</td>
<td>( -1.72X_4 - 3.88X_5 + 3.31X_6 )</td>
<td>9.36</td>
<td>78.50</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>( (-15)28.0 )</td>
<td>( (0.02)27.1 )</td>
<td>( (-0.04)7.0 )</td>
<td></td>
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</table>

**HF x SS crossbreds**

<table>
<thead>
<tr>
<th></th>
<th>( I )</th>
<th>( X_1 )</th>
<th>( X_2 )</th>
<th>( X_3 )</th>
<th>( X_4 )</th>
<th>( X_5 )</th>
<th>( X_6 )</th>
<th>( \Delta H )</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>( -0.08X_1 + 0.59X_2 - 0.39X_3 - 0.03X_4 - 0.54X_5 + 3.96X_6 )</td>
<td>196.84</td>
<td>91.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( (2.28)1.2 )</td>
<td>( (3.77)9.7 )</td>
<td>( (10.34)13.0 )</td>
<td>( (-1.16)83.5 )</td>
<td>( (0.22)0.9 )</td>
<td>( (0.51)4.70 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>( 0.10X_3 + 0.03X_3 + 0.01X_6 )</td>
<td>136.22</td>
<td>44.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( (11.19)18.9 )</td>
<td>( (8.36)3.4 )</td>
<td>( (0.95)14.4 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>( 0.04X_3 - 2.42X_4 + 2.61X_6 )</td>
<td>5.70</td>
<td>89.77</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( (0.82)3.5 )</td>
<td>( (-0.9)45.6 )</td>
<td>( (1.13)42.0 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>( -4.35X_4 + 2.57X_6 )</td>
<td>85.27</td>
<td>93.56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( (-1.13)70.0 )</td>
<td>( (0.35)2.4 )</td>
<td>( (0.16)8.9 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Figures in parentheses indicate the rate of genetic gain per unit of change in the index.

Figures underlined show the value of each variate in a selection index.

---
FIG 11.6: SELECTION INDEX MAP PATH COEFFICIENT USING THREE TRAITS OF BSW CROSSBRED CATTLE (II II IVI IV)
FIG. 12.16 SELECTION INDEX MAP (PATH COEFFICIENTS) USING SIX TRAITS OF HF ZSW CROSSBRED CATTLE (I)

- $G$ = Genotypic Correlations
- $X$ = Phenotypic
- $E$ = Environmental

$A_{G_1} = 0.4623$
$A_{G_2} = 0.4425$
$A_{G_3} = 0.4606$
$A_{G_4} = 0.4639$
$A_{G_5} = 0.4635$
$A_{G_6} = 0.4623$

$A_{X_1} = 0.4325$
$A_{X_2} = 0.4236$
$A_{X_3} = 0.4697$
$A_{X_4} = 0.4578$
$A_{X_5} = 0.4539$
$A_{X_6} = 0.4384$

$A_{E_1} = 0.4726$
$A_{E_2} = 0.4645$
$A_{E_3} = 0.4726$
$A_{E_4} = 0.4653$
$A_{E_5} = 0.4584$
$A_{E_6} = 0.4697$

$A_{G_1 X_1} = 0.6426$
$A_{G_2 X_2} = 0.6234$
$A_{G_3 X_3} = 0.6436$
$A_{G_4 X_4} = 0.6385$
$A_{G_5 X_5} = 0.6392$
$A_{G_6 X_6} = 0.6356$

$A_{G_1 E_1} = 0.6624$
$A_{G_2 E_2} = 0.6435$
$A_{G_3 E_3} = 0.6523$
$A_{G_4 E_4} = 0.6456$
$A_{G_5 E_5} = 0.6568$
$A_{G_6 E_6} = 0.6532$
FIGURE (b) Selection Index Map (Path Coefficient) Using Three Traits Of

HXSW Crossbred Catle (III I IV)

Diagram showing the relationship between three traits using a selection index map.
FIG 13(B) SELECTION INDEX MAP (PATH COEFFICIENT) USING $\text{N}^{\text{TH}}$ THREE TRAITS OF SWYHF CROSSBRED CATTLE (III III W)
DISCUSSION

Performance testing of body weights (5.1), growth rates (5.2) and production traits (5.3) of Sw, BSxSw and HFxSw-SwHF crossbreds was done by fitting least square constants. A comparative superiority of exotic x Sahiwal crosses over Sahiwal population and various genetic groups with different level of exotic inheritance over halfbreds was also tested for selected traits. The prediction equations of first lactation yield on the basis of some selected economic traits (Set I) and first lactation components (Set II) were drawn. The genetic estimates of traits (5.4) and selection indexes (5.5) constructed on selected traits are discussed.

5.1. Body weights (kg)

5.1.1. Weight at birth: The least square mean of birth weight of Sw female calves was 21.03±0.13 kg which was 1 to 2 kg higher (Mishra, 1973; More et al., 1974 and Bhatnager et al., 1974) and 0.6 to 0.8 kg lower (Sayer, 1936; Singh and Dutt, 1967; Mudgal and Ray, 1965a,b). However, Bhatnager et al. (1986) and
Taneja and Bhat (1970) observed the values quite close to the present observation. The birth weight of Sw female calves was significantly lower than its exotic crossbred female calves. Such observations were also made by Naidu and Desai (1965), Taneja and Bhat (1970) and Mishra (1973).

The average birth weight of BSxSw (25.51±0.22 kg) was quite close to that reported by Bhatnagar et al. (1973). The average value of HFxSw-SwxHF calves was 23.45±0.07 kg, which was quite similar (23.44±0.12) to that reported by Taneja (1973) but the value reported by Naidu and Desai (1965) was 1.7 to 3.4 kg higher. Lush (1945) and Pirchner (1969) stated that such differences between breeds within species is a matter of differences in gene and genotype frequencies.

Various grades of BSxSw and HFxSw-SwxHF crosses differed significantly. Out of total variation in birth weight 4.07 percent was due to BS and 1.41 percent due to HF inheritance. Similar differences in genetic grades of exotic x Zebu crosses were observed by Naidu and Desai (1965), Taneja and Bhat (1970), Pandey (1971), Ganpule (1971), Patil et al. (1974), Murty (1974) and Chauhan et al. (1975). The mean value of 25.19 kg of BSxSw halfbred was almost similar to that reported by Bhatnagar et al. (1975) and Chauhan et al. (1975). The average birth weight of various grade of HF inheritance was quite close to that observed by Pandey (1971), Taneja (1973) and Patil et al. (1974). The values reported by Naidu and Desai (1965) and Ganpule (1971) were higher than observed in this study.
The average weight of calves born in first and second parity was lower in birth weight than that of 3rd and higher order in all breed groups. The variation accounted due to parity of birth was 4.44 percent and was significant in BSxSw crossbred only. Arora et al. (1971) and Gurbachan Lal (1975) did observe the significant difference for parity order. The average weight of calves of Sw and HFxSw-SwxHF crosses increased with the increase in parity, though it was statistically not significant. Non-significant effect due to parity was claimed by Kohli et al. (1956) and Singh et al. (1968) in Haryana and Jayaramkrishna et al. (1970) in Sahiwal cattle.

Farm to farm variation in birth weight was significant for HFxSw-SwxHF crossbreds in order of 2.85 percent. This might be due to variation in parity order of cows, grade composition, agro-climatic condition and managemental factors. The calves born at Lucknow, Meerut and Ambala were positively deviated from their common mean, while Bareilly, Birdhantouri and Jullundur were negatively deviated. The average birth weight of Sw calves born at Meerut was 0.34 kg lower in weight than NDRI farm Karnal. Significant effects due to farm were also reported by Naidu and Desai (1965), Taneja and Bhat (1970), Pandey (1971), Taneja (1973) and Gurbachan Lal (1975).

FrisianxSahiwal crossbred calves born during March to May and BSxSw during June-August were significantly (P<0.05) higher in birth weight. This might be due to better growth of foetus in uterus, as the down calves had an advantage
of better fodder and climate at respective farms. Seasonal contribution was in order of 1.18 percent. Kohli et al. (1956), Singh et al. (1968), Parija (1972) and Taneja (1973) did not find significant effect due to season on birth weight, while Mudgal and Ray (1965a,b), Taneja and Bhat (1971), Mishra (1973) and Chauhan et al. (1975) reported significant effect.

Significant variation due to period was accounted 9.06 and 12.5 percent on birth weight of HF x Sw × HF and Sw calves respectively. Significant effect of period on birth weight was also observed by Taneja and Bhat (1970), Katpatal (1970), Mishra (1973) and Taneja (1973). Dhillon and Acharya (1971) did not find significant effect due to period on birth weight of Mariana calves. The period effect was non-significant in BS x Sw crossbreds. The linear decrease in birth weight of Sahiwal calves from 21.70 kg in 1st period to 19.11 kg in 5th period could be due to inbreeding depression in succeeding generations and less care given to Sw cows with the outcome of crossbred cows. The highest birth weight of BS x Sw crossbreds in first period could be due to maximum heterosis in small numbers (8) of halfbred (F₁) calves. Highest birth weight for HF x Sw × HF was found in the 5th period (1973-75), which might be due to increase in proportion of exotic inheritance and general improvement in management of the farms.

5.1.2. Weight at 2 months' age: The overall average weight (43.67±0.34 kg) of Sw female calves at 2 months age was 7.6 kg higher from Bhatnagar et al. (1973 and 1974) and 1.4 kg
higher from Mishra (1973). Bhatnager et al. (1973-1974) reported
from small number of observations with high standard error on
uncorrected records. Sahiwal female had significantly lower
weight than its BS and HF crossbreds. Lower weights of Zebu calves
than Exotic x Zebu crosses were reported (Rathore, 1949; Parija,
1972 and Mishra, 1973). The mean birth weight of BSxSw was 46.84 kg
which was 1 to 6 kg higher from Bhatnager et al. (1973 and 1974).
Taneja (1973) reported 5.7 kg lower weight than present estimate
of HFxSw-SwHF. The reason might be that Taneja reported on weekly
basis (8 weeks = 56 days) while this study was on two month = 60
days basis. Significant (P<0.01) difference among genetic groups
of HFxSw was observed due to the varying proportions of HF
inheritance. Such differences were also noticed by Taneja (1973).

The effect of parity on body weight at two months' age was confounding in three breed groups. Reports on parity
effect were not available from the literature consulted.

Significant effect due to farm observed for Sw and HFxSw-SwHF
was in agreement with the findings of Parija (1972) and Taneja
(1973). Deviations due to farm revealed that weight at 2 month
age at NDRI farm Karnal was 6.2 kg lower than at Meerut farm.
This could be largely due to differences in managerial practices.

Season of birth had no significant effect in Sw and its BS crosses.
Mishra (1973) also did not notice significant effect of season of
birth on two months' body weight of Sw calves. Significant effect
due to season of birth found for HFxSw-SwHF crossbreds was
contrary to the finding of Parija (1972), Mishra (1973) and Taneja
(1973).
The effect due to period of birth was significant (P<0.01) quite similar to other reports (Parija, 1972; Mishra, 1973 and Taneja, 1973).

5.1.3. Body weight at 4 months’ age:- The least square mean for S\textit{w} female calves was 70.24±0.61 kg which was higher from the reported values (61.65±10.36 kg by Mudgal and Ray, 1965a,b and 67.94±0.67 kg by Mishra, 1973). The body weight of BS\textit{x}S\textit{w} was 74.80±1.79 kg. This was 6.3 kg less than Bhatnagar \textit{et al.} (1973) and 5.5 kg higher than Bhatnagar \textit{et al.} (1974). Parija (1972) and Mishra (1973) reported significant effect of breed group in Zebu and their Friesian crosses. This was also observed in the present study. Highly significant (P<0.01) effect due to farm was observed for S\textit{w} and HF\textit{x}S\textit{w}–S\textit{w}xHF crossbreds which was in agreement with that of Parija (1972).

Significant effect due to season of birth was observed for BS\textit{x}S\textit{w} and HF\textit{x}S\textit{w}–S\textit{w}xHF crossbreds but non-significant in S\textit{w}. These results were in agreement with the finding of Mishra (1973). Highly significant (P<0.01) effect due to period of birth on four months’ weight reported in this study was in agreement with that of Mishra (1973). It was observed that calves born during 4th period had higher weight at four months’ age which might be due to better managemental conditions prevailed during that time.

5.1.4. Body weight at 6 months’ age:- Least square mean of 97.20±0.75 kg for S\textit{w} female was 0.90 kg higher than that reported by Mishra (1973). The weight of BS\textit{x}S\textit{w} 107.82±2.43 kg was lower from reported weight of 113.82±22.1 kg by Bhatnagar \textit{et al.} (1973) and
higher from 92.6+14.6 kg by Bhatnagar et al. (1974). The reason might be that this study was based on large number of records analyzed by least square technique, while Bhatnagar et al. (1973, 1974) reported simple mean from small number of unadjusted records. The overall average weight observed for HFxSw-SwxHF crossbreed was in agreement with that of Pandey (1971) and Taneja (1973). Significant difference in average weight of three breed groups observed in this study was as reported by Goswami and De (1963), Pandey (1971) and Mishra (1973). Significant (P<.05) effect among grades of HF and BS inheritance was similar to that reported by Pandey (1971) and Taneja (1973). Higher grades attained heavier weight than lower grades at six months' age. Out of total variation 4.12 and 1.22 percent in HFxSw-SwxHF and BSxSw grades respectively was due to fraction of exotic inheritance. The average body weight for each genetic group of HFxSw-SwxHF was slightly deviating from Ganpule (1971), Pandey (1971) and Taneja (1973).

About 0.94 percent variation due to parity of birth on six months' body weight was observed for BSxSw which was significant (P<.05). Calves born in second parity were heavier at 6 months' age. It appeared that the variation due to parity on birth weight was dwindled away by the time calves attained 6 month age. Highly significant (P<.01) effect due to farm was observed for Sw calves. The calves at NDRI farm, Karnal were on an average 20 kg lower in weight at 6 months' age than calves at Meerut farm. The farm to farm variation accounted for HFxSw-SwxHF grades was 12.09 percent (significant). Since uniform managemental
practices were followed on all military farms, the differences might have occurred due to differences in the genetic composition of the herd.

The observed significant (P \leq 0.01) effect due to season of birth for BSxSW and HFxSW-SxHF crossbreds was similar to that claimed by Pandey (1971), Misra (1973) and Taneja (1973). Mishra (1973) could not find significant effect of season for indigenous cattle and it was also observed in this study for SW cattle. The significant variation accounted due to period of birth for SW, BSxSW and HFxSW-SxHF was 4.50, 29.06 and 3.95 percent respectively. The improvement in managemental practices and change in genetic composition of herd may account for such differences. Significant difference due to period of birth was also reported by Mishra (1973) and Taneja (1973).

5.1.5. Body weight at 9 months' age: The overall average body weight at 9 months' age for SW, BSxSW and HFxSW-SxHF was 128.52\pm1.49, 136.28\pm2.49 and 158.71\pm0.64 kg respectively. Mishra (1973) reported 137.86\pm1.23 kg body weight for SW which was higher from this study. The reason might be that he had reported weight for Meerut farm only whereas in the present study there were two farms and a least square mean was derived. Significant difference in breed groups was observed in this study as reported by Parija (1972) and Mishra (1973).

The effects due to season and period of births were highly significant (P \leq 0.01) for all the breed groups studied and were in agreement with the findings of Mishra (1973). Weight at 9 months for each genetic group of HF inheritance reported by Murty (1974) was higher from this study.
5.1.6. Body weight at 12 months' age: Least square mean of body weight was found to be 159.54±1.78 kg which was 23.0 and 19.8 kg lower than reported by Taneja and Bhat (1971) and Mishra (1973) respectively but 4.34 kg higher from Bhatnagar et al. (1973). Variation in body weight might be due to different herd and period used for the estimate. Bhatnagar et al. (1973 and 1974) reported 182.7±28.7 kg and 162.2±3.04 kg body weight for BSxSw with high standard errors, these values were respectively higher and lower from this study. Overall average weight of HFxSw-SwHF crossbred was similar to that reported by Pandey (1971) and was about 9 kg lower than that of Taneja (1973). The average body weight at 12 months' age for each genetic group of HF inheritance was in the line of Ganpule (1971), Pandey (1971), Taneja (1973), Patil et al. (1974) and Murty (1974). Among all grades studied the highest and lowest weight was found for halfbreds and 1/8 grades, similar findings were observed by the above workers. The difference among mean of BS and HF exotic inheritance grades was significant as was in line of Pandey (1971), Taneja and Bhat (1972) and Taneja (1973). The variation due to HF and BS level of inheritance was found to be 3.53 and 3.01 per cent respectively. Grades with high exotic inheritance grow at faster rate to develop their higher body weight, as was reported by McDowell et al. (1969). Goswami and De (1963), Naidu and Desai (1963) and Murty (1974) reported higher growth and body weight for halfbred calves. Significant variation in order of 8.5 and 12.09 per cent due to farm observed in this study for Sw and HFxSw-SwHF cattle respectively was similar to the findings of Taneja and Bhat (1972), and Taneja (1973). Pandey
(1971) did not find significant difference due to farm in heavy rain fall area. Ambala, Lucknow and Meerut maintained higher weights at this age also. Parity of birth had no effect on weight at 12 months' age.

Sahiwal and BS×Sw calves born during June-August with higher birth weight had significantly higher body weight at 12 months' age. Variation due to season of birth was found to be 2.6, 2.41 and 5.39 per cent for Sw, HF×Sw×Sw×HF and BS×Sw crossbred calves respectively. Significant difference due to season was also observed by Tanaja and Bhat (1972), Parija (1972), Mishra (1973) and Tanaja (1973).

Variation observed due to period of birth in order of 3.45, 18.01 and 3.59 per cent for Sw, BS×Sw and HF×Sw×Sw×HF calves respectively was highly significant. Significant variation due to period of birth was in agreement with the findings of Tanaja and Bhat (1972), Mishra (1973) and Tanaja (1973).

5.1.7. Body weight at 15 months' age: The average weight of Sw female calves (189.97±2.23 kg) observed by least square mean was lower from reported weight of 209.5±1.65 kg by Mishra (1973) but recorded weight of Meerut farm was similar, due to same farm and similar material used in these two studies. Among three breed groups studied, Friesian crossbred females showed significantly (P<0.01) higher weight (224.95 kg) at 15 months' age, this might be due to the inheritance of superior genes of HF for higher weight gain. The observation made by Murty (1974) for
higher grades was similar to these findings but low, for lower grades. The effect due to the level of exotic inheritance was highly significant ($P<0.01$). Higher grade (7/8) of HF was negatively deviated from their common mean. This might be due to the reason that environmental level may not be adequate to permit this level of exotic inheritance to show the superior performance. Menzi (1970) stated that considering natural tolerance within a certain range in between two extremes genotype and environment have to be in accordance with the optima.

The effect due to season of birth was highly significant ($P<0.01$) for BSxSw crossbreds but non-significant for Sw and HFxSw-SwxHF crossbreds. Mishra (1973) reported significant effect of season on 15 months' weight for Zebu cattle but non-significant for HFxSw. The variation associated with period of birth was highly significant ($P<0.01$) in three breed groups studied. Similar significant effect was also reported by Mishra (1973) for indigenous and their Frisian crosses.

### 5.1.8. Body weight at 18 months' age - Least square mean

219.95 + 2.32 kg of Sahiwal cattle was about 16 kg lower than reported by Mishra (1973) but average weight observed for Meerut farm in this study was about 5.0 kg higher. The variation might be due to different farms and technique used for the estimate. Pandey (1971) reported lower overall average weight of HFxSw-SwxHF crossbreds for heavy rain fell areas. The effect due to genetic groups of exotic inheritance was significant. Halfbred and higher grades of BS and HF had higher weights from their lower
grades. The body weights reported by Pandey (1971), Ganoule (1971) and Murty (1974) for higher and lower grades were somewhat similar.

Effect associated due to farms was significant (P<.01) for Sw and HFxSw-SwXF at 18 months' body weight. Similar effects were observed by Pandey (1971) and Singh and Dessi (1971). The variation caused by season of birth was found significant for HFxSw-SwXF crossbred females as was reported by Mishra (1973) but effect due to season on Sw and BSxSw was not detectable statistically. Period of birth had significant effect on body weight at 18 months' age in three breed groups studied. Similar observations were also made by Mishra (1973).

5.1.9. Body weight at first fertile service:—The body weight 288.9±2.75 kg observed for Sw heifer was almost similar to reported weight 288.74±31.07 kg by Mudgal and Ray (1965a,b: 1966). Whereas Mishra (1973) reported 34 kg higher body weight from military farm records. Sahiwal heifer had about 14 kg higher weight from its BS crossbred heifers. The average body weight of HF crossbred heifers was 317.13±1.75 kg which was significantly higher from Sw and BSxSw heifers. Mishra (1973) observed about 23 kg higher body weight for halfbreds of HF at fertile service. The difference could be due to the statistical technique as Mishra reported simple mean but this study was made by fitting least square constants. The higher weight of HFxSw-SwXF heifer from Sw, BSxSw might be due to the better genes for growth inherited through Friesian germ plasm. Calves born to aged cows (5th or above parity) were higher in weight in all the breeds studied. Various grades of BS inheritance did not differ significantly while the grades of HF had
significant difference at fertile service. Further the body weights of BSxSw grades differed significantly up to 18 months age while HFxSw-SwxHF grades continued to differ up to weight at first calving. This might be due to the differences of gene functioning among grades of two exotic breeds.

The influence of the farms was significant (P<0.01) for Sw and HFxSw-SwxHF crossbreds which might be due to the disproportionate grade distribution at various farms, agro-climatic and management factors.

5.1.10. Body weight at first calving: The body weights at first calving were 331.55±2.18, 347.48±6.88 and 350.67±4.99 kg for Sw, BSxSw and HFxSw-SwxHF crossbreds. The difference between two exotic crossbred groups was non-significant. Similar finding was also noticed by Rathore (1949). The body weight at first calving reported by Mudgal and Ray (1965a,b), Khanna (1968) and Mishra (1973) was higher for Sw breed, which could be due to differences in number of records, generation improvement and statistical technique used in deriving the population mean. Pandey (1971), and Taneja (1973) reported higher body weight for HFxSw-SwxHF from present study. The improvement in breeds' composition and management has reduced the age at first calving which might have resulted in lower body weights. The effect due to grade of HF inheritance was significant (P<0.01) and was also reported by Rathore (1949), Naidu and Desai (1965); Ganpate (1971), Pandey (1971) and Taneja (1973) in HFxRS and HFxSw-SwxHF crossbreds. Non-significant effect due to BS inheritance indicated that all grades had similar body weight irrespective to
their level of exotic inheritance, because differences in weight were narrowed due to differences in age at first calving. It was observed that higher grades (6/8 and 7/8) and lowest grade 1/8 had low body weight than other grades which could be due to poor adaptability of higher grade and low level of exotic genes in lower grades. Higher weight of halfbreds at first calving was in agreement to that of reported by Institute of Agriculture Statistics (1982).

