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**GENETIC ANALYSIS OF PRODUCTION
AND REPRODUCTION TRAITS
IN MURRAH BUFFALOES**

**BY
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**DISSERTATION
SUBMITTED TO THE MARATHWADA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE DEGREE OF
Master of Veterinary Science
IN
ANIMAL GENETICS AND BREEDING**

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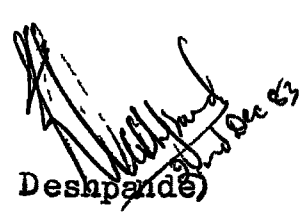


**DEPARTMENT OF ANIMAL GENETICS AND BREEDING
MARATHWADA AGRICULTURAL UNIVERSITY
PARBHANI**

1983

CERTIFICATE I

Shri. Uday Dattatrayrao Umrikar has satisfactorily prosecuted his course of research for a period of not less than two semesters and that the dissertation entitled GENETIC ANALYSIS OF PRODUCTION AND REPRODUCTION TRAITS IN MURRAH BUFFALOES submitted by him is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the dissertation or part thereof has not been previously submitted by him for a degree of any University.



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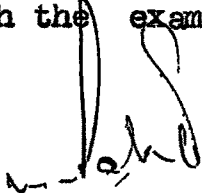
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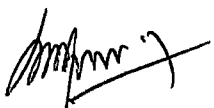
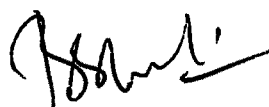
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CERTIFICATE II

This is to certify that the dissertation entitled
GENETIC ANALYSIS OF PRODUCTION AND REPRODUCTION TRAITS IN
MURRAH BUFFALOES submitted by Shri Uday Dattatrayao
Umrikar to the Marathwada Agricultural University in
partial fulfilment of the requirement for the degree of
Master of Veterinary Science in the subject of Animal
Genetics and Breeding has been approved by the students
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ACKNOWLEDGEMENT

Formidable is the task of adequately expressing one's emotions in words. Because then emotions are transformed into a mere formality. But formalities have to be completed. My acknowledgements are many times more than what I am expressing here.

I am extremely indebted to Dr. K.S. Deshpande, Professor of Animal Genetics and Breeding, Marathwada Agricultural University, Parbhani for his valuable guidance, critical suggestions and constant encouragement throughout the course of this investigation.

I am deeply indebted to Dr. P.G. Sakhare, Professor and Head, Department of Animal Management, for his esteemed interest and help during the course of investigation.

I express my deepest sense of gratitude to Dr S.K. Auradkar, Assistant Professor of, Department of Animal Management, and Dr B.S. Kulkarni, Assistant Professor Department of Statistics, MAU, Parbhani for their valuable help.

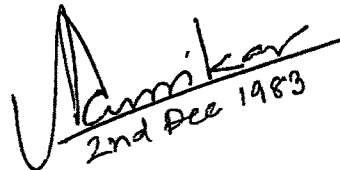
I am extremely thankful to Dr. K.V. Sathe, Senior Scientist, I.A.S.R.I. New Delhi, for his magnificent help in analysing the data. I am also thankful to the Director of Military Farms, New Delhi for according permission to collect and utilise the data at Military Farms. Thanks are due to the staff of Military Farms, at Ferozepore, Ambala and Jabalpur.

I am also thankful to Dr.P.T. Naidu, my colleague for his necessary help during the course of this investigation.

I express my sincere gratitude to Dr. M.A. Ghafoor, Associate Dean and Principal, College of Veterinary and Animal Sciences, MAU, Parbhani for providing the necessary facilities to conduct this study.

I am unable to transform in words, the patronage received from my beloved parents and ever-loving sister, who kept me boosted financially and morally throughout my career.

Last but not the least I express my gratitude to the Almighty and all those whom I might have forgotten due to my shortcomings.



Handwritten signature of U.D. Umrikar, dated 2nd Dec 1983.

Parbhani

(U.D. Umrikar)

Date: 2nd December, 1983

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CHAPTER 1

INTRODUCTION

Agriculture is the mainstay of Indian economy. Agriculture chiefly depends on the quality and quantity of livestock. Livestock contributes 18 per cent of the agricultural income. In our livestock industry cattle and buffaloes play a major role.

The total buffalo population of the world during 1980 was 131.4 million (FAO, 1980). India with 61.3 million buffaloes accounts for nearly 47 per cent of the global buffalo population. The importance of buffalo as a dairy animal can be illustrated by the fact that the buffalo population is only one-third of the cattle population and yet buffaloes contribute 60 per cent of the total milk produced in India. Moreover, buffalo milk has higher fat and SNF content.

The organized sector of the dairy industry mainly handles buffalo milk which constitutes nearly 95 per cent of the total milk handled by the dairy plants. Over generations, attention has been paid to cattle for producing bullocks for draft power for farm operations and buffaloes have been the mainstay as converters of straws and other agro-industries by-products into milk. At least 40 per cent of the buffaloes produce more than 1.5 Kg milk per day and in case of cattle this percentage is less than two. This is very well reflected from the livestock census, which shows that only

11.9 per cent of cattle are milch animals whereas this percentage is 24.4 per cent in case of buffaloes (Nagarcenkar, 1979).

India has source of the best buffalo breeds in the world. The most important Indian breeds of buffaloes are Murrah, Surti, Jafarabadi and Mehsana. Amongst these breeds, Murrah has a unique place of its own. It can be considered as the best buffalo breed of the world. Average lactation yield of Murrah buffaloes ranges between 1300 to 1900 Kg; individuals with 4000 Kg of milk with an average butterfat of 7 per cent are also known. The home tract of Murrah is in Haryana State. It is the most predominant breed and is maintained in around 100 organized farms distributed throughout the country.

Military dairy farms in India have done a remarkable job in the field of cattle and buffalo breeding. The most predominant breed of buffaloes maintained at Military dairy farms is Murrah and its grades. This is because of the high yields and higher butterfat percentages.

Milk yield alone cannot be the sole criterion for the improvement of the performance of buffaloes. Other important factors such as age at first calving, regularity of calving and consistency of production, also contribute to the overall economic viability of buffaloes as dairy animals. For this reason it is essential to find out some important and yet simple index traits of economic efficiency

in buffaloes. Such a trait should have moderate heritability, good genetic and phenotypic correlations with other economic traits of importance and should be easily computable. With this view, the present investigation was taken up.

The main objectives were:

1. To study the variation and range of different economic traits.
2. To study the different measures of economic efficiency that have a bearing on milk production in buffaloes.
3. To find out the extent of genetic and phenotypic association between different production and reproduction traits.
4. To estimate the genetic components of different economic traits.
5. To recommend a simple and yet useful index trait suitable under field conditions.

2 **Review of Literature**

CHAPTER 2

REVIEW OF LITERATURE

2.01 Peak yield:

Peak yield of a lactating animal is the initial maximum production of milk in a day. Peak yield is generally taken to be the criterion for evaluating dairy animals, because of the absence of pedigree and performance records and the market prices are fixed on the quantity of milk given by a buffalo as peak yield.

Table 2.01: Average peak yield and its heritability in Murrah buffaloes

Average peak yield (Kg)	S.E.	Heritability	S.E.	Reference
7.26	1.12 ⁹	0.48	0.29	Dhinsa (1963)
7.60	0.15	-	-	Dutt <u>et al.</u> (1965 b)
7.90	0.09	-	-	Rao <u>et al.</u> (1970)
9.00	0.13	-	-	Rao <u>et al.</u> (1970)
7.82	0.28	-	-	Raizada <u>et al.</u> (1971)
8.23	0.06	0.41	0.11	Sane <u>et al.</u> (1972 b)
7.72	0.24	-	-	Yadav (1980)
12.30	0.20	-	-	Tiwana <u>et al.</u> (1983)

7 Dhinsa (1963) reported average peak yield in Murrah buffaloes to be 7.26 ± 0.12 Kg⁹. Heritability of peak yield was 0.48 ± 0.29 . He reported a highly significant

genetic correlation of 0.346 ± 0.068 and a significant phenotypic correlation (0.62) between peak yield and 305-day milk yield.

Tomar and Desai (1967) analysed the data on buffaloes maintained at military farms. Peak yield averaged 7.22 ± 0.07 Kg and its heritability was 0.12 ± 0.12 . Farm had non-significant effect on peak yield. The intrahera phenotypic correlation of peak yield with lactation milk yield and lactation length were 0.733 and 0.179 respectively and the genetic correlation 1.205 and 0.583.

Rao et al. (1970) reported that, peak yield averaged 7.5 ± 0.15 , 9.3 ± 0.25 , 9.8 ± 0.30 and 9.6 ± 0.39 Kg in first to fourth lactation respectively in Murrah buffaloes at Mathura farm. The repeatability estimate was found to be 0.50 ± 0.04 .

Dave and Taylor (1971) reported highly significant effect of farm on peak yield in buffaloes maintained at Jabalpur military farm. They recorded a nonsignificant phenotypic correlation (0.133) between peak yield and lactation length.

Sane et al. (1972 a, b) analysed lactation records of Murran buffaloes. Repeatability and heritability of peak yield were 0.32 and 0.41 ± 0.11 respectively. They showed that season of calving influenced the peak yield significantly.

1) $\frac{1}{x^2} = x^{-2}$

Singh and Tiwana (1982) reported that the difference due to farm and period of calving were found significant on peak yield of Murrah buffaloes.

2.02 300-day milk yield:

Though the total lactation yield is a very important trait, it does not give us any idea about the duration of lactation length. Longer lactations are bound to produce higher lactation yields, but this may result into longer calving intervals and ultimately lesser life time production. A lactation length of 300-days is considered more ideal and the milk yielded by a buffalo in first 300 or lesser number of days in a lactation is called standard lactation production.

Singh and Desai (1962) reported average 300-day milk yield to be 2756.3 lb in Bhaadawari buffaloes and the repeatability of 300-day milk yield was found to be 0.39.

Basu et al. (1972) reported average lactation production in Murrah buffaloes to be 1432 Kg on 305 day basis. Lactation-wise milk production on 305-day basis was 1334, 1399, 1622 and 1301 Kg respectively for first to fourth lactation.

Rao et al. (1976) reported that the differences between farms were non-significant in respect of 300-day milk yield in Murran buffaloes. Longer lactation in off season calvers had only increased the total yield but not 300-day yield.

Table 2.02: Average 300-day milk yield and its heritability in Murrah buffaloes

Average 300-day milk yield (Kg)	S.E.	Herita- bility	S.E.	Reference
-	-	0.32	0.28	Dhinsa (1963)
1436.20	38.90	-	-	Dutt <u>et al.</u> (1965 b)
1432.00	-	-	-	Basu <u>et al.</u> (1972)
1619.00	21.30	-	-	Rao <u>et al.</u> (1976)
1577.60	36.30	-	-	Rao <u>et al.</u> (1976)
1658.33	36.52	-	-	Basu <u>et al.</u> (1976)
1647.34	19.23	0.22	0.20	Basu and Ghal (1978 a)
1631.32	33.98	-	-	Sharma and Basu (1980)
1472.53	23.77	-	-	Reddy and Mishra (1982)
1918.40	49.90	-	-	Tiwana <u>et al.</u> (1983)

Patro and Bhat (1979 a,b) studied lactation records of buffaloes maintained at military farms. Heritability estimates for 300-day milk yield were 0.24 ± 0.06 , 0.13 ± 0.06 , 0.25 ± 0.08 and 0.02 ± 0.07 for first to fourth lactations respectively. The genetic and phenotypic correlations between lactation yield and 300-day yield were 0.77 ± 0.17 and 0.89 ± 0.01 respectively. The genetic and phenotypic correlations between lactation length and 300-day milk yield were 0.21 ± 0.23 , and 0.48 ± 0.01 respectively. Farm, period and season affected significantly the 300-day milk yield in all lactations. The least squares

means for 300-day milk yield were 1573.4 ± 22.21 , 1790.4 ± 27.74 , 1878.0 ± 36.25 and 1963.8 ± 45.56 respectively for first to fourth lactations.

Reddy (1980) reported that the phenotypic correlations of 300-day first lactation milk yield with first service period, first lactation length were highly significant in Murrah buffaloes, while with dry period it had low and non-significant correlation except for Murrah buffaloes maintained at Secunderabad. The genetic correlation of 300-day first lactation milk yield with first lactation length and service period did not follow any definite trend for Murrah buffaloes at any of the four farms.

2.03 Lactation milk yield:

For any breeding or improvement programme, whether it is through selective breeding or through crossbreeding, the performance of dairy cattle in terms of production of milk has to be of top consideration. It has largely been the main criterion of selecting female as well as male breeding stock. Sometimes it constitutes the sole criterion in construction of a suitable breeding plan.

Dhinsa (1963) found average milk yields in Murrah buffaloes were 1538.9, 1706.5 and 1815.6 Kg for first to third lactations respectively. The heritability of first lactation yield was 0.324 ± 0.284 .

Singh and Singh (1967) reported nonsignificant effect of season of calving on milk yield in Murrah buffaloes.

Table 2.03: Average milk yield of Murrah buffaloes in first second and third lactations

Average first lactation milk yield (Kg)	Average second lactation milk yield (Kg)	Average third lactation milk yield (Kg)	Reference
1206.8 $\pm$ 100.8	1210.0 $\pm$ 87.5	1369.1 $\pm$ 78.7	Kohli and Malik (1960 a)
1538.9	1706.5	1815.6	Dhinsa (1963)
-	1404.3 $\pm$ 143.3	1428.1 $\pm$ 47.5	Ohri and Parekh (1969)
1442.8 $\pm$ 43.2	1479.0 $\pm$ 35.4	1553.4 $\pm$ 41.2	Iqbaluddin <u>et al.</u> (1970)
1483.7 $\pm$ 37.4	1682.4 $\pm$ 35.7	1681.8 $\pm$ 39.2	Iqbaluddin <u>et al.</u> (1970)
1557.7 $\pm$ 11.1	1757.6 $\pm$ 18.1	1823.0 $\pm$ 22.1	Jawarkar and Johar (1975 b)
1521.3 $\pm$ 22.5	1658.8 $\pm$ 47.5	1850.7 $\pm$ 55.4	Chhikara <u>et al.</u> (1978)
1618.5 $\pm$ 22.8	1880.0 $\pm$ 32.6	1964.0 $\pm$ 37.0	Patro and Bhat (1979 b)

Table 2.04: Heritability and repeatability estimates of first lactation milk yield in Murrah buffaloes

Heritability	S.E.	Repeatability	S.E.	References
0.32	0.28	-	-	Dhinsa (1963)
-	-	0.50	-	Sekhon and Gehlon (1966)
0.47	0.31	0.53	-	Pal <u>et al.</u> (1971)
-0.42	0.05	0.44	-	Gumani <u>et al.</u> (1972)
0.53	0.21	0.73	-	Sane <u>et al.</u> (1972 b)
-0.02	0.08	0.38	-	Jawarkar and Jonar (1975 b)
-	-	0.44	-	Gumani <u>et al.</u> (1976 a)
0.37	0.20	-	-	Jain (1982)

Gill and Dev (1970) found significant correlations of lactation yield with lactation length (0.64), dry period (-0.32), service period (0.28) in Murrah buffaloes.

Rathi et al. (1971) reported the off season calvers to be high producers when compared to normal season calvers in buffaloes maintained at military farms.

Sane et al. (1972 b) estimated average milk yield of Murrah buffaloes as 1564.70 ± 21.51 , 1717.85 ± 23.22 , 1775.88 ± 26.98 and 1796.31 ± 30.98 for first to fourth lactation respectively. Repeatability of milk yield was 0.73 and heritability was 0.53 ± 0.21 .

Patro and Bhat (1979 b) found that farms and seasons significantly affected milk yield in all lactations. The period effect was significant in all the lactations except second and fifth.

Jain (1982) found positive and significant phenotypic (0.84) and genetic (0.42) correlation of first lactation milk yield with first lactation 301-day milk yield in Murrah buffaloes.

2.04 Lifetime milk yield:

The importance of lifetime milk production has got an economic bearing on the upkeep of dairy animals. An animal which produces more milk during its productive life is bound to be the most profitable unit in a dairy enterprise. It would be of great help if we could locate the potentially profitable animals at an early age.

Johari and Bhat (1979 b) studied lactation records of buffaloes maintained at military farms. The average total milk yield of first three lactations was found to be 5249.68 ± 28.49 . Heritability estimate was 0.07 ± 0.06 . Farm and period had shown highly significant effect while season had shown non-significant effect on total milk yield in first three lactations. The phenotypic correlations with first lactation milk yield, first lactation length and first dry period were 0.72, -0.40 and 0.05 respectively. The genetic correlations were 0.38, -0.49 and 1.00 respectively, in ^{the} same sequence.

Singh (1979) reported average lifetime production based on first three lactations to be 5399.00 ± 414.00 and farm had a significant effect on lifetime milk yield in buffaloes maintained at military farms. The genetic correlations of lifetime milk production with first lactation milk yield, milk yield per day of first lactation length, milk yield per day of first calving interval and milk yield per day of age at second calving were found to be 0.726, 0.636, 0.685 and 0.730, respectively. The corresponding phenotypic correlations were found to be 0.553, 0.599, 0.717 and 0.551, respectively.

Gokhale and Nagarcenkar (1980) reported average lifetime milk production based on first three lactations and its heritability to be 5159.63 ± 38.51 and 0.25 ± 0.08 respectively in Murrah buffaloes.

2.05 Lactation length:

The amount of milk produced by a buffalo in a lactation depends on the initial maximum milk secretion, persistency of production and the lactation period. Lactation length of 300-day is considered desirable, since it closely associated with reproductive cycle of the buffalo calving once a year.

Since this is the only period that leaves returns to the animal breeder, it may be exploited to the fullest length provided the production is not at the cost of foetal growth; does not unnecessarily increase the interval between two consecutive calvings; and if,

nutritional and managemental standards are upto the mark, to ensure the proper health of the animal.

Table 2.05: Average first lactation length and its heritability in Murrah buffaloes

Average first lactation length (days)	S.E.	Heritability	S.E.	Reference
372.00	10.60	-	-	Rao <u>et al.</u> (1970)
358.00	8.90	-	-	Rao <u>et al.</u> (1970)
317.00	9.60	-	-	Amble <u>et al.</u> (1970)
351.00	13.00	-	-	Singh and Singh (1971)
266.00	-	-	-	Basu <u>et al.</u> (1972)
-	-	-0.42	0.05	Gurnani <u>et al.</u> (1972)
294.98	-	0.16	0.06	Jawarkar and Johar (1975 a)
283.00	6.00	-	-	Gurnani <u>et al.</u> (1976a)
295.90	1.00	0.11	0.04	Johari and Bhat (1979 b)
313.25	3.35	0.38	0.17	Yadav (1980)
296.39	3.17	0.06	0.06	Reddy (1980)
306.04	3.77	-	-	Jain (1982)
287.42	9.01	0.06	0.07	Gurung and Johar (1982)

Basu and Gnan (1978 b) reported correlation of lactation period with service period and dry period in Murrah buffaloes to be 0.59 and -0.18 respectively. The repeatability of lactation length was 0.32 ± 0.03 . Season of calving had no significant effect on lactation length.

Jonam and Bhat (1979 b) reported average first lactation length in Murrah buffaloes maintained at military farms to be 295.9 ± 1.0 days. Heritability estimate was 0.11 ± 0.04 . The phenotypic correlation of first lactation length with first lactation milk yield was positive and significant but their genetic association was not found to be significant. Farm and period had shown significant but season of calving had non-significant effect on first lactation length.

Patro and Bhat (1979 a,b) reported heritability estimates for first to fourth lactation to be 0.11 ± 0.05 , 0.06 ± 0.05 , -0.04 ± 0.06 , 0.03 ± 0.08 respectively in buffaloes maintained at military farms. They reported that farm and season affected lactation length significantly in all lactations. The period effect was significant in all the lactations except the second and fifth.

Reddy (1980) reported the phenotypic correlation of first lactation length with first dry period in Murrah buffaloes was low and it had significant genetic correlation with service period.

