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**STUDIES ON DIFFERENT ASPECTS OF PRODUCTION
AND REPRODUCTION IN BUFFALOES**

**BY
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Shri Padibandla Thyagaraja Naidu has satisfactorily prosecuted his course of research for a period of not less than two semesters and that the dissertation entitled "STUDIES ON DIFFERENT ASPECTS OF PRODUCTION AND REPRODUCTION IN 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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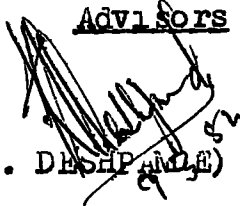
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This is to certify that the dissertation entitled "STUDIES ON DIFFERENT ASPECTS OF PRODUCTION AND REPRODUCTION IN BUFFALOES" submitted by Shri Padibandla Thyagaraja Naidu to the Marathwada Agricultural University in partial fulfilment of the requirements for the degree of Master of Veterinary Science in the subject of Animal Management has been approved by the student's advisory committee after oral examination in collaboration with the External Examiner.

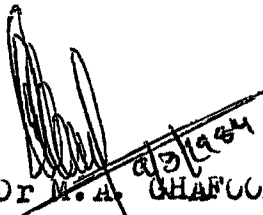

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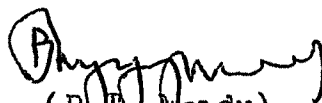
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CHAPTER I

1

INTRODUCTION

CHAPTER 1

INTRODUCTION

In India agriculture sector contributes 47 per cent of the national income. Livestock contributes 18 per cent of the agricultural income. In livestock industry cattle and buffaloes play a very important role. India ranks first among the countries of the world in buffalo population. About 47 per cent of the world buffalo population was in India. Water buffalo or riverine buffalo (Bubalus bubalis) was a triple purpose animal useful for milk, meat and as a working animal.

India had got 182.5 million cattle and 61.3 million buffaloes (F.A.O. 1980). The percentage of milking animals, was only 12.4 in cattle, whereas in buffaloes it was 26.5. The trend of livestock production in India revealed an increase of nearly 1.9 per cent in cattle and 13.1 per cent in buffaloes. The increase in breedable female population of cattle and buffaloes were in the ratio of 1:3 (Nagarankar, 1978). The average annual milk production of cow was only 157 Kg and for buffalo it was 504 Kg (Report. National. Comm. Agric. 1976). Though buffaloes were lesser in number than cattle, they contributed about 60 per cent of total milk production in India (Dev and Tiwana, 1978). Thus buffaloes formed the backbone of the dairy industry. Majority of the dairy plants were dependent or surviving on buffalo milk in India.

Buffalo milk was more popular than cows milk in our country due to its high nutritive value, by the presence of high fat percentage and more total solids and also due to its more cohesiveness property.

Methods of breeding, feeding and managerial practices that have been proved successful to the cows could be applied equally well to dairy buffaloes. Buffaloes were remarkably docile, calm, slow moving and easily controlled by the accustomed attendant. They were commonly managed by children and women. Buffalo possess remarkable ability to convert coarse fodder or roughages into milk and meat. Buffaloes were more efficient utilizers of coarse fibre, ether extract, calcium and phosphorus than zebu cattle. Due to their unique conversion capacity milk and meat could be produced more cheaply in buffaloes, than from cattle and perhaps any other animal (Chothani, 1978 and Cockrill, 1981).

// A large proportion of cattle, though economically worthless, were protected on religious grounds or in response to social sentiments although their production in terms of milk, meat were negligible. In case of buffaloes reverse was the case. Though buffaloes have good production potentialities, they remain neglected till recently. Research and developmental efforts for improving buffaloes have been meagre as compared to cattle. Buffaloes could tolerate adverse feeding and managerial practices, could

adapt readily to new feeding regimes and surroundings and also have got long productive life than cattle (Cockrill, 1981). As in the case of cattle there was no religious sentiments for slaughter of buffaloes in India, hence uneconomic buffaloes could be culled easily without affecting the economy of the dairy farmers.

Buffaloes were resistant and more immune to many infectious diseases as compared to cattle and other species. Some diseases were less prevalent in buffaloes than in cattle. buffaloes were immune to Nasal schistosomiasis, contagious bovine pleuropneumonia, infectious infertilities, ticks infestation, warble infestation, foot rot, foot abscess and hoof defects. Diseases like tuberculosis, brucellosis and mastitis, were less prevalent in buffaloes than in cattle. Like cattle unvaccinated buffaloes have no resistance to the major epizootics, viz. rinderpest, foot and mouth disease, haemorrhagic septicaemia and black quarter. There was no immunity to protozoosis (Babesiosis), Trypanosomiasis (surra) and east coast fever in buffaloes. By virtue of their habitat and wallowing habit incidence of fascioliasis infection was more prevalent in buffaloes than in cattle. And ascariasis (*neo-ascaris vitulorum*) was a menace to the buffalo farming as it causes heavy mortality in buffalo calves unlike in cattle.)

The average minimum nutritional requirements recommended by the nutrition expert group of the "Indian Council of Medical Research" was about 201 g of milk per head per day,

but the availability was only 122 g milk per head per day in 1980. It was lesser by 40 per cent of the requirements. The total protein availability for the Indian population per head per day in 1977-1979 was 48.2 g; out of which vegetable protein formed 44.4 g and the animal protein was only a meagre 3.8 g (F.A.O. 1980). In order to meet the increased demands of milk, milk production should be enhanced by maximum utilization of the efficient milk producing animals like buffaloes with the available resources.

/ In view of the good production potentialities and advantages of the buffaloes as a dairy animal the present investigation on buffaloes was undertaken with the following objectives: //

- 1) To study the genetic and non-genetic factors affecting the different traits, of production and reproduction.
- 2) To estimate the genetic and phenotypic correlations among the production and reproduction traits.
- 3) To find out the heritabilities of production and reproduction traits.

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

2.1 Age at first calving:

The age at first calving (A.F.C.) in buffaloes was a measure of reproductive and productive efficiency and had direct bearing on the productive life and economy of their rearing. A reduction in A.F.C. was desirable for economic milk production and reduced generation interval; it also allows early progeny testing of bulls. Due to the late sexual maturity and their longer gestation period, the average A.F.C. was also greater in buffaloes than in case of cattle. The A.F.C. along with other economic traits might constitute basis to provide early selection criteria individually or in combination with other traits for improving economic returns from buffaloes. A.F.C. was governed by age at first heat, conception rate, gestation length, feeding and other managerial practices.

The mean values of A.F.C. along with their heritabilities as reported by various research workers in different breeds of buffaloes have been shown in table 2.1.

Dhinsa (1963) studied the records of 165 Murrah graded buffaloes and estimated the phenotypic and genetic correlations of the A.F.C. with peak yield and 300 days milk yield in the first lactation as 0.177, 0.061 and -0.387 and -0.199 respectively. The genetic correlations of A.F.C. with peak yield and 300 days milk yield were highly significant

and significant respectively.

Tomar and Desai (1968) studied 477 Murrah graded buffaloes records and found the phenotypic correlations of A.F.C. with peak yield as highly significant at $P/0.01$, whereas the genetic correlations of A.F.C. with peak yield, 300 days milk yield, lactation length and service period in the 1st lactation were 0.537, 0.596, 0.745 and 0.066 respectively.

Bath et al. (1971) studied the records of 565 buffaloes from military dairy farms. They found that, genetically A.F.C. had high negative association with first lactation milk yield, but phenotypically it had very low negative association with milk yield.

Kanujia et al. (1974) analysed first lactation records of 820 buffaloes and reported the phenotypic correlation of A.F.C. with first service period as very low and the genetic correlation as very high.

Mohan (1977) worked on Murrah buffaloes and found the genetic and phenotypic correlation of A.F.C. with first lactation milk yield, first lactation length and first service period as negative and non-significant.

Bhat (1978) reported the correlations among different production and reproduction traits in Indian buffaloes. Phenotypic correlations of A.F.C. with first lactation milk yield (L.M.Y.) first lactation length and first service period were found to be 0.08, -0.02 and -0.0004 whereas, the genetic correlations in the same order were 0.41, 0.33 and

1.00 respectively.

Nagarcenkar (1978) reported the phenotypic correlations of A.F.C. with first lactation 300 days milk yield and first L.M.Y. as 0.001 and -0.004 and the genetic correlations in the same order were -0.659 and -0.752 respectively.

Reddy and Taneja (1980 b) analysed the records of 2465 Murrah buffaloes and 425 Nili-Ravi buffaloes. In Murrah buffaloes they found the phenotypic correlations of A.F.C. with 300 days milk yield and lactation length as low but significant; whereas the phenotypic correlation of A.F.C. with service period was low and non-significant. The genetic correlation between A.F.C. and service period was found to be 0.94. In case of Nili-Ravi buffaloes the phenotypic correlations of A.F.C. with 300 days milk yield and lactation length were low but significant; whereas the genetic correlations were 0.58 and -0.67 respectively. But the phenotypic correlation of A.F.C. with service period was very low and non-significant.