Significant effect due to farm for Sw, and HF$x$Sw–SwxHF was in agreement with that of Naidu and Dossi (1965), Pandey (1971) and Taneja (1973). The effect due to season of birth was significant for BS$x$Sw only. The effect due to period was significant (P≤0.01) for Sw and HF$x$Sw–SwxHF crossbreds, similar to that observed by Taneja (1973) for HF$x$Sw crossbreds. Mishra (1973) estimated significant effect due to period and non-significant due to season as was observed in Sw cattle in this study.

5.2. Growth rate (g/day) traits:

The growth rate (g/day) from birth to 2 months,
2–4, 4–6, 6–9, 9–12, 12–15 and 15–18 months' age are discussed below:

5.2.1. Growth rate from birth to 2 months' age: Least square mean indicated the similarity of Sw and BS$x$Sw crossbred females in weight gained per day from birth to 2 months' age. Significantly higher growth rate (505.2±3.1 g) per day of HF$x$Sw–SwxHF crossbreds suggested the superiority of Friesian genes. Rathi et al. (1974)
reported absolute weight gain for Hariana and its HF, B5 and Jersey crossbreds which were lower than this study. The rate of gain per day among different Friesian grades was significant. The grade 7/8 had highest average gain g/day and 1/8 grade had lowest average gain, which indicates the superiority of Friesian level of inheritance and genes functioning. Halfbreds of B5xSw grew at faster rate than its other grades which might be due to better heterotic phenomenon.

The effect due to farm on average gain per day for Sw and HFxSw-SwxHF was found highly significant (P<0.01). The reason could be managerial differences and unequal distribution of genetic grades at these farms. The effect due to parity was observed non-significant. It suggests that female calves born to heifers though they were lighter at birth gained slightly more to make-up their differences in body weight. Variation due to season of birth was significant for HFxSw-SwxHF and non-significant for Sw and B5xSw crossbreds. Significant (P<0.01) effect due to period of birth on growth rate was observed. Higher viability of growth during fourth period reflected the better management practices and birth of offspring with higher exotic germ plasm.

5.2.2. Growth rate from 2-4 months' age— The average growth rate g/day for Sw, B5xSw and HFxSw-SwxHF was respectively 436.4±4.5, 455.7±18.8 and 533.6±3.6 g. Rath et al. (1974) reported absolute weight gain 12.79, 12.77, 12.25 and 13.09 kg for Hariana, B5xHariana, JerseyxHariana and HFxHariana respectively. The average gain per day of HFxSw-SwxHF was significantly higher than B5xSw and Sw calves. Among exotic grades, the difference
between BSxSw grades was non-significant while HFxSw grades
differed significantly for growth velocity during this period.
The highest growth rate g/day was observed for 6/8 Frisian
grades. Halfbreds of BS inheritance showed greater average
gain/day in body weight. This might be due to heterotic effect.
Variation due to farm was observed highly significant for Sw
calves and for HFxSw SwxHF crossbreds.

The BSxSw female calves born in second parity had
significantly higher growth rate at this age interval, but such
differences were not discernable for Sw and HFxSw SwxHF calves.
Variation due to season of birth was highly significant \((P<0.01)\).
It was observed that HFxSw SwxHF and BSxSw calves born during
cold comfort (September to November) and cold (December to
February) season respectively grew at faster rate from 2-4 months
age. The season might be better environment and higher feed
conversion efficiency. High significant effect due to period of
birth gives a reflection of better managemental practices and
superior genotypic frequency.

5.2.3. Growth rate from 4-6 months' age - The maximum average
growth velocity per day was observed in three breed groups during
this period (Appendix T1,2,3). The respective values for Sw,
BSxSw and HFxSw SwxHF were 451.8±7.1, 531.0±20.7 and 541.6±3.9 g
per day. This might be that the genes responsible for growth
are functioning in full swing with their maximum expression.
Mudgal and Ray (1965a,b) in Sw; Singh and Desai (1971) in
Red Sindhi; Agarwal and Tomer (1972) in Haryana; Parija (1972)
in HF x Gir; Tanaja (1973) in HF x Sw and Hingane (1975) in HF x Gir reported that growth rate velocity increased to maximum by about 6 months of age which is in close agreement with the present findings. Raju (1953) reported highest growth rate at four months in Kangayam breed. This might be due to breed differences.

Significantly higher average gain per day of BS x Sw and HF x Sw-Sw x HF crossbreds than Sw observed in this study was in agreement to the finding of Rathore (1949) in Red Sindhi and its exotic crosses and Parija (1972) in Gir and its HF crosses, Mishra (1973) in Zebu and their HF crosses, Rathi et al. (1974) in Mariana and its exotic crosses and Hingane (1975) in Gir and its HF crosses. Significant (P<0.01) difference among HF grades in average gain per day reflected the level of Frissian gene pool in different grades. Higher grades of HF (5/8 to 7/8) grew at faster rate than halfbred and lower grades (Fig. 2b). The genetic group of 3/8 BS inheritance though grew at faster rate from 4-6 months’ age but its average gain g/day was not significantly different from halfbreds (Fig. 2a).

Variation caused by farm was found highly significant (P<0.01) which reflects the agro-climatic condition, management practices and composition of grades at various farms. Significant effect due to season of birth of crossbred on growth rate g/day revealed that female calves of BS x Sw born during December to February and HF x Sw-Sw x HF during September to November had still retained their higher growth rate. This might be due to agro-climatic location of the farms. The effect due to season of birth was found non-significant on average growth rate of Sw calves.
This indicates low environmental stress and uniformity of genotype. Variation due to period of birth on average gain per day was significant for BSxSw and HFxSw-SwxF crossbreds and not for Sw because of less expected change in genotype and poor growth potential of the breed.

5.2.4. Growth rate from 6-9 months' age—Significantly higher growth rate velocity of HFxSw-SwxF crossbred over BSxSw and Sw calves suggest the superiority of HF genes for growth. The growth of BSxSw females was lower than of Sahiwal at this age interval which might be due to cessation of milk feeding and change in feeding schedule as per management practices followed at NDRI farm, Karnal. Halfbreds of BSxSw, HFxSw-SwxF had higher growth which might be due to their hybrid vigour. Higher grades (7/8 and 6/8) of HF inheritance showed a decreasing trend of gain per day which suggests the differential response to local agro-climatic conditions.

Parity of birth and period of birth had no significant effect on growth at this age interval.

Significant variation due to farm still existed.

Variation caused by season of birth at an early growth rate varied at 6-9 months age for each grade which might be due to reduced environmental effect with the increase of age apart from genotype differences. The declining trend in growth rate from six month onward was observed as by Taneja (1971), Mishra (1973) and Hingane (1975).

5.2.5. Growth rate from 9-12 months' age—The average gain per day for Sw, BSxSw and HFxSw-SwxF was 339.7±16.8, 362.8±17.5
and 393.5±4.1 g respectively. The reported growth rate between 6-12 months was 411 g of HFxSw by Taneja (1971), and 398 g (Sw), 436 g (HFxSw), 462 g (HFxTharpara), 432 g (HFxRc) by Mishra (1973). These were not comparable to this study due to differences in age intervals considered. Hingane (1975) reported growth rate in HFxGir crossbreds which was quite close to the present value. The body weight of animal increased at declined rate of growth per day with the advancing age of females from 6 months' onward.

Among grades of B5 inheritance, halfbreds grew significantly at higher rate. Among HFxSw-SuHF grades, 3/8 had significantly higher gain per day, while higher grades (7/8 and 6/8) were negatively deviated from their least square mean. Variation due to farm was significant for Sw and its Friesian crossbreds. Significantly better growth rate of HFxSw crossbred at Ambala and Meerut, and highest growth rate g/day at Lucknow reflected the superiority in management practices and exotic gene pool.

The effect due to season of birth was found highly significant for growth rate at 9-12 months age in three breed groups studied. It was observed that calves born in March-May though they had lower growth rate in the beginning but had highest average gain per day at this age. The season might be due to falling in better agro-climatic condition at this age. The effect due to period of birth was non-significant for growth rate in Sw but it was highly significant in crossbreds. This might be due to breed group differences.
5.2.6. Growth rate from 12-15 months' age: The growth velocity of Sahiwal and its Friesian crossbred declined while that of BSxSw increased. Significant positive deviation of 5/8 and 3/8 grades of HF from their least square means indicated their overall superiority. Halfbreeds of BSxSw still retained their significant higher gain per day. Variation due to farm was significant for HFxSw-SwxHF crossbred but non-significant for Sw.

The effect due to season was observed significant \( (P \leq 0.01) \) in three breed groups. The female calves born during December-February had highest growth rate per day. This might be due to the fact that calves got favourable local environmental condition and better fodder during this age interval. The effect due to period of birth was significant for HFxSw-SwxHF but non-significant for Sw and its BS crosses for the trait.

5.2.7. Growth rate from 15-18 months' age: The lowest growth rate (g/day) was observed during this period. The least square means were 330.3±14.8, 314.6±22.5 and 343.0±4.6 g per day for Sw, BSxSw and HFxSw-SwxHF crossbreds respectively (Appendix T123). The effect due to level of exotic inheritance was non-significant in BSxSw and HFxSw-SwxHF crossbreds. This could be due to confounding effect of genotype - environment.

The effect due to season of birth was highly significant \( (P \leq 0.01) \) for three breed groups studied. Least square mean and deviation due to seasons revealed that female calves born during September-November and December-February had higher growth rate at this age interval because animal enjoyed more nutritive leguminous fodder (December-May) with higher feed conversion efficiency during
this season. The effect due to period of birth was highly significant for $S_w$ and its $H_F$ crossbreds but non-significant for $B_S x S_w$ crossbreds. Least square mean and period of deviation explained the higher growth rate per day in the last period in $S_w$ and $H_F x S_w$ (1973-75). This might be due to better genotypic combinations.

5.3. Production Traits

5.3.1. Age at first calving (months): The least square means for age at first calving were $38.65 \pm 0.27$, $30.41 \pm 0.57$ and $36.36 \pm 0.25$ months for $S_w$, $B_S x S_w$ and $H_F x S_w - S_w x H_F$ respectively. Khera (1934) reported lower age (36.5 and 37.5 months) while Ambre et al. (1958), Puri and Malik (1963), Puri and Sharma (1965), Sundarajan et al. (1965) and Koul (1968) reported $45.8 \pm 1.10$, $46.3 \pm 2.28$, $40.7 \pm 4.40$, $41.0$ to $42.0$ and $40.2 \pm 0.23$ months age at first calving of $S_w$ cattle respectively which were higher from present value. The values reported by Barra and Desai (1964), Ambre and Jain (1967), Singh and Desai (1967), Gopel and Bhatnagar (1972) and Nagpal and Bhatnagar (1971) are fairly in agreement with the present value of Sahiwal. The average age reported by Bhatnagar et al. (1975) was 1.5 month higher and the value of Mishra et al. (1975) was 0.8 month lower from the present value of $B_S x S_w$ crossbreds. This could be due to differences in statistical technique used and higher number of observations in deriving present estimates. Pandey (1971) and Taneja (1973) observed about 1.5 month higher average age for $H_F x S_w$ crossbreds.

Among grades of $H_F x S_w - S_w x H_F$ and $B_S x S_w$ crossbreds highly significant ($P < 0.01$) differences were observed due to level
of exotic inheritance. Bhatnagar et al. (1975) and Tandon and Mishra (1976) did observe significant grade differences for BS levels of inheritance. The average age for each grade of HF inheritance observed in this study was closely associated with the reported value of Naidu and Desai (1965), Ambra and Jain (1966), Singh and Desai (1967), Ganpule (1971), Taneja (1973), Murty (1974) and Gurbachan Lal (1975). Pandey (1971) and Patil et al. (1974) for 5/8 grade, Bhasin and Desai (1967), Koul (1968) and Patil et al. (1974) for 4/8 grade reported higher average age, and Singh and Desai (1967) for 6/8, Ganpule (1971) for 6/8 and 7/8, and Murty (1974) for 4/8, 5/8 and 6/8 reported lower average age at first calving than their respective grades in this study.

The higher grades of HF (7/8) and of BS (6/8) inheritance dropped their calves at an average of 1.3 to 2.5 months later than their respective halfbreds. The superiority of both halfbreds (BS and HF inheritance) might be due to a combined effect of heterosis and genotype x environment interactions. Low grades of HF and BS (1/8 to 3/8) deliver calf at an early age than purebred Sw. This revealed the superiority of exotic germ plasm over Zebu for the trait. The average genotype of HF grades showed curvilinear tendency on age at first calving and this was also revealed by the work of Tandon (1951), Naidu and Desai (1965) and Ganpule (1971).

The effect due to farm was highly significant. This was also reported by Koul (1968), Nagpal and Asharya (1971), Pandey (1971) and Taneja (1973). Least square constants for farm showed that Lucknow farm had an average lowest age at first calving
followed by Jullundur, Meerut and Ambala. The reason might be due to better gene pool and management.

Significant effect due to season of calving was observed in Sw and its HF crossbreds. Similar observations were made by Acharya (1966) in Hariana cows and Koul (1968) in HFxSw. Non-significant effects found for BSxSw were similar to Tandon (1951), Nagpal and Acharya (1970), Mishra (1973) and Taneja (1973). The effect due to season of calving (Appendix T_{1,2,3}) suggested that heifers calved during March to May had lower age at first calving in three breed groups studied. The reason could be that breedable heifers attained sexual maturity and body weight during better feeding seasons (December-May) and conceived during following season (June-September). This was similar to that observed by Mishra et al. (1975) in BSxSw crossbreds. Highly significant effect due to period of calving observed in three breed groups was also found by Sundaresan et al. (1965), Koul (1968), Dhillon et al. (1970), Nagpal and Acharya (1970), Taneja (1973) and Bhatnagar et al. (1975) but Dutt and Tomer (1972), Mishra (1973) and Mishra et al. (1975) reported non-significant effect due to period of calving. Least square mean and deviation due to each period indicated that age at first calving was lowest in the 5th period (1973-1975) in three breed groups studied. It suggest the improvement in management practices and genotype.

5.3.2. First lactation yield (kg):—The least square mean of complete lactation yield was 2022.11±38.87, 3288.95±133.27 and 2495.34±39.51 kg for Sw, BSxSw and HFxSw-SwHF crossbred respectively. Significant (P<0.01) difference showed the breed
group superiority of exotic germ plasm. Sundaresan et al. (1965), Gopal and Bhatnagar (1972) and Bhatnagar et al. (1975) reported higher values while Kartha (1934), McCusken (1937), Singh and Dutt (1963), Amble and Jain (1966), Khanna and Bhat (1971) reported lower average first lactation yield of Sahiwal cows. The values reported by San et al. (1953), Puri and Sharma (1965), Nagpal and Acharya (1971) and Mishra (1973) were quite low.

Difference due to BS and HF level of exotic inheritance was highly significant (P<0.01). Among BSxSw, 3/8 grade produced significantly higher milk yield (4006.21 kg) in a longer lactation period than other contemporary grades (Fig 3a,b), but the number of cows available for the study were only six. Genetic grade (6/8) and filial group (F₁,F₂) were negatively deviated from their common mean. Bhatnagar et al. (1975) reported 56 kg lower milk yield for halfbreds and 95 kg higher yield for 6/8 grades. These differences might be due to statistical technique and number of observations used. Among HF grades, higher grades were positively and lower grades were negatively deviated from their least square mean. Halfbreds and 6/8 grades produced almost equal quantity of milk (Fig. 4a,b) but were different in lactation period. This was similar to the findings of Choudhury et al. (1974).

Significant effect due to farm was observed for Sw and its HF crossbreds. This was similar to that reported by Pandey (1971), Taneja (1973) and Choudhury et al. (1974). The performance of Lucknow farm was higher followed by Meerut and Ambala farm.

The effect due to season of calving was non-significant on first lactation yield in three breed groups studied as reported by Nagpal and Acharya (1971) and Taneja (1973). Since lactation period embraces almost all seasons, therefore, this could be one
of the potent reason under balanced stall feeding of the herd. Some of the workers (Abraham, 1973; Singh and Pandey, 1970) observed significant effect of season. This might be due to topographical and managemental differences. The effect due to period was significant for HFxSw crossbred and similar were the findings of Singh and Pandey (1970), Nagpal and Acharya (1971), Tomar et al. (1971), Tanaje (1973) and Choudhury et al. (1974). Non-significant effect for Sw and BSxSw might be due to the uniform managemental practices with scientific feeding schedules followed at these farms.

5.3.3. First lactation components (kg)

(a) Initial yield—Average initial yield per day was 5.81±0.10, 10.40±0.46 and 8.49±0.17 kg for Sw, BSxSw and HFxSw—SwxHF respectively. Highly significant variation among three breed groups indicated the superiority of average gene pool. Significant (P<.01) difference due to level of genes of BS and HF inheritance was observed. Among BS grades, 3/8 produced highest quantity of milk followed by halfbreds, 3/4 grades but filial group (F2–F3) produced lower than overall mean of initial yield. Among HFxSw grades, least square mean and deviation due to each grade showed that various level of Frissian inheritance affected the initial milk yield in a curvilinear way. This showed that with the increase of Frissian germ plane beyond 5/8 level, the initial yield per day decreased.

Significant difference due to farm showed that average initial milk yield of Sw cows at Meerut farm was 1.5 kg higher than NORI farm. The average initial yield of HFxSw crossbred at Lucknow
and Meerkat farm was higher than other farms. The effect due to season of calving was significant for HFxSw crossbred. The heifers calved during March-May months produced significantly higher initial yield from those calved during June-August months. Non-significant effect for Sw and BSxSw crossbred showed that season of calving had less influence on the performance of heifers. Period of calving had significant effect on initial yield in Sw and HFxSw crossbred but non-significant for BSxSw. This could be due to breed group differences.

(b) Ascending milk yield: The breed differences were observed significantly for ascending milk yield per day. BSxSw crossbreds produced more milk during the increasing phase of milk yield. Effect due to level of BS and HF inheritance was highly significant. Grade (3/8) of BS inheritance produced higher yields at ascending phase of lactation. Milk yield at ascending phase increased with the increase of HF inheritance upto 6/8 grade and slightly decreased beyond this (7/8). This indicated that higher grades (7/8) could not get adequate environment for its full expression.

The effect due to season of calving was highly significant for HFxSw crossbreds. Heifers calved during December-February produced higher quantity of milk. This might be due to availability of better quality of leguminous fodder. The effect due to period of calving was significant for Sw and its HF crossbreds. Sahiwal heifers calved in the last period (1973-75) and HFxSw calved in the 4th period (1970-72) produced more milk at ascending phase. This might be due to genotypic composition of yielding group and management.
(c) Peak yield: The BSxSw produced average 5.6 kg and HFxSw crossbred 2.6 kg higher maximum yield per day than purebred Sw cows. The reason for significant difference among breeds might be due to higher genotypic frequency or better allelic combination of milk producing genes in population. Variation among grades due to BS and HF inheritance was significant (P<0.01) and similar to the findings of Pandey (1971), Choudhury et al. (1974) in HFxSw and Chauhan et al. (1974) in BSxSw. The grade (3/8) of BS inheritance produced an average about 2 kg higher from halfbreed and 5 to 6 kg higher from 6/8 and filial group (F_2F_3). This could be due to better gene combination or adaptability but the number of records available were low to draw any forceful conclusion at this stage. Among HF grades, lower grades were negatively and higher grades were positively deviated from their common mean. The increasing trend in peak yield with increasing level of HF genes in the Sw was observed in a curvilinear, while Ganpule (1971) and Patil et al. (1974) reported linear increase whereas Naidu (1962) and Pandey (1971) and Choudhury et al. (1974) could not find any specific trend in peak yield. The average peak yield observed in this study was fairly close to the reported value of Ganpule (1971) for Northern farm of HFxSw crosses and Choudhury et al. (1974). The effect due to farm was observed significant (P<0.01) as was also confirmed by the work of Choudhury et al. (1974). Pandey (1971) could not find significant effect due to farm much similar to Sw breed in this study. The cows at Lucknow farm produced maximum peak yield which might be due to their superiority in exotic inheritance combination with management.
Variation due to season of calving was significant for HF x Sw crossbred and similar observation was made by Choudhury et al. (1974). Non-significant effect found for BS x Sw crossbred was also reported by Chauhan et al. (1974) in same crossbred population. Heifers (HF x Sw) calved during December-February produced higher ascending, maximum (peak), descending and milking average than heifers calving in other seasons. Sahiwal heifer calved during December-February produced slightly higher initial, ascending, peak and descending yield which might be due to low yield and better seasonal adaptability. Chauhan et al. (1976) reported similar result for higher peak yield for cows calving during December-February. The effect due to period was found significant for Sw and HF x Sw. This was also observed by Choudhury et al. (1974). Peak yield (maximum yield) was observed higher in the last period (1973-75) which might be due to improved management with high average exotic gene pool.

(d) Descending yield: The average milk yield per day at decline phase of lactation (120th day after calving) was 6.65±0.10, 10.40±0.39 and 8.68±0.13 kg for Sw, BS x Sw and HF x Sw - Sw x HF crossbred. The significant differences among breeds for this trait revealed the difference in their genetic make up. Difference due to farm was significant at descending phase. The variation due to level of inheritance was found significant for BS and HF inheritance. Curvilinear trend of milk yield at descending phase was observed with the increase of exotic inheritance of HF breed. The grade 3/8 of BS and 4/8 of HF showed their superiority in producing higher milk yield per day.
The effect due to season of calving on descending milk yield was found significant for $S_w$, $B S \times S_w$ and $H F \times S_w - S_w \times H F$ crossbreds. Period variation was significant for $H F \times S_w$ but was not significant for $S_w$ and $B S \times S_w$ crossbreds.