Jain (1982) reported phenotypic correlations of first lactation length with first lactation milk yield, first lactational 301-day milk yield, service period, and dry period in Murrah buffaloes were 0.61, 0.57, 0.50 respectively.

Tiwana et al. (1983) reported the average lactation length for first to fourth lactation in Murrah buffaloes to be 336.5 ± 20.6 , 299.0 ± 19.3 , 320.7 ± 18.8 and 299.1 ± 16.6 , respectively.

2.06 Dry period:

It is the period during which an animal remains out of production. Nevertheless, its importance cannot be ignored. During lactation the animal is subjected to lactational stress. An optimum dry period or the period of rest is essential to recoup its depleting potentialities owing to production of milk for a prolonged period. This ensures building up of sufficient reserves for withstanding the stress of advanced pregnancy and also helps in the production of maximum amount of milk in the subsequent lactation.

Uhri and Prakash (1969) reported average first to fourth dry periods to be 199.50, 177.07, 153.15 and 168.60 respectively in Murran buffaloes.

Gill and Dev (1970) reported that dry period had a significant but negative association with lactation length and a non-significant association with service period in Murrah buffaloes. Repeatability of dry period was found to be 0.17 ± 0.06 .

Kanaujia et al. (1975) reported that season and period had a significant and farm had a non-significant effect on dry period in buffaloes maintained at military

farms. There was a decline in dry period with advance in lactation order.

Table 2.06: Average first dry period and its heritability in Murrah buffaloes

Average first dry period (days)	S.E.	Heritability	S.E.	Reference
153.00	-	-	-	Agrawala (1962)
138.70	-	-	-	Arora <u>et al.</u> (1962)
199.50	14.15	-	-	Ohri and Prakash(1969)
156.40	9.20	-	-	Gill and Dev (1970)
160.00	14.00	-	-	Singh and Singh (1971)
-	-	0.13	0.17	Gurnani <u>et al.</u> (1972)
178.27	-	0.20	-	Jawarkar and Johar (1974)
203.00	13.00	-	-	Gurnani <u>et al.</u> (1976a)
170.57	7.63	-	-	Basu <u>et al.</u> (1976)
197.30	-	-	-	Kanaujia (1978)
185.54	6.38	0.14	0.12	Reddy and Taneja (1980)
262.92	8.00	0.22	0.28	Jain (1982)

Johari and Bhat (1979 b) reported in buffaloes maintained at military farms that farm and period significantly affected dry period while season had a non-significant effect. Heritability of dry period was 0.05 ± 0.04 .

Reddy and Taneja (1980) reported significant positive phenotypic correlation of first day period with first service period, lactation length, and significant but negative phenotypic correlation with breeding efficiency in Murrah buffaloes.

Jain (1982) reported phenotypic correlation of first dry period with first lactation yield, 301-day lactation yield, lactation length and service period to be -0.11, -0.17, 0.07 and 0.88, respectively in Murrah buffaloes.

2.07 Service period:

The period between date of calving and date of conception is called service period. The calving interval has two components gestation period and service period. Since the variation in gestation period is very small, the calving interval is mostly dependent upon the length of service period. If we want the buffalo to calve regularly, service period must be kept optimum.

Gill and Dev (1970) reported averages for first to fourth service periods to be 151.30 ± 13.60 , 134.90 ± 17.10 , 150.10 ± 31.30 and 85.00 ± 24.70 , respectively in Murrah buffaloes. Repeatability of service period was found to be 0.30 ± 0.06 . There was a positive phenotypic correlation between service period and lactation period.

Singh et al. (1972) reported average service period in farmed and purchased Murrah buffaloes to be 131.93 ± 2.67 and 129.08 ± 3.68 days respectively. Effect of season

of calving on service period was significant.

Heritability by intra-sire regression and parental half-sib correlation was -0.42 and 0.03 respectively.

The coefficient of repeatability was 0.37. The correlation coefficients of service period with milk yield, lactation length and dry period were 0.76, 0.62 and 0.35, respectively.

Kanaujia et al. (1974) reported that season had significant and period had non-significant effect on service period in Indian buffaloes. Kanaujia et al. (1975) reported that farm, period and season of calving had significant effect on the service period, in military farm buffaloes. There was a decline in service period with advance in lactation order.

Table 2.07: Average first service period and its heritability in Murrah buffaloes

Average first service period (days)	S.E.	Heritability	S.E.	Reference
151.30	13.60	-	-	Gill and Dev (1970)
145.37	5.48	-	-	Singh <u>et al.</u> (1972)
-	-	0.10	0.03	Kanaujia <u>et al.</u> (1974)
169.26	12.54	-0.00	0.04	Johari and Bhat (1979a)
177.84	7.54	0.15	0.12	Reddy and Taneja (1980)

Rao et al. (1976) reported in Murrah buffaloes that service period differed significantly between seasons but not between farms. Service period was found to be highly correlated with total milk yield and lactation

length.

Reddy and Taneja (1980) reported phenotypic correlation of first service period which ranged from 0.44 to 0.62 with first lactation length, 0.65 to 0.86 with first dry period, -0.72 to -0.90 with breeding efficiency in Murrah buffaloes.

2.08 Milk yield per day of lactation length:

Buffaloes with high milk yield per day of lactation length are economic producers and have more lactation milk yield. Thus this trait is a combination of lactation milk yield and lactation length.

Amble et al. (1970) studied the lactation records of buffaloes maintained at military farms. They found that the average milk yields per day of first lactation length were ranged from 4.8 to 6.1 Kg with an overall average of 5.1 Kg. Repeatability of milk yield per day of lactation length for graded stock was 0.40, whereas the pooled estimate of heritability for this trait was 0.06, which was not significantly different from zero.

Raut and Singh (1971) studied the lactation records of the buffaloes maintained in villages of Hissar district. They found average milk yield per day of lactation length for first to fourth lactations to be 5.14 ± 0.34 , 5.90 ± 0.34 , 6.15 ± 0.39 and 6.18 ± 0.70 respectively.

Bhalaru (1977) analysed the lactation records of buffaloes maintained at military farms. He reported that period had a significant but farm had a non-significant

effect on milk yield per day of first lactation length. Repeatability estimate was 0.34 ± 0.02 .

Singh (1979) reported in military farm buffaloes that milk yield per day of first lactation length did not differ significantly at different farms. The genetic and phenotypic correlations of milk yield per day of first lactation length with first lactation milk yield, milk yield per day of age at second calving, milk yield per day of first calving interval, milk yield per day of productive life and lifetime milk production were positive and high.

Table 2.08: Average milk yield per day of first lactation length and its heritability in buffaloes

Breed	Average milk yield per day of first lactation length(Kg)	S.E.	Heritability	S.E.	Reference
Murrah	5.30	0.18	-	-	Amble <u>et al</u> (1970)
Graded	5.10	0.11	-	-	Amble <u>et al</u> (1970)
Indian buffaloes	5.14	0.34	-	-	Raut and Singh (1971)
Military farm buffaloes	5.51	0.97	0.29	0.10	Bhalaru (1977)
Indian buffaloes	2.24	0.13	-	-	Raut and Singh (1978)
Military farm buffaloes	5.38	0.38	0.22	0.12	Singh (1979)
Murrah	5.08	0.08	0.26	0.16	Yadav (1980)
Murrah	5.68	0.07	0.04	0.06	Reddy and Taneja (1980)

Yadav (1980) reported in Murrah buffaloes that the phenotypic correlation of milk yield per day of first lactation length with first service period, first lactation milk yield, first lactation length, peak yield, milk yield per day of first calving interval and first dry period was 0.14, 0.73, -0.11, 0.21, -0.09 and -0.04, respectively. The genetic correlations with last five traits were 0.02, 0.00, 0.43, 1, and 0.80, respectively.

Bhat et al. (1982) reported in military farm buffaloes that farm, period and season of calving had significant influence on milk yield per day of lactation length. Heritability estimate was 0.10 ± 0.04 .

2.09 Milk yield per day of calving interval:

Milk yield is an indicator of the productive efficiency, and the calving interval measures the reproductive efficiency of a dairy animal. Milk yield per day of calving interval is therefore a good measure of both the productive and reproductive efficiency of dairy animals. Animals with more milk yield per day of calving interval are not only efficient milk producers but have good reproductive efficiency also.

Amble et al. (1970) studied lactation records of buffaloes maintained at military farms. They found that the average milk yields per day of first calving interval were ranged from 2.9 to 4.0 Kg with an overall average of 3.3 Kg. Repeatability of milk yield per day of calving

interval for graded and Murrah stock were 0.29 and 0.57 respectively. The estimate of heritability of this character for Murrah buffaloes from Aarey was 0.43.

Table 2.09: Average milk yield per day of first calving interval and its heritability in buffaloes

Breed	Average milk yield per day of first calving interval (Kg)	S.E.	Heritability	S.E.	Reference
Murrah	3.60	0.12	-	-	Amble <u>et al.</u> (1970)
Graded	3.20	0.12	-	-	Amble <u>et al.</u> (1970)
Military farm buffaloes	3.37	0.81	0.19	0.09	Bhalaru (1977)
Military farm buffaloes	3.42	0.32	0.22	0.12	Singh (1979)
Murrah	3.11	0.31	0.06	0.01	Yadav (1980)
Murrah	3.68	0.06	0.01	0.06	Reddy and Taneja (1980)

Bhalaru (1977) analysed the lactation records of buffaloes maintained at military farms and reported that farm and period had a significant influence on milk yield per day of first calving interval. Repeatability was 0.31 ± 0.02 .

Singh and Desai (1978) reported that Murrah buffaloes calved during July to October had higher average milk yield per day of calving interval than those calved during

November to January and February to June.

Singh (1979) reported in military farm buffaloes that the milk yield per day of first calving interval did not differ significantly at different farms. The genetic and phenotypic correlations of milk yield per day of first calving interval with first lactation milk yield, milk yield per day of age at second calving, milk yield per day of productive life and lifetime milk production were positive and high.

Yadav (1980) reported the phenotypic correlations of milk yield per day of first calving interval with first service period, first lactation milk yield, first lactation length, peak yield, and first dry period were -0.06, -0.03, 0.16, 0.01 and -0.04, respectively in Murrah buffaloes. The genetic correlations were -0.9, 0.07, 0.00, > 1 and -0.15, respectively.

Bhat et al. (1982) reported that the farm, period and season of calving had significant influence on milk yield per day of calving interval in buffaloes maintained at military farms. Heritability was 0.09 ± 0.04 .

2.10 Milk yield per day of age at second calving.

This is a more comprehensive trait than the milk yield per day of calving interval. The milk yield per day of age at second calving is calculated by dividing the first lactation yield by the age at second calving reckoned as the total of the age at first calving and first calving interval. Since this measure combines three very important

economic traits viz. age at first calving, first lactation yield, and first calving interval, it also appears to be very useful criterion for comparing the economic merit of dairy animals.

Bhalaru (1977) analysed the lactation records of buffaloes maintained at military farms. He reported average milk yield per day of age at second calving to be 1.07 ± 0.03 and its heritability to be 0.30 ± 0.10 . Farm and period had shown a significant influence on this trait. The genetic and phenotypic correlation of milk yield per day of age at second calving with first lactation milk yield was positive and high.

Singh (1979) reported in military farm buffaloes that the milk yield per day of age at second calving averaged 0.91 ± 0.08 . Heritability was found to be 0.37 ± 0.11 . The milk yield per day of age at second calving did not differ significantly at different farms. The genetic and phenotypic correlations of milk yield per day of age at second calving with first lactation milk yield, milk yield per day of productive life and lifetime milk production were positive and high.

Bhat et al. (1982) reported that farm, period, and season had significant influence on milk yield per day of age at calving in buffaloes maintained at military farms.

2.11 Milk yield per day of productive life:

Buffaloes with high milk yield per day of productive

life are economic producers of milk throughout the productive life. Since we are interested in having buffaloes which can remain profitable throughout their productive life, this trait is most useful in making such an assessment.

Singh (1979) analysed lactation records of buffaloes maintained at military farms and reported average milk yield per day of productive life to be 3.94 ± 0.30 . The period from first to fourth calving was taken as productive life. The heritability of milk yield per day of productive life was 0.26 ± 0.12 . Farm had a significant effect on this trait. Genetic and phenotypic correlation of this trait with first lactation milk yield and lifetime milk production was positive and high.

2.12 Breeding efficiency:

Frequent reproduction or birth of many offspring at one time and/or during the lifetime reveals the genetic variability in an individual and thus allows more efficient chances for selection. The attention should be given on efficient breeding in order to produce more milk at lesser cost and more offspring in lesser time of breeding interval. Breeding efficiency is a measure of reproductive performance which is based on calving interval.

Bhadula and Desai (1973) reported average breeding efficiency of buffaloes maintained at military farms to be 80.78. Heritability was 0.20. Farm had non-significant effect

on breeding efficiency.

Table 2.10 : Average breeding efficiency and its heritability in buffaloes

Breed	Average breeding efficiency (%)	S.E.	Heritability	S.E.	Reference
Egyptian	74.10	-	0.05	-	Youssef and Asker (1959)
Murrah	78.70	1.30	0.27	0.12	Singh and Lutt (1964)
Italian	88.90	-	-	-	Succi and Foy Choudhary (1969)
Murrah	77.21	1.97	-	-	Gautam <u>et al.</u> (1965)
Military farm buffaloes	76.60	-	0.10	0.03	Singh (1966)
Military farm buffaloes	80.78	-	0.20	-	Bhadula and Desai (1973)
Nagpuri	86.68	2.15	0.38	-	Deb and Kadi (1977)
Bhadawari	83.10	2.60	0.19	-	Sharma and Singh (1978 a)
Murrah	80.10	1.05	0.06	0.11	Reddy and Taneja (1980)

Deb (1977) reported negative but non-significant correlation (-0.12) of breeding efficiency with lactation yield in Nagpuri buffaloes. It had a positive but non-significant correlation (0.064) with lactation length.

Sharma and Singh (1978 a,b) reported that the season of calving had a significant effect on breeding efficiency in Bhadawari buffaloes. The breeding efficiency had a significant correlation with first lactation milk yield.

Reddy and Taneja (1980) reported in Murrah buffaloes that the phenotypic correlations amongst breeding efficiency and other traits ranged from -0.21 to -0.30 for first lactation milk yield, -0.72 to -0.90 for first service period, -0.45 to -0.59 for lactation length, -0.79 to -0.87 for first dry period. The genetic correlation of first lactation length with breeding efficiency for Nili-Ravi buffaloes was -0.46 ± 0.38 .

3 Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

3.1 The data:

The data taken for the present studies on the production and reproduction records, were obtained from the pedigree sheets and history sheets of the Murrah buffaloes maintained at three Indian military farms under the control of Directorate of Military Farms.

Records of 678 buffaloes were collected from the three military dairy farms at Ambala, Ferozepore and Jabalpur covering the period of 15 years from 1968 to 1982. These 678 buffaloes represent the progeny of 24 Murrah buffalo bulls, maintained at one time or the other. Only those sires who had 20 or more daughters were included in the study. The farm-wise, period-wise, season-wise and age at calving-wise distribution of the buffaloes is presented in Table 3.1

The three farms where the buffaloes have performed represent three different environments. Even though many of the managerial practices like rearing of the calves, handling of the animals, selection criteria, feeding of the concentrates etc. are similar at three farms, they nevertheless represent different environments with their varying geographical situations, agro-climatic conditions, seasonal climatic variations and above all, availability of feeds and fodders.

Table 3.1: Frequency distribution of buffaloes

Factors	Code	First lacta- tion	Second lacta- tion	Third lacta- tion	Fourth lacta- tion	Overall
Total		678	678	678	678	2712
<u>Farm</u>						
Ambala	F ₁	260	260	260	260	1040
Ferozepore	F ₂	275	275	275	275	1100
Jabalpur	F ₃	143	143	143	143	572
<u>Period</u>						
1968-1972	P ₁	373	286	229	173	1061
1973-1977	P ₂	237	255	259	250	1001
1978-1982	P ₃	68	137	190	255	650
<u>Season</u>						
July-Dec	S ₁	549	585	572	542	2248
Jan-June	S ₂	129	93	106	136	464
<u>Age at calving</u>						
	A ₁	31	23	21	44	119
	A ₂	138	105	94	60	397
	A ₃	144	102	64	47	357
	A ₄	101	77	77	92	347
	A ₅	126	133	139	125	523
	A ₆	102	130	126	91	449
	A ₇	36	108	157	219	520

Records on the buffaloes completing atleast four lactations were included in this study, whereas those



producing less than 1000 Kg in a lactation and or having a lactation less than 150 days can hardly be considered as normal and hence such records were discarded. Abortions, pathological causes affecting lactation, calves born dead, abnormal, twins or premature births, and culling of animals in milk were considered as abnormal records and hence were excluded from the present investigation. However, the buffaloes which were culled subsequent to fourth lactation were included to remove the bias due to selection.

The actual milk yield given during a lactation period of 300 days or below has been reckoned as 300-day milk yield. In such of those buffaloes having longer lactation periods, the yield given over the 300-day periods have been excluded from their records.

Each datum was identified by the farm at which the performance was recorded rather than the farm at which the animal was born. Assuming the yearly variations follow a cyclic pattern repeatable every fifth year, the entire duration was divided into three periods of five years each.

Period 1 : 1968, 69, 70, 71, 72

Period 2 : 1973, 74, 75, 76, 77

Period 3 : 1978, 79, 80, 81, 82

The years were considered according to the date of calving. Years were further divided into two seasons viz.

Most calving season. July to December

Least calving season: January to June



The buffaloes were classified in seven groups according to the age at calving in each lactation. The seven groups of age at first calving were: Less than 1000, 1001 to 1100, 1101 to 1200, 1201 to 1300, 1301 to 1400, 1401 to 1500, and more than 1500 days, respectively. The seven groups of age at second calving were: Less than 1400, 1401 to 1500, 1501 to 1600, 1601 to 1700, 1701 to 1800, 1801 to 1900, and more than 1900 days, respectively. The seven groups of age at third calving were: Less than 1800, 1801 to 1900, 1901 to 2000, 2001 to 2100, 2101 to 2200, 2201 to 2300, and more than 2300 days, respectively. The seven groups of age at fourth calving were: Less than 2200, 2201 to 2300, 2301 to 2400, 2401 to 2500, 2501 to 2600, 2601 to 2700, and more than 2700 days, respectively.

Management and feeding:

Housing, feeding and other managerial practices are fairly uniform over all the farms. The animals are kept in paddocks, but adequate protection from adverse weather is always provided.

The calves are weaned after three days of calving and fed on whole milk from fourth day to twelfth week of age. Skimmed milk is fed from second week and stopped by 26th week of age.

Buffaloes are handmilked twice a day at equal intervals. Milk yield is recorded at each milking for each animal. Body weight at calving is recorded within

seven days of calving. Pedigree sheets are maintained for each animal giving the performance of parents and the individual itself.

Feeding is done according to the standards prescribed by the Directorate of Military Farms. The supply of fodder is ensured nearly throughout the year either as green fodder or as silage. Green jowar, berseem, rape, oats, and cowpeas are usually given as green fodder and wheat bhusa and kadbi (dry jowar) are used as dry fodder. The animals are stall fed and let loose in open sheds for sometime everyday in order to clean the sheds and to give exercise. Concentrates are fed at the time of milking. Extra allowance of concentrate ration is provided during pregnancy. The calf mortality has been brought below 5 per cent (Dahya, 1978).

The economic characters studied were:

1. Peak yield (Kg)
2. 300-day milk yield (Kg)
3. Lactation milk yield (Kg)
4. Lifetime milk yield (Kg): which includes total milk yield (Kg) from first to fourth lactation.
5. Lactation length (days)
6. Dry period (days)
7. Service period (days)
8. Milk yield per day of lactation length (Kg): It is computed by dividing lactation milk yield (Kg) with lactation length.

