CHAPTER V

DISCUSSION
DISCUSSION

Performance testing of body weights (5.1), growth rates (5.2) and production traits (5.3) of S, BSpSw and HFxSwe-SweHF crossbreds was done by fitting least squares 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 S female calves was 21.03±0.13 kg which was 1 to 2 kg higher (Mishra, 1973; Raza et al., 1974 and Bhatnagar et al., 1974) and 0.6 to 0.8 kg lower (Sayer, 1936; Singh and Dutt, 1968; Mudgal and Roy, 1965a,b). However, Bhatnagar et al. (1966) and
Tanaja and Bhat (1970) observed the values quite close to the present observation. The birth weight of Su female calves was significantly lower than its exotic crossbred female calves. Such observations were also made by Naidu and Desai (1965), Tanaja and Bhat (1970) and Mishra (1973).

The average birth weight of BSxSu (25.51±0.22 kg) was quite close to that reported by Bhatnagar et al. (1973). The average value of HFxSu-SuxHF calves was 23.45±0.07 kg, which was quite similar (23.44±0.12) to that reported by Tanaja (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 BSxSu and HFxSu-SuxHF 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), Tanaja and Bhat (1970), Pandey (1971), Ganpule (1971), Patil et al. (1974), Hurty (1974) and Chauhan et al. (1975). The mean value of 25.19 kg of BSxSu 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), Tanaja (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 cross 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 Mariana 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 management factors. The calves born at Lucknow, Meerut and Ambala were positively deviated from their common mean, while Bareilly, Birchantouri 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).

FriesianxSahiwal crossbred calves born during March to May and BSxSw during June-August were significantly (P<.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 Madge and Ray (1965), 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 HFxSw-SwxHF 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 B5xSw 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 B5xSw crossbreds in first period could be due to maximum heterosis in small numbers (8) of halfbred (F1) calves. Highest birth weight for HFxSw-SwxHF 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 (45.67±0.34 kg) of Sw female calves at 2 months age was 7.8 kg higher from Shatnagar et al. (1973 and 1974) and 1.4 kg
higher from Riehra (1973). Bhatnagar 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 crosses. Lower weights of Zebu calves than Exotic x Zebu crosses were reported (Rathore, 1949; Parija, 1972 and Riehra, 1973). The mean birth weight of BSxSw was 46.84 kg which was 1 to 6 kg higher from Bhatnagar et al. (1973 and 1974). Taneja (1973) reported 5.7 kg lower weight than present estimate of HFxSw-SwxHF. 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<.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-SwxHF 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 difference in managerial practices. Season of birth had no significant effect in Sw and its BS crosses. Riehra (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-SwxHF crossbreds was contrary to the finding of Parija (1972), Riehra (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 \(S\) female calves was \(70.24\pm0.61\) kg which was higher than the reported values (81.65±10.36 kg by Hudgal and Ray, 1965a,b and 67.94±0.67 kg by Mishra, 1973). The body weight of \(BxS\) was 74.00±1.79 kg. This was 6.3 kg less than Bhatnagar et al. (1973) and 5.5 kg higher than Bhatnagar 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 \(S\) and \(HFxS\)–\(SimHF\) crossbreds which was in agreement with that of Parija (1972).

Significant effect due to season of birth was observed for \(BxS\) and \(HFxS\)–\(SimHF\) crossbreds but non-significant in \(S\). 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 management conditions prevailed during that time.

5.1.4. Body weight at 6 months' age

The least square mean

of 97.20±0.75 kg for \(S\) female was 0.90 kg higher than that reported by Mishra (1973). The weight of \(BxS\) 107.02±2.43 kg was lower from reported weight of 113.82±22.1 kg by Bhatnagar 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-SxHF crossbreeds 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 Geewani and De (1963), Pandey (1971) and Rishra (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-SxHF and BSxSW grades respectively was due to fraction of exotic inheritance. The average body weight for each genetic group of HFxSW-SxHF 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-SxHF 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 \((P < 0.01)\) effect due to season of birth for BSxSw and HFxSw-SwHF crossbreeds was similar to that claimed by Pandey (1971), Mishra (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-SwHF was 4.50, 29.08 and 3.95 percent respectively. The improvement in managerial 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-SwHF was 128.52±1.49, 136.28±2.49 and 158.71±0.64 kg respectively. Mishra (1973) reported 137.86±1.23 kg body weight for Sw which was higher from this study. The reason might be that he had reported weight for Recut 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 \((P < 0.01)\) 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 Rishra (1973) respectively but 4.34 kg higher from Bhatnagar at al. (1973). Variation in body weight might be due to different herd and period used for the estimate. Bhatnagar at 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-SxHF 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 (1974), Pandey (1971), Taneja (1973), Patil at al. (1974) and Rurty (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 3.83 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 at al. (1969), Ganesan and De (1963), Shidu and Desai (1965) and Rurty (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-SxHF cattle respectively was similar to the findings of Taneja and Bhat (1972), and Taneja (1973).
(1971) did not find significant difference due to farm in heavy
rainfall 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 BSxSw 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, HFxSw-SuxHF and BSxSw crossbred
calves respectively. Significant difference due to season was
also observed by Tanaja and Bhat (1972), Parija (1972), Rishra
(1973) and Tanaja (1973).

Variation observed due to period of birth in order
of 3.45, 18.01 and 5.59 per cent for Sw, BSxSw and HFxSw-SuxHF
calves respectively was highly significant. Significant variation
due to period of birth was in agreement with the findings of
Tanaja and Bhat (1972), Rishra (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 Rishra (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 Rusty (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. Henzi (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-SwxF 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 Friesian 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
Narawat 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-SwxF crossbreds for heavy rain fall areas. The effect due
to genetic groups of exotic inheritance was significant. Halfbreds
and higher grades of BS and HF had higher weights from their lower
grades. The body weights reported by Pandey (1971), Ganpule (1971) and Murty (1974) for higher and lower grades were somewhat similar.

Effect associated due to farm was significant ($P<0.01$) for $S_w$ and $HFxS_w-SwxHF$ at 18 months' body weight. Similar effects were observed by Pandey (1971) and Singh and Desai (1971). The variation caused by season of birth was found significant for $HFxS_w-SwxHF$ crossbred females as was reported by Rishra (1973) but effect due to season on $S_w$ and $BSxS_w$ was not detectable statistically. Period of birth had significant effect on body weight at 10 months' age in three breed groups studied. Similar observations were also made by Rishra (1973).