(a) Milking average: $B S \times S_w$ and $H F \times S_w$ produced 3.6 and 2.0 kg higher average milk yield per day in contrast to purebred Sahiwal cows. The breed differences were highly significant. Variation due to farm was found significant for $S_w$ and its Friesian crosses. The milking average of $S_w$ cows at Karnal was better than that of Meerut while $H F \times S_w - S_w \times H F$ of Lucknow maintained the superiority in comparison to other military farms housing same crosses. The effect due to grades of $B S$ and $H F$ was significant. The grade 3/8 of $B S$ and 4/8 of $H F$ produced higher milking average. Curvilinear milking average was observed with the increase of $H F$ inheritance from 1/8 to 7/8. The reported average milk yield for $S_w$ was $5.19 \pm 1.05$ kg and for 4/8 and 5/8 $H F \times S_w$ crossbreds was $8.74 \pm 0.91$ and $7.63 \pm 0.79$ kg respectively (Gurbachan Lal, 1975). This was somewhat lower than the present observations.

The effect due to season and period of calving was found non-significant for $S_w$ and $B S \times S_w$ but was significant for $H F \times S_w$. Significant effect of period might be due to the shift in average genotypic frequency and variation in management.

5.3.4. First lactation period (days): Significant differences among three breed groups were noticed for first total lactation period. $B S \times S_w$ produced milk for longer period followed by $S_w$ and $H F \times S_w$. The observed lactation period of $321.98 \pm 4.50$ days of $S_w$ was higher than reported by Kartha (1934), Singh and Choudhury (1961),
Batra and Desai (1964), Ambale and Jain (1966) and Mishra (1973) but lower from Bhatnagar et al. (1975) while the value reported by John and Taylor (1973) was in close agreement. The average lactation length observed in BSxSw was almost similar to the reported value of Bhatnagar et al. (1975). The least square mean of lactation length of HFxSw (309.52±2.94 days) was 22 days higher from Taneja (1973) and 18 days higher from Pandey (1971).

Significant effect due to level of HF inheritance and non-significant due to BS inheritance was observed. This could be due to breed difference and agro-climatic conditions. The farm considered for BS crosses was situated at one place, while those of HFxSw were spread throughout Northern and Western India. The grade (6/8) of HFxSw produced milk for a longer period than other higher grade. Significant effect observed due to level of HF inheritance was similar to that reported by Pandey (1971), Taneja (1973) and Gurbachan Lal (1975) but dissimilar from Sandhu et al. (1973). Significant (P<.01) effect due to farm observed for Sw and HFxSw crossbreds was as reported by Pandey (1971), Tomer et al. (1972), Taneja (1973) and Sandhu et al. (1973). Mean deviation due to each farm indicated that cows at Ambala and Lucknow farm produced milk for a longer period. This could be due to managerial differences.

The variation due to season of calving was significant for HFxSw crossbred and non-significant for Sw and BSxSw crossbreds. Sandhu et al. (1973) and Taneja (1973) reported non-significant effect due to season of calving on lactation length. HFxSw crossbreds calved during June-August produced more milk for a longer period.
This might be due to agro-climatic conditions. The effect due to period of calving was observed significant ($P<0.01$) for $S_w$ and $H_f\times S_w$ crossbreads. Similar was reported by Tomer et al. (1972), Taneja (1973) and Sandhu et al. (1973).

5.3.5. First dry period (days):— Average first dry period of $S_w$, $B_s\times S_w$ and $H_f\times S_w$ was 134.7±14.9, 74.40±6.00 and 124.8±3.8 days respectively. Several workers had reported first dry period for $S_w$ and its exotic crossbreds. The reported first dry period for $S_w$ cows ranged from 130±4 days (Gurbachan Lal, 1975) to 296±5 days (Batra and Desai, 1964) and for $H_f\times S_w$ grades (pooled) it ranged from 116±1.7 days (Pandey, 1971) to 138.3±3.9 days (Taneja, 1973).

Sahiwal had significantly higher dry period than its exotic crossbreds which was in agreement with the findings of several workers (Tandon, 1961; Naidu and Desai, 1966; Mishra, 1973; Abraham, 1973 and Taneja, 1973).

The effect due to farm was found significant on first dry period as was reported by Naidu and Desai (1966), Pandey (1971) and Taneja (1973). Lower dry period at NDRI farm Karnal could be due to management philosophy followed at the farm or better breeding status of these crosses.

Among $H_f\times S_w$ crossbreds lowest dry period (116.9 days) and highest (144.7 days) was observed at Ambala and Bareilly farms respectively. Among grades of $B_s$ and $H_f$, the effect due to level of exotic inheritance was observed non-significant as the trait is mostly governed by management. The observation made by Naidu and Desai (1966), Pandey (1971) and Taneja (1973) was not well in line of these reports. The lowest average dry period (60.6 days) for
4/8 B5 and 116.2 days for 4/8 HF and average highest 82.0 days for 3/8 B5 and 130.4 days for 7/8 and 1/8 of HF were observed in this study. The values reported by Naidu and Desai (1966), Pandey (1971), Ganpule (1971), Mishra (1973) and Patil (1974) were close to the present observations.

Season of calving had significant effect on first dry period for HFxSw crosses but non-significant for Sw and BSxSw. Period of calving had significant effect for BSxSw and HFxSw crosses but non-significant for Sahiwal. The lowest dry period was observed during 2nd period (1964-66) 63 days in BSxSw and 100 days in last period of HFxSw (1973-1975), which could be attributed due to better genetic combination and management.

5.3.6. First lactation period (305 days or below) - The least square mean observed for Sw was higher from that reported by Singh and Choudhury (1961), Sandhu (1968) and Mishra (1973) but lower to Batra and Desai (1964) and Amba and Jain (1966). The values reported by McGuckin (1937) and Malik et al. (1968) were in agreement with this study.

In HFxSw crosses the average lactation length was 290.27±3.86. Similar period was reported by Pandey (1971) and 3 days less by Taneja (1973). Deviation due to grade of HF inheritance was highly significant. Halfbred and higher grades produced milk for comparatively longer period. The lactation period observed for each grade in this study was well in the line of Naidu and Desai (1966), Sandhu (1968), Ganpule (1971), Pandey (1971) and Tamhan (1973) but Amba and Jain (1966), Kaul (1968), Murty (1974) and Gurbachan Lal
(1975) reported somewhat higher lactation period. Difference due to farm was significant for Sw and HFxSw crossbreds. Deviation due to season of calving was highly significant for HFxSw crosses. Period to period variation was significant for Sw, BSxSw and HFxSw breeds studied.

5.3.7. First lactation yield (305 days or below):— This was usually considered as standard yield. The least square mean was 1853.61±33.32, 2888.89±92.43 and 2352.57±33.67 kg for Sw, BSxSw and HFxSw crossbreds respectively. Crossbreds produced significantly higher milk yield than purebred Sahiwal. Several workers reported first lactation yield of Sw ranged from 1770 kg (Puri and Sharma, 1965) to 2152 kg (Sundaresan et al., 1965). Pandey (1971) and Taneja (1973) reported about 350 kg low milk yield from pooled grades of HF but Choudhury et al. (1974) reported 2323.59 kg which was very close to the present value.

The deviation due to farm was significant. Sahiwal cows at NDRI farm Karnal produced 217 kg higher milk than that of Meerut farm. Similarly HFxSw at Lucknow farm produced higher yield than other farms, maintaining these crosses. The difference among farms was also detected by Pandey (1971), Taneja (1973) and Choudhury et al. (1974).

The effects due to the level of BS and HF inheritance were observed highly significant (P<0.01) as was also seen by Naidu and Desai (1965), Khanna (1968), Amba and Jain (1967), Pandey (1971), Taneja (1973), Choudhury et al. (1974) in HFxSw and Bhatnagar et al. (1975) in BSxSw crossbred. It
might be due to the effect of the level and better setting
of exotic germ plasm. Genetic group (3/8) of BSxSw was found
comparatively superior in milk yield than purebred Sahiwal or
its other grades of BS inheritance (Fig. 3a,b). Halfbreds of
HF inheritance had higher first lactation yield than other
grades (Fig. 4a,b). Grade (6/6) of BS produced 460 kg lower
milk than 3/8 grade but in HF 6/6 produced 370 kg higher milk
from 3/8 grade. Higher grades of HF yield 400–600 kg higher
milk from that of lower grades. This could be due to difference
in exotic gene pool or setting in better combination. The
average value for each grade reported by Naidu and Desei (1965),
Pandey (1971) and Taneja (1973) were lower but values of Ganpule
(1971) and Chaudhury et al. (1974) were close to the present
investigations.

Though BSxSw and HFxSw heifers calving during the
months of September–November and Sw during December–February did
produce somewhat more milk but seasonal differences were not
very marked. The seasonal differences in production traits are
mostly obliterated by the availability of quality of fodder.
Since good feeding practices were followed on all farms
throughout the years, these differences were not discernable at
statistical level of probability. The effect due to period was
found non-significant for Sw and BSxSw but significant for HFxSw
crossbreds. Since the feeding was mostly uniform the differences
might be due to the change in genetic composition or better
combination at allelic loci.
Prediction of first lactation yield on the basis of body weights, growth rate, lactation length and age at first calving (Set I)

The linear and quadratic prediction equations along with their $R^2$ values are given in Appendix T 7a, 8a, 9a, 10a.

All quadratic equations comprising of body weights and growth rate as independent traits gave higher $R^2$ values than linear equations. This showed that these traits had curvilinear relationship with first lactation yield. Wachal and Teslik (1966) also observed curvilinear relationship between body weight and milk yield in Red Spotted cows. The $R^2$ values of quadratic equation comprising lactation length indicated 0.03 to 0.3 per cent higher variation from linear equation.

The variation explained by quadratic equations ranged from 5.01 to 58.76 per cent in $S_w$, 4.13 to 54.99 per cent in $B_5 \times S_w$, 0.58 to 46.02 per cent in $H_F \times S_w$ and 1.10 to 45.30 per cent in $S_w \times H_F$ crossbred cattle. The highest variation was explained by first lactation length alone i.e. 55.10, 56.78, 34.63 and 40.61 per cent in $S_w$, $B_5 \times S_w$, $H_F \times S_w$ and $S_w \times H_F$ crossbred respectively by linear equations. The milk yield increased by $6.64 \pm 0.45$, $9.76 \pm 0.84$, $8.53 \pm 0.43$ and $6.42 \pm 0.38$ kg for every increase of one day lactation length.

Growth rate g/day explained low variation from 0.58 ($H_F \times S_w$) to 5.01 ($S_w$) per cent among four breed groups studied.

Birth weight accounted for significant variation of 7.02, 11.85, 0.59 per cent in $S_w$, $B_5 \times S_w$ and $H_F \times S_w$ respectively and non-significant 0.25 per cent for $S_w \times H_F$ crossbreds. Among body weights,
higher variation in first lactation (8.44 per cent) was explained by weight at 12 months age in $S_w$, 14.26 and 8.68 per cent by weight at first calving ($B_5xS_w$ and $H_FxS_w$) and 2.40 per cent by weight at 6 months ($S_wxH_F$). The inclusion of body weights (birth weight, weight at 6 and 12 months age and weight at first calving) in equation revealed 11.04 ($S_w$), 15.46 ($B_5xS_w$), 11.60 ($H_FxS_w$) and 5.03 ($S_wxH_F$) per cent variation in first lactation yield. Since higher variation in first lactation yield was explained by lactation length alone, so the inclusion of body weights and age at first calving increased the magnitude of $R^2$ from 55.10 to 58.76 ($S_w$), 56.78 to 64.99 ($B_5xS_w$), 34.63 to 46.02 ($H_FxS_w$) and 40.61 to 45.30 percent ($S_wxH_F$) in crossbreds. From quadratic equations and their respective $R^2$ it appeared that body weights account for low variation.

The complete prediction equation from seven independent traits (birth weight, weight at 6 and 12 months, weight at calving, growth rate 4–6 months age, age at first calving and first lactation length) explained 58.76, 64.99, 46.02 and 45.30 per cent variation in $S_w$, $B_5xS_w$, $H_FxS_w$ and $S_wxH_F$ crossbreds respectively. By deletion of an independent trait except lactation length, the prediction value was lowered by smaller magnitude. However, the inclusion of a body weight trait in the quadratic multiple regression equation had increased the efficiency.

Prediction of first lactation yield on the basis of first lactation components (Set II)

To estimate the variation in first lactation yield from its components (initial, ascending, peak and descending yields) linear and quadratic equations were solved. The values
are given in Appendix T7b,8b,9b,10b along with their $R^2$ values. The variation accounted for by these equations ranged from 16.31 to 55.55, 24.03 to 44.75, 19.98 to 55.02 and 23.86 to 42.10 per cent in $S_w$, $B_{SxS_w}$, $HF_{xS_w}$ and $SwxHF$ crossbreds respectively. These values were significant at 5 per cent level of probability. Among individual components of first lactation the lowest variation was explained by initial yield in $Sahwal$, $HF_{xS_w}$ and $SwxHF$ crossbreds and by ascending yield in $B_{SxS_w}$ and highest variation was revealed by descending yield in $S_w$, $B_{SxS_w}$ and $SwxHF$ crossbreds and by peak yield in $HF_{xS_w}$ crossbreds.

The results of these equations and their $R^2$ values revealed that quadratic equation followed almost similar trend as that of linear. The difference of about one per cent variation was observed between linear and quadratic equations in four breed groups studied. It indicates that linear simple and multiple equations are as much reliable as quadratic to observe variation in first lactation yield. The first total lactation yield increased by $142.15\pm14.98$, $150.42\pm18.23$, $137.03\pm7.41$ and $107.09\pm10.53$ kg for each increase in one kg initial yield in $S_w$, $B_{SxS_w}$, $HF_{xS_w}$ and $SwxHF$ crossbreds.

The inclusion of ascending, peak and descending yields in the initial yield equation revealed that the total variation explained was ranging from 16.31 to 55.55, 25.37 to 44.75, 19.98 to 55.02 and 13.59 to 42.10 per cent in $S_w$, $B_{SxS_w}$, $HF_{xS_w}$ and $SwxHF$ crossbreds respectively. Since initial yield per day explained low variation in whole lactation yield, it is suggested that the inclusion of ascending, peak yield in the linear
equation would increase the efficiency of the estimate. Moreover, these traits were recorded at an early stage of lactation and for comparison no report was available from the literature consulted.

5.4. Genetic Estimates

The genetic study on crossbred animals with different fraction of exotic inheritance was conducted by several workers. Heritability, genetic and phenotypic correlations were estimated by paternal half-sib correlation method by pooling the grades with different level of exotic inheritance, 4-15/32 and 16-23/32 grades (Naidu and Dasai, 1965), 4-30/64 and 36-63/64 (Taneja, 1973), pooling all grades (Tamhane, 1973), pooling above 1/2 grades (Basu and Ghai, 1975). All the above workers pooled the grades assuming non-significant differences among different fraction of exotic gene pool. Most of the genetic estimates were derived from halfbred population with small number of paternal half-sib groups (Koul, 1968; D’Souza, 1972; Parija, 1972; Arora, 1972; Gangwar et al., 1973; Mishra, 1973; Abraham, 1973 and Hingane, 1975), except a few considered each grade as a separate genetic population, practically lowering the precisions by reducing the number of records (Khanna, 1968 and Murty, 1974).

Significant differences for several traits among various grades of exotic inheritance had been observed (Naidu and Dasai, 1965; Koul, 1968; Taneja and Bhat, 1970; Pendey, 1971; Ganpule, 1971; Taneja, 1973; Choudhry et al., 1974; Gurbachan Lal, 1975; Chauhan et al., 1975 and Bhatnagar et al., 1975).

In this study, the differences among various grades of Exotic inheritance (BS and HF) were highly significant ($p<0.01$).
The data was adjusted for all possible nongenetic effects like, farm, parity, season and periods. The analysis was made from unadjusted, adjusted for nongenetic factors and adjusted for nongenetic and genetic deviations, occurring due to level of exotic inheritance grades. High precisions were obtained for $h^2$ estimates of all the 20 traits, when grade deviations were accounted. This might be due to the fact that half-sibs under each sire were comprised of unequal number of grades, with different fraction of exotic inheritance. The genetic analysis made on 2522 half-sibs of HFxSw crossbred sired by 40 Frissian bulls with average progeny per sire ranging from 40.0-60.5 for 20 traits is shown in Table 22. It is evident from table that $h^2$ with high precision was obtained when the data was completely adjusted for nongenetic and grade deviations. Genetic and phenotypic correlations are shown in Fig. 8a-b. Lush (1949) reported that the prediction of genetic improvement had more bearing on the accuracy of the knowledge of heritability in narrow sense. Nearly perfect accuracy of predicting a bull's genetic value can be achieved if enough daughters in many herds are analyzed (Schmidt and VanVleck, 1973). Moreover $h^2$ estimates from larger sample will be more accurate with minimum sampling error. It is stated that progress $(\Delta G)$ per generation is the product of three factors.

$$\text{Progress} \ (\Delta G) = \text{accuracy}, \ (\text{Genetic Variability}), \ (\text{Intensity}).$$

If any of them is zero, the progress will be zero, no matter how high the other two may be. Further presentation and discussion is confined to the genetic estimates which were
worked out from completely adjusted records of four breed
groups (Sw, BSxSw, HFxSw and SwxHF).

5.4.1. Heritability Estimates

5.4.1.1. Heritability estimates of body weight traits:

The $h^2$ estimates of body weight at birth, 2, 4, 6, 9,
12, 15 and 18 months age, weight at first fertile service and
weight at first calving of Sw, BSxSw, HFxSw and SwxHF are given
in Figs. 6, 7, 8a, b and 9.

(a) Birth weight: The $h^2$ estimates observed were
0.533±0.182, 0.297±0.124, 0.156±0.057 and 0.255±0.100 for Sw,
BSxSw, HFxSw and SwxHF crosses of Sw respectively. Batra and Dass
(1962), Taneja and Bhat (1970), Mishra (1973) and Taneja (1973)
reported low values with standard errors ranging from 0.14±0.14
to 0.234±0.152 in Sw breed by paternal half-sib correlation.

Naidu and Dass (1965) reported 0.29±0.21 $h^2$ from
pooled grade of 1/8 to 3/8 from Northern farm which is quite
close to the present finding of SwxHF crossbred but the $h^2$ value
0.60 (1/8 to 1/2) by Taneja and Bhat (1970), 0.61±0.13 (4-30/64)
by Taneja (1973) were higher. High $h^2$ value 0.62±0.19 (36-63/64
grade) reported by Taneja (1973) was higher from this study
(HFxSw). Since $h^2$ is the estimate of variance caused by
differences in additive gene effect in a particular population
at a particular time for a particular trait, therefore, such
variations in values are possible. Moreover it was felt that the
grade deviation technique on half-sibs with unequal number under
each sire should be adopted for crossbred data to achieve reliable
estimates.
(b) Weight at 2 months' age: The $h^2$ estimates were 0.593±0.191, 0.33±0.132, 0.261±0.082 and 0.603±0.160 for $S_w$, $B_5X_Sw$, $HFxS_w$ and $SwxHF$ crossbred cattle respectively (Figs.6,7,8a and 9). Taneja (1973) reported the $h^2$ 0.55±0.16 for $S_w$ cattle by the same method. Taneja (1973) found $h^2$ (0.42±0.11) of 4-30/64 grades and of 36-63/64 grades ($h^2 = 0.75±0.22$) of $HFxS_w$ by paternal half-sib correlation.

(c) Weight at 4 months' age: The $h^2$ estimates of weight at 4 months age of $S_w$ was 0.510±0.178, of $B_5X_Sw$ 0.370±0.166, of $HFxS_w$ 0.216±0.072 and of $SwxHF$ 0.321±0.116. No report was available from the literature consulted for the comparison of these values.

(d) Weight at 6 months' age: The $h^2$ estimates were 0.365±0.189, 0.437±0.179, 0.175±0.062 and 0.274±0.108 for $S_w$, $B_5X_Sw$, $HFxS_w$ and $SwxHF$ crossbred cattle respectively (Figs.6,7,8a and 9). Taneja (1973) and Mishra (1973) reported $h^2$ values 0.60±0.24 to 0.73±0.19 respectively for Sahiwal cattle. These values were lower than the present estimate. Taneja (1973) estimated higher $h^2$ 0.62±0.14 and 0.64±0.20 for 4-30/64 grades and 36-63/64 grades of $HFxS_w$ respectively. The high $h^2$ values observed by Taneja (loc.cit.) might be due to differences in classification of genetic material. Taneja did not account for grade deviation while in this study it was taken care of very well.

(e) Body weight at 9 months' age: The $h^2$ values of 0.294±0.174 of $S_w$, 0.411±0.174 of $B_5X_Sw$, 0.158±0.058 of $HFxS_w$ and 0.224±0.093 of $SwxHF$ were estimated (Figs.6,7,8a and 9).
$h^2$ value was low at 9 months age than estimates for body weights at preceding ages. It could be assumed that change in feeding schedule from milk to concentrate and fodder quality/quantity might have dampen the genetic variation. No report was available for comparison in the literature consulted.

(f) Body weight at 12 months' age: The $h^2$ values of $S_w$, $B5xS_w$, $HFxS_w$ and $S_wxHF$ were found to be $0.407\pm0.198$, $0.460\pm0.192$, $0.285\pm0.087$ and $0.305\pm0.114$ respectively. Taneja and Bhat (1971), Mishra (1973) and Taneja (1973) reported higher $h^2$ for $S_w$ ranging from $0.62\pm0.28$ to $1.05\pm0.25$.

Naidu (1962) reported $0.78$ $h^2$ of 4-15/32 grade of $HFxS_w$ located at Northern farms, Arora (1972) observed $h^2$ $0.77\pm0.35$ for 1/2 grade. Taneja (1973) found $0.66\pm0.14$ and $0.64\pm0.20$ for 4-30/64 and 36-63/64 grades of $HFxS_w$ crossbred respectively.

(g) Body weight at 15 months' age: The $h^2$ values of $0.363\pm0.126$, $0.571\pm0.213$, $0.322\pm0.095$ and $0.173\pm0.101$ for $S_w$, $B5xS_w$, $HFxS_w$ and $S_wxHF$ were respectively observed. The high $h^2$ of $B5xS_w$ could be assumed due to higher additive genetic variation with better managerial practices and low $h^2$ values of $S_wxHF$ crossbred could be due to the use of $S_w$ sires with less differences in their breeding values.

