

**STUDY OF PHENOTYPIC AND GENETIC  
RELATIONSHIPS BETWEEN GROWTH AND  
PRODUCTION TRAITS IN SAHIWAL AND  
SAHIWAL – FRIESIAN CROSSES**

By

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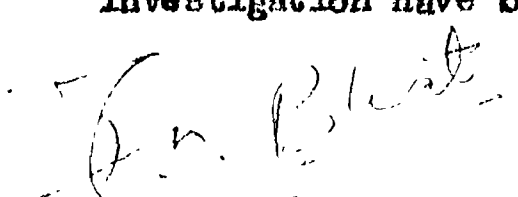
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CERTIFICATE I

This is to certify that this thesis entitled "Study of Phenotypic and Genetic relationships between Growth and Production traits in Sahiwal and Sahiwal - Friesian Crosses" submitted for the degree of Master of Science, in the subject of Animal Breeding, of the Punjab Agricultural University, is a bona fide research work carried out by Shri Rattan Sagar Khanna under my supervision and that no part of this thesis has been submitted for any other degree.

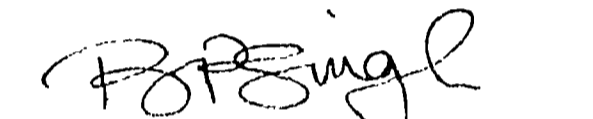
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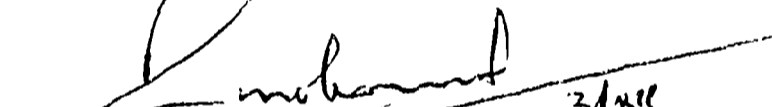
  
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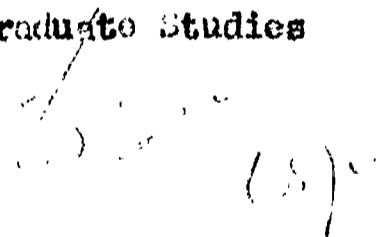
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CHAPTER I

I\_N\_T\_R\_O\_D\_U\_C\_T\_I\_O\_N

Fredeen (1967) in an article entitled, "Where should we be going in animal breeding research ?" has mentioned that, "The improvement of any breed or species of livestock is, in the simplest possible terms, a process of replacing an existing population of genotypes with another which is superior in some particular feature or features of net productive merit". The methods undertaken to improve the net productive merit of the dairy animals can be, the replacement of genes from animals of the same breed by rigorous selection. The goal may also be achieved by the introduction of new genes from the animals of some other breed. Both the methods can result in making desired improvement.

Selection within indigenous breeds of dairy cattle in India, which are very poor milkers, has not been successful in increasing their productive merit, as compared to those in crossbreeds. And it seems almost impossible to import large number of dairy animals of improved European breeds. The possibility of their adaptation to Indian environmental conditions is a matter of some concern. Replacement of present genes in Indian cattle by better ones seems to be the only solution for increasing their milk yielding capacity. In this context, we have to go in search of a superior source of germ-plasm beyond our shores. It is exactly in concordance with the suggestions of Mahadevan (1966) who has brought out - the current thinking on breeding for milk production in the intensive areas of tropics.

Crossbreeding of Indian cattle with improved European breeds of dairy cattle has been adopted as a solution for augmenting milk production. It is an attempt to evolve a new breed of dairy cattle which can well adapt to Indian conditions and yield considerably greater amount of milk as compared to the indigenous breeds. A number of methods have been suggested to achieve the aspired goal.

1. Crossbreeding based on utilising the first generation progeny for production but not for further breeding.
2. Backcrossing with European breeds to get purebreds by grading up.
3. Backcrossing with Indian cattle till such time that a suitable level of exotic inheritance has been fixed which should suit Indian conditions and has good producing ability.
4. Inter-se mating of  $F_1$ 's followed by selection.

Before any of these methods is decided upon a large number of breeding experiments ought to be conducted. A thorough investigation of the  $F_1$  generation and all possible backcrosses made on a comparative basis to search out the superiority in any one of them. The genetic architecture of each one of these crosses should be studied carefully. The studies will explore the possibility of a gene pool which can form the basis for the evolution of the future breed.

Indian Military farms have been crossbreeding Sahiwal with Holstein-Friesian in a somewhat planned way, for the last six decades. These data are valuable and can probably answer many of the questions with regard to the level of inheritance which is best suited under our conditions of climate, hygiene and management.

A thorough study of the genetic architecture of the population with regard to milk yielding capacity is necessitated. The lactation characters are manifested very late in life. In order to build a good yielding herd the study of characters manifested earlier in life and their relationship with milk yield may be undertaken. The studies may lead to development of a criterion for early selection and thus in establishment of a good herd. Various characters manifested before the lactation are, birth weight, weights at various subsequent

ages upto first calving, age at puberty, age at first calving etc.

To answer some of the questions being raised currently,

Military farm data were used to investigate the following :

1. To study the effect of genetic groups (grades), farms, periods, season of birth, breed of the sire and the number of lactation on 300-day milk production and weight at calving.
2. To study the genetic architecture of 300-day lactation yield, life time production and body weights at first, second and third calvings in pure bred Sahiwal and Sahiwal-Friesian crosses.
3. To study the phenotypic and genetic relationships of weights at birth, first, second and third calvings with 300-day lactation yields in corresponding lactations and life time production in pure bred Sahiwal and Sahiwal-Friesian crosses.
4. To study the relative efficiency of milk production and its genetic architecture in Sahiwal and various genetic groups of Sahiwal Friesian cross.

CHAPTER II

REVIEW OF LITERATURE

## EUROPEAN BREEDS

Milk Production

Heritability : Gowen (1934) was first to report the heritability of milk yield by daughter-dam comparison and full-sib correlation. The estimates of heritability for first lactation production reported by a number of workers have been summarised in Table I. The heritability estimates range from 0.12 to 0.58. The heritability has been estimated differently by various workers.

Miller and Mc Gilliard (1959) and Henderson (1964) reported the heritability of milk yield by half sib correlation in Holstein-Friesian cows. The estimates reported were 0.50 and 0.37 respectively. The heritability estimated by regression of daughter records on dam have been reported by O'Keness et al. (1960), Freeman (1960), Deaton and Mc Gilliard (1964, 65), Bereskin and Freeman (1965) and Van Vleck and Hart (1965). The estimates of heritability of milk production in Friesian cattle ranged between 0.22 to 0.52. Deaton and Mc Gilliard (1965) have estimated the heritability of milk production by assuming first an additive model including interaction and then excluding the interaction. The estimate of heritability when model with interaction was assumed was 0.12 as compared to 0.33 the estimate yielded by the no interaction model.

The heritability has been estimated for later lactation records by a number of workers. Johansson (1955) reported that the later lactation records had small heritability as compared to the earlier lactations. The results of Mendel et al. (1957), Freeman (1960), Clark et al. (1962), Barr and Van Vleck (1963) and Molinuevo and Lush (1964) are in agreement with his statement and confirmed the findings of Johansson (1955).

Table I. Heritability of First Lactation Milk Yield

Breed	Data	Method	Estimate	Reference
Jersey	-	b(Dd) & CovFS	0.50	Gowen (1934)
Jersey	501 (Cows)	HSC (IH)	0.50	Miller & Mc Gilliard (1959)
Jersey	1036 (rec)	HSC (IH)	0.00	Henderson (1964)
Guernsey	1001 (Cows)	HSC (IH)	0.32	Miller and Mc Gilliard (1959)
Guernsey	2174 (rec)	HSC (IH)	0.28	Henderson (1964)
Guernsey	904 (rec)	b(Dd)	0.32	Deaton & Mc Gilliard (1964)
Holstein				
Friesian	-	-	0.25	Touchberry (1951)
"	4677 (Cows)	HSC	0.50	Miller & Mc Gilliard (1959)
"	14727	ISDR	0.20	Mitchell <i>et al.</i> (1961)
"	842	b(Dd)	0.40 + 0.077	O'Flenness <i>et al.</i> (1960)
"	876	"	0.37	Freeman (1930)
"	22767 (rec)	HSC (IH)	0.37	Henderson (1964)
"	1592 (rec)	b(Dd)	0.52	Deaton & Mc Gilliard (1964)
"	7638 (Cows)	b(Dd)	0.38	Deaton & Mc Gilliard (1965)
"	7638 (Cows)	b <sub>HS(Cows)</sub>	0.25	Deaton & Mc Gilliard (1965)
"	7638 (Cows)	Intra dam Corr.	0.44	Deaton & Mc Gilliard (1965)
"	7638 (Cows)	Intra Sire (No Int. model)	0.33	Deaton & Mc Gilliard (1965)
"	7638 (Cows)	Intra Sire (Int. model)	0.12	Deaton & Mc Gilliard (1965)
"	39000 (rec)	b(Dd)	0.22	Bereskin & Freeman (1965)
"	38440 (rec)	b(Dd)	0.42	Van Vleck & Hart (1965)
		(Dev. for Herd mate Av.)		
Red				
Danish	13000 (rec)	HSC	0.57 + 0.03	Mason <i>et al.</i> (1957)
"	██████████ ██████████	HSC	0.75	Robertson & Mason (1956)

ISDR = Intra-Sire Daughter-dam Regression  
b(Dd) = Regression of daughter on dam  
HSC = Half Sib correlation  
IH = Intraherd  
rec = Records  
Int. = Interaction

In general the estimates of heritability in the first lactation records ranged from 0.12 to 0.52. Those in the second lactation varied from 0.27 to 0.37. The results of Molinuevo and Lush (1964) in Holstein-Friesian showed a remarkable decrease in the heritability. The heritability of 0.15 in first lactation declined to 0.04 in the second lactation while in the third lactation the heritability estimated was negative. Similar findings have been observed by the same authors in another herd having higher heritability than the first herd. The estimate of heritability of first lactation in the latter herd was 0.30 which declined to 0.09 for the second and 0.08 for the third lactation records. Similar decline has also been observed by many authors. Reports of these workers have been summarised in Table II.

The results of El-Shimy (1956) did not agree with those reported above. The heritability of first lactation production reported by the author was 0.34 which increased to 0.36 in the second and 0.38 in the third lactation records. The results reported by Martojo et al. (1963) also showed high heritability estimate in the second lactation as compared to that of the first. The heritability of first lactation reported by these workers was 0.31 which increased to 0.38 for the second lactation records. The report of Johnson and Corley (1961) in Brown Swiss cattle was not in agreement with either group of workers. The heritability of first lactation was 0.42 and that of the fourth lactation as 0.58. The estimate of heritability of the second lactation production was - 0.10 and that of the third lactation 0.11.

A critical examination of these estimates reveals that the first lactation records have higher heritability. It would be reasonable to believe that the heritability estimate of later lactations should be smaller

Table II Heritability of Consecutive Lactations (Milk Yield)

Lactation No. /Breed	I	II	III	IV	All	Reference
Holstein	0.34	0.36	0.33	-	-	El-Shimy (1956)
-	0.45	0.24	-	-	-	Rendel et al. (1957)
Holstein	0.53	0.24	0.26	-	-	Freeman (1959)
Holstein	0.44	0.37	-	-	0.45	Clark et al. (1932)
-	0.31	0.39	-	-	-	Martajo et al. (1955)
-	0.23	0.27	0.21	-	-	Barr and Van Fleck (1963)
Holstein	0.15	0.34	-0.02	-	-	Molinuevo & Lush (1964)
Holstein	0.50	0.09	0.08	-	-	Molinuevo & Lush (1964)
Holstein	0.37	0.50	0.24	-	-	Van Fleck and Bradford (1966)
Holstein	-	-	-	-	0.16 + 0.05	Mc Daniel and Legates (1965)
Brown Swiss	0.42	-0.10	0.11	0.59	-	Johnson and Corley (1961)

due primarily to an increase of the non-genetic variability in the later lactations.

Van Vleck and Bradford (1965) have reported that the heritability estimated by daughter-dam comparison was larger than that estimated by half-sib correlation. The estimates from the former method did not differ from those estimated by grand daughter-grand dam comparison. The authors suggested that these estimates are higher due to genetic maternal effects. The genetic maternal effects gradually vanish away and by the time animal reached the third lactation the estimates of heritability from both methods were reported to be similar.

Relationship between various Lactations : Freeman (1960) reported a declining trend in the genetic correlations as the animals attained maturity. He reported a genetic correlation of 0.68 between first and second lactations which decreased to 0.40 between first and third and second and third lactations. Van Vleck & Bradford (1963) had also reported that magnitudes of genetic inter-relationship between first and second lactation ( $r_g = 0.97$ ) was more than that between first and third lactation ( $r_g = 0.81$ ). Barker and Robertson (1963) working on Holstein-Friesian (Van Vleck's, 1964 data), British-Friesian and Holstein-Friesian animals imported to Britain have reported that the genetic correlations increased as the animals progressed towards maturity. The genetic correlations reported by these workers are summarised in Table III.

On the basis of higher heritability estimates of first lactation as compared to later lactation records and higher genetic correlation of first lactation record with later records, Van Vleck and Bradford (1966) have concluded that the selection made on the basis of first lactation

performance would result in nearly as great genetic progress as if the selection had been based on later records. They have supported the earlier findings of Johansson and Hansson (1940), Putman et al. (1943), Johansson (1955), Mendel et al. (1957), and Molinuevo and Lush (1964).

Repeatability of Milk Yield : Deaton and Mc Gilliard (1964) have reported the repeatability estimates of 0.52 in Friesian and 0.53 in the Guernsey cows. Similar estimates have been reported by Shrode et al. (1966) for Friesian (0.44) and Jersey (0.44) cattle. But the results of Stahl et al. (1966) in Black Pied Lowland cattle indicate the character to be non-repeatable. The estimates were 0.09 for first two lactations and 0.21 for second and third lactations. The estimates of repeatability have been summarised in Table IV.

#### Body Weight

Heritability : The heritability estimates of body weight at first calving have been reported in the range from 0.16 to 0.79. The estimate reported by Maroon et al. (1966) was 0.091 in Friesian cattle. In the same breed Henderson (1964) reported the heritability of the order of 0.16. Higher estimates of heritability of body weight have been reported by Miller and Mc Gilliard (1959) and Mc Daniel and Legates (1965) of the order of 0.67 and 0.44 respectively. The heritability estimates of body weight at later calvings do not show any specific trend relative to the weight at first calving. The results of Clark et al. (1962) and Maroon et al. (1966) showed a decline in heritability of later calving weights while Mc Daniel and Legates (1965) noted an increase in heritability estimates when compared to the weight at first calving.

Table No. III Correlations between Milk Yield at Various Lactations  
(Barker and Robertson, 1966)

Lactation No.	2	3	4	5	Breed
1	0.85	0.79	0.79	0.61	Holstein Friesian (Van Vleck's 1964 data)
2		0.95	0.92	0.89	
3			0.98	0.94	
4				0.95	
1	0.75 (0.40)	0.81 (0.40)			British Friesian
2		0.95 (0.44)			
1	0.86 (0.45)	0.78 (0.48)			Imported Friesian
2		0.87 (0.59)			

Figures in parentheses are phenotypic correlations

Table IV Repentability of Milk Yield in European Breeds

Breed	Estimate	Reference
Jersey	0.44	Shrode <i>et al.</i> (1966)
Guernsey	0.53	Deaton and Mc Gilliard (1964)
Black Pied Lowland Cattle (First two Lactations)	0.09	Stahl <i>et al.</i> (1966)
Black Pied Lowland Cattle (Second and third lactations)	0.21	-do-
Native cattle (Egypt)	0.54	El-Itriby and Asker (1956)
European cattle (Egypt)	0.29	-do-
Holstein	0.52	Deaton and Mc Gilliard (1964)
Holstein	0.44	Shrode <i>et al.</i> (1966)

Relationship of Milk Yield and Body Weight : Studies pertaining to the body size, measured in terms of weight, and its relationship with milk production in dairy cattle have been rigorously undertaken. The body size has been used as an index of feed conversion for growth, fat deposition and milk production. It was theorised that it would be more economical if the heifers matured earlier. The cost of rearing the heifers to early maturity being compensated by the amount of total milk produced. Lactation-wise comparison has also been studied in both types of heifers. Herman and Ragsdale (1946), Herman et al. (1948), and Burt (1956) have shown that the early maturing heifers produced less amount of milk in first, second and third lactations. Since, the early maturity increases the total productive life of the cow the life time production in such cows should be expected to be greater than their later maturing counterparts. Swanson (1957, 1960) argued that excess ration given to dairy heifers for early maturity would interfere with milk production in their later life. The author has opined the deposition of fat in the mammary tissue to be the primary cause for such reduction in milk production.

Reid et al. (1957) failed to support the conclusions of Swanson (1957) from their experiments and were of the view that heifers should mature early to be of economic value. From these studies it can be safely concluded that heifers ought to be given such rations as would reduce the age at maturity and at the same time avoid excessive deposition of fat.

Trowbridge et al. (1915) working with cattle and Mitchell et al. (1926) with sheep had reported that 14.2 per cent and 13.6 per cent of the live weight in cattle and sheep respectively was protein. Since the milk energy yield is representative of the work done by the lactating cow (Gaines, 1940) the milk produced by the animal is a function of the amount

Table V Heritability estimate of Body Weight

Breed	d.f.	Method	Estimate	Reference
Red Dane	-	-	0.34	Johanson (1964)
Jersey	-	ISDR	0.29	Turner (1929)
Jersey	501	HSC	0.79	Miller and Mc Gilliard (1959)
Jersey	1036	-	0.24	Henderson (1964)
Guernsey	1001	HSC	0.37	Miller and Mc Gilliard (1959)
Guernsey	2174	-	0.40	Henderson (1964)
Holstein	187 Dd pairs	b(Dd)	0.37	Touchberry (1951)
Holstein	4677	HSC	0.37	Miller & Mc Gilliard (1959)
Holstein	385 Dd pairs	b(Dd)	0.29 (Ist Calv)	Clark <u>et al.</u> (1962)
Holstein	385 Dd pairs	b(Dd)	0.05 (II Calv)	Clark <u>et al.</u> (1962)
Holstein	385 Dd pairs	b(Dd)	0.19 (All Calv comb.)	Clark <u>et al.</u> (1962)
Holstein	22767	-	0.16	Henderson (1964)
Holstein	-	HSC	0.44 + 0.11 - (Ist Calv)	Mc Daniel & Legates (1965)
Holstein	-	HSC	0.53 + 0.12 - (Late Calv upto 5 years)	Mc Daniel & Legates (1965)
Holstein	-	HSC	0.57 + 0.11 - (Late calv 5-10 years)	Mc Daniel & Legates (1965)
Holstein	-	HSC	0.51 + 0.07 - (All Calv. comb.)	Mc Daniel & Legates (1965)
Holstein	-	HSC	0.091 (Ist Calv)	Marcon <u>et al.</u> (1966)
Holstein	-	HSC	0.036 (III Calv)	Marcon <u>et al.</u> (1966)

of protoplasm present in the udder. The amount of protoplasm or "Work-stuff" being proportional to body weight (Gaines, 1946), the body weight tends to be related to the milk production. Turner et al. (1924), Gaines (1940), Davis et al. (1943), Beck and Turk (1943), Plum et al. (1952), Pfau and Bartlett (1954), Menge et al. (1960), and Reid et al. (1964) have established a positive relationship between body weight and milk production. Davis and Willet (1933), Touchberry (1951), and Holtz et al. (1961) did not support these findings. The phenotypic correlation between body weight and milk production range from zero in Red Danish cattle (Antic, 1964) to as high as 0.71 in Jersey breed (Miller Mc Gilliard, 1959). Table VI summarises the findings reported by various workers on the phenotypic and genetic correlations between lactations and their corresponding weights. There does not seem to be any definite trend with time. Touchberry (1951) reported a genetic correlation of  $-0.526$  estimated by daughter dam comparison of 187 pairs in Friesian cattle. The conclusions of later authors have established the traits as being positively genetically correlated. Miller and Mc Gilliard (1959) have reported the estimate as 0.19 in Guernsey and 0.53 in Jersey Cattle. Harville and Henderson (1966) have reported higher estimates of 0.40 and 0.45 in Guernsey and Friesian breeds respectively.

Elau (1950) working on Simmental, Pinzgau and Berne cows of Czechoslovakia found an increase in the milk yield with increasing body weight of the animal. Similar results on one set of Simmental cows confirmed the above finding (Potemkin, 1964). In another set of data the author got contradictory results. The author has explained the deviation in results to be due to a small sample size. Various other breeds of cattle viz. Suskun (Savenko et al., 1964), Iskur (Eftimov et al., 1964), Bulgarian

Table VI Correlations between Body Weight and Milk Production

Breed		Estimate	Reference
<u>PHENOTYPIC CORRELATION</u>			
Black Pied Lowland		0.18 - 0.29	Lauprecht and Doring (1950)
Grey Iskur		0.38	Eftimov <i>et al.</i> (1964)
Hungarian Spotted	I	0.43	Csomos (1965)
	II	0.39	Csomos (1965)
	III	0.41	Csomos (1965)
	IV	0.41	Csomos (1965)
	V	0.40	Csomos (1965)
	VI	0.32	Csomos (1965)
Hungarian Spotted	I	0.29	Balika (1963)
	II	0.37	Balika (1963)
Czechlovakian Red Spotted	I	0.14	Suchanek (1963)
	III	0.08	Suchanek (1963)
Slovakian spotted		0.26	Gabris and Kewek (1965)
Metohija Red cattle		0.50	Antick (1961)
Red Dane		0.00	Antic (1964)
Holstein-Friesian		0.56	Davis <i>et al.</i> (1943)
Holstein-Friesian		0.12+0.003	Ferrer and Valle (1951)
Holstein-Friesian		-0.047	Touchberry (1951)
Holstein-Friesian		0.24	Bailey and Broster (1954)
Holstein-Friesian		0.51	Miller and Mc Gilliard (1959)
Holstein-Friesian		0.26	Gerrutti <i>et al.</i> (1966)
Holstein-Friesian		0.08 - 0.17	Harville and Henderson (1966)
Guernsey		0.12	Davis <i>et al.</i> (1943)
Guernsey		0.42	Miller and Mc Gilliard (1959)
Jersey		0.55	Davis <i>et al.</i> (1943)
Jersey		0.71	Miller and Mc Gilliard (1959)
yrshire		0.40	Davis <i>et al.</i> (1943)
All Breeds		0.81	Davis <i>et al.</i> (1943)
<u>GENETIC CORRELATION</u>			
Holstein		-0.53	Touchberry (1951)
Holstein	I	0.02+ 0.34	Clark <i>et al.</i> (1962)
	II	-0.53 + 0.79	Clark <i>et al.</i> (1962)
	Overall	0.12	Clark <i>et al.</i> (1962)
Holstein		0.45	Harville and Henderson (1966)
Guernsey		0.40	Harville and Henderson (1966)
Guernsey		0.19	Miller and Mc Gilliard (1959)
Jersey		0.33	Miller and Mc Gilliard (1959)

I, II, III, IV, V, & VI indicates the lactation number of the milk yield and corresponding weight at calving.

Red cattle (Conev et al., 1965), Slovakian spotted cows (Gabris and Kewek, 1965) have shown similar tendency to increase the yield with increase in the weight. Nusov (1964) reported an increase in milk yield of Red Steppe cows weighing upto 550 kg. As the cows weighed above this level no further increase in yield was found. Lauprecht and Doring (1950) and Witt (1963) observed an increase of 300-500 kg. and 200-400 kg. respectively of milk yield for every increase of 100 kg. in body weight in Black Pied Lowland cattle of Germany. In Hungarian spotted cows Osomos (1965) has reported an increase of 551 kg., 548 kg., 627 kg., 565 kg., 550 kg., and 423 kg., per 100 kg. increase in body weight in first, second, third, fourth, fifth and sixth lactations respectively.

Working with Holstein Friesian, Jersey and Guernsey breeds, Erb and Ashworth (1961) found an increase of yield by 570 kg./100 kg. increase in body weight on an intrabreed basis. When the studies were conducted independent of age effects the increase in yield was only 236 kg. On 180-day production records of 1344 records of Friesian cows Clark et al. (1962) have estimated an increase of 134 kg. in yield for every 100 kg. of body weight. The results were similar from first through eighth lactation. On combining all the lactations (irrespective of lactation number) the authors concluded an increase of 400 kg. of yield for 100 kg. increase in body weight. Mc Daniel and Legates (1965) worked by grouping the data on age and lactation basis. Partial linear regression coefficients independent of age were estimated for first lactation (181 lbs.), for later lactations upto five years of age (157 lbs.), for later lactations after five years of age (143 lbs.) and for all lactations combined (101 lbs.) for every 100 lb. of live weight. The results of the authors showed that as the animals progressed towards maturity there was a gradual decline in the rate of

increase of milk with increasing size of the animal.

Bailey and Broster (1954), Mason et al. (1957) and Kidler et al. (1965) on the basis of these results have concluded that as far as the herd improvement on the basis of body weight was concerned, the selection should not be operated with body weight as the only criterion. The potential of the sire with respect of milk production should also be considered. Miller and Mc Gilliard (1959) stated, "if weight is important in determining the milk production and genotype is important to the association, size should receive attention in evaluating the genetic ability of the animals for milk production."

## EUROPEAN BREED CROSSES

Milk Production

Brandt et al. (1966) has reported the results of crossing Guernsey (G), with Friesian (F) and Brown Swiss (BS). With a view to produce three breed cross F X G and G X F crosses were mated to BS, and then a rotational system using Guernsey or Friesian bulls was followed. The results have shown that crosses with Guernsey inheritance improved in their milk producing capacity when compared to Guernsey herd mates, whereas the Friesian crosses did not excel their pure Friesian contemporaries. 66 per cent of the crosses with Brown-Swiss inheritance happened to excel the purebred Brown Swiss Cows. In these breed crosses, a negative heterosis has been reported for milk fat test in (G X F X G) groups while (F X G X BS X F X G) group had shown positive heterosis for milk yield (Fat-corrected) and milk fat. Touchberry and Bereskin (1966) in Friesian X Guernsey crosses have reported that (i) Non-additive genetic effects were of no consequence. The observation has been confirmed by Brandt et al. (1966) (ii) Some evidence of specific combining ability in some bulls and cow breed-groups. (iii) General breeding value of various bulls differed importantly providing an evidence of additive genetic variance. For most of growth traits it was observed that crossbreds were superior to purebreds at birth; as the animals attained maturity this effect was considerably diminished.

Relationship of Milk Yield with Body Weight : From the data of crossbreeding of Friesian-Guernsey at Illinois, Bereskin and Touchberry (1966) have reported significant correlation between body weight at first calving and

first lactation milk production. An increase of 395 kg. of milk yield for every 100 kg. body weight has been reported. The body weight retained its importance independent of age whereas the age had very little effect on yield, independent of the body weight. From these observations the authors have suggested that the body weight should be taken as an index of milk production during first lactation.

## INDIAN BREEDS

### Milk Yield

The information regarding the genetic make up of Indian breeds of cattle is in general scanty and wherever it is available the limited number of observations make the estimates largely meaningless. The need for detailed genetic investigation of these breeds can hardly be emphasized when we are in the midst of a milk famine. The estimates of genetic parameters for various production traits of important breeds have been reported by a number of workers.

Heritability : A number of workers have reported heritability estimates using various methods in Indian breeds of cattle. The results have been summarised in the Table VII. In the Haryana breed Singh and Desai (1961), Acharya (1966), Singh and Prasad (1967), Tiwana (1967), and others have reported estimates ranging from 0.13 to 0.44 for various herds. The ISDR estimates reported by Singh and Desai (1961), Singh and Prasad (1967) were very small when compared to the estimates reported by Acharya (1966) and Tiwana (1967) which were of the order of 0.40. The half sib estimates averaged around 0.37 while the ISDR estimates averaged around 0.23. The average of these estimates was around 0.28. It seems in general, the milk

Table VII Heritability of Milk Production in Indian Breeds

Breed	D.f.	Method of estimate	Estimate	S.E.	Reference
Hariana	81	ISDR	0.18	0.22	Annual Report IVRI (1955-58)
"	178	ISDR	0.15	0.04	Singh and Desai (1961)
"	178	HSC	0.20	0.01	-do-
"	322	HSC	0.13	0.12	-do-
"	223	ISDR	0.42	0.12	Acharya (1966)
"	419	HSC	0.38	0.11	Tiwana (1967)
"	504	HSC	0.40	0.16	-do-
"	-	ISDR	0.30	0.15	Singh and Prasad (1967)
"	-	ISDR	0.20	0.30	-do-
"	390	ISDR	0.44	0.10	Tiwana (1967)
Gir	-	-	0.67	0.40	Murty (1963)
Kangayam	-	-	0.58	0.10	-do-
Kankrej	-	-	0.13	0.42	-do-
Malvi	44	b <sub>Dd</sub>	0.43	0.20	Taneja and Khatnagar (1959)
Tharparker	335 Dd pairs	ISDR	0.22	0.02	Kooner (1963)
"	"	HSC	0.47	0.34	-do-
"	"	-	0.42	0.16	Murty (1963)
"	13	b <sub>Dd</sub>	0.017 (Ist)	-	Mishra <u>et al.</u> (1964)
"	"	"	-0.37 (II)	-	-do-
"	"	"	0.16 (III)	-	-do-
"	"	"	-0.10 (All lact. comb.)	-	-do-
Red Sindhi	91	"	0.20	-	Mahadevan (1955)
"	132	ISDR	0.34	0.18	Amble <u>et al.</u> (1953)
"	143	"	0.37	0.14	"
Sahiwal	-	-	0.26	-	Patel (1956)
"	127 pairs	ISDR	0.44	0.32	Kooner (1963)
"	"	HSC	0.37	0.37	"
"	-	-	0.14 (I)	-	-
"	-	-	0.34 (Highest Yield)	-	Mahadevan <u>et al.</u> (1952)
"	-	-	0.24 (All lact.)	-	-do-

production in this breed has a high heritability than has been reported for the improved dairy herds of the Western origin.

For Tharparker breed Kooner (1963), Murty (1966) reported estimates ranging from 0.22 to 0.47. For Red Sindhi breed Mahadevan (1955) and Amble et al. (1958) reported the estimates varying from 0.20 to 0.37. For Sahiwal cattle the estimates in the range of 0.26 to 0.44 have been reported by Mahadevan et al. (1952), Patel (1956) and Kooner (1963).

Murty (1966) reported estimates of heritability of the order of  $0.67 \pm 0.40$  for Gir,  $0.58 \pm 0.10$  for Kangayam and  $0.13 \pm 0.10$  for Kankrej breeds. Taneja and Dhatnagar (1959) reported estimate of  $0.43 \pm 0.20$  by regression of daughter on dam of Malvi breed of Rajasthan.

A critical study of these estimates revealed that in general, a large complement of genetic variability for milk production was present in most Indian breeds. Estimates reported by Acharya (1966) and Tiwana (1967) are from a herd selected for high milk production. It reflects that even after being subjected to selection, the heritability was higher both from ISDR and Half sib correlation method. Since ISDR is very effective to detect genetic variability at low heritability, it seems a large variability was present in this herd for milk production.

Mahadevan et al. (1952) have reported the heritability of 0.14 for first lactation yield of Sahiwal cattle of Kenya. The heritability for a later lactation having highest yield was higher when compared to the first lactation. The magnitude of the heritability of lactation with highest milk yield was of the order of 0.34. The estimates reported by Patel (1956) and Kooner (1966) in Sahiwal breed of cattle was larger by ISDR method when compared to those by Half sib analysis. These estimates

reflect a higher genetic variability for milk production in Sahiwal breed.

Repeatability : The repeatability estimates of milk production records in various breeds have been worked out by many workers. The estimates range from 0.37 to 0.68 in various breeds and are summarised in Table VIII. In Hariana breed Singh and Desai (1961), Acharya (1966), Singh and Prasad (1967) and Tiwana (1967) have reported the estimates which range from 0.37 to 0.63. Tiwana (1967) reported a pooled estimate of repeatability of  $0.61 \pm 0.18$  in Hariana cattle. Murty (1966) reported repeatability estimates of 0.62 for Kangayam, 0.63 for Kankrej, 0.66 for Gir and  $0.47 \pm 0.52$  for Tharparker. In the latter breed Kooner (1963) reported an estimate of  $0.49 \pm 0.06$ .

For Red Sindhi cows Mahadevan (1955), Amble et al. (1958) and others have reported the estimates of repeatability between 0.37 and 0.61. The repeatability of milk production for Sahiwal cattle has been reported as 0.48 (Leckey, 1951), 0.40 (Patel, 1956) and  $0.52 \pm 0.06$  (Kooner, 1963).

A study of these estimates showed that the milk production records in Indian breeds of cattle are highly repeatable. Therefore the first lactation records can be safely relied upon for various selection programme and predicting the later records of the animals.