5.1.9. Body weight at first fertile service: The body weight $288.91\pm2.75$ kg observed for $S_w$ heifer was almost similar to reported weight $288.74\pm31.07$ kg by Rudgal and Ray (1968a,b; 1966). Whereas Rishra (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 $317.13\pm1.75$ kg which was significantly higher from $S_w$ and $BSxS_w$ heifers. Rishra (1973) observed about 23 kg higher body weight for halfbreeds of HF at fertile service. The difference could be due to the statistical technique as Rishra reported simple mean but this study was made by fitting least square constants.

The higher weight of $HFxS_w-SwxHF$ heifer from $S_w$, $BSxS_w$ might be due to the better genes for growth inherited through Frisian genes. Calves born to aged sows (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 farm 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 331.65±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 Rudgal 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 breed 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); Ganpule (1971), Pandey (1971) and Taneja (1973) in HFxRS and HFxSw-SwxHF crossbreds. Non-significant effect due to B3 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 (1962).

Significant effect due to farm for Sw, and HFxSW-SxSWHF was in agreement with that of Naidu and Desai (1965), Pandey (1971) and Tanaja (1973). The effect due to season of birth was significant for BSxSW only. The effect due to period was significant (P<0.01) for SW and HFxSW-SxSWHF crossbreds, similar to that observed by Tanaja (1973) for HFxSW crossbreds. Risha (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 BSxSW crossbred females in weight gained per day from birth to 2 months' age. Significantly higher growth rate (805.2±3.1 g) per day of HFxSW-SxSWHF crossbreds suggested the superiority of Frisian genes. Rathi et al. (1974)
reported absolute weight gain for Hariana and its HF, BS and Jersey crossbreeds 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 gene functioning. Halfbreeds of BSxSw 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<.01). The reason could be managemental 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 BSxSw crossbreeds. Significant (P<.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 gene plasma.

5.2.2. Growth rate from 2-4 months’ age— The average growth rate g/day for Sw, BSxSw and HFxSw-SwxHF was respectively 436.4±6.5, 455.7±18.8 and 533.8±3.6 g. Rathi et al. (1974) reported absolute weight gain 12.79, 12.77, 12.25 and 13.09 kg for Hariana, BSxHariana, JerseyxHariana and HFxHariana respectively. The average gain per day of HFxSw-SwxHF was significantly higher than BSxSw 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. Halfbreeds 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 crossbreeds.

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<.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 Roy (1965a,b) in Sw, Singh and Desai (1971) in Red Sindhi; Agarwal and Tomer (1972) in Hariana; Parija (1972)
J. H. Taneja (1973) in HF x Gir, 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 (1983) 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 - Ssw 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 Parida (1972) in Gir and its HF crosses, Mishra (1973) in Zebu and their HF crosses, Nathi 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 Frisian 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 - Ssw 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-SwxHF 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-SwxHF 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 managerial practices followed at NDRI farm, Karnal. Halfbreds of BSxSw, HFxSw-SwxHF 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 Toneja (1971), Risheh (1973) and Hingane (1975).

5.2.5. Growth rate from 9-12 months' age: The average gain per day for Sw, BSxSw and HFxSw-SwxHF was 339.9±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 Tanaja (1974), and 398 g (Sw), 436 g (HFxSw), 462 g (HFxTharparker), 432 g (HFxRS) by Misra (1973). These were not comparable to this study due to differences in age intervals considered. Hingane (1975) reported growth rate in HFxGir crossbreeds 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 BS inheritance, half breeds grew significantly at higher rates. Among HFxSxSwxFF 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 Frisian crossbreeds. Significantly better growth rate of HFxSw crossbred at Ambala and Harout, 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 May-Sept 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 crossbreeds. 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 of B5xSw increased. Significant positive deviation of 5/8 and 3/8 grades of HF from their least square means indicated their overall superiority. Halfbreeds of B5xSw still retained their significant higher gain per day. Variation due to farm was significant for HFxSw-SwHF crossbred but non-significant for Sw. The effect due to season was observed significant (P≤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 get favourable local environmental condition and better fodder during this age interval. The effect due to period of birth was significant for HFxSw-SwHF 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, B5xSw and HFxSw-SwHF crosses respectively (Appendix T1,2,3). The effect due to level of exotic inheritance was non-significant in B5xSw and HFxSw-SwHF crosses. This could be due to confounding effect of genotype - environment.

The effect due to season of birth was highly significant (P≤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 Sw and its HF crossbreds but non-significant for
BSxSw crossbreds. Least square mean and period of deviation
explained the higher growth rate per day in the last period in
Sw and HFxSw (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±0.27, 30.41±0.57 and
36.36±0.25 months for Sw, BSxSw and HFxSw-SwuHF respectively.
Kartha (1934) reported lower age (36.5 and 37.5 months) while
Amble and Malik (1963), Puri and Shams (1965),
Sunderesan and Koul (1966) reported 45.6±1.10,
46.3±2.28, 40.7±4.40, 41.0 to 42.0 and 40.2±0.23 months age at
first calving of Sw cattle respectively which were higher from
present value. The values reported by Batra and Desai (1964),
Amble and Jain (1967), Singh and Desai (1967), Gopal and Bhatnagar
(1972) and Nappol 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
Rishra et al. (1975) was 0.8 month lower from the present value of
BSxSw 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 HFxSw crossbreds.

Among grades of HFxSw-SwuHF and BSxSw crossbreds
highly significant (P≤0.01) differences were observed due to level
of exotic inheritance. Bhatnager 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 Haidu and Desai (1965), Anble and Jain (1966), Singh and Desai (1967), Gampule (1971), Taneja (1973), Hurty (1974) and Gurbachan Lal (1973). 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, Gampule (1971) for 6/8 and 7/8, and Hurty (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 gene pool 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 (1971), Haidu and Desai (1965) and Gampule (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 T12T3) 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. (1973) in BSxSw crossbreds. Highly significant effect due to period of calving observed in three breed groups was also found by Sundarasan et al. (1965), Koul (1968), Dhillon et al. (1970), Nagpal and Acharya (1970), Taneja (1973) and Bhatnagar et al. (1973) but Dutt and Tamer (1972), Mishra (1973) and Mishra et al. (1973) 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, 3208.95±133.20 and 2493.34±39.51 kg for Sw, BSxSw and HFxSw-SwHF crossbred respectively. Significant (P<.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), McGuickan (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 Sen 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<.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 (6/6) and filial group (F2-F3) were negatively deviated from their common mean. Bhatnagar et al. (1975) reported 56 kg lower milk yield for halfbreeds 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. Halfbreeds 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 Amala 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 HFxS\(_2\) crossbred and similar were the findings of Singh and Pandey (1970), Nagpal and Asharya (1971), Tomer et al. (1971), Taneja (1973) and Chaudhary et al. (1974). Non-significant effect for Sw and B\(_2\)xSw 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, B\(_3\)xSw and HF\(_2\)xSw-SuvHF 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 halfbrades, 3/4 grades but filial group (F\(_2\)-F\(_3\)) produced lower than overall mean of initial yield. Among HF\(_2\)xSw grades, least square mean and deviation due to each grade showed that various level of Frisian inheritance affected the initial milk yield in a curvilinear way. This showed that with the increase of Frisian germ plasma beyond 3/8 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 NDRI farm. The average initial yield of HF\(_2\)xSw crossbred at Lucknow
and Meerut farm was higher than other farms. The effect due to season of calving was significant for HF x Sw crossbreds. 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 BS x Sw crossbreds 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 HF x Sw crossbreds but non-significant for BS x Sw. This could be due to breed group differences.