9. Milk yield per day of calving interval (Kg): It is computed by dividing lactation milk yield (Kg) with calving interval (days)
10. Milk yield per day of age at second calving (Kg). It is computed by dividing first lactation milk yield (Kg) with age at second calving (days)
11. Milk yield per day of productive life (Kg): It is computed by dividing the lifetime milk yield (Kg) with the productive life (days) i.e. the period from the date of first calving to the last date of fourth lactation.
12. Breeding efficiency (Wilcox): It is calculated in percentage by the formula proposed by Wilcox (1957).

$$\text{B.E. \%} = \frac{365 (n-1)}{D} \times 100$$

Where,

n = Total number of parturations

D = Total number of days from first to last parturition

In this formula, the first reproductive cycle as well as cycles after fourth parturition were excluded because of the excessive influence of the environment and of suspected bias caused by special managerial practices etc. respectively. From this formula it will be clear that the animals with 100 per cent breeding efficiency will be those whose intercalving period is one year.

13. Breeding efficiency (Tomar): It is calculated in percentage by formula proposed by Tomar (1965) for buffaloes.

$$\text{B.E. \%} = \frac{[n(365) + 1040]}{AC + C_1} \times 100$$

Where,

n = The number of calving intervals

365 = The desired calving interval in days

1040 = The desired age at first calving in days

AC = The actual age at first calving in days

C_1 = The some of the actual calving intervals studied (in days).

The traits numbered 1, 2, 3, 5, 6, 7, 8, 9 were studied for first, second, third, and fourth lactations and also a overall study of all four lactations for each of these traits was carried out.

3.2 Methodology used:

With disproportionate subclass numbers the different kinds of effects such as farms, periods, seasons, and age at calving, cannot be separated directly with the ordinary methods of analysis of variance. In such a case least squares method of analysis (Harvey, 1966) was employed. The principle of this technique is to minimise the error sum of squares, sum of squared differences between observed and expected values, called the residual sum of squares.

Mathematical model:

$$Y_{ijklm} = \mu + F_i + P_j + S_k + A_l + e_{ijklm}$$

Where,

Y_{ijklm} is the record of m th buffalo calved at i th farm, in j th period, in k th season, and at l th age at calving

μ is the population mean common to all observations.

F_i is the effect of i th farm ($i=1\dots3$)

P_j is the effect of j th period ($j=1\dots3$)

S_k is the effect of k th season ($k=1\dots2$)

A_l is the effect of l th age at calving ($l=1\dots7$)

e_{ijklm} = random error assumed NID $(0, \sigma^2_e)$

3.2.1 Least squares analysis of data:

The procedure adopted was as follows.

Setting up normal equations:

From the mathematical model a system of normal equations were set up and these are represented in table 3.2 To estimate the 16 unknown constants, 16 normal equations were formed and these were 1 for μ , 3 for farms, 3 for periods, 2 for seasons, and 7 for age at calving. These equations then set up in the form of matrix.

Table 3.2: Set of normal equations

Model:	$Y_{ijklm} = U + F_i + P_j + S_k + A_l + e_{ijklm}$					
	U	F _i	P _j	S _k	A _l	RHM
U:	n...	n _i ...	n..j	n..k	n...l =	Y.....
F _i :	n _i ...	n _i ...	n _{ij} ..	n _i .k	n _i ..l =	Y _i
P _j :	n..j...	n _{ij} ...	n..j...	n..jk..	n..jl. =	Y..j...
S _k :	n..k..	n _i .k..	n..jk..	n..k..	n..kl.=	Y..k..
A _l :	n...l.	n _i ..l.	n..j.l	n..kl.	n...l =	Y...l.

Imposing the restrictions:

Since the equations are not independent, a unique solution could not be obtained. For obtaining the estimates of the constants, following constraints or restrictions were imposed.

$$\sum_i F_i = \sum_j P_j = \sum_k S_k = \sum_l A_l = 0$$

By imposing the restrictions on the estimates of constants, it is possible to compute the F_i, P_j, S_k and A_l. The restrictions were imposed in the following manner.

Imposing restrictions for main effects:

Since there were three farms, the n_{ij} values in the column corresponding to 3rd farm were subtracted from n_{ij} values of all previous columns (two in number). In the row-wise reduction, n_{ij} values in 3rd row were subtracted

from n_{ij} values of all previous rows. The similar procedure was adopted while imposing the restrictions period-wise, season-wise, and age at calving-wise. Third period, second season and seventh group of age at calving were suppressed.

Reduction of R.H.M. (Column vector):

The same procedure adopted in column-wise reduction of n_{ij} matrix was followed for reducing R.H.M. The μ element was left undisturbed and manipulations were made in coefficients of main effects.

Estimation of constants:

The reduced n_{ij} matrix is symmetrical about its main diagonal and is of the dimension 12×12 , made up of 1 row and column for μ 2 for farms, 2 for periods, 1 for season, and 6 for age at calving. Similarly reduced R.H.M. is a column vector of 12 rows. Constants were obtained as follows from the inverse of reduced matrix and RHM's of the equations.

$$\begin{array}{ccc} \text{Reduced } n_{ij} \text{ matrix} & \times & \text{constants} = \text{Reduced RHM} \\ 12 \times 12 & & 12 \times 1 \quad \quad 12 \times 1 \end{array}$$

$$\text{constants} = \text{Reduced } n_{ij} \text{ matrix}^{-1} \times \text{Reduced RHM}$$

The estimates corresponding to the elements that were suppressed while reductions were carried out, were

obtained using following relationships.

$$F_3 = -(F_1 + F_2)$$

$$P_3 = -(P_1 + P_2)$$

$$S_2 = -(S_1)$$

$$A_7 = -(A_1 + A_2 + A_3 + A_4 + A_5 + A_6)$$

Least squares analysis of variance:

Computing sums of squares (S.S.)

1. Total uncorrected sum of squares

$$\sum_i \sum_j \sum_k \sum_l \sum_m Y^2_{ijklm} \text{ was obtained for each}$$

character by the usual method.

2. Sums of squares for main effects were estimated using the values of constants obtained and the value of variance-covariance matrix.

$$\begin{aligned} \text{Error S.S.} &= \sum_i \sum_j \sum_k \sum_l \sum_m Y^2_{ijklm} \\ &\quad - R(\mu, F_1, P_j, S_k, A_l) \end{aligned}$$

Where, R is RHM element corresponding to the constants μ , F_1 , P_j , S_k , and A_l . Sum of squares due to main effects were obtained by using the following expressions:

$$\text{S.S. for the } i\text{th set of main effects} = \begin{matrix} 1 & -1 \\ B_i & Z & B_i \\ 1 & 1 & 1 \end{matrix}$$

Where, B_i is the column vector for the constants for i th set of main effects.

B_i^1 is the transpose of B_i i.e. row vector.

Z_i^{-1} is the inverse of the segment of the inverse of the variance-covariance matrix corresponding by row and column for i th set of constants.

After obtaining the values of total S.S., error S.S. and main effects S.S., analysis of variance table was set up. The pattern of analysis of variance is shown in table 3.3.

Table 3.3: Pattern of analysis of variance

Source	d.f.	S.S.	M.S.	'F' ratio
Farms	$i-1$	$B_i^1 Z_i^{-1} B_i$	S.S./d.f	M.S.F./M.S.E.
Periods	$j-1$	$B_j^1 Z_j^{-1} B_j$	S.S./d.f	M.S.P./M.S.E.
Season	$k-1$	$B_k^1 Z_k^{-1} B_k$	S.S./d.f	M.S.S./M.S.E.
Age at calving	$l-1$	$B_l^1 Z_l^{-1} B_l$	S.S./d.f.	M.S.A./M.S.E.
Error	residual	$\sum_i \sum_j \sum_k \sum_l \sum_m Y_{ijklm}^2 - R(U, F_l, P_j, S_k, A_l)$	S.S./d.f,	
Total	$n \dots - 1$	$\sum_i \sum_j \sum_k \sum_l \sum_m Y_{ijklm}^2$	S.S./d.f.	

The mean squares were obtained by dividing the sum of squares of each effect by corresponding d.f. The ratio of mean squares for each of the effects and that for the error provided the 'F' value for testing the significance of

different effects.

3.2.2 Estimation of least squares means and standard errors:

Least squares means were obtained from known values of μ and least squares constants by using the following expressions.

Least squares mean for $F_1 = \mu + F_1$

Least squares mean for $P_j = \mu + P_j$

Least squares mean for $S_k = \mu + S_k$

Least squares mean for $A_l = \mu + A_l$

Standard errors for least squares mean of main effect were obtained by using the values of error mean squares σ_e^2 , and the elements of variance-covariance matrix.

$$S.E. \mu = \sqrt{(C \mu \mu)}$$

$$S.E. (\mu + a_l) = \sqrt{(C \mu \mu + C_{11} + C \mu_1) \sigma_e^2}$$

Where,

$C \mu \mu$ is the element of variance-covariance matrix corresponding to μ row and column, C_{11} is the element corresponding to 1th effect by row and column, $C \mu_1$ is the element in the μ th row and 1th column.

3.2.3 Duncan's Multiple Range Test (DMRT):

After completion of analysis of variance the significant effects were further analysed to make all pairwise comparisons using the DMRT as modified by Kramer (1957). The test was performed in the following steps (Harvey, 1966).

1. Least squares means for a particular effect under study

were arranged in a descending manner, largest to the left and smallest to the right.

2. $(\bar{Y}_a - \bar{Y}_b)$ values were estimated where $\bar{Y}_a$ is equal to least squares mean for treatment a, $\bar{Y}_b$ is equal to least squares mean for treatment b.

3.
$$\left[\bar{Y}_a - \bar{Y}_b \left(\sqrt{\frac{2}{C_{aa} + C_{bb} - 2C_{ab}}} \right) \right]$$

was then estimated where C_{aa} , C_{bb} are diagonal elements of variance-covariance matrix, corresponding to a and b respectively, while C_{ab} is the element corresponding to ath row and bth column.

4. The value $(6e Z_{pn_2})$ was determined, Z_{pn_2} from the table given for significant studentized ranges (Table A-7. Steel and Torrie, 1980) and $6e = \sqrt{\text{Error M.S.}}$

P = Number of means in the range chosen, and

n_2 = Number of degrees of freedom for error

5. If the value
$$\left[(\bar{Y}_a - \bar{Y}_b) \left(\sqrt{\frac{2}{C_{aa} + C_{bb} - 2C_{ab}}} \right) \right]$$

was found greater than $(6e Z_{pn_2})$ the differences between the least squares means a and b was considered significant.

Estimation of values in variance-covariance matrix corresponding to the absorbed elements that were suppressed:

For all possible comparisons among least squares means, it was necessary to obtain the diagonal and off-diagonal element of all the effects including those that were suppressed. These values were estimated from the available

values of variance-covariance matrix in the following manner.

$$CU + F_3 = \sqrt{[CU + CF_3F_3 + 2(CU F_3)]} \quad 6e$$

Where, CU is the value of variance-covariance matrix corresponding to U row and column.

$$CF_3F_3 = -(CF_1F_3 + CF_2F_3)$$

Where,

$$CF_1F_3 = -(CU + F_1 + CF_1CF_2)$$

$$CF_2F_3 = -(CU + F_2 + CF_2F_1)$$

$$\text{and } CU F_3 = -(CU F_1 + CU F_2)$$

using the same technique, values of variance-covariance matrix corresponding to other suppressed elements were found out.

3.2.4 Correction of the data:

Records were corrected for significant effects for each character using the relationship.

$$CY_{ijklm} = Y_{ijklm} - C.F.$$

Where,

$$CY_{ijklm} = \text{Corrected record}$$

$$Y_{ijklm} = \text{Uncorrected record}$$

$$C.F. = \text{Correction factor}$$

3.2.5 Estimation of genetic and phenotypic parameters.

Heritabilities, genetic and phenotypic correlations of various traits were estimated from the corrected data.

The following generalised model was used to estimate the components of genetic variance and covariance.

$$Y_{ij} = \mu + S_i + e_{ij}$$

where,

Y_{ij} = j th observation of i th sire

μ = overall mean

S_i = The effect due to i th sire common to all its daughters and

e_{ij} = The random error which is NID $(0, \sigma_e^2)$

Assumptions, $E(S_i) = E(e_{ij}) = 0$

$$E(S_i)^2 = \sigma_s^2 \text{ and } E(e_{ij})^2 = \sigma_e^2$$

Heritabilities were estimated by parental analysis correlation method as outlined by Hazel and Terrell (1945). The estimated sire component of variance was used as an estimate of one fourth of the additive genetic variance.

Table 3.4: Analysis of variance for estimation of heritability

Source	d.f.	M.S.S.	Component
Sires	S-1	MSs	$\sigma_e^2 + \bar{k} \sigma_s^2$
Error	N-S	MSe	σ_e^2

$$\sigma_s^2 = \frac{MSs - MSe}{\bar{k}}$$

$\bar{k}$ is the average number of progeny per sire and is estimated by the following formula.

$$\bar{k} = \frac{(\sum k)^2 - \sum k^2}{k \sum (n-1)}$$

$$h^2 = \frac{4 \sigma_s^2}{\sigma_s^2 + \sigma_e^2}$$

The standard error of heritability was estimated by the method described by Dickerson (1960).

$$\sigma_s = \sqrt{\frac{2 (MS)_s + (MS)_w}{k^2 n_s n_w}}$$

where (MS)_s and (MS)_w are mean squares for sires and error respectively with degree of freedom n_s and n_w . The k is coefficient of the sire component.

Genetic correlations:

The estimation of genetic correlation coefficients rests on the resemblance between relatives in a manner analogous to the estimation of heritabilities. In this case, instead of computing the components of variance of one trait from the analysis of variance, the components of covariance of the two traits were computed from analysis of covariance. The crossproducts of values of the two characters for each individual were summed and the total sum of products were partitioned according to the sources of variation.

The genetic correlation coefficients among production and reproduction traits were estimated by paternal half-sib analysis of covariance as described by Hazel et al. (1943).

The genetic correlation coefficient (r_G) was estimated as follows.

$$r_{Gij} = \frac{\text{Cov. } (S_i S_j)}{\sqrt{(V_{S_i} V_{S_j})}}$$

where,

Cov. ($S_i S_j$) = Component of covariance between sire group for two traits (i, j)

V_{S_i} = Component of sire variance, for i th trait

V_{S_j} = Component of sire variance for j th trait

Standard Error (SE) of genetic correlation was estimated after Robertson (1959), by the following formula:

$$SE \ rG = \frac{1-rG^2}{\sqrt{2}} \sqrt{\frac{\frac{2}{(hx)} \quad \frac{2}{(hy)}}{\frac{2}{hx} \quad x \quad \frac{2}{hy}}}$$

where,

rG = genetic correlation between character x and y
 h^2_x and h^2_y = the heritability of characters x and y respectively.

Phenotypic correlations:

The phenotypic correlations were estimated by the method described by Searle (1961).

$$r_{P_i P_j} = \frac{\text{Cov. } T_i T_j}{\sqrt{(V_{T_i}) (V_{T_j})}}$$

Where,

Cov. $T_i T_j$ = Total component of covariance of i th and j th character.

V_{T_i} , V_{T_j} = Total components of variance of i th and j th characters respectively.

$r_{P_i P_j}$ = Phenotypic correlation between i th and j th characters.

S.E. of $P_i P_j$ was calculated by the formula as follows (Panse and Suknathme, 1967).

$$S.E. (r_{P_i P_j}) = \frac{1-r^2_{P_i P_j}}{\sqrt{N-2}}$$

where, N is total number of animals.

Repeatability:

Repeatability is the ratio of the genetic variance (σ^2_G) and the variance due to permanent environmental effects to the total variance.

$$r = \frac{\sigma^2_G + \sigma^2_{Ep}}{\sigma^2_G + \sigma^2_{Ep} + \sigma^2_{Et}} = \frac{\sigma^2_G + \sigma^2_{Ep}}{\sigma^2_P}$$

Where,

σ^2_G = Genetic variance

σ^2_{Ep} = Variance due to permanent environment

σ^2_{Et} = Variance due to temporary environment

σ^2_P = Total phenotypic variance

Repeatability can be estimated as intraclass correlation or as a correlation among different records of the same buffalo.

The following model was considered as explaining a record of a buffalo:

$$Y_{ij} = \mu + c_i + e_{ij}$$

where,

Y_{ij} is the j th record of i th buffalo

μ is the overall mean

c_i is the effect common to all records of i th buffalo

e_{ij} is the random error

It was assumed that $S(c_i) = E(e_{ij}) = 0$

$$E(c_i)^2 = \sigma^2_c; E(e_{ij})^2 = \sigma^2_e$$

The analysis of variance was carried out as below:

Table 3: Analysis of variance (Model)

Source of variation	Degree of freedom	Sum of squares	M.S.	E.M.S.
Total	N-1	$\sum_{ij} Y_{ij}^2 - \frac{Y_{..}^2}{N}$		
Between buffaloes	n-1	$\sum_i \frac{Y_{i.}^2}{n} - \frac{Y_{..}^2}{N}$	A	$\sigma^2_e + K \sigma^2_c$
Within buffaloes	N-n	By subtraction	E	σ^2_e

$$K = \frac{1}{n-1} \left[N - \frac{\sum_i n_i^2}{N} \right]$$

$$\sigma^2_c = \frac{A-E}{K}$$

Then,

$$\text{Repeatability (t)} = \frac{\sigma^2_c}{\sigma^2_c + \sigma^2_e}$$

σ^2_c is the variance of buffaloes

σ^2_e is the variance of error

K is the number of records per buffalo

Standard error (S.E) of repeatability is calculated by the method described by Cockerham (1948).

S.E. of repeatability =

$$\sqrt{\frac{2(1-R)^2}{K^2(n-1)(K-1)n} \left[n(K-1) \{1+R(K-1)\}^2 + n-1 \{1-R(K-1)\} \right]}$$

Where,

R = Repeatability

K = Number of records per buffalo

n = Number of buffaloes

4 Results

CHAPTER 4

RESULTS

4.01 Peak yield:

The data on first to fourth lactation peak yields were available for 678 buffaloes. Least squares analysis of variance was carried out (Table 4.01) to estimate the influence of different factors on peak yield in buffaloes. Farm had a highly significant influence on peak yields during second and third lactation and significant influence during fourth lactation. Period had highly significant influence during all the lactations. Season had highly significant influence during fourth lactation. Age at calving had highly significant influence during first lactation and significant influence during third lactation. However, on overall basis, farm, period, season and age at calving all these factors had highly significant influence on peak yield in buffaloes.

The least squares mean peak yields (Table 4.02) for first, second, third and fourth lactations were 8.44 ± 0.12 , 9.69 ± 0.14 , 10.21 ± 0.14 and 10.49 ± 0.13 Kg, respectively. The overall least squares mean peak yield was 9.72 ± 0.07 Kg.

Duncans Multiple Range Test (DMRT) revealed that least squares means for buffaloes calved at Ambala farm had a distinct overall superiority in peak yields. The differences between Jabalpur and Ferozepore farms were not significantly different.