Yadav (1980) studied 392 Murrah buffaloes and found the phenotypic correlation of A.F.C. with first service period and the genetic correlation of A.F.C. with peak yield as positive and significant in both the cases.

Gokhale (1981) analysed the Murrah buffalo records of military dairy farms and reported the genetic correlation of A.F.C. with first L.M.Y. as -0.75.

Mangurkar and Desai (1981) studied first lactation records

of 593 buffaloes and found the phenotypic correlation of A.F.C. with peak yield and L.M.Y. as -0.020 and -0.039 and the genetic correlations in the same order were -0.328 and 0.301 respectively.

2.2 Peak Yield:

Peak yield (P.Y.) was an important production trait, which expresses the producing ability of the animal in early period of lactation indicating the prospects of the L.M.Y. and hence it could be an important criterion for selection of animals at an early age. The mean values of P.Y. heritability estimates and their correlations with other traits as reported by various research workers were as follows.

Dninsa (1963) studied first lactation records of 165 Murrah graded buffaloes and found the average P.Y. and heritability as 7.25 Kg and 0.48 respectively. The phenotypic correlations of the P.Y. with 300 days milk yield and calving interval were found to be 0.605 and -0.021 respectively. The genetic correlations in the same order were 0.346 and 0.855 respectively.

Dutt et al. (1965) analysed 92 Murrah buffaloes first lactation records and found the average P.Y. as 7.60 Kg.

Tomar and Desai (1967) studied the P.Y. of 477 Murrah graded buffaloes. They found the average P.Y. and heritability as 7.21 Kg and 0.118 respectively. The phenotypic correlations of P.Y. with 300 days milk yield, L.M.Y. and lactation length (LL) were found to be same

0.712, 0.733 and 0.179 respectively. Genetic correlations in the same order were 0.978, 1.205 and 0.583 respectively. All correlations were highly significant at $P < 0.01$.

Rao et al. (1970) analysed 632 records of first five lactations belonging to Murrah buffaloes of Mathura and Babugarh farms. The average P.Y. were found to be 7.5, 9.3, 9.8, 9.6 and 10.6 kg for first five lactations respectively for Mathura farm. The values for Babugarh farm were 6.9, 7.9, 8.5, 8.6 and 8.1 kg for the first five lactations, respectively.

Dave and Taylor (1971) studied 267 first lactation records of Murrah graded buffaloes. The average P.Y. was found to be 7.32 Kg. The P.Y. was found to be highly correlated with L.M.Y. and L.L.

Sane et al. (1972) analysed records of 409 Murrah buffaloes. The overall P.Y. of 1231 first five lactations was found to be 8.23 Kg. The average P.Y. in the first five lactations were found to be 7.49, 8.30, 8.60, 8.76 and 8.71 Kg respectively. The P.Y. increased gradually from first to fourth lactation and then declined.

Nagarcenker (1978) reported the average P.Y. and heritability for 1473 lactations of Murrah graded buffaloes as 8.27 Kg and 0.447 respectively.

Apparao (1978) studied 886 lactations of Murrah buffaloes and found to be the average P.Y. as 10.69 Kg. The correlations of P.Y. with 300 days milk yield, L.M.Y.,

L.L., dry period (D.P.), service period (S.P.) and calving interval (C.I.) were found to be 0.485, 0.438, 0.083, -0.064, 0.023 and 0.076 respectively in pluriparous animals.

Yadav (1980) studied records of 392 Murrah buffaloes and reported the average P.Y. as 8.23 Kg. In the first lactation the phenotypic correlations of P.Y. with L.M.Y., S.P., D.P. and C.I. were found to be positive and significant; whereas, the genetic correlations of P.Y. with A.F.C., S.P., C.I. were zero or negative.

Chowdhary and Chaudhary (1981) analysed 207 lactation records from second to fifth lactation pertaining to Mehsana and Surti buffaloes. The average P.Y. found to be 7.85 and 7.39 Kg for Mehsana and Surti buffaloes respectively. The buffaloes in the fifth lactation had significantly higher P.Y. than in other lactations.

Garcha and Tiwana (1981) studied 863 records (first to sixth lactation) pertaining to 280 Murrah graded buffaloes and reported the average P.Y. as 10.85 Kg. The phenotypic correlations between P.Y. and L.M.Y. was found to be 0.58 which was significant.

Mangurkar and Desai (1981) analysed first lactation records of 593 Murrah graded buffaloes. The average P.Y. and heritability were found to be 8.0 Kg and 0.114 respectively. The phenotypic and genetic correlations of P.Y. and L.M.Y. were found to be 0.691 and 1.09 respectively.

Singh and Tiwana (1981) studied 2607 lactations of

Murrah graded buffaloes. The overall P.Y. was found to be 9.77 Kg. The P.Y. in the first five lactations were found to be 8.62, 9.69, 10.24, 10.27 and 10.03 Kg respectively. The P.Y. showed an increasing trend upto fourth lactation, followed by slight decrease in the fifth lactation. It was also found that the P.Y. of buffaloes which calved in the least calving season (January to June) was significantly higher than those calved in the most calving season (July to December).

Cheema and Basu (1983) analysed 1156 lactation records of 545 Murrah buffaloes. The overall P.Y. and heritability were found to be 10.30 Kg and 0.51 respectively. The phenotypic and genetic correlations of P.Y. with 43 weeks (301 days) milk yield were 0.64 and 0.68 respectively.

2.3 300-days milk yield:

Milk production depends upon the physiological condition and genetic make up of the dairy animal, environmental conditions, viz season of calving, feeding and managerial practices and parity of the milking animals. The mean values of 300 days milk yield along with their heritabilities as reported by various workers in different breeds of buffaloes have been shown in Table 2.2. Some highlights of work done on 300 days milk yield, heritability estimates and their correlations with other traits in different parities as reported by various research workers were as follows.

Dhinsa (1963) analysed 540 lactation records of Murrah

grades and found that the overall 300 days milk yield and heritability as 1740.55 Kg and 0.324 respectively. The 300 days milk yield in the first five lactations were found to be 1538.57, 1709.05, 1815.17, 1944.36 and 1963.27 Kg respectively. The phenotypic and genetic correlations of 300 days milk yield with C.I. were found to be 0.383 and 0.211 respectively.

Eltawal et al. (1976) reported the first and second lactation 300 days milk yield as 1004.30 and 1552.70 Kg respectively in Egyptian buffaloes.

Apparao (1978) studied 872 lactations of Murrah buffaloes and found the correlations of 305 days milk yield with total L.M.Y., L.L., D.P., S.P. and C.I. as 0.957, 0.626, -0.174, 0.251 and 0.257 respectively.

Basu and Ghai (1978b) studied the records of Murrah buffaloes and reported the 300 days milk yield and heritability as 1647.34 Kg and 0.22 respectively. The phenotypic correlations of 300 days milk yield with L.L., D.P., S.P. and C.I. were estimated as 0.677, -0.278, 0.279 and 0.288 respectively. All were found to be highly significant

Basu et al. (1979) analysed the records of Murrah buffaloes maintained at N.D.R.I. Karnal and reported the average 305 days milk yield for 243 lactations as 1678.00 Kg. Further they reported the 300 days milk yield in the first five lactations as 1453.0, 1596.0, 1674.0, 1630.0 and 1651.0 respectively. The heritability for 305 days milk yield was

found to be 0.25.

Patro and Bhat (1979 a) studied 6547 lactation records of first six lactations, of buffaloes maintained at 11 military dairy farms. The heritability estimates for 300 days milk yields in the first five lactations were estimated as 0.244, 0.135, 0.252, 0.028 and 0.203 respectively. In the first five lactations the phenotypic correlations between 300 days milk yield and L.M.Y. were found to be 0.89, 0.93, 0.85, 0.97 and 0.97 respectively; whereas the genetic correlations were found to be 0.77, 1.06, 0.66 and 1.01 respectively for the first four lactations. For the first five lactations, the phenotypic correlations between 300-days milk yield and L.L. were estimated as 0.49, 0.46, 0.43, 0.42 and 0.46 respectively. For the same traits the genetic correlations were estimated as 0.21, 0.23 and -0.30 in the first three lactations and 1.09 in the fifth lactation.

In another study Patro and Bhat (1979 b) estimated the overall 300 days milk yield in the first five lactations as 1573.39, 1790.40, 1878.00, 1963.80a and 1959.70 Kg respectively. In the same study for Murrah buffaloes in the first five lactations, 300 days milk yield were found to be 1532.1, 1717.6, 1844.4, 1874.8 and 1928.4 Kg respectively. The corresponding values for Murrah grades were 1568.2, 1787.3, 1905.0, 1953.3 and 1870.10 Kg respectively. The 300 days milk yield gradually increased and attained highest in the fourth lactation and then gradually declined. The buffaloes calved in least calving

season (January to June) had significantly higher milk yield than those calved in the most calving season (July to December).