Relationship of Milk Production with Body Weight : Very little work has been reported on weights at calving and their relationship with milk production in Indian breeds of cattle. Rajgopalan (1952) reported the results of the investigation on 81 Red Sindhi and 31 Kangayam cows between weight at first calving and first lactation production. The phenotypic correlation was of the order of 0.22 and 0.55 in the two breeds respectively.

Table VIII Repeatability of Milk Yield in Indian Breeds

Breed	d.f.	Estimate	S.E.	Reference
Hariana	188 cows (3 lact. each)	0.37	0.05	Singh and Desai (1961)
"	1864	0.63	0.02	Acharya (1966)
"	232 cows (3 lact. each)	0.49	0.04	Singh and Prasad (1967)
"	846	0.59	0.03	Tiwana (1967)
Kangayan	-	0.62	-	Murty (1966)
Kankrej	-	0.63	-	"
Gir	-	0.66	-	"
Tharparker	-	0.48	0.08	Koerner (1965)
"	-	0.47	0.52	Murty (1966)
Red Sindhi	-	0.41	-	Mahadevan (1955)
"	922	0.61	-	Amble <u>et al.</u> (1958)
"	-	0.37	0.12	Koerner (1965)
"	-	0.54	-	Murty (1966)
Sahiwal	-	0.48	-	Leckey (1951)
"	-	0.40	-	Patel (1956)
"	-	0.52	0.06	Koerner (1965)

He reported the correlation of 0.20 and 0.29 between the two traits in Red Sindhi and Kangayam cows respectively where age at first calving was kept constant. The author concluded that the live weight was important than the age at first calving as an index of better production. His conclusions are based on small correlation between age at first calving and first lactation milk production.

#### Relative Efficiency

Singh and Desai (1964) reported the result of their studies on relative efficiency of Sahiwal cattle stationed at military dairy farms. The partial regression coefficients of first lactation milk yield on body weight, when age was kept constant, were reported. The magnitude of coefficients was 5.3 lb., - 0.5 lbs. and - 9.5 lb. per lb. of body weight for the weight groups 751-850 lb., 851-950 lb. and 951-1050 lb. respectively. The relative efficiency of Sahiwal cattle reported by these authors was 4.4 lb./lb. body weight.

The heritability of relative efficiency has been reported as  $0.51 \pm 0.39$ .

## INDIAN BREED CROSSES

Milk Production

The Veterinary Department, Kenya (1961) have reported pure Sahiwal cows to be better milk yielders when compared to the animals with  $1/2$ ,  $1/4$ , and  $1/8$  Guernsey inheritance produced by crossing Zebu Guernsey cows with Sahiwal bulls. However, animals with  $1/16$  Guernsey inheritance ( $15/16$  Sahiwal) proved better than their pure Sahiwal contemporaries. It can be concluded from this report that the Guernsey cows should not be bred to Sahiwal bulls but the Sahiwal animals should be maintained as pure. Mac Owen and Black (1963) have worked on cross breeding Zebu Short horn with Sahiwal cattle in Kenya for improvement of their cattle. The  $F_1$  progeny of the cross had shown 55 per cent increase in milk yield than their Kenyan herd mates. Further increase of Sahiwal inheritance resulted in proportionate increase in milk yield.

Grading of Gangatiri herd to Haryana has been reported by Dutt and Desai (1965) wherein the lactation yield improved to 1256 kg. (exclusive of the milk sucked by calf). The repeatability of milk yield has been reported by them as 0.524 which has high magnitude and is in agreement with the results reported in the literature for other Indian breeds aforementioned.

To increase milk production in India, Intensive cattle Development Projects were set up in various states. The number of projects for each state were Andhra Pradesh (2), Bihar (2), Gujrat (2), Madhya Pradesh (1), Madras (3), Mysore (1), Maharashtra (3), Orissa (1), U.P. (3), West Bengal (1). It was decided to grade up the non-descript and other poor milk

yielding animals of the states to bulls of Tharparker, Sahiwal, Red Sindhi, Hariana and Gir breeds. Each scheme covers about one lakh breedable cows. The results of these projects are being processed.

Bhasin and Desai (1967) have reported the results of crossing Hariana with Sahiwal and Red Sindhi. Hariana-Sahiwal  $F_1$ 's have yielded  $4238 \pm 96$  lb. milk against  $3814 \pm 136$  lb. of milk produced by Hariana cows and  $4018 \pm 227$  lb. of milk produced by Sahiwal cows. The yield of  $F_1$ 's is higher than both the parents, thereby indicating the possible presence of hybrid vigour. The  $F_1$ 's of Hariana-Red Sindhi cross proved better than their Red Sindhi parents but did not excel the other parent. The  $F_1$ 's yielded  $3014 \pm 337$  lb. versus  $2897 \pm 207$  lb. of Red Sindhi cows.

## EXOTIC INDIAN BREED CROSSES

Milk Yield

With a view to improve the productive economy of Indian cattle, Sikka (1931) and Maoguckin (1937) suggested the importation of European breeds for the purpose of crossbreeding. Sen et al. (1953) reported the results of crossing Ayrshire (A) with Sahiwal (S), Red Sindhi (R) and Hariana (H); and Holstein-Friesian (F) with Red Sindhi cattle.  $3/4$  A ( $1/4$  H),  $1/2$  A ( $1/2$  S),  $5/8$  A ( $3/8$  R) and  $1/2$  F ( $1/2$  S) were the best milk producers. Red Sindhi have also been crossed with Brown Swiss (B) and Jersey (J).  $1/2$  B ( $1/2$  R) produced 53 per cent more milk than Red Sindhi cows (Stonaker, 1953). Agarwala (1966) has reported that  $1/2$  Jersey inheritance resulted in more than twice the milk produced by Red Sindhi contemporaries. As the level of Jersey inheritance was increased above 50 per cent a gradual decline in milk production was observed. The author has reported that synthesis of 'Jersind' breed - a triple cross having ( $1/2$  B,  $1/4$  J and  $1/4$  R) inheritance. This new evolved breed was significantly inferior to various crosses with 50 per cent Jersey inheritance. 25 per cent Brown Swiss was significantly superior to the crosses with 50 per cent Brown Swiss inheritance and 25 per cent Jersey. However, no significant difference was found between  $F_1$ 's with 50 per cent Jersey or Brown Swiss inheritance. From crossbreeding experiments at various experimental stations in United States, Branton et al. (1961, 66) have reported  $1/2$  and  $3/4$  Red Sindhi to be physiologically adaptable but they were poor performers when compared to their Friesian, Brown Swiss and Jersey contemporaries.  $7/8$  and  $3/4$  exotic inheritance with Brown Swiss equalled their European contemporaries.

Punganur cattle of Chittor district have been crossed with bulls

imported from Kerry county of Ireland for increasing milk production in the short-statured cattle. The results reported by Venkatratnam and Venkayya (1964) have indicated an increase of milk production in  $F_1$  progeny by 278 per cent in comparison to the Punganur cows.

Crossbreeding of Hariana, Red Sindhi and Sahiwal with Holstein-Friesian was taken up at Birla Dairy Farm, Pilani (Rajasthan). Bhasin and Desai (1967) reported the results of this investigation summarised as follows.

Among various grades of Hariana (H) Friesian (F) cross the half breeds had shown an improvement by 198 per cent in milk yield. Backcrossing to either of the breeds was detrimental. A sharp decline was noted by backcrossing to Hariana.  $1/2$  F ( $1/2$  H) demonstrated a remarkable increase by 213 per cent than their pure Red Sindhi herdmates. Triple breed cross having ( $1/4$  F,  $1/4$  H,  $1/2$  R) and ( $1/2$  F,  $1/4$  H,  $1/4$  S) were evolved. The former one proved to be inferior to its halfbred contemporaries, whereas the latter cross excelled all other crosses and pure indigenous contemporaries. This cross showed an improvement by 216 per cent and 222 per cent over its Sahiwal and Hariana herdmates respectively. The  $F_1$  progeny of Sahiwal-Friesian cross showed an improvement by 182 per cent over its Sahiwal herdmates. This study also establishes that the crossbreeds do not require any special environments as they were able to raise the herd under extreme Rajasthan desert conditions.

An increase of 14-21 per cent in first lactation milk yield has been observed by Desai (1966) in various grades of Sahiwal-Friesian crosses when compared to pure Sahiwal contemporaries. Among these grades highest milk producers suited to Northern region were  $3/8$ ,  $1/2$  and  $5/8$  and for

Southern region  $3/4$  Friesian (Naidu and Desai, 1966).

Padmanabhan (1966) and Amble and Jain (1967) reported that for all types of exotic Indian crosses  $1/2$  and  $5/8$  exotics performed the best. They have reported a decline in the average merit of the animals with milk production with a deviation of exotic inheritance on either side of  $1/2$  and  $5/8$  Friesians.

Heritability : Mahadeven (1954) reported the heritability of first lactation yield irrespective of exotic inheritance as 0.19. The estimate was found by regressing 1102 daughter records on their dam's records. Naidu and Desai (1966) have reported the heritability of first lactation total milk yield as  $0.18 \pm 0.19$  for northern region and  $0.50 \pm 0.27$  for Southern region crossbreds having  $4-15/32$  Friesian inheritance. The authors suggested the reason for such a difference in estimates to be due to the wider differences between dams mated to sires in northern region.

Repeatability : Estimates of repeatability for the milk has been estimated by Mahadeven (1954) and Naidu and Desai (1966) for various grades of European-Indian crosses (Table IX). Variation between the estimates does not seem to follow the level of exotic inheritance. Based on 300 records of exotic-Indian crosses irrespective of the level of exotic inheritance, Mahadeven(1954) has reported an average repeatability estimate for milk yield as 0.51. Similar estimate (0.472) has also been obtained by El-Itaby and Asker (1956) from the data of Egyptian-European crosses. The estimates are high to provide the first lactation as basis of selection for future performance. The high magnitude of the estimates might have been due to epistatic and/or dominance components in addition to the contribution of permanent environments.

Table IX Estimates of Repeatability in Indian European Crosses

Level of Exotic Inheritance	No. of animals	No. of Records	Estimate Total yield	M.E. yield	Reference
<u>NORTHERN REGION</u>					
4-7/32 Fries.	24	77	0.54	0.49	Naidu and Desai (1966)
8-11/32 "	45	175	0.52	0.61	"
12-15/32 "	113	432	0.53	0.51	"
20-23/32 "	53	194	0.47	0.49	"
24-27/32 "	182	734	0.54	0.54	"
<u>Southern Region</u>					
8-11/32 "	41	165	—	0.47	Naidu and Desai (1966)
12-15/32 "	98	397	—	0.55	"
20-23/32 "	28	156	—	0.37	"
24-27/32 "	30	162	—	0.51	"
1/4	299	—	0.58	—	Mahadevan (1954)
1/2	630	—	0.55	—	"
5/8	260	—	0.65	—	"
3/4	309	—	0.40	—	"

Table X Correlation between Milk Yield at various Lactations  
(Mahadevan, 1954)

European Blood level	Lactation No.	IInd	III	IV
1/4	I	0.63	0.37	0.44
	II		0.63	0.67
	III	--	--	0.70
1/2	I	0.60	0.52	0.41
	II	--	0.59	0.53
	III	--	--	0.41
5/8	I	0.75	0.71	0.40
	II	--	0.74	0.50
	III	--	--	0.40
3/4	I	0.48	0.32	0.34
	II	--	0.42	0.49
	III	--	--	0.30

Relationship between Milk Yield at various Lactations : Mahadeven (1954)

has found the correlations between milk yields at various lactations in Exotic-Indian crossbreds (Table X). In 1/4 exotic animals there was an increase in the magnitude of correlations from heifer lactation towards maturity. There was a decrease in the magnitude of the correlations in all other grades.

Relationship of Milk Yield and Body Weight : Naidu (1962) working with Sahiwal Friesian crosses estimated the correlation between milk yield at first lactation and body weight at first calving in Half sibs (4/32 to 15/32 Friesian). The intraherd correlation was 0.24 and the genetic correlation 0.19. Singh and Desai (1964) have estimated partial regression of first lactation milk production on body weight at first calving independent of the age at first calving (12/32 to 15/32 Friesian). The regression coefficients for Southern and Northern region crossbreds are 14.9 and 8.4 for animals weighing between 751-850 lbs; - 11.4 and 0.9 for animals weighing between 851-950 lb. and 31.7 and - 9.7 for those weighing between 951-1050 lb., respectively.

Relative Efficiency

Relative efficiency - a term identical to "Gross Efficiency" of milk yield in Sahiwal-Friesian crosses has been reported by Singh and Desai (1964). The average relative efficiency in Northern region crossbreds and Southern region crossbreds has been reported as 4.9 lb./lb. body weight and 4.8 lb./lb. body weight respectively. According to the level of Friesian inheritance the relative efficiency is said to have increased upto 3/4 Friesian in Northern crossbreds and 5/8 Friesian in Southern Crossbreds and thereafter it gradually

declined. The authors have mentioned that the relative efficiency of the crossbreds having more than  $3/4$  or  $5/8$  Friesian inheritance in the two regions did not fall below the level of halfbreds. However, the relative efficiency of crossbreds in both regions was higher than that of the pure Sahiwal.

Heritability estimate of the relative efficiency has been reported as  $0.51 \pm 0.25$  for animals of Northern region and  $0.77 \pm 0.31$  for animals of Southern region.

CHAPTER III  
M A T E R I A L

The data for carrying out the investigation were collected from Indian Military dairy farms at Ambala, Dehradun, Jabalpur, Jullundur, Lucknow, Meerut and Mhow.

#### A. Military Dairy Farms

The most extensive cross breeding work in India has been conducted at military dairy farms since 1900 (Macquackin, 1937). A number of European breeds viz. Jersey, Ayrshire, Shorthorn and Holstein-Friesian were tried with Red Sindhi, Sahiwal Tharparker and Mariana. Forman (1927) contended Friesian to be superior to Ayrshire for cross breeding with Indian cattle. And with experience the Holstein-Friesian has been found to be more adaptable to Indian environmental conditions so this is in use extensively.

#### B. Classification of Data

The data were classified according to genetic groups, periods, seasons and breed of sire as follows :

(1) Genetic Groups (Grades): The pure Sahiwals were recorded separately and the cross breeds were classified into eight groups based on the level of Friesian inheritance. The animals having less than 4/64 Friesian inheritance were discarded and rest were classified into following genetic groups :

1/8	( 4-11/64 Friesian)
1/4	(12-19/64 Friesian)
3/8	(20-27/64 Friesian)
1/2	(28-35/64 Friesian)
5/8	(36-43/64 Friesian)
3/4	(44-51/64 Friesian)
7/8	(52-59/64 Friesian)

and the animals having more than 60/64 level of Friesian inheritance were included in the pure exotic breed group. All these genetic groups have

been considered as separate populations.

Some of the Friesian-Sahiwal crosses were observed to have some level of Ayrshire, Red Sindhi, Hariana and non-descript inheritance. Those having more than 5/84 level of blood from any of these breeds were considered as triple crosses and therefore discarded.

(ii) Periods : The data collected for analysis covered a period of 30 years (1937 to 1966). It is not uncommon to think that one year would differ from the other year. But the variation caused by two consecutive years would not be too much to warrant the studying of each year separately. However, a substantial difference can be expected between two years which are five years apart from each other. It was on this basis that the data were classified into six periods of five years duration each. The six periods were :

1. 1937-1941
2. 1942-1946
3. 1947-1951
4. 1952-1956
5. 1957-1961
6. 1962-1966

(iii) Seasons : A month-wise frequency distribution according to the birth of the animals was made from the data. It was observed that maximum birth occurred during the months of November to April while from May to October there was lesser calvings. The criterion led to the definition of 'most calving season' in former case and 'least calving season' in the latter case.

(iv) Breed of Sire : The half-breds were divided into two groups according to whether they were sired by a Friesian bull or a Sahiwal bull. Animals having more than 50% Friesian blood were all sired by Friesian bulls and

those having less than 50 per cent Friesian inheritance were Sahiwal-sired. The animals having a cross bred sire were not included in the present investigation.

### C- Standardisation of Data

The animals completing at least one lactation were recorded for present investigation. The animals yielding less than 400 kg. in a lactation, in my view, should not be considered as dairy animals. Therefore, such animals were excluded from the data for the studies pertaining to milk yield. Culling in the middle of lactation, abortions, and other pathological causes which affected the lactation data were considered as abnormalities. Therefore, such records have been discarded. However, the lactations in which still births or premature births were reported have been included, based on the fact that animals retain their physiological adaptability without calves.

To make the data uniform, all the records in pounds have been converted to kilograms by dividing them with 2.2.

The lactation yield is defined as the milk yielded by the cow, in 300 or less number of days. Those yielding for more than the specified period have been brought at level by the formula which is in use at the military farms. The formula is :

$$SLP = LY - \left[ \frac{(LD-300) \times AV}{LD} + \frac{AV}{3} \right] \quad (LD-300)$$

where SLP is standard lactation production for 300 days,

AV is average daily yield during lactation,

LD is lactation period in days,

and LY is the total lactation yield.

#### D - Breeding Policy

At the initiation of crossbreeding at Indian Military Farm, forward crossing to the bulls of exotic breeds was considered best to increase the milk production. As the higher crosses became available the farm authorities, on the basis of some preliminary observations decided that higher levels of Friesian over 3/4 were not suitable to Indian environments. Since these the Military farm authorities have laid down a set plan of breeding Indian cows to the improved European breeds. It has been dictated to keep the ratio of Exotic-Indian inheritance around 50 per cent. To maintain it, alternate crossing with Friesian and Sahiwal bulls has been practised. This continuous alternate crossing generated in all about 64 different levels of exotic inheritance.

#### E - Feeding

A uniform pattern of feeding was practised at Indian Military Farms. The experts have laid down the feeding standards according to the age group considering the maintenance, growth and production requirements. The animals were stall fed. Following are the ration schedules :

##### 1. Calves from Birth to six Months :

Age (Days)	Colostrum (kg.)	Whole Milk (kg.)	Separated Milk (kg.)	Calf Starter (kg.)	Conc. Mixture (kg.)
1	2	3	4	5	6
0-3	2.6	-	-	-	-
4-7	-	3.5	-	-	-
8-14	-	3.5	0.9	0.05	-
15-21	-	2.6	1.8	0.10	-

1	2	3	4	5	6
22-28	-	2.6	3.1	0.15	-
29-30	-	1.8	3.5	0.50	-
31-35	-	1.8	3.5	0.45	-
36-49	-	1.3	3.1	0.70	-
50-56	-	1.3	3.1	0.90	-
57-63	-	1.3	3.1	0.45	0.45
64-70	-	0.9	2.6	0.23	0.90
71-84	-	0.9	2.6	-	1.35
85-112	-	-	2.2	-	1.35
113-146	-	-	1.8	-	1.35
147-168	-	-	1.3	-	1.35
169-182	-	-	0.9	-	1.35

For the first three days the calves were given 2.6 kg. of colostrum three times a day. The calves too weak to suckle were bottle fed till they were able to use the pail. Later they were reared on cow's milk and separated milk containing lime water. The quantity of separated milk was gradually increased to replace whole milk. The calf starter mixture was given along with the separated milk till the whole milk was completely stopped. The calves were given concentrate mixture from the 9th week and its amount gradually increased to compensate the decreasing quantity of separated milk. The compositions of calf starter mixture and concentrate mixture are :

Calif starter Mixture

Maize	10 parts	
Barley	10 parts	
Bran	10 parts	
Ground nut cake	34 parts	
Gram	15 parts	
Wheat	10 parts	
Slaked lime	3 parts	(Lime-water was prepared from slaked lime and given to calves along with milk.)
Molasses	5 parts	
Mineral mixture	3 parts	

Concentrate Mixture

Gram	2 parts
Bran	2 parts
Ground nut cake	1 part

The separated milk was usually not fed after the calves were six months old. However, when the separated milk was surplus, it was fed to the herd. For every 4 kg. of separated milk a out of 1 kg. in concentrate mixture was practised. The milk was fed in the following order of priority :

- a. Young stock over six months to one year
- b. Young stock over one year
- c. Dry stock
- d. Milking stock

The milk was converted to curd to feed to the animals which dialiked separated milk. The curd was prepared by adding sulphuric acid to the milk. The curd was thoroughly rubbed with concentrate

mixture in a ratio of 1:1 for young stock and 1:2 for dry stock and cows-in-milk. 0.5 per cent salt was added to this mixture and fed to animals.

Roughage for the calves varied with the season. It contained :

1. Husa
2. Hay (Oat, Jowar, Berseem, Monsoon grass)
3. Silage (Oat, Jowar, Lucerne)
4. Green fodders (Berseem, Lucerne, Maize, Jowar, Oat)

The amount of roughage fed to calves upto six months :

<u>Age (Days)</u>	<u>Green Fodder (kg.)</u>	<u>Dry Fodder (kg.)</u>
16-28	4.5	-
29-56	7.0	0.23
56-84	9.0	0.49
85-112	11.5	0.70
113-140	13.5	0.90
141-161	16.0	0.90
162-182	22.5	1.15

The calves were not allowed any roughage until 15 days of age and dry fodder was allowed after one month.

## 2. Animals above six months

The herd above six months age was fed according to the body weight. The following table details the ration schedule for various categories of animals. The categories were formed according to the amount of Friesian inheritance :

Group 1 - Pure Friesian and animals with more than 50 per cent Friesian inheritance

Group 2 - High yielding Sahiwal cows and those with less than 50 per cent Friesian inheritance

Group 3 - Indigenous cattle

Depending on the availability of green and concentrate three classes of ration schedules have been laid -

A class - More concentrate, less green

B class - Green fodder available with normal amount of concentrates

C class - Excessive amounts of green fodder which compensated for less concentrates mixture

Weight (kg.)	Ration A			Ration B			Ration C		
	Group	Group	Group	Group	Group	Group	Group	Group	Group
	1	2	3	1	2	3	1	2	3
Upto 180	1.8	1.8	1.3	1.3	1.3	1.3	1.3	1.3	1.3
181-225	1.8	1.8	1.3	1.8	1.3	1.3	1.3	1.3	1.3
226-270	2.2	1.8	1.3	1.8	1.3	1.3	1.3	1.3	1.3
271-315	2.7	1.8	1.5	1.8	1.3	0.9	1.3	1.3	0.9
316-360	2.7	1.8	1.3	1.8	1.3	0.9	1.3	1.3	0.9
361-450	2.7	1.8	1.3	1.8	1.3	0.9	1.3	1.3	0.9
451-540	3.2	2.2	1.3	1.8	1.3	0.9	1.3	1.3	0.9
541-630	3.2	2.7	1.8	2.2	1.3	0.9	1.3	1.3	0.9
Over 631	3.2	2.7	1.8	2.2	1.8	0.9	1.8	1.3	0.9

In addition to these amounts the animals were also given allowances for milk production, and pregnancy. The adult down-calvers (3 months before pregnancy) were given 0.9 kg. while the heifer down calvers were given 1.8 kg. of concentrate ration in addition to their basic daily requirements.

To compensate for the seasonal variations the animals were fed extra amount of concentrate @ 0.5 kg. when atmospheric temperature was 45 to 50°F, and 0.9 kg. when the temperature fell below 45°F.

#### F - Management

To ensure good care, management and feeding the herd was classified into following stocks on the basis of their age as under :

1. Young calves : Birth to six months
2. Calves : Six months to one year
3. Young stock 2 : One year to two years
4. Young stock 1 : Two years to puberty. The puberty was measured in terms of age at first calving
5. Dry stock and pregnant cows
6. Down calvers : The animals which were due to calve in 10-15 days were separated from the dry stock and kept in calving lines
7. Cows-in-milk

The calves were weaned three days after birth and kept on milk and calf starter mixture. At the age of 15 days the male calves were separated from females, castrated and sold for draught purpose. The females having good pedigree records, growing normally and attaining sexual maturity in normal time were selected for the first lactation performance on which the final selection was based.

Recording of weights was regularly conducted from within three days after birth to one year of age at weekly intervals. The weighing was done at monthly intervals till the first calving. Thereafter the animals were weighed within 15 days of calving. The milk recording was started from fourth day onwards after calving. Cows were milked twice a

day in early hours of morning and evening. The cows which conceived were dried two months prior to calving and transferred to the dry stock.

All the stocks were kept in separate barns. All the enclosures were constructed such as to ensure the protection of animals from severe climatic conditions. These were provided with good ventilation and lighting arrangements. During hot weather the animals were protected by continuous sprinkling of water. Pure Friesian and crossbred animals with high Friesian blood were kept in fan-cooled barns. Daily sweeping and washing of barns maintained thorough cleanliness throughout the day.

CHAPTER IV  
M E T H O D O L O G Y

### I. Least Square Analysis

To study the main tangible causes of variation, and to overcome the difficulty of disproportionate sub-class numbers and non-orthogonality, the data were analysed by least square technique (Harvey, 1966) as described below :

#### Model :

A six-way, cross-classification, no-interaction, fixed-effects model (Model 1 of Eisenhart, 1947) was constructed for the analysis. The model is :

$$Y_{ijklmnp} = \mu + G_i + F_j + P_k + S_l + B_m + L_n + e_{ijklmnp}$$

$$\begin{aligned} i &= 1 \dots\dots\dots 9 \\ j &= 1 \dots\dots\dots 7 \\ k &= 1 \dots\dots\dots 6 \\ l &= 1, 2 \\ m &= 1, 2 \\ n &= 1 \dots\dots\dots 5 \end{aligned}$$

where  $Y_{ijklmnp}$  is  $p^{\text{th}}$  observation of  $i^{\text{th}}$  grade,  $j^{\text{th}}$  farm,  $k^{\text{th}}$  period and  $n^{\text{th}}$  lactation, and its sire belonging to  $m^{\text{th}}$  breed.

$$\begin{aligned} \mu &= \text{Overall mean when equal sub-class numbers exist,} \\ G_i &= \text{effect of } i^{\text{th}} \text{ grade,} \\ F_j &= \text{effect of } j^{\text{th}} \text{ farm,} \\ P_k &= \text{effect of } k^{\text{th}} \text{ period,} \\ S_l &= \text{effect of } l^{\text{th}} \text{ season,} \\ B_m &= \text{effect of } m^{\text{th}} \text{ breed of sire,} \\ L_n &= \text{effect of } n^{\text{th}} \text{ lactation (calving)} \end{aligned}$$

and  $e_{ijklmnp}$  is the effect of  $p^{\text{th}}$  observation in  $ijklmnp^{\text{th}}$  sub-class, which is NID  $(0, \sigma_e^2)$ .

$$\begin{aligned} \mu &\text{ is an overall mean and } G_i, F_j, P_k, S_l, B_m \\ &\text{ and } L_n \text{ are deviations from } \mu, \text{ it is assumed that} \\ \sum G_i &= \sum F_j = \sum P_k = \sum S_l = \sum B_m = \sum L_n = 0. \end{aligned}$$

All possible interactions are also assumed as zero.

## Analysis

### A. Generation of Least Square Equations

Frequencies of the 300-day lactation yield for five lactations and weight at calving from first through fifth calving were calculated and arranged in the form of a 32x32 square matrix. Values of the frequencies at each level of the main effect were added to get the right hand members (RHM). Since there were six independent equations, the restriction  $\sum_i g_i = \sum_j f_j = \sum_k p_k = \sum_l s_l = \sum_m b_m = \sum_n l_n = 0$  was imposed. The last equation of each effect i.e.,  $G_9, F_7, P_6, S_2, B_2$  and  $L_5$  were set equal to zero. The equations were deleted by subtracting the coefficients of these equations from other columns and rows corresponding to them. A corresponding reduction in the right hand members was also done in the same fashion.

### B. Constants

The least square matrix having 26 equations was inverted. The inverse elements were multiplied with the right hand members which gave 26 values. The first value was  $Q$  - the overall mean; and among others 8 constants for grades, 6 constants for farms, 5 constants for periods, one constant each for season and breed and the last four constants for the lactation number (calving number). Other constants were obtained as follows :

$$g_9 = -\sum_i g_i, \quad f_7 = -\sum_j f_j, \quad p_6 = -\sum_k p_k, \\ s_2 = -s_1, \quad b_2 = -b_1 \quad \text{and} \quad l_5 = -\sum_n l_n.$$

### C. Sum of Squares

(i) The total sum of squares were estimated by the formula

$$\sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \sum_p Y_{ijklmnp}^2 = Y^2 \dots \dots / N$$

(ii) Grade sum of squares : Sub matrix of grades from the inverted matrix (Z) was taken out and re-inverted  $(Z)^{-1}$ . The transpose  $(B')$  of the corresponding constants was multiplied with  $(Z)^{-1}$  and the result so obtained was multiplied again with the column vector (B) of the constants. So that result of  $[(B') (Z)^{-1} (B)]$  was the sum of squares due to grades.

The sum of squares for farms, periods, seasons, breed of sire and lactation number were obtained exactly in the same fashion.

(iii) Sum of Squares due to Error was obtained as shown under :

$$\sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \sum_p Y_{ijklmnp}^2 - R (C, g_1, f_j, p_k, a_l, b_m, l_n)$$

#### Analysis of Variance

Source	d.f.	S.S.	M.S.	Variance Ratio	R <sup>2</sup> (%)
Total	N-1	SS <sub>T</sub>	-	-	100
Grades	G-1	SS <sub>G</sub>	SS <sub>G</sub> / G-1 = MS <sub>G</sub>	MS <sub>G</sub> / MS <sub>E</sub>	SS <sub>G</sub> / SS <sub>T</sub> x 100
Farms	F-1	SS <sub>F</sub>	SS <sub>F</sub> / F-1 = MS <sub>F</sub>	MS <sub>F</sub> / MS <sub>E</sub>	SS <sub>F</sub> / SS <sub>T</sub> x 100
Periods	P-1	SS <sub>P</sub>	SS <sub>P</sub> / P-1 = MS <sub>P</sub>	MS <sub>P</sub> / MS <sub>E</sub>	SS <sub>P</sub> / SS <sub>T</sub> x 100
Seasons	S-1	SS <sub>S</sub>	SS <sub>S</sub> / S-1 = MS <sub>S</sub>	MS <sub>S</sub> / MS <sub>E</sub>	SS <sub>S</sub> / SS <sub>T</sub> x 100
Breed of Sire	B-1	SS <sub>B</sub>	SS <sub>B</sub> / B-1 = MS <sub>B</sub>	MS <sub>B</sub> / MS <sub>E</sub>	SS <sub>B</sub> / SS <sub>T</sub> x 100
Lactation Number	L-1	SS <sub>L</sub>	SS <sub>L</sub> / L-1 = MS <sub>L</sub>	MS <sub>L</sub> / MS <sub>E</sub>	SS <sub>L</sub> / SS <sub>T</sub> x 100
Error	By Subt. = E	SS <sub>E</sub>	SS <sub>E</sub> / E = MS <sub>E</sub>	-	SS <sub>E</sub> / SS <sub>T</sub> x 100

## II. Estimation of Heritability

Lush (1940, 1948, 1949) has discussed advantages,

disadvantages and method of estimation of finding out the heritability.

The heritability is defined as, the portion of the total observed variance which can be attributable to the additive effect of genes (Lush, 1948). It is expressed as :

$$h^2 = \frac{\sigma_A^2}{\sigma_P^2} = \frac{\sigma_A^2}{\sigma_A^2 + \sigma_D^2 + \sigma_I^2 + \sigma_E^2 + \sigma_{GE}^2}$$

**Half-sib Correlation :** In the present investigation the heritability was estimated by paternal half-sib correlation. It is reliable method since except for a small fraction of the epistatic variance the sire component has of no other variance but the additive genetic variance. However, it has a limitation that error due to sampling or incorrect estimation of environmental components are multiplied by four and therefore increase the heritability estimate. The error due to sampling to a large extent also depends upon the degree of freedom for estimation of sire component. Larger the degree of freedom for sire, preciser the estimate of heritability.

For computing heritability estimates the following model was used :

$$Y_{ijk} = \mu + F_i + S_j(1) + e_k(1j)$$

$$i = 1 \dots \dots \dots f$$

$$j = 1 \dots \dots \dots s_1$$

$$k = 1 \dots \dots \dots n_{1j}$$

$$\sum_{1j} n_{1j} = \sum_i n_i = N.$$

- where  $Y_{ijk}$  is the  $k^{\text{th}}$  daughter born to the  $j^{\text{th}}$  sire in the  $i^{\text{th}}$  farm;
- $\alpha$  is the overall mean common to all observations and is a fixed constant ;
- $F_i$  is the effect of  $i^{\text{th}}$  farm peculiar to individuals of particular farm, which is NID  $(0, \sigma_f^2)$  ;
- $S_j(i)$  is the effect of  $j^{\text{th}}$  sire common to all its daughters in the  $i^{\text{th}}$  farm, which is NID  $(0, \sigma_s^2)$  ;
- $e_{k(ij)}$  is the random error peculiar to each observations, which is NID  $(0, \sigma_e^2)$ .