Table 4.01: Least squares analysis of variance for peak yield

Source	d.f.	1st lactation		IInd lactation		IIId lactation		IVth lactation		Overall	
		M.S.S.	F	M.S.S.	F	M.S.S.	F	M.S.S.	F	d.f.	M.S.S. F
Farm	2	3.79	1.02	43.08	9.12 ^{**}	45.26	8.59 ^{**}	19.49	3.38 [*]	2	44.30 ^{**} 8.32
Period	2	54.62	17.32 ^{**}	59.16	12.53 ^{**}	51.85	9.85 ^{**}	52.00	9.01 ^{**}	2	579.87 ^{**} 108.88
Season	1	6.23	1.98	4.56	0.96	2.27	0.43	47.08	8.15 ^{**}	1	43.43 ^{**} 8.15
Age at calving	6	9.24	2.93 ^{**}	3.62	0.77	13.35	2.54 ^{**}	10.42	1.80	6	45.72 ^{**} 8.58
Error	666	3.16		4.72		5.26		5.77		2700	5.33
Total	677									2711	

^{**}, Significant at P/0.01 ^{*}, Significant at P/0.05

Table 4.02: Least squares means and standard error for the factors affecting peak yield

Source of variation	Code	1st lactation		IInd lactation		IIInd lactation		IVth lactation		Overall	
		Mean(kg)	S.E.	Mean(kg)	S.E.	Mean(kg)	S.E.	Mean(kg)	S.E.	Mean(kg)	S.E.
μ		8.44	0.12	9.69	0.14	10.21	0.14	10.49	0.13	9.72	0.07
Farm.											
Ambala											
	F ₁	8.52 a	0.14	10.21	0.18	10.71a	0.18	10.79 a	0.19	9.99	0.09
Ferozapore	F ₂	8.29 a	0.14	9.53 a	0.17	10.30 a	0.18	10.64 ab	0.18	9.65 a	0.08
Jabalpur	F ₃	8.50 a	0.18	9.32 a	0.22	9.61	0.23	10.04 b	0.23	9.53 a	0.11
Period:											
1968-1972	P ₁	7.84	0.12	9.05	0.18	9.59	0.20	9.80	0.22	8.76	0.09
1973-1977	P ₂	8.66 a	0.14	9.92 a	0.18	10.41 a	0.19	10.74 a	0.19	9.99	0.09
1978-1982	P ₃	8.81 a	0.23	10.09 a	0.21	10.63 a	0.20	10.93 a	0.18	10.42	0.10
Season											
July-Dec	S ₁	8.30 a	0.11	9.56 a	0.11	10.13 a	0.12	10.14	0.12	9.55	0.06
Jan-June	S ₂	8.57 a	0.18	9.81 a	0.24	10.29 a	0.24	10.84	0.23	9.89	0.11
Age at calving.											
	A ₁	7.80 d	0.33	9.13 a	0.47	9.16 b	0.52	10.43 abc	0.38	9.15 ce	0.22
	A ₂	8.09 cd	0.18	9.64 a	0.25	10.11 ab	0.26	10.05 c	0.33	9.30 de	0.13
	A ₃	8.44 abcd	0.17	10.03 a	0.23	10.71 a	0.30	10.67 abc	0.35	9.67 cd	0.13
	A ₄	8.75 ab	0.19	9.67 a	0.26	10.63 a	0.27	10.31 abc	0.27	9.87 abd	0.13
	A ₅	8.34 bcd	0.18	9.70 a	0.22	9.94 ab	0.22	10.67 abc	0.24	9.76 bc	0.11
	A ₆	8.45 abcd	0.21	9.71 a	0.22	10.64 a	0.23	11.06 a	0.26	10.11 a	0.12
	A ₇	9.19 a	0.31	9.94 a	0.23	10.27 ab	0.20	10.24 bc	0.18	10.20 ab	0.11

Note: Means connected by the same letter are not significantly different

Table 4.03- Phenotypic and genetic correlations amongst various first lactational economic traits

Sr. No.	Traits	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Peak yield	0.18 ^{**} ±0.02	0.63 ^{**} ±0.03	0.53 ^{**} ±0.03	0.46 ^{**} ±0.03	-0.13 ^{**} ±0.04	-0.07 ^{**} ±0.04	-0.11 ^{**} ±0.04	0.70 ^{**} ±0.03	0.55 ^{**} ±0.03	0.58 ^{**} ±0.03	0.47 ^{**} ±0.03	0.08 ^{**} ±0.04	0.06 ^{**} ±0.04
2.	300-day milk yield	0.51 ^{**} ±0.07	0.13 ^{**} ±0.02	0.54 ^{**} ±0.01	0.84 ^{**} ±0.03	0.29 ^{**} ±0.04	0.04 ^{**} ±0.04	0.18 ^{**} ±0.04	0.80 ^{**} ±0.02	0.73 ^{**} ±0.03	0.93 ^{**} ±0.01	0.52 ^{**} ±0.03	-0.08 ^{**} ±0.04	-0.10 ^{**} ±0.04
3.	Lactation milk yield	1.09 ^{**} ±0.09	1.07 ^{**} ±0.07	0.09 ^{**} ±0.01	0.65 ^{**} ±0.03	0.50 ^{**} ±0.03	0.16 ^{**} ±0.04	0.37 ^{**} ±0.03	0.68 ^{**} ±0.03	0.62 ^{**} ±0.03	0.92 ^{**} ±0.01	0.45 ^{**} ±0.03	-0.17 ^{**} ±0.04	-0.19 ^{**} ±0.04
4	Lifetime milk yield	1.02 ^{**} ±0.02	>1 ^{**}	>1 ^{**}	0.13 ^{**} ±0.02	0.29 ^{**} ±0.04	0.00 ^{**} ±0.04	0.14 ^{**} ±0.04	0.45 ^{**} ±0.04	0.47 ^{**} ±0.03	0.64 ^{**} ±0.03	0.70 ^{**} ±0.03	-0.23 ^{**} ±0.04	-0.24 ^{**} ±0.04
5	Lactation length	0.61 ^{**} ±0.22	0.50 ^{**} ±0.30	0.13 ^{**} ±0.44	0.53 ^{**} ±0.28	-0.05 ^{**} ±0.01	0.28 ^{**} ±0.04	0.67 ^{**} ±0.03	-0.25 ^{**} ±0.04	-0.10 ^{**} ±0.04	0.32 ^{**} ±0.04	-0.02 ^{**} ±0.04	-0.35 ^{**} ±0.04	-0.34 ^{**} ±0.04
6.	Dry period	0.15 ^{**} ±0.57	0.35 ^{**} ±0.58	0.11 ^{**} ±0.74	-0.12 ^{**} ±0.64	-0.36 ^{**} ±0.49	0.04 ^{**} ±0.01	0.88 ^{**} ±0.02	-0.04 ^{**} ±0.04	-0.54 ^{**} ±0.03	-0.08 ^{**} ±0.04	-0.30 ^{**} ±0.04	-0.45 ^{**} ±0.03	-0.41 ^{**} ±0.03
7.	Service period	0.92 ^{**} ±0.16	>1 ^{**}	0.50 ^{**} ±1.02	0.57 ^{**} ±0.80	<1 ^{**}	>1 ^{**}	0.01 ^{**} ±0.01	-0.13 ^{**} ±0.04	-0.46 ^{**} ±0.03	0.09 ^{**} ±0.04	-0.23 ^{**} ±0.04	-0.50 ^{**} ±0.03	-0.47 ^{**} ±0.03
8	Milk yield per day of lactation length	>1 ^{**}	>1 ^{**}	>1 ^{**}	>1 ^{**}	>1 ^{**}	0.41 ^{**} ±0.86	>1 ^{**}	0.03 ^{**} ±0.01	0.77 ^{**} ±0.02	0.76 ^{**} ±0.25	0.51 ^{**} ±0.03	0.08 ^{**} ±0.04	0.06 ^{**} ±0.04
9	Milk yield per day of calving interval	0.99 ^{**} ±0.01	0.75 ^{**} ±0.29	0.96 ^{**} ±0.06	>1 ^{**}	0.73 ^{**} ±0.26	-0.45 ^{**} ±0.74	0.05 ^{**} ±1.66	0.63 ^{**} ±0.32	0.07 ^{**} ±0.01	0.78 ^{**} ±0.02	0.62 ^{**} ±0.03	0.26 ^{**} ±0.04	0.21 ^{**} ±0.04
10	Milk yield per day of age at second calving	0.99 ^{**} ±0.01	0.97 ^{**} ±0.03	1.02 ^{**} ±0.02	>1 ^{**}	0.42 ^{**} ±0.36	-0.07 ^{**} ±0.73	0.47 ^{**} ±1.04	>1 ^{**}	0.97 ^{**} ±0.03	0.14 ^{**} ±0.00	0.55 ^{**} ±0.03	-0.03 ^{**} ±0.04	-0.03 ^{**} ±0.04
11	Milk yield per day of productive life	0.47 ^{**} ±0.32	0.05 ^{**} ±0.13	0.97 ^{**} ±0.03	0.85 ^{**} ±0.13	0.60 ^{**} ±0.25	-0.64 ^{**} ±0.39	-0.45 ^{**} ±0.96	0.95 ^{**} ±0.07	>1 ^{**}	>1 ^{**}	0.12 ^{**} ±0.02	0.43 ^{**} ±0.03	0.40 ^{**} ±0.03
12.	Breeding efficiency (Miles)	-0.49 ^{**} ±0.35	-0.36 ^{**} ±0.46	-0.33 ^{**} ±0.53	0.04 ^{**} ±0.51	0.15 ^{**} ±0.44	<1 ^{**}	<1 ^{**}	-0.71 ^{**} ±0.42	0.75 ^{**} ±0.32	-0.06 ^{**} ±0.58	0.57 ^{**} ±0.36	0.07 ^{**} ±0.01	0.94 ^{**} ±0.01
13	Breeding efficiency (Tomas)	-0.49 ^{**} ±0.32	-0.34 ^{**} ±0.43	-0.30 ^{**} ±0.50	0.05 ^{**} ±0.47	0.14 ^{**} ±0.40	<1 ^{**}	<1 ^{**}	-0.68 ^{**} ±0.41	0.68 ^{**} ±0.36	-0.05 ^{**} ±0.54	0.60 ^{**} ±0.31	1.02 ^{**} ±0.17	0.09 ^{**} ±0.01

**, Significant at P/0.01

*, Significant at P/0.05

Note. Figures on the diagonal are heritabilities, off diagonal are phenotypic correlations, and below diagonal are genetic correlations

Table 4.04: Phenotypic and genetic correlations amongst various second lactational economic traits

Sr No.	Traits	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Peak yield	0.84 ^{**} ±0.03	0.69 ^{**} ±0.03	0.62 ^{**} ±0.03	0.54 ^{**} ±0.03	-0.05 ±0.04	-0.07 ±0.04	-0.06 [*] ±0.04	0.75 ^{**} ±0.03	0.64 ^{**} ±0.03	0.34 ^{**} ±0.04	0.54 ^{**} ±0.03	0.06 ±0.04	-0.01 ±0.04
2.	300-day milk yield	-1.02 ^{**} ±0.05	-0.02 [*] ±0.01	0.96 ^{**} ±0.01	0.75 ^{**} ±0.02	0.34 ^{**} ±0.04	-0.03 ±0.04	0.14 ^{**} ±0.04	0.77 ^{**} ±0.02	0.73 ^{**} ±0.02	0.42 ^{**} ±0.03	0.60 ^{**} ±0.03	-0.11 ±0.04	-0.14 ±0.04
3.	Lactation milk yield	0.78 ^{**} ±0.07	-1.00 ^{**} ±0.00	-0.02 [*] ±0.01	0.74 ^{**} ±0.03	0.53 ^{**} ±0.03	0.05 ±0.04	0.30 ^{**} ±0.04	0.66 ^{**} ±0.03	0.64 ^{**} ±0.03	0.39 ^{**} ±0.03	0.53 ^{**} ±0.03	-0.21 ±0.04	-0.24 ^{**} ±0.04
4	Lifetime milk yield	>1	0.86 ^{**} ±0.24	0.26 ^{**} ±0.80	0.13 ±0.02	0.30 ^{**} ±0.04	-0.06 ±0.04	0.10 [*] ±0.04	0.56 ^{**} ±0.03	0.56 ^{**} ±0.03	0.61 ^{**} ±0.03	0.73 ^{**} ±0.03	-0.20 ±0.04	-0.23 ^{**} ±0.04
5,	Lactation length	<-1	<-1	<-1	<-1	-0.01 [*] ±0.01	0.23 ^{**} ±0.04	0.62 ^{**} ±0.03	-0.23 ^{**} ±0.04	-0.03 [*] ±0.04	0.11 ^{**} ±0.04	0.01 ±0.03	-0.44 ^{**} ±0.03	-0.42 ^{**} ±0.03
6	Dry period	-0.91 ^{**} ±0.13	<-1	-0.94 ^{**} ±0.11	<-1	>1	0.07 ±0.01	0.81 ^{**} ±0.02	-0.13 ^{**} ±0.04	-0.54 ^{**} ±0.03	-0.14 ^{**} ±0.04	-0.31 ^{**} ±0.04	-0.41 ^{**} ±0.03	-0.43 ^{**} ±0.03
7	Service period	<-1	<-1	<-1	<-1	0.77 ^{**} ±0.70	>1	0.05 ^{**} ±0.01	-0.21 ^{**} ±0.04	-0.46 ^{**} ±0.03	-0.04 ^{**} ±0.04	-0.26 ^{**} ±0.04	-0.56 ^{**} ±0.03	-0.57 ^{**} ±0.03
8	Milk yield per day of lactation length	0.94 ^{**} ±0.11	0.32 ±0.13	0.14 ±0.17	>1	<-1	<-1	<-1	0.05 ±0.01	0.79 ^{**} ±0.02	0.34 ^{**} ±0.04	0.60 ^{**} ±0.03	0.15 ±0.04	0.09 ±0.04
9	Milk yield per day of calving interval	>1	0.91 ^{**} ±0.16	0.65 ^{**} ±0.45	>1	<-1	-1.03 ^{**} ±0.35	<-1	0.65 ^{**} ±0.14	0.10 ±0.01	0.39 ^{**} ±0.03	0.68 ^{**} ±0.03	0.27 ±0.04	0.24 ^{**} ±0.04
10	Milk yield per day of age at second calving	>1	>1	0.92 ^{**} ±0.17	>1	<-1	<-1	<-1	>1	>1	0.14 ±0.00	0.49 ^{**} ±0.03	-0.08 ±0.04	0.01 ±0.04
11	Milk yield per day of productive life	>1	1.06 ^{**} ±0.12	0.69 ^{**} ±0.43	0.95 ^{**} ±0.05	<-1	-0.96 ^{**} ±0.04	<-1	>1	>1	>1	0.12 ±0.02	0.42 ±0.03	0.31 ±0.04
12	Breeding efficiency (Wilcox)	>1	0.83 ^{**} ±0.34	0.50 ^{**} ±0.20	0.41 ^{**} ±0.21	0.20 ±0.54	-0.19 ±0.64	-0.07 ±0.75	0.62 ^{**} ±0.51	0.66 ^{**} ±0.34	0.20 ±0.73	0.71 ±0.28	0.07 ±0.01	0.85 ^{**} ±0.02
13	Breeding efficiency (Tomar)	0.66 ^{**} ±0.06	>1	>1	0.53 ^{**} ±0.57	>1	0.29 ±0.82	0.82 ^{**} ±0.33	-0.03 ±0.11	0.50 ±0.60	-0.21 ±0.98	0.54 ±0.54	0.46 ±0.76	0.09 ±0.01

** Significant at P/0.01, * Significant at P/0.05

Note: Figures on the diagonal are heritabilities, off diagonal are phenotypic correlations, and below diagonal are genetic correlations

Table 4.05: Phenotypic and genetic correlations amongst various third lactational economic traits

Sr. No	Traits	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Peak yield	0.06 ±0.01	0.67 ±0.03	0.61 ±0.03	0.58 ±0.03	-0.04 ±0.04	0.00 ±0.04	-0.01 ±0.04	0.74 ±0.03	0.59 ±0.03	0.27 ±0.04	0.56 ±0.03	0.02 ±0.04	-0.05 ±0.04
2.	300-day milk yield	1.04 ±0.06	0.04 ±0.01	0.95 ±0.01	0.74 ±0.03	0.34 ±0.04	0.04 ±0.04	0.21 ±0.04	0.78 ±0.02	0.72 ±0.03	0.33 ±0.04	0.59 ±0.03	-0.14 ±0.04	-0.23 ±0.04
3.	Lactation milk yield	0.84 ±0.18	1.03 ±0.13	0.06 ±0.01	0.75 ±0.02	0.54 ±0.03	0.10 ±0.04	0.36 ±0.04	0.66 ±0.03	0.63 ±0.03	0.33 ±0.04	0.52 ±0.03	-0.23 ±0.04	-0.31 ±0.04
4	Lifetime milk yield	1.05 ±0.04	>1	>1	0.13 ±0.02	0.31 ±0.04	-0.05 ±0.04	0.12 ±0.04	0.58 ±0.03	0.61 ±0.03	0.63 ±0.03	0.77 ±0.02	-0.15 ±0.04	-0.19 ±0.03
5	Lactation length	0.57 ±0.41	>1	1.01 ±0.01	0.92 ±0.08	0.08 ±0.01	0.25 ±0.04	0.71 ±0.03	-0.24 ±0.04	-0.09 ±0.04	0.12 ±0.04	-0.03 ±0.04	-0.42 ±0.03	-0.46 ±0.03
6	Dry period	-0.48 ±0.58	-0.08 ±0.91	0.09 ±0.72	-0.30 ±0.56	0.61 ±0.44	0.08 ±0.01	0.83 ±0.02	-0.10 ±0.04	-0.54 ±0.03	-0.03 ±0.04	-0.29 ±0.04	-0.35 ±0.04	-0.40 ±0.03
7.	Service period	0.13 ±0.67	0.83 ±0.26	0.73 ±0.31	0.40 ±0.47	0.91 ±0.11	0.94 ±0.05	0.07 ±0.01	-0.19 ±0.04	-0.44 ±0.03	0.04 ±0.03	-0.23 ±0.04	-0.47 ±0.03	-0.54 ±0.03
8	Milk yield per day of lactation length	>1	-0.13 ±1.58	0.21 ±1.22	>1	0.45 ±0.97	-1.02 ±0.07	-0.07 ±1.37	-0.01 ±0.01	0.81 ±0.02	0.27 ±0.04	0.63 ±0.03	0.11 ±0.04	0.04 ±0.04
9	Milk yield per day of calving interval	>1	0.69 ±0.68	0.82 ±0.33	>1	0.86 ±0.26	-1.06 ±0.15	0.06 ±1.11	-0.23 ±2.04	0.02 ±0.01	0.30 ±0.04	0.71 ±0.03	0.19 ±0.04	0.15 ±0.04
10	Milk yield per day of age at second calving	>1	>1	>1	>1	>1	-0.24 ±1.08	0.86 ±0.28	>1	>1	0.14 ±0.00	0.49 ±0.03	-0.12 ±0.04	0.01 ±0.04
11.	Milk yield per day of productive life	0.90 ±0.10	0.90 ±0.12	0.80 ±0.19	0.84 ±0.13	0.55 ±0.35	-0.72 ±0.30	-0.12 ±0.56	>1	>1	>1	0.12 ±0.02	0.40 ±0.03	0.23 ±0.04
12.	Breeding efficiency (Mlcox)	0.19 ±0.64	-0.24 ±0.77	-0.24 ±0.61	0.09 ±0.55	-0.62 ±0.37	-0.72 ±0.36	-0.92 ±0.10	>1	0.72 ±0.52	-0.19 ±0.98	0.65 ±0.32	0.07 ±0.01	0.73 ±0.03
13	Breeding efficiency (Tovar)	<-1	<-1	<-1	<-1	<-1	<-1	<-1	<-1	<-1	<-1	-1.06 ±0.22	>1	0.09 ±0.01

**, Significant at P/0.01

*, Significant at P/0.05

Note: Figures on the diagonal are heritabilities, off diagonal are phenotypic correlations, and below diagonal are genetic correlations

Table 4.06 Phenotypic and genetic correlations amongst various fourth lactational economic traits