Ready and Taneja (1980 b) studied 2465 records of Murrah and 425 records of Nili-Ravi buffaloes and estimated their first lactation 300 days milk yield as 1634.83 and 1706.53 Kg respectively. The corresponding heritability estimates were found to be 0.13 and 0.08 for Murrah and Nili-Ravi respectively. In Murrah buffaloes the phenotypic correlations of 300 days milk yield with L.L. ranged from 0.42 to 0.58, with S.P. from 0.18 to 0.31 and with C.I. from 0.24 to 0.30 respectively in different farms. Whereas, in Nili-Ravi buffaloes the phenotypic correlations of 300 days milk yield with L.L., S.P. and C.I. were 0.51, 0.27 and 0.29 respectively. All correlations were significant at $P < 0.01$.

2.4 Lactation Milk Yield:

The lactation milk yield (L.M.Y.) had been studied very extensively by various workers in different breeds of buffaloes. The mean L.M.Y. in different breeds of buffaloes have been presented in Table 2.3. The important work done on L.M.Y., heritability estimates and its correlation with other traits in different lactations and in different breeds as reported by various workers were as follows.

Khishin et al. (1963) studied 223 lactations of Egyptian buffaloes and reported a significant correlation between first L.M.Y. and first S.P. as 0.28.

Venkayya and Anantakrishnan (1964) analysed 136 lactations of Murrah buffaloes and found a non-significant correlation of 0.16 between preceding D.P. and subsequent L.M.Y.

Alim (1967) studied 2738 lactations of Egyptian buffaloes from a commercial herd and found the average L.M.Y. as 1769.04 Kg and the correlation between L.M.Y. and L.L. as 0.85.

Roychoudhary and Cesarini (1969) analysed 496 lactations of Italian buffaloes and found non-significant correlation of -0.02 between preceding D.P. and L.M.Y.

Gill and Dev (1970) studied 207 lactations of Murrah buffaloes and reported the first and third L.M.Y. as 1360.0 and 1475.0 Kg. respectively. They found significant phenotypic correlations of L.M.Y. with L.L., S.P. and C.I. as 0.63, 0.28 and 0.27 respectively.

Sane et al. (1972 b) analysed records of 409 Murrah buffaloes and found L.M.Y. of first five lactations as 1564.70, 1717.85, 1775.88, 1796.31 and 1798.65 Kg respectively and heritability of L.M.Y. was found to be 0.53.

Jawarkar and Johar (1974) analysed records of 670 Murrah buffaloes and reported the phenotypic correlations of the first three preceding dry periods with L.M.Y. as 0.43, -0.13 and -0.02 respectively.

Kaut et al. (1974) studied records of 500 Murrah buffaloes and found the first L.M.Y. and overall L.M.Y. to be

1585.0 and 1710.0 Kg respectively. There was a highly significant correlation of 0.58 between L.M.Y. and L.L.

Jawarkar and Johar (1975 b) studied the first five lactation records and found the average L.M.I. as 1557.75, 1757.63, 1823.05, 1796.80 and 1800.48 Kg respectively.

Singh et al. (1976) studied 878 records of Murrah buffaloes and found a significant correlation of 0.21 between L.M.Y. and C.I.

Belorkar et al. (1977) studied Nagpuri buffaloes and reported the L.M.Y. in the first five lactations as 926.728, 1006.72, 1104.96, 1156.27 and 1139.00 Kg respectively. The correlations of L.M.Y. with S.P. and preceding D.P. were found to be positive and significant; and positive and non-significant respectively.

Polikhronov et al. (1977 a) reported that in 1098 Bulgarian x Murrah crosses the milk yield in the first four lactations were found to be 1492.0, 1740.0, 1841.0 and 1850.0 Kg respectively.

Alim (1978) studied Egyptian buffaloes and reported the correlations of L.M.Y. with L.L. and C.I. as 0.74 and 0.30 respectively.

Apparao (1978) studied lactations of Murrah buffaloes and found the correlations of L.M.Y. with L.L., D.P., S.P. and C.I. as 0.74, -0.12, 0.36 and 0.37 respectively.

Basu (1978) analysed 711 lactation records of Murrah buffaloes and found the significant correlations of L.M.Y.

with L.L., S.P., D.P. and C.I. as 0.68, 0.28, -0.28 and 0.29 respectively.

Bhat (1978) reported average L.M.Y. in Bhadawari, Marathwada, Nili-Ravi, Non-descript and Surti buffaloes as 1111.00, 960.00, 1855.20, 541.00 and 1772.00 Kg respectively. In 2842 first lactations of Murrah buffaloes, the average L.M.Y. and heritability estimates were found to be 1597.30 Kg and 0.08 respectively. In first lactation the phenotypic correlation of L.M.Y. with L.L., D.P. and C.I. were found to be 0.63, 0.12 and 0.36 respectively. The genetic correlations in the same order were 0.46, -0.47 and 0.23 respectively.

Chikara et al. (1978) studied the records of 380 Murrah buffaloes and found the lactation wise milk yield in first five lactations as 1521.27, 1658.81, 1850.69, 1779.21 and 1744.15 Kg respectively.

Dharmeshwar Das (1978) analysed records of 733 Murrah graded buffaloes and found that the L.M.Y. increased gradually from first lactation 1587.86 Kg and reached maximum in the fourth lactation 1896.45 Kg. The buffaloes calved in the least calving season (January-June) produced more milk and had longer L.L. than those calved in most calving season (July-December).

Johari and Bhat (1979 b) analysed 2842 first lactation records of Murrah grades and reported the L.M.Y. and heritability as 1597.30 Kg and 0.08 respectively. There were significant phenotypic correlations of first L.M.Y.

with, first L.L. and first D.P. (0.63 and 0.12 respectively), but their genetic association was not found to be significant. Especially the genetic correlation between first L.M.Y. and D.P. was negative and non-significant.

Patro and Bnat (1979 a) studied 6547 lactation records of buffaloes. The heritability estimates for L.M.Y. in the first five lactations were found to be 0.03, 0.14, 0.08, 0.04 and 0.18 respectively. The phenotypic correlations of L.M.Y. with L.L. in the first five lactations were found to be 0.65, 0.61, 0.64, 0.57 and 0.60 respectively. The genetic correlations were 0.34, 0.39, -0.57 in the first three lactations and 1.03 in the fifth lactation.

In another study Patro and Bnat (1979 b) analysed 7362 lactation records of buffaloes. In the first five lactations, the overall mean lactation milk yields were estimated as 1618.50, 1880.00, 1964.00, 2039.50 and 2024.30 Kg respectively. For Murrah buffaloes lactation wise milk yield in first five lactations were found to 1575.8, 1791.0, 1931.5, 1931.8 and 2009.0 Kg respectively. The corresponding values for Murrah grades were 1609.8, 1870.0, 1977.1, 2030.9 and 2916.8 Kg respectively. The L.M.Y. consistently increased from first to fourth lactation and later declined. The buffaloes that calved in least calving season (January-June) had significantly higher L.M.Y. than those calved during the most calving season (July-December).

Basu and Ghal (1981) analysed 711 lactations of Murrah buffaloes and reported a highly significant correlation of

-0.28 between L.M.Y. and D.P.

Garcha and Tiwana (1981) analysed 863 lactations of Murrah graded buffaloes and reported a significant correlation of 0.53 between L.M.Y. and L.L.

Gupta et al. (1981) studied 268 lactations of 70 Murrah buffaloes and found the lactation wise milk yield in first five lactations as 1538.70, 1419.30, 1523.70, 1500.20 and 1408.60 Kg respectively.

Khanna and Kanujia (1981) analysed 1125 lactations of Murrah graded buffaloes and found the correlations between L.M.Y. and preceding D.P. in first six lactations as non-significant and they varied from -0.06 to 0.10.

Gurung and Johar (1982 a) analysed 896 first lactations of Murrah buffaloes and reported the average L.M.Y. and heritability as 1665.25 Kg and 0.16 respectively. The phenotypic and genetic correlations between first L.M.Y. and L.L. were found to be 0.58 and 0.26 respectively.

Caoy et al. (1983) studied 5716 lactations of 2 Hill-Ravi herds, in Pakistan and found that the effects of season of calving, parity, L.L., S.P. and C.I. were significant on L.M.Y.

Khure et al. (1983) analysed 297 lactations of Nagpuri buffaloes and reported the average L.M.Y. in the first five lactations as 942.89, 1075.75, 1079.37, 1004.37 and 1118.01 Kg respectively.

2.5 Lactation length:

Lactation length (L.L.) was one of the important traits

having a major impact on the milk yield of buffalo during lactation. The L.L. was found to be a variable trait in buffaloes which depends upon the breed, season of calving, service period, parity, managerial practices and nutritional status of the animal. The average values of lactation length along with their heritabilities as reported by various workers in different breeds of buffaloes have been shown in Table 2.4. The work carried out on the L.L., heritability estimates and correlations with other traits in various breeds of buffaloes in different lactations were as follows.

Kohli and Malik (1960) studied 180 lactations of Murran buffaloes and found the average L.L. as 288.27 days. They reported that the first L.L. was longer than the rest of the lactation lengths. There was a highly significant correlation of first L.L. with first S.P. In the subsequent lactations the correlations between L.L. and S.P. were not significant.

Polikhronov (1965) studied 712 lactations of Bulgarian buffaloes and reported the correlation of 0.43 between L.L. and S.P. The correlations ranged from 0.37 to 0.62 in different lactations.