## Analysis of Variance

Source	d.f.	Sum of Squares	Mean square	E.M.S
Total	$N-1$	$\sum_{ijk} Y_{ijk}^2 - \frac{Y_{...}^2}{N}$	$MS_T$	
Farms	$F-1$	$\sum_i \frac{Y_{i..}^2}{n_{i.}} - \frac{Y_{...}^2}{N}$	$MS_F$	$\sigma_e^2 + k_2 \sigma_s^2 + k_3 \sigma_f^2$
Sires/Farms	$(S-1)$	$\sum_i \sum_j \frac{Y_{ij.}^2}{n_{ij}} - \sum_i \frac{Y_{i..}^2}{n_{i.}}$	$MS_S$	$\sigma_e^2 + k_1 \sigma_s^2$
Error	$(n_{ij}-1)$	$\sum_{ijk} Y_{ijk}^2 - \sum_{ij} \frac{Y_{ij.}^2}{n_{ij}}$	$MS_E$	$\sigma_e^2$

K-values :

$$k_1 = \frac{1}{\sum_i (S_i - 1)} \left[ \frac{\sum_j n_{ij}^2}{N - \sum_i \frac{\sum_j n_{ij}^2}{n_{i.}}} \right]$$

$$k_2 = \frac{1}{F-1} \left[ \frac{\sum_j n_{ij}^2}{\sum_i n_{i.}} - \frac{\sum_{ij} n_{ij}^2}{N} \right]$$

$$k_3 = \frac{1}{F-1} \left[ \frac{\sum_i n_{i.}^2}{N} \right]$$

Estimation of components :

$$\sigma_e^2 = \frac{MS_E}{k_1} ;$$

$$\sigma_f^2 = MS_F - \left[ K_2 / k_1 (MS_S - MS_E) + MS_E \right]$$

$$\text{Total variance} = \sigma_p^2 = \sigma_s^2 + \sigma_f^2 + \sigma_e^2$$

$$h^2 = \frac{4 \sigma_s^2}{\sigma_p^2}$$

Expected value of various components of Analysis of Variance in terms of Genetic components :

$\sigma_e^2$  - the variance within individuals includes whole of the random environmental variance, 3/4 of the additive genetic variation, whole of the dominance variance, most of the part of epistatic variance.

$\sigma_s^2$  - the variance between sires equals only 1/4 of the additive genetic variance and part of the non-active interaction variance, i.e.

$\frac{1}{16} \sigma_{AA}^2 + \frac{1}{64} \sigma_{AAA}^2 + \dots$ . It will also include a variance which is caused by correlation between the sires.

Standard error of heritability was calculated by the formula given by Dickerson (1960) :

$$\text{S.E.}h^2 = \frac{4 \sqrt{\frac{2}{k_1^2} \left( \frac{MS_B^2}{DF_B} + \frac{MS_E^2}{DF_E} \right)}}{\sigma_p^2}$$

#### Heritability of Relative Efficiency :

The variance of a ratio has been estimated in a way as would take care of the basic distribution of the ratio. This can be done by normalizing the distribution by transforming the ratio on a logarithmic scale.

To avoid any such transformation Pearson (1897) had derived a formula for estimating the variance of a ratio. Tanner (1949) suggested that plots of ratio of means of the two variables and the regression of one on the other would run parallel with a vertical distance of  $\hat{a}$  (a constant) between them. If the value of the constant was reduced to zero, the two lines would be identical. It is from these concepts that the formula for the

heritability of a ratio has been derived by modifying Pearson's (1997) formula. Sutherland (1965) has reported the formula for calculating the heritability estimates of ratio of the two variables. The formula is :

$$h^2(x_1/x_2) = \frac{h_1^2 \cdot c_1^2 + h_2^2 \cdot c_2^2 - r_{g12} h_1 \cdot h_2 \cdot c_1 \cdot c_2}{c_1^2 + c_2^2 - r_{12} \cdot c_1 \cdot c_2}$$

where  $h^2(x_1/x_2)$  is the heritability of the ratio of two variables,

$c_1$  is coefficient of variation of first variable,

$c_2$  is coefficient of variation of second variable,

$h_1^2$  is heritability of first variable,

$h_2^2$  is heritability of second variable,

$r_{g12}$  is genetic correlation between two variables,

and  $r_{12}$  is phenotypic correlation between two variables.

To facilitate calculations the formula has been reduced as under :

$$h^2(x_1/x_2) = \frac{h_2^2 (1 + k^2 k_h^2 - 2 r_{g12} \cdot k \cdot k_h)}{1 + k^2 - 2 r_{12} \cdot k}$$

where  $k = c_1 / c_2$

$k_h = h_1 / h_2$

other symbols have the usual meaning.

Since the relative efficiency of milk production is the ratio of milk produced by the animal to her live weight at calving it was necessary to either transform the relative efficiency or that heritability should be estimated from the ratio of the heritabilities of 300-day milk production in first lactation and the weight at first calving. The formula given above has been used to calculate the heritability of relative efficiency.

### III. Correlations

A phenotypic correlation between two characters in the same animal results from two causes (Harvey and Lush, 1952).

1. One or more of the variations in the environments which happened to the individual may have affected both characters.
2. One or more of the genes may have affected both characters alike or oppositely.

The former cause of the phenotypic correlation is due to environments and is called the environmental correlation and the latter part is due to genes is the genetic correlation. The genetic correlation is a result of variety of circumstances which are :

(1) Pleiotropic effect of genes :

The reason as to why the pleiotropism occurs as hypothesised by Grünberg (1938) is - number of observable characteristics in an organism are infinite, while the number of genes is limited. Therefore, diversity of action of single gene is necessitated. The ways in which a single gene produces manifold effect, as proposed by Grünberg are :

- (a) A gene may affect two characteristics directly but in independent ways.
- (b) A gene may affect two characteristics essentially in the same way ; its primary product may affect them alike.
- (c) A gene may affect one characteristic directly and this characteristic will affect another characteristic.

Grünberg called the first method as "genuine pleiotropy" and the other two methods as "Spurious pleiotropy".

Dobzhansky (1926), Dobzhansky and Holz (1943) working on Drosophila melanogaster and Russel (1949) on mouse have given evidences in support of the pleiotropism.

(ii) Linkage between genes affecting two characteristics which is a cause only when the coupling double heterozygotes are more abundant than the repulsion ones or vice versa.

(iii) Heterogeneity in previous breeding practices in the population.

Genetic correlation is estimated from Half sib analysis by running analysis of variance and co-variance as follows :

Analysis of Co-variance

Source	D.F.	Squares of X	Squares of Y	Sum of cross products XY
Total	N-1	$SX_T$	$SX_T$	$SXY_T$
Farms	F-1	$SX_F$	$SX_F$	$SXY_F$
Sires/Farms	$\sum_i (S_i - 1)$	$SX_S$	$SX_S$	$SXY_S$
Error	$\sum_i \sum_j (n_{ij} - 1)$	$SX_E$	$SX_E$	$SXY_E$

Expected Mean Squares

Source	EMS (Y)	EMS (X)	EMS Cov (XY)
Farms	$\sigma_{e_y}^2 + k_2 \sigma_{s_y}^2 + k_3 \sigma_{f_y}^2$	$\sigma_{e_x}^2 + k_2 \sigma_{s_x}^2 + k_3 \sigma_{f_x}^2$	$\sigma_{e_{xy}} + k_2 \sigma_{s_{xy}} + k_3 \sigma_{f_{xy}}$
Sires/Farms	$\sigma_{e_y}^2 + k_1 \sigma_{s_y}^2$	$\sigma_{e_x}^2 + k_1 \sigma_{s_x}^2$	$\sigma_{e_{xy}} + k_1 \sigma_{s_{xy}}$
Error	$\sigma_{e_x}^2$	$\sigma_{e_x}^2$	$\sigma_{e_{xy}}$

Values of  $k_1$ ,  $k_2$  and  $k_3$  are given under the heritability estimation.

$$\text{Genetic correlation : } r_{G_{xy}} = \frac{\sigma_{s_{xy}}}{\sqrt{\sigma_{s_x}^2 \cdot \sigma_{s_y}^2}}$$

$$\text{Phenotypic correlation : } r_{p_{xy}} = \frac{\sigma_{e_{xy}} + \sigma_{s_{xy}} + \sigma_{f_{xy}}}{\sqrt{(\sigma_{e_x}^2 + \sigma_{s_x}^2 + \sigma_{f_x}^2) \cdot (\sigma_{e_y}^2 + \sigma_{s_y}^2 + \sigma_{f_y}^2)}}$$

$$\text{Environmental Correlation : } r_{E_{xy}} = \frac{r_{p_{xy}} - r_{G_{xy}} \sqrt{(h_x^2 \cdot h_y^2)}}{\sqrt{e_x^2 \cdot e_y^2}}$$

where  $h_x^2$  and  $h_y^2$  are heritabilities of x and y traits respectively.

$$e_x^2 = (1-h_x^2)$$

$$\text{and } e_y^2 = (1-h_y^2)$$

CHAPTER V  
R E S U L T S

The data were collected from Military dairy Farms in India on pure Sahiwal and crossbred cows of Sahiwal-Friesian cross. The crossbred animals <sup>were</sup> classified into eight genetic groups (grades) as detailed under materials. The pure Sahiwal cattle were present only at Ambala, Lucknow and Meerut. A frequency distribution of animals over farms was made. Meerut had the largest number of animals both pure Sahiwal and crossbreds combined. Jabalpur had largest number of crossbreds only. A similar distribution over various genetic groups showed that records were available on 400 animals each of pure Sahiwal,  $3/8$  and  $1/4$  Friesian animals. The records for  $1/8$ ,  $1/2$ ,  $5/8$  and  $3/4$  Friesian animals were available only on 140-180 individuals. Lowest number of animals were in  $7/8$  Friesian group (35) and the Friesian group (60).

The frequency distribution for 300-day milk yield and body weight at calving were plotted for each genetic group. The distributions were approximately normal. The data were analysed to assess the central tendency and dispersion of each trait. The averages and their standard errors were calculated for each character at each farm within a grade.

### 300-day Milk Yield

Table 1 (a-o) details the averages for 300-day lactation yields (First through Fifth) with their standard errors and percentage coefficients of variation, within genetic group for each farm.

Sahiwal : Sahiwal cows at Ambala were high milk yielders for all the five lactations. The cows at Meerut were the lowest producers upto four lactations. The average of fifth lactation at Meerut exceeded that of Lucknow. A comparative study of the five lactations for each farm was made

Table 1a Averages of 300-day First Lactation Yield, Standard Errors, Coefficients of Variations (%) for Grades within Farms

Farm	Sehwal	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Friesian
Ambela	1	111	50	86	15	16	8	1	4
	2	1678.52	1752.52	1823.90	1884.53	2029.06	2280.25	1496.0	1862.25
	3	40.82	74.57	55.55	96.74	91.59	189.28	-	290.84
	4	25.62	30.45	28.24	19.83	18.06	23.48	-	29.64
Dehradun	1	-	11	66	68	15	32	9	17
	2	-	1713.64	1567.15	1807.51	2350.62	2174.25	2063.67	2149.41
	3	-	148.75	57.71	76.37	157.72	105.36	185.07	131.72
	4	-	28.78	29.92	74.84	24.19	27.41	26.90	25.27
Jabalpur	1	-	32	75	31	18	35	8	14
	2	-	1660.61	1758.75	2025.96	2575.77	2128.31	1853.0	2134.21
	3	-	89.80	53.30	50.48	107.0	95.75	166.68	144.46
	4	-	30.59	26.25	29.27	25.08	26.62	25.44	25.33
Jullundur	1	-	24	58	18	29	24	4	2
	2	-	1740.46	1806.29	1932.44	1848.28	2168.0	2336.0	2613.0
	3	-	108.65	58.37	61.13	119.51	89.49	249.18	161.22
	4	-	30.58	24.61	23.88	27.43	20.22	21.33	8.73
Lucknow	1	104	17	7	4	16	6	1	1
	2	1618.85	1819.29	1693.86	2221.75	2037.0	1802.33	1675.0	3180.0
	3	37.92	123.07	92.60	193.65	176.65	127.75	-	-
	4	23.39	27.89	14.46	17.43	34.69	17.36	-	-
Meerut	1	188	25	59	29	52.00	22	9	17
	2	1537.85	1695.44	1781.51	2028.21	1998.81	2253.64	1946.78	2890.65
	3	32.88	82.87	59.70	102.24	59.06	119.19	97.26	132.63
	4	23.39	24.44	25.74	27.15	21.31	24.81	14.99	18.92
Mhow	1	-	15	43	5	11	16	1	-
	2	-	1912.20	1971.44	2286.80	1955.45	2017.19	2288.00	-
	3	-	154.37	72.75	415.10	126.88	113.18	-	-
	4	-	31.27	24.20	40.59	21.52	23.43	-	-

1. No. of observations      2. Average (Kg.)  
 3. Standard Error (Kg.)      4. Coefficient of Variations (%)

Table 1b Average of 300-day Second Lactation Yield, Standard Errors, Coefficients of Variation (%) for Grades within Farms

Farm	Sahival	1/8	1/4	3/8	1/2	5/8	5/4	7/8	Friesian	
Ambala	1	106	29	67	40	14	4	1	4	
	2	1920.66	2049.17	2055.94	2151.03	2024.71	2471.75	2870.20	2176.00	2615.25
	3	52.04	106.15	68.60	81.97	171.14	441.81	279.96	-	230.54
	4	27.89	27.90	27.61	24.10	31.62	35.75	21.81	-	17.63
Dehradun	1	-	5	48	34	62	5	20	9	16
	2	-	1962.60	1873.48	2251.88	2195.61	3390.20	2568.15	3097.00	2092.44
	3	-	215.01	69.32	115.53	83.00	187.50	175.11	181.71	180.53
	4	-	24.50	25.65	30.18	29.77	12.37	30.49	22.74	34.51
Jabalpur	1	-	14	60	121	29	17	30	8	12
	2	-	1917.14	1995.45	2395.61	2595.86	2372.06	2495.87	2228.50	2540.00
	3	-	149.17	72.71	63.45	157.42	131.23	131.84	249.55	185.92
	4	-	29.11	23.22	29.25	32.66	22.81	20.93	31.67	25.26
Jullundur	1	-	8	45	52	16	5	6	2	2
	2	-	1852.75	1919.76	2062.19	2126.94	2614.40	2260.00	3146.50	3325.50
	3	-	186.07	98.59	91.51	165.27	106.96	205.77	173.60	855.25
	4	-	23.41	33.07	32.00	30.23	9.15	22.30	7.80	36.37
Lucknow	1	77	12	4	10	1	15	4	1	1
	2	1326.74	2169.42	2166.75	2486.00	2203.00	2300.73	2512.50	1786.00	2146.00
	3	68.10	177.88	450.88	304.45	-	179.21	373.90	-	-
	4	32.71	23.40	39.78	39.04	-	30.17	29.76	-	-
Meerut	1	118	12	50	62	13	34	14	6	14
	2	1345.35	2032.42	2139.76	2106.53	2099.08	2410.71	2544.29	2074.17	3351.57
	3	51.48	147.48	100.59	93.84	208.25	106.41	129.11	138.78	290.78
	4	50.31	25.14	33.24	35.08	35.75	25.74	13.99	16.38	32.46
Mhow	1	-	10	33	45	3	4	9	-	-
	2	-	2253.30	2267.85	2535.02	2827.67	2655.75	2740.44	-	-
	3	-	221.61	136.99	115.48	377.47	200.66	134.44	-	-
	4	-	31.10	34.70	29.29	23.12	15.23	14.72	-	-

1. No. of observations      2. Average (Kg.)  
 3. Standard Error (Kg.)      4. Coefficient of Variation (%)

Table 1c Average of 300-day Third Lactation Yield Standard Errors,  
Coefficients of variation (%) for Grades within Farms

Farm	Sahiwal		1/4		5/8		1/2		5/8		3/4		7/8		Friesian
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
Amabala	98	17	47	54	13	1	3	1	2	1	3	1	2	2	
	2001.2	2017.18	2250.45	2614.88	2128.00	1877.00	2095.61	1925.00	2762.50						
	56.52	197.18	102.95	117.59	165.59	-	167.79	-	406.94						
	27.96	40.30	31.36	26.22	28.06	-	13.88	-	20.83						
Dehradun	-	3	53	27	54	4	17	8	16						
	1936	1936.67	1946.09	2482.07	2543.94	4054.75	2689.59	2768.88	2559.19						
	-	174.26	94.18	123.53	91.29	614.90	188.54	323.69	176.49						
	-	15.59	27.80	25.92	28.62	30.48	28.90	33.07	27.58						
Jabalpur	-	9	40	107	25	12	24	8	8						
	-	2293.33	2051.23	2371.58	2697.72	2530.92	2577.79	2828.50	2809.75						
	-	192.16	63.95	70.09	191.32	236.11	135.10	293.70	286.69						
Jullundur	-	25.10	27.42	30.57	35.46	33.32	25.68	29.36	28.86						
	-	4	51	44	14	1	-	1	2						
	-	2349.75	1902.84	2172.59	2118.29	1095.00	-	3029.00	3967.50						
	-	610.71	114.41	81.07	165.23	-	-	-	496.74						
Lucknow	-	51.98	33.48	24.75	29.19	-	-	-	17.71						
	53	9	5	4	-	11	3	1	-						
	1895.85	2341.11	2175.00	2228.50	-	2629.91	2745.33	3231.00	-						
	62.26	171.91	558.97	420.03	-	207.35	399.62	-	-						
	23.91	22.03	44.51	36.58	-	26.15	25.21	-	-						
Meerut	86	9	37	46	7	17	9	5	8						
	1872.27	2232.22	2206.27	2255.96	2504.57	2627.65	2562.56	2293.00	3969.58						
	63.28	198.28	100.59	132.01	384.52	165.28	180.17	359.03	214.02						
	31.34	26.65	27.73	39.69	40.62	25.93	21.09	35.01	15.25						
Mkov	-	5	23	40	3	1	3	-	-						
	-	1991.00	2693.83	2483.05	2991.67	2612.00	2618.67	-	-						
	-	175.13	160.60	125.92	182.79	-	434.06	-	-						
	-	19.67	28.59	32.07	10.58	-	28.71	-	-						

1. No. of observations      2. Average (Kg.)  
3. Standard Error (Kg.)    4. Coefficient of Variation (%)

Table 1d Average of 300-day Fourth Lactation Yield, Standard Errors, Coefficients of variation (%) for Grades within Farms

Farm	Sahiwal	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Friesian
Ambala	1	78	8	32	34	12	1	1	2
	2	2164.29	2475.75	2583.69	2497.00	2559.00	1540.00	2515.00	3395.00
	3	56.52	113.35	114.90	120.51	245.21	-	-	57.93
	4	27.96	12.98	27.27	28.14	33.19	-	-	2.42
Dehradun	1	-	2	19	23	45	4	8	12
	2	-	2266.00	1953.95	1404.48	2249.97	3856.50	2687.63	2519.00
	3	-	258.80	97.40	130.92	104.43	532.45	248.31	183.86
	4	-	16.15	21.95	26.11	31.14	28.80	26.13	26.67
Jabalpur	1	-	8	27	77	24	11	5	8
	2	-	1337.63	2169.41	2416.49	2813.85	2695.73	2736.00	3177.13
	3	-	279.17	156.29	88.67	169.99	239.34	284.82	291.59
	4	-	41.33	37.43	32.20	29.42	29.45	23.28	25.96
Jullundur	1	-	4	21	37	11	-	1	2
	2	-	2471.50	2126.71	2285.41	2424.91	-	3022.00	4115.50
	3	-	602.49	154.24	122.39	135.47	-	-	748.47
	4	-	48.76	35.24	32.57	18.53	-	-	25.72
Lucknow	1	33	4	3	5	-	10	1	1
	2	1983.30	2547.00	2701.67	2859.33	-	2573.40	3357.00	1650.00
	3	77.10	90.39	478.49	385.22	-	209.23	-	-
	4	22.28	7.10	30.63	23.33	-	25.71	-	-
Meerut	1	68	7	26	55	4	13	5	5
	2	1950.93	2160.00	2138.53	2308.37	2295.75	2746.85	2334.00	3617.40
	3	73.35	250.17	148.33	123.91	193.46	187.50	289.81	542.00
	4	32.27	30.64	34.56	31.76	16.85	24.61	25.77	33.50
Mhow	1	-	1	11	33	3	1	-	-
	2	-	1973.00	2173.64	2510.09	2583.33	2521.00	3000.50	-
	3	-	-	242.91	142.70	442.72	-	74.80	-
	4	-	-	36.98	32.66	29.63	-	3.52	-

1. No. of observations  
 2. Standard Error (Kg.)  
 2. Average (Kg.)  
 4. Coefficient of Variation (%)

Table 1a Average of 300-day Fifth Lactation Yield, Standard Errors, Coefficients of variation (%) for Grades within Farms

Farm	Sahiwal	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Friesian
Ambala	1	57	4	23	10	1	1	1	2
	2	2171.75	2465.00	2137.83	2582.10	2496.80	3067.00	1620.00	2571.00
	3	85.66	256.11	115.31	153.31	211.64	-	-	149.91
	4	29.78	20.78	25.87	27.80	26.81	-	-	8.25
Dehradun	1	-	-	6	21	39	14	6	11
	2	-	-	1331.17	2500.57	2141.16	4040.00	2645.67	2648.91
	3	-	-	231.45	145.09	115.82	517.38	285.00	225.48
	4	-	-	30.96	29.59	33.34	22.18	26.56	23.25
Jabalpur	1	-	5	14	54	19	17	3	5
	2	-	1992.60	2143.86	2421.61	2679.05	2930.44	3532.00	2969.80
	3	-	134.71	165.64	102.57	221.59	254.50	346.37	589.87
	4	-	15.12	23.87	32.12	36.05	26.03	16.99	44.41
Jullundur	1	-	3	14	31	8	-	1	2
	2	-	1640.35	2135.64	2183.52	2551.00	-	2831.00	4985.00
	3	-	443.90	211.05	116.81	205.55	-	-	355.88
	4	-	46.87	36.97	29.72	24.70	-	-	9.53
Lucknow	1	13	-	1	3	-	2	1	1
	2	1821.67	-	1395.00	2693.33	-	3179.89	3750.00	1182.00
	3	105.93	-	-	321.23	-	80.96	-	-
	4	24.67	-	-	20.64	-	3.43	-	-
Meerut	1	50	4	20	24	5	7	5	3
	2	1982.80	2239.25	2172.70	2243.71	2418.67	2806.20	2857.71	2334.00
	3	95.07	353.11	198.00	170.33	333.84	291.76	275.35	390.54
	4	35.19	31.53	33.96	37.11	23.91	23.25	25.49	36.94
Mhow	1	-	-	5	24	3	2	-	-
	2	-	-	1962.67	2576.21	3514.00	2570.00	3234.50	-
	3	-	-	169.79	184.33	359.84	-	220.26	-
	4	-	-	21.20	35.05	17.74	-	9.63	-

1. No. of observations  
 2. Average (kg.)  
 3. Standard Error (kg.)  
 4. Coefficient of Variation (%)

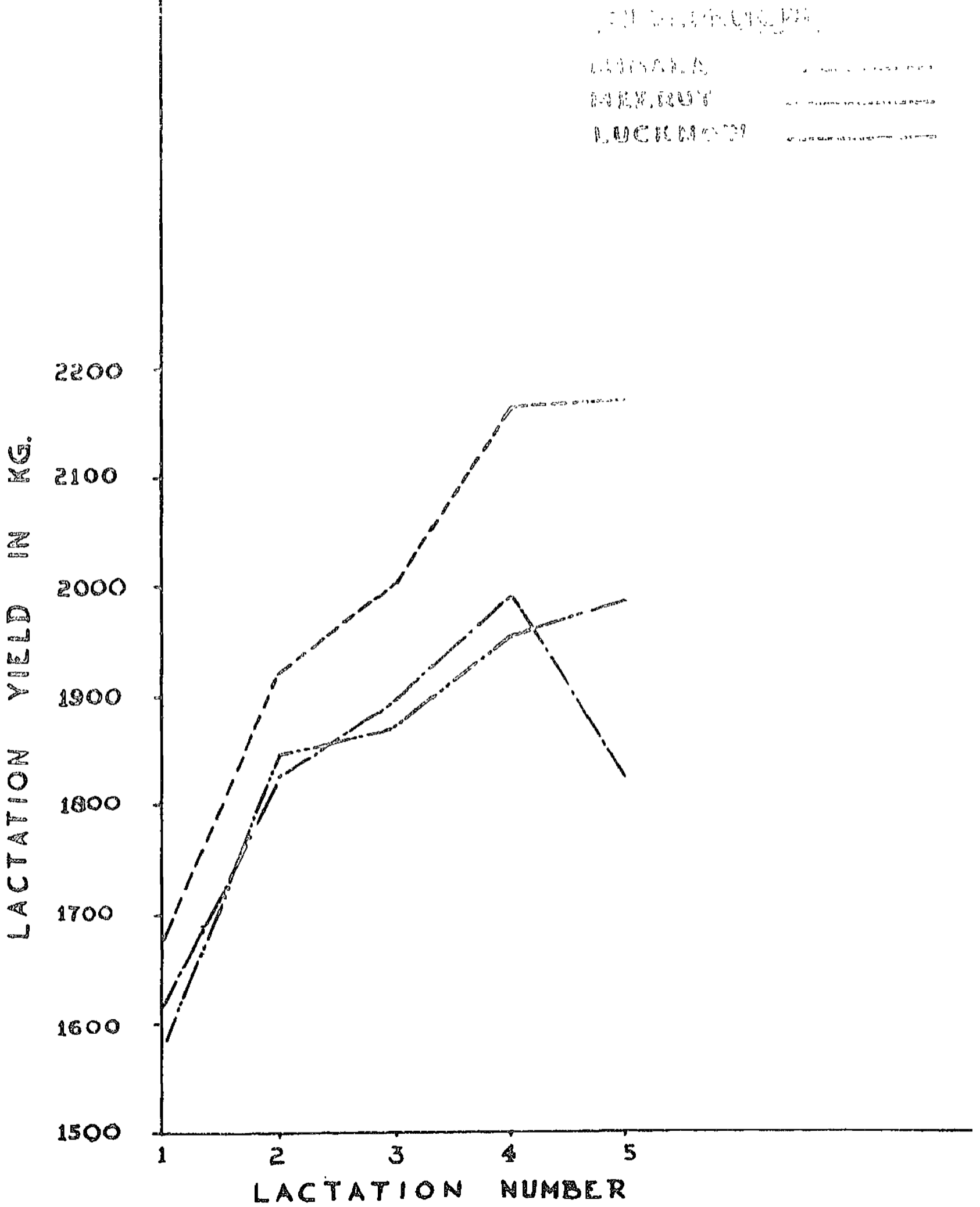


FIG.1.1

and is detailed in Figure 1.1. A continuous increase in milk yield in the five lactations was observed at Ambala and Meerut. At Lucknow the fourth lactation had the highest production, followed by a sharp decline in the fifth lactation. Coefficient of variability was of the same magnitude in all the lactations at Ambala. At other two farms the coefficient of variation showed wider range of differences. At Lucknow coefficient of variability of second lactation was higher (32.7%) than that of the first lactation (23.9%) and the third lactation (23.9%). The highest first lactation and fifth lactation averages of milk yield of Sahiwal cows were  $1678.32 \pm 40.92$  kg. and  $2171.75 \pm 85.66$  kg. respectively.

Crossbreds : Comparison of each lactation of 1/8 genetic group over all farms indicated that the animals at Mhow had the highest first and second lactation averages. The third, fourth and fifth lactation yields were highest at Jullundur, Lucknow and Ambala respectively. The third lactation averages of animals at Jullundur and Lucknow were  $2349.75 \pm 610.71$  kg. and  $2341.11 \pm 171.91$  kg. respectively. Their coefficients of variability were 51.98 per cent and 22.03 per cent. The third lactation average of 1/8 Friesian animals at Lucknow was highest when compared to other farms. Figure 1.2 shows the comparison of five lactations over the seven locations. Increase in milk yield upto third lactation was observed at Jullundur, Jabalpur, Lucknow and Meerut. A sharp decline was observed in the milk yield of the third lactation at Mhow and considerably smaller decline at Ambala and Dehradun.

The animals with 1/4 Friesian inheritance at Mhow had the highest first, second and third lactation averages. The animals at Lucknow and Meerut had the highest fourth and fifth lactation averages. A lactation

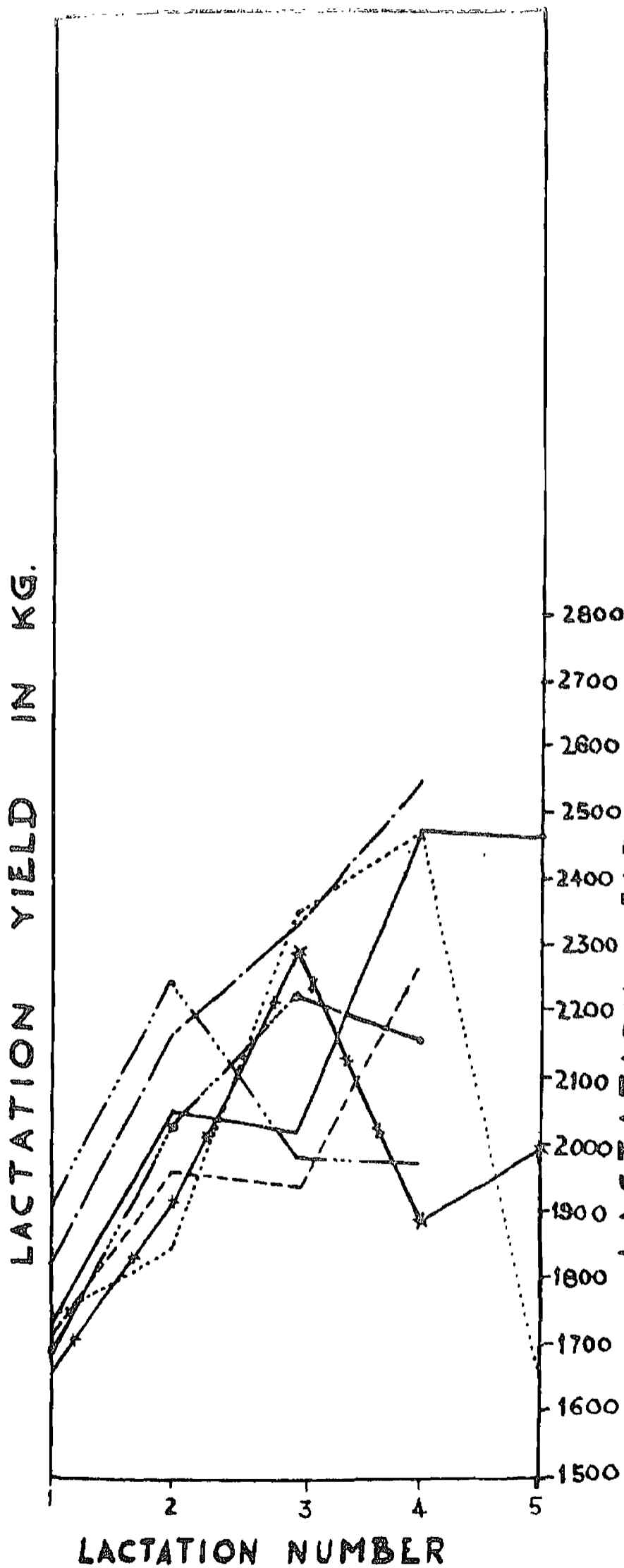


FIG 1.2

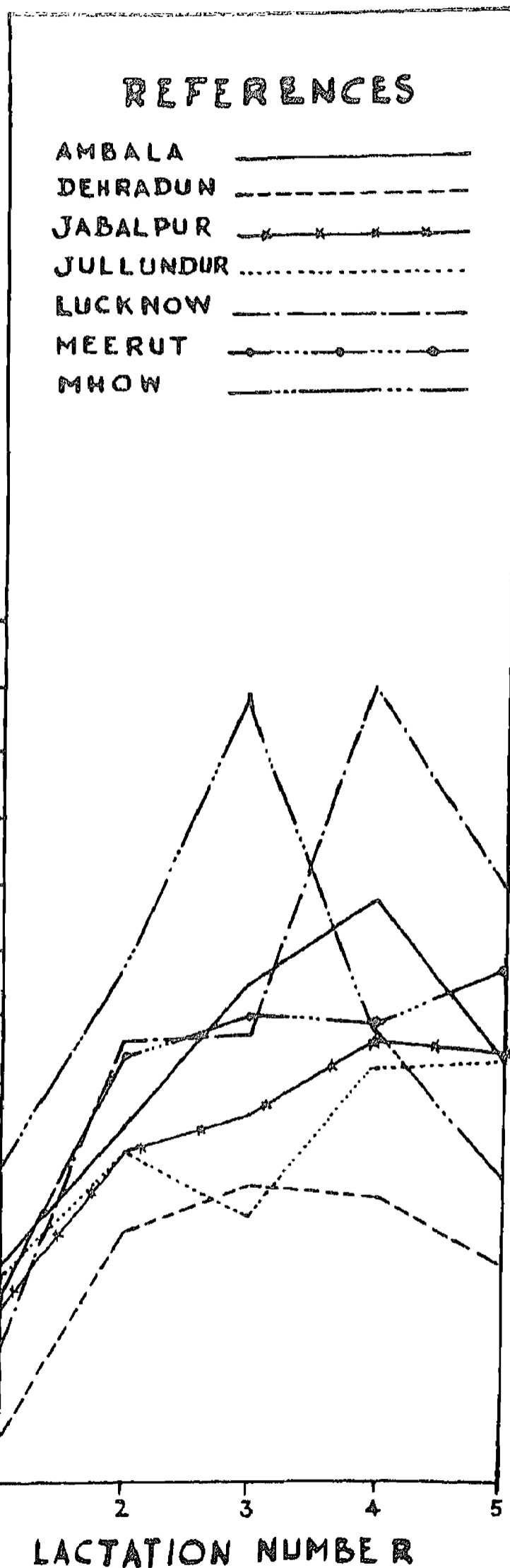


FIG 1.3

wise comparison showed third lactation to be high at Dehradun and Mhow. The fifth lactation average was highest in animals stationed at Meerut. At all other farms the fourth lactation average was highest.