(h) Body weight at 18 months' age: The values of $h^2$ were $0.457\pm0.186$, $0.415\pm0.276$, $0.340\pm0.099$ and $0.184\pm0.072$ for $S_w$, $B5xS_w$, $HFxS_w$ and $S_wxHF$ crossbreeds respectively. The increase in $h^2$ values from 9 to 18 months indicated the higher expression of additive genes for the traits which could result in higher genetic variation.
(1) Body weight at first fertile service: The $h^2$ values of $5w$, $B5x5w$, $HFx5w$ and $5wxHF$ crossbreds were found to be $0.525 \pm 0.241$, $0.177 \pm 0.161$, $0.117 \pm 0.048$ and $0.326 \pm 0.115$ respectively. Mishra (1973) reported $0.55 \pm 0.23$ $h^2$ which was quite similar to the present estimate of $5w$ cattle. The agreement for high $h^2$ of $5w$ might be due to more variation in age and weight at fertile service occurred due to genetic constitution of animals.

(2) Body weight at first calving: The $h^2$ values of $5w$, $B5x5w$, $HFx5w$ and $5wxHF$ were $0.501 \pm 0.253$, $0.169 \pm 0.203$, $0.192 \pm 0.085$ and $0.105 \pm 0.112$ respectively. Naidu and Desai (1970) reported higher ($0.75 \pm 0.33$) and Bhat and Khanna (1970) lower value ($h^2 = 0.43 \pm 0.21$) for Sahiwal breed. Very low values $0.06 \pm 0.11$ to $0.18 \pm 0.10$ on $5w$ cattle (paternal half-sib correlation) were reported by Mishra (1973) and Tanuja (1973) respectively. The value reported by Mishra (1973) was not far away from zero. One of the reasons could be the small number of records used.

The $h^2$ estimates reported by Naidu and Desai (1965) for 4–15/32 grades was higher and of Tanuja (1973) for 4–30/64 and 36–63/64 grades of $HFx5w$ were close to the present estimates.

5.4.1.2. Heritability estimates of growth rate (g/day): The $h^2$ estimates of growth rate g/day from birth to 2 months, 2–4, 4–6, 6–9, 9–12, 12–15 and 15–18 months age are shown in Figs. 6, 7, 8a and 9).

(a) Birth to 2 months age: The $h^2$ estimates of growth rate (g/day) from birth to 2 months age were $0.816 \pm 0.192$, $0.245 \pm 0.139$, $0.149 \pm 0.046$ and $0.444 \pm 0.126$ for $5w$, $B5x5w$, $HFx5w$ and $5wxHF$ crossbreds respectively. No report was available from literature consulted for Dairy Cattle but reported value of $h^2$ from Hereford herd
(Swiger, 1961) was similar to the present estimate. The $h^2$ of growth rate for this interval of age was highest than other intervals in four breed groups studied. The reason might be that growth rate velocity of calves was influenced by its own genotype and maternal effects while the effect of environment was less during this age interval.

(b) From 2 to 4 months’ age:— The $h^2$ estimate of $S_w$, $B_5 \times S_w$, $H F \times S_w$ and $S w \times H F$ were $0.084 \pm 0.0131$, $0.178 \pm 0.118$, $0.063 \pm 0.035$ and $0.158 \pm 0.077$ respectively. The report on dairy cattle was not available for comparison from the literature consulted. However this was well in agreement to the reported literature on exotic beef cattle (Angus, Hereford) by Swiger (1961) and Swiger and Hazel (1961).

(c) From 4 to 6 months’ age:— The estimates at this age interval were $0.064 \pm 0.093$, $0.152 \pm 0.118$, $0.052 \pm 0.026$ and $0.155 \pm 0.076$ for $S_w$, $B_5 \times S_w$, $H F \times S_w$ and $S w \times H F$ crossbred respectively. The values of $B_5 \times S_w$ crossbred and $S w \times H F$ crossbred showed their higher genetic variation under similar agro-climatic conditions. This might be due to breed differences or genotype environmental effects. From Figs. 6, 7, 8a and 9, it appeared that $h^2$ estimates were in declining phase due to higher influence of environment.

(d) From 6 to 9 months’ age:— The $h^2$ estimates for $S_w$, $B_5 \times S_w$, $H F \times S_w$ and $S w \times H F$ were $0.029 \pm 0.048$, $0.205 \pm 0.131$, $0.046 \pm 0.031$ and $0.038 \pm 0.059$ respectively. The $h^2$ values of $B_5 \times S_w$ crossbred were found slightly higher which might be due to better action of additive genes inherited through $B_5$ sires.
(e) From 9 to 12 months' age: The $h^2$ values were 0.013±0.167, 0.131±0.130, 0.095±0.037 and 0.058±0.065 for $Sw$, $BSxSw$, $HFxSw$ and $SwxHF$ crossbreds respectively.

(f) From 12 to 15 months' age: The $h^2$ estimates were respectively 0.243±0.171, 0.243±0.147, 0.038±0.024 and 0.074±0.072 for $Sw$, $BSxSw$, $HFxSw$ and $SwxHF$ crossbreds. Sahiwal and $BSxSw$ had higher estimates. The reason could be high genetic variability.

(g) From 15 to 18 months' age: The $h^2$ values were estimated 0.137±0.178, 0.181±0.143, 0.025±0.022 and 0.060±0.069 for $Sw$, $BSxSw$, $HFxSw$ and $SwxHF$ crossbreds respectively.

All the growth traits except birth to 2 month age had low $h^2$ estimates. The declining trend in four breed groups studied for first four traits of growth rate revealed the continuous increase of environmental influence and dwindling of maternal influence with the advancing age. It could be suggested that genes responsible for growth may be same throughout the growth period. Further it indicated that selection response of heifer at an early age might be same as at later age. Similar was reported by Swiger and Hazel (1961) in beef cattle.

5.4.1.3. Heritability estimates of production traits

Heritability estimates for traits like age at first calving, first lactation yield, first lactation components, first lactation period, first dry period and first, second and third lactation (≤305 days) yield are discussed below:

(a) Age at first calving: The $h^2$ values were 0.745±0.205, 0.482±0.223, 0.454±0.123 and 0.635±0.187 for $Sw$, $BSxSw$, $HFxSw$ and $SwxHF$ crossbreds respectively (Figs. 6, 7, 8a and 9). Low $h^2$
values $0.16\pm0.29$ by intrasire regression of daughter on dam
(Abble et al., 1956); $0.186\pm0.139$ and $0.21\pm0.09$ by paternal half-sib
 correlation by Koul (1968) and Das et al. (1971) respectively and
moderate values 0.31 (Naidu and Desai, 1965), 0.46\pm0.18 (Nagpal
and Acharya, 1970), 0.37\pm0.19 (Mishra, 1973) and 0.25\pm0.11 (Taneja,
1973) were observed in Sahiwal cattle. Naidu (1962) reported $h^2$
values of 0.31 and -0.13 for 4-15/32 grades of HF$x^2$w from Northern
and Southern military dairy farms respectively. Taneja (1973)
observed the values 0.13\pm0.06 and 0.36\pm0.13 for 4-50/64 and 36-63/64
HF grades respectively. Tamhank (1973) pooled all grades of HF$x^2$w
and recorded comparatively lower value (0.30\pm0.03) while Basu and
Ghai (1975) pooled half and above grades and found higher value
(0.63\pm0.21) from the present estimates. The high $h^2$ estimates
observed in four breed groups indicate the favourable result of
accounting the effect of grade deviations.

(b) First lactation yield: The $h^2$ of $S^w$ was $0.238\pm0.140$.
Nagpal and Acharya (1971) reported low value ($0.15\pm0.14$) whereas
others observed moderately high values ($0.41\pm0.21$, $0.41\pm0.14$,
$0.48\pm0.15$ by Khanna and Bhat, 1971; Taneja, 1973 and Mishra, 1973
respectively) by paternal half-sib correlation method. Kooner and
Sundaresan (1970) estimated $0.44\pm0.32$ and $0.37\pm0.20$ values by
intrasire regression and paternal half-sib correlation method
respectively for $S^w$ breed. The value ($0.21\pm0.29$) reported by Singh
and Desai (1967) was quite close to the present estimate. The
estimates of $h^2$ for BS$x^5$w, HF$x^5$w and $S^w\times HF$ were $0.124\pm0.166$,
$0.191\pm0.074$ and $0.062\pm0.076$ respectively. The $h^2$ reported by Naidu
and Desai (1965) for 4-15/32 grades of HF$x^5$w was 0.07 from Northern
farm and 0.19 from Southern farm. Gupta (1974) pooled all grades
of HF and recorded $h^2 = 0.22 \pm 0.11$ while Taneja (1973) for 4-30/64 and 36-63/64 grades observed heritability values 0.17±0.07 and 0.07±0.08 respectively. These all reported values of HFxSw grades were low and almost similar to this study.

First lactation components:

(i) Initial yield: The $h^2$ values of average initial yield per day were 0.241±0.129, 0.157±0.175, 0.164±0.058 and 0.152±0.063 for Sw, BSxSw, HFxSw and SwxHF crossbreds respectively. No report was available for comparison from literature consulted. Sahiwal heifer being a local breed was less influenced by the agro-climatic conditions.

(ii) Ascending yield: The $h^2$ estimates of ascending yield per day for Sw, BSxSw, HFxSw and SwxHF were 0.495±0.171, 0.171±0.180, 0.101±0.044 and 0.092±0.066 respectively. The variation increased with the increase of yield could be one of the reason of such estimates.

(iii) Peak yield: The estimates of this trait for Sw, BSxSw, HFxSw and SwxHF were 0.553±0.192, 0.298±0.110, 0.391±0.131 and 0.275±0.140 respectively (Figs.6,7,8a and 9). Naidu and Dasi (1970) reported $h^2 = 0.390 \pm 0.254$ for Sw which was lower than this. The reported values of HFxSw grades (1/8 to 3/8) were 0.39 and 0.23 for Northern and Southern farms were very close to the present findings. The higher $h^2$ of peak yield of all four breed groups studied might be due to the fact that genes responsible for milk production were functioning in full swing at this stage of lactation.
(iv) Descending yield: The estimates of $h^2$ were 0.415±0.163, 0.231±0.197, 0.301±0.112 and 0.163±0.094 for $S_w$, $B_s x S_w$, $H_f x S_w$ and $S_w x H_f$ crossbreds respectively. It may be suggested from these estimates that at the declining phase of milk production the genetic variability was narrowed.

(v) Milking average: The $h^2$ values of $S_w$, $B_s x S_w$, $H_f x S_w$ and $S_w x H_f$ crossbreds were 0.454±0.176, 0.288±0.212, 0.188±0.072 and 0.370±0.134 respectively. It was observed that for average milk yield the genetic variability for $S_w x H_f$ crossbred was higher than other lactation components of first lactation.

(c) First lactation period and period of 305 days or below:

The $h^2$ of total lactation period was 0.132±0.118, 0.051±0.111, 0.074±0.044 and -0.096±0.045 for $S_w$, $B_s x S_w$, $H_f x S_w$ and $S_w x H_f$ crossbred respectively. The $h^2$ values of 170-375 days lactation period followed the respective trend of 0.197±0.144, 0.015±0.130, 0.026±0.037 and -0.053±0.046.

Sandhu (1968) and Mishra (1973) reported 0.32±0.20 and 0.45±0.14 $h^2$ by paternal half-sib correlation method respectively for $S_w$ cattle which were higher from present estimate but the values reported by Taneja (1973) 0.16±0.10 was very close to this estimate. Naidu (1962) reported 0.18 from 4-15/32 grades and Taneja (1973) reported $h^2$ values 0.08±0.06 and 0.15±0.09 for 4-30/64 and 36-63/64 grades of $H_f x S_w$ respectively. Tanehan (1973) pooled all grades of $H_f x S_w$ crossbred and found the $h^2$ 0.16±0.07. It appeared from the estimates of crossbred that selected exotic sire used for crossbreeding of these herds were having low genetic variability for the trait.
(d) First dry period: The $h^2$ estimates of first dry period were $-0.141 \pm 0.071$, $0.193 \pm 0.207$, $0.007 \pm 0.030$ and $0.272 \pm 0.157$ for $S_w$, $B_S x S_w$, $H_F x S_w$ and $S_w x H_F$ crossbreds respectively. Naidu (1962) reported $-0.33$ and $0.02$ $h^2$ for 4-15/32 grades of $H_F x S_w$ from Northern and Southern farms. Taneja (1973) reported $0.17 \pm 0.11$, $0.11 \pm 0.07$ and $0.24 \pm 0.12$ $h^2$ for $S_w$, 4-30/64 and 36-63/64 grades of $H_F x S_w$ crossbreeds respectively. Basu and Ghai (1975) reported lower ($0.03 \pm 0.12$) $h^2$ for pooled of 1/2 and grade of $H_F x S_w$. As this trait is mostly governed by management practices rather than genetic, make up of the animal such low values not far from zero are expected.

(e) First, second and third lactation yield (305 days or below):

(i) The heritability estimates for $S_w$, $B_S x S_w$, $H_F x S_w$ and $S_w x H_F$ crossbreds were $0.476 \pm 0.259$, $0.157 \pm 0.174$, $0.168 \pm 0.072$ and $0.152 \pm 0.131$ respectively. The estimate of $S_w$ was higher from reported value of Singh and Dassii (1967) and Nagpal and Acharya (1971) but was quite close to Khanna (1968), Kooner and Sundaresan (1970), Khanna and Bhat (1971), Taneja (1973) and Mishra (1973).

The $h^2$ values reported by Naidu and Dassii (1965) from 4-15/32 grades of $H_F x S_w$ of Southern farms ($h^2 = 0.18 \pm 0.19$) and Taneja (1973) from 4-30/64 grades of $H_F x S_w$ ($h^2 = 0.17 \pm 0.07$) and Gupta (1971) from pooled grades of $H_F x S_w$ ($h^2 = 0.22 \pm 0.11$) were very close to the present estimate but values reported by Naidu and Dassii (1965) from 4-15/32 grades of Northern farms and Taneja (1973) from 36-63/64 grades were low.

(ii) The heritability estimates for second lactation were $0.586 \pm 0.237$, $0.091 \pm 0.032$, $0.231 \pm 0.135$ and $0.176 \pm 0.112$ for $S_w$, $B_S x S_w$, $H_F x S_w$ and $S_w x H_F$ crossbred respectively. The estimates
reported by Acharya and Nagpal (1971) and Mishra (1973) were slightly higher from present value of Sahiwal whereas estimate (0.56±0.27) observed by Khanna and Bhat (1971) by paternal half-sib correlation was quite close. Gupta (1971) reported 0.12±0.12 \( h^2 \) values from pooled all grades which were close to the values of \( S_{wx}^{HF} \) and \( BSxSW \) crossbreeds.

(iii) The heritability values for 3rd lactation of \( S_{w} \), \( BSxSW \), \( HFxSW \) and \( S_{wx}^{HF} \) were 0.256±0.219, -0.048±0.266, 0.245±0.138 and 0.356±0.169 respectively. Khanna and Bhat (1971) and Mishra (1973) reported high values of \( h^2 \) 0.93±0.37 and 0.66±0.22 respectively for Sahiwal but value (0.29±0.23) reported by Acharya and Nagpal (1971) was in agreement with present estimate. Gupta (1971) reported 0.53±0.13 heritability from pooled grades of \( HFxSW \) which was higher from this study. The \( h^2 \) estimate of \( BSxSW \) was about zero. The reason could be small number of genetic groups with (9 sires) half-sib families apart from other causes detailed above.

5.4.2. Genotypic and Phenotypic correlations

The genotypic and phenotypic correlations among traits taken for this study are discussed under three heads:

1. Genetic and phenotypic correlations among body weights.
2. Genetic and phenotypic correlations among production traits.
3. Genetic and phenotypic correlations among body weights and production traits.
5.4.2.1. Genetic and phenotypic correlations among body weights

(i) Genetic correlations ($r_G$): Highly significant ($P < 0.01$)

$r_G$ among body weights at various intervals from birth, 2, 4, 6, 9, 12, 15 and 18 months of age were observed in $5w$, $85x5w$, $HFx5w$ and $5wxHF$ crossbreds. The extent of $r_G$ among body weights ranged from $-0.09 \pm 0.39$ (weight at 2 months and weight at first calving) to $> 1.0$ (weight at 9 months and weight at 12 months) in Sahiwal;

$-0.04 \pm 0.24$ (weight at 18 months and weight at first calving) to $> 1.0$ (weight at 2 months and weight at 4 months) in $85x5w$;

$0.17 \pm 0.24$ (weight at 2 months and weight at first fertile service) to $> 1.0$ (weight at 2 months and weight at 4 months) in $HFx5w$ and

$-0.03 \pm 0.93$ (weight at 9 months and weight at first calving) to $> 1.0$ (weight at 6 months and weight at 9 months age) in $5wxHF$ crossbreds.

Highly significant genetic correlation indicated that gene functioning at an early age were the same up to 18 months age.

Arora (1972) estimated $r_G$ of birth weight with weight at 6 and 12 months age in $HFx5w$ halfbred which was found to be lower from these estimates but values between 6 months weight and 12 months weight were almost similar. The estimates reported by Taneja (1973) for $5w$, 4-30/64 grades and 36-63/64 grades of $HFx5w$ were quite close to the present values. Murty (1974) in $HFx5w$ crossbreds and Govindeiah (1973) in Sahana females observed low values except in a few cases where the values were low as well as negative. This was due to sample variance as indicated by Murty (loc.cit.).

Weight at first calving was negatively correlated,

with weight at 2, 6, 15 and 18 months age in Sahiwal; with weight
at birth, 9, 12, 15, 18 months and weight at first fertile service in $B_s \times S_w$ and with 9 months weight in $S_w \times H_F$ crossbreds. Body weights at lower age intervals were significantly positively correlated with weight at first calving in $H_F \times S_w$ crossbreds. In $S_w \times H_F$ crossbreds weights at 2, 4, 6 and 9 months were negatively correlated with weight at first fertile service. Negative $r_G$ was also observed between weight at 9 months and weight at first calving. Malidu (1963) reported negative $r_G$ ($-0.57$) between birth weight and weight at first calving in 4-15/32 grades of $H_F \times S_w$ from Northern Military Farm. Taneja and Bhat (1971) reported low $r_G$ between body weights than present estimate of $S_w$. Values reported by Taneja (1973) for $S_w$ and $H_F \times S_w$ grades were quite close to the present estimates. Values reported by Arora (1972) were lower from $H_F \times S_w$ but higher from $S_w \times H_F$ crossbred cattle. One of the reasons might be that in this study these two populations were considered as different breed groups, while Arora combined these as one group. Kurty (1974) reported low $r_G$ from $H_F \times S_w$ crossbreds. The observation made by several workers between birth weight and weight at first calving in other breeds was almost similar to the present estimate of Sahiwal and its $H_F \times S_w$ crossbreds (Batra and Desai, 1962; Singh et al., 1969 and Tamer and Arora, 1972).

(ii) Phenotypic correlations: From figures 6, 7, 8a and 9 it is evident that phenotypic correlation among body weight traits was positive in $S_w$, $B_s \times S_w$, $H_F \times S_w$ and $S_w \times H_F$ breed groups except weight at 4, 6 and 9 months age with weight at first fertile service in $S_w \times H_F$ crossbreds. In general the $r_p$ values were higher among adjacent body weights but the magnitude of their associations
declined as the interval between two records widened. This might be due to environmental effect. Birth weight with other body weights and body weights at different age intervals with weight at first calving had low \( r_p \) as compared to other correlation values in all four breed groups. The phenotypic correlation between birth weight and weight at first calving of Sahiwal was 0.10±0.06. This was lower than reported by Batra and Desai (1962) but was in agreement with that of Taneja (1973). Naidu (1962) worked out \( r_p \) between birth weight and weight at calving from 4-15/32 grades of HFxSw of Northern military farm and found quite low \( (r_p = 0.03) \) from present estimate of SwxHF crossbreds. The \( r_p \) values reported for Sw cattle (Taneja and Bhat, 1971) and for Sw, 4-30/64 and 36-63/64 grades of HFxSw (Taneja, 1973) for birth weight with weight at 6, 12 and weight at calving were somewhat close to the present findings.

Arora (1972) and Murty (1974) observed \( r_p \) between birth weight, weight at 6 months, 12 months and weight at first calving in HFxSw halfbreds which were higher from the present estimates. Several other workers observed \( r_p \) among body weights and a few between birth weight and weight at first calving (Stonaker et al., 1953 in Red Sindhi and its Jersey crossbreds; Singh et al., 1969 in Mariana; Tomer and Arora, 1972 in Mariana; Govindiah, 1973 in Mariana and Hingane, 1975 in Gir and its HF crosses). These estimates were well within the range of four breed groups studied except a few with a small variation. In general phenotypic correlations were low than genetic correlations among body weights. This might be due to varied effect of environment on correlated traits.
5.4.2.2. Genetic and phenotypic correlations among production traits (Figs. 6, 7, 8a and 9).

(i) Genetic correlation:- Age at first calving was positively correlated with all production traits (first lactation yield, first lactation length, initial, ascending, peak, descending and milking average). The correlations were ranging from $0.36 \pm 0.40$ (with milking average) to $0.76 \pm 0.18$ (with descending yield) in $S_w$ cattle. Age at first calving was significantly negatively correlated with production traits in $H_FxS_w$ crossbreds ranging from $-0.43 \pm 0.18$ (with descending yield per day) to $-0.75 \pm 0.11$ (with ascending yield per day). In $B_xS_w$ crossbreds age at first calving was significantly negatively correlated with initial, ascending and peak yield per day but it was positively correlated with total first lactation yield, descending yield, milking average and lactation period. In $S_wxH_F$ crossbreds, age at first calving was significantly positively correlated with first lactation yield ($0.21 \pm 0.56$) and its components except initial yield when $r_G$ was $-0.07 \pm 0.25$. Genetic correlation between age at first calving and first lactation yield ($0.58 \pm 0.12$) observed by Nagpal and Acharya (1970) in $S_w$ cattle was higher from present estimate. The genetic correlation of age at first calving with first lactation yield, lactation length and peak yield reported by Naidu (1967) and Naidu and Dass (1970) in 4-15/32 grades of $H_FxS_w$ crossbreds were in same order with small variations. Tanaja (1973) estimated $r_G$ between age at first calving, first lactation yield and first lactation length in $S_w$ and 4-30/64 grades and 36-63/64 grades of $H_FxS_w$ crossbreds and values were $0.38 \pm 0.23$ to $0.74 \pm 0.15$. 
-0.10±0.32 to 0.44±0.34 and 0.38±0.23 to 0.74±0.15 respectively. These values were mostly very close to the present finding except to that of HFxSw crossbreds. One of the reasons could be the difference in method of pooling grades before deriving these estimates.