(b) Ascending milk yield: The breed differences were observed significantly for ascending milk yield per day. BS x Sw 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 up to 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 HF x Sw 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 HF x Sw 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 Hf x Sw 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 Hf x Sw and Chauhan et al. (1974) in BSxSw. The grade (3/8) of BS inheritance produced on an average about 2 kg higher from halfbreed and 5 to 6 kg higher from 6/8 and filial group (F₂-F₃). 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 Hf x Sw 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 HFxSw crossbred and similar observation was made by Choudhury et al. (1974). Non-significant effect found for BSxSw crossbred was also reported by Chauhan et al. (1974) in same crossbred population. Heifers (HFxSw) 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 HFxSw. 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, BSxSw and HFxSw—SxHF crossbred. The significant differences among breeds for this trait revealed the difference in their genetic make up. Difference due to sire 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 Sw, BSxSw and HFxSw-SxHF crossbreds. Period variation was significant for HFxSw but was not significant for Sw and BSxSw crossbreds.

(a) Milking average: BSxSw and HFxSw 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 Sw and its Friesian crosses. The milking average of Sw cows at Kamal was better than that of Rehmat while HFxSw-SxHF of Lucknow maintained the superiority in comparison to other military farms housing same crosses. The effect due to grades of BS and HF was significant. The grade 3/8 of BS and 4/8 of HF produced higher milking average. Curvilinear milking average was observed with the increase of HF inheritance from 1/8 to 7/8. The reported average milk yield for Sw was 5.19±1.05 kg and for 4/8 and 5/8 HFxSw crossbreds was 8.74±0.89 and 7.63±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 Sw and BSxSw but was significant for HFxSw. 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. BSxSw produced milk for longer period followed by Sw and HFxSw. The observed lactation period of 321.98±4.50 days of Sw was higher than reported by Kartha (1934), Singh and Chaudhury (1961),
Batra and Desai (1964); Ambal and Jain (1968) and Rishra (1973) but lower from Bhatnagar et al. (1975) while the value reported by Johar 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 (509.52±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 (6/6) 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<0.01) effect due to farm observed for Sw and HFxSw crossbreds was as reported by Pandey (1971), Taneja 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 managemental 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 \((P \leq 0.01)\) for \(S\) and \(HF\times S\) crosses. Similar was reported by Tamer \textit{et al.} (1972), Taneja (1973) and Sandhu \textit{et al.} (1973).

5.3.5. First dry period (days): Average first dry period of \(S\), \(BS\times S\) and \(HF\times S\) was 134.7±4.9, 74.4±6.00 and 124.8±5.8 days respectively. Several workers had reported first dry period for \(S\) and its exotic crosses. The reported first dry period for \(S\) cows ranged from 130±4 days (Gurbachan Lal, 1975) to 296±5 days (Batra and Desai, 1964) and for \(HF\times S\) 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 crosses 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 \(HF\times S\) crosses lowest dry period (116.9 days) and highest (144.7 days) was observed at Ambala and Bareilly farms respectively. Among grades of \(BS\) and \(HF\), 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 BS and 116.2 days for 4/8 HF and average highest 82.0 days for 3/8 BS 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 crossbreds but non-significant for Sw and BSxSw. Period of calving had significant effect for BSxSw and HFxSw crossbreds 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 Chaudhury (1961), Sandhu (1968) and Mishra (1973) but lower to Batra and Desai (1964) and Amble and Jain (1968). The values reported by McGuckin (1937) and Malik et al. (1968) were in agreement with this study.

In HFxSw crossbreds 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 Amble and Jain (1966), Koul (1968), Murty (1974) and Gurbachan Lal
(1975) reported somewhat higher lactation period. Difference due
to farm was significant for Su and HFxSw crosses. Deviation
due to season of calving was highly significant for HFxSw crosses.
Period to period variation was significant for Su, 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 crosses respectively. Crossbreds produced
significantly higher milk yield than purebred Sahiwal. Several
workers reported first lactation yield of Sw ranged from 1170 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<.01) as was
also seen by Naidu and Deasi (1965), Khanna (1968), Ambale and
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). Halfbreeds of HF inheritance had higher first lactation yield than other grades (Fig. 4a,b). Grade (6/8) of BS produced 460 kg lower milk than 3/8 grade but in HF 6/8 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 Dossi (1965), Pandey (1971) and Taneja (1973) were lower but values of Ganpule (1971) and Choudhury 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 discernible at statistical level of probability. The effect due to period was found non-significant for Sw and BSxSw but significant for HFxSw crossbreeds. 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 T7a,8a,9,10a.

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. Washal and Teallik (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 Sw, 4.13 to 54.99 per cent in BSxSw, 0.58 to 46.02 per cent in HFxSw and 1.10 to 45.30 per cent in SwxHF 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 Sw, BSxSw, HFxSw and SwxHF crossbred respectively by linear equations. The milk yield increased by 6.64±0.45, 9.76±0.84, 8.33±0.43 and 8.42±0.38 kg for every increase of one day lactation length.

Growth rate g/day explained low variation from 0.58 (HFxSw) to 5.01 (Sw) per cent among four breed groups studied.