Gill and Dev (1970) studied 207 records of Murran buffaloes and found the first L.L. as 307 days. They found the phenotypic correlations of L.L. with S.P. and C.I. as positive and significant. The correlation between L.L. and D.P. was found to be negative but significant.

Rao et al. (1970) studied 698 lactations of Murrah buffaloes and found the L.L. in the first five lactations as 372, 353, 313, 334 and 357 days respectively.

Kaut et al. (1974) analysed 500 Murrah buffaloes data and reported a non-significant correlation of 0.087 between L.L. and the preceding D.P.

Jawarkar and Johar (1975 a) studied 3116 lactations of Murrah buffaloes and found the highly significant correlations of 0.95, 0.56, 0.56 and 0.61 in between first four lactation lengths, and lactation milk yields, respectively.

Kanujia and Balane (1975 a) analysed 576 Murrah graded buffalo records and found the first L.L. as 303.83 days. They also reported that, the buffaloes which calved in least calving season (January to June) had longer L.L. and produced more L.M.Y than the buffaloes which calved in most calving season (July-December).

Belonkar et al. (1977) studied 348 lactations of Nagpur buffaloes and found the correlation between L.L. and S.P. as positive but non-significant. The average L.L. in the first five lactations were found to be 295.43, 297.41, 271.46, 271.02 and 270.85 days respectively.

Apparao (1978) analysed 741 lactation lengths in pluriparous buffaloes and found the correlations of L.L. with S.P. and C.I. as 0.557 and 0.621 respectively.

Alim (1978) studied Egyptian buffaloes and reported the average L.L. as 311.10 days. The correlation between L.L.

and C.I. was found to be 0.488.

Basu and Ghal (1978 c) studied 732 lactations of Murrah buffaloes and found the correlations of L.L. with b.P. and C.I. as positive. The correlation between L.L. and D.P. was found to be negative.

Bhat (1978) analysed the first lactation records of Murrah grades and reported the phenotypic correlations of L.L. with A.F.C., L.M.Y., D.P. and C.I. as -0.02, 0.63, 0.21 and 0.59 respectively. The genetic correlations in the same order were found to be 0.33, 0.46, -0.74 and 0.12 respectively.

Dhameswar Das (1978) analysed the data of 733 Murrah graded buffaloes and found that, the L.L. significantly affected the L.M.Y. in all the lactations. He also reported that, the buffaloes which calved in the least calving season (January-June) had longer L.L. and produced more milk than those calved during the most calving season (July-December).

Basu et al. (1979) studied the records of Murrah buffaloes maintained at W.D.K.L. Karnal and reported the lactation lengths of first five lactations as 302, 280, 288, 279 and 282 days respectively.

Johari and Bhat (1979 b) analysed 2842 first lactation lengths of buffaloes and found the average L.L. as 295.9 days. The heritability of L.L. was found to be 0.11. The phenotypic correlations of first L.L. with L.M.Y. and D.P. were found to be positive and significant. The genetic

correlation between first L.L. and L.M.Y. was associated with large standard error and therefore inconclusive, but there was a significant correlation of -0.74 between L.L. and D.P.

Patro and Bhat (1979 a) studied 6547 lactation records of buffaloes. They reported the heritability estimates in the first five lactations as 0.11, 0.05, -0.04 , 0.03 and 0.07 respectively.

In another study Patro and Bhat (1979 b) analysed 7362 lactation records and reported the first five lactation lengths as 297.80, 300.00, 298.30, 291.30 and 290.80 days respectively. The buffaloes that calved in least calving season (January-June) had significantly longer L.L. and produced higher L.M.Y. than those calved during most calving season (July-December).

Reddy and Taneja (1980 b) studied 2465 records of Murrah and 425 records of Nili-Ravi buffaloes. There were highly significant phenotypic correlation of L.L. with S.P., D.P. and C.I. in both Murrah and Nili-Ravi buffaloes in different farms (0.44 to 0.62, 0.19 to 0.26 and 0.51 to 0.62 respectively). The genetic correlations of L.L. with S.P. in both the breeds were not estimable or had high standard errors. The genetic correlations of L.L. within D.P. and C.I. in Nili-Ravi buffaloes were found to be 0.69 and 0.85 respectively.

Yadav (1980) analysed data pertaining to 392 Murrah buffaloes and found the correlations of first L.L., with P.Y.

and first S.P. as non-significant and positive but significant respectively.

Basu and Ghal (1981) studied 711 lactations of Murrah buffaloes and found the phenotypic correlation of L.L. with D.P. as -0.18 which was highly significant, but the correlation between L.L. and S.P. was high and positive.

Sastry et al. (1982) studied 174 calvings of Murrah buffaloes and found the average L.L. as 294 days. They reported a significant correlation of 0.67 between L.L. and C.I.

2.6 Dry period:

Dry period (D.P.) was essential for the dairy animals to restore or recoup the body reserves and to get ready for the next lactation. Buffaloes do not milk for about one third of their calving interval, during which they have to be fed and looked after resulting in high cost of milk production. The D.P. being the unproductive period, it shortens the productive life of the buffaloes and reduces the margin of profit to the dairy farmer. The D.P. should be reduced to the minimum possible extent by suitable breeding and managerial practices, without affecting the milk yield in the succeeding lactations. The D.P. was mostly influenced by managerial efficiency, season of calving, parity and breed of the buffaloes. The mean values of D.P. along with their heritabilities as reported by various research workers in different breeds of buffaloes were presented in Table 2.5. The work done on D.P. and its

correlations with other traits in various breeds of buffaloes, in different lactations were as follows.

Venkayya and Anantakrishnan (1964) analysed 136 lactations of Murrah buffaloes maintained at N.D.R.I. Bangalore and reported the average D.P. as 183 days. There was a non-significant correlation of 0.161 between preceding D.P. and subsequent L.M.Y.

Ohril and Prakasa (1969) analysed records of Murrah buffaloes and found the average D.P. as 171.0 days. There was a negative but highly significant correlation of -0.38 between preceding D.P. and subsequent L.M.Y.

Roychoudhary and Cesarini (1969) studied 496 lactations of Italian buffaloes. They reported a non-significant correlation of -0.02 between the preceding D.P. and subsequent L.M.Y.

Gill and Dev (1970) analysed 207 lactation records of Murrah buffaloes. The phenotypic correlations were found to be as follows. The correlations of D.P. with L.L. was negative and significant. The correlation between D.P. and S.P. was found to be 0.24, which was non-significant. The correlation of D.P. with C.I. was found to be positive and significant.

Singh et al. (1972) analysed 1614 lactations of Murrah buffaloes. The correlation of D.P. with S.P. was found to be 0.35, while the correlation between the preceding D.P. and S.P. was 0.84 both correlations were significant.

Jawarkar and Johar (1974) studied 2790 lactations of Murrah buffaloes and reported the phenotypic correlations of first 3 preceding dry periods with lactation milk yields, as 0.431, -0.131 and -0.017 respectively. The correlations of first D.P. with first L.M.Y., and first D.P. with second L.M.Y. were highly significant; other correlations were found to be non-significant. The significant correlations between first D.P. and second L.M.Y. indicated that the increase in the length of the D.P. was associated with increased L.M.Y. in succeeding lactation. The correlation between second D.P. and third L.M.Y. was negative, but significant. The correlation between third D.P. and fourth L.M.Y. was also negative but non-significant. The first D.P. was found to be longest and it gradually reduced as the number of lactations increased.

Kanujia and Balaine (1975 a) analysed 576 first lactation records of Murrah graded buffaloes and found the correlations of D.P. with S.P. and L.L. as significant. There was non-significant effects of season over the D.P. Though the seasonal differences were non-significant, the buffaloes that calved during least calving season (January-June) had shorter D.P. and longer L.L. and produced more L.M.Y than, the buffaloes that calved during most calving season (July-December).

Kanujia *et al.* (1975 b) studied 674 lactations of Murrah grades and found a declining trend in the D.P. as the lactations progressed.

Gurunani et al. (1976 b) analysed 489 calvings of Murrah buffaloes and reported that, the season of calving had no significant effect on D.P.

Belorkar et al. (1977) studied 348 lactations of Nagpur buffaloes. In the first five lactations the average dry periods were found to be 155.13, 135.61, 122.66, 117.62 and 123.51 days respectively. There was a positive and significant correlation between preceding D.P. and S.P.

Mohan (1977) analysed records of Murrah buffaloes and reported the genetic and phenotypic correlation of first D.P. with first C.I. as positive and significant.

Alim (1978) studied Egyptian buffaloes and found a correlation of 0.54 between D.P. and C.I. He also reported that the preceding D.P. had no effect on the L.M.Y. in succeeding lactation.

Apparao (1978) studied 740 dry periods in Murrah buffaloes and found the correlations of D.P. with P.Y, 305 days milk yield, L.M.Y., S.P. and C.I. as -0.06, -0.17, -0.12, 0.59 and 0.71 respectively.

Bhat (1978) reported the highly significant phenotypic correlations of first D.P. with first L.M.Y and first L.L. as 0.12 and 0.21 respectively. The genetic correlations in the same order were -0.47 and -0.74 respectively.