The highest first lactation average in the animals with 3/8 Friesian inheritance was  $2025.96 \pm 50.48$  kg. recorded at Jabalpur. Animals at Mhow had the highest second lactation average ( $2585.02 \pm 115.48$  kg.) The highest third lactation was recorded at Ambala ( $2614.88 \pm 117.59$  kg.). At Lucknow the fourth and fifth lactations were highest. The magnitude of these lactations was  $2859.33 \pm 385.22$  kg. and  $2696.33 \pm 321.23$  respectively. A decline from second to third lactation was observed (Fig. 1.3) in animals at Lucknow but they showed the maximum yield in the fourth lactation. Fifth lactation was the highest lactation at Dehradun and Jabalpur farms. The coefficients of variation at different farms were of different magnitudes.

Among various farms Lucknow had minimum number of halfbreds and none with complete records of more than two lactations. At Mhow five animals had completed first lactation and three the subsequent lactations. Highest second, third and fifth lactation averages were observed in animals at Mhow. Jabalpur had the largest number of animals with complete five lactations. The averages of lactation yields of animals at Jabalpur were  $2375.77 \pm 107.00$  kg. (First),  $2595.86 \pm 157.42$  kg. (Second),  $2697.72 \pm 191.52$  kg. (Third),  $2813.83 \pm 168.99$  kg. (Fourth) and  $2679.05 \pm 221.59$  kg. (Fifth). A lactation wise comparison of 1/2 Friesian animals revealed that fourth was the model lactation at which the peak was attained. At Dehradun and Meerut third lactation had attained the highest average. Animals at Mhow attained peak at the fifth lactation. The third and the

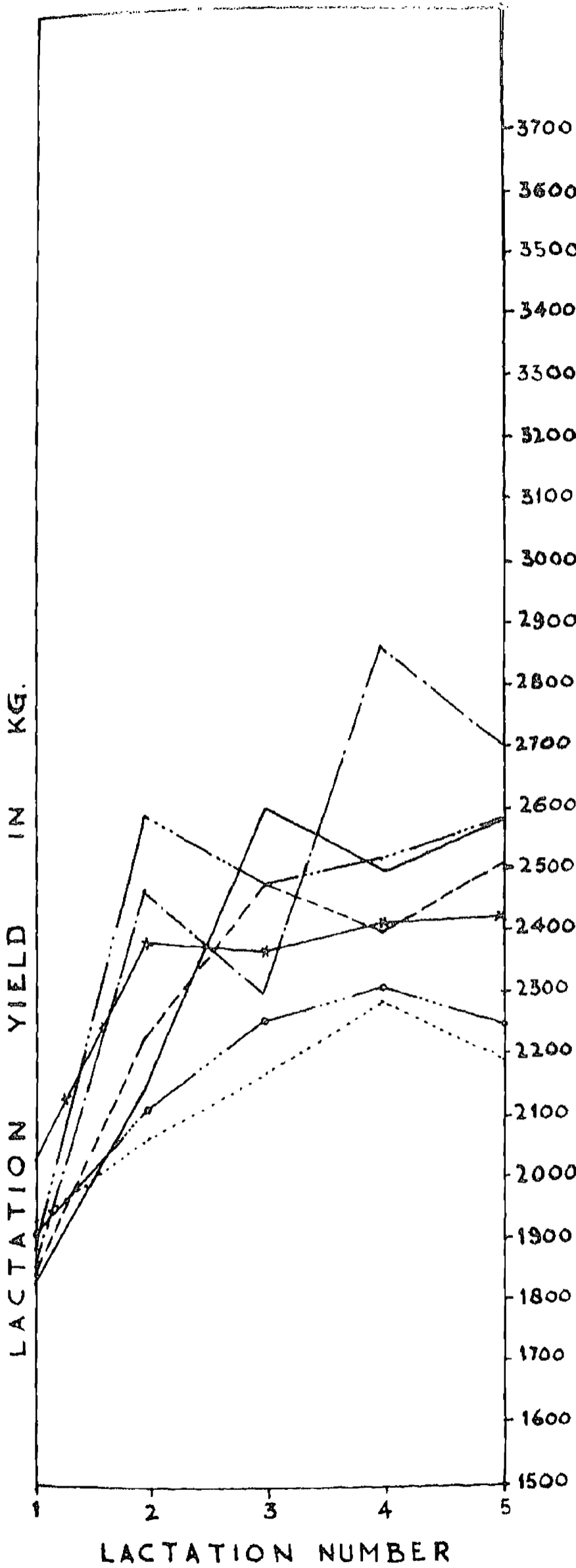


FIG. 1.4

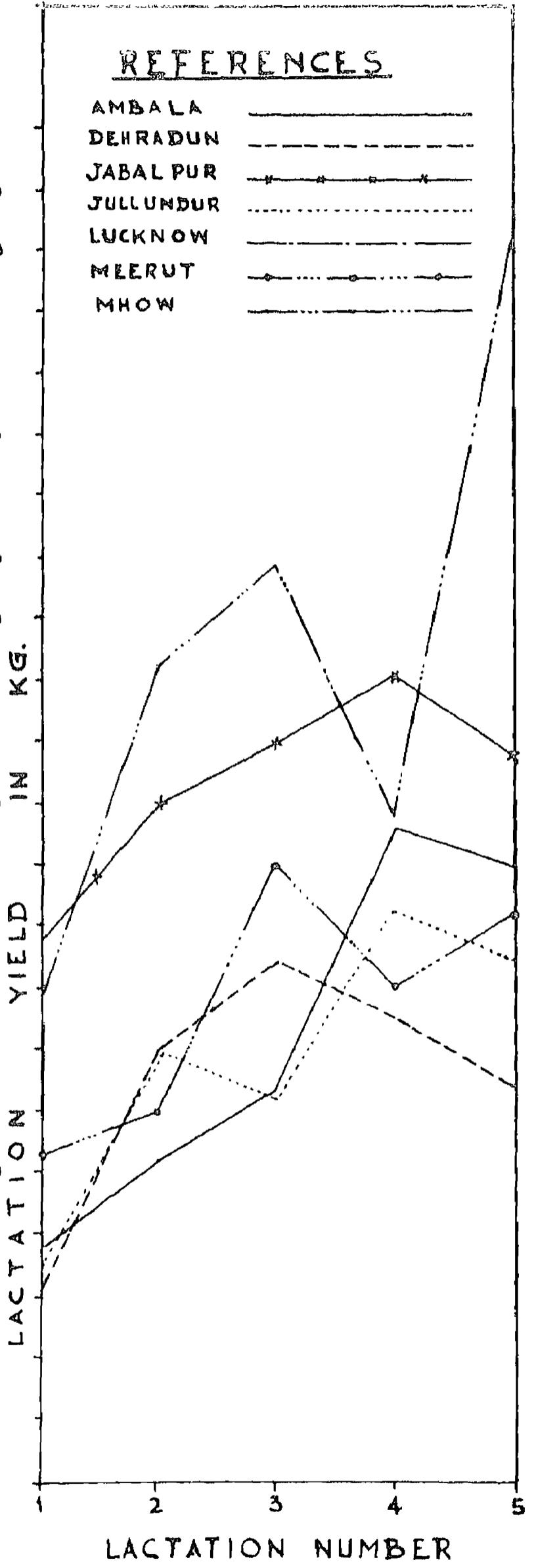


FIG. 1.5

### REFERENCES

- AMBALA \_\_\_\_\_
- DEHRADUN \_\_\_\_\_
- JABALPUR \_\_\_\_\_
- JULLUNDUR \_\_\_\_\_
- LUCKNOW \_\_\_\_\_
- MEERUT \_\_\_\_\_
- MHOW \_\_\_\_\_

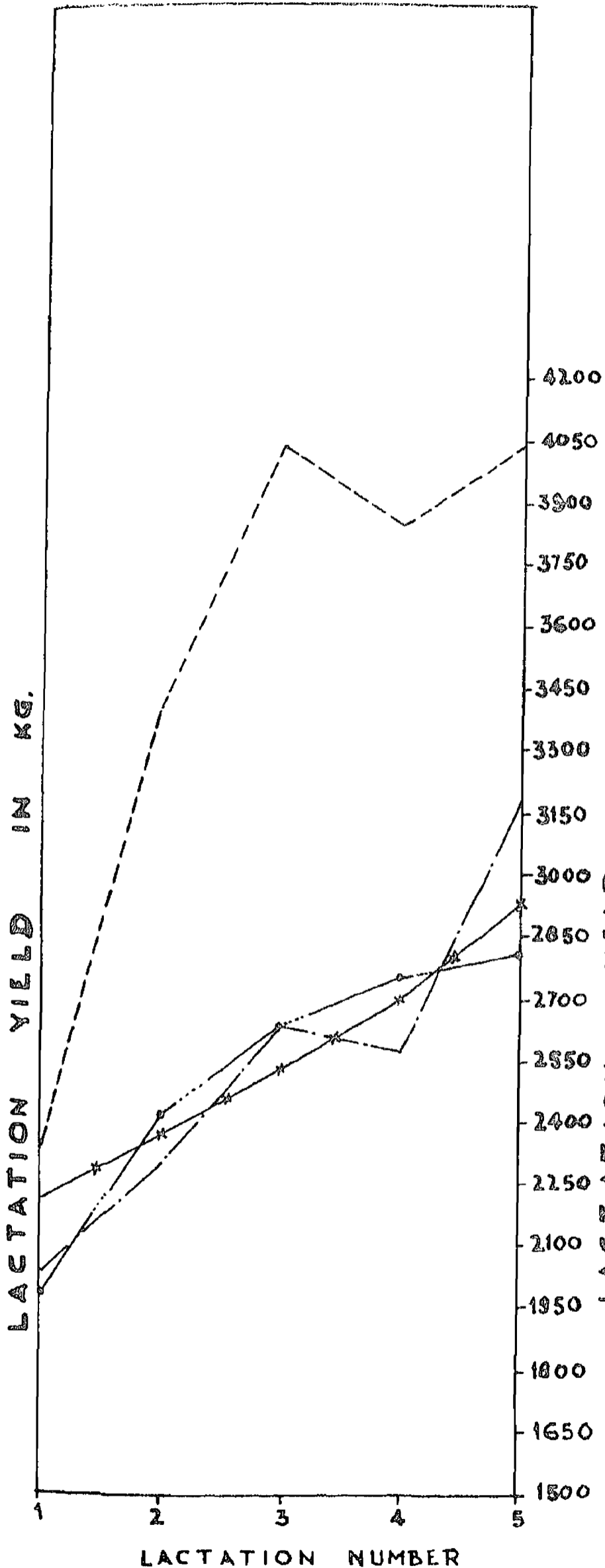


FIG. 1.6

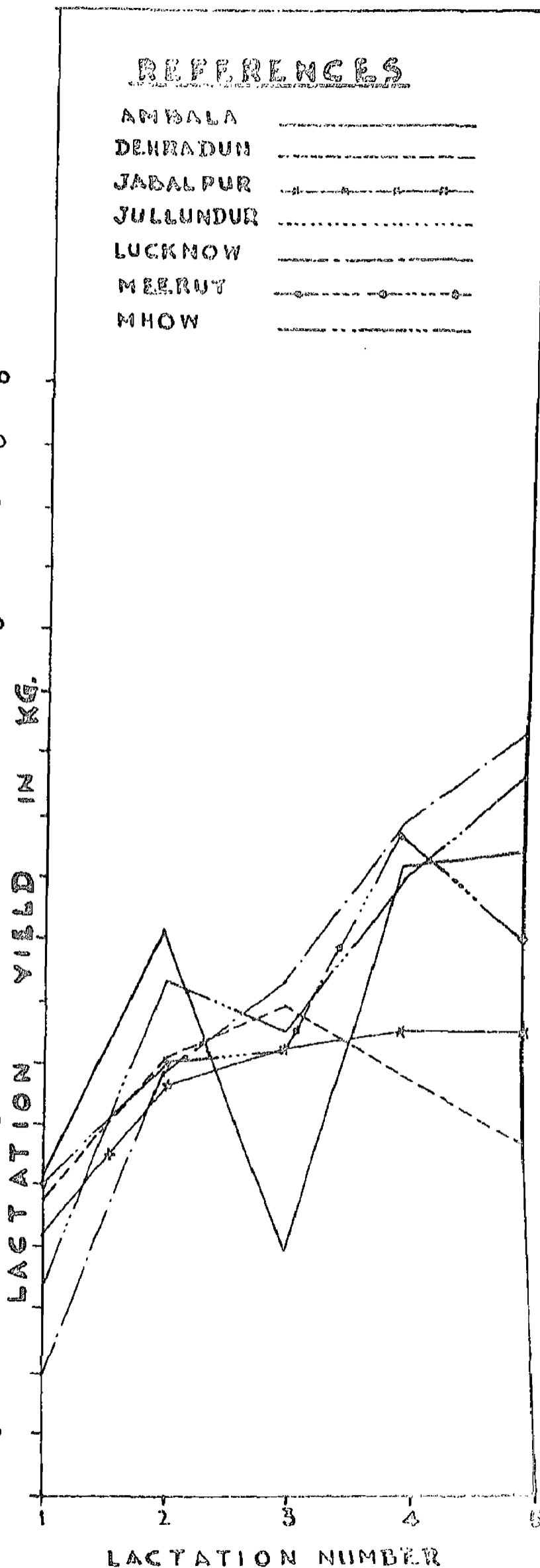


FIG. 1.7

There was a small number of animals of 7/8 Friesian inheritance, only one animal each at Ambala, Lucknow and Mhow. Among the four animals at Jullundur, only one had completed all the five lactations. The averages of first two lactations were highest at Dehradun while yield of other lactations was highest at Jabalpur. The highest average milk yield of five lactations in order are 2035.67  $\pm$  185.07 kg. (Dehradun), 3097.00  $\pm$  181.71 kg. (Dehradun), 2829.50  $\pm$  293.70 kg. (Jabalpur), 2756.00  $\pm$  264.82 kg. (Jabalpur), 3552.00  $\pm$  346.57 kg. (Jabalpur). The third lactation had the largest standard error and coefficient of variation at all farms. Figure 1.8 showed the plot of five lactations against yield for each farm. It showed that third lactation yield attained peak at Dehradun, fourth at Meerut, and fifth at Jabalpur. From these results Jabalpur may be considered as better suited for animals with 7/8 Friesian inheritance, as compared to other farms.

The Friesian group of animals at Meerut had the highest first, second and third lactation averages, fourth and fifth lactation averages of Friesian animals at Jullundur should be considered as highest when compared to those at other farms. Highest averages of five lactations in order of lactation were 2890.65  $\pm$  152.65 kg. (Meerut), 3351.57  $\pm$  290.78 kg. (Meerut), 3969.38  $\pm$  214.02 kg. (Meerut), 4115.50  $\pm$  748.47 kg. (Jullundur), 4983.00  $\pm$  835.88 kg. (Jullundur). Figure 1.9 shows the comparison of lactation for each farm. Fifth lactation had the highest yield at Dehradun, Jullundur and Meerut. The fourth lactation was highest at Ambala and Jabalpur.

#### Weight at Calving

A study of various weights at calving was made in order to adjudge the growth of the animals. The table 1 (f-j) gives the averages

REFERENCES

- AMBALA
- DEHRADUN
- JABALPUR
- JULLUNDUR
- LUCKNOW
- MEERUT
- MHOW

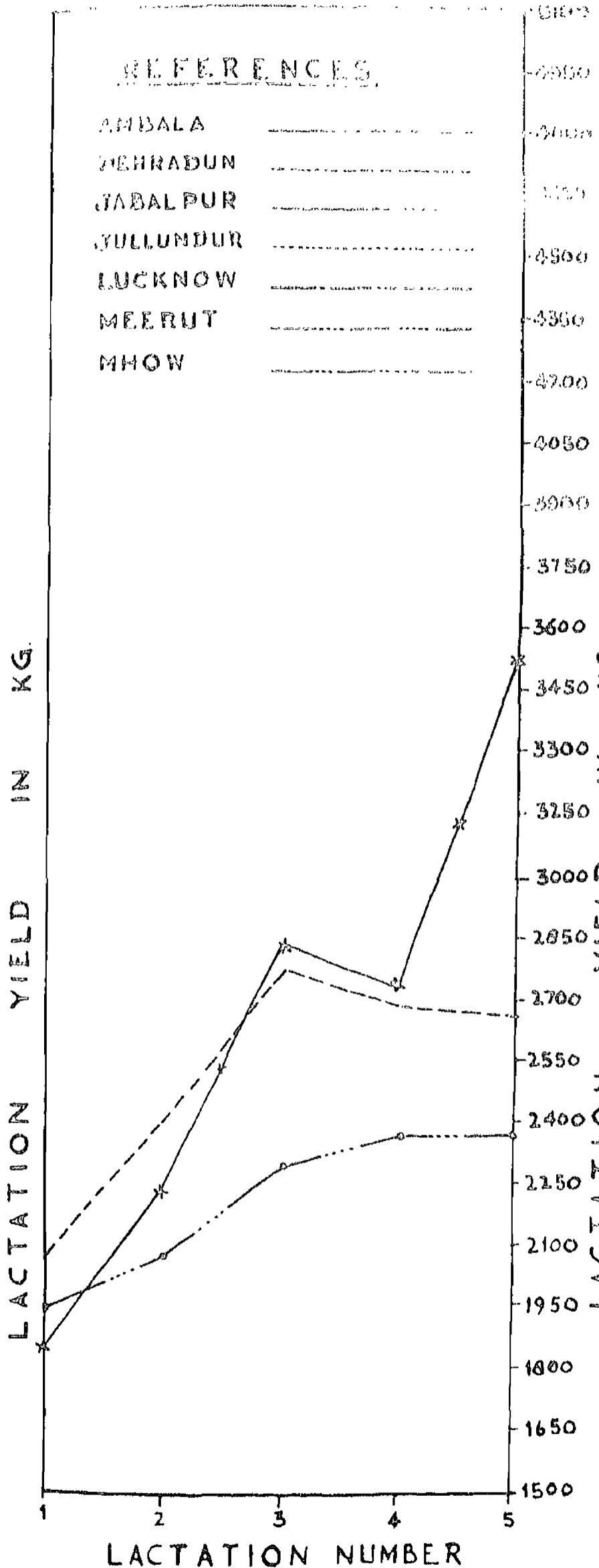


FIG. 1.8

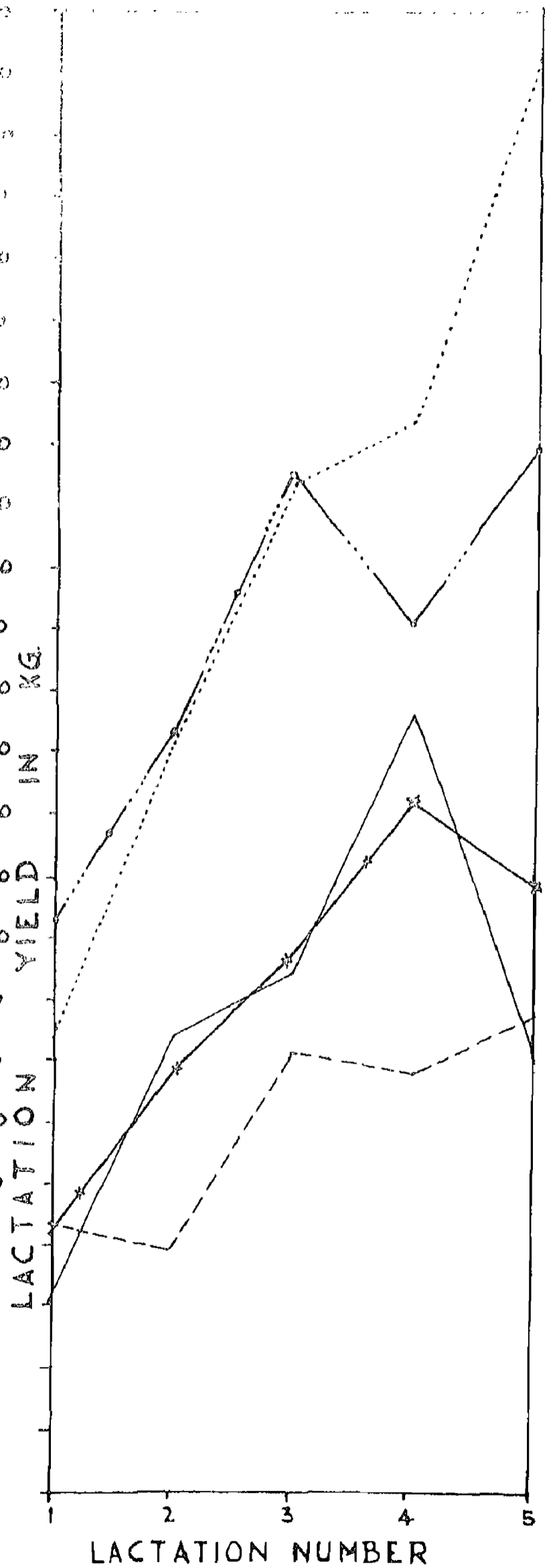


FIG. 1.9

of weights at calving from first through fifth calving, their standard errors and coefficients of variability.

Sahiwal : Sahiwal heifers at Ambala were heavier than their counterparts at Lucknow and Meerut. But they did not grow at the same rate as the heifers at Lucknow. Animals stationed at Lucknow attained more weight at subsequent calvings than the animals at Ambala.

Crossbreds : The animals with  $1/8$  Friesian inheritance were heaviest at Jullundur and grew at a faster rate from second calving onwards while those at Lucknow grew at a faster rate from first calving. The rate of growth declined in the later calvings. Animals at Dehradun farm showed a decline in weight at second calving which was gradually recovered in later calvings.

The animals with  $1/4$  Friesian inheritance at Mhow had a faster rate of growth. The animals at Lucknow and Meerut were heavier at first calving than those at other farms. A decline in weight was observed between second and third calvings in animals of Dehradun farm and between first and second calvings in animals of Lucknow farm.

The animals with  $3/8$  Friesian inheritance were heaviest at Ambala and Mhow. The weight of animals at Ambala increased from  $402.41 \pm 7.57$  kg. at first calving to  $437.77 \pm 9.40$  kg. at fifth calving. Those at Mhow weighed  $409.66 \pm 7.19$  kg. at first calving and were heaviest at the fourth calving weighing  $434.50 \pm 10.83$  kg. Animals at Dehradun had the lowest body weight.

The heaviest animals with  $1/2$  Friesian inheritance were at Mhow weighing between  $418.25 \pm 7.57$  kg. at first calving and  $444.50$

Table 1f Averages of Weight at First Calving, Standard Errors, Coefficients of Variation (%) for Grades within Farms

Farm	Sehwal	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Friesian
Ambala	108	55	76	56	15	16	7	1	4
	374.29	369.33	370.75	402.41	410.70	345.46	356.45	372.00	390.00
	4.14	5.37	4.38	7.57	10.81	6.77	10.58	-	16.41
	11.50	10.77	10.30	11.50	9.50	7.33	7.71	-	8.41
Dehradun	-	11	68	41	68	15	33	8	17
	-	350.46	350.46	364.00	382.70	365.51	363.61	368.83	383.65
	-	15.02	6.22	8.79	5.71	13.57	9.82	7.29	10.73
	-	14.22	15.52	15.44	12.30	13.27	15.52	5.59	11.38
Jabalpur	-	34	73	136	29	18	36	8	15
	-	343.77	353.50	383.60	397.69	368.00	367.53	365.13	349.31
	-	5.71	5.08	3.71	7.96	8.96	6.98	17.42	15.36
	-	9.69	12.10	11.33	10.78	10.35	11.40	13.49	15.85
Jullundur	-	21	53	52	17	21	14	4	2
	-	375.76	370.40	339.36	391.76	377.48	393.86	385.25	419.50
	-	8.64	6.70	6.26	8.00	9.17	13.19	21.51	1.77
	-	10.59	13.18	11.58	8.42	11.15	12.53	11.17	0.60
Lucknow	89	15	8	15	4	17	5	1	1
	369.11	366.49	394.25	378.47	392.25	381.59	376.40	331.00	339.00
	4.18	9.01	17.22	8.74	12.85	9.29	16.42	-	-
	10.68	9.51	12.56	8.94	6.55	10.04	10.94	-	-
Meerut	191	28	57	67	27	50	23	11	19
	370.53	367.00	383.29	393.07	383.77	394.12	404.00	393.09	419.74
	3.05	6.93	5.77	5.78	7.20	6.01	9.69	12.59	15.60
	11.17	9.99	11.59	12.02	9.73	10.79	11.50	10.62	16.39
Mhow	-	14	39	44	4	9	15	1	-
	-	375.93	376.92	409.63	418.25	338.00	353.53	360.00	-
	-	10.05	6.22	7.19	7.57	9.63	12.41	-	-
	-	10.01	10.51	11.61	3.62	8.59	13.40	-	-

1. No. of observations  
 2. Average (kg.)  
 3. Standard Error (kg.)  
 4. Coefficient of variation (%)

Table 1g Averages of Weight at Second Calving, Standard Errors, Coefficients of variation (%) for Grades within Farms

Farm	Sahiwal	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Friesian
Ambala	94	20	57	27	5	2	4	1	4
	577.72	391.70	332.28	412.56	421.20	402.50	373.75	408.00	581.75
	4.25	9.79	5.16	10.30	13.02	22.98	21.09	-	10.74
	10.85	11.18	8.22	12.98	6.91	8.07	11.14	-	5.65
	-	5	40	30	60	5	22	8	16
Dehradun	-	355.40	356.15	381.40	392.25	390.29	384.95	367.13	391.63
	-	4.43	7.10	9.19	5.14	19.29	10.73	9.58	11.06
	-	2.99	14.03	13.20	10.15	11.06	13.08	7.38	11.39
	-	26	52	103	22	13	29	8	12
Jabalpur	-	343.93	371.90	393.41	403.72	371.92	385.28	378.25	380.58
	-	5.07	5.18	3.54	8.01	8.57	6.53	17.00	12.66
	-	9.52	10.06	9.40	9.31	8.11	9.12	12.71	11.52
	-	4	21	31	10	-	1	1	2
Jullundur	-	333.75	392.00	405.16	409.90	-	331.00	390.00	444.50
	-	17.38	9.64	7.43	10.71	-	-	-	6.72
	-	9.22	11.27	10.28	8.26	-	-	-	2.14
	56	3	5	7	-	10	4	1	1
Lucknow	387.70	407.00	349.40	379.86	-	401.30	402.00	352.00	404.00
	6.58	10.03	21.07	11.38	-	8.42	26.51	-	-
	12.71	4.28	13.49	7.91	-	6.63	13.19	-	-
	107	12	39	56	11	18	10	6	13
Meerut	369.93	372.17	384.65	395.83	385.72	407.39	435.50	414.00	457.69
	3.78	11.79	7.31	5.72	9.50	11.96	13.39	9.95	15.18
	10.64	10.98	11.83	10.82	8.17	12.50	9.72	5.89	11.96
	-	4	20	38	4	1	4	-	-
Mhow	-	407.15	398.60	412.15	453.75	363.00	421.00	-	-
	-	19.32	10.94	7.91	9.85	-	11.26	-	-
	-	9.49	12.28	11.90	4.53	-	5.35	-	-

1. No. of observations  
 2. Average (Kg.)  
 3. Standard Error (Kg.)  
 4. Coefficient of variation (%)

Table 1h Averages of Weight at Third Calving, Standard Errors, Coefficients of variation (%) for Grades within Farms

Farm	Sahiwal		1/4		5/8		1/2		5/8		3/4		7/8		Friesian		
	1/8	1/4	1/4	5/8	5/8	1/2	1/2	5/8	5/8	3/4	3/4	7/8	7/8	7/8	7/8	Friesian	
Ambala	1	79	11	28	25	8	8	4	3	391.00	391.00	391.00	391.00	391.00	391.00	391.00	391.00
	2	384.62	402.0	399.75	427.57	427.57	420.57	420.57	420.57	420.57	420.57	420.57	420.57	420.57	420.57	420.57	420.57
	3	4.26	13.76	7.32	9.25	9.25	11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67
	4	9.83	11.38	9.7	10.80	10.80	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85
Dehradun	1	-	3	33	28	56	4	4	14	16	16	16	16	16	16	16	16
	2	-	343.34	350.37	398.42	398.42	400.12	400.12	400.12	400.12	400.12	400.12	400.12	400.12	400.12	400.12	400.12
	3	-	17.85	7.88	9.5	9.5	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17	5.17
	4	-	9.01	12.95	12.16	12.16	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67	9.67
Jabalpur	1	-	8	30	83	19	14	14	14	22	22	22	22	22	22	22	22
	2	-	363.13	390.73	404.14	404.14	412.78	412.78	412.78	412.78	412.78	412.78	412.78	412.78	412.78	412.78	412.78
	3	-	11.65	7.51	4.17	8.92	8.92	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67
	4	-	8.93	10.53	9.41	9.41	9.42	9.42	9.42	9.42	9.42	9.42	9.42	9.42	9.42	9.42	9.42
Jullundur	1	-	3	18	26	10	10	10	10	1	1	1	1	1	1	1	1
	2	-	400.67	413.11	418.88	418.88	408.4	408.4	408.4	408.4	408.4	408.4	408.4	408.4	408.4	408.4	408.4
	3	-	16.31	8.72	6.61	8.23	8.23	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67
	4	-	7.05	8.96	8.05	8.41	8.41	6.51	6.51	6.51	6.51	6.51	6.51	6.51	6.51	6.51	6.51
Lucknow	1	31	1	2	1	-	-	-	-	3	3	3	3	3	3	3	3
	2	389.71	418.0	392.0	427.0	427.0	-	-	-	398.0	398.0	414.67	414.67	414.67	414.67	414.67	414.67
	3	9.00	-	8.49	-	-	-	-	-	6.0	6.0	14.95	14.95	14.95	14.95	14.95	14.95
	4	12.87	-	3.06	-	-	-	-	-	4.52	4.52	6.25	6.25	6.25	6.25	6.25	6.25
Meerut	1	75	6	24	43	6	13	13	13	9	9	5	5	5	5	5	5
	2	370.39	371.12	366.33	404.88	404.88	392.66	392.66	392.66	420.69	420.69	439.56	439.56	439.56	439.56	439.56	439.56
	3	4.56	9.11	9.23	7.37	7.37	8.32	8.32	8.32	13.85	13.85	13.04	13.04	13.04	13.04	13.04	13.04
	4	10.65	6.94	11.70	11.94	11.94	5.19	5.19	5.19	11.96	11.96	8.90	8.90	8.90	8.90	8.90	8.90
Mhow	1	-	1	10	28	4	4	4	4	2	2	2	2	2	2	2	2
	2	-	370.00	413.50	423.50	423.50	441.25	441.25	441.25	413.50	413.50	413.50	413.50	413.50	413.50	413.50	413.50
	3	-	-	11.40	9.48	9.48	8.09	8.09	8.09	6.01	6.01	6.01	6.01	6.01	6.01	6.01	6.01
	4	-	-	8.66	11.84	11.84	2.76	2.76	2.76	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06