Birth weight accounted for significant variation of 7.02, 11.65, 0.59 per cent in Sw, BSxSw and HFxSw respectively and non-significant 0.25 per cent for SwxHF crossbreds. Among body weights,
higher variation in first lactation (8.44 per cent) was explained by weight at 12 months age in 5w, 14.26 and 8.68 per cent by weight at first calving (BSxSw and HFxSw) and 2.40 per cent by weight at 6 months (SwxHF). The inclusion of body weights (birth weight, weight at 6 and 12 months age and weight at first calving) in equation revealed 11.04 (5w), 15.46 (BSxSw), 11.60 (HFxSw) and 5.03 (SwxHF) 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 56.76 (5w), 56.78 to 64.99 (BSxSw), 44.63 to 46.02 (HFxSw) and 40.61 to 45.30 percent (SwxHF)-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, 48.02 and 45.30 per cent variation in 5w, BSxSw, HFxSw and SwxHF 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 alongwith their R² values. The variation accounted for by these equations ranged from 16.31 to 55.55, 24.83 to 44.75, 19.98 to 55.02 and 23.86 to 42.10 per cent in S, BSxS, HFxS and SwxHF crosses bred 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 Sahiwal, HFxS and SwxHF crosses bred and by ascending yield in BSxS and highest variation was revealed by descending yield in S, BSxS and SwxHF crosses bred and by peak yield in HFxS crosses bred.

The results of these equations and their R² 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 indicate 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 142.18±14.98, 150.42±18.23, 137.03±7.41 and 107.09±10.93 kg for each increase in one kg initial yield in S, BSxS, HFxS and SwxHF crosses bred.

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, 24.83 to 44.75, 19.98 to 55.02 and 23.86 to 42.10 per cent in S, BSxS, HFxS and SwxHF crosses bred 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 estimates. 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 (Naik and Desai, 1965), 4-30/64 and 36-63/64 (Taneja, 1973), pooling all grades (Takhan, 1973), pooling above 1/2 grades (Basu and Chai, 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'Souz, 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 (Naik and Desai, 1965; Koul, 1968; Taneja and Bhat, 1970; Pandey, 1971; Gangula, 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 non-genetic effects like, farm, parity, season and periods. The analysis was made from unadjusted, adjusted for non-genetic factors and adjusted for non-genetic 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 (Table 22).

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 HF\( \times \)Su crossbred sired by 40 Frisian bulls with average progeny per sire ranging from 40.0-40.5 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 non-genetic 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.

\[
\text{Progress (\Delta G)} = (\text{accuracy}), (\text{Genetic Variability}), (\text{Intensity}). \quad \text{If any of them is zero, the progress will be zero, no matter how high the other two may be. Further presentation and discussion is confined to the genetic estimates which were}
\]
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 crossbreds respectively. Batra and Desai (1962), Taneja and Bhat (1970), Mishra (1973) and Taneja (1973) reported low values with standard errors ranging from 0.14±0.14 to 0.344±0.152 in Sw breed by paternal half-sib correlation.

Naidu and Desai (1965) reported 0.29±0.21 $h^2$ from pooled grade of 1/6 to 3/6 of 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 than 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 $0.593 \pm 0.191$, $0.334 \pm 0.132$, $0.261 \pm 0.082$ and $0.803 \pm 0.160$ for $S_w$, $B_S \times S_w$, $H_F \times S_w$ and $S_w \times H_F$ crossbred cattle respectively (Figs. 6, 7, 8a and 9). Taneja (1973) reported the $h^2$ of $0.55 \pm 0.16$ for $S_w$ cattle by the same method. Taneja (1973) found $h^2$ of $(0.42 \pm 0.11)$ of 4-30/64 grades and of 36-63/64 grades ($h^2 = 0.75 \pm 0.22$) of $H_F \times S_w$ by paternal half-sib correlation.

(c) Weight at 4 months' age— The $h^2$ estimates of weight at 4 months age of $S_w$ were $0.510 \pm 0.178$, of $B_S \times S_w$ $0.370 \pm 0.166$, of $H_F \times S_w$ $0.216 \pm 0.072$, and of $S_w \times H_F$ $0.321 \pm 0.116$. 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 $0.365 \pm 0.189$, $0.437 \pm 0.179$, $0.175 \pm 0.062$ and $0.274 \pm 0.108$ for $S_w$, $B_S \times S_w$, $H_F \times S_w$ and $S_w \times H_F$ crossbred cattle respectively (Figs. 6, 7, 8a and 9). Taneja (1973) and Rishra (1973) reported $h^2$ values of $0.60 \pm 0.24$ to $0.73 \pm 0.19$ respectively for Sahiwal cattle. These values were higher from the present estimate. Taneja (1973) estimated higher $h^2$ of $0.62 \pm 0.14$ and $0.64 \pm 0.20$ for 4-30/64 grades and 36-63/64 grades of $H_F \times S_w$ respectively. The high $h^2$ values observed by Taneja (1973) might be due to differences in classification of genic 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 $0.294 \pm 0.174$ of $S_w$, $0.411 \pm 0.174$ of $B_S \times S_w$, $0.158 \pm 0.058$ of $H_F \times S_w$ and $0.224 \pm 0.093$ of $S_w \times H_F$ were estimated (Figs. 6, 7, 8a and 9). The
"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 dampened 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 SW, BSxSW, HFXSW and SWxHF were found to be 0.407±0.198, 0.460±0.192, 0.285±0.087 and 0.305±0.114 respectively. Taneja and Bhat (1971), Mishra (1973) and Taneja (1973) reported higher h^2 for SW ranging from 0.62±0.26 to 1.05±0.25.

Naidu (1962) reported 0.78 h^2 of 4-15/32 grade of HFXSW located at Northern farms, Arora (1972) observed h^2 0.77±0.35 for 1/2 grade. Taneja (1973) found 0.66±0.14 and 0.64±0.20 for 4-30/64 and 36-63/64 grades of HFXSW crossbred respectively.

(g) Body weight at 15 months' age— The h^2 values of 0.363±0.126, 0.571±0.213, 0.322±0.095 and 0.173±0.101 for SW, BSxSW, HFXSW and SWxHF were respectively observed. The high h^2 of BSxSW could be assumed due to higher additive genetic variation with better managemental practices and low h^2 values of SWxHF crossbred could be due to the use of SW sires with less differences in their breeding values.