Genetic association between age at first calving and first lactation yield was observed significantly negative in HFxSw crossbreds. This was also reported by several workers in other breeds (Sundaresan et al., 1954 in Red Sindhi; Ahmed, 1961 in Mariana; Reddy and Bhatnagar, 1971 in Tharparkar cattle; Dutt and Tomer, 1972 in Mariana; Abraham, 1973 in Jersey x Local Kerala cattle). The rG between lactation length and lactation yield were observed positive in Sw (0.73±0.28) and HFxSw crossbreds (0.74±0.17) and were negative in BSxSw (-0.02±0.86) and SwxHF crossbreds (-0.66±0.14). The values observed in Sw and HFxSw were similar to the reported values of Naidu and Desai (1970) in HFxSw crossbreds.

The genetic correlation between peak yield and milk yield was high and significant in four breed groups studied and values ranged from 0.81 (BSxSw) to 1.0 (Sw and SwxHF). High correlation explained the synergistic action of genes for these traits. Such high rG was also recorded by Naidu (1962) in 4-15/32 grades of HFxSw.

Initial yield per day was positively correlated with first total lactation yield in four breed groups studied. The values were 0.80±0.16, 0.66±0.52, 0.69±0.14 and 0.33±0.63 for Sw, BSxSw, HFxSw and SwxHF crossbreds respectively. This explained the possibility of selection for milk yield at an early stage of
first lactation. The genetic correlations between first lactation components and first lactation yield were high in four breed groups. This indicates that genes responsible for initial, ascending, peak and descending yields were the same for whole lactation. No report was available from literature consulted for $r_G$ between lactation components and lactation yield. Radwan et al. (1955) in HF cows, VanVleek and Henderson (1961a) in HF, Khan and Ahmed (1972) in Hariana, Hickman (1960) in Ayrshire, HF and Jersey, Singh et al. (1967) in Hariana, Singh and Acharya (1969) in Hariana studied $r_G$ of part lactation yield (monthly) and cumulative yield with total lactation yield and reported high genetic correlation approaching unity. They emphasized that the prediction of first lactation yield from monthly or part lactation yield could be reasonably accurate.

The genetic correlation between first 170-305 days lactation yield, and first 170-305 days lactation length was $0.34 \pm 0.34$, $0.38 \pm 0.28$, $-0.02 \pm 0.04$ and $-0.24 \pm 0.44$ in $S_w$, $B_5 \times S_w$, $H_F \times S_w$ and $S_w \times H_F$ crossbred cattle respectively. Naidu (1962) observed negative genetic correlation ($-0.367$) for 4-15/32 grades of $H_F \times S_w$ which was similar to the present finding but Tanuja (1973) observed positive associations between these two traits ($0.74 \pm 0.15$, $0.44 \pm 0.34$ and $0.74 \pm 0.15$) from $S_w$, 4-30/64 and 36-63/64 grades of $H_F \times S_w$ crossbreds respectively. Abraham (1973) observed $-0.02$ in Red Sindhi x Local Kerala cattle which was close to that of $H_F \times S_w$ crosses of this study. The genetic correlations of first dry period with first and second lactation yield were $-0.05 \pm 0.33$ and $-0.45 \pm 0.27$ in $S_w$; $-0.82 \pm 0.19$ and $-0.84 \pm 0.55$ in $B_5 \times S_w$;
0.04±0.76 and 0.06±0.44 in SwxHF, and -0.31±0.30 and -0.45±0.44 in HFxSw crossbreds. The estimate reported by Abraham (1973) was somewhat dissimilar from this finding.

In Sw, $r_g$ of first lactation yield with second and third and 2nd with 3rd lactation were $0.99±0.01$, $0.56±0.33$ and $0.71±0.35$ and in BSxSw, 1.0, 1.0 and $0.29±0.29$ respectively. High $r_g$ observed in this study was also reported by Khanna and Bhat (1971), Acharya and Nagpal (1971) and Gurnani et al. (1976) in Sw cattle. Such high $r_g$ between these traits were also observed in Holstein-Friesian by VanVleck and Bradford (1966) and Barker and Robertson (1966). The genetic correlations $0.48±0.52$, $0.24±0.43$ and $0.91±0.06$ in SwxHF and $0.33±0.26$, $0.16±0.37$ and $-0.21±0.37$ in HFxSw of first lactation with second and third and of second with third respectively were found low than above breed groups.

The genetic correlations among traits with high $h^2$ values give a tool to the breeder for applying in selection technique. The genetic correlation indicates the genetic architecture of animal. The role of genes functioning synergistically/antagonistically at different period of life for various traits help in constructing selection index.

(ii) Phenotypic correlation

of age at first calving with first total lactation yield was $0.03±0.05$, $0.04±0.07$, $0.01±0.03$ and $0.10±0.04$ in Sw, BSxSw, HFxSw and SwxHF crossbreds (Figs. 6, 7, 8a and 9). These correlations were low and non-significant in these breed groups except SwxHF. Low but positive $r_p$ values observed in Sw were lower than Batra and Desai (1964) but contrary to the findings of Puri and Sharma (1965) and Nagpal and Acharya (1970) who had reported negative $r_p$ in
Sahiwal between these two traits. Values recorded by Naidu (1962) from 4-15/62 grades of HFxSw and Taneja (1973) from 4-30/64 and 36-63/64 grades of HFxSw were very close to the present finding of HFxSw crossbreeds. Bhatnagar at al. (1975) reported higher r_p 0.64 in F_1 B_s x Sw crossbreeds.

Age at first calving was negatively correlated with first lactation period in Sw, B_s x Sw and HFxSw crossbreeds but positively in Sw x HF crossbreeds. Naidu (1962) observed (r_p = 0.08) from 4-15/32 grades and Taneja (1973) observed r_p 0.10±0.04. These values were similar to the present observations.

The phenotypic correlations between first lactation yield and first lactation period were high and significant. The value ranged from 0.58±0.01 (HFxSw) to 0.77±0.01 (Sahiwal). These values were quite close to that reported by Taneja (1973) for Sw, 4-30/64 HFxSw and 36-63/64 grades of HFxSw and Patil and Prasad (1970) in Gaolao breed. The estimate (0.58±0.04) reported by Banaline at al. (1970) was quite close to the values observed in HFxSw crossbreeds.

The correlations between peak yield and first lactation yield were 0.62±0.02, 0.49±0.04, 0.69±0.01 and 0.57±0.02 in Sw, B_s x Sw, HFxSw and Sw x HF crossbreeds respectively. Naidu and Desai (1970) reported higher r_p (0.72) in 4-15/32 grades of HFxSw crossbreeds and Banaline at al. (1970) in Marana cattle. The value (r_p = 0.27) reported by Ohri and Singh (1971) in Rathi cattle was low. The phenotypic correlation (0.63) observed by Staynev (1972) from Bulgarian Brown Swiss cows was similar to present value of Sw cattle.

The phenotypic correlations of initial yield per day
with first total lactation yield were 0.42±0.03, 0.44±0.04, 0.44±0.01 and 0.35±0.03 for $S_w$, $B_8S_8S_w$, $HF_8S_w$ and $S_wH_8F$ crossbreds respectively. Gravert and Baptist (1973) observed 0.75 $r_p$ between initial yield and total yield. The $r_p$ of initial, ascending, peak, descending yield with first lactation yield were significant and positive and comparatively higher than other correlations in four breed groups studied. Such types of correlations explain that initial yield and ascending yield may be a function of total lactation yield.

Several workers studied the correlations of part lactation (monthly or cumulative) with total lactation yield (VanVleck and Henderson, 1961a,b; O’Connor and Stewart, 1958; Hickman, 1960; Dutt et al., 1964; Singh and Acharya, 1969 and Khan and Ahmed, 1972) and observed high phenotypic correlations.

The phenotypic correlation of first 170-305 days lactation period with first 170-305 days lactation yield were found to be 0.49±0.03, 0.61±0.03, 0.46±0.02 and 0.32±0.02 in $S_w$, $B_8S_8S_w$, $HF_8S_w$ and $S_wH_8F$ crossbred cattle respectively. These observations were quite similar to that reported by Naidu (1962) from 4-15/32 grades of $HF_8S_w$, Shukla and Prasad (1970), Balaine et al. (1970) and Patil and Prasad (1970) in Gir, Hariana and Gaolao breeds respectively. The observation made by Taneja (1973) in $S_w$, 4-30/64 grades and 36-63/64 grades of $HF_8S_w$ crossbred was somewhat higher for this study. Koener (1963) reported inter-class correlation between first and second, first and third and second and third lactation yields as 0.56±0.17, 0.53±0.21 and 0.48±0.12 in Sahiwal cattle and 0.60±0.18, 0.26±0.24 and 0.46±0.22
in Red Sindhi cattle. These values were quite in line to that observed in this study. The $r_p$ of first dry period with first and second lactation yield was $-0.15 \pm 0.06$, $-0.04 \pm 0.07$ in $S_w$; $-0.40 \pm 0.11$ and $-0.19 \pm 0.12$ in $B_s S_w$, $-0.91 \pm 0.04$ and $0.05 \pm 0.05$ in $H F_x S_w$ and $-0.07 \pm 0.03$ and $0.10 \pm 0.04$ in $S_w x H F$.

The phenotypic correlations of first lactation yield with second and third with third lactation yield observed in $S_w$, $B_s S_w$, $H F_x S_w$ and $S_w x H F$ breeds were in agreement with that of Acharya and Nagpal (1971) and Gurnani et al. (1976), Khanna and Bhat (1971) reported low correlation (0.115 and 0.116) of first lactation with second and third lactation, whereas correlation between second and third lactation was quite similar to that observed for $S_w$ in this study.

5.4.2.3. Genetic and phenotypic correlations between body weight and production traits (Figs. 6, 7, 8a and 9).

(i) **Genetic correlations**— The body weight traits were genetically negatively correlated with age at first calving in $S_w$ cattle. The values ranged from $-0.01 \pm 0.21$ (birth weight) to $-0.65 \pm 0.23$ (weight at first calving). In $B_s S_w$ weights at birth, 2, 6 and 15 months' age were negatively correlated with age at first calving. Age at first calving was negatively correlated with body weight traits of $H F_x S_w$ cattle and $r_g$ ranged from $(-0.01 \pm 0.24$ weight at first fertile service) to $(-0.86 \pm 0.08$ weight at first calving). Similarly age at first calving was also negatively correlated with body weights in $S_w x H F$ cattle except with weight at 4 and 12 months age. The values ranged from $-0.05 \pm 0.21$ (weight at 6 months age) to $-0.85 \pm 0.10$ (15 months weight). The genotypic correlations between birth weight and age at first calving $-0.222$. 

Batra and Desai (1962) and 0.203 ± 0.372 by Naidu and Desai (1970) in Sw cattle were higher but observations made by Koul (1968) and Taneja (1973) respectively $r_G = -0.03$ and $-0.04 ± 0.32$ were more near to the estimated values. Taneja and Bhat (1971) reported that age at first calving was negatively correlated with body weight at various ages.

The reported $r_G = -0.20$, -0.12, -0.11 ± 0.22 and -0.16 ± 0.04 between birth weight and age at first calving respectively noted by Naidu (1962) in 4-15/32 HF x Sw grades, Koul (1968) in HF x Sw halfbreds and Taneja (1973) in 4-30/64 and 36-63/64 grades of HF x Sw were quite close the present estimates of HF x Sw and Sw x HF crossbreds. Parije (1972) observed high negative $r_G$ in Gir cattle. Ambre et al. (1963) in Red Sindhi and Khanna and Bhat (1972) in Sahiwal cattle reported higher negative $r_G$ from the present estimates. Taneja (1973) reported $r_G$ of weight at 2, 6, 12 months and weight at first calving with age at first calving in Sw, 4-30/64 and 36-63/64 grades of HF x Sw. These values are slightly varying from the observed values in this study for Sw, HF x Sw and Sw x HF crossbreds.

The genetic correlations of body weights with first total lactation yield were significantly positive in HF x Sw crossbreds. It was also positive in Sw except with weights at 2, 4 and 6 months. The correlations were significantly negative in BS x Sw and Sw x HF crossbred cattle. In HF x Sw it appeared that genes responsible for growth were the same those for milk production. Harville and Henderson (1964) reported $r_G$ 0.45 and 0.40 between adjusted live weight and milk yield in HF and Guernsey. Wilk et al. (1963) observed $r_G$ 0.43 between body weight at 12 months age and
milk yield and they concluded that there was no genetic antagonism between body weight and milk production.

Tanuja (1973) reported genetic correlation of weight at 2, 6, 12 months age and weight at calving with first lactation yield in Sw, 4-30/64 HF x Sw and 36-63/64 HF x Sw grades which were not in full agreement of these estimates. Murty (1974) estimated \( r_G \) between body weights at birth, 6, 12, 18 and 24 months of age with first lactation yield for each grade of HF x Sw crossbred and found low and non-significant \( r_G \) except with weight at 24 months where it was negative but statistically significant.

Miller Mc Gilliard (1959) reported \( r_G \) 0.30 between weight at first calving and first lactation yield in HF cows which was lower from Sw estimates of this study. Significant positive \( r_G \) of body weights at 6, 12, 18 and 24 months of age with first lactation yield were observed by Singh and Dassi (1971) in Red Sindhi cattle similar to as was observed in Sw and HF x Sw crossbreds. Clark and Touchberry (1962) found negative \( r_G \) between milk yield and body weight with high standard error as was observed in BS x Sw crossbreds. Erb and Ashworth (1961) concluded that the effect of live weight on milk yield was not linear although they did find that increase in body weight was generally associated with improvement in yield.

(ii) Phenotypic correlations: Phenotypic correlations of body weights with production traits, in general, were low in order. Body weight traits except weight at first calving were
negatively correlated with age at first calving in $S_w$ and $BSxS_w$ crossbreds, except weight at first fertile service and weight at first calving in $HFxS_w$ and except weight at 4, 9 months' age and weight at calving in $SwxHF$ crossbreds.

The $r_p$ (-0.09) between birth weight and age at first calving reported by Koul (1968) and -0.09±0.04 by Taneja (1973) in Sahiwal cattle were quite similar to the present value of $r_C$ = -0.09±0.05 but values reported by Batra and Desai (1962) and Naidu and Desai (1970) were slightly higher. Naidu (1962) estimated $r_p$ between birth weight and age at first calving in 4-15/32, 16-23/32 and 24-30/32 grades of $HFxS_w$ from Northern military dairy farms and found -0.024, 0.076 and 0.074 respectively and for 4-15/32 grades of Southern farms the value -0.162 which were quite similar to the observed estimate of this study. Taneja (1973) also observed low and tallying estimates from 4-30/64 and 36-63/64 grades of $HFxS_w$. Singh et al. (1969) reported very low negative (-0.002) but Tomar and Arora (1972) observed higher $r_p$ (-0.552) in Mariana cattle.

The phenotypic correlations of body weights with total lactation yield were positive in $BSxS_w$, $HFxS_w$ and $SwxHF$ (except of 2 months weight) crossbreds. In $S_w$ cattle positive correlations of age at first calving with weight at birth, 2, 4, 6 and weight at calving were observed. All these $r_p$ values were low.

Similarly low phenotypic correlations between birth weight and first lactation yield were observed by Anantakrishnan and Lazarus (1953) in Red Sindhi, Gir, Ayrshire x Red Sindhi; Singh and Desai (1959) in Mariana; Batra and Desai (1962) in $Sw$; Naidu (1962) in $HFxS_w$ grades and Taneja (1973) in $Sw$ and $HFxS_w$ grades. Khanna and Bhat (1972) reported negative $r_p$ (-0.052) in $Sw$ which was contrary
to the present finding.

Taneja (1973) estimated $r_p$ of weight at 2, 6, 12 months age and weight at first calving with first lactation yield and reported values in $S_w$ and 4-30/64 grades of $HF_xSw$ were quite similar to the present value in respective breed group but values reported for 36-63/64 $HF_xSw$ were dissimilar from $HF_xSw$ crossbreds. This could be due to variation in standardization of genetic groups used in these two studies.

Singh and Desai (1971) observed significant positive phenotypic correlation between body weight at 6, 12, 18 and 24 months of age with first lactation yield in Red Sindhi cattle which were dissimilar to the present finding in Sahiwal cattle. Murty (1974) estimated phenotypic correlation of body weight at birth, 6, 12, 18 and 24 months of age with first lactation yield and found lower correlations. These values are found to be lower than $HF_xSw$ crossbreds values observed for fully standardized data of this study.

Phenotypic correlations between body weights and first lactation components—initial, ascending, peak, descending and milking average were found positive in $HF_xSw$ and $Sw_xHF$ crossbreds. The values were ranging from $0.03 \pm 0.02$ (Birth weight and initial yield) to $0.32 \pm 0.03$ (weight at first calving and milking average) in $HF_xSw$ and $0.03 \pm 0.04$ (birth weight and milking average) to $0.21 \pm 0.04$ (weight at first calving and ascending yield) in $Sw_xHF$ crossbreds.
5.5. **Selection Indexes**

Four selection indexes for each breed group of $5w$, $BSx5w$, $HFx5w$ and $SwxHF$ crossbreds are presented in Table 23 along with their weighted coefficients (b's) and correlation between index and aggregate genetic value ($R_{IH}$). The genetic improvement as a result of the index selection will depend upon the magnitude of $R_{IH}$. Therefore, when the relative efficiency ($R_{IH}$) values of different indexes were compared, it was observed that index IV had higher value in each breed group. The correlation coefficients between index and aggregate breeding value in index IV were 93.89, 90.86, 78.50 and 93.56 per cent in $5w$, $BSx5w$, $HFx5w$ and $SwxHF$ breed groups respectively. Selection index I comprising of six traits i.e. body weight at 6, 12 months age, weight at first calving, age at first calving, peak yield (kg) and milking average (kg) had slightly lower values i.e. 91.24, 74.02, 58.21 and 91.04 per cent respectively in $5w$, $BSx5w$, $HFx5w$ and $SwxHF$ breed group than index IV. The lowest correlation between index and aggregate genetic value was found for index II of $BSx5w$, $HFx5w$ and $SwxHF$ crossbreds and index III of $5w$ breed.

Ahmed (1961) constructed three selection indexes for Hariana cattle incorporating the five traits i.e. age at first calving, first calving interval, first lactation milk yield, body weight at first calving and butter fat percentage. He found most efficient third index ($R_{IH} = 0.625$) comprising of age at first calving, first calving interval and first lactation milk yield.
Acharya (1966) developed selection index for Muriana cattle involving age at first calving, first lactation yield and first calving interval and found 0.86 relative efficiency for this index. Singh et al. (1960) constructed several indexes incorporating six economic traits with different combinations and observed $R_{IH}$ values which ranged from 12.56 to 94.99 per cent. They found that selection based on an index that combined only milk yield and the age at first calving was most efficient for genetic progress.

Similarly in the present study, higher efficiency of the selection indexes was observed when age at first calving, peak yield and milking average were combined, though it was not comparable with the above findings because of inclusion of different traits. Prasad and Prasad (1973) observed $R_{IH}$ value 56.5 per cent in Tharparker cattle for a selection index which was developed from three traits (first lactation milk yield in pounds, age at first calving (mths) and first lactation period (days)).

There is no doubt that age at first calving is one of the most important economic trait to be considered for the economy of Dairy Husbandry. In general slow growth rate and higher age at first calving and low milking average per day are common in Zebu cattle. Therefore, it is very desirable to bring genetic improvement in these traits for economic gain. The present findings signify that index I with lower efficiency than index IV, showed higher genetic gain in the next generation. The selection index with six traits gave an aggregate genetic gain of Rs. 245.65, 197.60, 239.95 and 196.84 for $S_w$, $BS_xS_w$, HF$xS_w$ and $S_w$HF crossbreds respectively upto first lactation yield of the next generation.
Correlation between the selection index and aggregate breeding value was 91.24, 74.02, 50.21 and 91.04 per cent respectively in Sw, BSxSw, HFxSw and SwxHF breed groups.

On the basis of direct selection (index I) the genetic progress for average milk yield (milking average/day) was expected to be in order of 0.78, 1.15, 1.81 and 0.51 kg; peak yield 0.86, 0.39, 1.59 and 0.22 kg in Sw, BSxSw, HFxSw and SwxHF breed groups respectively. It was also noticed that the age at first calving would decline in next generation by 1.2, 1.6, 0.12 and 1.2 months, with the increase of weight at 6 months at the rate of 0.81, 0.11, 2.22 and 2.28 kg; at 12 months at the rate of 4.06, 3.45, 3.03 and 3.77 kg and weight at first calving at the rate of 12.13, 2.61, 9.89 and 10.34 kg in Sw, BSxSw, HFxSw and SwxHF breed groups respectively (Table 23).

Selection index III would result an increase of body weight at first calving at the rate of 7.47, 6.78 and 0.82 kg in Sw, HFxSw and SwxHF but lower (-0.56 kg) in BSxSw crossbred cattle. It would increase peak milk yield per day by 0.42, 0.74 and 0.85 kg in Sw, BSxSw and HFxSw but decrease in SwxHF crossbreds.

The milking average would increase at the rate of 0.94, 0.13, 0.55 and 0.13 kg in four breed groups respectively. The expected total genetic gain ($\Delta H$) in the next generation would be $\Delta H$ 86.96, 18.87, 72.54 and 5.70 in Sw, BSxSw, HFxSw and SwxHF crossbreds respectively which was found to be lower than other indexes (Table 23).

The index IV involving age at first calving, peak yield and milking average would result a genetic gain of $\Delta H$ 96.66, 47.31, 9.88 and 85.27 in the next generation of Sw, BSxSw, HFxSw
and SwxHF respectively. This index seemed to be the most efficient with $R_{IH}$ values 93.89, 90.86, 78.50 and 93.56 per cent for these breed groups respectively. The use of this index would reduce the age at first calving in next generation at the rate of 1.01, 0.62, 0.15 and 1.13 months, peak yield would increase and decrease respectively at the rate of 0.76, -0.46, 0.02 and 0.35 kg and milking average at the rate of 0.39, 0.56, -0.04 and 0.16 kg in Sw, BSxSw, HFxSw and SwxHF breed groups.