1. No. of observations  
 2. Average (Kg.)  
 3. Standard Error (Kg.)  
 4. Coefficient of variation (%)

Table 11 Averages of Weight at Fourth Calving, Standard Errors  
Coefficients of variation (%) for Grades within Farms

Farm	Sahival	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Friesian
Ambala	59	1	20	22	8	-	1	1	2
	387.36	480.00	414.80	426.86	428.75	-	460.00	413.00	447.00
	4.54	-	6.5	9.88	8.94	-	-	-	43.13
	9.00	-	7.00	10.85	5.9	-	-	-	13.65
Dehradun	-	3	20	18	42	3	14	7	13
	-	361.67	362.25	410.89	400.50	429.33	420.56	385.00	383.31
	-	20.32	9.41	10.84	6.37	22.93	11.97	12.84	8.61
	-	9.73	11.62	11.20	10.32	9.25	10.66	8.82	8.10
Jabalpur	-	2	20	55	16	12	21	4	7
	-	357.50	407.30	407.81	439.68	394.50	410.19	410.50	408.45
	-	37.12	9.05	5.01	6.29	10.47	8.60	5.94	18.84
	-	14.68	9.33	9.11	5.72	9.19	9.60	2.90	12.20
Jullundur	-	2	11	20	7	-	-	1	2
	-	423.50	403.27	419.30	439.00	-	-	398.00	481.50
	-	1.76	11.76	8.69	19.55	-	-	-	12.37
	-	0.58	9.55	9.26	11.78	-	-	-	3.63
Lucknow	18	1	2	1	-	10	2	1	-
	414.78	428.00	419.00	400.00	-	417.10	453.00	363.00	-
	12.77	-	7.07	-	-	14.06	1.41	-	-
	13.06	-	2.39	-	-	10.63	0.44	-	-
Meerut	59	4	16	23	3	8	8	5	4
	332.36	395.50	397.81	402.08	353.00	450.88	444.13	410.40	447.50
	4.51	16.11	12.90	10.83	10.82	16.97	14.93	13.92	33.17
	9.05	8.14	12.97	12.92	5.21	11.14	9.51	7.59	14.33
Mhow	-	-	4	24	4	1	2	-	-
	-	-	443.50	434.50	444.50	372.00	457.50	-	-
	-	-	15.19	10.83	16.11	-	11.67	-	-
	-	-	6.84	11.98	7.25	-	3.77	-	-

1. No. of observations  
3. Standard Error (Kg.)

2. Average (Kg.)  
4. Coefficient of variation (%)

Table 1j Averages of Weight at Fifth Calving, Standard Errors, Coefficients of variation (%) for Grades within Farms

Farm	Sahival	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Friesian
Ambala	1	47	13	17	6	-	1	1	2
	2	394.02	404.76	437.77	468.33	-	463.00	440.00	463.50
	3	5.29	7.27	9.40	13.33	-	-	-	37.83
	4	9.21	6.47	8.84	6.97	-	-	-	11.54
Dehradun	1	-	10	18	35	2	9	5	10
	2	-	410.00	392.70	410.22	399.00	408.78	401.00	389.40
	3	-	-	12.78	6.81	45.35	14.38	17.99	10.85
	4	-	-	13.69	9.82	12.53	10.55	10.03	8.84
Jabalpur	1	-	12	34	12	8	16	5	5
	2	-	420.50	418.58	436.91	427.88	424.56	418.67	419.40
	3	-	10.76	4.89	11.19	10.46	9.92	6.77	11.18
	4	-	3.88	6.80	8.87	6.91	9.34	2.80	5.96
Jullundur	1	-	10	16	5	-	-	-	2
	2	-	445.00	457.25	432.80	-	-	-	435.50
	3	-	3.53	8.40	18.36	-	-	-	10.25
	4	-	1.12	7.70	9.48	-	-	-	3.53
Lucknow	1	9	2	1	-	5	2	1	1
	2	410.34	411.50	481.00	-	415.80	459.50	374.00	390.00
	3	21.45	10.93	-	-	12.76	3.89	-	-
	4	15.63	3.76	-	-	6.86	1.20	-	-
Meerut	1	42	10	14	2	6	7	4	5
	2	380.28	410.00	400.29	394.50	428.33	445.57	385.25	461.67
	3	5.15	18.05	14.14	3.19	17.35	9.93	12.65	46.10
	4	8.77	6.09	13.20	1.14	9.92	5.89	6.55	17.30
Mhow	1	-	2	21	3	1	2	-	-
	2	-	434.50	451.14	443.33	367.80	461.50	-	-
	3	-	16.61	11.17	21.72	-	24.40	-	-
	4	-	5.40	11.89	8.48	-	7.68	-	-

1. No. of observations  
 2. Average (Kg.)  
 3. Standard Error (Kg.)  
 4. Coefficient of variation (%)

+ 16.11 kg. at fourth calving.

The animals with 5/8 Friesian inheritance were heaviest at Meerut. Their weight increased from 394.12 ± 6.01 kg. at first calving to 430.88 ± 16.97 kg. in the fourth calving. Animals at Dehradun farm grew faster than the animals at other farms.

The animals with 3/4 Friesian inheritance at Meerut were the heaviest among the group. They weighed 404.00 ± 9.89 kg. at first calving and 445.57 ± 9.93 kg. in the fifth calving. Animals at Dehradun grew at a faster rate.

There was a small number of animals with 7/8 Friesian inheritance. The heaviest weight at first calving was 393.09 ± 12.59 kg. (Meerut), at second calving 414.00 ± 9.95 kg. (Meerut), at third calving 417.75 ± 18.71 kg. (Jabalpur), at fourth calving 410.50 ± 5.94 kg. (Jabalpur) and at fifth calving 418.67 ± 6.77 kg. (Jabalpur).

Largest number of animals of Friesian group attained maximum weight at Meerut. Heaviest average weight was recorded as 481.50 ± 12.37 kg. in fourth calving in Friesian animals at Jullundur.

### Relative Efficiency

Relative efficiency is the amount of milk produced per unit of body weight of the animal. The weight of the animals was taken within 15 days of calving. A comparative study of relative efficiency of milk production for each grade over all farms was made. Table 1k gives the average of relative efficiency with its standard error, and coefficients of variation (%) for various farms within each genetic group.

Sahiwal : The relative efficiency of milk production of Sahiwal cattle was maximum at Lucknow. The animals at Ambala were heaviest as well as

Table 1k Averages of Relative Efficiency, Standard Errors, Standard Errors, Coefficients of variation (%) for Grades within Farms

Farm	Sahival	1/8	1/4	3/8	1/2	5/8	3/4	7/8	Friesian
Ambala	105	48	74	36	13	15	7	1	4
	4.55	4.77	4.91	4.50	4.74	5.89	6.59	4.00	5.08
	0.12	0.22	0.17	0.23	0.21	0.26	0.61	-	0.80
Dehradun	26.29	32.18	30.13	30.14	16.00	17.51	24.35	-	31.66
	-	11	62	41	67	13	32	8	17
	-	5.18	4.80	5.32	4.80	6.51	5.82	5.56	5.57
	-	0.49	0.18	0.52	0.22	0.39	0.30	0.57	0.31
Jabalpur	-	31.28	29.85	44.99	36.71	21.54	29.09	28.78	23.19
	-	31	72	134	28	18	35	8	13
	-	4.87	4.96	5.32	6.07	6.09	5.80	5.01	6.29
	-	0.28	0.16	0.15	0.27	0.32	0.26	0.50	0.46
Jullundur	-	31.90	27.92	27.73	23.55	22.44	26.67	16.70	26.08
	-	21	53	51	16	21	13	4	2
	-	4.95	4.98	5.10	4.75	6.02	5.57	6.05	6.25
	-	0.32	0.19	0.17	0.30	0.32	0.30	0.71	0.39
Lucknow	-	29.93	28.01	24.15	24.88	24.12	19.40	23.59	8.80
	87	15	7	15	4	16	5	1	1
	4.54	5.35	4.43	5.06	5.70	5.59	5.06	5.00	8.00
	0.12	0.29	0.19	0.33	0.56	0.38	0.47	-	-
Meerut	25.59	21.04	11.45	25.20	19.69	27.00	20.75	-	-
	181	25	55	68	27	50	22	9	17
	4.40	4.70	4.67	4.89	5.30	5.11	5.56	4.91	6.98
	0.10	0.25	0.18	0.19	0.23	0.16	0.28	0.33	0.34
Mhow	29.49	26.71	28.47	31.91	22.61	22.18	23.81	20.35	20.25
	-	14	38	45	4	9	15	1	-
	-	5.36	5.38	4.64	5.45	5.85	5.67	6.40	-
	-	0.48	0.21	0.14	1.22	0.46	0.25	-	-
	-	35.40	23.70	20.07	45.03	23.82	16.30	-	-

1. Number of observations  
 2. Average ( Kg./Kg. body weight)  
 3. Standard Error (Kg./Kg. body weight)  
 4. Coefficient of variation (%)

highest milk producers. The relative efficiency of animals at Ambala did not differ significantly from those at Lucknow. The relative efficiency of milk production of Sahiwals at Lucknow was  $4.54 \pm 0.12$  kg./kg. body weight.

Crossbreds : The animals with  $1/8$  Friesian inheritance had a relative efficiency of  $5.35 \pm 0.29$  kg./kg. body weight at Lucknow and  $5.36 \pm 0.48$  kg./kg. body weight at Mhow. The animals at Mhow were heavier than those at other farms, they were also high milk yielders. The animals at Jabalpur were even heavier than those at Mhow but they were not good milk yielders.

The animals with  $1/4$  Friesian inheritance at Mhow had a relative efficiency of  $5.38 \pm 0.21$  kg./kg. body weight. In this group the animals at Lucknow were least economical having a relative efficiency of  $4.43 \pm 0.19$  kg./kg. bodyweight.

The animals with  $3/8$  Friesian inheritance at Jabalpur had a relative efficiency of  $5.32 \pm 0.13$  kg./kg. body weight. The relative efficiency of this group at Dehradun was  $5.32 \pm 0.32$  kg./kg. body weight not significantly different from that at Jabalpur. The animals at Jabalpur were highest milk yielders. The animals at Dehradun were heaviest among the group.

Half Friesian animals had a high relative efficiency of  $6.07 \pm 0.27$  kg./kg. body weight at Jabalpur which were the highest milk yielders as well. Next economical herd of halfbred animals was at Lucknow having relative efficiency of  $5.70 \pm 0.56$  kg./kg. body weight.

The animals with  $5/8$  Friesian inheritance had a relative efficiency of  $6.51 \pm 0.39$  kg./kg. body weight at Dehradun,  $6.02 \pm 0.32$  kg./kg. body weight at Jullundur and  $6.09 \pm 0.32$  kg./kg. body weight at

Jabalpur. The animals at Dehradun were lighter ( $363.31 \pm 13.37$  kg.) as well as highest milk yielders ( $2350.62 \pm 157.62$  kg.) in the group. The animals at Jabalpur and Jullundur were next in order of milk production.

The animals with  $3/4$  Friesian inheritance had highest relative efficiency of  $6.59 \pm 0.61$  kg./kg. body weight at Ambala which was high as compared to that of other farms. The relative efficiency at other farms varied from  $5.06 \pm 0.47$  kg./kg. body weight at Lucknow to  $5.82 \pm 0.30$  kg./kg. body weight at Dehradun. Animals at Ambala were heaviest in the group weighing  $356.43 \pm 10.39$  kg. They were also highest milk producers.

The animals with  $7/8$  genetic group were not relatively efficient in milk production. Animals at Jullundur besides having large body weight ( $385.25 \pm 21.51$  kg.) had a relative efficiency of  $6.05 \pm 0.71$  kg./kg. body weight. They were the highest milk producers among all the farms. Other farms having animals with higher relative efficiency were Dehradun and Jabalpur.

The Friesian cows had the highest relative efficiency of milk production. Those at Meerut yielded  $6.98 \pm 0.34$  kg. milk per kg. body weight. Friesian at Jabalpur had the next economic performance.

The best relative performers among various genetic groups were  $1/8$  at Lucknow,  $1/4$  at Mhow,  $3/8$  at Jabalpur and Dehradun,  $1/2$  at Jabalpur,  $5/8$  at Dehradun,  $3/4$  at Ambala,  $7/8$  at Jullundur and Friesians at Meerut. Among farms Jabalpur and Dehradun had most economic producers. Jabalpur had best  $3/8$ ,  $1/2$ , good  $5/8$  and Friesians; while Dehradun had best  $3/8$ ,  $5/8$  and good  $3/4$  and  $7/8$  genetic groups.

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- GRADE 1/4 \_\_\_\_\_
- GRADE 3/8 \_\_\_\_\_
- GRADE 1/2 \_\_\_\_\_
- GRADE 5/8 \_\_\_\_\_
- GRADE 3/4 \_\_\_\_\_
- GRADE 7/8 \_\_\_\_\_
- FRIESIAN \_\_\_\_\_

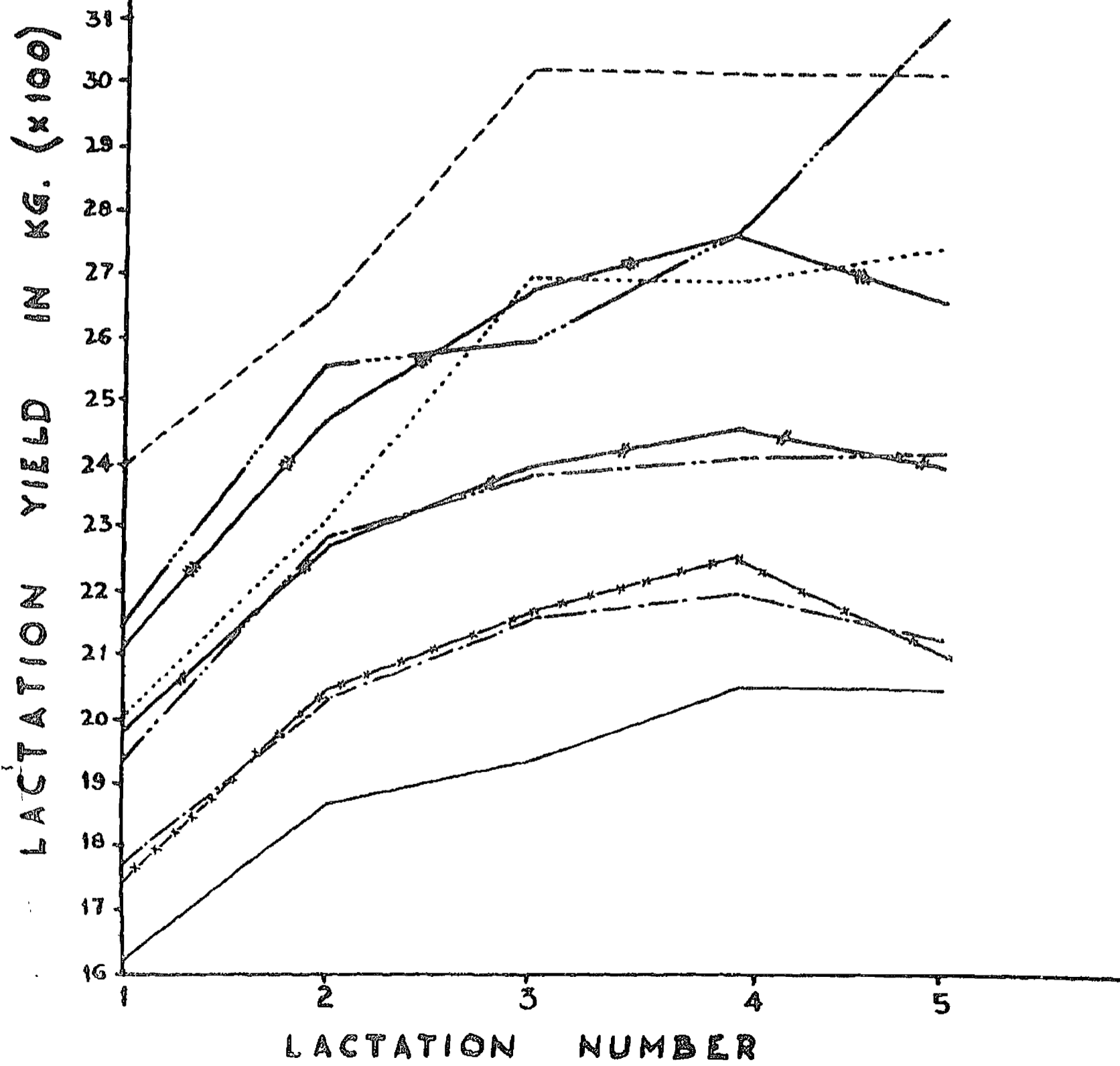


FIG 2.1

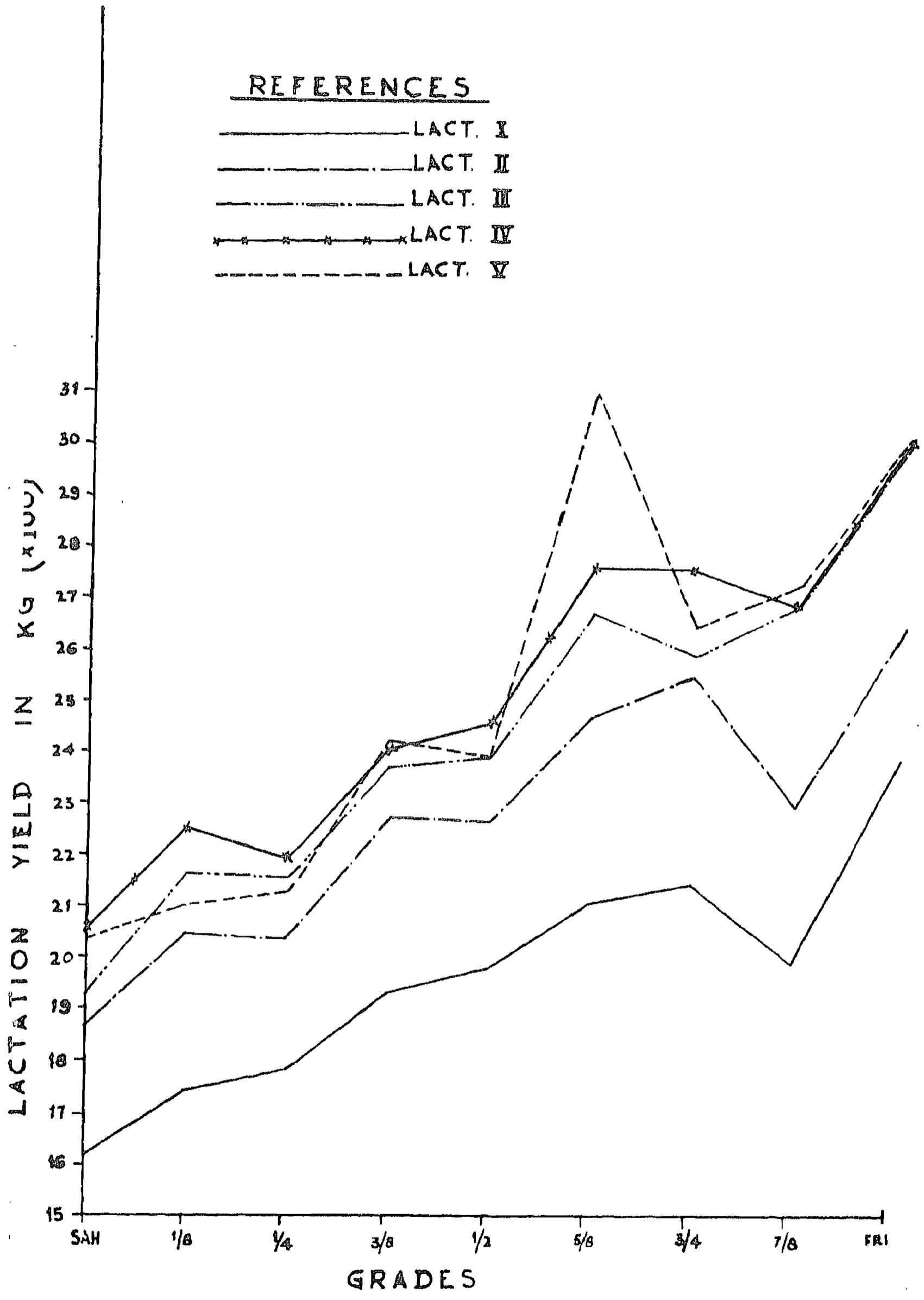


FIG. 2.2

### Comparison of Genetic Groups

300-day Milk Yield : Table 2a details the averages of 300-day lactation yield (first through fifth) for various genetic groups with their standard errors and coefficients of variation (%). The average first lactation yield in Sahiwal was  $1620.77 \pm 21.47$  kg. and in Friesian  $2396.67 \pm 67.69$  kg. There was a range of 776 kg. between the two lactations. Kramer's modification of Duncan's multiple range test was employed to compare the milk yield of various genetic groups. The yield of Sahiwal animals did not differ significantly from  $1/8$  and  $1/4$  Friesian animals. There was no significant difference between the milk production of  $3/8$  and  $1/2$  Friesian animals and  $5/8$  and  $3/4$  Friesian animals. However, there was significant ( $p < 0.05$ ) difference between  $1/4$ ,  $3/8$ ,  $5/8$  Friesians and Friesian animals. The animals with  $1/2$  Friesian inheritance yielded significantly less milk than Friesian and more milk than Sahiwal. Sahiwal,  $1/8$  and  $1/4$  genetic groups formed one group, animals with  $3/8$  and  $1/2$  Friesian inheritance could be put together, and the animals with  $5/8$  and  $3/4$  Friesian inheritance constituted the third group.

In the second lactation, Sahiwal produced  $1367.11 \pm 52.43$  kg. the lowest lactation yield as compared to other crossbred animals. The production was significantly lesser than Friesian animals ( $2655.90 \pm 139.63$  kg.). Animals with  $3/4$  Friesian inheritance were the next high yielders ( $2550.95 \pm 71.70$  kg.). The multiple range test applied to the various genetic groups in this lactation also showed the same results as for the first lactation milk production. In addition, it was observed that  $3/4$ ,  $5/8$  and Friesian did not differ significantly in milk yield.

In the third lactation the Sahiwal animals were producing lowest

Table No. 2a Averages of 300-day Lactation Yields (First through Fifth), Standard Errors, and Coefficients of Variation (%) for Various Genetic Groups (Grades)

Grade	First Lactation			Second Lactation			Third Lactation			Fourth Lactation			Fifth Lactation							
	No. of obs.	Mean (Kg.)	S.E. (Kg.)	C.V. (%)	No. of obs.	Mean (Kg.)	S.E. (Kg.)	C.V. (%)	No. of obs.	Mean (Kg.)	S.E. (Kg.)	C.V. (%)	No. of obs.	Mean (Kg.)	S.E. (Kg.)	C.V. (%)				
Sahival	408	1,320.77	21.47	26.59	301	1887.11	32.45	30.14	237	1930.84	35.31	23.55	179	2050.79	44.89	29.29	125	2045.76	57.21	31.28
1/8	174	1737.87	45.18	29.74	90	2042.84	61.85	28.72	56	2165.77	94.67	32.71	34	2253.26	122.07	51.59	16	2106.31	160.24	30.45
1/4	394	1773.34	24.37	27.23	307	2040.48	36.19	31.07	214	2154.88	46.65	31.67	139	2195.90	61.32	32.92	84	2127.79	78.84	33.01
3/8	409	1932.92	27.30	23.56	302	2273.90	37.70	31.51	302	2376.04	42.70	31.23	242	2409.24	48.44	31.28	196	2418.77	53.21	31.60
1/2	170	1933.72	47.97	31.53	138	2236.03	62.48	32.39	116	2395.80	72.28	32.50	99	2455.46	76.29	30.91	81	2393.09	90.97	34.21
5/8	155	2106.59	45.75	27.04	84	2467.30	70.82	26.31	47	2674.32	131.19	33.63	40	2762.58	133.96	30.67	26	3097.46	153.17	25.04
3/4	143	2146.92	45.30	25.23	88	2550.95	71.70	26.37	59	2593.66	89.36	26.46	55	2763.35	96.27	25.84	43	2649.79	106.61	26.38
7/8	33	1991.55	82.65	23.94	27	2300.04	114.96	25.95	24	2687.90	173.98	31.74	21	2687.90	142.34	24.27	17	2765.29	209.47	31.57
Irishian	55	2396.07	87.09	27.14	49	2655.90	139.63	36.80	36	3017.78	153.92	30.60	30	3013.63	182.53	33.18	24	3015.54	234.65	38.12

when compared to other genetic groups. They yielded on an average only  $1950.84 \pm 35.81$  kg. as compared to  $3017.78 \pm 153.92$  kg. produced by Friesian animals. In this lactation the yield of Friesian animals was not significantly different from  $5/8$  and  $3/4$  but was significantly higher than Sahiwal and  $1/2$  Friesian animals.

Similar results were obtained for various genetic groups for fourth lactation yield. The milk yield in this lactation for Friesian animals was  $3013.63 \pm 182.53$  kg. and that of Sahiwal was  $2050.79 \pm 44.89$  kg.

In the fifth lactation it was observed that  $5/8$  Friesian cows yielded much higher milk than all other groups. It was significantly higher ( $447.67$  kg.) when compared to  $3/4$  Friesian animals. The Friesian animals did not differ significantly in milk yield from  $5/8$  Friesian animals. The fifth lactation production in two genetic groups was  $3015.54 \pm 234.65$  kg. and  $3097.46 \pm 158.17$  kg., respectively.

It was observed that with an increase in Friesian inheritance there was a progressive increase in milk production upto  $3/4$  level of Friesian inheritance. There was a decline in the  $7/8$  Friesian group. Pure Friesian animals had the highest milk yield in all lactations except fifth lactation. Figure 2.1 details lactation yield in kg. against lactation number for all the grades. It was observed that curve of  $5/8$  Friesian animals closely followed the  $3/4$ . These two genetic groups were the only genetic groups which gave highest milk yield next to pure Friesian animals under the conditions of management and health prevalent in military dairy farms. Figure 2.2 shows lactation yield against genetic groups for five lactations. There was definite increase in the milk yield from first to fourth lactation. The  $5/8$  Friesian animals had the highest

fifth lactation yield as compared to all other genetic groups. Thus the peak in all genetic groups was fourth lactation except for 5/8 Friesian animals where the fifth lactation was significantly different from fourth lactation. The average lactation production of the halfbred animals was significantly different from Sahiwal and Friesian animals. The weighted average of the two parents (Average of Sahiwal and Friesian groups) was calculated and tested against the 300-day lactation average of the halfbreds. It was observed that in all the lactations halfbred animals produced significantly higher amount of milk as compared to the mid parent value (Average of two groups). There was an increase of 269 kg., 320 kg., 321 kg., 236 kg., and 190 kg. in first, second, third, fourth and fifth lactation, respectively.

#### Life Time Production

The first three or five lactation yields of each animal were added to study the life time production. Table 2c details the averages of life time production upto three lactations and upto five lactations, their standard errors and percentage coefficient of variation. The Friesian animals had the highest life time production differing significantly from all other genetic groups. Sahiwal cows had the lowest life time production. Magnitudes of life time production upto three lactations of Sahiwal and Friesian cows were  $5677.94 \pm 94.15$  kg. and  $8145.89 \pm 351.87$  kg. There was an increase in life time production upto three lactations with increasing level of exotic inheritance. In life time production upto five lactations the 1/8 genetic group had the lowest average of  $9698.92 \pm 675.23$  kg. Sahiwal animals produced  $10018.87 \pm 221.28$  kg. There was no significant difference between the yields of Sahiwal, 1/8 and

Table No. 2b Averages of Heights at Calving (First through Fifth),  
Standard Errors, and Coefficients of Variation (%)  
for various Genetic Groups (Grades)

Grade	First Calving			Second Calving			Third Calving			Fourth Calving			Fifth Calving							
	No. of obs.	Mean (Kg.)	S.E. (Kg.)	C.V. (%)	No. of obs.	Mean (Kg.)	S.E. (Kg.)	C.V. (%)	No. of obs.	Mean (Kg.)	S.E. (Kg.)	C.V. (%)	No. of obs.	Mean (Kg.)	S.E. (Kg.)	C.V. (%)				
Sahival	388	371.26	2.11	11.17	257	375.82	2.68	11.41	185	379.71	3.05	10.94	136	388.82	3.37	10.11	98	389.64	4.01	10.18
1/8	178	363.75	2.99	10.96	74	368.97	4.91	11.43	35	381.29	6.74	10.45	13	395.92	13.34	12.16	6	420.00	9.50	5.55
1/4	374	364.04	2.47	13.17	214	377.01	3.06	11.90	145	387.21	3.89	12.09	93	399.59	4.70	11.36	59	406.33	4.82	9.11
3/8	391	388.40	2.41	12.30	292	397.78	2.60	11.17	232	410.25	2.91	10.82	161	415.30	3.80	11.00	121	421.04	4.13	10.80
1/2	162	389.88	3.57	11.02	112	391.21	3.66	9.72	105	406.00	3.65	9.14	80	414.85	4.84	10.44	63	423.71	5.44	10.20
5/8	144	375.25	3.65	11.67	49	393.88	6.06	10.77	40	401.78	6.41	10.09	34	412.12	7.67	10.85	22	419.86	8.08	9.08
3/4	133	374.37	4.37	13.46	74	393.72	5.39	11.70	57	414.58	5.22	9.50	48	422.89	6.13	10.04	37	429.62	6.63	9.39
7/8	34	376.47	6.90	10.84	25	383.38	7.75	10.09	21	400.29	9.51	10.89	19	398.11	6.97	7.63	14	401.43	8.78	8.19
Friesian	50	380.68	9.04	15.48	48	408.40	7.97	13.51	35	411.17	8.43	12.12	28	410.32	10.32	13.31	23	415.83	10.61	12.23

1/4 Friesian animals. 3/8 Friesian animals produced more milk than 1/2 Friesian upto five lactations but the difference was not significant. Animals with 5/8 Friesian inheritance though not significantly different from 3/4 produced more milk by 569.10 kg. 7/8 animals produced significantly less milk than 5/8 and Friesian animals. The Friesian cows were the highest producers of milk upto five lactation (14632.61 + 751.21 kg.).

#### Weight at Calving

The results of weights at first, second, third, fourth and fifth calving of various groups of Friesian inheritance are presented in table 2b. Among animals of various levels of Friesian inheritance the 1/2 Friesian heifers were the heaviest weighing 389.88 ± 3.37 kg. Sahiwal heifers were heavier than 1/8 and 1/4 genetic groups. There was no significant difference between the weights of (1/4 and 1/8); (3/8, 1/2 and Friesian); (5/8, 3/4 and 7/8) genetic groups.