(h) Body weight at 18 months' age— The values of h^2 were 0.457±0.186, 0.415±0.276, 0.340±0.099 and 0.184±0.072 for SW, BSxSW, HFXSW and SWxHF crossbreds 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 $S_w$, $BSxSW$, $HFxSW$ and $SWxHF$ crosses bred 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 $S_w$ cattle. The agreement for high $h^2$ of $S_w$ 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 $S_w$, $BSxSW$, $HFxSW$ and $SWxHF$ 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 $0.16 \pm 0.10$ on $S_w$ cattle (paternal half-sib correlation) were reported by Mishra (1973) and Tanaja (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 were higher and of Tanaja (1973) for 4-30/64 and 36-63/64 grades of $HFxSW$ 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 $0.616 \pm 0.192$, $0.245 \pm 0.139$, $0.149 \pm 0.046$ and $0.444 \pm 0.126$ for $S_w$, $BSxSW$, $HFxSW$ and $SWxHF$ crosses bred 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 $Sw$, $BxSw$, $HFxSw$ and $SwxHF$ were $0.084\pm0.131$, $0.178\pm0.118$, $0.063\pm0.035$ and $0.158\pm0.077$ 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 $0.064\pm0.093$, $0.152\pm0.118$, $0.082\pm0.026$ and $0.155\pm0.076$ for $Sw$, $BxSw$, $HFxSw$ and $SwxHF$ crossbred respectively. The values of $BxSw$ crossbred and $SwxHF$ 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 $Sw$, $BxSw$, $HFxSw$ and $SwxHF$ were $0.029\pm0.048$, $0.205\pm0.131$, $0.046\pm0.031$ and $0.038\pm0.059$ respectively. The $h^2$ values of $BxSw$ crossbred were found slightly higher which might be due to better action of additive genes inherited through $B$ sires.
(e) From 9 to 12 months' age— The $h^2$ values were 0.013±0.167, 0.13±0.130, 0.098±0.037 and 0.08±0.065 for $S_u$, $B_S X S_u$, $H_F X S_u$ and $S_u X H_F$ crossbreds respectively.

(f) From 12 to 15 months' age— The $h^2$ estimates were respectively 0.243±0.171, 0.245±0.147, 0.03±0.024 and 0.074±0.072 for $S_u$, $B_S X S_u$, $H_F X S_u$ and $S_u X H_F$ crossbreds. Sahiwal and $B_S X S_u$ had higher estimates. The reason could be high genetic variability.

(g) From 15 to 18 months' age— The $h^2$ values were estimated 0.13±0.178, 0.181±0.143, 0.025±0.022 and 0.060±0.069 for $S_u$, $B_S X S_u$, $H_F X S_u$ and $S_u X H_F$ 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 (1981) 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, 0.45±0.123 and 0.035±0.187 for $S_u$, $B_S X S_u$, $H_F X S_u$ and $S_u X H_F$ crossbred respectively (Figs.6,7,8a and 9). Low $h^2$
values $0.16 \pm 0.29$ by intra sire regression of daughter on dam 
(Abbott et al., 1958); $0.186 \pm 0.139$ and $0.21 \pm 0.09$ by paternal half-sib 
correlation by Koul (1958) and Das et al. (1971) respectively and 
moderate values $0.31$ (Naidu and Desai, 1965), $0.48 \pm 0.18$ (Nagpal 
and Acharya, 1970), $0.37 \pm 0.19$ (Rahara, 1973) and $0.25 \pm 0.11$ (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$x^5w$ from Northern 
and Southern military dairy farms respectively. Taneja (1973) 
observed the values $0.13 \pm 0.06$ and $0.36 \pm 0.13$ for 4-30/64 and 36-63/64 
HF grades respectively. Tanaja (1973) pooled all grades of HF$x^5w$ 
and recorded comparatively lower values $(0.30 \pm 0.03)$ while Bhat 
and Ghai (1975) pooled half and above grades and found higher value 
$(0.65 \pm 0.21)$ 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 $0.238 \pm 0.140$. 
Nagpal and Acharya (1974) reported low value $(0.18 \pm 0.14)$ whereas 
others observed moderately high values $(0.51 \pm 0.21, 0.41 \pm 0.14, 
0.44 \pm 0.15$ by Khanna and Bhat, 1971; Taneja, 1973 and Rahara, 1973 
respectively) by paternal half-sib correlation method. Koomer 
and Sundaresan (1970) estimated $0.44 \pm 0.32$ and $0.37 \pm 0.20$ values by 
intrasire regression and paternal half-sib correlation method 
respectively for $S_w$ breed. The value $(0.21 \pm 0.29)$ reported by Singh 
and Desai (1967) was quite close to the present estimate. The 
estimates of $h^2$ for $SxS_w$, $HFxS_w$ and $SxHF$ were $0.124 \pm 0.166,
0.191 \pm 0.074$ and $0.062 \pm 0.076$ respectively. The $h^2$ reported by Naidu 
and Desai (1965) for 4-15/32 grades of $HF$x$S_w$ was $0.07$ from Northern 
form and $0.19$ from Southern form. Gupta (1971) 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 $0.17 \pm 0.07$ and $0.07 \pm 0.08$ respectively. These all reported values of HFxSm 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 $0.241 \pm 0.129$, $0.157 \pm 0.175$, $0.164 \pm 0.058$ and $0.152 \pm 0.083$ 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 $0.495 \pm 0.171$, $0.171 \pm 0.180$, $0.101 \pm 0.044$ and $0.092 \pm 0.066$ 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 $0.553 \pm 0.192$, $0.290 \pm 0.110$, $0.391 \pm 0.131$ and $0.275 \pm 0.140$ respectively (figs.6,7,8a and 9). Naidu and Ossai (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 $0.415\pm0.163$, $0.231\pm0.197$, $0.301\pm0.112$ and $0.163\pm0.094$ for $5w$, $BSx5w$, $HFx5w$ and $SwxHF$ 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 $5w$, $BSx5w$, $HFx5w$ and $SwxHF$ crossbreds were $0.454\pm0.176$, $0.288\pm0.212$, $0.186\pm0.072$ and $0.370\pm0.134$ respectively. It was observed that for average milk yield the genetic variability for $SwxHF$ 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 $0.132\pm0.118$, $0.051\pm0.111$, $0.074\pm0.044$ and $-0.096\pm0.045$ for $5w$, $BSx5w$, $HFx5w$ and $SwxHF$ crossbred respectively. The $h^2$ values of 170-305 days lactation period followed the respective trend of $0.197\pm0.144$, $0.015\pm0.130$, $0.026\pm0.037$ and $-0.053\pm0.046$.

Sandhu (1968) and Rishra (1973) reported $0.32\pm0.20$ and $0.45\pm0.14$ $h^2$ by paternal half-sib correlation method respectively for $5w$ cattle which were higher from present estimate but the values reported by Tanaja (1973) $0.16\pm0.10$ was very close to this estimate. Naidu (1962) reported $0.18$ from 4-15/32 grades and Tanaja (1973) reported $h^2$ values $0.08\pm0.06$ and $0.15\pm0.09$ for 4-30/64 and 36-63/64 grades of $HFx5w$ respectively. Tanaja (1973) pooled all grades of $HFx5w$ crossbred and found the $h^2$ $0.16\pm0.07$.