Kanujia (1978) studied records of 820 Murrah graded buffaloes and found the average first D.P. as 197.33 days.

The D.P. was longest in the first lactation, afterwards declining trend was observed till fourth lactation. The effect of season was found to be significant on the D.P.

Basu et al. (1979) studied the records of Murrah buffaloes maintained at N.D.H.I. Karnal and found the correlation coefficient of D.P. with 305 days milk yield, L.L., S.P., and C.I. as -0.278, -0.182, 0.643 and 0.648 respectively. All correlations were highly significant.

Johari and Baat (1979 b) studied 2539 lactation dry periods of Murrah graded buffaloes. The significant phenotypic correlation of first D.P. with first L.M.Y. was found to be 0.12, but the genetic correlation was negative and non-significant associated with large standard error. The phenotypic correlation of first D.P. with first L.L. was positive and significant, but the genetic correlation was negative and significant. (-0.74).

Reddy and Taneja (1980 b) studied 2465 records of Murrah and 425 records of Nili-Ravi buffaloes. They found the significant phenotypic correlations of D.P. with L.L., S.P. and C.I. as 0.19 to 0.26, 0.65 to 0.86 and 0.90 to 0.94 respectively in different farms. For both the breeds the genetic correlations of D.P. with S.P. and C.I. were not estimable or had high standard errors. The genetic correlation of D.P. with L.L. was not estimable for Murrah buffaloes. But in case of Nili-Ravi the genetic correlation between D.P. and L.L. was estimable and it was found to be 0.69.

Basu and Ghai (1981) analysed 710 lactations of Murrah buffaloes and found the highly significant phenotypic correlations of D.P. with L.M.Y., L.L., S.P. and C.I. as -0.28, -0.18, 0.64 and 0.65 respectively. The effect of season, parity and S.P. on the D.P. were significant. Summer Calvers (April-June) had smallest D.P. (142.7 days), than the buffaloes which calved in other seasons (162 days). The D.P. increased with the number of lactations, it was lowest (135.0 days) in the first lactation and highest (172.9 days) in the seventh lactation.

Khanna and Manujia (1981) studied 1125 lactations of Murrah graded buffaloes and found that, there was a non-significant correlation of -0.06 to 0.10 in different lactations between the preceding D.P. and L.M.Y.

Sastry et al. (1982) studied 174 lactations of Murrah buffaloes and found a significant correlation of 0.34 between D.P. and C.I. The season of calving had no significant effect on D.P. in buffaloes.

2.7 Service Period:

Lower reproductive efficiency, seasonality of breeding hamper the buffaloes production ability. The rate of efficiency of reproduction should be the primary importance for the economic milk production in buffaloes. The buffaloes were known for their lethargic breeding. The service period (S.P.) plays a major and vital role in the reproduction efficiency of the buffaloes. The S.P. in buffaloes was

generally reported to be very long and that was attributable to various causes like, silent heat, anovulatory heat, ovarian inactivity, embryonic mortality, impaired fertility, infertile services, poor and improper management etc. without giving sufficient rest to the uterus, unnecessary shortening of the S.P. had an unfavourable influence on both health and milk yield. wide variation in S.P. among the buffaloes have been observed. The S.P. was influenced by season of calving, parity, breed of the buffaloes and managerial practices etc. The mean values of S.P. along with their heritabilities as reported by various workers in different breeds of buffaloes have been presented in Table 2.6. The research findings of different workers on S.P. and its correlations with other traits of production and reproduction in various breeds of buffaloes, in different lactations were as follows.

Konli and Malik (1960) studied 180 lactations of Murrah buffaloes and found the maximum S.P. in the first lactation, followed by a steady decline in subsequent lactations.

Khishin et al. (1963) studied 223 lactations of Egyptian buffaloes and found that, the length of S.P. decreased gradually upto the fifth lactation.

Venkayya and Anantakrishnan (1966) studied 105 lactations of Murrah buffaloes belonging to M.D.K.I. Bangalore, and found that, the season of calving had significant effect on the length of S.P.



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Goswami and Kumar (1966) studied 3039 service periods of Murrah buffaloes and found that, the S.P. was longer for off-season calvers, than those calved in other seasons. From the first to fourth lactation the service periods were found to be 129.71, 112.11, 111.25 and 112.51 days respectively.

Roychoudhary and Succi (1969) studied 523 calvings of Italian buffaloes and found that, the effect of season of calving over the length of S.P. was significant at $P < 0.05$.

Gill and Dev (1970) studied 207 lactations of Murrah buffaloes and found a highly significant phenotypic correlation of 0.86 between S.P. and C.I.

Singh et al. (1972) analysed 1614 lactation records of Murrah buffaloes and found that, the S.P. was highest in the first lactation and thereafter it declined. The season of calving was found to have a significant effect on the S.P. The significant correlation coefficients of S.P. with L.L. and C.I. were found to be 0.62 and 0.95 respectively.

Rao et al. (1973) studied 281 service periods of Surti buffaloes and found that, the effect of season was highly significant over the S.P. The monsoon calvers had shortest (90.5 days), while the summer calvers had the longest (219.0 days) S.P.

Belorkar et al. (1977) studied Nagpuri buffaloes and reported the first to fifth lactation service periods as 130.60, 98.17, 85.83, 73.41 and 81.31 days respectively.

Mohan (1977) studied the Murrah buffaloes and reported the phenotypic and genetic correlations of first S.P. with first L.M.Y. as positive and non-significant; whereas the phenotypic and genetic correlations of first S.P. with first C.I. was positive and significant. The effect of season, over the S.P. was found to be significant. The heritabilities of first five service periods were found to be 0.05, 0.01, 0.21, -0.22 and -0.03 respectively.

Basu et al. (1978 a) studied 732 lactations of Murrah buffaloes and found a highly significant phenotypic correlations of 0.96 between the S.P. and C.I.

Basu and Ghal (1978 b) studied lactation records of Murrah buffaloes and found the phenotypic correlations of S.P. with L.L. and C.I. as 0.59 and 0.98 respectively.

Bhat (1978) reported the range of phenotypic correlations between the S.P. and L.M.Y. They varied from 0.25 to 0.50.

Kanujia (1978) studied data of 820 Murrah graded buffaloes and reported that, the S.P. was longest in the first lactation, after that a declining trend was observed till fourth lactation. The effects of season and parity were significant over the S.P.

Basu et al. (1979) analysed the records of Murrah buffaloes maintained at N.D.R.I. Karnal, and found the first five service periods as 141.49, 135.52, 137.95, 130.46 and 117.50 days respectively.

Johari and Bhat (1979 a) analysed the records of Murrah grades and found a highly significant phenotypic correlation of 0.98 between first S.P. and C.I.

Amolkar (1980) studied 684 calvings of Nagpuri buffaloes and found that, the S.P. was lowest for the buffaloes which calved during the normal calving season (August-December), than the other season calvers.

Reddy and Taneja (1980 b) analysed 2465 lactations of Murrah buffaloes and found the phenotypic correlations of S.P. with C.I. to be 0.73 to 0.93 in different farms. The genetic correlations of S.P. with other traits were either not estimable or had high standard errors.

Swain (1980) studied the records of 446 Murrah buffaloes maintained at M.D.R.I. Karnal and reported the correlation between S.P. and A.F.C. as -0.08, which was non-significant. The S.P. was found to be, significantly affected by the parity and season.

Ladav (1980) analysed the data of 392 Murrah buffaloes and found that, the first S.P. had significant and positive phenotypic correlations with L.M.Y. and C.I.

Porwal et al. (1981) studied 151 calvings of Murrah buffaloes and reported that, the season of calving had a significant effect on the S.P. The summer calvers had the longest (235.43 days) S.P., while the rainy season calvers had the shortest (186.85 days) S.P.

Raizasa and Pandey (1981) studied reproductive patterns in buffaloes and found that, the S.P. was significantly higher

in off-season (March-June) calvers, than in the normal season (September-February) calvers.

Sastry et al. (1982) analysed 174 calvings of Murrah buffaloes and found a significant correlation of 0.58 between S.P. and C.I. The S.P. was longest (265 days) for winter calvers and shortest (134 days) for the buffaloes calved in July and August.

2.8 Calving Interval:

The period between the two consecutive calvings was called as calving interval (C.I.) and its components were the S.P. and gestation period. The C.I. was most important reproduction trait, as it represents the reproductive efficiency of the animal and hence it was of vital interest to the dairy farmer from the economic point of view. The C.I. was found to be mostly influenced by the environmental factors, rather than genetic factors. In buffaloes the C.I. depends upon the S.P., season of calving, parity, breed of the animal and managerial practices. The longer calving intervals were one of the major constraints in the buffalo farming. It could be reduced in buffaloes by adapting suitable managerial practices round the year.

The mean values of calving intervals along with their heritabilities, as reported by various research workers in different breeds of buffaloes have been shown in Table 2.7. The research findings of different workers on C.I. and its

correlations with other traits of production and reproduction in various breeds of buffaloes, in different lactations were as follows.

Goswami and Nair (1965) studied the calving patterns of Murrah grades and found that, the C.I. of off-season calvers were longer than the normal season calvers. Irrespective of season of calving, the calving intervals became shorter and shorter as the age of the buffalo advanced.