When selection is based on index II comprising weight at 12 months age, weight at first calving and milking average per day of first lactation, the expected total genetic gain in the next generation would be Rs 172.62, 134.97, 149.65 and 136.22 in Sw, BSxSw, HFxSw and SwxHF crossbred cattle. This index had lower relationship between index and aggregate genetic value than index I and IV. Adoption of this index would result an increase in the order of 8.64, 8.49, 11.83 and 11.19 kg body weight at 12 months age; 12.12, 8.47, 10.16 and 8.36 kg body weight at first calving and 0.82, 1.10, 0.76 and 0.95 kg milking average in Sw, BSxSw, HFxSw and SwxHF breed groups respectively. Since this index increased milking average at higher order in BSxSw, HFxSw and SwxHF crossbreds with increase in body weight than index III and IV, it may be considered superior for bringing improvement in genetic gain for this trait.
The present investigation was undertaken to study the genetic architecture of growth and production traits of 689 Sw (Sahiwal), 639 B5xSw (Brown Swiss x Sahiwal) and 3802 HFxSw—SwxHF (a population of crossbreds where HF and Sw sires were used) cattle collected from 7 farms in Northern India were used. The crossbreds of HFxSw—SwxHF were classified into seven genetic groups (1/8 to 7/8) with the fraction of 12.5 per cent Frisian inheritance and B5xSw crossbreds in five genetic groups (6/8, 4/8, 3/8, 2/8 and \(F_2-F_3\)). The data were spread over a period of 15 years (1961-75). The entire period was divided into 5 periods each of 3 years duration. Year was divided into 4 seasons based on climate. Parity of birth was considered in four groups (I, II, III—IV, V). Ten body weights (weight at birth, 2, 4, 6, 9, 12, 15, 18 months, at first fertile service and at first calving), seven growth rates (g/day) worked out from body weights up to 18 months' age and 11 production traits (age at first calving, first lactation yield, and its components — initial, ascending, peak, descending — milking average in kg, first 170-305 days lactation yield in kg, first lactation length in days, 170-305 days lactation length and first dry period in days) were considered in this study.
Farms, genetic groups within crosses, parity, seasons and period of birth were considered as factors of importance for 17 traits of growth. For production traits, farm, genetic groups, season and period of calving were considered. Least square technique was used to derive the population mean, the constants and to study the influence of these factors affecting the growth and production.

The female calves of $B_5 \times S_6$ inheritance were significantly heavier at birth ($25.51\pm0.22$ kg) than $H_6 \times S_6 = S_6 \times H_6$ ($23.45\pm0.07$) and purebred $S_6$ ($21.03\pm0.13$ kg). Among $S_6$ and its crosses with $B_5$ and $H_6$, $6/8$ $B_5 \times S_6$ had the highest birth weight ($27.31\pm0.15$ kg). The body weights at various ages were in general higher for $H_6 \times S_6$ crosses followed by $B_5 \times S_6$ and $S_6$ respectively. However, the weights at first calving were almost similar ($331.65\pm2.18$ kg of Sahiwal, $347.49\pm6.08$ of $B_5 \times S_6$ and $350.67\pm4.99$ kg of $H_6 \times S_6 = S_6 \times H_6$) in these three breed groups with significant variation in their respective ages. The growth rate (g/day) was maximum between 4-6 months and lowest in 15-18 months age interval in all breed groups. The maximum and minimum growth rate values were $451.8\pm7.1$, $330.3\pm14.8$ ($S_6$), $531.0\pm20.7$, $314.6\pm22.5$ ($B_5 \times S_6$) and $541.6\pm3.9$, $343.0\pm4.6$ ($H_6 \times S_6 = S_6 \times H_6$) g per day.

The average age at first calving was $38.7\pm2.7$ months ($S_6$), $30.4\pm0.6$ months ($B_5 \times S_6$) and $36.4\pm0.3$ months ($H_6 \times S_6 = S_6 \times H_6$). Among $S_6$ and its various genetic groups with $B_5$ and $H_6$ crosses,
halfbred (4/8) of BSxSw had the lowest age at first calving (29.8 months) followed by 3/8 (28.9 months), 3/4 (31.2 months), F2-F3 (32.7 months). For HFxSw crosses, the 4/8 to 5/8 level of HF inheritance had the lower age 35.4 and 35.5 months respectively.

Average first lactation yield was highest in BSxSw crosses (3288.95±133.20 kg) followed by HFxSw-SuwHF (2495.34±39.5 kg) and Sw (2022.11±38.07 kg). Similar trend was noted for first 170-305 days yield. For first lactation components based on an average of two days yield, defined as initial, ascending, peak, descending yield and milking average, the highest values were observed for BSxSw crosses, followed by HFxSw-SuwHF and Sw respectively. The average first lactation length and dry period were respectively 322.0±4.5, 134.7±4.9 days (Sw), 336.4±10.1, 74.4±6.0 days (BSxSw) and 309.5±2.9, 124.8±3.7 days (HFxSw-SuwHF).

Among genetic groups of BSxSw high yielder were noted 3/8 (4006.2 kg) followed by halfbred (3496.2 kg) while for HFxSw-SuwHF 6/8 (2808.8 kg) followed by 4/8 (2799.4 kg) and 5/8 (2735.4 kg). The relative performance of different genetic groups of BSxSw and HFxSw-SuwHF revealed the superiority of 3/8 to 4/8 (BSxSw) and 4/8 to 5/8 (HFxSw-SuwHF) over other grades in their respective genetic groups and Sahiwal cattle.

The effect due to farms was significant for all body weight and growth rate traits in Sw and HFxSw-SuwHF except for weight at birth, 12-15 and 15-18 months growth rate (Sw). The effect due to level of exotic inheritance was significant for all growth traits in BSxSw and HFxSw-SuwHF except weight at
2 months, weight at first fertile service and at first calving; growth rates from birth to 2 months, 4 to 6 months in BSxSw and 12 to 15 and 15 to 18 months in HFxSw-SwxHF crosses.

Significant effect due to parity of birth was observed for weight at 9 months age, weight at first fertile service in Sw; weight at birth, 4, 6 months, at first fertile service, 2-4 months and 12-15 months growth rate in BSxSw and non-significant for other growth traits. The effect due to parity of birth was non-significant for all growth traits in HFxSw-SwxHF.

The effect due to season of birth was observed significant for weight at 9 and 12 months age; growth rate from 6-9, 9-12, 12-15 and 15-18 months age intervals while it was significant for all traits in BSxSw and HFxSw-SwxHF except weight at 2, 18 months, at first fertile service, birth to 2 months' growth in BSxSw and for weight at 15 months, first fertile service and weight at first calving in HFxSw-SwxHF crosses. The effect due to period of birth was significant for all growth traits in Sw, BSxSw and HFxSw-SwxHF crosses except 4-6, 6-9, 9-12 and 12-15 months growth rate in Sw, weight at birth, at first calving, 6-9, 12-15 and 15-18 months growth rate in BSxSw and 6-9 months growth rate in HFxSw-SwxHF crosses.

The effect due to farms was significant for all production traits in Sw and HFxSw-SwxHF crosses except age at first calving, ascending, peak and descending yield in Sw cattle. The effect due to genetic groups within crosses was significant for all production traits except first lactation length (BSxSw)
and first dry period in BSxSw and HFxSw-SwxHF. The effect due to season of calving was significant for age at first calving (Sw), descending yield (Sw and BSxSw) while it was found significant for all production traits in HFxSw-SwxHF except first lactation yield. The effect due to periods of calving was significant for age at first calving, first lactation, initial, ascending and peak yield in Sw, age at first calving, first 170-305 days lactation length and first dry period in BSxSw and significant for all production traits in HFxSw-SwxHF crosses.

The $h^2$ estimate for body weight ranged between 0.29±0.17 (weight at 9 months age) to 0.59±0.19 (weight at 2 months age) in Sw, 0.17±0.20 (weight at first calving) to 0.57±0.21 (weight at 15 months) in BSxSw, 0.12±0.04 (weight at first fertile service) to 0.34±0.09 (weight at 18 months age) in Holstein sire group and 0.11±0.11 (weight at first calving) to 0.60±0.16 (weight at 2 months age) in Sw sire group. The $h^2$ estimated from growth rate (g/day) traits was found low except for growth rate from birth to 2 months age where the $h^2$ values were 0.62±0.19 (Sw), 0.25±0.14 (BSxSw), 0.15±0.05 (HFxSw) and 0.44±0.13 (SwxHF). The $h^2$ values for age at first calving were 0.75±0.21 (Sw), 0.48±0.22 (BSxSw), 0.45±0.12 (HFxSw), 0.84±0.19 (SwxHF). For first lactation yield $h^2$ values were 0.24±0.14 (Sw), 0.12±0.17 (BSxSw), 0.19±0.07 (HFxSw), 0.06±0.08 (SwxHF). Low to moderate $h^2$ values were observed for all components of first lactation yield in four breed groups. The values for lactation period and first dry period were close to zero or low. The $h^2$ estimates of 1st, 2nd and 3rd (305 days and below) lactation yield were respectively
0.48 ± 0.26, 0.59 ± 0.24 and 0.26 ± 0.22 ($SW$), 0.16 ± 0.17, 0.09 ± 0.03 and -0.05 ± 0.27 ($BSxSW$), 0.17 ± 0.07, 0.23 ± 0.14 and 0.25 ± 0.14 ($HFxSW$), 0.15 ± 0.13, 0.18 ± 0.11 and 0.36 ± 0.17 ($SWxHF$).

The phenotypic correlations (four breed groups) among body weights and among production traits were in general moderate to high while between any two adjacent traits it was invariably high. The phenotypic correlations among growth traits were low to moderate whereas correlations of growth rate and body weights with production traits were mostly low.

Simple linear, multiple and quadratic functions using different combination of traits were used for the prediction of first lactation yield. The quadratic equations accounted for better estimate ($R^2$) than simple linear and multiple equations for predicting first lactation yield based on 4 body weight traits viz. weight at birth, 6 months, 12 months and at first calving. The maximum growth rate (4–6 months) explained low variation in first lactation yield in four breed groups ($R^2 = 0.58$ to 5.01 per cent). The $R^2$ values using different combination of traits revealed that first lactation length alone explained larger variation for first lactation yield. The $R^2$ values were 55.10, 56.78, 34.63 and 40.61 per cent in $SW$, $BSxSW$, $HFxSW$, $SWxHF$ respectively.

First lactation yield was also predicted using lactation components. Multiple and quadratic equations were found equally effective. Among lactation components peak yield and descending yield explained the maximum variation in four breed groups. The $R^2$ values using these traits ranged between
41.38 (SxHM) to 34.65 (HxFxSw).

Genetic correlations of age at first calving with body weights at different ages and growth traits were either low or negative in the four breed groups. The $r_G$ of first lactation yield with body weights were also either low or negative except those with body weights at later ages. The correlation of age at first calving with production traits ranged between 0.36 to 0.76 in Sw. Similar trends were noted in BSxSw, HxFxSw and SwxHF crosses where the estimates were either negative or ranged between low to moderate. The $r_G$ of first lactation yield with lactation components were high ($>0.60$) in all the four breed groups.

For each breed group, four selection indexes were constructed using different combination of economic traits viz. body weight at 6 months, 12 months and at first calving; age at first calving, peak yield and milking average. Expected genetic gain for traits included in these indexes indicated that index IV had the highest efficiency with $R_{IM}$ values in percentage as 93.89, 90.86, 78.50 and 93.56 respectively for Sw, BSxSw, HxFxSw and SwxHF breed groups. The next in order were index I, II and III (Sw), I, III and II (BSxSw and SwxHF), III, I and II (HxFxSw). These estimates of indexes were also compared with the results that are likely to be obtained by direct application of individual or mass selection on each trait. Index IV would reduce the age at first calving in next generation by 1.01, 0.62, 0.15 and 0.13 months, peak yield would increase and decrease respectively at the rate of 0.76, -0.46, -0.02 and 0.35 kg,
milking average 0.39, 0.56, -0.04 and 0.16 kg in $S_w$, $B_5 x S_w$, $H_5 x S_w$ and $S_w x H_5$ breed groups respectively. The efficiency of selection indexes were increased by combining age at first calving, peak yield and milking average.

Genetic architecture inherent in growth and production records of famous dairy animals in Northern India revealed that Friesian genes had superiority in growth rate (g/day) and on body weights at chronological ages while Brown Swiss genes in production performance based on first lactation yield and its components. Brown Swiss germ plasm though studied at one farm only showed an edge over Holstein-Friesian inheritance for age at first calving and first lactation yield. The methodology employed and results achieved at farms in Northern India indicate that exotic inheritance could be generated around 50 per cent for getting optimum results (3/8 to 4/8 in $B_5 x S_w$ and 4/8 to 5/8 in $H_5 x S_w$) under present feeding and management technology. This will leave an ample scope of forward/backward blood level engineering in the hands of future geneticists till more valid conclusions are available.
Table 1: Least square means (±) with standard errors and constants for non-genetic factors affecting several traits of SW cattle

<table>
<thead>
<tr>
<th>Non-genetic factors</th>
<th>Birth weight (kg)</th>
<th>Wt. at 2 mths (kg)</th>
<th>Wt. at 4 mths (kg)</th>
<th>Wt. at 6 mths (kg)</th>
<th>Wt. at 9 months (kg)</th>
<th>Wt. at 15 months (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>u</td>
<td>21.03±0.13</td>
<td>43.67±0.34</td>
<td>70.24±0.61</td>
<td>97.20±0.75</td>
<td>128.52±1.49</td>
<td>159.54±1.78</td>
</tr>
<tr>
<td></td>
<td>(689)</td>
<td>(523)</td>
<td>(516)</td>
<td>(504)</td>
<td>(333)</td>
<td>(331)</td>
</tr>
<tr>
<td>Farm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>-0.17(212)</td>
<td>3.09(211)</td>
<td>5.29(211)</td>
<td>9.83(211)</td>
<td>16.67(210)</td>
<td>19.37(209)</td>
</tr>
<tr>
<td>F2</td>
<td>0.17(479)</td>
<td>-3.09(312)</td>
<td>-5.29(305)</td>
<td>-9.83(293)</td>
<td>-16.67(123)</td>
<td>-19.37(122)</td>
</tr>
<tr>
<td>Parity of birth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>0.20(162)</td>
<td>0.08(120)</td>
<td>0.58(119)</td>
<td>1.31(115)</td>
<td>2.80(80)</td>
<td>3.10(80)</td>
</tr>
<tr>
<td>P2</td>
<td>-0.12(164)</td>
<td>0.00(134)</td>
<td>-1.73(129)</td>
<td>4.58(84)</td>
<td>-4.72(83)</td>
<td>-1.39(93)</td>
</tr>
<tr>
<td>P3</td>
<td>0.06(230)</td>
<td>-0.81(166)</td>
<td>-0.98(164)</td>
<td>-1.04(161)</td>
<td>-0.70(94)</td>
<td>-1.39(93)</td>
</tr>
<tr>
<td>P4</td>
<td>0.26(133)</td>
<td>0.73(103)</td>
<td>0.40(102)</td>
<td>1.46(99)</td>
<td>2.48(75)</td>
<td>3.01(75)</td>
</tr>
<tr>
<td>Season of birth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>0.07(143)</td>
<td>-0.01(103)</td>
<td>-1.92(102)</td>
<td>-1.99(100)</td>
<td>1.73(49)</td>
<td>-0.13(48)</td>
</tr>
<tr>
<td>S2</td>
<td>-0.35(203)</td>
<td>0.40(148)</td>
<td>0.68(148)</td>
<td>1.33(147)</td>
<td>0.53(118)</td>
<td>-5.30(118)</td>
</tr>
<tr>
<td>S3</td>
<td>0.13(192)</td>
<td>-0.64(156)</td>
<td>-0.78(152)</td>
<td>-0.16(147)</td>
<td>-4.98(95)</td>
<td>-0.79(95)</td>
</tr>
<tr>
<td>S4</td>
<td>0.15(151)</td>
<td>0.25(116)</td>
<td>2.02(114)</td>
<td>0.82(110)</td>
<td>3.79(71)</td>
<td>6.23(70)</td>
</tr>
<tr>
<td>Period of birth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pd1</td>
<td>0.68(230)</td>
<td>-2.33(88)</td>
<td>-3.46(87)</td>
<td>-7.04(85)</td>
<td>-8.27(81)</td>
<td>-10.51(81)</td>
</tr>
<tr>
<td>Pd2</td>
<td>0.43(156)</td>
<td>-0.00(151)</td>
<td>-0.23(150)</td>
<td>0.82(149)</td>
<td>-2.75(67)</td>
<td>-1.12(67)</td>
</tr>
<tr>
<td>Pd3</td>
<td>0.26(120)</td>
<td>0.36(110)</td>
<td>-2.16(108)</td>
<td>-2.47(102)</td>
<td>0.54(23)</td>
<td>-0.76(23)</td>
</tr>
<tr>
<td>Pd4</td>
<td>-0.46(148)</td>
<td>4.05(139)</td>
<td>6.80(136)</td>
<td>8.84(136)</td>
<td>12.05(133)</td>
<td>13.65(133)</td>
</tr>
<tr>
<td>Pd5</td>
<td>-0.91(35)</td>
<td>-1.36(35)</td>
<td>-0.94(35)</td>
<td>-0.15(32)</td>
<td>-1.57(29)</td>
<td>-1.27(27)</td>
</tr>
</tbody>
</table>
### Non-genetic factors

<table>
<thead>
<tr>
<th></th>
<th>Wt. at 15 mths (kg)</th>
<th>Wt. at 18 mths (kg)</th>
<th>Wt. at 1st fertile service (kg)</th>
<th>Wt. at 1st calving (kg)</th>
<th>Growth rate g/day Birth to 2 mths</th>
<th>2 to 4 mths</th>
</tr>
</thead>
<tbody>
<tr>
<td>u</td>
<td>189.97 ± 2.23</td>
<td>219.95 ± 2.32</td>
<td>288.91 ± 2.75</td>
<td>331.65 ± 2.18</td>
<td>375.9 ± 5.5</td>
<td>436.4 ± 6.5</td>
</tr>
<tr>
<td>Farc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F₁</td>
<td>17.51(203)</td>
<td>19.60(202)</td>
<td>24.73(183)</td>
<td>29.05(161)</td>
<td>52.3(211)</td>
<td>53.5(211)</td>
</tr>
<tr>
<td>F₂</td>
<td>-17.51(117)</td>
<td>-19.60(113)</td>
<td>-24.73(101)</td>
<td>-29.05(136)</td>
<td>-52.3(310)</td>
<td>-53.5(302)</td>
</tr>
</tbody>
</table>

### Parity of birth

| P₁₁          | 3.92(76)            | 1.44(74)            | -7.03(64)                       | -0.44(68)                | -0.7(119)                        | 6.4(118)    |
| P₁₂          | -4.70(80)           | -3.85(80)           | -0.51(77)                       | -4.69(81)                | 6.7(133)                         | -6.9(131)   |
| P₁₃          | -2.99(91)           | -2.80(90)           | -3.44(79)                       | -1.50(85)                | -3.1(166)                        | 5.5(162)    |
| P₁₄          | 3.77(73)            | 5.20(71)            | 10.98(64)                       | 6.83(63)                 | 2.1(103)                         | -5.0(182)   |

### Season of birth

| S₁           | -4.95(48)           | 5.27(47)            | 0.71(42)                        | -1.42(53)                | -9.2(103)                        | -16.8(102)  |
| S₂           | -6.85(203)          | 0.36(112)           | -3.83(96)                       | -4.96(89)                | 14.3(148)                        | -2.6(148)   |
| S₃           | -0.24(91)           | -4.21(91)           | -0.76(84)                       | -2.86(84)                | -9.3(154)                        | 3.6(150)    |
| S₄           | 4.14(66)            | 1.42(65)            | 3.88(62)                        | 9.04(61)                 | 4.2(116)                         | 15.8(113)   |

### Period of birth

| P₁₁          | -9.70(80)           | -20.31(80)          | -13.65(75)                      | 8.00(73)                 | -40.4(87)                        | -55.1(88)   |
| P₁₂          | -1.32(66)           | 2.54(66)            | 10.34(63)                       | 5.34(69)                 | -4.3(151)                        | -0.4(150)   |
| P₁₃          | 0.10(23)            | 0.32(23)            | 12.10(31)                       | 0.36(62)                 | -19.5(110)                       | -20.6(108)  |
| P₁₄          | 15.12(131)          | 16.13(130)          | -8.78(115)                      | -13.70(93)               | 72.4(138)                        | 56.6(135)   |
| P₁₅          | -4.20(20)           | 1.33(16)            | -                        | -8.2(35)                 | 19.5(35)                         |             |

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contd.......

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contd.......