St. No.	Traits	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Peak yield	0.03 ±0.01	0.70 ±0.03	0.63 ±0.03	0.60 ±0.03	-0.01 ±0.04	-0.08 ±0.04	-0.07 ±0.04	0.73 ±0.03	0.55 ±0.03	0.28 ±0.04	0.61 ±0.03	0.06 ±0.04	0.02 ±0.04
2.	300-day milk yield	>1	0.02 ±0.01	0.96 ±0.01	0.74 ±0.03	0.35 ±0.04	-0.06 ±0.04	0.15 ±0.04	0.78 ±0.02	0.77 ±0.02	0.30 ±0.04	0.64 ±0.03	-0.01 ±0.04	-0.08 ±0.04
3.	Lactation milk yield	>1	>1	0.00 ±0.01	0.75 ±0.25	0.54 ±0.03	-0.01 ±0.04	0.30 ±0.04	0.67 ±0.03	0.68 ±0.03	0.30 ±0.04	0.59 ±0.03	-0.03 ±0.04	-0.10 ±0.04
4.	Lifetime milk yield	0.29 ±0.59	>1	>1	0.13 ±0.02	0.30 ±0.04	-0.05 ±0.04	0.14 ±0.04	0.60 ±0.03	0.59 ±0.03	0.62 ±0.03	0.81 ±0.02	-0.14 ±0.04	-0.17 ±0.04
5.	Lactation length	-0.67 ±0.27	<1	<1	-0.10 ±0.35	-0.08 ±0.01	0.17 ±0.04	0.70 ±0.03	-0.21 ±0.04	-0.04 ±0.04	0.08 ±0.04	0.06 ±0.04	-0.09 ±0.04	-0.08 ±0.04
6.	Dry period	-1.07 ±0.18	<1	<1	<1	-0.99 ±0.01	0.03 ±0.01	0.79 ±0.02	-0.16 ±0.04	-0.57 ±0.03	0.02 ±0.04	-0.11 ±0.04	-0.08 ±0.04	-0.05 ±0.04
7.	Service period	<1	<1	<1	-0.99 ±0.01	<1	-0.23 ±0.92	-0.04 ±0.01	-0.24 ±0.04	-0.44 ±0.03	0.07 ±0.04	-0.05 ±0.04	-0.13 ±0.04	-0.08 ±0.04
8.	Milk yield per day of lactation length	0.98 ±0.02	>1	>1	0.72 ±0.23	-0.35 ±0.32	-0.80 ±0.33	-0.74 ±0.25	0.07 ±0.01	0.83 ±0.02	0.28 ±0.04	0.62 ±0.03	0.04 ±0.04	-0.05 ±0.04
9.	Milk yield per day of calving interval	1.03 ±0.04	>1	>1	0.99 ±0.00	-0.20 ±0.35	-1.07 ±0.14	-0.77 ±0.22	0.95 ±0.05	0.09 ±0.01	0.24 ±0.04	0.59 ±0.03	0.05 ±0.04	-0.02 ±0.04
10.	Milk yield per day of age at second calving	>1	>1	>1	0.57 ±0.58	0.27 ±0.58	<1	<1	>1	>1	0.14 ±0.00	0.47 ±0.03	-0.17 ±0.04	0.03 ±0.04
11.	Milk yield per day of productive life	0.80 ±0.23	>1	>1	0.92 ±0.07	-0.01 ±0.35	<1	-1.04 ±0.04	0.94 ±0.05	>1	>1	0.12 ±0.02	0.35 ±0.04	0.12 ±0.04
12.	Breeding efficiency (MILCOX)	>1	>1	>1	0.15 ±0.80	-0.12 ±0.60	<1	-0.94 ±0.12	0.76 ±0.36	1.00 ±0.01	-0.47 ±1.13	0.60 ±0.51	0.07 ±0.01	0.60 ±0.03
13.	Breeding efficiency (FLOMAR)	0.14 ±0.76	-0.70 ±0.52	<1	<1	-0.38 ±0.36	0.46 ±0.81	-0.05 ±0.63	-0.37 ±0.50	-0.44 ±0.47	<1	-1.00 ±0.00	-0.33 ±0.87	0.09 ±0.01

**, Significant at P/0.01 *, Significant at P/0.05

Note: Figures on the diagonal are heritabilities, off diagonal are phenotypic correlations and below diagonal are genetic correlations

Table 4.07: Overall phenotypic and genetic correlations amongst various economic traits

Str. No.	Traits	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Peak yield	0.09 ±0.00	0.69 ±0.01	0.62 ±0.01	0.49 ±0.02	-0.07 ±0.02	-0.08 ±0.02	-0.10 ±0.02	0.75 ±0.01	0.65 ±0.01	0.32 ±0.02	0.51 ±0.02	0.09 ±0.02	0.08 ±0.02
2.	300-day milk yield	1.01 ±0.01	0.10 ±0.00	0.95 ±0.01	0.68 ±0.01	0.31 ±0.02	0.02 ±0.02	0.14 ±0.02	0.79 ±0.01	0.75 ±0.01	0.45 ±0.02	0.58 ±0.01	-0.05 ±0.02	-0.08 ±0.02
3.	Lactation milk yield	1.02 ±0.01	1.00 ±0.00	0.09 ±0.00	0.70 ±0.01	0.51 ±0.02	0.06 ±0.03	0.30 ±0.02	0.68 ±0.01	0.66 ±0.01	0.45 ±0.02	0.52 ±0.02	-0.13 ±0.02	-0.15 ±0.02
4.	Lifetime milk yield	1.02 ±0.01	1.06 ±0.03	1.08 ±0.04	0.13 ±0.02	0.30 ±0.02	-0.03 ±0.02	0.13 ±0.02	0.52 ±0.02	0.53 ±0.02	0.63 ±0.01	0.74 ±0.01	-0.20 ±0.02	-0.22 ±0.02
5.	Lactation length	>1	1.02 ±0.04	1.03 ±0.05	>1	0.00 ±0.00	0.23 ±0.02	0.68 ±0.01	-0.24 ±0.02	-0.09 ±0.02	0.16 ±0.02	0.00 ±0.02	-0.33 ±0.02	-0.33 ±0.03
6.	Dry period	-0.61 ±0.20	-0.65 ±0.17	-0.69 ±0.16	-0.60 ±0.18	-0.43 ±0.82	0.06 ±0.00	0.83 ±0.01	-0.12 ±0.02	-0.55 ±0.02	-0.06 ±0.03	-0.26 ±0.02	-0.35 ±0.02	-0.37 ±0.02
7.	Service period	-0.49 ±0.28	-0.56 ±0.25	-0.61 ±0.23	-0.42 ±0.28	-0.55 ±0.84	1.03 ±0.02	0.03 ±0.00	-0.22 ±0.02	-0.46 ±0.02	0.04 ±0.02	-0.20 ±0.19	-0.44 ±0.02	-0.45 ±0.02
8.	Milk yield per day of lactation length	0.97 ±0.02	1.00 ±0.00	1.00 ±0.00	1.01 ±0.00	1.06 ±0.11	-0.72 ±0.15	-0.62 ±0.23	0.08 ±0.00	0.82 ±0.01	0.37 ±0.02	0.58 ±0.02	0.13 ±0.02	0.95 ±0.02
9.	Milk yield per day of calving interval	0.53 ±0.04	0.91 ±0.03	0.94 ±0.03	0.94 ±0.03	0.83 ±0.26	-0.88 ±0.06	-0.84 ±0.10	0.96 ±0.02	0.14 ±0.00	0.39 ±0.02	0.63 ±0.01	0.22 ±0.02	0.20 ±0.02
10.	Milk yield per day of age at second calving	1.02 ±0.01	1.06 ±0.03	1.07 ±0.04	0.97 ±0.01	>1	-0.47 ±0.22	-0.26 ±0.33	0.98 ±0.01	0.88 ±0.05	0.14 ±0.00	0.49 ±0.02	-0.11 ±0.02	-0.01 ±0.02
11.	Milk yield per day of productive life	0.94 ±0.03	0.90 ±0.05	0.90 ±0.05	0.83 ±0.07	0.52 ±0.60	-0.86 ±0.07	-0.89 ±0.07	1.00 ±0.00	1.01 ±0.00	0.75 ±0.10	0.12 ±0.02	0.41 ±0.02	0.28 ±0.02
12.	Breeding efficiency (MILCOX)	0.19 ±0.25	0.09 ±0.25	0.06 ±0.26	0.05 ±0.24	<1	-0.85 ±0.08	<1	0.32 ±0.24	0.46 ±0.20	-0.08 ±0.25	0.55 ±0.16	0.07 ±0.01	0.80 ±0.01
13.	Breeding efficiency (Tumar)	-0.03 ±0.29	-0.09 ±0.28	-0.14 ±0.29	-0.14 ±0.26	<1	-0.76 ±0.13	-1.09 ±0.18	0.07 ±0.30	0.29 ±0.25	-0.30 ±0.25	0.32 ±0.23	0.92 ±0.04	0.09 ±0.01

*, Significant at P/0.01

*, Significant at P/0.05

Note: Figures on the diagonal are heritabilities, off diagonal are phenotypic correlations, and below diagonal are genetic correlations

Table 4.08: Repeatability of various economic traits

Sr. No.	Trait	Repeatability estimate	S.E.
1.	Peak yield	0.35 $\pm$ 0.02	✓
2.	300-day milk yield	0.37 $\pm$ 0.02	✓
3.	Lactation milk yield	0.35 $\pm$ 0.02	
4.	Lactation length	0.15 $\pm$ 0.02	
5.	Dry period	0.07 $\pm$ 0.02	
6.	Service period	0.06 $\pm$ 0.02	✓
7.	Milk yield per day of lactation length	0.34 $\pm$ 0.02	✓
8.	Milk yield per day of calving interval	0.34 $\pm$ 0.02	✓

Least squares means for different periods revealed that peak yields were significantly lower during first period in all the lactations. Same trend was reflected in overall figures. Buffaloes calved during second and third period did not differ significantly in their peak yields.

Season of calving had non-significant influence on the peak yield in first three lactations. However, the buffaloes calved during second season, had significantly higher peak yields in fourth lactation. This trend was also reflected in overall figures.

Age at calving had non-significant trend of the influence on peak yields in different lactations.

Genetic correlations of peak yield (Table 4.03 to 4.07) with all other traits were estimated. It had highly significant and positive genetic correlations with all other traits, during first lactation, except dry period and breeding efficiency. This trend was not consistent in subsequent lactations.

Peak yield had highly significant and positive phenotypic correlations, during first lactation, with all other traits except breeding efficiency, lactation length, dry period and service period. It had negative phenotypic correlations with the latter three traits. The trend of negative phenotypic correlations with these three traits continued even in subsequent lactations and same was the overall picture.

Heritabilities of peak yield was estimated separately for all the four lactations. Heritability of peak yield was 0.18 ± 0.02 in first lactation which varied in subsequent lactations.

Repeatability of peak yield (Table 4.08) was 0.35 ± 0.02 .

4.02 300-day milk yield:

Least squares analysis of variance was carried out (Table 4.09) to estimate the influence of different factors on 300-day milk yield in buffaloes. Farm and period had a highly significant influence on 300-day milk yields in all the lactations. Season had highly significant influence during fourth lactation. Age at calving had significant influence in third lactation. However, on overall basis, farm, period, season and age at calving, all these factors had highly significant influence on 300-day milk yield in buffaloes.

The least squares mean 300-day milk yields (Table 4.10) for first, second, third and fourth lactations were 1784.40 ± 24.84 , 1959.20 ± 27.97 , 2025.37 ± 27.62 and 2061.45 ± 26.74 Kg, respectively. The overall least squares mean 300-day milk yield was 1955.56 ± 12.77 kg.

DMRT revealed that least squares means for buffaloes calved at Jabalpur farm were significantly lower. The differences between Ampala and Ferozepore farms were not significantly different during second, third and fourth lactations.

Table 4.09: Least squares analysis of variance for 300-day milk yield

Source	d.f.	1st lactation		IInd lactation		IIInd lactation		IVth lactation		Overall	
		M.S.S.	F	M.S.S.	F	M.S.S.	F	M.S.S.	F	d.f	M.S.S.
Farm	2	1956317.80	13.77 ^{**}	2550823.50	13.18 ^{**}	2439241.50	12.37 ^{**}	1647127.90	7.11 ^{**}	2	7403686.50
Period	2	1825281.20	12.85 ^{**}	1858627.80	9.60 ^{**}	1812766.10	9.19 ^{**}	1393577.00	6.02 ^{**}	2	11638884.00
Season	1	8871.67	0.06	115091.30	0.59	239091.23	1.22	2988186.90	14.91 ^{**}	1	1426508.10
Age at calving	6	243462.70	1.71	216702.38	1.12	544700.15	2.76 [*]	275697.18	1.19	6	1437957.00
Error	666	142073.64		193585.33		197139.55		231485.10		2700	199196.95
Total	677									2711	

^{**}, Significant at P/0.01 *, Significant at P/0.05

Table 4.10: Least squares means and standard error for the factors affecting 300-day milk yield

Source of variation	Code	1st lactation		IInd lactation		IIIrd lactation		Fourth lactation		Overall	
		Mean (kg)	S.E.	Mean (kg)	S.E.	Mean (kg)	S.E.	Mean (kg)	S.E.	Mean (kg)	S.E.
Herds											
A		1784.40	24.84	1959.20	27.97	2025.37	27.62	2061.45	26.74	1955.56	12.77
Farms											
Ambala	F ₁	1791.46	30.84	2027.38	35.91	2073.71	35.78	2128.04	37.49	1996.46	16.90
Ferozepore	F ₂	1885.68	28.96	2046.31	35.08	2127.87	35.55	2130.12	36.59	2040.73	16.34
Jabalpur	F ₃	1676.04	39.24	1803.91	44.20	1874.52	44.83	1926.18	47.15	1829.48	21.79
Periods											
1968-1972	P ₁	1704.03	24.73	1871.35	35.66	1919.52	39.57	1950.46	44.96	1822.99	16.97
1973-1977	P ₂	1870.76	30.92	2056.26	36.13	2118.48	36.43	2144.45	37.63	2047.60	17.56
1978-1982	P ₃	1778.40	49.21	1949.99	43.28	2038.10	38.36	2089.43	36.74	1996.08	19.93
Seasons											
July-Dec.	S ₁	1789.36	22.75	1939.53	22.44	1998.55	22.48	1974.05	23.67	1924.44	10.79
Jan-June	S ₂	1779.44	38.80	1978.87	48.60	2052.18	46.93	2148.84	45.31	1986.67	21.91
Age at calving											
	A ₁	1721.11	69.23	1857.84	94.82	1793.85	100.23	1954.23	77.01	1831.14	42.19
	A ₂	1711.47	38.07	1930.45	49.92	1947.10	51.05	2031.63	65.67	1884.18	24.87
	A ₃	1775.96	36.40	1967.62	46.81	2147.92	57.48	2171.02	71.00	1968.86	24.63
	A ₄	1785.61	40.31	1942.05	52.48	2097.88	52.95	2042.17	54.42	1960.15	24.88
	A ₅	1764.91	38.60	1966.45	44.07	2045.11	43.29	2114.14	47.93	1983.67	21.90
	A ₆	1815.77	45.36	1991.40	45.58	2093.71	44.02	2080.18	51.27	2020.83	23.29
	A ₇	1915.98	66.79	2058.60	46.42	2052.01	38.74	2036.77	35.46	2040.07	20.96

Note: Means connected by the same letter are not significantly different

Least squares means for different periods revealed that 300-day milk yields were significantly lower during first period in all the lactations. Same trend was reflected in overall figures. Buffaloes calved during second and third period did not differ significantly in their 300-day milk yields.

Season of calving had non-significant effect on the 300-day milk yields in first three lactations. However, the buffaloes calved during second season had significantly higher 300-day milk yields in fourth lactation. This trend was also reflected in overall figures.

Age at calving had no significant trend of the influence on 300-day milk yields in different lactations.

Genetic correlations of 300-day milk yield (Table 4.03 to 4.07) with all other traits were estimated. It had highly significant, and positive genetic correlations with all other traits during first lactation except dry period and breeding efficiency. This trend was not consistent in subsequent lactations.

300-day milk yield had highly significant and positive phenotypic correlations, during first lactation, with all other traits except dry period and breeding efficiency. It had negative phenotypic correlations with the latter trait. The trend of negative phenotypic correlations with this trait continued even in subsequent lactations and same was the overall picture.

Heritabilities of 300-day milk yield was estimated separately for all the four lactations. Heritability of 300-day milk yield was 0.13 ± 0.02 in first lactation which declined in subsequent lactations.

Repeatability of 300-day milk yield (Table 4.08) was 0.37 ± 0.02 .

4.03 Lactation milk yield:

Least squares analysis of variance was carried out (Table 4.11) to estimate the influence of different factors on lactation milk yield in buffaloes. Farm and period had a highly significant influence on lactation milk yields in all lactations. Season had a highly significant influence during fourth lactation. Age at calving had highly significant influence during third lactation. However, on overall basis farm, period, season and age at calving had highly significant influence on lactation milk yield in buffaloes.

The least squares mean lactation milk yields (Table 4.12) for first, second, third and fourth lactations were 1853.43 ± 28.45 , 2040.88 ± 31.15 , 2101.52 ± 30.79 and 2141.52 ± 29.75 kg, respectively. The overall least squares mean lactation milk yield was 2037.29 ± 14.21 kg.

DMRT revealed that buffaloes calved at Jabalpur farm were having significantly lower lactation milk yields. The differences between Ambala and Ferozepore farms were not significantly different except for first lactation.

Table 4.11: Least squares analysis of variance for lactation milk yield

Source	d.f.	1st lactation			IInd lactation			IIIrd lactation			IVth lactation			Overall		
		M.S.S.	F		M.S.S.	Y		M.S.S.	Y		M.S.S.	F		d.f	M S S	F
Farm	2	2675646.40	14.35	**	2605964	50	10.85	2189273.90	8	94	1815219.50	6	34	2	7845163.50	31 81
Period	2	3045071.40	16.33	**	2312949.30	30	9.63	2625398.20	10	72	1635477.60	5	71	2	14193670	57.56
Season	1	29983	0.16		565742.42	2	35	865829.48	3	54	4464233.00	15	58	1	4080975.60	16.55
Age at calving	6	208919.00	1.12		322470.66	1	34	771448.48	3	15	301763.23	1	05	6	1947295	7.90
Error	666	186444.48			240248.25			244864.59			286470.99			2700	246601.73	
Total	677														2711	

**, Significant at P/0.01; *, Significant at P/0.05

Table 4.12: Least squares means and standard errors for the factors affecting lactation milk yield

Source of variation	Code	1st lactation		IInd lactation		IIIrd lactation		Fourth lactation		Overall	
		Mean (kg)	S.E.	Mean (kg)	S.E.	Mean (kg)	S.E.	Mean (kg)	S.E.	Mean (kg)	S.E.
Farm:											
M		1853.43	28.45	2040.86	31.15	2101.52	30.79	2141.52	29.75	2037.29	14.21
Ambala											
P ₁		1863.55	35.33	2113.90 a	40.01	2150.07 a	39.88	2221.88 a	41.71	2083.56 a	18.80
P ₂		1971.22	33.18	2125.41 a	39.08	2196.97 a	39.62	2202.90 a	40.70	2122.27 a	18.18
P ₃		1725.52	44.95	1883.33	49.24	1957.53	49.96	1999.78	52.45	1906.03	24.24
Period:											
1968-1972											
P ₁		1769.24 a	28.34	1949.26 a	39.73	1987.05 a	44.10	2024.42	50.01	1897.60	18.88
1973-1977											
P ₂		1981.51	35.42	2152.84	40.25	2223.63	40.60	2235.34 a	41.86	2151.75	19.54
1978-1982											
P ₃		1809.55 a	56.37	2021.54 a	48.22	2093.88 a	42.75	2164.80 a	40.87	2062.51	22.18
Season:											
July-Dec											
S ₁		1844.30 a	26.06	1997.27 a	25.00	2050.58 a	25.05	2034.70	26.33	1984.66	12.00
Jan-June											
S ₂		1862.56 a	44.45	2084.49 a	54.14	2152.46 a	52.30	2248.34	50.41	2089.92	24.38
Age at calving:											
A ₁		1783.23 a	79.30	1916.14 a	105.63	1817.99 a	111.71	2017.37 a	85.67	1890.72 a	46.95
A ₂		1794.42 a	43.61	2000.31 a	55.61	2018.58 bc	56.90	2122.91 a	73.05	1966.42 de	27.67
A ₃		1868.64 a	41.70	2068.65 a	52.15	2249.75 a	64.06	2231.65 a	78.99	2063.64 abc	27.41
A ₄		1857.10 a	46.18	2014.58 a	58.46	2143.52 ab	59.01	2094.98 a	60.53	2022.20 cd	27.68
A ₅		1821.91 a	44.22	2047.07 a	49.10	2121.87 ab	48.25	2204.01 a	53.32	2061.23 bc	24.37
A ₆		1896.60 a	51.97	2084.53 a	50.78	2197.56 a	49.06	2176.97 a	57.04	2116.94 ab	25.91
A ₇		1958.10 a	76.51	2154.88 a	51.71	2161.39 ab	43.18	2142.74 a	39.45	2139.85 a	23.32

Notes: Means connected by the same letter are not significantly different

Least squares means for different periods revealed that lactation milk yields were significantly higher during second period, in all lactations. Same trend was reflected in overall figures. Buffaloes calved during first and third period did not differ significantly in their lactation milk yields except for fourth lactation.