Goswami and Kumar (1967a) studied the lactation records of 1484 Murrah buffaloes and found that, the low yielding buffaloes have smaller calving intervals, whereas high yielding buffaloes have longer calving intervals in all the lactations studied. The first C.I. was found to be more than the subsequent calving intervals. There was a continuous falling trend in the length of calving intervals, as the number of lactations advanced.

Mal (1975) studied records of Murrah buffaloes and reported a declining trend in the C.I. from 455 to 440 days from the year 1959 to 1972, which indicated the gradual improvement in the herd for that trait.

Gurnani et al. (1976 b) analysed 489 calvings of Murrah buffaloes and reported that the season of calving had significant ($P < 0.01$) effect on C.I. The buffaloes calved during rainy season (July-October) and winter season (November-February) had shortest C.I. of 424 days. In case of late winter (January-February) and Summer (March-June) calvers the calving intervals were found to be longer.

Singh et al. (1976) studied records of 878 Murrah buffaloes. Parity and season of calving was found to have significant effect on the C.I. Buffaloes that calved in February had maximum (493.76 days) and those calved in July had the minimum (408.65 days) C.I. Buffaloes calved in Summer had longer C.I. of 457.83 days, than the other season calvers.

Monan (1977) studied records of Murrah buffaloes and reported that, there were significant effects of parity and season of calving over the C.I. The heritabilities of first four calving intervals were found to be 0.23, 0.05, 0.41 and 0.55 respectively. In the first lactation the correlations of C.I. with L.M.Y., L.L., D.P. and S.P. were found to be positive and significant.

Alim (1978) analysed the records of Egyptian buffaloes and reported the correlations of C.I. with L.M.Y., L.L. and D.P. as 0.30, 0.49 and 0.54 respectively.

Apparao (1978) studied 662 calving intervals of Murrah buffaloes and found a correlation of 0.79 between C.I. and S.P. in pluriparous animals.

Basu et al. (1978 a) studied 732 records of Murrah buffaloes and reported that, the effect of season of calving was significant ($P < 0.01$) on the C.I. The buffaloes which calved in Summer (April-June) had the maximum C.I. (461.93 days), but it was minimum (428.26 days) for rainy season (July-September) calvers.

Bhat (1978) reported that, in buffaloes the length of first C.I. decreased with an increase in the number of calvings. The first C.I. was found to be longer for high yielders, than for low yielders.

Kanujia (1978) studied the data of 820 Murrah graded buffaloes and found that, the C.I. was longest in the first lactation, thereafter declining trend was observed till fourth lactation. The C.I. was significantly affected by the season of calving and parity.

Basu et al. (1979) analysed the Murrah buffalo records, belonging to N.D.R.I. Karnal and reported that, the summer season calvers had the maximum (452.93 days) C.I., whereas the rainy season calvers had the minimum (417.18 days) C.I. The first four calving intervals, were found to be 455.29, 436.71, 445.65 and 431.22 days respectively.

Yadav (1980) analysed the data of 392 Murrah buffaloes and reported that, the seasons had significant effect on the first C.I.

Ahmad et al. (1981) analysed 1274 calving intervals of Nili-Ravi buffaloes of Pakistan and found that, the buffaloes calved in January have longest C.I. (609.90 days), while those calved in June have the shortest C.I. (502.80 days), the differences were highly significant. The winter season calvers have significantly longer C.I. (569.10 days) than summer season calvers (506.60 days).

Gupta et al. (1981) studied 268 calvings of Murrah

buffaloes and found that, the parity and level of milk production have significant effects on C.I. The first four calving intervals averaged 467, 467, 447 and 467 days respectively.

Raizada and Pandey (1981) studied 62 off-season and 38 normal season buffalo calvers. The C.I. was found to be significantly higher (544.46 days) in off-season (March-September) calvers, than (417.14 days) in normal season (September-February) calvers.

hoj et al. (1981) analysed 386 lactation records of Murrah buffaloes and reported that, the effect of parity was significant on the C.I. The first C.I. was found to be longest (490.38 days) than the subsequent calving intervals.

Khire et al. (1983) studied data of 53 Nagpuri buffaloes and found the first four calving intervals as 441.13, 404.24, 377.78 and 392.33 days respectively. The differences between the C.I. were found to be non-significant.

Naidu (1983) studied 113 calvings of Murrah buffaloes and found that, the season of calving had a highly significant effect on the subsequent calving intervals.

Table 2.1: Age at first calving

Breed	No. of observations	Character mean (months)	Heritability	Name of the workers and year
Bnadawari	96	48.00	0.45	Nagarcenkar (1978)
-do-	-	51.00	-	Nagarcenkar (1978)
-do-	96	45.39	-	Sharma <u>et al.</u> (1981)
Egyptian	193	-	0.29	Malossini <u>et al.</u> (1963)
-do-	1200	39.90	-	El. Sheikh <u>et al.</u> (1967)
Murrah	300	46.80	-	Amble <u>et al.</u> (1970)
-do-	110	41.00	-	Gurnani <u>et al.</u> (1971)
-do-	-	40.29	-	Krishnamacharyulu <u>et al.</u> (1973)
-do-	500	48.60	-	Raut <u>et al.</u> (1974)
-do-	123	41.00	-	Gurnani <u>et al.</u> (1976a)
-do-	-	42.24	0.18	Mohan (1977)
-do-	-	41.30	-	Bhat (1978)
-do-	-	42.40	-	Bhat (1978)
-do-	1468	42.52	0.12	Nagarcenkar (1978)
-do-	-	-	0.26	Nagarcenkar (1978)
-do-	1926	44.00	-	Sasomma <u>et al.</u> (1979)
-do-	107	41.00	0.38	Basu <u>et al.</u> (1979)
-do-	2465	43.10	0.15	Reddy <u>et al.</u> (1980b)
-do-	-	-	0.29	Reddy <u>et al.</u> (1980b)
-do-	162	42.71	0.38	Reddy <u>et al.</u> (1980a)
-do-	392	55.78	-	Yadav (1980)
-do-	-	44.11	0.12	Gokhale (1981)
-do-	936	-	0.35	Gurung <u>et al.</u> (1982 c)
Murrah grades	477	40.60	0.25	Tomar <u>et al.</u> (1968)
-do-	293	41.51	-	Dave <u>et al.</u> (1969)
-do-	857	42.00	-	Amble <u>et al.</u> (1970)
-do-	1985	41.00	-	Sreedharan <u>et al.</u> (1973)
-do-	-	43.30	-	-do-

Table 2.1: Continued

Breed	No. of observations	Character mean (months)	Heritability	Name of the workers and year
Murrah grades	820	42.69	0.25	Kanujia <u>et al.</u> (1974)
-do-	356	40.30	0.30	Bhullar (1975)
-do-	3250	42.39	0.37	Bhat (1978)
-do-	733	44.32	-	Dharmeswar Das (1978)
-do-	-	42.40	0.37	Johari <u>et al.</u> (1979a)
-do-	593	42.70	0.34	Mangurkar <u>et al.</u> (1981)
Nagpuri	76	54.46	-	Khire <u>et al.</u> (1977)
Nili-Ravi	204	39.91	0.24	Bhullar (1975)
-do-	305	45.57	-	Ishfaq <u>et al.</u> (1975)
-do-	611	47.07	-	Choudhary <u>et al.</u> (1978)
-do-	425	41.99	0.14	Reddy <u>et al.</u> (1980b)
Non-descript	-	49.50	-	Bhat (1978)
Surti	-66	53.70	-	Singh <u>et al.</u> (1977)
-do-	-	44.50	-	Bhat (1978)

Table 2.2 : 300 days milk yield

Breed	No. of observations	Character mean (Kg)	Heritability	Name of the workers and year
Egyptian	-	1004.30	-	Eltawil <u>et al.</u> (1976)
Mehsena	-	1290.00	-	Dev <u>et al.</u> (1978)
Murrah	-	1363.52	-	Agarwala (1962)
-do-	149	1409.24	-	Dutt <u>et al.</u> (1965 a)
-do-	92	1436.20	-	Dutt <u>et al.</u> (1965 b)
-do-	-	-	0.47	Iqbaludain <u>et al.</u> (1970)
-do-	-	1658.33	-	Basu <u>et al.</u> (1976)
-do-	-	1637.34	-	Basu <u>et al.</u> (1977)
-do-	-	1647.34	0.22	Basu <u>et al.</u> (1978 b)
-do-	-	1700.00	-	Dev <u>et al.</u> (1978)
-do-	2038	1610.24	-	Nagarckenkar (1978)
-do-	1926	1457.60	-	Sasomma <u>et al.</u> (1978)
-do-	2089	1610.24	-	Gokhale <u>et al.</u> (1979)
-do-	243	1678.00	0.25	Basu <u>et al.</u> (1979)
-do-	2465	1634.83	0.13	Reddy <u>et al.</u> (1980 b)
-do-	1466	1472.53	-	Reddy <u>et al.</u> (1982)
-do-	1156	-	0.18	Cheema <u>et al.</u> (1983)
-do-	113	1500.00	-	Naidu (1983)
Murrah grades	540	1740.55	0.32	Dhinsa (1963)
-do-	58	1587.00	-	Singh (1966)
-do-	1392	1611.69	0.17	Nagarckenkar (1978)
-do-	593	1722.90	0.01	Mangurkar <u>et al.</u> (1981)
Nilhi-Kavi	50	1561.29	-	Chaudhary <u>et al.</u> (1965)
-do-	-	1819.00	-	Dev <u>et al.</u> (1978)
-do-	425	1706.53	0.08	Reddy <u>et al.</u> (1980 b)