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### Appendix

**contd. (Table 17)**

<table>
<thead>
<tr>
<th>Non-genetic factors</th>
<th>Growth rate g/day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 to 6 mths</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>u</td>
<td>451.8±7.1 (503)</td>
</tr>
<tr>
<td>Fama</td>
<td></td>
</tr>
<tr>
<td>F4</td>
<td>64.0(211)</td>
</tr>
<tr>
<td>F2</td>
<td>-64.0(292)</td>
</tr>
<tr>
<td>Parity of birth</td>
<td></td>
</tr>
<tr>
<td>P11</td>
<td>12.9(115)</td>
</tr>
<tr>
<td>P12</td>
<td>-18.9(129)</td>
</tr>
<tr>
<td>P13</td>
<td>2.7(160)</td>
</tr>
<tr>
<td>P14</td>
<td>3.3(99)</td>
</tr>
<tr>
<td>Season of birth</td>
<td></td>
</tr>
<tr>
<td>s1</td>
<td>-8.7(100)</td>
</tr>
<tr>
<td>s2</td>
<td>9.2(148)</td>
</tr>
<tr>
<td>s3</td>
<td>10.1(146)</td>
</tr>
<tr>
<td>s4</td>
<td>-10.6(109)</td>
</tr>
<tr>
<td>Period of birth</td>
<td></td>
</tr>
<tr>
<td>Pd1</td>
<td>-31.4(83)</td>
</tr>
<tr>
<td>Pd2</td>
<td>16.8(149)</td>
</tr>
<tr>
<td>Pd3</td>
<td>-5.8(103)</td>
</tr>
<tr>
<td>Pd4</td>
<td>23.2(132)</td>
</tr>
<tr>
<td>Pd5</td>
<td>-2.8(32)</td>
</tr>
<tr>
<td>Non-genetic Factor</td>
<td>Age at 1st calving (mths)</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>$u$</td>
<td>38.65±2.69 (579)</td>
</tr>
<tr>
<td>$F_{1}$</td>
<td>0.37(196)</td>
</tr>
<tr>
<td>$F_{2}$</td>
<td>-0.37(383)</td>
</tr>
</tbody>
</table>

**Season of calving**

| $S_{1}$           | 0.79(101)                 | -20.99(77)             | -0.18(91)          | -0.31(91)            | -0.25(91)      | -0.12(88)             |
| $S_{2}$           | -0.46(173)                | -14.15(158)            | 0.23(162)          | 0.28(161)            | 0.48(158)      | 0.61(148)             |
| $S_{3}$           | -1.24(184)                | 32.47(151)             | 0.07(171)          | 0.29(171)            | 0.07(170)      | -0.29(162)            |
| $S_{4}$           | 0.91(171)                 | 2.63(99)               | -0.12(114)         | -0.18(114)           | -0.29(114)     | -0.20(111)            |

**Period of calving**

| $P_{d1}$          | -1.43(80)                 | 159.43(67)             | -0.60(76)          | 0.44(76)             | 0.77(75)       | 0.30(73)              |
| $P_{d2}$          | 0.41(144)                 | -39.43(120)            | -0.79(133)         | -0.69(133)           | -0.74(133)     | -0.39(130)            |
| $P_{d3}$          | 2.58(128)                 | 38.80(116)             | 0.45(121)          | 0.40(121)            | 0.04(121)      | 0.02(120)             |
| $P_{d4}$          | 2.70(116)                 | -30.20(100)            | 0.19(109)          | 0.31(109)            | 0.13(108)      | 0.05(104)             |
| $P_{d5}$          | -4.27(111)                | -128.37(62)            | 0.74(99)           | -0.47(98)            | 0.19(96)       | 0.02(82)              |

contd...
<table>
<thead>
<tr>
<th>Non-genetic factors</th>
<th>First Milking Average (kg)</th>
<th>First Lact. length (days)</th>
<th>First dry period (days)</th>
<th>First 170 to 305 days lact. period (kg)</th>
<th>Int170-305 days lact. yield (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>u</td>
<td>6.36±0.07</td>
<td>321.98±4.50</td>
<td>134.66±4.90</td>
<td>282.62±1.50</td>
<td>1853.61±35.32</td>
</tr>
<tr>
<td></td>
<td>(465)</td>
<td>(478)</td>
<td>(412)</td>
<td>(465)</td>
<td>(461)</td>
</tr>
<tr>
<td>F_{1}</td>
<td>-0.17(176)</td>
<td>-36.21(176)</td>
<td>27.94(148)</td>
<td>-7.15(176)</td>
<td>-108.76(175)</td>
</tr>
<tr>
<td>F_{2}</td>
<td>0.17(289)</td>
<td>36.21(302)</td>
<td>-27.94(264)</td>
<td>7.15(286)</td>
<td>108.76(286)</td>
</tr>
</tbody>
</table>

**Season of calving**

| S_{1}              | 0.10(77)                    | -8.43(80)                 | -6.94(72)               | -0.78(77)                                | 20.84(78)                  |
| S_{2}              | 0.08(138)                   | -4.63(143)                | -11.94(122)             | -1.15(138)                               | 37.90(134)                 |
| S_{3}              | -0.12(151)                  | 11.08(154)                | 11.24(152)              | 0.56(151)                                | -61.71(155)                |
| S_{4}              | -0.06(99)                   | 1.98(101)                 | 7.64(86)                | 1.37(99)                                 | 2.97(94)                   |

**Period of calving**

| P_{d1}             | 0.26(67)                    | 15.90(67)                 | 7.55(59)                | 1.41(67)                                 | 87.66(64)                  |
| P_{d2}             | -0.11(120)                  | -2.33(126)                | 15.47(110)              | -7.74(120)                               | -111.62(125)               |
| P_{d3}             | -0.18(116)                  | 20.96(119)                | 5.73(111)               | 2.84(116)                                | -27.46(118)                |
| P_{d4}             | 0.03(100)                   | -0.34(102)                | -10.02(89)              | 3.73(100)                                | 90.97(97)                  |
| P_{d5}             | 0.01(62)                    | -35.19(64)                | -18.74(43)              | -0.23(62)                                | -39.55(57)                 |
Appendix Table 2. Least square means (\( \bar{u} \)) with standard errors and constants for non-genetic factors affecting body weights of BSx5w crossbreds

<table>
<thead>
<tr>
<th>Non-genetic factor</th>
<th>Wt. at birth (kg)</th>
<th>Wt. at 2 mths (kg)</th>
<th>Wt. at 4 mths (kg)</th>
<th>Wt. at 6 mths (kg)</th>
<th>Wt. at 9 mths (kg)</th>
<th>Wt. at 12 mths (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \bar{u} )</td>
<td>25.51±0.22</td>
<td>46.24±1.03</td>
<td>74.80±1.89</td>
<td>107.82±2.43</td>
<td>136.28±2.49</td>
<td>171.16±2.96</td>
</tr>
<tr>
<td></td>
<td>(639)</td>
<td>(592)</td>
<td>(579)</td>
<td>(544)</td>
<td>(422)</td>
<td>(395)</td>
</tr>
<tr>
<td>Parity of birth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( p_{1} )</td>
<td>-1.28(217)</td>
<td>-1.33(201)</td>
<td>-0.90(193)</td>
<td>-2.05(176)</td>
<td>-3.32(133)</td>
<td>-4.54(123)</td>
</tr>
<tr>
<td>( p_{2} )</td>
<td>-0.04(140)</td>
<td>1.10(128)</td>
<td>3.17(127)</td>
<td>4.82(122)</td>
<td>5.19(87)</td>
<td>4.70(85)</td>
</tr>
<tr>
<td>( p_{3} )</td>
<td>-0.08(199)</td>
<td>-0.19(183)</td>
<td>-1.50(182)</td>
<td>-0.63(171)</td>
<td>-0.20(138)</td>
<td>-0.75(128)</td>
</tr>
<tr>
<td>( p_{4} )</td>
<td>1.40(83)</td>
<td>0.42(80)</td>
<td>-0.68(77)</td>
<td>-1.33(75)</td>
<td>-1.67(64)</td>
<td>0.99(59)</td>
</tr>
<tr>
<td>Season of birth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( s_{1} )</td>
<td>-0.84(130)</td>
<td>-0.04(125)</td>
<td>0.89(124)</td>
<td>0.40(123)</td>
<td>3.59(103)</td>
<td>-7.90(94)</td>
</tr>
<tr>
<td>( s_{2} )</td>
<td>0.27(217)</td>
<td>-1.27(188)</td>
<td>3.22(184)</td>
<td>4.05(186)</td>
<td>-3.74(121)</td>
<td>-9.93(121)</td>
</tr>
<tr>
<td>( s_{3} )</td>
<td>0.25(193)</td>
<td>0.28(183)</td>
<td>-1.52(179)</td>
<td>-3.54(164)</td>
<td>-6.06(126)</td>
<td>3.94(122)</td>
</tr>
<tr>
<td>( s_{4} )</td>
<td>0.32(99)</td>
<td>-1.50(96)</td>
<td>-2.59(92)</td>
<td>-0.91(91)</td>
<td>6.21(72)</td>
<td>13.89(58)</td>
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<tr>
<td>( p_{d_{1}} )</td>
<td>0.25(8)</td>
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<td>7.02(8)</td>
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<td>( p_{d_{2}} )</td>
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<td>4.58(49)</td>
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<td>( p_{d_{3}} )</td>
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<td>-3.62(100)</td>
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<td>-15.55(91)</td>
<td>-11.98(37)</td>
<td>-13.93(37)</td>
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<td>( p_{d_{4}} )</td>
<td>0.03(224)</td>
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<tr>
<td>( p_{d_{5}} )</td>
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<td>-6.86(199)</td>
<td>-7.81(176)</td>
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<th>Wt. at 15mths (kg)</th>
<th>Wt. at 18mths (kg)</th>
<th>Wt. at 1st Fertile Service (kg)</th>
<th>Wt. at 1st Calving (kg)</th>
<th>Growth rate g/day</th>
<th>Birth to 2 mths age (kg)</th>
<th>2 to 4 mths age (kg)</th>
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<tbody>
<tr>
<td>U</td>
<td>204.49±3.39 (399)</td>
<td>231.65±3.26 (325)</td>
<td>274.76±9.13 (248)</td>
<td>347.48±6.88 (229)</td>
<td>375.4±14.9</td>
<td>455.7±18.8</td>
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<td>-3.95±(96)</td>
<td>-12.11±(70)</td>
<td>-8.97±(66)</td>
<td>-0.5±(201)</td>
<td>2.5±(193)</td>
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<tr>
<td>P_r2</td>
<td>3.48±(76)</td>
<td>3.98±(69)</td>
<td>7.15±(59)</td>
<td>2.27±(71)</td>
<td>15.2±(127)</td>
<td>37.2±(125)</td>
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<tr>
<td>P_r3</td>
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<td>6.50±(88)</td>
<td>6.01±(87)</td>
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<td>P_r4</td>
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<td>-1.54±(31)</td>
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<td>-26.6±(77)</td>
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<td>-11.41±(59)</td>
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<td>-19.41±(39)</td>
<td>-7.85±(46)</td>
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<td>P_d4</td>
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<tr>
<td>P_d5</td>
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<td>-2.46±(119)</td>
<td>-2.81±(34)</td>
<td>8.66±(7)</td>
<td>-65.9±(236)</td>
<td>344.5±(229)</td>
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<th>Growth rate g/day</th>
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<tr>
<td>P1</td>
<td>-11.9(176)</td>
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<tr>
<td>P2</td>
<td>12.6(119)</td>
</tr>
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<td>P3</td>
<td>12.2(171)</td>
</tr>
<tr>
<td>P4</td>
<td>-12.9(75)</td>
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<td>Season of birth</td>
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</tr>
<tr>
<td>S1</td>
<td>-8.8(125)</td>
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<tr>
<td>S2</td>
<td>22.9(164)</td>
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<td>S3</td>
<td>-28.8(163)</td>
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<td>S4</td>
<td>15.1(89)</td>
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<td>Period of birth</td>
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<tr>
<td>Pd1</td>
<td>161.7(7)</td>
</tr>
<tr>
<td>Pd2</td>
<td>-56.2(47)</td>
</tr>
<tr>
<td>Pd3</td>
<td>-98.9(89)</td>
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<tr>
<td>Pd4</td>
<td>49.3(189)</td>
</tr>
<tr>
<td>Pd5</td>
<td>-55.9(209)</td>
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contd.
<table>
<thead>
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<th>Non-genetic factor</th>
<th>Age at 1st calving (mths)</th>
<th>First lact. yield (kg)</th>
<th>Initial yield (kg)</th>
<th>Ascending yield (kg)</th>
<th>Peak yield (kg)</th>
<th>Descending yield (kg)</th>
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<tbody>
<tr>
<td><em>u</em></td>
<td>30.41±0.57</td>
<td>3288.95±133.20</td>
<td>10.40±0.46</td>
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<td>14.58±0.45</td>
<td>10.40±0.39</td>
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<tr>
<td></td>
<td>(287)</td>
<td>(211)</td>
<td>(276)</td>
<td>(275)</td>
<td>(269)</td>
<td>(228)</td>
</tr>
<tr>
<td>Season of calving</td>
<td></td>
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</tr>
<tr>
<td><em>S_1</em></td>
<td>0.08(31)</td>
<td>140.63(30)</td>
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<td>-0.14(31)</td>
<td>0.49(31)</td>
<td>0.95(31)</td>
</tr>
<tr>
<td><em>S_2</em></td>
<td>0.41(96)</td>
<td>65.99(72)</td>
<td>0.15(95)</td>
<td>0.07(94)</td>
<td>0.17(94)</td>
<td>0.46(76)</td>
</tr>
<tr>
<td><em>S_3</em></td>
<td>-0.32(111)</td>
<td>50.39(75)</td>
<td>0.53(107)</td>
<td>0.88(107)</td>
<td>0.30(103)</td>
<td>-0.29(81)</td>
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<tr>
<td><em>S_4</em></td>
<td>-0.16(49)</td>
<td>-257.02(33)</td>
<td>-0.30(43)</td>
<td>-0.81(43)</td>
<td>-0.96(41)</td>
<td>-1.12(37)</td>
</tr>
<tr>
<td>Period of calving</td>
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</tr>
<tr>
<td><em>Pd_2</em></td>
<td>0.15(16)</td>
<td>285.39(16)</td>
<td>0.07(16)</td>
<td>-0.02(16)</td>
<td>0.30(16)</td>
<td>0.26(16)</td>
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<td><em>Pd_3</em></td>
<td>0.74(35)</td>
<td>-0.68(35)</td>
<td>-0.60(35)</td>
<td>-0.41(35)</td>
<td>-0.76(35)</td>
<td>-0.31(35)</td>
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<td><em>Pd_4</em></td>
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<td>-93.70(93)</td>
<td>-0.12(109)</td>
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<td>-0.29(110)</td>
<td>-0.33(109)</td>
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<tr>
<td><em>Pd_5</em></td>
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<td>-113.22(66)</td>
<td>0.86(116)</td>
<td>0.46(114)</td>
<td>0.74(108)</td>
<td>0.38(69)</td>
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contd(T.)

<table>
<thead>
<tr>
<th>Non-genetic factor</th>
<th>Milking Average (kg)</th>
<th>First lact. length (days)</th>
<th>First dry period (days)</th>
<th>First 170 to 305 days lactation length</th>
<th>First 170 to 305 days lact. yield (kg)</th>
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<tbody>
<tr>
<td>u</td>
<td>9.98±0.28</td>
<td>336.40±10.10</td>
<td>74.40±6.00</td>
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<td>2888.89±92.43</td>
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<td>(211)</td>
<td>(211)</td>
<td>(180)</td>
<td>(211)</td>
<td>(211)</td>
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Season of calving

<table>
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<tr>
<th>Season of calving</th>
<th>Milking Average (kg)</th>
<th>First lact. length (days)</th>
<th>First dry period (days)</th>
<th>First 170 to 305 days lactation length</th>
<th>First 170 to 305 days lact. yield (kg)</th>
</tr>
</thead>
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<tr>
<td>$S_1$</td>
<td>0.28(30)</td>
<td>4.88(30)</td>
<td>-8.84(29)</td>
<td>7.96(30)</td>
<td>237.81(30)</td>
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<td>$S_2$</td>
<td>-0.05(72)</td>
<td>5.06(73)</td>
<td>1.21(68)</td>
<td>-0.15(72)</td>
<td>-1.94(72)</td>
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<tr>
<td>$S_3$</td>
<td>-0.28(75)</td>
<td>14.38(75)</td>
<td>4.62(58)</td>
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<td>-82.68(75)</td>
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<td>$S_4$</td>
<td>0.05(33)</td>
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<td>-153.19(33)</td>
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Period of calving

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<th>Milking Average (kg)</th>
<th>First lact. length (days)</th>
<th>First dry period (days)</th>
<th>First 170 to 305 days lactation length</th>
<th>First 170 to 305 days lact. yield (kg)</th>
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<td>$P_{d_2}$</td>
<td>0.07(16)</td>
<td>25.11(16)</td>
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<td>119.66(16)</td>
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<td>-0.47(35)</td>
<td>7.65(35)</td>
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<td>-123.63(35)</td>
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<td>$P_{d_4}$</td>
<td>0.18(93)</td>
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<td>17.87(81)</td>
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<td>-53.48(93)</td>
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<td>$P_{d_5}$</td>
<td>0.22(66)</td>
<td>-17.09(67)</td>
<td>0.33(50)</td>
<td>-0.51(66)</td>
<td>57.46(66)</td>
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Figures in parentheses indicate the number of observations.
### Appendix Table 3. Least square means (u) with standard errors and constants for non-genetic factors affecting several traits of HF x Suy x MF crossbreed

<table>
<thead>
<tr>
<th>Non-genetic Factors</th>
<th>Wt. at birth (kg)</th>
<th>Wt. at 2 months (kg)</th>
<th>Wt. at 4 months (kg)</th>
<th>Wt. at 6 months (kg)</th>
<th>Wt. at 8 months (kg)</th>
<th>Wt. at 12 months (kg)</th>
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<tbody>
<tr>
<td>u</td>
<td>(3802)</td>
<td>(376)</td>
<td>(3718)</td>
<td>(3698)</td>
<td>(3622)</td>
<td>(3538)</td>
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<td>Farns</td>
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<td>Fx</td>
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<tr>
<td>F1</td>
<td>0.03(80)</td>
<td>1.41(80)</td>
<td>1.73(798)</td>
<td>1.42(797)</td>
<td>1.53(792)</td>
<td>3.48(794)</td>
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<td>-0.70(480)</td>
<td>-0.89(479)</td>
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<tr>
<td>F3</td>
<td>0.67(424)</td>
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<td>-6.92(423)</td>
<td>-13.27(424)</td>
<td>-15.64(419)</td>
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<td>-0.07(656)</td>
<td>-0.68(634)</td>
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<td>-1.06(603)</td>
<td>-0.58(589)</td>
<td>-1.65(566)</td>
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<td>0.75(455)</td>
<td>0.37(453)</td>
<td>2.39(452)</td>
<td>7.41(452)</td>
<td>10.51(432)</td>
<td>14.07(411)</td>
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<tr>
<td>F6</td>
<td>0.86(947)</td>
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<td>8.58(932)</td>
<td>9.53(905)</td>
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<td>0.93(1168)</td>
<td>0.79(1141)</td>
<td>0.94(1118)</td>
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<td>Pz2</td>
<td>-0.13(791)</td>
<td>-0.03(783)</td>
<td>-0.20(781)</td>
<td>-0.40(776)</td>
<td>-0.89(758)</td>
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<td>-0.09(1320)</td>
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<td>0.70(1285)</td>
<td>0.05(1248)</td>
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<td>0.00(448)</td>
<td>-0.53(445)</td>
<td>-0.13(443)</td>
<td>-0.57(438)</td>
<td>0.15(430)</td>
</tr>
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<td>Season of birth</td>
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<tr>
<td>S1</td>
<td>-0.47(1126)</td>
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<td>2.78(1108)</td>
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<td>6.05(1065)</td>
<td>2.46(1055)</td>
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<td>S2</td>
<td>0.02(1081)</td>
<td>0.75(1056)</td>
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<td>-4.69(1033)</td>
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<td>-5.99(687)</td>
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<tr>
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<td>-1.04(878)</td>
<td>-2.14(872)</td>
<td>-2.98(870)</td>
<td>3.64(836)</td>
<td>4.49(785)</td>
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<td>Pd1</td>
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<td>-6.96(173)</td>
<td>-9.13(173)</td>
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<td>-14.28(173)</td>
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<td>3.35(285)</td>
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<tr>
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<td>-0.80(1462)</td>
<td>3.49(1470)</td>
<td>6.44(1466)</td>
<td>5.80(1464)</td>
<td>6.48(1457)</td>
<td>8.93(1453)</td>
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<tr>
<td>Pd5</td>
<td>1.56(882)</td>
<td>3.61(871)</td>
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<td>5.35(843)</td>
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<th>Wt. at 18mths (kg)</th>
<th>Wt. at First fertile service (kg)</th>
<th>Wt. at First calving (kg)</th>
<th>Birth to 2 mths age (kg)</th>
<th>2 to 4 mths age (kg)</th>
<th>Growth rate g/day</th>
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<td>-24.9(692)</td>
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<td>16.38(1427)</td>
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<th>9 to 12th age</th>
<th>12 to 15th age</th>
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<td>(3615)</td>
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<td>(3313)</td>
<td>(3166)</td>
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<td>-8.5(562)</td>
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<td>-9.6(1012)</td>
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<td>8.0(1153)</td>
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<td>-0.6(437)</td>
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<td>9.1(409)</td>
<td>0.4(399)</td>
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<td>-28.7(172)</td>
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<tr>
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<td>-6.6(913)</td>
<td>-7.3(917)</td>
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<td>7.6(1455)</td>
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<td>27.1(1410)</td>
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<td>$P_{d5}$</td>
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<td>-4.9(780)</td>
<td>33.9(699)</td>
<td>69.3(554)</td>
<td>33.8(407)</td>
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<th>First lact yield (kg)</th>
<th>Initial yield (kg)</th>
<th>Ascending yield (kg)</th>
<th>Peak yield (kg)</th>
<th>Descending yield (kg)</th>
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<td>36.36±0.25</td>
<td>2495.34±39.51</td>
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<td>8.68±0.13</td>
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<td>(2693)</td>
<td>(2062)</td>
<td>(2655)</td>
<td>(2646)</td>
<td>(2640)</td>
<td>(2577)</td>
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</table>

**fame**

| f1                  | -0.13(849)               | 52.87(601)           | -0.42(828)         | -0.49(926)           | -0.81(841)     | -0.42(811)            |
|                     |                          |                      |                    |                      |                |                       |
| f2                  | 2.68(337)                | -258.58(257)         | -0.79(326)         | -0.83(326)           | -1.12(319)     | -0.67(314)            |
|                     |                          |                      |                    |                      |                |                       |
| f3                  | -0.57(549)               | -108.38(440)         | -0.08(548)         | 0.13(548)            | -0.10(542)     | -0.47(537)            |
|                     |                          |                      |                    |                      |                |                       |
| f4                  | -1.47(339)               | 242.18(288)          | 0.69(339)          | 0.80(338)            | 1.46(335)      | 0.89(319)             |
|                     |                          |                      |                    |                      |                |                       |
| f5                  | -0.50(619)               | 71.90(476)           | 0.61(612)          | 0.32(608)            | 0.55(603)      | 0.67(596)             |
|                     |                          |                      |                    |                      |                |                       |