Season of calving had non-significant influence on the lactation milk yield in first three lactations. However, the buffaloes calved during second season had significantly higher lactation milk yield in fourth lactation. This trend was also reflected in overall figures.

Age at calving had no significant trend of the influence on lactation milk yields in different lactations.

Genetic correlations of lactation milk yield (Table 4.03 to 4.07) with all other traits were estimated. Lactation milk yield had highly significant and positive genetic correlations with all traits, during first lactation except lactation length, dry period, service period, and breeding efficiency. This trend was not consistent in subsequent lactations.

Lactation milk yield had highly significant and positive phenotypic correlations during first lactation with all other traits except breeding efficiency with which, it had highly significant but negative phenotypic correlations. The trend of negative phenotypic correlations with these traits continued even in subsequent lactations and same was the overall picture.

Heritabilities of lactation milk yield was estimated separately for all the four lactations. Heritability of lactation milk yield was 0.09 ± 0.01 in first lactation which varied in subsequent lactations.

Repeatability of lactation milk yield (Table 4.08) was 0.35 ± 0.02 .

4.04 Lifetime milk yield:

Least squares analysis of variance was carried out (Table 4.23) to estimate the influence of different factors on lifetime milk yields in buffaloes. Farm, period and age at calving had highly significant and season had non-significant influence on lifetime milk yield.

The least squares mean lifetime milk yield (Table 4.24) was 7890.44 ± 93.38 kg.

The least squares mean for buffaloes calved at Jabalpur farm was significantly lower. The difference between Ambala and Ferozepore farms was not significantly different.

Least squares means for different periods revealed that lifetime milk yield was significantly higher during second period. Buffaloes calved during first and third period did not differ significantly in their lifetime milk yields.

Season of calving had non-significant influence on lifetime milk yields.

Age at calving had no significant trend of the influence on lifetime milk yields.

Genetic correlations of lifetime milk yield (Table 4.03 to 4.07) with all other traits were estimated. Lifetime milk yield had highly significant and positive genetic correlations with all other traits during first lactation except service period, breeding efficiency and dry period.

Lifetime milk yield had highly significant and positive phenotypic correlations with all other traits during first lactation except dry period and breeding efficiency. It had highly significant but negative phenotypic correlations with latter trait. This trend of negative phenotypic correlation continued even in subsequent lactations and same was the overall picture.

Heritability of lifetime milk yield was 0.13 ± 0.02 .

4.05 Lactation length:

Least squares analysis of variance was carried out (Table 4.13) to estimate the influence of different factors on lactation length in buffaloes. Farm had highly significant influence on lactation length during first lactation and a significant influence during second lactation. Period had highly significant influence during first and third lactations. Season had highly significant influence during second and fourth lactations and significant influence during first and third lactations. Age at calving had highly significant influence during third lactation. However, on overall basis farm, period, season and age at calving all these factors had highly significant influence on lactation length in buffaloes.

Table 4.13: Least squares analysis of variance for lactation length

Source	d.f.	1st lactation			IInd lactation			IIVth lactation			IVth lactation			Overall		
		M.S.S.	F	M.S.S.	M.S.S.	F	M.S.S.	M.S.S.	F	M.S.S.	M.S.S.	F	M.S.S.	d.f.	M.S.S.	F
Farm	2	24416.90	9.01	10853.59	3.57	1247.25	0.41	420.01	0.12	2	25100.58	8.11				
Period	2	14214.78	5.25	4867	16	1.60	23626.70	7.77	0.21	2	31809.66	10.27				
Season	1	11964.50	4.42	31822.08	10.47	18797.10	6.18	57371.91	16.17	1	127776.37	41.27				
Age at calving	6	3078.92	1.14	3660	34	1.20	8872.60	2.92	2.05	6	13097.02	4.23				
Error	666	2079.14		3039.79		3040.64		3547.14		2700	3096.17					
Total	677									2711						

*, significant at P/0.01 **, significant at P/0.05

Table 4.14: Least squares means and standard errors for the factors affecting lactation length

Source of variation	Code	1st lactation		IInd lactation		IIIrd lactation		IVth lactation		Overall	
		Mean (days)	S.E.	Mean (days)	S.E.	Mean (days)	S.E.	Mean (days)	S.E.	Mean (days)	S.E.
Area											
Period:											
1968-1972		300.87	3.43	300.32	3.50	296.81	3.43	303.30	3.31	302.21	1.59
1973-1977											
1978-1982											
Season:											
July-Dec.											
Jan-June											
Age at calving:											
Farm:											
Ambala	F ₁	304.00	4.26	302.16	4.50	294.82	4.44	304.94	4.64	304.01	2.11
Ferozapore	F ₂	311.14	4.00	307.62	4.40	299.14	4.41	303.48	4.53	307.50	2.04
Jabalpur	F ₃	287.46	5.42	291.17	5.54	296.46	5.57	301.50	5.84	295.12	2.72
Period:											
1968-1972	P ₁	303.53	3.42	302.09	4.47	292.64	4.91	301.21	5.56	302.38	2.12
1973-1977	P ₂	311.04	4.27	304.64	4.53	308.88	4.52	305.56	4.66	308.52	2.19
1978-1982	P ₃	288.04	6.80	294.22	5.42	288.90	4.76	303.15	4.55	295.73	2.49
Season:											
July-Dec.	S ₁	295.10	3.14	289.97	2.81	289.30	2.79	291.19	2.93	292.90	1.34
Jan-June	S ₂	306.63	5.36	310.66	6.09	304.31	5.83	315.41	5.61	311.52	2.73
Age at calving:											
Farm:											
Ambala	A ₁	304.52	9.56	290.34	11.88	276.32	12.45	291.66	9.53	293.40	5.26
Ferozapore	A ₂	305.69	5.26	295.39	6.25	291.42	6.34	307.88	8.13	301.89	3.10
Jabalpur	A ₃	304.59	5.03	309.24	5.87	305.85	7.14	298.93	8.79	307.72	3.07
	A ₄	294.59	5.57	297.43	6.58	285.44	6.58	294.50	6.74	293.05	3.10
	A ₅	292.67	5.33	296.98	5.52	303.38	5.38	310.62	5.93	303.10	2.73
	A ₆	308.45	6.26	304.79	5.71	306.58	5.47	304.16	6.35	307.25	2.90
	A ₇	288.58	9.22	308.03	5.82	308.67	4.81	315.36	4.39	309.05	2.61

Note: Means connected by the same letter are not significantly different

The overall least squares mean lactation lengths (Table 4.14) for first, second, third and fourth lactations were 300.87 ± 3.43 , 300.32 ± 3.50 , 296.81 ± 3.43 , 303.30 ± 3.31 days, respectively. The overall least squares mean lactation length was 302.21 ± 1.59 days.

DMRT revealed that farm had nonsignificant effect on the lactation length during third and fourth lactations. However, buffaloes calved at Jabalpur farm had significantly lower lactation length in first and second lactations and same trend was also reflected in overall figures.

Least squares means for buffaloes calved during different periods did not differ significantly in second and fourth lactations. However, in overall figures least squares means differed significantly during different periods.

Season of calving had significant effect on the lactation length, in all four lactations and in overall figures. However, the buffaloes calved during second season had significantly higher lactation lengths.

Age at calving had no significant trend of the influence on lactation lengths in different lactations.

Genetic correlations of lactation length (Table 4.03 to 4.07) with all other traits were estimated. Lactation length had highly significant and positive genetic correlation with all other traits during first lactation, except lactation milk yield, dry period, service period and breeding efficiency. This trend was not consistent in subsequent lactations.

Lactation length had highly significant and positive phenotypic correlation with all other traits during first lactation except peak yield, milk yield per day of lactation length, milk yield per day of calving interval, milk yield per day of productive life and breeding efficiency, with which it had negative phenotypic correlations. The trend of negative phenotypic correlations with these traits continued in subsequent lactations except milk yield per day of productive life and same was the overall picture.

Heritabilities of lactation length was estimated separately for all four lactations. Heritability of lactation length was -0.05 ± 0.01 in first lactation which varied in subsequent lactations.

Repeatability of lactation length (Table 4.08) was 0.15 ± 0.02 .

4.06 Dry period:

Least squares analysis of variance was carried out (Table 4.15) to estimate the influence of different factors on dry periods in buffaloes. Farm had non-significant influence during all lactations. Period had highly significant influence during first lactation. Season had highly significant influence during all four lactations. Age at calving had a highly significant influence during third lactation and a significant influence during fourth lactation. However, on overall basis, period and season had highly significant and farm and age at calving had significant influence on dry periods in buffaloes.

Table 4.15: Least squares analysis of variance for dry period

Source	d.f.	1st lactation			IInd lactation			IIVth lactation			Overall		
		M.S.B	F	M.S.S	M.S.S	F	M.S.S.	M.S.S	F	M.S.S.	d.f	M.S.S.	F
Farm	2	21545.66	2.94	952.12	0.12		15484.71	8216.65	1.58		2	21638.58	3.32
Period	2	51124.86	6.98	11553.54	1.49		3978.45	781.40	0.15		2	57355.76	8.80
Season	1	119670.25	16.34	120966.09	15.63		78446.95	89125.73	17.14		1	532881.22	81.77
Age at calving	6	4923.52	0.67	6450.79	0.79		17225.88	13751.66	2.64		6	13768.98	2.11
Error	666	7324.31		7739.90			5528.89	5198.90			2700	6516.47	
Total	677										2711		

** Significant at P/0.01 *, Significant at P/0.05

Table 4.16: Least squares means and standard errors for the factors affecting dry period

Source of variation	First lactation			Second lactation			Third lactation			Fourth lactation			Overall	
	code	mean (days)	S.E.	mean (days)	S.E.		mean (days)	S.E.		mean (days)	S.E.		Mean (days)	S.E.
Farm	A	168 73	5 64	170 43	5 59		150 12	4 63		150 21	4 01		162 44	2 31
	Ambala													
	F ₁	169 96 ab	7.00	172 14 a	7.18		158 88 a	5 99		154 88 a	5 62		167 87 a	3 05
	F ₂	179.17 a	6 58	171 72 a	7 01		143.78 b	5 95		143 90 a	5 48		163 16 a	2 96
Period.	Jabalpur													
	F ₃	157 05 b	8 91	167 42 a	8 84		147 72 ab	7 51		151 85 a	7.07		156 27	3 94
	P ₁	187 38 a	5.62	172 54 a	7 13		152 47 a	6 63		149 65 a	6 74		171 86	3 07
	P ₂	173.66 a	7.02	161 79 a	7 22		152 91 a	6 10		152 26 a	5 64		160 62 a	3 18
Season	1978-1982													
	P ₃	145 15	11 17	176 95 a	8 65		144 99 a	6 42		148 72 a	5 51		154 83 a	3 60
	S ₁	150.50	5 16	150 26	4 49		134 79	3.76		135 12	3 55		143 42	1.95
	S ₂	186 96	8.81	190 59	9 72		165 46	7 86		165 30	6 79		181 45	3 96
Age at calving.														
	A ₁	178.60 a	15 72	163 28 a	18 96		123 72 c	16 78		133 75 c	11 54		154 01 a	7 63
	A ₂	162.01 a	8 64	160 70 a	9 98		147 73 bcde	8.55		148 39 abc	9.84		159.71 a	4 10
	A ₃	173 49 a	8 26	172 44 a	9 36		160 65abcde	9.63		140 39 bc	10 64		169 60 a	4.45
Note means connected by the same letter are not significantly different	A ₄	165 89 a	9 15	180 86 a	10 49		140 51 cd	8 86		143 30 abc	8 15		159 61 a	4.50
	A ₅	168.41 a	8 76	162 53 a	8 81		144 04 cde	7.25		150.35 abc	7 18		157 18 a	3 96
	A ₆	155 79 a	10 30	172 75 a	9 11		163 24abcde	7 37		171 09 a	7 68		166.48 a	4 21
	A ₇	176 91 a	15 16	180 44 a	9 28		170 98 a	6 49		164 21 abc	5 31		170 45 a	3.79

Note means connected by the same letter are not significantly different

The least squares mean dry periods (Table 4.16) for first, second, third and fourth lactations were 168.73 ± 5.64 , 170.43 ± 5.59 , 150.12 ± 4.63 and 150.21 ± 4.01 days respectively. The overall least squares mean dry period was 162.44 ± 2.31 days.

DMRT revealed that the differences between farms were not significantly different for dry period.

Dry periods of buffaloes calved during different periods did not differ significantly except for first and overall dry period.

Season of calving had a significant influence on dry period. Buffaloes calved in first, season had significantly lower dry period.

Age at calving had no significant trend of the influence on dry period in different lactations.

Genetic correlations of dry period (Table 4.03 to 4.07) with all other traits were estimated. Dry period had highly significant and negative genetic correlation with milk yield per day of productive life during first lactation. This trend was not consistent in subsequent lactations.

Dry period had highly significant and negative phenotypic correlations with all other traits during first lactation except milk yield per day of lactation length peak yield, 300-day milk yield, lifetime milk yield, lactation milk yield, lactation length, service period. It had highly significant but positive phenotypic correlations with latter three traits. This trend was not consistent in subsequent lactations.

Heritabilities of dry period was estimated separately for all the four lactations. Heritability of dry period was 0.04 ± 0.01 in first lactation which varied in subsequent lactations.

Repeatability of dry period (Table 4.08) was 0.07 ± 0.02 .

4.07 Service period:

Least squares analysis of variance was carried out (Table 4.17) to estimate the influence of different factors on service period in buffaloes. Farm had highly significant influence on service period during first lactation. Period had highly significant influence on service period during first lactation and a significant influence during third lactation. Season had highly significant influence during all four lactations. Age at calving had highly significant influence during third and fourth lactations. However, on overall basis farm, period, season and age at calving had highly significant influence on service period in buffaloes.

The least squares mean service periods (Table 4.18) for first, second, third and fourth lactations were 160.49 ± 7.31 , 164.74 ± 6.93 , 139.32 ± 6.45 and 144.50 ± 5.54 days, respectively. The overall least squares mean service period was 156.50 ± 3.05 days.

DMRT revealed that the differences between three farms were not significantly different for service period for second, third and fourth lactations. Jabalpur farm had significantly lower services period for first lactation

Table 4.17: Least squares analysis of variance for service period

Source	d.f.	1st lactation		IInd lactation		IIIRD lactation		IVth lactation		Overall	
		M.S.S.	F	M.S.S.	F	M.S.S.	F	M.S.S.	F	d.f.	M.S.S.
Farm	2	99063.96	8.05 ^{***}	17770.30	1.50	9894.40	0.92	11594.26	1.17	2	68163.58
Period	2	82204.89	6.68 ^{***}	3356.46	0.28	32396.26	3.02 [*]	5582.34	0.56	2	95234.89
Season	1	220777.05	17.94 ^{***}	347343.64	29.25 ^{***}	192608.60	17.94 ^{***}	304239.94	30.62 ^{***}	1	1297758.60
Age at calving	6	3783.05	0.31	13841.92	1.17	48853.39	4.55 ^{***}	35439.38	3.57 ^{***}	6	49193.28
Error	666	12303.43		11874.65		10737.51		9935.82		2700	11358.67
Total	677									2711	

^{***} Significant at P/0.01 ^{*} Significant at P/0.05

Table 4.18: Least squares means and standard errors for the factors affecting service period

Source of variation	Code	1st lactation		IInd lactation		IIIrd lactation		IVth lactation		Overall	
		Mean (days)	S.E.	Mean (days)	S.E.	Mean (days)	S.E.	Mean (days)	S.E.	Mean (days)	S.E.
R		160.49	7.31	164.74	6.93	139.32	6.45	144.50	5.54	156.50	3.05
Farm:											
Ambala	F ₁	165.82 a	9.07	167.81 a	8.89	146.28 a	8.35	149.58 a	7.77	163.59 a	4.03
Ferozepore	F ₂	181.80 a	8.52	173.75 a	8.69	134.19 a	8.30	136.73 a	7.58	162.01 a	3.90
Jabalpur	F ₃	133.97	11.55	152.67 a	10.95	137.48 a	10.46	147.18 a	9.77	143.91	5.20
Period:											
1968-1972	P ₁	179.36 a	7.28	167.27 a	8.83	137.90 ab	9.24	139.31 a	9.31	164.87 a	4.05
1973-1977	P ₂	176.50 a	9.14	160.10 a	8.95	152.32 a	8.50	150.69 a	7.79	161.20 a	4.19
1978-1982	P ₃	125.63	14.48	166.86 a	10.72	127.73 b	8.95	143.49 a	7.61	143.44	4.76
Season:											
July-Dec.	S ₁	135.73	6.69	130.57	5.56	115.29	5.24	116.61	4.90	126.83	2.58
Jan-June	S ₂	185.26	11.42	198.91	12.04	163.34	10.95	172.38	9.39	186.18	5.23
Age at calving:											
A ₁		169.74 a	20.37	147.23 a	23.48	95.36 a	23.39	113.82 d	15.95	137.75 e	10.07
A ₂		158.88 a	11.20	151.99 a	12.36	130.62 dce	11.91	146.83abcd	13.60	153.74 de	5.94
A ₃		170.09 a	10.71	176.33 a	11.59	157.80 abd	13.42	130.67 bed	14.71	169.45 ad	5.88
A ₄		154.60 a	11.86	169.79 a	13.00	117.43 ce	12.36	130.39 cd	11.27	144.83 cde	5.94
A ₅		160.26 a	11.36	155.07 a	10.92	138.97bcde	10.10	152.66abcd	9.93	152.73 bde	5.23
A ₆		156.14 a	13.35	170.03 a	11.29	159.91 abd	10.27	165.71 ab	10.62	164.57 abd	5.56
A ₇		153.76 a	19.65	182.75 a	11.50	175.14 a	9.04	171.39 a	7.35	172.44 a	5.00

Note. Means connected by the same letter are not significantly different

and same was the overall picture.

Buffaloes calved during different periods did not differ significantly in their service period, except for first and third lactation.

Season of calving had a significant influence on service period. Buffaloes calved during first season had significantly lower service period.

Age at calving had no significant trend of the influence on service periods in different lactations.

Genetic correlations of service period (Table 4.03 to 4.07) with all other traits were estimated. Service period had highly significant and positive genetic correlation with peak yield during first lactation. This trend was not consistent in subsequent lactations.

Service period had highly significant and negative phenotypic correlations with all other traits during first lactation except milk yield per day of age at second calving, 300-day milk yield, lactation milk yield, lifetime milk yield, lactation length and dry period with which it had highly significant but positive phenotypic correlations. This trend was not consistent in subsequent lactations.

Heritability of service period was estimated separately for all the four lactations. Heritability of service period was 0.01 ± 0.01 in first lactation which varied in subsequent lactations.

Repeatability of service period (Table 4.08) was 0.06 ± 0.02 .

4.08 Milk yield per day of lactation length.

Least squares analysis of variance was carried out (Table 4.19) to estimate the influence of different factors on milk yields per day of lactation length in buffaloes. Farm had a highly significant influence during second, third and fourth lactations. Period had highly significant influence during all lactations. Season had a significant influence during first and second lactations. Age at calving had highly significant influence during first lactation and a significant influence during third lactation. However, on overall basis farm, period and age at calving had highly significant and season had non-significant influence on milk yields per day of lactation length in buffaloes.