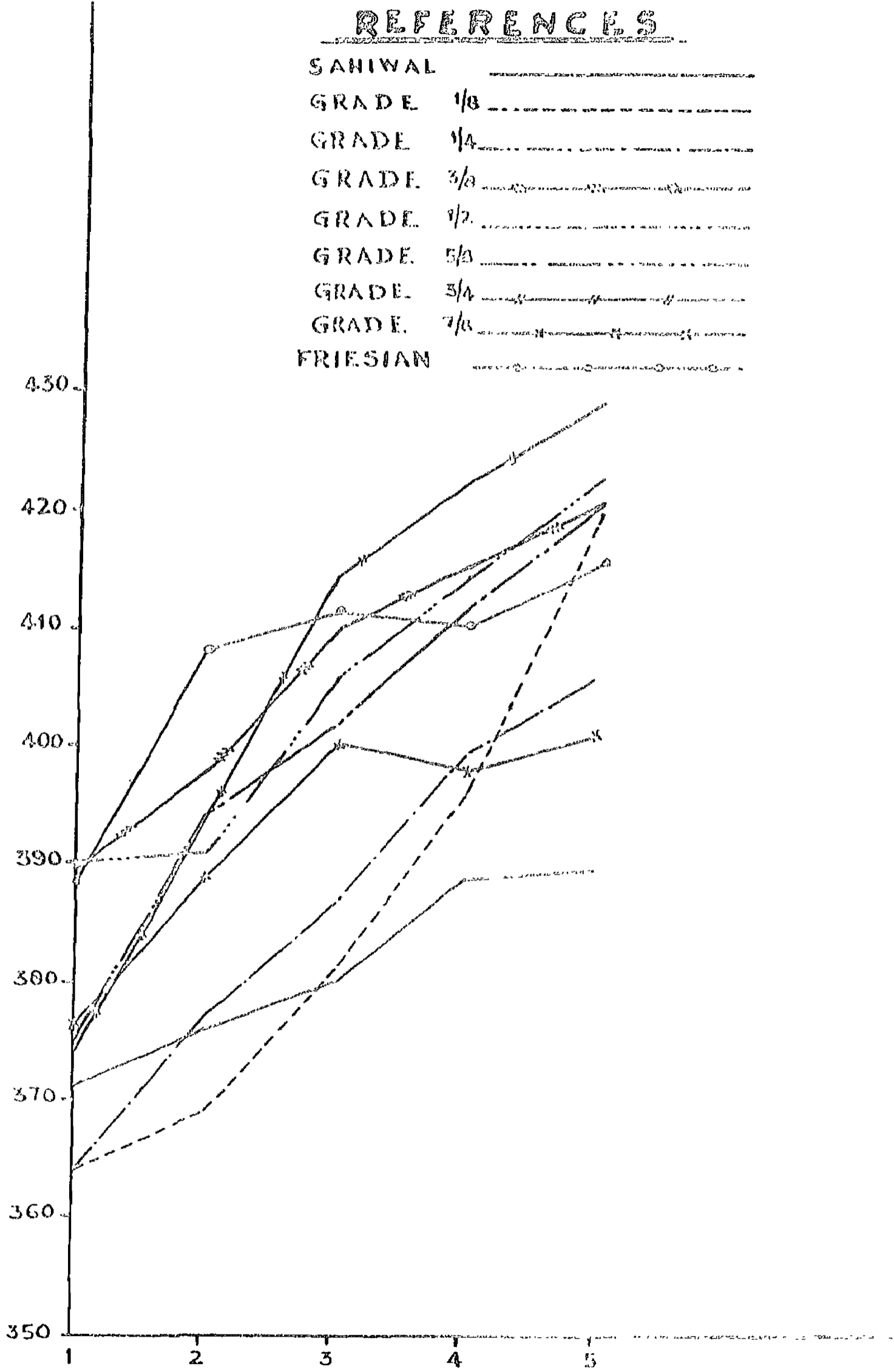
At second calving, weight of 1/4 Friesian was not significantly higher than that of Sahiwal. There was no significant difference in weights at calving between (3/8, 1/2, 5/8 and 3/4) Friesian animals. But they differed significantly from Sahiwal and Friesian animals. Friesian animals had the highest body weight at second calving (403.40 ± 7.97 kg.) as compared to other genetic groups. 1/8 Friesian animals weighed least among all (368.97 ± 4.91 kg.).

At the third calving animals with 3/4 Friesian inheritance had highest body weight of 414.58 ± 5.22 kg. which did not differ significantly from 3/8 and Friesian animals. The body weights at third calving of genetic groups 1/2, 5/8 and 7/8 were not significantly different from each

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- GRADE  $\frac{1}{4}$
- GRADE  $\frac{3}{8}$
- GRADE  $\frac{1}{2}$
- GRADE  $\frac{5}{8}$
- GRADE  $\frac{3}{4}$
- GRADE  $\frac{7}{8}$
- FRIESIAN

WEIGHT AT CALVING IN G.



NUMBER OF CALVING

FIG. 2.3

REFERENCES

- CALVING I
- - - - - CALVING II
- · - · - CALVING III
- · · · - CALVING IV
- \* - \* - CALVING V

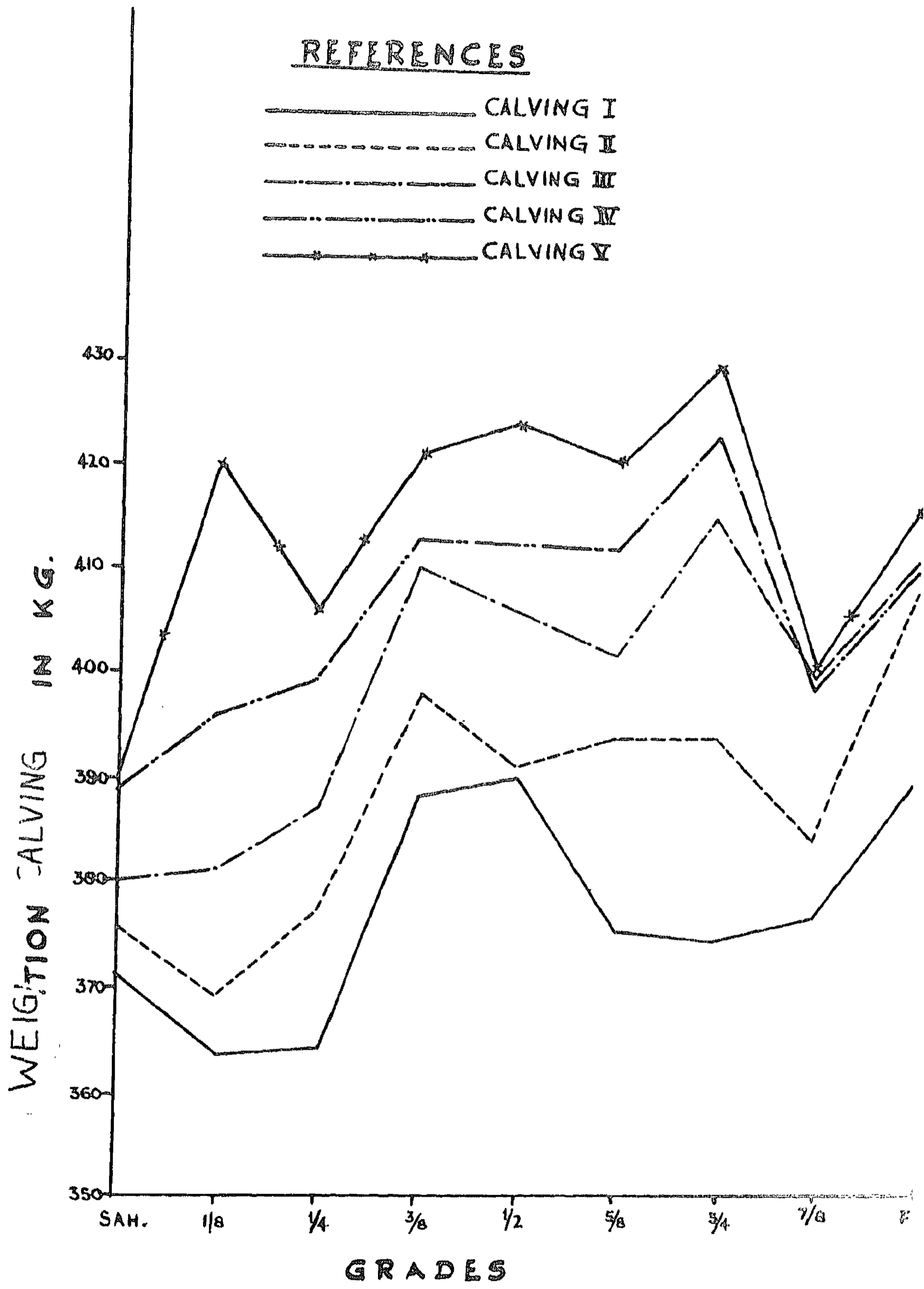


FIG. 2.4

Table 2c Average of Life Time Production and Relative Efficiency, Standard Errors, Coefficients of Variation (%) for various Genetic Groups

	Three Lactations			Five Lactations			Relative Efficiency					
	No. of obs.	Mean (Kg.)	S.E. (Kg.)	C.V. (%)	No. of obs.	Mean (Kg.)	S.E. (Kg.)	C.V. (%)	No. of obs.	Mean (Kg.)	S.E. (Kg.)	C.V. (%)
Sahiwal	222	5677.94	94.15	24.71	121	10018.87	221.23	24.29	373	4.47	0.06	27.73
1/8	50	5273.03	245.53	27.66	12	9698.92	675.23	24.12	165	4.95	0.12	30.56
1/4	204	6235.60	115.63	26.29	82	10701.63	287.36	24.52	361	4.91	0.07	23.44
3/8	297	6305.70	104.23	26.39	132	11995.53	207.71	23.56	388	5.05	0.06	30.63
1/2	114	6956.02	191.34	27.41	80	11698.10	358.51	27.41	180	5.14	0.13	30.91
5/8	45	7578.44	234.66	25.20	26	13903.58	641.69	23.53	142	5.68	0.12	24.20
3/4	57	7677.56	247.67	24.56	42	13534.48	455.71	21.18	129	5.74	0.13	25.44
7/8	25	7480.70	405.31	25.98	16	12986.33	710.74	21.89	32	4.26	0.22	23.96
Friesian	37	8145.89	351.87	23.28	25	14632.61	751.21	24.62	54	6.22	0.21	25.30

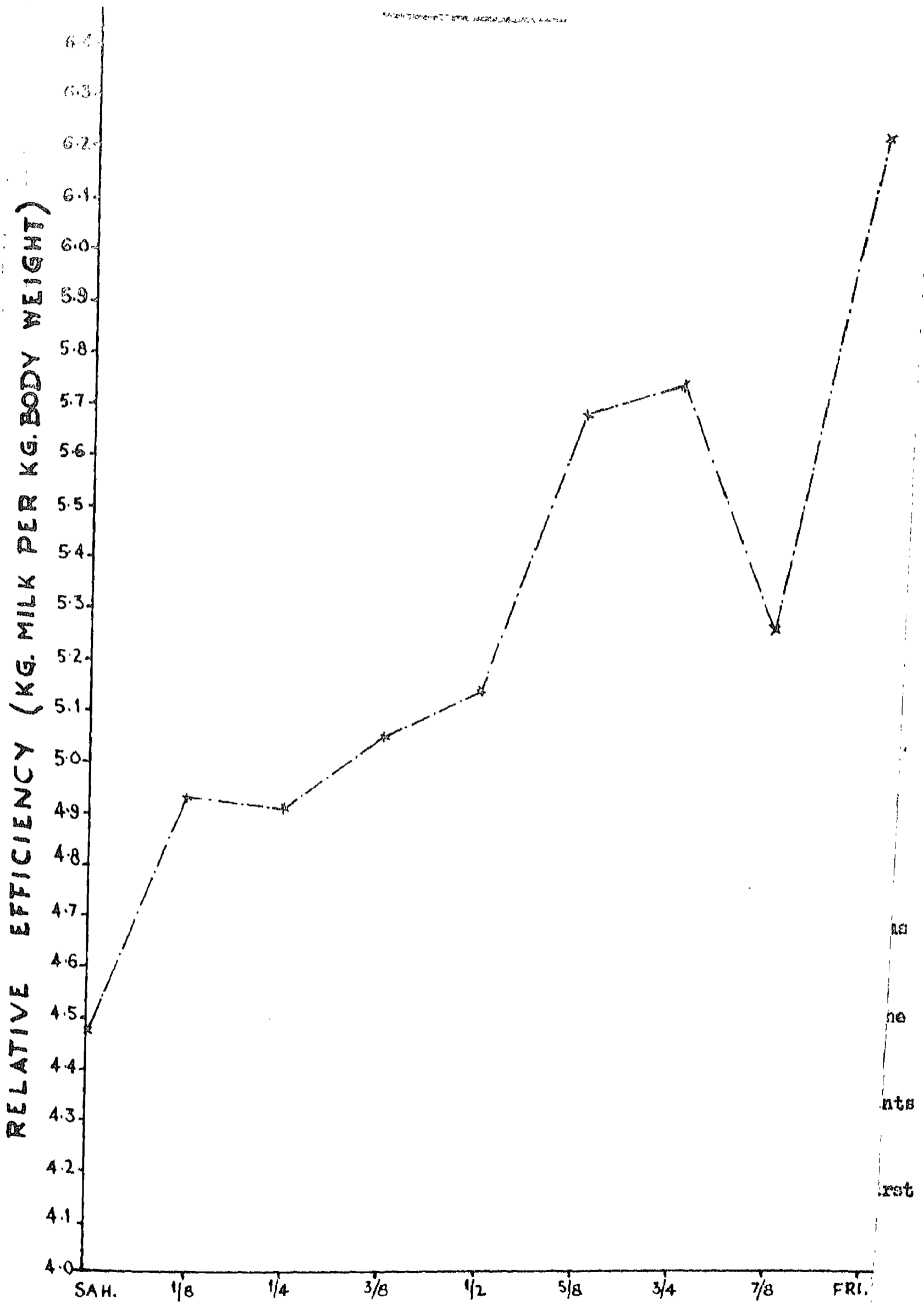
other. Animals with  $3/8$  and  $1/2$  Friesian inheritance also did not differ significantly in weight at third calving. Sahiwal animals had the lowest body weight of  $379.71 \pm 3.05$  kg.

At fourth calving body weights of  $3/8$ ,  $1/2$ ,  $5/8$  and Friesian animals were not significantly different. There was no significant difference between  $1/8$ ,  $1/4$ , and  $7/8$  Friesian animals. Animals with  $3/4$  Friesian inheritance had significantly higher body weight, at fourth calving  $422.89 \pm 6.13$  kg. than Friesian animals.

At fifth calving animals with  $1/8$ ,  $3/8$ ,  $1/2$ ,  $5/8$ , and  $3/4$  Friesian inheritance weighed more than Friesian animals.  $3/4$  Friesian animals were significantly heavier than Friesian. The  $3/4$  Friesian animals weighed  $429.62 \pm 6.63$  kg., while Friesian animals weighed  $415.83 \pm 10.61$  kg. Sahiwal had the lowest body weight of  $389.64 \pm 4.01$  kg.

Figure 2.3 shows the growth after calving of each genetic group. It was observed that Sahiwal animals were heavier than  $1/8$  and  $1/4$  Friesians at first calving. They had the lowest body weight at fifth calving. Growth of  $1/4$  and  $1/8$  Friesian animals was rapid when compared to Sahiwal. The  $1/8$  Friesian animals gained maximum weight between fourth and fifth calving so that <sup>at</sup> fifth calving they exceeded the Friesian also. The most rapid growth was exhibited by  $3/4$  Friesian animals. They gained maximum weight at earlier calving. At third, fourth and fifth calving they weighed more than Friesian animals.

Relative Efficiency : Table 2c details the averages of relative efficiency of milk production in various genetic groups. Among various genetic groups the Friesian animals had the highest relative efficiency of  $6.22 \pm 0.21$  kg./kg. body weight. Sahiwal animals had significantly lower relative efficiency of milk production as compared to crossbreds. There



GRADES  
FIG. 3

was no significant difference between relative efficiency of  $1/8$  and  $1/4$ ;  $3/8$ ,  $1/2$  and  $7/8$ ;  $5/8$  and  $3/4$  genetic groups. Among crossbreds  $5/8$  and  $3/4$  genetic groups had the highest relative efficiency.

Figure 3 shows the curve of relative efficiency of milk production against each genetic group. It is evident from the figure that the relative efficiency of milk production increased with increase in the level of Friesian inheritance. Increase in relative efficiency continued upto  $3/4$  genetic group after which a decline occurred upto  $7/8$ . Friesian animals had highest relative efficiency of milk production.

#### LEAST SQUARE ANALYSIS

The data were collected from seven farms extending over a period of 50 years and the records were available on more than 2000 animals of Sahiwal breed and various genetic groups with different levels of exotic inheritance. It was considered desirable to study the effects of such factors as grades, farms, periods, seasons, breed of sire and lactation number (calving number) so as to see if there was a need for correcting the data for these effects. Due to disproportionate sub class numbers and non-orthogonality of the data a generalized least square analysis was run using a six-way cross classification, fixed effects model (Model 1, Eisenhart, 1947). The main effects were considered to be important. The interactions were thought to be insignificant and their relative contribution to the total variability very little. Least square constants for each effect were estimated. Analysis was run on 300-day lactation yield from first through fifth lactation and weights at calving from first through fifth calving.

Table 3 Analysis of Variance (Least Square) for 300-day Lactation Yield and Weights at Calving

Source	Lactation Yield			Weight at Calving		
	D.F.	Mean sum of squares	R <sup>2</sup> (%)	D.F.	Mean sum of squares	R <sup>2</sup> (%)
Between Grades	8	12841047.50 <sup>***</sup>	3.3710	8	55700.1237 <sup>***</sup>	2.14533
Between Farms	6	4087006.00 <sup>**</sup>	0.8140	6	75153.8767 <sup>**</sup>	2.17095
Between Periods	5	7886503.20 <sup>**</sup>	1.1941	5	74588.8360 <sup>**</sup>	1.79547
Between Seasons	1	9389.16	0.0006	1	29488.6570	0.14197
Between Breeds of Sires	1	471672.97	0.0015	1	2012.7377	0.09690
Between Lactation (Nos.)	4	39637862.50 <sup>***</sup>	5.2034	4	102908.1425 <sup>**</sup>	1.98179
Error	5841	465908.56	39.3150	4850	3923.5100	91.75070

\*\* Significant at P = 0.99

\*\*\* Significant at P = 0.9995

300-day Milk Yield : The analysis of variance of 300-day lactation records is presented in the table 3. The effects of grade and lactation number were significant ( $p < 0.0005$ ). Effects of farms and periods were significant ( $p < 0.01$ ). Season of the year in which the animal was born and the breed of its sire had no effect. Contribution of the lactation number, grades, periods, farms to the total variability was 5.2 per cent, 3.37 per cent, 1.20 per cent and 0.81 per cent respectively. The contributions of seasons of birth and breeds of sire were negligible.

The least square constants for each of the main effects are given in table 4. There was an increase in the value of constants for grades with increase in the level of Friesian inheritance except for the animals with  $7/8$  Friesian inheritance for which the value of constant was - 3.06. Constants for farms varied from - 148.07 for Dehradun to 126.58 for Mhow. The values of constant for periods were decreasing with time. Highest value of 200.22 was for the period 1937-1941. It decreased continuously so that the value of the last period 1962-63 was - 188.23. The constant for the season was of very small magnitude, - 1.28 for most calving season. The value of constant for the Sahiwal sires was - 52.34. The constants for the lactation number showed an increase in their value from first through fourth lactation. The value of constant for first lactation was - 301.73, and for the fourth lactation 137.41. The value for the fifth lactation (112.60) was smaller than that for the fourth lactation (137.41).

The analysis of variance on 4876 records of weights at calving is given in table 3. The effect of grades was significant ( $p < 0.0005$ ). The effect of farm, period and number of calving were significant ( $p < 0.01$ ). 92 per cent of the total variation was explained by causes other than the main effects. The contribution of the farms, grades, periods and number

Table 4 Least Square Constants

Effect		300-day Lactation Yield	Weight at calving
u		2396.1920	399.6973
Grades :	Sahiwal	-393.3608	-23.1739
	1/8	-150.9759	-15.8559
	1/4	-149.9238	-13.7777
	3/8	14.8809	0.4565
	1/2	47.1016	10.8508
	5/8	133.1937	5.8506
	3/4	134.6143	14.2638
	7/8	-3.0588	4.1809
	Friesian	367.5285	19.7029
Farms :	Ambala	27.2983	60.1800
	Dehradun	-148.0677	-22.1653
	Jabalpur	6.7732	-9.7219
	Jullundur	1.9330	3.9604
	Lucknow	-8.9990	3.8734
	Meerut	-25.4962	4.5471
	Mhow	126.5584	-43.6732
Periods :	1937-41	200.2215	3.9032
	1942-46	107.7225	6.0555
	1947-51	93.0150	-0.3714
	1952-56	-85.5300	13.4315
	1957-61	-127.1997	-6.0532
	1962-66	-188.2294	-16.9656
Seasons :	Most Calving	-1.2802	-2.4863
	Least Calving	1.2802	2.4863
Breed of Sire :	Sahiwal	-52.3374	3.4105
	Friesian	52.3374	-3.4105
Number of Lactation (Calving)	First	-301.7333	-15.1800
	Second	-24.4643	-7.3301
	Third	76.1882	1.1992
	Fourth	137.4119	8.4869
	Fifth	112.5980	12.8240

of calving was 2.17 per cent, 2.15 per cent, 1.80 per cent and 1.98 per cent respectively. The breed of sire and the season of birth contributed only 0.10 per cent and 0.14 percent to the total variation. Both these effects were non-significant.

The constants for the weight at calving have been presented in the table 4. The constants showed a similar trend for this character also. The constant for Sahiwal,  $1/8$  and  $1/4$  Friesian animals were negative, their magnitudes were - 26.17, - 15.26, -13.78 respectively. All other grades had a positive value of constants. Animals of  $3/8$  genetic group had the lowest value of 0.46 and the highest value was 19.70 for the Friesian animals. Among other genetic groups the value of constants for the halfbreds was 10.85,  $5/8$  was 5.85,  $3/4$  was 14.26 and for the  $7/8$  Friesian animals was 4.18. The constants of the farms showed a variation from - 43.67 for Mhow to 60.18 for Ambala. The constants for Dehradun and Jabalpur were - 22.17 and - 9.72 respectively. The value of other constants was not much different, 6.96 for Jullundur, 3.87 for Lucknow and 4.55 for Meerut. Largest value among constants for periods was 13.43 for 1952-56 and the smallest - 16.97 for 1962-63. The constants for other periods were 3.90 (1937-41), 6.03 (1942-46), - 0.37 (1947-51) and - 6.05 (1957-61). The constants for seasons and breeds of sire were of smaller magnitudes. The value of constant for most calving season was - 2.49 and for the Sahiwal sires it was 3.41. The values of the constants for calving number showed a regular increase from first through fifth lactation. The constants for weight at calvings from first through fifth calving are - 15.18, - 7.36, 1.20, 8.49 and 12.82 respectively.

Table 5 Mean Sum of Squares (Hierarchical classification)  
for 300-day Lactation Yield

Grade	First Lactation		Second Lactation		Third Lactation	
	Farms	Sires	Farms	Sires	Farms	Sires
Sahiwal	370350.00	307045.40 <sup>**</sup>	99795.00	478113.77 <sup>**</sup>	335575.00	577708.50 <sup>**</sup>
1/8	470933.33	356208.96	275548.33	412663.57	432536.66	765041.25
1/4	939100.00	231131.11	379540.00	677200.00 <sup>**</sup>	223496.00 <sup>*</sup>	470702.90
3/8	430800.00	525492.59 <sup>**</sup>	1921260.00 <sup>*</sup>	559330.18	372380.00	350910.86
1/2	1511027.50	555159.13	611780.00	449415.33	834420.00	525896.92
5/8	680458.33	247233.33	1554033.00	609810.00	3113033.30	1125646.60
3/4	32026.67	545823.75 <sup>*</sup>	268493.33	742900.18	377036.66	474524.00
7/8						
Friesian	2633330.00	175983.18	4089080.00	544805.00	4014205.00	330546.00

\* Significant at 0.05 level of probability

\*\* Significant at 0.01 level of probability

Table 5b Mean Sum of Squares (Hierarchical classification)  
 For Height at First, Second and Third Calvings

Grade	First Calving		Second Calving		Third Calving	
	Farms	Sires	Farms	Sires	Farms	Sires
Salinval	198.50	2480.17 <sup>*</sup>	9747.00	2598.78	8977.50	2001.97
1/8	3415.00	2198.59 <sup>*</sup>	8170.01	1755.04	2506.45	4351.90
1/4	23553.00 <sup>**</sup>	2447.07	8094.20 <sup>*</sup>	1880.47	14259.20 <sup>**</sup>	1828.59
3/8	3327.20 <sup>*</sup>	4536.35 <sup>*</sup>	6799.80 <sup>*</sup>	3462.32 <sup>**</sup>	4757.20 <sup>**</sup>	2977.31
1/2	1344.25	2448.95	684.50	1252.27	167.50	1568.59
5/8	6594.17 <sup>*</sup>	2529.35	4551.60	4999.50	4916.90	2508.20
3/4	6326.55	4220.94 <sup>*</sup>	2610.55	2252.15	971.85	804.80
7/8						
Friedon	6307.45	4180.50	14870.25	2061.42	12456.95	2280.78

\* Significant at 0.05 level of probability

\*\* Significant at 0.01 level of probability

## HIERARCHICAL CLASSIFICATION ANALYSIS

The least square analysis revealed that most factors did not contribute very much to the total variability. Consequently, the corrections using the constants would not have changed the results substantially. Besides the data has been analysed using hierarchical classification model for each genetic group separately with farm effect as the main effect. From this analysis various genetic parameters were estimated for each trait.

### Mean Sum of Squares

300-day Milk Yield: Table 5a gives the mean sum of squares due to farms, sires and error for 300-day lactation yield for first, second, and third lactations. The farm effect was significant for 3/8 genetic group in second lactation ( $p < 0.05$ ) and for 1/4 genetic group in third lactation ( $p < 0.05$ ). The sire differences were significant ( $p < 0.01$ ) in Sahiwal for all the three lactation yields; in 3/8 genetic group ( $p < 0.01$ ) for first lactation; in 3/4 genetic group ( $p < 0.05$ ) for first lactation and in 1/4 genetic group ( $p < 0.01$ ) for second lactation yield.

Weight at Calving: Table 5b details mean sum of squares for weight at first, second and third calving. The effect of farm was significant in animals with 1/4 ( $p < 0.01$ ), 3/8 ( $p < 0.05$ ), 5/8 ( $p < 0.05$ ) Friesian inheritance for weight at first calving; in animals with 1/4 ( $p < 0.05$ ) and 3/8 ( $p < 0.05$ ) Friesian inheritance for weight of second calving and in 1/4 ( $p < 0.01$ ) genetic group for weight at third calving. The sire differences were significant in Sahiwal ( $p < 0.05$ ), 1/8 ( $p < 0.05$ ), 5/8 ( $p < 0.01$ ) and

Table 6a Analysis of Variance (Hierarchical classification) :  
 Variance components of Farm, Sire, Error and Total and  
 Additive Genetic Variance for 300-day First Lactation Yield

Grade	VARIANCE COMPONENTS				Additive Genetic Variance
	Farm	Sire	Error	Total	
Sahival	-218.8262	24706.4280	168461.860	192949.460	98825.7120
1/8	2449.5220	36597.0660	222989.90	262036.460	146383.2640
1/4	10899.9970	6729.6531	230184.5600	249814.21	34918.6124
3/8	-4814.5825	51113.5070	259954.7700	506253.890	204454.0280
1/2	57421.6070	-3481.8040	349379.020	403318.820	-13927.2160
5/8	35236.9770	-14144.6830	317807.1500	333929.44	-56578.5320
3/4	-36544.3480	66664.1460	242822.4200	272941.7100	286656.5840
7/8					
Friesian	206620.47	2854.2189	108325.4500	378330.1300	11416.8756

Table 6b Analysis of Variance (Hierarchical classification) :  
 Variance components of Farm, Sire, Error and Total and  
 Additive Genetic Variance for 300-day Second Lactation Yield

Grade	VARIANCE COMPONENTS				Additive Genetic Variance
	Farm	Sire	Error	Total	
Subtotal	-6114.3515	44104.9460	276499.45	314490.04	176419.7840
1/8	-21292.6250	40438.2490	308584.47	327730.09	161752.9960
1/4	-2060.2291	62021.8530	347732.88	407694.45	248087.4120
3/8	26448.8600	27421.3840	426239.27	480109.51	109685.5360
1/2	10483.5640	9541.5077	405149.62	425179.69	38161.0308
5/8	98819.4990	73084.6660	348446.96	520351.12	292338.6640
3/4	-84125.3020	72934.8580	504872.50	513882.05	291739.4520
7/8					
Friesian	463808.44	-139490.17	893307.22	1218125.40	-557960.5800

Table 6c Analysis of Variance (Hierarchical classification) :  
 Variance components of Farm, Sire, Error and Total and  
 Additive Genetic Variance for 500-day Third Lactation Yield

Grade	VARIANCE COMPONENTS				Additive Genetic Variance
	Farm	Sire	Error	Total	
Sahival	-6677.7039	72349.5660	248670.85	322342.71	289598.2640
1/8	-71397.5200	94530.8640	547195.78	570329.12	378123.4560
1/4	59639.1270	11975.4580	418124.17	489738.75	47901.8320
3/8	3260.8065	36787.1540	479641.26	519689.22	147148.6160
1/2	29479.8210	24335.8770	412386.96	466202.65	97343.5080
5/8	304124.4500	149255.7100	651005.50	1104385.60	597022.8400
3/4	-14951.5240	-19416.4710	545578.33	511210.34	-77665.8840
7/8					
Friesian	612353.5400	-67729.8610	491745.07	1063866.70	-270919.4440

3/4 ( $p < 0.05$ ) genetic groups for weight at first calving; for 3/8 genetic group for weight at second calving ( $p < 0.01$ ) and third calving ( $p < 0.05$ ).

#### Variance Components

300-day Milk Yield : The variance components for farms, sires, error, total phenotypic variance and additive genetic variance of the first 300-day lactation yield are given in table 6a. The farm component for Sahiwal, 3/8 and 3/4 genetic groups were negative. The sire component of 1/2 and 5/8 Friesian animals were also negative.

Table 6b details the same components for 300-day lactation yield of second lactation. The farm component was negative in Sahiwal, 1/8, 1/4 and 3/4 genetic groups. The sire component was negative for Friesian animals only.

The aforementioned components for the 300-day third lactation yield are detailed in the table 6c. Animals with 1/8 and 3/4 Friesian inheritance had negative farms component. The sire component for 3/4 Friesian and Friesian animals were negative.

In records of 300-day lactation yield on Sahiwal and animals with 3/4 Friesian inheritance the farm component was negative in all the three lactations. In 3/8 genetic group farm component was negative in second and third lactation records.

Weight at Calving : Tables 6d, 6e and 6f give various variance components of weight at first, second and third calving. The sire component was negative in halfbreds at second calving and 3/4 genetic group at third calving. It showed a decrease in magnitude from first through third calving. Farm component was negative in Sahiwal at first calving, 5/8

Table 6d Analysis of Variance (Hierarchical classification) :  
 Variance components of Farm, Sire, Error and Total and  
 Additive Genetic Variance for Weight at First Calving

Grade	VARIANCE COMPONENTS				Additive Genetic Variance
	Farm	Sire	Error	Total	
Senival	-26.1490	176.9399	1487.3855	1658.1744	707.7596
1/8	41.9558	238.7572	1279.4298	1560.1428	955.0288
1/4	566.8292	95.4125	1912.9485	2375.1901	381.6492
3/8	95.6949	408.4551	1898.9728	2405.1028	1635.7404
1/2	-25.5772	124.8237	1746.7674	1848.0139	499.2948
5/8	311.1548	225.8559	1512.5886	2049.5793	905.4336
3/4	56.8327	562.5504	1985.5764	2604.7596	2249.4016
7/8					
Friesian	195.9318	993.8992	1686.0863	2875.9474	3975.5968

Table 6e Analysis of Variance (Hierarchical classification) :  
 Variance components of Farm, Sire, Error and Total and  
 Additive Genetic Variance for Weight at Second Calving

Grade	VARIANCE COMPONENTS			Total	Additive Genetic Variance
	Farm	Sire	Error		
Sehwal	92.5818	195.9088	1549.1436	1837.6343	783.6352
1/8	699.3425	271.5479	1021.9515	1992.8419	1086.1916
1/4	206.9238	41.5764	1717.5971	1966.0973	166.2956
3/8	65.3837	445.4511	1449.0157	1959.8506	1781.8044
1/2	-70.5432	-17.3976	1321.3333	1233.0924	-70.7904
5/8	-235.8524	1059.5150	1391.1000	2164.5606	4157.2520
3/4	55.7883	207.6800	1450.0281	1713.4965	830.7200
7/8					
Friesian	1351.5639	385.0046	1208.9647	2925.5332	1460.0184

Table 6f Analysis of Variance (Hierarchical classification) :  
 Variance components of Farm, Sire, Error and Total and  
 Additive Genetic Variance for Weight at Third Calving

Grade	VARIANCE COMPONENTS			Total	Additive Genetic Variance
	Farm	Sire	Error		
Sahiwal	34.1077	120.6173	1521.3770	1676.1021	482.4692
1/8	-507.1474	1332.5929	566.1474	1942.1597	7530.5716
1/4	618.2395	120.2713	1428.5454	2167.0563	481.0852
3/8	38.2395	320.7816	1335.7153	2024.7974	1285.1264
1/2	-125.5106	99.5300	1124.5500	1098.3994	397.4400
5/8	501.5042	564.1234	964.4000	1850.0527	2256.5136
3/4	14.2719	-258.9176	1645.2000	1598.5543	-1035.6704
7/8					
Friesian	1379.8250	422.8328	1302.2454	3404.9532	1691.5312

Table 7a Estimates of Heritability and Standard Errors of Production Traits

Grade	First Lactation Yield	Second Lactation Yield	Third Lactation Yield	Life Time Production (3)	Life Time Production (5)					
	$h^2$	S.E	$h^2$	S.E	$h^2$	S.E				
Sahiwal	0.5121	0.2115	0.5609	0.2690	0.9265	0.3695	1	0.5571	0.9241	0.5348
1/8	0.5586	0.4124	0.4955	0.8122	0.6329	1	-	-	-	-
1/4	0.1397	0.1709	0.6085	0.2897	0.0978	0.2411	0.4550	-	0.3504	-
3/8	0.6375	0.2593	0.2284	0.1977	0.2851	0.2375	0.2426	0.2411	0.3108	0.3892
1/2	-0.0345	0.2706	0.901	0.5434	0.2088	0.4017	0.4131	0.4566	0.5645	0.6168
5/8	-0.1669	0.2967	0.5618	1	0.5405	1	0.3836	0.9965	0.0591	1
3/4	0.9769	0.6325	0.5679	0.7982	-0.1519	0.7246	1	1	0.1748	1
7/8*	-	-	-	-	-	-	-	-	-	-
Friesian	0.0301	0.3329	-0.4590	0.5293	-0.2612	0.4610	0.3948	0.6942	-	-

\* Sire component was zero.

genetic group at second calving and  $1/3$  genetic group at third calving.