**Season of calving**

| s1                  | 0.61(667)                | 6.47(537)            | -0.43(679)         | -0.69(678)           | -0.30(678)     | 0.33(669)             |
|                     |                          |                      |                    |                      |                |                       |
| s2                  | -0.51(895)               | -1.61(690)           | 0.15(883)          | 0.66(881)            | 0.67(876)     | 0.58(841)             |
|                     |                          |                      |                    |                      |                |                       |
| s3                  | -0.51(526)               | -43.00(420)          | 0.39(514)          | 0.48(508)            | 0.17(505)     | -0.63(491)            |
|                     |                          |                      |                    |                      |                |                       |
| s4                  | 0.41(585)                | 38.13(415)           | -0.10(579)         | -0.41(579)           | -0.54(581)     | -0.26(578)            |
|                     |                          |                      |                    |                      |                |                       |

**Period of calving**

| p1                  | 1.50(22)                 | 49.78(20)            | -0.80(22)          | -0.95(22)           | -0.63(22)     | -0.41(22)             |
|                     |                          |                      |                    |                      |                |                       |
| p2                  | 0.88(93)                 | -239.89(180)         | -0.21(184)         | -0.56(183)          | -0.12(187)    | -0.66(181)            |
|                     |                          |                      |                    |                      |                |                       |
| p3                  | 0.57(275)                | -173.31(268)         | 0.28(264)          | 0.97(264)           | -0.24(275)    | -0.30(264)            |
|                     |                          |                      |                    |                      |                |                       |
| p4                  | -0.41(918)               | 191.48(894)          | 0.61(914)          | 0.72(914)           | 0.51(915)     | 0.52(912)             |
|                     |                          |                      |                    |                      |                |                       |
| p5                  | -2.55(1285)              | 171.94(700)          | 0.12(1271)         | 0.69(1263)          | 1.09(1241)    | 0.85(1198)            |

---------- contd ----------
<table>
<thead>
<tr>
<th>Non-genetic factors</th>
<th>Milk yield average (kg)</th>
<th>First lactation length (days)</th>
<th>First dry period (days)</th>
<th>First 170-305 days lactation length (days)</th>
<th>First 170-305 days lactation yield (kg)</th>
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<td>u</td>
<td>8.35±0.11 (2062)</td>
<td>309.52±2.94 (2069)</td>
<td>124.78±3.75 (1763)</td>
<td>284.14±1.16 (2042)</td>
<td>2352.57±33.67 (2042)</td>
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<td>-0.30(600)</td>
<td>14.77(601)</td>
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<td>17.90(584)</td>
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<td>-0.39(259)</td>
<td>-16.26(263)</td>
<td>19.92(221)</td>
<td>-8.01(255)</td>
<td>-172.67(255)</td>
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<td>-97.78(439)</td>
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<td>201.41(285)</td>
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<tr>
<td>S1</td>
<td>0.07(537)</td>
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<td>29.98(530)</td>
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<td>Pd4</td>
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<td>-24.74(484)</td>
<td>-0.35(690)</td>
<td>135.03(690)</td>
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Figures in parentheses indicate the number of observations.
Appendix Table 4. Analysis of Variance (Least Square technique) of Sahiwal cattle traits

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<th>Wt. at birth</th>
<th>Wt. at 2 mths</th>
<th>Wt. at 4 mths</th>
<th>Wt. at 6 mths</th>
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<td>d.f.</td>
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<td>(kg)</td>
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<td>(kg)</td>
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*Significant (P<.05)
Appendix Table 5. Analysis of Variance (Least square technique) of Blue/Gray crossbreed traits

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<th>Source of variation</th>
<th>Wt. at birth</th>
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<th>Wt. at 9 mths</th>
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<table>
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<th>Wt. at 18 mths</th>
<th>Wt. at 1st fertile service</th>
<th>Wt. at calving</th>
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<th>Age at 1st calving</th>
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<th>Initial yield (kg)</th>
<th>Ascending yield (kg)</th>
<th>Peak yield (kg)</th>
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<th>1st dry period (days)</th>
<th>1st lact. yield (170-305 days) (kg)</th>
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*Significant (P ≤ 0.05)
Appendix Table 6. Analysis of Variance (Least square technique) of HF x Sr - SrHF crossbreed traits

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*Significant (P<.05)
### Appendix Table 7a. Prediction equations to estimate first lactation yield (Set I) - Sahiwal

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*F value significant at p<0.05*
Appendix Table 8a. Prediction equations to estimate first lactation yield (Set I) - BSxBS crossbreds.

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<td>32</td>
<td>$1372.22(x_1)$</td>
<td>$48.13(x_1)$</td>
<td>$-11.49(x_2)$</td>
<td>$18.14(x_3)$</td>
<td>$-0.62(x_1^2)$</td>
<td>$0.04(x_2^2)$</td>
<td>$-0.04(x_3^2)$</td>
<td>12.74 *</td>
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<td>$1557.60(x_1)$</td>
<td>$-8.63(x_2)$</td>
<td>$24.28(x_3)$</td>
<td>$-491.24(x_5)$</td>
<td>$-0.03(x_2^2)$</td>
<td>$-0.06(x_3^2)$</td>
<td>$361.96(x_5^2)$</td>
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<tr>
<td>34</td>
<td>$1018.75(x_1)$</td>
<td>$-107.18(x_1)$</td>
<td>$3.28(x_2)$</td>
<td>$-7.76(x_3)$</td>
<td>$21.96(x_4)$</td>
<td>$-672.01(x_5)$</td>
<td>$2.15(x_2^2)$</td>
<td>$-0.02(x_3^2)$</td>
<td>$0.02(x_1^2)$</td>
<td>$-0.03(x_4^2)$</td>
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* F value significant at $p \leq 0.05$
### Appendix Table 9a. Prediction equations to estimate first lactation yield (Set I) - HF x w crossbreds

<table>
<thead>
<tr>
<th>Equation No.</th>
<th>Coefficients</th>
<th>Y (%)</th>
<th>R² (%)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>3115.45(a), -1.99(x₁), 2.92(x₂), 3.26(x₃), 5.83(x₄), 48.36(x₅), -0.88(x₆), 8.51(x₇)</td>
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<td>45.14</td>
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<td>45.13</td>
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<td>3</td>
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<td>8</td>
<td>1424.23(a), 8.80(x₂)</td>
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<td>3.55</td>
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<td>1294.03(a), 6.07(x₃)</td>
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<td>2344.67(a), 3.23(x₆)</td>
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<td>-170.68(a), 8.53(x₇)</td>
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<td>14</td>
<td>610.85(a), 2.02(x₁), 3.96(x₂), 2.88(x₃), 5.74(x₄)</td>
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<td>11.05</td>
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<td>15</td>
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<td>16</td>
<td>1110.19(a), 4.85(x₂), 191.62(x₅)</td>
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<td>4.38</td>
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<td>17</td>
<td>-622.16(a), 3.04(x₁), 2.93(x₂), 2.77(x₃), 5.75(x₄), 235.78(x₅)</td>
<td></td>
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...cont'd.
| 18 | -3553.24(a) | 35.87(x_1) | -19.50(x_2) | 1.06(x_3) | 3.97(x_4) | 652.27(x_5) | 25.59(x_6) | 15.87(x_7)   |
|    |       | -0.81(x_1^2) | 0.10(x_2^2) | 0.01(x_3^2) | 0.00(x_4^2) | -583.56(x_5^2) | -0.37(x_6^2) | -0.01(x_7^2) | 46.02 |
| 19 | -3262.79(a) | 19.48(x_2) | 0.20(x_3) | 4.38(x_4) | 647.71(x_5) | 27.17(x_6) | 15.79(x_7) | 0.10(x_2^2) | 45.98 |
|    |       | 0.01(x_3^2) | 0.00(x_4^2) | -572.74(x_5^2) | -0.39(x_6^2) | -0.01(x_7^2) |        |            |        |
| 20 | -3641.54(a) | -2.58(x_3) | 3.83(x_4) | 13.78(x_5) | 25.55(x_6) | 15.40(x_7) | 0.02(x_3^2) | 0.00(x_4^2) | 45.50 |
|    |       | 139.78(x_5^2) | -0.37(x_6^2) | -0.01(x_7^2) |        |            |        |            |        |
| 21 | -3587.52(a) | 6.21(x_4) | -4.53(x_5) | 7.37(x_6) | 15.37(x_7) | 0.00(x_4^2) | 365.85(x_5^2) | -0.21(x_6^2) | 44.23 |
|    |       | -0.01(x_7^2) |        |            |            |            |        |            |        |
| 22 | -2783.55(a) | 403.71(x_5) | 80.19(x_6) | 13.75(x_7) | 119.17(x_5^2) | -1.03(x_6^2) | 0.01(x_7^2) |        | 35.91 |
| 23 | -2656.71(a) | 65.87(x_6) | 14.04(x_7) | -1.13(x_2^2) | 0.01(x_7^2) |        |        |        | 34.96 |
| 24 | 1806.91(a) | 35.45(x_1) | -0.31(x_1^2) |        |        |        |        |        | 0.59 |
| 25 | 2133.10(a) | 3.60(x_2) | 0.05(x_2^2) |        |        |        |        |        | 3.66 |
| 26 | 160.96(a) | 18.19(x_3) | -0.03(x_3^2) |        |        |        |        |        | 3.52 |
| 27 | 540.42(a) | 4.56(x_4) | 0.00(x_4^2) |        |        |        |        |        | 8.68 |
| 28 | 2115.35(a) | 589.04(x_5) | 100.29(x_5) |        |        |        |        |        | 0.58 |

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<th>312.73(a)</th>
<th>113.66(x_6)</th>
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<td>-17.73(x_2)</td>
<td>21.48(x_3)</td>
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<td>33</td>
<td>1012.45(a)</td>
<td>-26.28(x_2)</td>
<td>21.04(x_3)</td>
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<td>317.05(a)</td>
<td>0.42(x_1^2)</td>
<td>-32.37(x_2)</td>
<td>20.05(x_3)</td>
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*F value significant at P<0.05*
Appendix Table 10a. Prediction equations to estimate first lactation yield (Set I) - SmxHF crossbreeds

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<th>( R^2(%) )</th>
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<td>(-592.21(a))</td>
<td>(2.08(x_1))</td>
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<td>2</td>
<td>(-553.44(a))</td>
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<td>(-479.23(a))</td>
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<td>(-229.28(a))</td>
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<td>(297.68(a))</td>
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<td>(2320.38(a))</td>
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<td>9</td>
<td>(2093.38(a))</td>
<td>(2.03(x_1))</td>
</tr>
<tr>
<td>10</td>
<td>(1848.44(a))</td>
<td>(1.82(x_1))</td>
</tr>
<tr>
<td>11</td>
<td>(2492.59(a))</td>
<td>(10.00(x_1))</td>
</tr>
<tr>
<td>12</td>
<td>(2028.35(a))</td>
<td>(12.51(x_1))</td>
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<td>13</td>
<td>(494.39(a))</td>
<td>(6.42(x_1))</td>
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<td>14</td>
<td>(1837.95(a))</td>
<td>(6.42(x_1))</td>
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<td>(2252.76(a))</td>
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<td>16</td>
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<td>(2252.76(a))</td>
<td>(-8.73(x_1))</td>
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<th>39.67(x_2)</th>
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<td>-0.12(x^2_1)</td>
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<td>-0.01(x^2_4)</td>
<td>920.49(x^2_5)</td>
<td>-0.38(x^2_6)</td>
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<td>6.96(x_4)</td>
<td>-1234.32(x_5)</td>
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<td>-0.01(x^2_4)</td>
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<td>1608.43(x^2_3)</td>
<td>-0.34(x^2_6)</td>
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<td>-2103.41(x_5)</td>
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<td>22</td>
<td>265.99(a)</td>
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<td>-61.30((x_2))</td>
<td>9.34((x_3))</td>
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<td>1.24((x_1^2))</td>
<td>0.25((x_2^2))</td>
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<td>-58.46((x_2))</td>
<td>13.54((x_3))</td>
<td>1.59((x_1^2))</td>
<td>0.24((x_2^2))</td>
<td>-0.03((x_3^2))</td>
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<td>4248.34(a)</td>
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<td>-1594.10((x_5))</td>
<td>0.19((x_2^2))</td>
<td>-0.02((x_3^2))</td>
<td>0.13((x_5^2))</td>
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<td>34</td>
<td>4041.01(a)</td>
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<td>-45.65((x_2))</td>
<td>7.42((x_3))</td>
<td>6.87((x_4))</td>
<td>-1908.49((x_5))</td>
<td>0.99((x_1^2))</td>
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*F value significant at \(P < 0.05\)

\(Y = \) First total lactation yield, \(X_1 = \) Birth weight, \(X_2 = \) Weight at six months,
\(X_3 = \) Weight at 12 months, \(X_4 = \) Weight at first calving, \(X_5 = \) Growth rate 4-6 mths (Max. average gain per day)
\(X_6 = \) Age at 1st calving (mths), \(X_7 = \) First total lactation period (days)
### Appendix Table 7b. Prediction equations to estimate first lactation yield on the basis of 1st lactation components (Set II) - Sahiwal

<table>
<thead>
<tr>
<th>Equation</th>
<th>R² (%)</th>
</tr>
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<td><strong>1</strong></td>
<td>-140.85(a) 7.51(x₁) 55.00(x₂) 45.80(x₃) 187.03(x₄)</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>-130.16(a) 60.14(x₂) 45.37(x₃) 186.89(x₄)</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>-133.69(a) 94.79(x₃) 188.93(x₄)</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>1168.06(a) 142.15(x₁)</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>573.31(a) 189.14(x₂)</td>
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<tr>
<td><strong>6</strong></td>
<td>273.50(a) 189.55(x₃)</td>
</tr>
<tr>
<td><strong>7</strong></td>
<td>246.76(a) 260.69(x₄)</td>
</tr>
<tr>
<td><strong>8</strong></td>
<td>266.83(a) 4.07(x₁) 68.58(x₂) 190.67(x₃)</td>
</tr>
<tr>
<td><strong>9</strong></td>
<td>574.90(a) -1.29(x₁) 189.94(x₂)</td>
</tr>
<tr>
<td><strong>10</strong></td>
<td>-350.97(a) 78.99(x₁) -152.75(x₂) 193.01(x₃) 217.03(x₄) -5.33(x₁²) 12.96(x₂²) -7.59(x₃²) -2.27(x₄²)</td>
</tr>
<tr>
<td><strong>11</strong></td>
<td>-285.69(a) -101.27(x₂) 194.48(x₃) 204.20(x₄) 1.04(x₂²) -7.79(x₃²) -1.37(x₄²)</td>
</tr>
<tr>
<td><strong>12</strong></td>
<td>-321.87(a) 131.49(x₃) 193.43(x₄) -1.86(x₃²) -0.36(x₄²)</td>
</tr>
<tr>
<td><strong>13</strong></td>
<td>1173.05(a) 140.48(x₁) 0.13(x₁²)</td>
</tr>
<tr>
<td><strong>14</strong></td>
<td>905.52(a) 100.71(x₂) 5.40(x₂²)</td>
</tr>
<tr>
<td><strong>15</strong></td>
<td>-58.72(a) 260.92(x₃) -3.59(x₃²)</td>
</tr>
<tr>
<td><strong>16</strong></td>
<td>324.57(a) 237.52(x₄) 1.59(x₄²)</td>
</tr>
<tr>
<td><strong>17</strong></td>
<td>885.83(a) 52.32(x₁) 65.21(x₂) -4.23(x₂²) 7.72(x₂²)</td>
</tr>
<tr>
<td><strong>18</strong></td>
<td>-10.25(a) 78.36(x₁) -174.33(x₂) 340.42(x₃) -5.49(x₁²) 15.12(x₂²) -10.88(x₃²)</td>
</tr>
</tbody>
</table>

* If value significant at P<0.05
### Appendix Table 8b. Prediction equations to estimate first lactation yield on the basis of first lactation components (Set II) BSxSw crossbreed

| Equation No. | $a$ | $b$ | $c$ | $d$ | $e$ | $f$ | $g$ | $h$ | $i$ | $j$ | $k$ | $l$ | $m$ | $n$ | $o$ | $p$ | $q$ | $r$ | $s$ | $t$ | $u$ | $v$ | $w$ | $x$ | $y$ | $z$ | $R^2(\%)$ |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1           | 173.48 | 48.64 | 1.05 | 51.45 | 162.71 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 44.54 |
| 2           | 89.67  | 31.99 | 64.62 | 164.11 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 43.70 |
| 3           | 90.03  | 92.38 | 163.74 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 43.45 |
| 4           | 1567.33 | 150.42 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 24.74 |
| 5           | 1101.18 | 164.22 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 24.83 |
| 6           | 475.13  | 182.99 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 30.86 |
| 7           | 787.62  | 226.38 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 38.54 |
| 8           | 566.44  | 54.91 | -6.51 | 142.74 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 32.12 |
| 9           | 1142.94 | 82.42 | 91.32 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 27.27 |
| 10          | -366.63 | 89.95 | -3.46 | 97.03 | 169.59 | -1.83 | 0.06 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 44.75 |
| 11          | -445.47 | 22.17 | 130.63 | 189.09 | 0.27 | -2.08 | -1.23 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 43.81 |
| 12          | -550.01 | 150.39 | 209.18 | 1.90 |     | -2.22 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 43.62 |
| 13          | 1050.16 | 253.05 | -4.62 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 25.37 |
| 14          | 1018.40 | 168.09 | -0.15 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 24.83 |
| 15          | -379.45 | 302.23 | -3.98 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 31.14 |
| 16          | 656.34  | 253.25 | -1.28 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 38.56 |
| 17          | 874.46  | 222.07 | 16.63 | -6.53 | 3.19 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 28.14 |
| 18          | -56.34  | 168.37 | 41.04 | 108.75 | -5.11 | -2.10 | 1.35 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     | 33.06 |

*F value significant at $p < 0.05$
### Appendix Table 9b. Prediction equations to estimate first lactation yield on the basis of 1st lactation components (Set II) - HF x SW crossbreds

<table>
<thead>
<tr>
<th>Equation No.</th>
<th>$x^y$</th>
<th>$y^z$</th>
<th>$R^2(X)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>252.11(a)</td>
<td>4.72($x_1$)</td>
<td>-11.09($x_2$)</td>
</tr>
<tr>
<td>2</td>
<td>260.57(a)</td>
<td>-9.68($x_2$)</td>
<td>118.55($x_3$)</td>
</tr>
<tr>
<td>3</td>
<td>250.86(a)</td>
<td>111.33($x_3$)</td>
<td>110.87($x_4$)</td>
</tr>
<tr>
<td>4</td>
<td>1076.58(a)</td>
<td>76.79($x_1$)</td>
<td>78.05($x_2$)</td>
</tr>
<tr>
<td>5</td>
<td>334.80(a)</td>
<td>13.48($x_1$)</td>
<td>-12.46($x_2$)</td>
</tr>
<tr>
<td>6</td>
<td>1337.49(a)</td>
<td>137.03($x_1$)</td>
<td>19.97 *</td>
</tr>
<tr>
<td>7</td>
<td>1344.55(a)</td>
<td>116.53($x_2$)</td>
<td>22.25 *</td>
</tr>
<tr>
<td>8</td>
<td>350.43(a)</td>
<td>185.11($x_3$)</td>
<td>48.35 *</td>
</tr>
<tr>
<td>9</td>
<td>745.97(a)</td>
<td>202.79($x_4$)</td>
<td>48.77 *</td>
</tr>
<tr>
<td>10</td>
<td>9.27(a)</td>
<td>29.20($x_1$)</td>
<td>-10.90($x_2$)</td>
</tr>
<tr>
<td>11</td>
<td>47.09(a)</td>
<td>-6.29($x_2$)</td>
<td>99.30($x_3$)</td>
</tr>
<tr>
<td>12</td>
<td>38.13(a)</td>
<td>94.24($x_3$)</td>
<td>184.86($x_4$)</td>
</tr>
<tr>
<td>13</td>
<td>110.06(a)</td>
<td>14.23($x_1$)</td>
<td>-47.91($x_2$)</td>
</tr>
<tr>
<td>14</td>
<td>844.84(a)</td>
<td>-16.86($x_1$)</td>
<td>190.07($x_2$)</td>
</tr>
<tr>
<td>15</td>
<td>1397.63(a)</td>
<td>122.17($x_1$)</td>
<td>0.83($x_2^2$)</td>
</tr>
<tr>
<td>16</td>
<td>684.14(a)</td>
<td>216.53($x_2$)</td>
<td>-2.98($x_2^2$)</td>
</tr>
<tr>
<td>17</td>
<td>122.42(a)</td>
<td>224.96($x_3$)</td>
<td>-1.63($x_2^2$)</td>
</tr>
<tr>
<td>18</td>
<td>544.97(a)</td>
<td>251.08($x_4$)</td>
<td>-2.63($x_2^2$)</td>
</tr>
</tbody>
</table>

* value significant at 0.05
**Appendix Table 10b**. Prediction equations to estimate first lactation yield on the basis of 1st lactation components (*S*<sub>l</sub> II) - *S*<sub>2</sub> x HF crossbreds

<table>
<thead>
<tr>
<th>Equation</th>
<th>( R^2 (X) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41.56 *</td>
</tr>
<tr>
<td>2</td>
<td>41.51 *</td>
</tr>
<tr>
<td>3</td>
<td>41.38 *</td>
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<tr>
<td>4</td>
<td>34.30 *</td>
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<tr>
<td>5</td>
<td>23.95 *</td>
</tr>
<tr>
<td>6</td>
<td>13.55 *</td>
</tr>
<tr>
<td>7</td>
<td>23.77 *</td>
</tr>
<tr>
<td>8</td>
<td>34.00 *</td>
</tr>
<tr>
<td>9</td>
<td>34.23 *</td>
</tr>
<tr>
<td>10</td>
<td>42.10 *</td>
</tr>
<tr>
<td>11</td>
<td>42.00 *</td>
</tr>
<tr>
<td>12</td>
<td>41.40 *</td>
</tr>
<tr>
<td>13</td>
<td>13.59 *</td>
</tr>
<tr>
<td>14</td>
<td>23.86 *</td>
</tr>
<tr>
<td>15</td>
<td>34.04 *</td>
</tr>
<tr>
<td>16</td>
<td>34.25 *</td>
</tr>
<tr>
<td>17</td>
<td>24.05 *</td>
</tr>
<tr>
<td>18</td>
<td>34.86 *</td>
</tr>
</tbody>
</table>

\( Y = \) Total 1st lact. yield, \( x_1 = \) Initial yield, \( x_2 = \) Ascending yield, \( x_3 = \) Peak yield, \( x_4 = \) Descending yield

*F value significant at \( P \leq 0.05 \)
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