The least squares mean milk yields per day of lactation length (Table 4.20) of first, second, third and fourth lactations were 6.17 ± 0.09 , 6.75 ± 0.09 , 7.06 ± 0.09 and 7.09 ± 0.09 Kg, respectively. The overall least squares mean milk yield per day of lactation length was 6.74 ± 0.04 Kg.

DMRT revealed that least squares means for buffaloes calved at Jabalpur farm had significantly lower milk yields per day of lactation length except for, first lactation. The differences between Ambala and Ferozepore farms were not significantly different.

Least squares means for different periods revealed that milk yields per day of lactation length were significantly lower during first period in all the lactation. Same trend was reflected in overall figures. Buffaloes calved during

Table 4.19: Least squares analysis of variance for milk yield per day of lactation length

Source	d.f.	Ist lactation		IIInd lactation		IIIrd lactation		IVth lactation		Overall	
		M.S.S.	F	M.S.S.	F	M.S.S.	F	M.S.S.	F	M.S.S.	F
Farm	2	3.82	2.23	11.17	5.21 ^{**}	21.88	9.85 ^{**}	12.68	5.14 ^{**}	2	30.42
Period	2	24.26	14.15 ^{**}	23.87	11.13 ^{**}	12.75	5.74 ^{**}	15.81	6.41 ^{**}	2	145.63
Season	1	7.20	4.20 [*]	8.75	4.08 [*]	0.39	0.18	2.74	1.12	1	7.17
Age at calving	6	6.49	3.79 ^{**}	1.29	0.60	5.56	2.50 [*]	5.04	2.05	6	10.12
Error	666	1.71		2.14		2.22		2.47		2700	2.28
Total	677									2711	

^{**}, Significant at P/0.01, ^{*}, Significant at P/0.05

Table 4.20: Least squares means and standard errors for the factors affecting milk yield per day of lactation length

Source of variation	Ist lactation		IInd lactation		IIInd lactation		IVth lactation		Overall	
	Code	Mean (kg)	S.E.	Mean (kg)	S.E.	Mean (kg)	S.E.	Mean (kg)	S.E.	Mean (kg)
Farm:										
H		6.77	0.09	6.75	0.09	7.06	0.09	7.09	0.09	6.74
Ambala	F ₁	6.13 a	0.11	6.97 a	0.12	7.28 a	0.12	7.29 a	0.12	6.85 a
Farosepore	F ₂	6.32 a	0.10	6.84 a	0.12	7.32 a	0.12	7.26 a	0.12	6.88 a
Jabalpur	F ₃	6.05 a	0.14	6.44 a	0.15	6.59	0.15	6.71	0.15	6.47
Period:										
1968-1972	P ₁	5.80	0.09	6.39	0.12	6.75	0.13	6.71	0.15	6.25
1973-1977	P ₂	6.39 a	0.11	7.05 a	0.12	7.18 a	0.12	7.36 a	0.12	6.98 a
1978-1982	P ₃	6.31 a	0.17	6.80 a	0.14	7.25 a	0.13	7.19 a	0.12	6.98 a
Season										
July-Dec.	S ₁	6.31	0.08	6.92	0.07	7.11 a	0.07	7.00 a	0.08	6.81 a
Jan-June	S ₂	6.02	0.13	6.58	0.16	7.03 a	0.16	7.17 a	0.15	6.67 a
Age at calving.										
A ₁	5.80 f	0.24	6.55 a	0.31	6.49 a	0.34	6.98 ab	0.25	6.44 c	0.14
A ₂	5.84 ef	0.13	6.72 a	0.17	6.92 de	0.17	6.92 ab	0.21	6.51 bc	0.08
A ₃	6.11 cdef	0.13	6.69 a	0.16	7.39 abcd	0.19	7.48 a	0.23	6.73 abc	0.08
A ₄	6.34 abcd	0.14	6.67 a	0.17	7.48 a	0.18	7.11 ab	0.18	6.88 a	0.08
A ₅	6.03 cef	0.13	6.83 a	0.15	6.97 cde	0.14	7.13 ab	0.16	6.78 ac	0.07
A ₆	6.14 bcdef	0.16	6.78 a	0.15	7.22 bcde	0.15	7.22 a	0.17	6.91 a	0.08
A ₇	6.90 a	0.23	6.99 a	0.15	6.98 bcde	0.13	6.77 b	0.12	6.91 a	0.07

Note: Means connected by the same letter are not significantly different

second and third period did not differ significantly in their milk yields per day of lactation length.

Season of calving had non-significant influence on the milk yield per day of lactation length, except for first and second lactations, during which buffaloes calved in first season had higher yields.

Age at calving had no significant trend of the influence on milk yields per day of lactation length in different lactations.

Genetic correlations of milk yield per day of lactation length (Table 4.03 to 4.07) with all other traits were estimated. It had highly significant and positive genetic correlations with milk yield per day of productive life, milk yield per day of calving interval during first lactation. With breeding efficiency it had negative genetic correlation. This trend was not consistent in subsequent lactations.

Milk yield per day of lactation length had highly significant and positive phenotypic correlations with all other traits during first lactation except breeding efficiency, dry period, lactation length and service period. With latter three traits it had negative phenotypic correlations. The trend of negative phenotypic correlations with these three traits continued even in subsequent lactations and same was the overall picture.

Heritabilities of milk yield per day of lactation length was estimated separately for all the four lactations. Heritability estimate was 0.03 ± 0.01 in first lactation which varied in subsequent lactations.

Repeatability of milk yield per day of lactation length (Table 4.08) was 0.34 ± 0.02 .

4.09 Milk yield per day of calving interval:

Least squares analysis of variance was carried out (Table 4.21) to estimate the influence of different factors on milk yield per day of calving interval in buffaloes. Farm had a highly significant influence during third and fourth lactations and a significant influence during second lactation. Period had highly significant influence during first, second and third lactations and a significant influence during fourth lactation. Season had highly significant influence during first and second lactation. Age at calving had significant influence during third and fourth lactations. However, on overall basis farm, period and season had highly significant, and age at calving had a significant influence on milk yield per day of calving interval in buffaloes.

The least squares mean (Table 4.22) of first, second third and fourth lactations were 3.99 ± 0.07 , 4.40 ± 0.08 , 4.75 ± 0.08 and 4.80 ± 0.07 Kg respectively. The overall least squares mean milk yield per day of calving interval was 4.45 ± 0.04 Kg.

Table 4.21: Least squares analysis of variance for milk yield per day of calving interval

Source	d.f.	Ist lactation		IInd lactation		IIIrd lactation		IVth lactation		Overall		
		M.S.S.	F	M.S.S.	F	M.S.S.	F	M.S.S.	F	d.f.	M.S.S.	F
Farm	2	0.74	0.68	6.22	4.12*	11.27	7.51**	10.42	5.95**	2	15.24	9.79**
Period	2	19.35	17.58**	13.12	8.69**	9.66	6.44**	6.35	3.63*	2	95.26	61.21**
Season	1	20.88	18.98**	15.62	10.34**	5.59	3.73	0.87	0.50	1	46.28	29.74**
Age at calving	6	1.76	1.60	0.73	0.48	3.23	2.15*	3.88	2.22*	6	4.33	2.78*
Error	666	1.10		1.51		1.50		1.75		2700	1.56	
Total	677									2711		

** Significant at P/0.01

* Significant at P/0.05

Note: Means connected by the same letter are not significantly different

DMRT revealed that least squares means for buffaloes calved at Jabalpur farm had significantly lower milk yields per day of calving interval except for first lactation. The differences between Ambala and Ferozepore farms were not significantly different.

Least squares means of different periods for different lactations revealed no significant trend in the influence of period on milk yield per day of calving interval.

Season of calving had significant influence on milk yield per day of calving interval except for fourth lactation. Buffaloes calved during first season had significantly higher yields.

Age at calving had no significant trend of the influence on milk yields per day of calving interval in different lactations.

Genetic correlations of milk yield per day of calving interval (Table 4.03 to 4.07) with all other traits were estimated. It had highly significant and positive genetic correlations with all other traits during first lactation except dry period and service period. This trend was not consistent in subsequent lactations.

Milk yield per day of calving interval had highly significant and positive phenotypic correlations with all other traits during first lactation except lactation length, dry period and service period. It had significant but negative phenotypic correlation with latter three traits.

The trend of negative phenotypic correlations with these three traits continued even in subsequent lactations and the same was the overall picture.

Heritabilities of milk yield per day of calving interval was estimated separately for all the four lactations. Heritability estimate was 0.07 ± 0.01 in first lactation which varied in subsequent lactations.

Repeatability of milk yield per day of calving interval (Table 4.08) was 0.34 ± 0.02 .

4.10 Milk yield per day of age at second calving:

Least squares analysis of variance was carried out (Table 4.23) to estimate the influence of different factors on milk yields per day of age at second calving in buffaloes. Farm, period and age at calving had highly significant and season had non-significant influence on milk yield per day of age at second calving in buffaloes.

The least squares mean milk yield per day of age at second calving (Table 4.24) was 1.05 ± 0.02 Kg.

DMRT revealed that least squares mean for milk yield per day of age at second calving was significantly higher for Ferozepore farm. The differences between Ambala and Jabalpur farm were not significantly different.

Least squares mean for different periods revealed that milk yield per day of age at second calving were significantly lower during first period. Buffaloes calved during second and third period did not differ significantly.

Table 4.23: Least squares analysis of variance for production efficiency and breeding efficiency traits

Source	d.f.	Lifetime milk yield		Milk yield per day of age at second calving		Milk yield per day of productive life		Breeding efficiency (Wiscor)		Breeding efficiency (Hogar)	
		M.S.B.	F	M.S.B.	F	M.S.B.	F	M.S.B.	F	M.S.B.	F
Farm	2	39412046.00	18.26 ^{**}	0.38	6.30 ^{**}	6.62	6.99 ^{**}	149.88	1.08	5.75	0.13
Period	2	33738486.00	15.63 ^{**}	1.62	26.87 ^{**}	7.52	7.95 ^{**}	768.88	5.52 ^{**}	85.77	2.02
Season	1	1193421.40	0.55 ^{**}	0.08	1.28	9.43	9.96 ^{**}	1659.66	11.92 ^{**}	202.46	4.77 ^{**}
Age at calving	6	8018049.30	3.71 ^{**}	0.31	5.07 ^{**}	1.71	1.81	2157.66	15.50 ^{**}	4705.23	110.86 ^{**}
Error	666	2158480.70		0.06		0.95		139.17		42.44	
Total	677										

^{**}, Significant at P/0.01

Table 4.2: Least squares means and standard errors for the factors affecting production efficiency and breeding efficiency

Source of variation	Lifetime milk yield			Milk yield per day of age at second calving			Milk yield per day of productive life			Breeding efficiency (Wilcox)			Breeding efficiency (Tomar)								
	Code	Mean (kg)	S E	Mean (kg)	S E	Mean (kg)	S E	Mean (%)	S E	Mean (%)	S E	Mean (%)	S E								
Farm		7890	44	93	38	1	05	0	02	4	70	0	06	80	97	0	75	83	90	0	41
Ambala																					
Ferozepore	F ₁	8117	69 a	119.93		1	04 a	0	02	4	81 a	0	08	80	90 a	0	96	83	79 a	0	53
	F ₂	8264	23 a	117.14		1	09	0	02	4	83 a	0	08	80	06 a	0	94	83	76 a	0	52
Jabalpur	F ₃	7289	40	147	58	1	01 a	0	02	4	44	0	10	81	96 a	1	18	84	13 a	0	65
Period																					
1968-1972	P ₁	7518	88 a	119	07	0	95	0	02	4	48	0	08	81	52 a	0	96	83	57 a	0	53
1973-1977	P ₂	8306	01	120	65	1	11 a	0	02	4	84 a	0	08	78	74	0	97	83	39 a	0	53
1978-1982	P ₃	7846	43 a	144	54	1	08 a	0	02	4	77 a	0	10	82	65 a	1	16	84	73 a	0	64
Season																					
July-Dec	S ₁	7953	78 a	74	94	1	06 a	0	01	4	87	0	05	83	33	0	60	84	72	0	33
Jan-June	S ₂	7827	19 a	162	29	1	03 a	0	03	4	52	0	11	78	61	-1	39	83	07	0	72
Age at calving																					
	A ₁	7107	64 d	316	61	1	13 a	0	05	4	53 ab	0	21	87	35 a	2	54	96	08	1	40
	A ₂	7684	43 cd	166	68	1	10 a	0	03	4	89 a	0	11	87	22 a	1	34	91	75	0	74
	A ₃	8065	55 abc	156	31	1	10 a	0	03	4	85 a	0	10	81	78 abc	1	25	86	81	0	69
	A ₄	7831	16 bcd	175	23	1	03 abc	0	03	4	65 ab	0	12	80	07 bd	1	41	82	45 a	0	78
	A ₅	7966	84 abc	147	17	1	03 ab	0	02	4	73 ab	0	10	80	59 bcd	1	18	80	85 a	0	65
	A ₆	8222	73 ab	152	20	1	00 bc	0	02	4	71 ab	0	10	77	53 d	1	22	77	89	0	67
	A ₇	8354	74 a	155	01	0	95 c	0	26	4	50 b	0	10	72	46 e	1	24	71	42	0	69

Note Means connected by the same letter are not significantly different

Season of calving had non-significant effect on the milk yield per day of age at second calving.

Age at calving had no significant trend of influence on milk yields per day of age at second calving.

Genetic correlations of milk yield per day of age at second calving (Table 4.03 to 4.07) with all other traits were estimated. It had highly significant and positive genetic correlations with all other traits during first lactation except service period, dry period and breeding efficiency, with breeding efficiency it had negative genetic correlations. This trend was not consistent in subsequent lactations.

Milk yields per day of age at second calving had highly significant and positive phenotypic correlations with all other traits during first lactation except service period, dry period, and breeding efficiency. With service period it had a significant and positive phenotypic correlations and with dry period and breeding efficiency it had negative phenotypic correlations. This trend was not consistent in subsequent lactations.

Heritability of milk yield per day of age at second calving was 0.14 ± 0.00 .

4.11 Milk yield per day of productive life:

Least squares analysis of variance was carried out (Table 4.23) to estimate the influence of different factors on milk yield per day of productive life in buffaloes. Farm, period and season had a highly significant and age at calving

had non-significant influence of milk yield per day of productive life in buffaloes.

The least squares mean (Table 4.24) milk yield per day of productive life was found to be 4.70 ± 0.06 kg.

DMRT revealed that least squares means of buffaloes calved at Jabalpur farm were significantly lower. The differences between Ambala and Ferozepore farms were not significantly different.

Least squares means for different periods revealed that milk yields per day of productive life were significantly lower during first period. Buffaloes calved during second and third period did not differ significantly in their milk yields per day of productive life.

Season of calving had significant influence on milk yield per day of productive life. The buffaloes calved during first season and higher yields.

Age at calving had no significant trend of the influence on milk yield per day of productive life.

Genetic correlations of milk yield per day of productive life (Table 4.03 to 4.07) with all other traits were estimated. It had highly significant and positive genetic correlations with all other traits during first lactation except dry period and service period. With dry period it had highly significant but negative genetic correlations. This trend was not consistent in subsequent lactations.

Milk yield per day of productive life had highly significant and positive phenotypic correlations with all other traits during first lactation except lactation length, dry period and service period. With latter two traits it had highly significant but negative phenotypic correlations. This trend was not consistent in subsequent lactations.

Heritability of milk yield per day of productive life was 0.12 ± 0.02 .

4.12 Breeding efficiency (wilcox):

Least squares analysis of variance was carried out (Table 4.23) to estimate the influence of different factors on breeding efficiency (wilcox) in buffaloes. Period, season and age at calving had highly significant and farm had non-significant influence on breeding efficiency (wilcox) in buffaloes.

The least squares mean (Table 4.24) breeding efficiency (wilcox) was 80.97 ± 0.75 per cent.

DMRT revealed that differences between farms were not significantly different for breeding efficiency (wilcox).

Least squares means for different periods revealed that breeding efficiency (wilcox) was significantly lower during second period. Buffaloes calved during first and third period did not differ significantly in their breeding efficiency (wilcox).

Season of calving had a significant influence on breeding efficiency (wilcox). Buffaloes calved during first

season had significantly higher breeding efficiency (Wilcox).

The breeding efficiency (Wilcox) decreased with increase in the age at calving.

Genetic correlations (Table 4.03 to 4.07) of breeding efficiency (Wilcox) with all other traits were estimated. Breeding efficiency (Wilcox) had highly significant and negative genetic correlations with peak yield, milk yield per day of lactation length, during first lactation. With milk yield per day of calving interval milk yield per day of productive life and breeding efficiency (Tomar) it had highly significant but positive genetic correlations. This trend was not consistent in subsequent lactations.

Breeding efficiency (Wilcox) had highly significant and negative phenotypic correlations with all other traits during first lactation except milk yield per day of age at second calving, 300-day milk yield, peak yield, milk yield per day of lactation length, milk yield per day of calving interval, milk yield per day of productive life and breeding efficiency (Tomar). With latter three traits it had highly significant but positive phenotypic correlations. With peak yield and milk yield per day of lactation length it had significant but positive phenotypic correlations. The trend of negative phenotypic correlations with these traits continued even in subsequent lactations and same was the overall picture.

Heritability of breeding efficiency (Wilcox) was 0.07 ± 0.01 .

4.13 Breeding efficiency (Tomar) :

Least squares analysis of variance was carried out (Table 4.23) to estimate the influence of different factors on breeding efficiency (Tomar) in buffaloes. Season, age at calving had highly significant and farm and period had nonsignificant influence on breeding efficiency (Tomar).

The least squares mean (Table 4.24) breeding efficiency (Tomar) was 83.90 ± 0.41 per cent.

DMRT revealed that the differences between the farms were not significantly different for breeding efficiency (Tomar).

Least squares means revealed that the buffaloes born during different periods did not differ significantly in their breeding efficiency (Tomar).

Season of calving had significant influence on breeding efficiency (Tomar). The buffaloes calved during first season had significantly higher breeding efficiency (Tomar).

The breeding efficiency (Tomar) decreased with the every increase in the age at calving.

Genetic correlations (Table 4.03 to 4.07) of breeding efficiency (Tomar) with all other traits were estimated. Breeding efficiency (Tomar) had highly significant and negative genetic correlations with peak yield, milk yield per day of lactation length during first lactation, with milk yield per day of calving interval, milk yield per day of productive life and breeding efficiency (Wilcox)

it had highly significant but positive genetic correlations. This trend is not consistent in subsequent lactations.

Breeding efficiency (Tomar) had highly significant and negative phenotypic correlation with all other traits during first lactation except peak yield, milk yield per day of lactation length, milk yield per day of age at second calving, milk yield per day of calving interval, milk yield per day of productive life and breeding efficiency (Walcox). With latter three traits it had highly significant but positive phenotypic correlations. This trend was not consistent in subsequent lactations.

Heritability of breeding efficiency (Tomar) was 0.09 ± 0.01 .

CHAPTER 5

DISCUSSION

It is a recognised fact that the genetic potential of animals, with regards to the expression of economic traits, is greatly influenced by environmental conditions. This is evident from the low to moderate heritability of most of the economic traits. For the optimum expression of genetic potential of animals, scientific feeding, breeding, disease control and sanitation are essential. The reproductive status of the buffaloes needs close monitoring. This high level of environmental manipulation helps buffaloes to express their genetic capability to the fullest extent.

5.1 Means:

The data were subjected to least squares analysis. The overall means of different traits are summarised below.

The mean peak yields in first four lactations were 8.44, 9.69, 10.21 and 10.49 Kg respectively. The overall mean was 9.72 Kg. There was an increasing trend. Peak yields had registered an increase in each succeeding lactation. Peak yield in second lactation had registered more than 14 per cent increase over the peak yield in first lactation. Increase in the peak yields were lower in the later^t lactations. Every ascent in physiological terms has to reach a plateau before it embarks a declining phase. Increase in the peak yield in fourth lactation when compared with third lactation is as low as 2.6 per cent indicating almost a plateau, to

be followed perhaps by a descending amount of peak yield in fifth lactation. The estimated overall mean is higher than the similar estimate reported by Dhinsa (1963) and Sane et al., (1972 b) in Murrah buffaloes but is lower than the one reported by Tiwana et al. (1983) in Murrah buffaloes.