#### GENETIC PARAMETERS

##### Heritability

The estimates of heritability of pure Sahiwal and its crosses with Friesian were estimated from half-sib analysis. The standard errors of the estimates were calculated after Dickerson (1960).

300-day Milk Yield : The estimate of heritability and their standard errors for first, second and third, 300-day lactation yields are given in table 7a. The heritability of first lactation milk production in Sahiwal cows was  $0.51 \pm 0.21$ . Among various crossbreds, all genetic groups had high heritability while  $1/4$  genetic group had low heritability. The heritability of first lactation milk production for Friesians and animals with  $1/2$  and  $5/8$  Friesian inheritance was not significantly different from zero. The heritability of second lactation milk production in Sahiwal was  $0.56 \pm 0.27$ . The heritability of second lactation production for  $1/2$  and  $5/8$  Friesian and Friesian animals was not different from zero. The heritability of the third lactation yield for Sahiwal was  $0.93 \pm 0.37$ . It was small in genetic groups with  $1/4$ ,  $1/3$ ,  $5/8$  and  $3/4$  Friesian inheritance and in Friesian animals. The heritability of milk production in general increased from first to the third lactation in Sahiwal cattle. In genetic group with  $1/4$  Friesian inheritance, the heritability increased from first to second lactation but in the third lactation its magnitude was very small and had high standard error. In  $3/8$  genetic group heritability of milk yield decreased from first to second but increased in the third lactation.

The heritability of milk yield in all the three lactations was not different from zero in 5/8 Friesian and Friesian animals.

Life Time Production : The heritability and standard error estimates of life time production (three lactations) for various genetic groups are given in table 7a. The estimate for Sahiwal animals was unity. The estimate of heritability of life time production for all genetic groups had very high standard error.

Weight at Calving : The estimates of heritability of first, second and third weights at calving are given in table 7b. The heritability of weight at first calving in Sahiwal animals was  $0.43 \pm 0.21$ . Among Sahiwal-Friesian crosses  $1/8$ ,  $3/8$ ,  $5/8$  and  $3/4$  showed higher heritability estimates for weight at first calving. The animals with  $1/4$  and  $1/2$  Friesian inheritance had smaller heritability estimates of  $0.16 \pm 0.16$  and  $0.27 \pm 0.39$  respectively. The heritability in Sahiwal cows at the second calving was  $0.43 \pm 0.26$ . The weight at second calving had a small heritability estimate in  $1/2$  and  $5/8$  genetic groups. The animals with  $1/4$  and  $3/8$  Friesian inheritance showed high heritability estimates of  $0.83 \pm 0.25$  and  $0.91 \pm 0.34$  respectively. The weight at third calving had a heritability of  $0.29 \pm 0.31$  in Sahiwal while in  $1/8$ ,  $5/8$  and  $3/4$  genetic groups the heritability was around zero.

Sahiwal animals showed decline in heritability from first through third weights at calving. In animals with  $1/8$ ,  $5/8$  and  $3/4$  Friesian inheritance, increase in Friesian inheritance showed a decline in heritability. The second weight at calving had higher heritability estimate than first and the third in animals with  $1/4$ ,  $3/8$  Friesian inheritance. In halfbreds the heritability estimate of weight at calving decreased from

Table 7b Heritability and Standard Error of Heritability of Weights at Calving and Relative Efficiency.

Grade	Weight at First calving		Weight at Second calving		Weight at Third calving		Relative Efficiency		Method 2 $h^2$
	$\hat{h}^2$	S.E.	$h^2$	S.E.	$h^2$	S.E.	Method 1, $h^2$	S.E.	
Sahival	0.4520	0.2074	0.4264	0.2645	0.2873	0.3084	0.4537	0.2145	0.6259
1/8	0.6121	0.4007	0.5453	0.5449	1.0	1.0	0.4418	0.4128	0.3524
1/4	0.1816	0.1612	0.8845	0.2538	0.2219	0.2984	-0.0046	0.1664	0.0235
3/8	0.6798	0.2588	0.9091	0.3409	0.6537	0.3590	0.5762	0.2481	0.6006
1/2	0.2701	0.3919	-0.0574	0.3726	0.3618	0.5302	-0.2807	0.2558	-
5/8	0.4407	0.4154	1.0	1.0	1.0	1.0	0.1661	0.3684	-
3/4	0.3635	0.5334	0.4348	0.7274	-0.8229	0.7365	0.4383	0.5323	1
7/8	-	-	-	-	-	-	-	-	-
Friesian	1.0	1.0	0.4990	0.6185	0.4967	0.7949	0.1360	0.5298	0.0991

first to second calving, it increased in third calving.

Relative Efficiency : The heritability estimate of relative efficiency was estimated in two ways. First, considering the relative efficiency as a variable and a regular half-sib analysis was run. Second, the heritability estimate was calculated from the heritability estimates, coefficients of variation, phenotypic and genetic correlations of the two variables i.e. 300-day first lactation yield and weight at first calving. The heritability was estimated following Sutherland (1965) as detailed under methodology. The estimates from the second method would be more valid because they would be independent of scale effects. The heritability estimates of relative efficiency are given in table 7b. The heritability estimates from both the methods show that the relative efficiency was highly heritable in Sahiwal, 1/8, 3/8 and 1/4 genetic groups. The results of heritability estimated by considering it as a ratio are given in parentheses. The magnitude of heritability estimates was  $0.45 \pm 0.21$  (0.63),  $0.44 \pm 0.41$  (0.35),  $0.58 \pm 0.23$  (0.60) and  $0.43 \pm 0.53$  ( $>1$ ) respectively. The heritability of relative efficiency of 1/2 and 5/8 Friesian animals could not be estimated by second method due to the negative heritability estimates of first 300-day lactation yield.

The standard errors of heritability estimates in general, and in animals having more than 1/2 Friesian inheritance in particular, were very high. The estimates with higher standard errors (even higher than estimates themselves) were not (considered) significantly different from zero. Heritability estimates with negative signs were not significantly different from zero.

## Correlations

### Relationships between Production Traits

300-day Lactation Yields at various Lactations : Phenotypic and genetic correlations between the milk yield from first through fifth lactation have been presented in tables 8a and 8b respectively. The phenotypic correlation between first and second lactation yield was 0.12 in Sahiwal. The correlation between the two lactations increased in animals with  $1/8$ ,  $1/4$  and  $3/8$  Friesian inheritance. In  $1/2$  and  $5/8$  Friesians the phenotypic correlations decreased. The estimates were of the order of 0.49 and 0.30 respectively. The phenotypic correlations increased in  $3/4$  Friesian and Friesian animals. The magnitude of correlations was 0.63 and 0.76 respectively.

The genetic correlations between the two traits were more than unit in Sahiwal and in animals with  $1/8$  Friesian inheritance. Animals with  $1/4$  and  $3/8$  Friesian inheritance had genetic correlations of 0.37 and 0.43 respectively between first and second lactation milk production. Animals with  $3/4$  Friesian inheritance had high genetic correlation of 0.85 between the two traits.

The phenotypic correlation between various lactations had the highest magnitude of 0.66 among all possible phenotypic correlations in Sahiwal cattle. The phenotypic correlation between first and fifth lactation had the lowest magnitude (0.09).

The genetic correlation between first lactation milk yield with second and third; and second lactation milk yield with third and fourth

Table No. 8a Phenotypic Correlations Between various  
300-day Lactation Yields

Lactation No.		Second	Third	Fourth	Fifth
First	Sahiwal	0.1156	0.1590	0.1616	0.0919
	1/8	0.4072	0.5222	0.3958	-
	1/4	0.5434	0.5513	0.4089	0.3717
	3/8	0.5601	0.4441	0.2680	0.2092
	1/2	0.4895	0.4447	0.4857	0.3811
	5/8	0.8958	0.5252	0.4710	-0.0500
	3/4	0.6634	0.6374	0.6335	0.3025
	7/8				
	Friesian	0.7603	0.5961	0.2963	0.3325
Second	Sahiwal		0.5412	0.5420	0.4149
	1/8		0.5173	0.0724	-
	1/4		0.6151	0.5899	0.5954
	3/8		0.5369	0.3765	0.3587
	1/2		0.6520	0.6812	0.4861
	5/8		0.7085	0.6065	0.9961
	3/4		0.7032	0.5380	0.0557
	7/8				
	Friesian		0.6872	0.4384	0.4792
Third	Sahiwal			0.5815	0.6317
	1/8			1.0000	-
	1/4			0.5014	0.5376
	3/8			0.4869	0.4834
	1/2			0.6950	0.5840
	5/8			1.0000	0.6142
	3/4			0.5140	0.3630
	7/8				
	Friesian			0.5997	0.3376
Fourth	Sahiwal				0.0561
	1/8				-
	1/4				0.7644
	3/8				0.4258
	1/2				0.7435
	5/8				0.4771
	3/4				0.3813
	7/8				
	Friesian				-0.0005

Table No. 8b Genetic Correlation between various  
300-day Lactation Yields

Lactation No.		Second	Third	Fourth	Fifth
First	Sahiwal	>1.0000	>1.0000	0.6396	=
	1/8	>1.0000	>1.0000	>1.0000	=
	1/4	0.3713	>1.0000	>1.0000	>1.0000
	3/8	0.4327	0.7869	>1.0000	=
	1/2	=	=	=	=
	5/8	=	=	=	=
	3/4	0.3530	=	0.8334	<1.0000
	7/8	=	=	=	=
	Friesian	=	=	=	=
Second	Sahiwal		>1.0000	0.9535	=
	1/8		>1.0000	>1.0000	=
	1/4		0.3582	>1.0000	=
	3/8		0.9639	>1.0000	=
	1/2		>1.0000	>1.0000	>1.0000
	5/8		0.3633	-0.1331	>1.0000
	3/4		=	>1.0000	-0.4340
	7/8		=	=	=
	Friesian		-0.0173	0.4311	>1.0000
Third	Sahiwal			>1.0000	=
	1/8			>1.0000	=
	1/4			>1.0000	0.3053
	3/8			>1.0000	=
	1/2			>1.0000	0.6028
	5/8			<1.0000	>1.0000
	3/4			=	=
	7/8			=	=
	Friesian			>1.0000	-0.2088
Fourth	Sahiwal				=
	1/8				=
	1/4				0.7603
	3/8				=
	1/2				0.5232
	5/8				-0.0009
	3/4				-0.9397
	7/8				=
	Friesian				-0.6099

lactation yields were greater than unity. The genetic correlation of first and second lactation production with fourth lactation production were 0.64 and 0.95 respectively.

Animals with  $1/8$  Friesian inheritance showed an increase in phenotypic correlation between lactations. The magnitude of phenotypic correlation between milk yield of first and second lactation was 0.41, of second and third lactation was 0.52 and of third and fourth lactation was 1.0. The genetic correlations between lactations in this group were greater than unity.

The phenotypic correlations between first and second, second and third, third and fourth, and fourth and fifth lactation yields of  $1/4$  genetic group were of the order of 0.54, 0.61, 0.50, 0.76 respectively. This showed an increase of relationship between the lactations as the animals matured. The magnitude of phenotypic correlation of first lactation with later lactations showed a decrease. The genetic correlation between first and second lactation production was 0.37, between second and third lactation production was 0.36 and between fourth and fifth lactation production was 0.76. The genetic correlation between second and fifth lactation production was 0.87 and between third and fifth was 0.31. All other genetic correlations in  $1/4$  Friesian animals were greater than unity.

The animals with  $3/8$  Friesian inheritance showed a decrease in the phenotypic correlation from first through fifth lactation. The phenotypic correlation between first and second lactation was 0.56 which was higher than phenotypic correlation of 0.53 between second and third lactation, 0.48 between third and fourth and 0.43 between fourth and fifth

lactation yield. The genetic correlations showed an increasing trend with attainment of maturity in  $3/8$  Friesian cattle.

in  $1/2$  Friesian group the magnitude of phenotypic correlation between first and second, second and third, third and fourth and fourth and fifth lactation was 0.49, 0.85, 0.70 and 0.74 respectively. The genetic correlations between all possible lactations were greater than unity. The genetic correlation between fourth lactation and fifth lactation production was 0.52.

The  $5/8$  Friesian animals had lowest phenotypic correlation between first and second lactation milk production among all the genetic groups. The magnitude was 0.30. The phenotypic correlation increased to 0.71 in second and third lactation and reached unity between third and fourth lactations. But the correlation between fourth and fifth lactation was as low as 0.48 when compared to the earlier lactations. The genetic correlation between second and third lactation production was 0.37. All other genetic correlations were negative except correlation between second and fifth lactation which was equal to 1. The genetic correlation between third and fourth lactation yield was - 1.

Animals with  $3/4$  Friesian inheritance showed phenotypic correlation of 0.63 between first and second lactation milk production. The correlation was 0.70 between second and third lactation but in later lactations the magnitude decreased. Phenotypic correlation between third and fourth, fourth and fifth lactation production was 0.51 and 0.38 respectively. A high genetic correlation of 0.85 between milk production in first and second lactation was observed in the  $3/4$  Friesian group. The genetic correlation of less than - 1, and - .99 were observed between the

Table No. 8c Correlations between Production Traits

Corr.	Character	Grade	First Lactation	Life time production(3)	Life time production (5)		
<u>Pheno.</u>	Relative Efficiency	Sahiwal	0.8432	0.6537	0.5930		
		1/8	0.9256	0.4987	-		
		1/4	0.8477	0.6703	0.4408		
		3/8	0.8595	0.6430	0.4193		
		1/2	0.9538	0.6895	0.6987		
		5/8	0.8724	0.6334	-		
		3/4	0.8023	0.5819	0.6716		
		7/8	-	-	-		
		Friesian	0.8110	0.4396	0.2600		
		<u>Genetic</u>	"	Sahiwal	>1.0000	>1.0000	>1.0000
				1/8	>1.0000	-	-
				1/4	- <sub>4</sub>	-	-
				3/8	0.8378	>1.0000	0.3679
				1/2	<-1.0000	-	-
5/8	-			-	-		
3/4	>1.0000			>1.0000	>1.0000		
7/8	-			-	-		
Friesian	<-1.0000	>1.0000	-0.1474				
<u>Pheno.</u>	First Lactation	Sahiwal		0.7204			
		1/8		0.7713			
		1/4		0.8311			
		3/8		0.8119			
		1/2		0.7477			
		5/8		0.5814			
		3/4		0.8793			
		7/8		-			
		Friesian		0.6951			
		<u>Genetic</u>	"	Sahiwal		>1.0000	
1/8				>1.0000			
1/4				>1.0000			
3/8				>1.0000			
1/2				-			
5/8				-			
3/4				>1.0000			
7/8				-			
Friesian		>1.0000					

first and second and fourth and fifth lactations respectively.

A decline was observed in the phenotypic correlation between various lactation yields of Friesian animals. They had the highest phenotypic correlation of 0.76 between first and second lactation, which decreased to 0.69 between second and third lactation, 0.60 between third and fourth lactation and zero in the fourth and fifth lactation. Genetic correlation of -0.02 between second and third, -0.61 between fourth and fifth lactation yield was observed. Genetic correlation of greater than one was observed between third and fourth lactation yield.

300-day First Lactation Yield with Life Time Production (three lactations) :

The first lactation milk yield had a high phenotypic correlation with life time production. The phenotypic and genetic correlations between the two traits are given in table 8c.

Phenotypic correlation of 0.72 was observed between 300-day first lactation yield with life time production. Similar correlations in crossbreds revealed that the first lactation yield had highest phenotypic correlation of 0.83 with life time production in 3/4 Friesian animals. The lowest phenotypic correlation between first lactation production and life time production of 0.58 was observed in 5/8 genetic group. Genetic correlation between these traits was observed to be more than unity except in 1/2 and 5/8 Friesian animals in which the sire component of the first lactation yield was negative.

Relative Efficiency with Life Time Production (Three Lactations ; Five Lactations) :

The phenotypic and genetic correlations between relative efficiency of milk production and life time production upto three lactations and upto

five lactations are detailed in Table 8c.

The relative efficiency had a high phenotypic correlation with life time production (three lactations) ranging from 0.44 for Friesian cattle to 0.69 in 1/2 Friesian. The phenotypic correlation for Sahiwal cows was 0.65. The phenotypic correlation of relative efficiency with life time production (five lactations) was also of a high magnitude. There was a positive correlation of 0.59 for Sahiwal cows. The correlation was highest for 1/2 Friesians (0.70) and lowest for Friesians (0.28). The phenotypic correlation of relative efficiency and life time production (five lactations) for the 3/4 Friesian animals was 0.67.

The sire component of life time production was negative in genetic groups with 1/8, 1/4, 1/2 and 5/8 Friesian inheritance. Consequently, no genetic correlation could be estimated with relative efficiency in these genetic groups. The genetic correlation between relative efficiency and life time production for three lactations was greater than unity in cross breeds. The genetic correlation of relative efficiency with life time production (five lactations) was greater than unity in Sahiwal and 3/4 Friesian cattle. In the 3/8 genetic group the genetic correlation between relative efficiency and life time production (five lactations) was 0.37. There was a negative genetic correlation (-0.15) between the two traits in Friesian cattle.

#### Relationships between Growth and Production Traits

##### Birth Weight with 300-day Lactation Yield (First, second and third) :

The phenotypic correlation between the birth weight and the

Table No. 9a Correlation of Birth Weight with Production Traits

Correlation	Grade	Birth weight x First lactation	Birth weight x Second lactation	Birth weight x Third lactation	Birth weight x Relative Efficiency	Birth weight x Life time Production (3 lactation)
<u>Phenotypic</u>						
	Sahiwal	-0.0520	0.0079	0.0320	-0.1125	0.0606
	1/8	0.0641	0.1112	-0.0012	0.0316	0.1525
	1/4	0.1784	0.1927	0.2135	0.0810	0.2553
	3/8	-0.0456	-0.0079	-0.0208	0.1893	0.0077
	1/2	0.0992	0.0600	0.0777	0.0496	0.0879
	5/8	-0.0254	0.1337	0.0395	-0.0851	-0.0532
	3/4	0.0672	0.2950	0.2726	-0.1110	0.4627
	7/8	-0.1209	0.2093	-0.2386	-	-0.2625
	Friesian	0.4501	0.6754	0.3703	0.1113	0.8079
<u>Genetic</u>						
	Sahiwal	-0.4897	-0.5385	-0.6133	-0.5488	-0.4175
	1/8	0.3021	-0.2138	0.9836	0.7269	0.2178
	1/4	0.5425	0.0807	0.8207	-	0.6133
	3/8	0.1022	0.3741	0.6454	-0.1304	0.3946
	1/2	-	0.3031	0.4972	-	-0.1602
	5/8	-	0.6869	-0.0874	-0.9557	0.9784
	3/4	0.2398	0.3514	-	-0.2160	0.1537
	7/8	-	-	-	-	-
	Friesian	<-1	-	-	<-1	-0.4372

first lactation yield was of very small magnitude. In Sahiwal birth weight was negatively correlated with the first lactation milk production. This correlation was negative for 3/8 and 5/8 genetic groups. The magnitude of phenotypic correlation in these groups was - 0.05, - 0.04, - 0.02 respectively. The phenotypic correlation of 0.45 between birth weight and first lactation production was estimated in Friesian group. In other genetic groups the birth weight had a small positive correlation ranging from 0.06 to 0.18.

The birth weight had negative genetic correlation with the first lactation milk production in Sahiwal cows (- 0.49) and Friesian cows (- 1.0). Birth weight had a positive genetic correlation with first lactation production in 1/8 (0.30), 1/4 (0.54), 3/8 (0.10) and 3/4 (0.29) genetic groups. Genetic correlation could not be estimated in 1/2 and 5/8 genetic groups because the sire component was negative.

The phenotypic correlation of birth weight and second lactation milk yield was ranging from 0.01 to 0.30 in all genetic groups. In Friesian cows a high correlation of 0.68 between birth weight and second lactation milk production was estimated.

There was a negative genetic correlation of the order of - 0.54 between birth weight and second lactation production in Sahiwal cows. The genetic correlation between the two traits was - 0.21 in 1/8 genetic group. In other genetic groups the genetic correlation between birth weight and milk production ranged from 0.03 to 0.37 but in 5/8 genetic group the genetic correlation was of the order of 0.69.

Birth weight was negatively correlated with the milk production in third lactation in 1/8 (- 0.001), 3/8 (- 0.02) genetic groups. In other genetic groups the phenotypic correlation between birth weight and

third lactation production ranged from 0.03 in Sahiwal to 0.37 in Friesian.

A high negative genetic correlation between birth weight and third lactation production was ( $-0.61$ ) in Sahiwal cows. Negative genetic correlation of  $-0.09$  was observed between birth weight and third lactation production in  $5/8$  Friesians.

The phenotypic correlation between birth weight and milk production in first and second lactation increased in Sahiwal,  $1/8$ ,  $1/4$ ,  $3/8$ ,  $5/8$ ,  $3/4$  Friesian and Friesian animals. Similar increase in genetic correlation was observed in animals with  $3/8$ ,  $1/2$ ,  $5/8$ ,  $3/4$  Friesian inheritance. In Sahiwal,  $1/8$ , and  $1/4$  genetic groups there was a decrease in genetic correlations. The genetic correlation between birth weight and milk production in third lactation was of higher magnitude in all genetic groups.

Birth Weight with Life Time Production (Three lactations) : The phenotypic correlation between birth weight and life time production in all the genetic groups was higher as compared to the phenotypic correlation between birth weight and first lactation. The magnitudes of phenotypic correlation varied from 0.06 in Sahiwal cattle to 0.81 in Friesian animals. The birth weight was negatively genetically correlated with life time production (three lactations) in Sahiwal,  $1/2$  Friesian and Friesian animals. These correlations were higher than those of the birth weight and first lactation milk yield. The birth weight was positively correlated with life time production (three lactations) in all other genetic groups. The genetic correlation was highest (0.98) in  $5/8$  genetic group and ranged from 0.15 to 0.61 in other genetic group.

Birth Weight with Relative Efficiency : The birth weight had a negative

phenotypic and genetic correlation with relative efficiency in Sahiwal, 5/8 and 3/4 genetic groups. The phenotypic correlation had low magnitude varying from 0.05 to 0.19 in other genetic groups. The 1/4 genetic group had a high genetic correlation of 0.73 between birth weight and relative efficiency while the 5/8 genetic group had genetic correlation of - 0.26 between birth weight and relative efficiency. The results showed that birth weight had negative genetic correlation with the relative efficiency in all the genetic groups except 1/4.

Weight at 19 weeks with 300-day First Lactation Milk Yield : The weight at 19 weeks was negatively correlated with first lactation yield. The phenotypic genetic correlation between the two traits in Sahiwal cows was - 0.04 and - 0.36 respectively. (Table 9b). The magnitude of phenotypic correlation between the 19 weeks weight and first lactation yield was small ranging from - 0.11 to 0.23 in all genetic groups. The Friesian animals showed a high phenotypic correlation between 19 weeks body weight and first lactation milk production. The genetic correlation between 19 weeks body weight and first lactation yield in Sahiwal 1/4 and 3/4 genetic groups were - 0.36, - 0.12 and - 0.12 respectively.

Weight at first Calving with 300-day First Lactation Yield : There was positive phenotypic and genetic correlation between weight at first calving and first lactation milk yield in all genetic groups. The results of the correlation are detailed in table 9b. Phenotypic correlation between weight at first calving and first lactation production was 0.15 in Sahiwal. Among other genetic groups the phenotypic correlation between the two characters ranged from 0.05 in 1/8 to 0.67 in 1/4. The genetic correlation between weight at first calving and first lactation yield was

Table No. 9b Correlation between Growth and Production traits

Correlation	Grade	Weight at	Weight at	Weight at	Weight at
		19 weeks x 1st Lact. Yield.	1st calving x 1st Lact. Yield.	2nd calving x 2nd Lact. Yield.	3rd calving x 3rd Lact. Yield.
<u>Phenotypic</u>					
	Sahiwal	-0.0350	0.1461	0.1623	0.1616
	1/8	0.0526	0.0465	0.3322	-0.0840
	1/4	0.2466	0.6704	0.2758	0.5104
	3/8	-0.1114	0.1287	0.1476	0.4441
	1/2	0.2810	0.0919	0.0243	0.4447
	5/8	0.1273	0.2577	0.3245	0.2994
	3/4	0.0021	0.3122	0.4946	0.4567
	7/8	0.2021	0.2436	0.4229	-0.4299
	Friesian	0.4650	0.4633	0.4234	0.6029
<u>Genetic</u>					
	Sahiwal	-0.3643	0.0772	0.0899	0.6393
	1/8	-	0.5020	<-1	<-1
	1/4	-0.1219	0.0994	0.4513	>1
	5/8	-	0.2349	0.7136	0.7869
	1/2	-	-	-	-
	5/8	-	-	0.6641	0.5717
	3/4	0.1156	0.1075	-0.0759	<-1
	7/8	-	-	-	-
	Friesian	-	>1	-	-

0.03 in Sahiwal, 0.50 in 1/8, 0.10 in 1/4, 0.23 in 3/8, 0.11 in 3/4 genetic groups. The genetic correlation between these characters exceeded unity in Friesian animals.

Weight at Second calving with 300-day Second Lactation Yield : The phenotypic correlations between weight at second calving and second lactation milk production in various genetic groups ranged from 0.03 to 0.49. The phenotypic correlation between the two characters in Sahiwal cows was 0.16. The lowest phenotypic correlation of 0.03 was estimated in halfbreds and highest correlation of 0.49 in 3/4 genetic group. The genetic correlation between these two characters in all the genetic groups ranged between - 0.08 to 0.71. The genetic correlation between weight at second calving and second lactation production was less than - 1 in 1/8 genetic group.

Weight at third Calving with 300-day Third Lactation Yield: Weight at third calving was positively correlated with third lactation production in Sahiwal cows (0.13) and all other genetic groups except 1/8 which had a negative correlation of - 0.08. The phenotypic correlation of two traits in other genetic groups ranged from 0.30 to 0.86. A high genetic correlation between body weight at third calving and third lactation production was observed in Sahiwal, 1/4, 3/8 and 5/8 genetic groups. The magnitude of genetic correlations was 0.64, greater than one, 0.79 and 0.57 respectively. The weight at third calving was negatively correlated with third lactation production in animals having 1/8 and 3/4 Friesian inheritance.

An exhaustive study of the correlations between growth and

lactation characters revealed that the production characters were negatively correlated to body weight in earlier stages. As the animals grew there was increase in correlations, so that the correlations were positive when the animals reached first lactation. A further increase in the correlations was observed with the weight at later calvings.

CHAPTER VI  
D I S C U S S I O N

### 300-day Milk Yield

Sahiwal : Pure bred Sahiwal animals kept at Ambala were best milk yielders and maintained this superiority throughout their lactational life when compared to the Sahiwal animals of other farms.

Crossbreds : The animals with  $1/8$  Friesian inheritance had the highest first and second lactation records at Mhow. From second lactation onwards, the animals of  $1/8$  genetic group at Lucknow, were the best performers. Among the  $1/4$  genetic group at various locations, the animals at Mhow performed best through third lactation. The animals with  $3/8$  Friesian inheritance had best lactation records at Jabalpur and Mhow for first two lactations. In later lactations their performance was best at Ambala and Lucknow. Halfbred animals at Mhow were the best performers as compared to those at other locations.

From the results it became evident that animals with less than  $1/2$  Friesian inheritance at Jabalpur and Mhow yielded more milk in earlier lactations. In later lactations those at Ambala and Lucknow were comparatively better producers.

The  $5/8$  genetic group was the best performer for all the five lactations at Dehradun. Animals with  $3/4$  Friesian inheritance had highest lactation yield at Ambala in earlier lactations and at Lucknow in later lactations. The animals of  $7/8$  genetic group performed best at Dehradun in first and second lactation and at Jabalpur in later lactations. Performance of Friesian animals was invariably good at Meerut as compared to those at other farms.

Various genetic groups at these farms showed that animals with  $1/2$  or less Friesian inheritance performed best at Jabalpur and Mhow. While

those with higher Friesian inheritance did well at Dehradun and Ambala.

The hypothesis under test was that some genetic groups did consistently well at some locations as compared to others. Tandon (1951), Singh and Desai (1964), Naidu and Desai (1966) have accepted the proposition that the animals maintained at Northern zone farms performed similarly, and those in Southern zone also performed similarly. This contention led them to divide the farms in two zones. So the analysis reported by these authors was within each region separately. The results from this investigation do not support their contention because the farms effect is significant. The results show that animals with 50 per cent or less Friesian inheritance did better at farms which have low temperature and high rainfall and the animals with more than 1/2 Friesian inheritance did better at farms having hot climate and less rainfall.

Kramer's (1957) modification of Duncan's Multiple range test showed that, in lower crosses 1/8 and 1/4 Friesians, the lactation yield was not significantly ( $p < 0.05$ ) different from Sahiwal. The animals with 3/8 and 1/2 Friesian inheritance were not significantly ( $p < 0.05$ ) different from each other but differed significantly ( $p < 0.05$ ) from Sahiwal, 1/8 and 1/4 genetic groups. The animals of 3/4 genetic group were not significantly different ( $p < 0.05$ ) from 5/8 genetic group in milk production for all the five lactations. But they yielded significantly higher milk than 1/2, 3/8 and 7/8 Friesian animals. Friesian animals had the highest yield of milk followed by (5/8, 3/4) and next highest were (1/2, 3/8, 7/8). The (Sahiwal, 1/8, 1/4) were poor milk yielders.

From these results it became evident that the milk production increased with increase in Friesian inheritance upto  $3/4$  Friesian. There was a decline in milk yield between  $3/4$  to  $7/8$ . The optimal Friesian inheritance for high milk production was ( $5/8$  to  $3/4$ ). It seems that milk production in crossbreds was not only dependant on Friesian inheritance but the contribution of Sahiwal inheritance was also important for higher milk production. The Sahiwal inheritance, optimal for milk production, was between ( $5/8$  to  $1/4$ ). There was nothing to gain by going above  $3/4$  Friesian and  $5/8$  Sahiwal.

The average production of halfbreds when compared to the weighted mean of the production of two contemporaries (Sahiwal and Friesian animals in the data) showed that the halfbreds had significantly higher yield than that of the mid parent value. There was a significant increase of 269 kg. in first, 320 kg. in second, 321 kg. in third, 236 kg. in fourth and 190 kg. in fifth lactation over the corresponding mid parent values. Evidently, it may be concluded that the effect of genes for milk production was not primarily additive, the dominance deviation was also there. Heterosis in crossbreds was also reported by Bhasin and Desai (1967) in halfbreds of Haryana-Sahiwal cross. In their results the halfbreds yielded higher than the superior parent. Similar type of hybrid vigour has been reported in crosses between Friesian, Ayrshire and Jersey from the work done at the Institute of Animal Genetics, Edinburgh (A. Robertson, 1965 & F. Robertson, 1965). Bereskin and Buchberry (1966) have also given a report of heterotic vigour for milk production in  $F_1$  produced by crossing.

In the present investigation it was observed that the effect of heterosis was increasing from first lactation upto third lactation, after which the effect of heterosis gradually decreased. The effect of heterosis

seems to have some relation with the maturity of the animal.

Similar observations were true for the life time production upto three lactations and upto five lactations. In halfbred animals there was an increase of 904 kg. milk upto three lactations and 788 kg. upto five lactations when average of halfbred animals was compared to the mid parent value.

A comparison (Fig. 2.1) of lactation curves of various genetic groups showed that lactational maturity was attained at fourth lactation in all the genetic groups. This reflected that there was an increase in number of functional genes responsible for milk yield which increased the yield from one lactation to other and most genes expressed completely around fourth lactation. During this time the genes responsible for body growth would have completely switched over their action and would have indirectly influenced the production of milk.