Table 2.3: Lactation milk yield

Breed	No. of observations	Character mean (Kg)	Heritability	Name of the workers and year
Bulgarian x Murrah	1068	1524.00	-	Peeva (1977)
-do-	189	1789.00	-	Polikhronov <u>et al.</u> (1977 b)
-do-	2017	1488.00	-	Polikhronov <u>et al.</u> (1977 c)
-do-	-	1731.00	-	Polikhronov <u>et al.</u> (1977 c)
-do-	841	1550.00	-	Vankov <u>et al.</u> (1979)
-do-	220	1689.00	-	Vankov <u>et al.</u> (1979)
Egyptian	2738	1769.04	-	Alim (1967)
-do-	-	2021.70	-	Alim (1978)
-do-	4903	1968.00	-	Abdul Aziz <u>et al.</u> (198
Italian	496	1879.00	-	Roycnoudhury <u>et al.</u> (1969 a)
-do-	588	1853.00	-	Roycnoudhury (1970)
Murrah	180	1277.32	-	Kohli <u>et al.</u> (1960)
-do-	301	1735.02	-	Arora <u>et al.</u> (1962)
-do-	1321	2251.22	-	Arora <u>et al.</u> (1962)
-do-	136	2005.82	-	Venkayya <u>et al.</u> (1964)
-do-	1472	1505.00	-	I.A.R. (S). I. (1964)
-do-	1051	1603.00	-	Goswami <u>et al.</u> (1965b)
-do-	300	1639.00	-	Amble <u>et al.</u> (1970)
-do-	409	1725.48	0.53	Sane <u>et al.</u> (1972 b)
-do-	500	1710.00	-	Raut <u>et al.</u> (1974)
-do-	2189	1728.24	0.16	Jowarkar <u>et al.</u> (1975b)
-do-	-	1921.31	-	Lal (1975)
-do-	489	1476.00	-	Gurmani <u>et al.</u> (1976b)
-do-	-	0.17	0.17	Rao <u>et al.</u> (1977)
-do-	-	-	0.53	Rao <u>et al.</u> (1977)
-do-	-	1388.00	0.16	Bnat (1978)
-do-	-	1855.00	0.47	Bnat (1978)
-do-	2045	1540.65	0.26	Nagarcenkar (1978)

Table 2.3: Continued

Breed	No. of observations	Character mean (Kg)	Heritability	Name of the workers and year
Murrah	1926	1555.30	-	basomma <u>et al.</u> (1978)
-do-	979	1787.74	-	Swain (1980)
-do-	392	1643.38	-	Yadav (1980)
-do-	268	1575.50	-	Gupta <u>et al.</u> (1981)
-do-	896	1665.25	0.16	Gurung <u>et al.</u> (1982a)
-do-	1466	1535.71	-	Reddy <u>et al.</u> (1982)
-do-	176	1492.00	-	Sastry <u>et al.</u> (1982)
-do-	-	-	0.24	Chakravorthy (1983)
Murrah grades	413	-	0.16	Mahadevan (1960)
-do-	1472	1339.00	-	I.A. R. (S) I. (1964)
-do-	293	1483.00	-	Dave <u>et al.</u> (1969)
-do-	1744	1434.00	0.28	Amble <u>et al.</u> (1970)
-do-	565	1597.00	low	Rathi <u>et al.</u> (1971)
-do-	1985	1751.00	-	breedharan <u>et al.</u> (1973)
-do-	356	1564.81	0.32	bnillar (1975)
-do-	573	1709.54	-	Kanujia <u>et al.</u> (1975a)
-do-	674	1736.29	-	Kanujia <u>et al.</u> (1975b)
-do-	936	1692.00	0.19	Bhalari <u>et al.</u> (1978)
-do-	2842	1744.00	0.08	Bhat (1978)
-do-	733	1764.45	-	Dharmeswar Das (1978)
-do-	-	1781.79	low	Kanujia (1978)
-do-	1734	1867.38	-	Kumar <u>et al.</u> (1978b)
-do-	1433	1693.35	0.12	Nagarcenkar (1978)
-do-	2842	1597.30	0.08	Johari <u>et al.</u> (1979b)
-do-	2137	1618.50	0.03	Patro <u>et al.</u> (1979 a & b)
-do-	1716	1880.00	0.14	Patro <u>et al.</u> (1979 a & b)
-do-	1348	1964.00	0.08	Patro <u>et al.</u> (1979 a & b)
-do-	1005	2039.50	0.04	Patro <u>et al.</u> (1979 a & b)
-do-	702	2024.30	0.18	Patro <u>et al.</u> (1979 a & b)
-do-	988	-	0.16	Bawa <u>et al.</u> (1980)

Table 2.3: Continued

Breed	No. of observations	Character mean (Kg)	Heritability	Name of the workers and year
Murrah grades	-	-	0.22	Bawa <u>et al.</u> (1980)
-do-	-	-	0.24	Bawa <u>et al.</u> (1980)
-do-	863	1732.91	-	Garcha <u>et al.</u> (1981)
-do-	1125	1822.00	-	Khanna <u>et al.</u> (1981)
Nagpuri	348	1060.20	-	Belorkar <u>et al.</u> (1977)
-do-	297	1049.66	-	Khire <u>et al.</u> (1983)
Nili-navi	204	1570.37	0.28	Bhullar (1975)
-do-	-	2000.00	-	Chaudhary <u>et al.</u> (1978)
-do-	-	2700.00	-	Chaudhary <u>et al.</u> (1978)
-do-	5716	1702.00	0.25	Cady <u>et al.</u> (1983)
-do-	-	2064.00	-	Cady <u>et al.</u> (1983)

Table 2.4: Lactation length

Breed	No. of observations	Character mean (days)	Heritability	Name of the workers and year
Bhadawari	246	276.00	-	Singh <u>et al.</u> (1962)
Bulgarian	712	266.80	-	Polikhronov (1965)
Bulgarian x Murrah	2046	210.00	-	Peeva (1979)
Egyptian	-	311.10	-	Alim (1978)
Murrah	180	288.27	-	Kohli <u>et al.</u> (1960)
Murrah	236	290.50	-	Venkatratnam <u>et al.</u> (1964)
-do-	1051	284.00	-	Goswami <u>et al.</u> (1965b)
-do-	300	317.00	-	Amble <u>et al.</u> (1970)
-do-	79	307.00	-	Gill <u>et al.</u> (1970)
-do-	382	269.00	-	Gurnani <u>et al.</u> (1971)
-do-	500	300.00	-	Raut <u>et al.</u> (1974)
-do-	3116	293.18	0.16	Jawarkar <u>et al.</u> (1975a)
-do-	-	315.00	-	Lal (1975)
-do-	-	304.25	-	Basu <u>et al.</u> (1976)
-do-	123	283.00	-	Gurnani <u>et al.</u> (1976a)
-do-	489	267.40	-	Gurnani <u>et al.</u> (1976b)
-do-	513	296.30	-	Singh <u>et al.</u> (1977)
-do-	-	273.53	-	singh <u>et al.</u> (1977)
-do-	732	278.28	-	Basu <u>et al.</u> (1978c)
-do-	-	315.00	0.11	Bhat (1978)
-do-	-	279.00	-	Bhat (1978)
-do-	1926	301.40	-	basomma <u>et al.</u> (1978)
-do-	1437	299.01	0.07	Nagarcenkar (1978)
-do-	242	284.00	-	Basu <u>et al.</u> (1979)
-do-	-	269.00	-	basu <u>et al.</u> (1979)
-do-	2465	296.39	-	Reddy <u>et al.</u> (1980b)
-do-	392	314.00	-	Yadav (1980)
-do-	100	317.60	-	Raizada <u>et al.</u> (1981)
-do-	909	287.40	0.06	Gurung <u>et al.</u> (1982b)

Table 2.4: Continued

Breed	No. of observations	Character mean (days)	Heritability	Name of the workers and year
Murrah	174	294.00	-	Sastry <u>et al.</u> (1982)
-do-	113	293.80	-	Naidu (1983)
-do-				
Murrah graces	413	-	0.06	Mahadevan (1960)
-do-	1744	279.00	0.26	Amble <u>et al.</u> (1970)
-do-	576	303.83	-	Kanujia <u>et al.</u> (1975a)
-do-	674	272.88	-	Kanujia <u>et al.</u> (1975b)
-do-	733	294.29	-	Dharmeswar Das (1978)
-do-	-	292.80	-	Kanujia (1978)
-do-	820	296.72	-	Kanujia (1978)
-do-	1734	286.30	-	Kumar <u>et al.</u> (1978a)
-do-	2842	295.90	0.11	Johari <u>et al.</u> (1979b)
-do-	863	320.10	-	Garcha <u>et al.</u> (1981)
Nagpuri	348	279.56	-	Belorkar <u>et al.</u> (1977)
-do-	297	297.85	-	Khire <u>et al.</u> (1983)
Nili-Ravi	-	316.00	-	Bhat (1978)
-do-	-	285.00	-	Nagarcenkar (1978)
-do-	-	326.00	-	Nagarcenkar (1978)
-do-	425	306.13	low	Reddy <u>et al.</u> (1980b)