It appeared from the estimates of crossbred that selected exotic sires 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 \(-0.141\pm0.071, 0.193\pm0.207, 0.007\pm0.030 \) and \( 0.272\pm0.157 \) for \( S_w, BSxSw, HFxSw \) and \( SwxHF \) crosses respectively. Naidu (1962) reported \(-0.33 \) and \( 0.02 \) \( h^2 \) for 4-15/32 grades of HFxSw from Northern and Southern farms. Taneja (1973) reported \( 0.17\pm0.11, 0.11\pm0.07 \) and \( 0.24\pm0.12 \) \( h^2 \) for \( S_w, 4-30/64 \) and \( 36-63/64 \) grades of HFxSw crosses respectively. Basu and Ghai (1975) reported low \( (0.03\pm0.12) \) \( h^2 \) for pooled of 1/2 and grade of HFxSw. As this trait is mostly governed by managemental practices rather genetic make up of the animal such low values not far from zero are expected.

(a) First, second and third lactation yield (305 days or below)*

(i) The heritability estimates for \( S_w, BSxSw, HFxSw \) and \( SwxHF \) crosses were \( 0.476\pm0.289, 0.157\pm0.174, 0.168\pm0.072 \) and \( 0.152\pm0.131 \) respectively. The estimate of \( S_w \) was higher from reported value of Singh and Desai (1967) and Nagpal and Acharya (1971) but was quite close to Khanna (1968), Keshar and Sundaresan (1970), Khanna and Bhat (1971), Taneja (1973) and Niaha (1973).

The \( h^2 \) values reported by Naidu and Desai (1965) from 4-15/32 grades of HFxSw of Southern farms (\( h^2 = 0.18\pm0.19 \)) and Taneja (1973) from 4-30/64 grades of HFxSw (\( h^2 = 0.17\pm0.07 \)) and Gupta (1971) from pooled grades of HFxSw (\( h^2 = 0.22\pm0.11 \)) were very close to the present estimate but values reported by Naidu and Desai (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 \( 0.586\pm0.237, 0.091\pm0.032, 0.231\pm0.135 \) and \( 0.176\pm0.112 \) for \( S_w, BSxSw, HFxSw \) and \( SwxHF \) crosses respectively. The estimates
reported by Asharya and Nagnal (1971) and Rishehra (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 $Sw\times HF$ and $BSxSw$ crossbreds.

(iii) The heritability values for 3rd location of $Sw$, $BSxSw$, $HFxSw$ and $Sw\times HF$ were 0.256±0.219, 0.846±0.266, 0.245±0.138 and 0.356±0.169 respectively. Khanna and Bhat (1971) and Rishehra (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 Asharya and Nagnal (1971) was in agreement with present estimate. Gupta (1971) reported 0.83±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.
8.4.2.1. 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 Sw, BSxSw, HFxSw and SwxHF crosses. The extent of $r_g$ among body weights ranged from $-0.09±0.39$ (weight at 2 months and weight at first calving) to $>1.0$ (weight at 9 months and weight at 12 months) in Sahiwal; $-0.04±0.24$ (weight at 10 months and weight at first calving) to $>1.0$ (weight at 2 months and weight at 4 months) in BSxSw; $0.17±0.24$ (weight at 2 months and weight at first fertile service) to $>1.0$ (weight at 2 months and weight at 4 months) in HFxSw and $-0.03±0.93$ (weight at 9 months and weight at first calving) to $>1.0$ (weight at 6 months and weight at 9 months age) in SwxHF crosses.

Highly significant genetic correlation indicated that gene functioning at an early age could affect body weight up to 18 months age.

Asera (1972) estimated $r_g$ of birth weight with weight at 6 and 12 months age in HFxSw halfbred which was found to be lower than these estimates but values between 6 months weight and 12 months weight were almost similar. The estimates reported by Taneja (1973) for Sw, 4-30/84 grades and 36-63/84 grades of HFxSw were quite close to the present values. Murty (1974) in HFxSw crosses and Gavindiah (1973) in Mariana 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 (in press).

Weight at first calving was negatively correlated with weight at 2, 6, 9, 15 and 18 months age in Sahiwal, with weight
at birth, 9, 12, 15, 18 months and weight at first fertile service in BSxSw and with 9 month weight in SwxF crossbreds. Body weights at lower age intervals were significantly positively correlated with weight at first calving in HFxF crossbreds. In SwxF crossbreds weights at 2, 4, 6 and 9 months were negatively correlated with weight at first fertile service. Negative $r_p$ was also observed between weight at 9 months and weight at first calving. Naidu (1962) reported negative $r_p (-0.57)$ between birth weight and weight at first calving in 4-15/32 grades of HFxF from Northern Military Farm. Taneja and Bhag (1971) reported low $r_p$ between body weights than present estimate of Sw. Values reported by Taneja (1973) for Sw and HFxF grades were quite close to the present estimates. Values reported by Arora (1972) were lower from HFxF but higher from SwxF crossbred cattle. One of the reason might be that in this study these two populations were considered as different breed groups, while Arora combined those as one group. Murty (1974) reported low $r_p$ from HFxF 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 HFxF crossbreds (Batra and Desai, 1962; Singh et al., 1969 and Tamer and Arora, 1972).