#### Weight at Calving

It has been observed that the animals with  $1/2$  or less Friesian inheritance showed rapid growth at Mhow and Ambala while those with more than  $1/2$  Friesian inheritance grew best at Meerut and Ambala. From the point of view of growth of the animals effect of Mhow was significant for animals with  $1/2$  or less level of Friesian inheritance and of Meerut for those with more than  $1/2$  Friesian inheritance.

A comparative study of various genetic groups showed that the growth of Sahiwal cattle was poor (Fig. 2.3) as compared to various crossbreds. The Sahiwal cows, however, were significantly heavier than  $1/8$  and  $1/4$  genetic groups at first calving (Fig. 2.4). But their weight was significantly lower than  $1/8$  genetic group at the third calving. From third calving onwards the  $1/8$  Friesian animals gained weight so rapidly that at the fifth

calving the weight of animals with  $1/8$  Friesian inheritance was more than that of Friesian animals. There was no significant difference between the weights at first calving of animals with  $5/8$ ,  $3/4$  and  $7/8$  Friesian inheritance. Among these genetic groups the growth of  $3/4$  Friesian animals was most rapid. (Fig. 2.3). Growth in animals with  $5/8$  Friesian inheritance from second calving onwards was much the same as that of  $1/2$  Friesian, there was no significant difference ( $p < 0.05$ ) between the two genetic groups. The animals with  $3/8$  and  $1/2$  Friesian inheritance did not differ significantly ( $p < 0.05$ ) but both of them had significantly lesser weight than animals with  $5/8$  Friesian inheritance at the first calving. At fifth calving animals with  $1/8$ ,  $3/8$ ,  $1/2$ ,  $5/8$  and  $3/4$  Friesian inheritance were heavier than the Friesian cows. However,  $3/4$  genetic group was the only one which differed significantly ( $p < 0.05$ ) from the Friesian group.

Weights of halfbreds were significantly larger than the mid-parent value. A substantial increase in body weight of 16.5 kg. at first, 9.8 kg. at second, 21.4 kg. at third, 22.6 kg. at fourth and 29.8 kg. at the fifth calving above the mid-parent mean was observed. This increase in body weight was probably due to the non additive genetic effect of the genes influencing the body weight of the animal. Goswami and De (1963) while working with crossbreds of Red Sindhi and Sahiwal with Friesian showed pronounced heterosis for the weight at 12 months. The authors have reported that there was no heterotic effect on the birth weight of the halfbreds. The birth weight and other initial weights may not be affected by heterosis because they are considerably influenced by maternal effects. The maternal effects masked the effect of genes. Gradually the maternal effects diminish such that in later stages the animals become adapted to the

farm conditions. Therefore, the later weights show heterotic vigour which increases with the maturity.

#### Relative Efficiency :

The relative efficiency of milk production in Sahiwal animals was similar at all farms. The animals with  $1/8$  and  $1/4$  Friesian inheritance did not differ significantly ( $p < 0.05$ ) from each other and performed well at Mhow. The  $3/8$  and  $1/2$  genetic groups performed best at Jabalpur. The animals with  $1/2$  Friesian inheritance at Jabalpur had significantly higher relative efficiency when compared to halfbreds at other farms. The  $5/8$  genetic group showed better relative efficiency at Dehradun. This was because the animals at this place were lighter as well as highest milk yielders. The animals with  $3/4$  Friesian inheritance performed well at Ambala and Dehradun. Jullundur had the  $7/8$  genetic group with better relative efficiency. The Friesian cows at Meerut were the heaviest as well as the highest milk producers as compared to the Friesians at other farms. Therefore, the relative efficiency of the Friesian animals was very high at Meerut as compared to their counterparts at other farms.

The relative efficiency of milk production was lowest in Sahiwal animals and differed significantly ( $p < 0.05$ ) from all other grades. Though there was no difference between the first lactation production of Sahiwal,  $1/8$  and  $1/4$  genetic groups but both  $1/8$  and  $1/4$  animals had significantly ( $p < 0.05$ ) lower body weight. Therefore, the relative efficiency of  $1/8$  and  $1/4$  differed significantly ( $p < 0.05$ ) from that of Sahiwal. The magnitudes of relative efficiency were of the order of  $4.47 \pm 0.08$  kg./kg. body weight for Sahiwal,  $4.95 \pm 0.12$  kg./kg. body weight for  $1/8$  and  $4.91 \pm 0.07$  kg./kg. body weight for  $1/4$  genetic groups.

With an increase in Friesian inheritance there was an increase in relative efficiency of milk production. However, ( $1/8$  and  $1/4$ ), ( $3/8$  and  $1/2$ ), ( $5/8$  and  $3/4$ ) genetic groups differed significantly from each other. Among various crossbreds  $3/4$  genetic groups had highest relative efficiency of  $5.74 \pm 0.13$  kg. per kg. body weight while  $5/8$  produced  $5.68 \pm 0.12$  kg. of milk per kg. body weight. With increase in Friesian inheritance from  $3/4$  to  $7/8$  there was a sharp decline in the relative efficiency of milk production. The relative efficiency of  $7/8$  was not significantly different ( $p < 0.05$ ) from the  $1/2$  Friesian. The Friesian animals had the highest relative efficiency because they had significantly high milk production as compared to all other genetic groups. The relative efficiency of Friesian animals was  $6.22 \pm 0.21$  kg. per kg. body weight. The average of relative efficiency of Sahiwal animals from this investigation is in agreement with that reported by Singh and Desai (1964). The authors reported the relative efficiency of 4.4 lb./lb. body weight. But results of relative efficiency in crossbred groups reported in this investigation are not in agreement with those of Singh and Desai (1964). Their results showed  $1/2$  to be most efficiency in Northern region and  $5/8$  in the Southern region. It was observed from results reported herein that ( $3/4$  and  $5/8$ ) had the highest relative efficiency. There was a decline from  $3/4$  Friesian onwards.

As for other traits the animals with  $1/2$  Friesian inheritance differed significantly ( $p < 0.05$ ) in relative efficiency of milk production from Sahiwal and Friesian animals. The relative efficiency of  $1/2$  breeds was 0.45 kg. per kg. body weight higher than the mid parent value. The relative efficiency of halfbreds differed significantly from the mid parent

value. As was expected, from the heterosis for milk yield at first lactation and weight at first calving, the relative efficiency has also shown that the genes affecting it were not simply additive. The dominance deviation was also important.

#### LEAST SQUARE ANALYSIS

300-day Lactation Yield : It was hypothesised a priori that the grades, farms, periods and the lactation number or calving number would contribute significantly to the total variability. To study the contribution of each one of the main effects to the total variability of 300-day milk production and weights at calving, the data were subjected to a six-way cross classification fixed-effects model. All interactions were assumed to contribute very little to the total variation.

Among the main effects the lactation number contributed largest to the total variability. The cause of so much variation can be simply explained from Figure 2.1. It was observed that in all the genetic groups peak yield was attained at fourth lactation. Consequently, a progress in the production of milk was observed from the first lactation till such time that the lactational maturity was attained. This led to the contribution of lactation number to be large. The contribution of grades (genetic groups) was 3.37 per cent, which though statistically significant ( $p < 0.0005$ ) was not of a high magnitude. The effect of grades was obviously due to the diversity between various genetic groups, which are actually different populations. The effect of farms, and periods was significant but had smaller contribution of 0.81 per cent and 1.20 per cent respectively to the total variation. The effect

of farms was due to the difference in geographical situation and variation of climates from farm to farm which was reflected in the between farm component. Since the data has been collected over a period of thirty years, it would be difficult to suppose that there would not be any difference between years. However, there would be negligible difference between two or three consecutive years but there would be large differences between the periods. These differences may be due to the climatic variation over years e.g. heavy rainfall in one year and draught in the other. Such natural differences in environments accounted for the period effect. The effect due to breed of sire was not significant because the breed of sire is confounded with the genetic group, so it was accounted for by that effect. As mentioned under material the breed of sire classification of the data was affecting only the halfbred group in which both types of sires were used. All other genetic groups had same breed of the sire. The genetic groups having more than  $1/2$  level of Friesian inheritance were classified in the Friesian breed group and those having less than  $1/2$  level of Friesian inheritance were classified under the Sahiwal group. The breed of sire contribution was probably due to (i) both Sahiwal and Friesian sires had produced halfbred progeny by crossing of a Friesian female with Sahiwal bull and vice-versa; (ii) mating of a sire of one breed (Friesian) to a cow belonging to the genetic group produced by a sire of another breed (Sahiwal). This cross produced individuals which were classified in genetic groups with high Friesian inheritance having a Sahiwal grand parent. So the effect of breed of sire was not completely confounded with grade effect. Precisely, it can be said that the alternate crossing of the animals was the reason for the breed of sire contribution. The lowest contribution of the seasons proved that the season of birth of the animals did not affect the milk production.

Weight at Calving : The same analysis was run for the weights at calving, the results were similar. 91.75 per cent of the total variability was explained by error. Only 8.25 per cent contribution was due to main effects. The farm contribution was maximum which was due to climatic variations. The effects of grades, periods and number of calving were significant while those of seasons and breeds of sire were insignificant.

#### GENETIC PARAMETERS

The analysis of variance by least square technique showed that effect of various factors was significant. The relative magnitude of each factor was small. The largest contribution was that of grades and farms when lactation number was not considered since each lactation yield has been considered singly. This suggested that nothing would be gained by correcting the data for all these factors. However, the contribution of these effects, using a nested hierarchical model, running within grade analysis with farms ~~as~~ as the main effect, would take care of these. The analysis of variance was run on 300-day first, second, and third lactation yield, life time production, relative efficiency, weights at first, second and third calving. The results of mean squares, and variance components have been presented in Tables 5(a-b) respectively.

#### Heritability

The heritability was estimated by half sib correlation and the standard error of heritability was estimated after Fickerson (1960).

Heritability of 300-day First Lactation Milk Yield : Heritability of first lactation 300-day milk yield was  $0.51 \pm 0.21$  which showed it to be a highly heritable trait. The estimate was in agreement with results reported by Kooner (1963) and Patel (1956).

The estimates of heritability in various genetic group vary from - 0.03 to 0.98. The standard error of heritability estimate in 1/2 and higher levels of Friesian inheritance were higher than the estimates themselves. These estimates were not significantly different from zero. The estimates of heritability for the milk yield at first lactation in animals with 1/2, 5/8, and 3/4 Friesian inheritance and the Friesian animals was of a small magnitude. This could be due to small number of animals in each sire group. The magnitude of estimates of heritability for animals with 1/4, 1/8, and 3/8 Friesian inheritance was  $0.14 \pm 0.17$ ,  $0.56 \pm 0.41$  and  $0.67 \pm 0.26$ . The estimates are not comparable to the heritability of 0.19 reported by Mahadevan (1954). The author reported the estimate irrespective of the level of Friesian inheritance. The estimates of heritability reported by Naidu and Desai (1960) for the first lactation milk yield in animals with 4-15/32 Friesian inheritance was  $0.18 \pm 0.19$  for Northern region and  $0.50 \pm 0.27$  in the similar genetic group for Southern region.

Heritability of Later Lactations : The Sahiwal animals have shown an increase in heritability of later lactations when compared to that of first lactation milk yield. The heritability was  $0.56 \pm 0.27$  for second lactation and  $0.93 \pm 0.37$  for the third lactation. These results are similar to estimates of Mahadevan et al. (1952). In their case the heritability estimate of first lactation production was 0.14 which had increased to 0.34 for the later highest yielding lactation. The probable reason for the

third lactation to have a large magnitude of heritability might be the sire-year interaction which has inflated the sire component. This is partially reflected in the analysis where the period effect was significant and the constant for the third lactation was larger than that of the earlier lactations. The inflation of the sire component is evident from the tables 6b and 6c. It would be seen that the error component for second lactation milk yield was nearly same as that of the third lactation but the sire component in the third lactation was almost twice (less than twice) that of the second lactation milk production. The estimates of heritability of second and third lactations were not significantly different from zero in 1/8, 1/2, 5/8, 3/4 and Friesian animals. This was because the standard errors had exceeded the estimates themselves. The estimate of heritability for second lactation in animals with 1/4 Friesian inheritance was  $0.61 \pm 0.29$  much higher than that of the first lactation yield. Increase in heritability of later lactations was reported in Holstein animals by El Shimy (1956). The author showed that the estimate increased from 0.34 in first lactation to 0.36 in the second and 0.38 in the third lactation. Similar increase was reported by Martojo *et al.* (1963) who reported the heritability of second lactation to be 0.38 while that of the first lactation was 0.31.

Heritability of Life Time Production : The life time production of an animal is the milk produced by her (upto three lactations), (five lactations). As was expected from the higher heritability estimate of third lactation production the heritability of life time production in Sahiwal animals was unity with high standard error. The heritability of life time production (five lactations) in Sahiwal cattle was  $0.92 \pm 0.63$ .

Among the crossbreds 1/2, 5/8, 3/4 and Friesian animals had higher standard error estimates than the heritability itself. The heritability estimates for life time production (three lactations) were varying from 0.24 to 0.46. The heritability of life time production (three lactations) was  $0.46 \pm 0.33$ ,  $0.24 \pm 0.24$  and  $0.41 \pm 0.46$  for 1/4, 3/8 and 1/2 genetic groups respectively. The estimate for the life time production for five lactations was  $0.31 \pm 0.39$  for 3/8 and  $0.56 \pm 0.62$  for 1/2 genetic group.

Heritability of Weights at Calving : The estimate of heritability for body weight at first calving of Sahiwal was  $0.43 \pm 0.21$ . The heritability of estimates for weight at first calving in other crossbred genetic groups was also of a high magnitude except for the 1/4 genetic group. The heritability of body weight at first calving for animals with 1/4 level of Friesian inheritance was  $0.16 \pm 0.16$ . The estimate of heritability for other groups was  $0.61 \pm 0.40$  for 1/8;  $0.68 \pm 0.26$  for 3/8;  $0.27 \pm 0.39$  for 1/2;  $0.44 \pm 0.42$  for 5/8;  $0.86 \pm 0.59$  for 3/4 genetic group. The estimate exceeded unity in Friesian animals. This shows that the trait is highly heritable in all the genetic groups except for 1/4, in which it is less heritable. The results are in close agreement with those reported for Holstein, Jersey and Guernsey by Miller and Mc Gilliard (1959) Mc Daniel and Legates (1965).

Heritability of Weights at Later Calving : The heritability estimates for second and third calving have been reported in Table 7b. The body weight at second and third calving was less heritable than the weight at first calving. The heritability estimates of second and third calving in Sahiwal animals were  $0.43 \pm 0.26$  and  $0.29 \pm 0.31$  respectively. The heritability of weight at second calving in 1/8 genetic group had shown a decrease

( $0.55 \pm 0.54$ ). The heritability of weight at second calving in  $1/4$  and  $3/8$  genetic groups was much higher,  $0.88 \pm 0.25$  and  $0.91 \pm 0.34$ . But in the third calving the heritability had decreased, the magnitude of heritability was  $0.22 \pm 0.30$  for  $1/4$  and  $0.65 \pm 0.34$  for the  $3/8$  genetic group. The results from the present investigation support the conflicting reports in the literature. Clark et al. (1962) from his results on Holstein cows had shown that the heritability showed a decline in later calvings. The results of Mc Daniel and Legates (1965) reported an increase of heritability from body weight at first calving ( $0.44 \pm 0.11$ ) to the later calvings upto 5 years ( $0.58 \pm 0.11$ ) and the later calvings from 5-10 years ( $0.57 \pm 0.11$ ).

Heritability of Relative Efficiency : The heritability of relative efficiency was estimated by two methods first considering the relative efficiency of milk yield as a variable and second considering it as a ratio of two variables. The estimates of heritability by second method was more reliable since the heritabilities of both the traits are taken into consideration. The heritability of relative efficiency of Sahiwal animals was  $0.45 \pm 0.22$  by the first method and  $0.63$  by the second method. The results showed that the trait is highly heritable in Sahiwal cattle. The results are in agreement with those reported by Singh and Desai (1964).

Among the crossbreds  $1/8$ ,  $3/8$  the heritability estimate of relative efficiency of milk production were  $0.43 \pm 0.41$  and  $0.58 \pm 0.25$  as estimated by half sib analysis, and  $0.35$  and  $0.60$  as calculated by the second method. The crossbred with more than  $1/2$  Friesian inheritance had standard error higher than the estimates themselves. Heritability estimates for  $1/2$  and  $5/8$  genetic groups were  $-0.28 \pm 0.26$  and  $-0.17 \pm 0.37$  respectively as

computed by half sib correlation. The estimates could not be calculated by the second method as the heritability of the first lactation yield in both genetic groups was negative. The heritability estimates of relative efficiency in 5/4 genetic group and Friesians was  $0.41 \pm 0.53$  and  $0.14 \pm 0.53$  respectively. The heritability as calculated by second method resulted in estimates of greater than one for 3/4 genetic group and 0.19 for Friesian. The estimates of heritability in literature are of crossbreds without considering the level of exotic inheritance. Such estimates have been reported by Singh and Desai (1964). Crossbreds of Northern region and Southern regions had heritability as high as  $0.51 \pm 0.25$  and  $0.77 \pm 0.31$  respectively. These results cannot be compared to those of the present investigation.

When all the estimates of heritability for various production and growth traits were observed simultaneously, it was seen that the heritability for genetic groups with 1/2 or more than 1/2 Friesian inheritance had much higher standard errors as compared to the magnitude of estimates. This is definitely indicative of large contribution of sampling variance due to a very small sample size in these genetic groups.

### CORRELATIONS

#### Relationship between Production Traits

300-day Milk Yield at various Lactations : In Sahiwal animals there was an increase in magnitude of phenotypic correlations from first lactation towards maturity. The correlation between first and second, second and third, third and fourth, and fourth and fifth lactation yields were 0.12, 0.54, 0.58 and 0.66 respectively. The corresponding genetic correlations were of the order of 1. .

The phenotypic correlation between first and second, second and third lactation yields in  $1/8$  genetic group were 0.41, 0.52 respectively. Beyond this the correlations approached unity. The genetic correlations were equal to one in this group. The phenotypic correlation between first and second, second and third, third and fourth, fourth and fifth lactation in  $1/4$ ,  $1/2$ , and  $5/8$  genetic groups showed an increasing trend towards maturity. The  $3/8$  and  $3/4$  Friesian and Friesian animals did not show such a trend. In all the genetic groups there was an increasing trend of genetic correlations from earlier lactations to the lactation yield at maturity so that at maturity the genetic correlations approximated unity.

Mahadevan (1954) reported the correlations between various lactations in crossbreds. The correlations were increasing with maturity only in animals with  $1/4$  European inheritance. The crossbreds with  $1/2$ ,  $5/8$  and  $3/4$  European inheritance showed decrease in genetic correlations. Similar decreasing trend has been observed in the present investigation in animals with  $3/8$  and  $3/4$  Friesian inheritance. But most of the crossbreds have shown an increasing trend of correlations with maturity. Barker and Robertson (1966) and Van Vleck and Bradford (1966) have reported an increase in the genetic correlations with maturity. The correlations reported by these authors were not significantly different from unity.

The correlation between first lactation with later lactations were either similar or showed some decline such that consecutive lactations had higher correlations as compared to other lactations. These results also confirm those reported by Barker and Robertson (1966).

First 300-day Lactation Yield with Life Time Production (three Lactation) :

The first lactation production had a very high phenotypic correlation with the life time production (three lactations). The magnitude of phenotypic correlations in Sahiwal,  $1/8$ ,  $1/4$ ,  $3/8$ ,  $1/2$ ,  $5/8$ ,  $3/4$  and Friesian animals was 0.73, 0.77, 0.83, 0.81, 0.75, 0.58, 0.83 and 0.70 respectively. The genetic correlations were not different from unity in all genetic groups. In  $1/2$  and  $5/8$  the sire component of the first lactation was negative so the genetic correlation could not be estimated. Such high correlation suggest the first lactation to be a good indication of the life time production of the animal.

Relative Efficiency with Life Time Production (three Lactation & Five

Lactations) : The relative efficiency was highly correlated with life time production (three lactations and five lactations) in all the genetic groups. The Friesian animals had a low phenotypic correlation of 0.26 between relative efficiency and life time production (three lactations). The genetic correlations between lifetime production (three lactations) and relative efficiency was unity in Sahiwal,  $3/8$ ,  $3/4$ , and Friesian animals. The correlation for other genetic groups could not be estimated owing to small size of the data. These correlations showed that the relative efficiency can be effectively used to predict the life time production of the animals. This is more reliable than either the lactation or the body weight alone since the relative efficiency takes care of both the traits.

Relationship between Growth and Production Traits

Birth weight with 300-day Lactation Yield (First, Second and Third) : The

phenotypic correlation of birth weight with first 300-day lactation yield

in Sahiwal cows was - 0.052 which was not significantly different from zero. The magnitudes of correlation of birth weight with first lactation yield in all genetic groups were very small. The results are in agreement with those reported by Munkassi (1955), Amble et al. (1963) and Liu (1964). Amble et al. (1963) have reported low correlation between birth weight and milk yield in Red Sindhi, Kangayam and Tharparker breeds. Klokko (1960) and Vajakh and Borozdina (1960) stated that the high yielding animals had more often lower than average birth weight.

The birth weight had a negative genetic correlation with first lactation milk yield of the order of - 0.49 in Sahiwal and less than - 1 in Prionian animals. But in 1/8, 1/4, 3/8 and 3/4 genetic groups the birth weight was genetically correlated with the first lactation yield. The magnitudes of correlations were 0.30, 0.54, 0.10, and 0.29 in respective groups. These results are quite in agreement with the results of Naidu and Desai (1962). They have reported the genetic correlation between birth weight and first lactation production as 0.35.

The phenotypic correlation between birth weight and second lactation yield were higher than those with the first lactation in all the genetic groups. The genetic correlations also increased in 3/8, 1/2, 5/8 and 3/4 genetic groups but decreased in Sahiwal, 1/8 and 1/4 genetic groups. The genetic correlations between birth weight and third lactation were higher than those between birth weight and second lactation in 1/8, 1/4, 3/8, 1/2 genetic groups.

Birth weight with Life time Production (Three lactations) : The phenotypic correlation of birth weight with life time production was 0.03 in Sahiwal cattle but in other genetic groups, it was of higher order except in 3/8

and 5/8 genetic groups in which the correlations were 0.01 and - 0.05 respectively. In all the population it was observed that these phenotypic correlations were higher when compared to the phenotypic correlation between birth weight and first lactation production. The genetic correlation between birth weight and life time production was higher than the genetic correlation between birth weight and first lactation production in Sahiwal, 1/4, 3/8, 1/2, 5/8 and Friesian groups.

Birth Weight with Relative Efficiency : The phenotypic correlations between birth weight and the relative efficiency were very small. The phenotypic and genetic correlations between the two traits were - 0.11 and - 0.55 in Sahiwal, 0.03 and 0.73 in 1/8, 0.19 and - 0.12 in 3/8, - 0.09 and - 0.96 in 5/8, - 0.11 and - 0.22 in 3/4 and 0.11 and - 1 in Friesian groups. The results showed that the birth weight was negatively correlated with the relative efficiency of milk production.

Weight at 19 weeks with 300-day First Lactation Yield : The magnitude of correlation between 19 weeks and first lactation was small in all the genetic groups. The correlation was - 0.04 in Sahiwal, 0.05 in 1/8, 0.25 in 1/4, 0.11 in 3/8, 0.23 in 1/2, 0.13 in 5/8, 0.002 in 3/4, and 0.47 in Friesian animals. The 19 weeks weight was negatively genetically correlated with 300-day lactation yield in Sahiwal (- 0.36) and 1/4 (- 0.12) but the 3/4 had a positive correlation of 0.12. The magnitude of phenotypic correlations were larger as compared to those of birth weight and first lactation yield.

Weight at first Calving with 300-day First Lactation Yield : The phenotypic

relationship between body weight and first lactation yield in Sahiwal, 1/8, 1/4, 3/8, 1/2, 5/8, 3/4 and Friesian animals was 0.15, 0.05, 0.67, 0.13, 0.10, 0.26, 0.31 and 0.47 respectively. The correlations were in agreement with the results reported on various breeds by a number of workers. The phenotypic correlation between the two traits as reported in Holstein Friesian cattle was 0.56 (Davis et al., 1943) 0.51 (Miller and Mc Gilliard, 1959). The phenotypic correlation of 0.47 between the two characters from the present investigation is in agreement with those reported by these authors. A small magnitude of phenotypic correlation in Sahiwal cattle is comparable to the results reported by Rajgopalan (1952) in Red Sindhi cows. The author had reported a phenotypic correlation of 0.22.

The genetic correlation between the two traits in Sahiwal, 1/8, 1/4, 3/8 and 3/4 genetic groups was 0.03, 0.50, 0.10, 0.24 and 0.11 respectively. The Holstein group had a genetic correlation of 1. Such a high genetic correlation between the traits has not been reported.

These correlations when compared to the correlation between earlier growth characters and the first lactation production showed that there was a definite increase of the relationship. Such an increase of the relationship with passage of time continued upto the third lactation to be discussed later.

#### Weight at Second calving and Third Calving with corresponding 300-day

Lactation Yields : The results of these relationships showed increase in the phenotypic and genetic correlations with time in most of the genetic groups. Balika (1966) has reported such an increase in the phenotypic correlation. He reported phenotypic correlation between weight at first calving and first lactation yield as 0.29 and between weight at second calving

and second lactation yield as 0.37 in Hungarian spotted cows. In the same breed Gsomos (1985) reported a declining trend of the correlations. The correlation between first weight at calving and lactation yield was 0.43 while in second and third lactation the correlation with corresponding weights at calving were 0.39 and 0.41 respectively.

A study of the correlations between growth and production traits of the various genetic groups, in general, revealed that the correlations were of smaller magnitude between birth weight and production traits. There was a small increase in correlations of 19 weeks body weight with production traits. As the growth progressed, and animal attained the weight at first calving, the correlations were positive and had larger magnitudes. A gradual increase, though small, occurred upto the third calving. This increase of the relationship can be explained as follows.

The birth weight is an expression of the maternal effects than the trait of the individual itself (Dickinson, 1960). The maternal effects eclipse the genetic components so that it has no correlation with milk yield. During the period from birth to 19 weeks the calves get adapted to the environments and just start getting the concentrate mixture. This character is, thus, an effect of environments during which the animals get adapted to them. Some maternal effects will also be there, however, the effect will be much lesser. Dickinson (1960) had shown that the maternal influences go on diminishing as the calves progress towards maturity. The weight at first calving is completely an expression of the genotype of the animal. The correlation is comparatively of higher magnitude since both the traits at this age are the expression of the genetic structure of the animal.

CHAPTER VII

SUMMARY & CONCLUSIONS

## SUMMARY AND CONCLUSIONS

The genetic architecture of production traits of Sahiwal and Sahiwal - Friesian crosses was studied in order to assess the level of Friesian inheritance optimal for milk production under Indian conditions of management and climate. Relationship of these traits with body weight at various ages was studied to find out the optimal relationship between milk yield and body weight.

Data were collected from seven Military dairy Farms situated at Ambala, Dehradun, Jabalpur, Jullundur, Lucknow, Meerut and Mhow on nine genetic groups e.g. Sahiwal,  $1/8$ ,  $1/4$ ,  $3/8$ ,  $1/2$ ,  $5/8$ ,  $3/4$ ,  $7/8$  and Friesian. The data extended over a period of 30 years (1937-1966). Records were available on 1987 cows.

Averages of 300-day lactation yield for first lactation ranged from  $1620.77 \pm 21.47$  kg. in Sahiwal to  $2396.67 \pm 87.69$  kg. in Friesian. For second lactation  $1867.11 \pm 32.43$  kg. in Sahiwal and to  $2655.90 \pm 139.63$  kg. in Friesian. The fourth lactation was peak lactation in all genetic groups except  $5/8$  ranging from  $2050.79 \pm 44.89$  in Sahiwal to  $3013.63 \pm 132.53$  kg. in Friesian. Duncan's multiple range test was employed to compare the milk yield of various genetic groups. The yield of Sahiwal did not differ significantly from  $1/8$  and  $1/4$  Friesian animals. There was no significant difference between milk yield of animals with  $3/8$  and  $1/2$ ,  $5/8$  and  $3/4$  Friesian inheritance. On the basis of this test Sahiwal,  $1/8$  and  $1/4$  Friesian inheritance formed one group; animals with  $3/8$  and  $1/2$  Friesian inheritance another group and animals with  $5/8$  and  $3/4$  Friesian inheritance constituted the third group. Same grouping was valid for all the five lactations studied.

Lactational maturity in all these groups was observed in fourth lactation except in 5/8 in which fifth lactation had the highest yield. Milk yield increased with increase in Friesian inheritance upto 3/4 Friesian. There was a decline in milk yield between 3/4 and 7/8. The optimal Friesian inheritance for high milk yield was between 5/8 and 3/4. It was observed that milk production in crossbreds was not only dependant upon Friesian inheritance but the contribution of Sahiwal inheritance was also important for high milk production. The Sahiwal inheritance optimal for milk production was between 5/8 and 1/4. There was nothing to gain by going above 3/4 Friesian and 5/8 Sahiwal. The average milk yield of half bred when compared to weighted mean of the milk yield of the two parent breeds showed that half bred had significantly higher milk yield than that of mid-parent breed value. There was a significant increase of 269 kg. in first, 320 kg. in second, 321 kg. in third, 256 kg. in fourth and 190 kg. in fifth lactation over the corresponding mid-parent breed values. There was considerable heterosis for milk production which increased from first lactation to third lactation. The effect of heterosis seemed to have some relation with maturity of the animal.

The estimate of heritability for first lactation in Sahiwal was  $0.51 \pm 0.21$ . These estimates ranged from - 0.05 to 0.98 in other genetic groups. The estimate of heritability was  $0.56 \pm 0.27$  for second lactation and  $0.93 \pm 0.37$  for third lactation in Sahiwal. The phenotypic correlations in Sahiwal animals between first and second, second and third, third and fourth, fourth and fifth lactation yields were 0.12, 0.54, 0.58,

0.66 respectively. The corresponding genetic correlations were of the order of unity. Magnitude of phenotypic correlation between first lactation milk yield and life time production (Three lactations) in Sahiwal, 1/8, 1/4, 3/8, 1/2, 5/8 and 3/4 and Friesian animals was 0.73, 0.77, 0.83, 0.81, 0.75, 0.58, 0.88, and 0.70 respectively. The genetic correlations were not different from unity in all genetic groups.

Phenotypic correlation between birth weight and 300-day first lactation production was not significantly different from zero in Sahiwal and other genetic groups. Birth weight had a negative correlation between first lactation yield of - 0.49 in Sahiwal. The phenotypic correlation between body weight at first calving and first lactation milk yield in Sahiwal, 1/8, 1/4, 3/8, 1/2, 5/8, 3/4 and Friesian animals was 0.15, 0.05, 0.13, 0.10, 0.28, 0.31 and 0.47 respectively. The genetic correlation between these traits in Sahiwal, 1/8, 1/4, 3/8 and 3/4 genetic groups were 0.03, 0.50, 0.10, 0.24 and 0.11 respectively.

The magnitudes of relative efficiency were of the order of  $4.47 \pm 0.06$  kg./kg. body weight for Sahiwal and  $6.22 \pm 0.21$  kg./per kg. body weight for Friesian. There was an increase in relative efficiency of milk production with increase in Friesian inheritance. Among various crossbreds, 3/4 genetic group had highest relative efficiency of  $5.74 \pm 0.13$  kg./kg. body weight. The heritability of relative efficiency of Sahiwal animals was  $0.45 \pm 0.22$  (By treating relative efficiency as a variable) and 0.63 (after Sutherland, 1965). Phenotypic correlation between relative efficiency and life time production was high in all genetic groups. The phenotypic and genetic correlation between birth weight and relative efficiency were - 0.11, and - 0.55 in Sahiwal, - 0.09 and - 0.96 in 5/8,

- 0.11 and - 0.22 in 3/4 Friesian groups.

Generalised least square analysis was run to study the effect of various genetic and non-genetic factors on milk yield and body weight. The contribution of grades, (3.37%), Farms (0.81%), periods (1.29%) and parity (5.20%) was significant ( $p < 0.05$ ) for 300-day milk yield. The relative contribution of grades was 2.15%, farms 2.17%, periods 1.79% and of parity 1.98% for the weight at calving.

It was observed that for high milk production over all the five lactations and relative efficiency of milk production, 5/8 to 3/4 level of Friesian inheritance was optimal.

CHAPTER VIII

BIBLIOGRAPHY

## BIBLIOGRAPHY

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