The mean 300 day milk yields in first four lactations were 1784.40, 1959.20, 2025.37 and 2061.45 Kg respectively. The overall mean was 1955.56 Kg. 300-day milk yields registered an increase from first to fourth lactation in a manner similar to peak yield. The estimated overall mean is similar to the estimate reported by Tiwana et al. (1983) for average 300-day milk yield in Murrah buffaloes, while it is higher than the similar estimates reported by Basu et al. (1976) and Rao et al. (1976) in Murrah buffaloes.

The mean lactation milk yields in first four lactations were 1853.43, 2040.88, 2101.52 and 2141.52 Kg, respectively and the overall mean was 2037.29 Kg. Lactation milk yield registered an increasing trend from first to fourth lactation. Milk yield, being a physiological phenomenon, goes on increasing with the advancement of age till the lactational maturity is reached. The actual increase in lactation milk yield is 2 per cent in fourth lactation when compared with third lactation. This perhaps indicates that the maximum lactational milk yield is reached in fourth lactation. The estimated first lactation milk yield is higher than the similar estimate reported by Chhikara et al. (1978), Patro and Bhat (1979 b).

The mean lifetime milk yield based on first four lactation was 7890.44 Kg. The lifetime production is completed in around 2900 days. This means around 2.7 Kg of milk per day from the date of birth to the conclusion of fourth lactation. This works out to be a reasonable figure which can meet the cost of maintenance and production. But for higher profits, lifetime milk yield should be improved. The lifetime milk yield based on first three lactations is reported to be 5249 Kg by Johari and Bhat (1979 b).

The mean first to fourth lactation length were 300.87, 300.32, 296.81 and 303.30 days respectively and the overall mean was 302.21 days. The overall mean lactation length is very close to the ideal length of around 300 days. The estimated first lactation length is higher than the similar estimate reported by Gurnani et al. (1976 a), Reddy (1980) in Murrah buffaloes, but it is lower to the one reported by Rao et al. (1970) and Amble et al. (1970) in Murrah buffaloes.

The mean first to fourth dry periods were 168.73, 170.43, 150.12 and 150.21 days respectively and the overall mean was 162.44 days. The overall mean dry period of 162 days appears to be on the higher side, and suitable managemental efforts should be made to bring it down to around 100 days. Reduction in dry period can render the buffaloes economically more efficient. The estimated first dry period is higher than the similar estimate reported by Basu et al. (1977) in Murrah buffaloes, but it is lower to

the one reported by Kanaujia (1978) and Jain (1982) in Murrah buffaloes.

The mean first to fourth service periods were 160.49, 164.74, 139.32 and 144.50 days respectively and the overall mean was 156.50 days. The overall mean service period is on the higher side and has increased the length of the dry period and the calving interval thereby adversely affecting the breeding programme. Service period being the function of reproduction and occurring during the beginning of the lactation period, when it is in a rising phase due attention should be given in managing the herd. The feeding schedules of the lactating cows should be such as to meet the increasing demands of nutrient needed to sustain milk production and also to bring them in heat. The estimated first service period is higher than the similar estimate reported by Singh et al. (1972), and Gill and Dev (1970) in Murran buffaloes but it is lower to the one reported by Reddy and Taneja (1980) in Murrah buffaloes.

The mean milk yields per day of lactation length were 6.17, 6.75, 7.06 and 7.09 kg respectively and the overall mean was 6.74 kg. Though the mean appears satisfactory, there is scope for further improvement to make the buffaloes more economic producers of milk. The estimated milk yield per day of first lactation length is higher than the similar estimate reported by Amble et al. (1970) and Reddy and Taneja (1980) in Murrah buffaloes.

The mean milk yields per day of calving interval were 3.99, 4.40, 4.75 and 4.80 Kg respectively and the overall mean milk yield per day of calving interval was 4.45 Kg. This estimate is a better indicator of the productivity of buffaloes since it includes the lactation length and also the dry period. The estimated milk yield per day of first calving interval is higher than the similar estimate reported by Ambale et al. (1970) and Reddy and Taneja (1980) in Murrah buffaloes.

The mean milk yield per day of age at second calving was 1.05 Kg. This is a more comprehensive trait than milk yield per day of lactation length or milk yield per day of calving interval, because it includes lactation length, dry period and also age at first calving. This trait is a suitable combination of production and reproduction aspects. Besides, it is very easy to compute the age at second calving when we know age at first calving and the date of second pregnancy. The present estimate appears low and needs improvement. The estimated milk yield per day of age at second calving is higher than the similar estimate reported by Singh (1979) in military farm buffaloes but is slightly lower to the one reported by Bhalaru (1977) in military farm buffaloes.

The mean milk yield per day of productive life was 4.70 Kg. This trait judges the production efficiency of animals from a different angle from the day of first calving to the day of concluding the fourth lactation.

a
na

If age at first calving is brought down to the optimum level, 4.7 Kg of milk per day of productive life appears quite an economic level of production. Of course a target of 6 Kg plus would be more desirable. The estimated milk yield per day of productive life is higher than the similar estimate reported by Singh (1979) in military farm buffaloes.

The mean breeding efficiency (Wilcox) and breeding efficiency (Tomar) were 80.97 and 83.90 per cent respectively. Both the methods of estimating breeding efficiency appear similar in merit. The breeding efficiency (Tomar) appears slightly superior to that of breeding efficiency (Wilcox) because of its higher heritability. The ideal breeding efficiency is 100 and therefore there is scope for improving this trait through judicious management. The estimated breeding efficiency (Wilcox) was similar to the estimate reported by Reddy and Taneja (1980) in Murrah buffaloes, Bhadula and Desai (1973) in military farm buffaloes.

5.2 Effect of farm:

Effect of farms reflects the total impact on animal managerial conditions including handling of animals, feeding, health and sanitation and various elements of macro and micro climate prevailing at that farm.

Least squares analysis of variance was conducted to find out the extent of influence exerted by various genetic and non-genetic factors on the production and reproduction traits.

Farms had highly significant influence on all the production and reproduction traits taken up in the present study except on dry period on which it had significant and on breeding efficiency on which it had non-significant influence. This overwhelming influence of farms could have been due to differences in management and climatic conditions prevailing at different farms. A small influence could have been also due to the use of sires of different merits at different farms. Similar results were reported by Dave and Taylor (1971), Bhadula and Desai (1973), Kanaujia et al. (1974), Bhalaru (1977), Johari and Bhat (1979 b), Patro and Bhat (1979 b), Singh (1979) and Bhat et al. (1982).

5.3 Effect of period:

Period suggests the influence of total management as well as climatic factors in different years.

Periods had highly significant influence on all the traits taken up in the present study except breeding efficiency (Tomar). Thus period appears to be a strongly influencing factor.

There has been distinct improvement in such vital traits as dry period and service period over the years. Dry period which was 171.86 days in first period has been reduced to 154.83 days in third period. Similarly service period has also been reduced from 164.87 days to 143.44 days in the corresponding period. This reflects a continued improvement in managerial practices at the military farms over the years. Of course, dry period and service period

need further reduction. Perhaps timely detection of heat, timely breeding and vigorous follow-up help in bringing down the dry period and service period further, thereby rendering the buffaloes more efficient producers of milk.

Important production traits like 300-day milk yield, lactation milk yield, milk yield per day of age at second calving, milk yield per day of productive life registered an increase in the second period over the first. But this was followed by a decline during the third period. This slide back or slippage could have been due to the usage of sires with lower sire indices and also due to less than optimum package of management practices. Since these production traits are moderately heritable, use of sires of high merit coupled with vigorous culling of inferior buffaloes may help in improving the productivity of buffaloes. These measures should be accompanied by optimum level of feeding and management. Similar findings were reported by Kanaujia et al. (1975), Bhalara (1977), Johari and Bhat (1979 b), Patro and Bhat (1979 b), Bhat et al. (1982), and Singh and Tiwana (1982).

5.4 Effect of season:

Seasons reflect the response of animals to different attributes of the climate such as ambient temperature, relative humidity, solar radiation, rainfall etc. Apart from the direct influence of these factors on animal body functions, climate affects the animal productivity indirectly through supply of feeds and fodders.

Season of calving had highly significant influence on all the traits studied except lifetime milk yield, milk yield per day of lactation length, and milk yield per day of age at second calving.

Buffaloes calved during January to June had somewhat higher level of production when compared to buffaloes calved during July to December. This difference could have been due to differences in climate and also due to differences in the availability of feeds and fodders in the two different seasons. Similar results were reported by Sane et al. (1972 a), Kanaujia et al. (1975), Sharma and Singh (1978 a), Johari and Bhat (1979 b), Patro and Bhat (1979 b), and Bhat et al. (1982).

5.5 Effect of age at calving:

Age at calving had a significant influence on all the traits taken up in the present investigation except milk yield per day of productive life. This is quite predictable. Milk yield per day of productive life does not include age at calving.

All the production traits like peak yield, 300-day milk yield, lactation milk yield, milk yield per day of lactation length and milk yield per day of calving interval showed an increasing trend along with the increase in the age at calving. However, the rate of increase was maximum only upto third group(A3) of age at calving. Subsequent increases were somewhat lower thereby indicating that further increase in age at calving would be uneconomic.

The rate of increase in production is not commensurate with the increased overhead charges required for maintaining the animals for the additional period.

Age at calving had highly significant influence on breeding efficiency. This is quite understandable because of least breeding efficiency (Tomar) incorporates age at calving. Breeding efficiency (Wilcox) incorporates calving intervals which are the components of all the age at calvings except first.

5.6 Heritabilities:

Heritabilities are estimated the present study by half-sib correlation method from the data corrected for significant effects (Table 4.03 to 4.07),

In first lactation the heritabilities were: peak yield (0.18), 300-day milk yield (0.13), lactation milk yield (0.09), lactation length (-0.05), dry period (0.04), service period (0.01), milk yield per day of lactation length (0.03) and milk yield per day of calving interval (0.07).

The heritabilities were: lifetime milk yield (0.13), milk yield per day of age at second calving (0.14), milk yield per day of productive life (0.12). Heritabilities of breeding efficiency (Wilcox) and breeding efficiency (Tomar) were 0.07 and 0.09 respectively.

Heritabilities in subsequent lactations were reduced in magnitude probably because of the increase in the error term.

Heritabilities of reproduction traits are low and range between 1 to 7 per cent. This indicates that there is hardly any scope for improving these traits, through selective breeding and most of the improvement should come through a package of appropriate management practices. Improvement in reproduction traits can make these animals more economic.

The heritabilities of production traits are higher than those of reproduction traits but still are in the range of low to medium. The production traits can be improved through selective breeding. C = - 1 - 1.4204

5.7 Repeatabilities:

Repeatabilities are estimated as intraclass correlation or as a correlation among different records of the same buffalo (Table 4.08).

Repeatabilities were: peak yield (0.35), 300-day milk yield (0.37), lactation milk yield (0.35) lactation length (0.15), dry period (0.07), service period (0.06), milk yield per day of lactation length (0.34) and milk per day of calving interval (0.34).

Repeatabilities of lactation length, dry period and service period are low and range between 6 to 15 per cent. This indicates that the values obtained in the first lactation are poor indicators of future performance.

All the production traits have high repeatabilities ranging between 34 to 37 per cent indicating that the first observation has high merit in predicting future

performance. This can enable us to base our selection on the basis of first observation itself.

5.8 Correlations:

The overall genetic correlations amongst peak yield, 300-day milk yield, lactation milk yield, lifetime milk yield, lactation length, milk yield per day of lactation length, milk yield per day of calving interval, milk yield per day of age at second calving, and milk yield per day of productive life were positive and highly significant. This suggests that these traits are affected by at least some of the same physiological pathways. High genetic correlations amongst these traits indicate that physiologically, as well as genetically the traits are correlated or influenced by the same genes. This indicates that improvement in one trait can bring about genetic improvement in other traits and thus there are good chances of satisfactory correlated response, if selection is based on peak yield. *Here*

Dry period had highly significant and positive genetic correlation with service period. This is quite understandable since dry period and service period are closely related and are components of calving interval. Calving interval is the function of lactation length and dry period in lactational phase, and service period and gestation period in breeding phase.

Lactation length had negative genetic correlation with dry period and service period. This indicates that the genes influenced lactation length in one direction and the other

two traits (dry period and service period) in apposite direction. However, genetic correlations amongst these three traits are of less practical value because of the low genetic variability present in these trait as indicated by low estimates of heritability. Since all these traits are controlled by managerial factor, the optimum length of these periods should be maintained by suitable management practices.

Breeding efficiency had a low and non-significant genetic correlations with production traits like peak yield, 300-day milk yield, lactation milk yield, and lifetime milk yield, indicating that genetically breeding efficiency is a different trait than production traits. However, breeding efficiency had highly significant and positive genetic correlations with production efficiency traits like milk yield per day of lactation length, milk yield per day of calving interval, and milk yield per day of productive life, indicating that production efficiency is closely related and dependent upon breeding efficiency.

The overall phenotypic correlations amongst peak yield, 300-day milk yield, lactation milk yield, lifetime milk yield, milk yield per day of lactation length, milk yield per day of calving interval, milk yield per day of age at second calving, and milk yield per day of productive life were highly significant and positive, further confirming the trend evident in genetic correlations. The very high genetic and phenotypic correlations indicate that there are no

inherent antagonisms amongst these traits. Improvement in one trait can bring about positive improvement in other traits. Since all these traits are different measures of milk production, it is probable that the same set of genes might be controlling these traits and selection based on phenotypic performance is likely to bring about simultaneous genetic improvement in these production traits.

Dry period had highly significant and positive phenotypic correlation with service period. The highly significant genetic as well as phenotypic correlations of high magnitude are only to the expected as dry period and service period are closely associated and are the components of calving interval.

Lactation length had highly significant and positive phenotypic correlations with dry period and service period. This is quite antagonistic to genetic correlations of lactation length with these two traits. This shows that environmental effects are working in a reverse direction masking the real genetic effects. This indicates that genetics and environmental sources of variation affect the characters through different physiological mechanisms.

Lactation length had highly significant and positive phenotypic correlation with 300-day milk yield, lactation milk yield, and lifetime milk yield. This is in conformity with genetic correlations. These correlations suggest that increase in the length of lactation can improve these traits. But since lactation length in the present study is around the ideal of 300-days, there is no scope for any changes in

the length of lactation.

Breeding efficiency had a highly significant and positive phenotypic correlations with production efficiency traits like milk yield per day of lactation length, milk yield per day of calving interval, and milk yield per day of productive life. The highly significant and positive genetic as well as phenotypic correlations of these traits indicate that there are no antagonisms between breeding efficiency and production efficiency traits. In fact, for attaining high production efficiency high breeding efficiency is a must.

On the basis of these results and discussion, it may be concluded that production efficiency and breeding efficiency are highly associated and breeding efficiency needs an improvement to bring about further improvement in production efficiency. Breeding efficiency can be improved by higher level of management practices which may include the introduction of teaser bulls for timely detection of heat. The buffaloes in heat should be bred at a proper time and vigorous follow-up programme for timely detection of pregnancies should be carried out. This should be coupled with appropriate feeding levels.

The present study also indicates that breeding bulls of high merit should be employed for selective breeding to improve the productivity of buffaloes. This is urgently needed because there has been a slide back in the performance of buffaloes during third period (1978 to 1982).

We are not interested in milk yield alone. We are interested in maximum milk yield per unit time. Thus an ideal milk yielder should also have the capacity of early age at first calving and optimum calving interval.

The present study also indicates that milk yield per day of age at second calving can be used as an index trait in selection programme. This trait incorporates first lactation yield, age at first calving and first calving interval. Thus this trait incorporates a fine combination of production as well as reproduction aspect. This trait had highly significant and positive genetic and phenotypic correlations with all production traits including peak yield, 300 day milk yield, lactation milk yield, lifetime milk yield, milk yield per day of lactation length, milk yield per day of calving interval, and milk yield per day of productive life. Besides, this trait was 14 per cent heritable. Thus this trait qualifies to be a comprehensive and ideal trait for selection under field conditions.

CHAPTER 6

SUMMARY

With a view to study the genetic behaviour in relation to economic traits of Murrah buffaloes, the present investigation was undertaken on the data of three military dairy farms.

The quantitative traits considered in present study were:

1. Peak yield
2. 300-day milk yield
3. Lactation milk yield
4. Lifetime milk yield
5. Lactation length
6. Dry period
7. Service period
8. Milk yield per day of lactation length
9. Milk yield per day of calving interval
10. Milk yield per day of age at second calving
11. Milk yield per day of productive life
12. Breeding efficiency (Wilcox)
13. Breeding efficiency (Tomar)

The performance records were corrected for the significant effects of farm, period, season and age at calving and then were analysed to estimate the genetic and phenotypic parameters of first four lactations.

The overall least squares means for different traits were peak yield (9.72 kg), 300-day milk yield (1955.56 kg), lactation milk yield (2037.29 kg), lifetime milk yield

(7890.44 kg), lactation length (302.21 days), dry period (162.44 days), service period (156.50 days), milk yield per day of lactation length (6.74 kg), milk yield per day of calving interval (4.45 kg), milk yield per day of age at second calving (1.05 kg), and milk yield per day of productive life (4.70 kg). Overall least squares mean breeding efficiency (Wilcox) and breeding efficiency (Tomar) were 80.97 and 83.90 per cent respectively.

Least squares analysis of variance showed that the farms had highly significant influence on all the production and reproduction traits except breeding efficiency. Period of calving also had highly significant influence on all the traits except breeding efficiency (Tomar). Season of calving had highly significant influence on all the traits studied except lifetime milk yield, milk yield per day of lactation length, and milk yield per day of age at second calving. Age at calving had a significant influence on all the traits taken up in the present investigation except milk yield per day of productive life. It appears that an age at first calving between 1101 to 1200 days is optimum.

Heritabilities were estimated by half-sib correlation method from the data corrected for significant effects. Heritabilities for production traits in first lactation were low to moderate: peak yield (0.18), 300-day milk yield (0.13), lactation milk yield (0.09), lifetime milk yield (0.13), milk yield per day of lactation length (0.03),

milk yield per day of calving interval (0.07), milk yield per day or age at second calving (0.14), and milk yield per day of productive life (0.12). These heritabilities suggest that selective breeding would be effective. Heritabilities were very low for lactation length and all the reproduction traits: lactation length (-0.05), dry period (0.04), service period (0.01). Heritabilities of breeding efficiency (Wilcox) and breeding efficiency (Tomar) were 0.07 and 0.09 respectively. These low heritability estimates indicate that, these traits are largely influenced by environmental factors and can be controlled by improving the managerial practices.

Repeatabilities were estimated by intraclass correlation method, from the data corrected for significant effects. Repeatabilities of different production traits were high: peak yield (0.35), 300-day milk yield (0.37), lactation milk yield (0.35), milk yield per day of lactation length (0.34), and milk yield per day of calving interval (0.34). These high repeatabilities indicate that selection can be based on the first observation itself. Repeatabilities of other traits were low: lactation length (0.15), dry period (0.07), and service period (0.06). This indicates that the values obtained in the first lactation are poor indicators of future performance.

The overall genetic correlations amongst all the production traits were positive and highly significant.

This indicates that improvement in one trait can bring about genetic improvement in other production traits and there are good chances of satisfactory correlated response. Since the reproduction traits had low heritabilities, genetic correlations amongst them are not of much importance. These traits can be improved by suitable managerial practices.

The overall phenotypic correlations amongst production trait were positive, highly significant and of high magnitude, further confirming the trend evident in genetic correlations amongst production traits. This indicates that there are no inherent antagonisms amongst these traits. Improvement in one trait can bring about positive improvement in other traits. Dry period had highly significant and positive phenotypic as well as genetic correlations with service period. This is ~~only to be~~ expected as dry period and service period are closely associated and are the components of calving interval.

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