(ii) Phenotypic correlations - From figures 6, 7, 8 and 9 it is evident that phenotypic correlation among body weight traits was positive in Sw, BSxSw, HFxFsw and SwxF breed groups except weight at 4, 6 and 9 months age with weight at first fertile service in SwxF 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 \( \pm 0.06 \). This was lower than reported by Batra and Desai (1962) but was in agreement with that of Taneja (1973). Naidu (1982) worked out \( r_p \) between birth weight and weight at calving from 4-15/32 grades of Hf x Sw of Northern military farms and found quite low (\( r_p = 0.03 \)) from present estimate of Sw x HF crossbred. The \( r_p \) values reported for Sw cattle (Taneja and Ghai, 1971) and for Sw, 4-30/64 and 38-63/64 grades of Hf x Sw (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 Hf x Sw 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 crossbreed; Singh et al., 1959 in Hariana; Tomar and Arora, 1972 in Hariana; Govindaiah, 1973 in Hariana and Hingana, 1973 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 lower 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±0.40 (with milking average) to 0.76±0.18 (with descending yield) in $\text{S}_w$ cattle. Age at first calving was significantly negatively correlated with production traits in MF$_x$Sw crossbreds ranging from -0.43±0.18 (with descending yield per day) to -0.75±0.11 (with ascending yield per day). In BS$_x$Sw 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 SwMF crossbreds, age at first calving was significantly positively correlated with first lactation yield (0.21±0.56) and its components except initial yield when $r_G$ was -0.07±0.23. Genetic correlation between age at first calving and first lactation yield (0.58±0.12) observed by Nagpal and Asharya (1970) in $\text{S}_w$ 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 (1962) and Naidu and Desai (1970) in 4-15/32 grades of MF$_x$Sw crossbred were in same order with small variations. Tanuja (1973) estimated $r_G$ between age at first calving, first lactation yield and first lactation length in $\text{S}_w$ and 4-30/64 grades and 36-63/64 grades of MF$_x$Sw crossbreds and values were 0.38±0.23 to 0.74±0.15,
These values were mostly very close to the present finding except to that of HF\times S_w crossbreds. One of the reason 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 HF\times S_w crossbreds. This was also reported by several workers in other breeds (Sundaresan et al., 1954 in Red Sindhi, Ahmed, 1961 in Hariana, Reddy and Bhatnager, 1971 in Tharparkar cattle; Dutt and Tomar, 1972 in Hariana; Abraham, 1973 in Jersey x Local Kerala cattle). The \( r_g \) between lactation length and lactation yield were observed positive in S_w \( (0.73\pm0.29) \) and HF\times S_w crossbreds \( (0.74\pm0.17) \) and were negative in B_S\times S_w \( (-0.02\pm0.86) \) and S_w\times HF crossbreds \( (-0.66\pm0.14) \). The values observed in Sw and HF\times S_w were similar to the reported values of Naidu and Desai (1970) in HF\times S_w 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 \( (B_S\times S_w) \) to 1.0 \( (S_w \) and S_w\times HF). High correlation explained the synergistic action of genes for these traits. Such high \( r_g \) was also recorded by Naidu (1962) in 4-15/32 grades of HF\times S_w.

Initial yield per day was positively correlated with first total lactation yield in four breed groups studied. The values were 0.80\pm0.16, 0.66\pm0.52, 0.69\pm0.14 and 0.33\pm0.65 for S_w, B_S\times S_w, HF\times S_w and S_w\times HF 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. Reddan et al. (1955) in HF cows, VanVleck and Henderson (1961a) in HF, Khan and Ahmed (1972) in Mariana, Hickman (1960) in Ayrshire, HF and Jersey, Singh et al. (1967) in Mariana, Singh and Acharya (1969) in Mariana 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±0.34, -0.38±0.26, -0.02±0.04 and -0.24±0.44 in SW, BSxSW, HFxSW and BSxHF crossbred cattle respectively. Naidu (1962) observed negative genetic correlation (-0.367) for 4-15/32 grades of HFxSW which was similar to the present finding but Taneja (1973) observed positive associations between these two traits (0.74±0.15, 0.44±0.34 and 0.74±0.15) from SW, 4-30/64 and 36-63/64 grades of HFxSW crossbreds respectively. Abraham (1973) observed -0.02 in Red Sindhi x Local Kerala cattle which was close to that of HFxSW crosses of this study. The genetic correlations of first dry period with first and second lactation yield were -0.05±0.33 and -0.45±0.27 in SW, -0.82±0.19 and -0.84±0.56 in BSxSW.
0.04±0.76 and 0.06±0.44 in SuXHF, and -0.31±0.38 and -0.45±0.44 in HFXSu crossbreds. The estimate reported by Abraham (1973) was somewhat dissimilar from this finding.

In Su, $r_g$ 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 BSuSu, -1.0, 4.0 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 Guzani et al. (1976) in Su cattle. Such high $r_g$ between three traits were also observed in Holstein-Frisian by VanVleck and Bradford (1968) and Barker and Robertson (1968). The genetic correlations 0.48±0.52, 0.24±0.43 and 0.91±0.06 in SuXHF and 0.33±0.26, 0.16±0.37 and -0.21±0.37 in HFXSu 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 an 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 correlations— Phenotypic correlation of age at first calving with first total lactation yield was 0.03±0.05, 0.04±0.07, 0.04±0.03 and 0.10±0.04 in Su, BSuSu, HFXSu and SuXHF crossbreds (Figs. 6, 7, 8a and 9). These correlations were low and non-significant in these breed groups except SuXHF. Low but positive $r_p$ values observed in Su were lower than Batra and Desai (1964) but contrary to the findings of Puri and Sharm (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 HFxFsw and Taneja (1973) from 4-30/64 and 36-63/64 grades of HFxFsw were very close to the present finding of HFxFsw crossbreds. Bhutnagar at al. (1975) reported higher $r_p$ 0.64 in $F_1$ B5xFw crossbreds.

Age at first calving was negatively correlated with first lactation period in Sw, B5xSw and HFxFsw crossbreds but positively in SwHF crossbreds. 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 (HFxFsw) to 0.77±0.01 (Sahiwal). These values were quite close to that reported by Taneja (1973) for Sw, 4-30/64 HFxFsw and 36-63/64 grades of HFxFsw and Patil and Presad (1970) in Gasola breed. The estimate (0.58±0.04) reported by Balaine at al. (1970) was quite close to the values observed in HFxFsw crossbreds.

The correlations between peak yield and first lactation yield were 0.62±0.02, 0.63±0.04, 0.68±0.01 and 0.57±0.02 in Sw, B5xSw, HFxFsw and SwxHF crossbreds respectively. Naidu and Desai (1970) reported higher $r_p$ (0.72) in 4-15/32 grades of HFxFsw crossbreds and Balaine at al. (1970) in Muriana 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 Steynov (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 $0.42 \pm 0.03$, $0.44 \pm 0.04$, $0.44 \pm 0.01$ and $0.38 \pm 0.03$ for $S_u$, $B_S x S_u$, $H_F x S_u$ and $S_u x H_F$ crossbreds respectively. Gravert and Baptist (1973) observed $0.76$ $r_p$ 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, 1961; O’Connor and Stewart, 1968; Hickman, 1960; Dutt et al., 1964; Singh and Asharya, 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 $0.49 \pm 0.03$, $0.61 \pm 0.03$, $0.46 \pm 0.02$ and $0.32 \pm 0.02$ in $S_u$, $B_S x S_u$, $H_F x S_u$ and $S_u x H_F$ crossbred cattle respectively. These observations were quite similar to that reported by Naidu (1962) from 4-15/32 grades of $H_F x S_u$, Shukla and Prasad (1970), Salaria et al. (1970) and Patil and Prasad (1970) in Gir, Hariana and Gealse breeds respectively. The observation made by Tanaja (1973) in $S_u$, 4-30/64 grades and 36-63/64 grades of $H_F x S_u$ crossbred was somewhat higher for this study. Keenan (1963) reported interclass correlation between first and second, first and third and second and third lactation yields as $0.56 \pm 0.17$, $0.53 \pm 0.21$ and $0.48 \pm 0.12$ in Sahiwal cattle and $0.80 \pm 0.18$, $0.26 \pm 0.24$ and $0.46 \pm 0.22$
in Red Sindhi cattle. These values were quite in line to that observed in this study. The $r_g$ 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 $S_B x S_w$, $-0.91 \pm 0.04$ 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 and second with third lactation yield observed in $S_w$, $S_B x S_w$, $H_F x S_w$ and $S_w x H_F$ breeds were in agreement with that of Acharya and Negpal (1971) and Guinaitl 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 value ranged from $-0.01 \pm 0.21$ (birth weight) to $-0.65 \pm 0.23$ (weight at first calving). In $S_B x S_w$ 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 $-0.05 \pm 0.24$ (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 $-0.222$ by
Batra and Oaaai (1962) and \(0.203 \pm 0.0372\) by Naidu and Oaeai (1970) in \(S_w\) cattle were higher but observations made by Koul (1968) and Taneja (1973) respectively \(r_g \approx -0.03\) and \(-0.04 \pm 0.32\) 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 \(r_g \approx -0.20, -0.12, -0.11 \pm 0.22\) and \(-0.16 \pm 0.04\) between birth weight and age at first calving respectively noted by Naidu (1962) in \(4-15/32\) HF\(x_S\)w grades, Koul (1968) in HF\(x_S\)w halfbreeds and Taneja (1973) in \(4-50/64\) and \(36-63/64\) grades of HF\(x_S\)w were quite close to the present estimates of HF\(x_S\)w and Su\(xHF\) crossbreeds. Parija (1972) observed high negative \(r_g\) in Gir cattle. Ambile 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 \(S_w\), \(4-30/64\) and \(36-63/64\) grades of HF\(x_S\)w. These values are slightly varying from the observed values in this study for \(S_w\), HF\(x_S\)w and Su\(xHF\) crossbreeds.

The genetic correlations of body weights with first total lactation yield were significantly positive in HF\(x_S\)w crossbreeds. It was also positive in \(S_w\) except with weights at 2, 4 and 6 months. The correlations were significantly negative in BS\(x_S\)w and Su\(xHF\) crossbred cattle. In HF\(x_S\)w 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. Milk 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.

Tanaja (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 HFxSw and 36-63/64 HFxSw 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 HFxSw crossbred and found low and non-significant $r_G$ except with weight at 24 months where it was negative but statistically significant.

Miller McGilliard (1959) reported $r_G$ 0.30 between weight at first calving and first lactation yield in HF sows 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 Desai (1971) in Red Sindhi cattle similar to as was observed in Sw and HFxSw crossbreds. Clark and Touchbury (1962) found negative $r_G$ between milk yield and body weight with high standard error as was observed in BSxSw 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 Sw and BSxSw crossbred, except weight at first fertile service and weight at first calving in HFxSw 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 \( r_p = -0.09±0.05 \) 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 HFxSw 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 tainting estimates from 4-30/64 and 36-63/64 grades of HFxSw. Singh et al. (1969) reported very low negative (-0.002) but Tamer and Arora (1972) observed higher \( r_p \) (-0.552) in Hariana cattle.

The phenotypic correlations of body weights with total lactation yield were positive in BSxSw, HFxSw and SwxHF (except of 2 months weight) crossbreds. In Sw cattle positive correlation 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, Sir, Ayrshire x Red Sindhi; Singh and Desai (1959) in Hariana; Batra and Desai (1962) in Sw; Naidu (1962) in HFxSw grades and Taneja (1973) in Sw and HFxSw grades. Khanne and Bhat (1972) reported negative \( r_p \) (-0.052) in Sw which was contrary.
Tanoja (1973) estimated \( r \) 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 \( H_F \times S_w \) were quite similar to the present value in respective breed group but values reported for 36-63/64 \( H_F \times S_w \) were dissimilar from \( H_F \times S_w \) 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. Rusty (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 \( H_F \times S_w \) 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 \( H_F \times S_w \) and \( S_w \times H_F \) crossbreds. The values were ranging from 0.03±0.02 (Birth weight and initial yield) to 0.32±0.03 (weight at first calving and milking average) in \( H_F \times S_w \) and 0.03±0.04 (birth weight and milking average) to 0.21±0.04 (weight at first calving and ascending yield) in \( S_w \times H_F \) crossbreds.
5.5. Selection Indexes

Four selection indexes for each breed group of Sw, BSxSw, HFxSw 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 values 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 Sw, BSxSw, HFxSw 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 Sw, BSxSw, HFxSw and SwxHF breed group than index IV. The lowest correlation between index and aggregate genetic value was found for index II of BSxSw, HFxSw and SwxHF crossbreds and index III of Sw breed.

Ahmed (1984) constructed three selection indexes for Mariana 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 a selection index for Mariana 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. (1969) constructed several indexes incorporating six economic traits with different combinations and observed $R_{IH}$ values which ranged from 12.36 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 (mths)).

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 per Sw, B5xSw, HFxSw and SwxHF crossbreds respectively up to first lactation yield of the next generation.
Correlation between the selection index and aggregate breeding value was 91.24, 74.02, 56.21 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 0.96, 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, 0.92 and 1.2 months, with the increase of weight at 6 months at the rate of 0.81, 0.11, 2.22 and 2.26 kg; at 12 months at the rate of 4.06, 3.45, 3.05 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, 6.76 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 crossbred.

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 (ΔH) in the next generation would be ₹ 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 ₹ 96.66, 47.31, 9.88 and 85.27 in the next generation of Sw, BSxSw, HFxSw and SwxHF crossbred.
and SwxHF respectively. This index seemed to be the most efficient with $R^2_{xH}$ 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 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 6.64, 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 crossbreeds with increase in body weight than index III and IV, it may be considered superior for bringing improvement in genetic gain for this trait.