Table 2.5: Dry period

Breed	No. of observations	Character mean (days)	Heritability	Name of the workers and year
Bulgarian x Murrah	189	144.50	-	Polikhronov <u>et al.</u> (1977b)
Egyptian	223	263.00	-	Khishin <u>et al.</u> (1963)
-do-	-	200.30	-	Alim (1978)
Italian	496	152.60	-	Roychoudnury <u>et al.</u> (1969a)
Murrah	1321	127.00	-	Arora <u>et al.</u> (1962)
-do-	236	160.80	-	Venkataratnam <u>et al.</u> (1964)
-do-	60	171.00	-	Ohri <u>et al.</u> (1969)
-do-	207	158.40	-	Gill <u>et al.</u> (1970)
-do-	2790	153.19	0.14	Jawarkar <u>et al.</u> (1974)
-do-	-	156.28	-	Basu <u>et al.</u> (1977)
-do-	123	203.00	-	Gurnani <u>et al.</u> (1976a)
-do-	-	150.00	-	Gurnani <u>et al.</u> (1976a)
-do-	489	176.40	-	Gurnani <u>et al.</u> (1976b)
-do-	732	149.39	-	Basu <u>et al.</u> (1978a)
-do-	-	127.00	0.05	Bhat (1978)
-do-	374	176.00	-	Basu <u>et al.</u> (1979)
-do-	709	156.00	-	Basu <u>et al.</u> (1979)
-do-	2465	185.54	0.14	Reddy <u>et al.</u> (1980b)
-do-	392	263.77	-	Yadav (1980)
-do-	711	157.11	-	Basu <u>et al.</u> (1981)
-do-	174	178.00	-	Sastry <u>et al.</u> (1982)
Murrah grades	574	195.90	-	Kanujia <u>et al.</u> (1975a)
-do-	674	159.70	-	Kanujia <u>et al.</u> (1975b)
-do-	-	169.36	low	Kanujia (1978)
-do-	820	197.33	-	Kanujia (1978)
-do-	2539	183.40	0.05	Johari <u>et al.</u> (1979b)
-do-	1125	163.90	-	Knanna <u>et al.</u> (1981)
Nagpuri	348	129.07	-	Belorkar <u>et al.</u> (1977)
Nili-Ravi	1253	198.00	-	Chaudhary <u>et al.</u> (1978)
Nili-Ravi	425	202.26	-	Reddy <u>et al.</u> (1980b)

Table 2.6: Service period

Breed	No. of observations	Character mean (days)	Heritability	Name of the workers and year
Italian	523	92.70	-	Roychoudhury <i>et al.</i> (1969b)
-do-	588	96.99	-	Roychoudhury (1970)
Murrah	180	187.13	-	Konli <i>et al.</i> (1960)
-do-	105	149.36	-	Luktuke <i>et al.</i> (1964)
-do-	105	173.90	-	Venkayya <i>et al.</i> (1966)
-do-	3039	117.00	-	Goswami <i>et al.</i> (1968)
-do-	237	135.00	-	Guddi <i>et al.</i> (1969)
-do-	1614	131.93	-	Singh <i>et al.</i> (1972)
-do-	473	129.08	-	Singh <i>et al.</i> (1972)
-do-	-	140.45	0.16	Mohan (1977)
-do-	732	133.27	-	Basu <i>et al.</i> (1978a)
-do-	695	125.34	-	Basu <i>et al.</i> (1979)
-do-	2465	177.84	0.15	Reddy <i>et al.</i> (1980b)
-do-	1027	138.30	-	Swain (1980)
-do-	392	276.31	-	Yadav (1980)
-do-	150	206.14	-	Porwal <i>et al.</i> (1981)
-do-	100	188.47	-	Kalzada <i>et al.</i> (1981)
-do-	174	161.00	-	Sastry <i>et al.</i> (1982)
Murrah grades	820	187.53	low	Kanujia <i>et al.</i> (1974)
-do-	674	112.71	-	Kanujia <i>et al.</i> (1975b)
-do-	2286	169.30	-0.001	Bhat (1978)
-do-	-	125.00	-	Bhat (1978)
-do-	-	249.00	-	Bhat (1978)
-do-	820	183.50	-	Kanujia (1978)
-do-	-	152.05	low	Kanujia (1978)
-do-	1044	144.11	0.11	Nagarcenkar (1978)
-do-	-	169.30	-0.001	Johari <i>et al.</i> (1979a)
Wagpuri	348	97.50	-	Belorkar <i>et al.</i> (1977)
-do-	76	132.86	-	Khire <i>et al.</i> (1977)
-do-	684	139.54	-	Ambalkar (1980)
Nili-Ravi	1207	211.00	-	Chaudhury <i>et al.</i> (1978)
Surti	281	163.76	-	Rao <i>et al.</i> (1973)

Table 2.7: Calving interval

Breed	No. of observations	Character mean (days)	Heritability	Name of the workers and year
Bhadawari	246	453.60	-	Singh <u>et al.</u> (1962)
Egyptian	223	524.40	-	Khushin <u>et al.</u> (1967)
-do-	1200	484.74	-	Al-Sheikh <u>et al.</u> (1967)
-do-	-	507.90	-	Alim (1978)
Murrah	-	476.80	-	Tomar <u>et al.</u> (1960)
-do-	238	513.40	-	Bhatnagar <u>et al.</u> (1961)
-do-	-	442.00	-	Agarwala (1962)
-do-	236	451.00	-	Venkatraman <u>et al.</u> (1964)
-do-	266	461.00	-	Guddi <u>et al.</u> (1969)
-do-	300	477.00	-	Amble <u>et al.</u> (1970)
-do-	207	451.90	-	Gill <u>et al.</u> (1970)
-do-	382	439.00	-	Gurnani <u>et al.</u> (1971)
-do-	-	457.00	-	Lal (1975)
-do-	123	481.00	-	Gurnani <u>et al.</u> (1976a)
-do-	489	434.00	-	Gurnani <u>et al.</u> (1976b)
-do-	582	433.46	-	Singh <u>et al.</u> (1976)
-do-	296	436.63	-	Singh <u>et al.</u> (1976)
-do-	-	445.31	0.10	Mohan (1977)
-do-	732	444.90	-	Basu <u>et al.</u> (1978a)
-do-	2589	479.50	0.01	Bhat (1978)
-do-	-	495.10	-	Bhat (1978)
-do-	-	-	0.34	Nagarajkar (1978)
-do-	732	435.25	-	Basu <u>et al.</u> (1979)
-do-	2465	483.15	0.05	Reddy <u>et al.</u> (1980b)
-do-	944	446.06	-	Swain (1980)
-do-	392	636.00	-	Yadav (1980)
-do-	268	477.00	-	Gupta <u>et al.</u> (1981)
-do-	150	517.00	-	Porwal <u>et al.</u> (1981)

Table 2.7: Continued

Breed	No. of observations	Character mean (days)	Heritability	Name of the workers and year
Murrah	100	496.39	-	Raizada <u>et al.</u> (1981)
-do-	386	468.42	-	Roy <u>et al.</u> (1981)
-do-	174	467.00	-	Sastry <u>et al.</u> (1982)
-do-	113	459.00	-	Waidu (1983)
Murrah grades	165	495.00	0.34	Dminsra (1963)
-do-	-	414.00	-	Goswami <u>et al.</u> (1965a)
-do-	1744	454.00	-	Amble <u>et al.</u> (1970)
-do-	820	497.63	-0.10	Kanujia <u>et al.</u> (1974)
-do-	674	430.11	-	Kanujia <u>et al.</u> (1975b)
-do-	820	487.36	-	Kanujia (1978)
-do-	-	461.70	-	Kanujia (1978)
-do-	-	479.50	0.01	Johari <u>et al.</u> (1979a)
Nagpuri	292	403.00	-	Knire <u>et al.</u> (1983)
Mili-Ravi	350	524.00	-	Ishaq <u>et al.</u> (1975)
-do-	1424	530.00	-	Chaudhary <u>et al.</u> (1978)
-do-	425	508.39	-	Reddy <u>et al.</u> (1980b)
Non-descript	-	481.00	-	Bnat (1978)
-do-	-	465.00	-	Raut <u>et al.</u> (1978)

CHAPTER 3

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

3.1 Background of the data:

The present data on production and reproduction traits in buffaloes were obtained from the history and pedigree sheets of 835 Murrah graded buffaloes belonging to Ambala, Ferozpur and Jabalpur military dairy farms, maintained over a period of 15 years, from 1968 to 1982. The farm, period and season wise frequency distribution of buffaloes in different lactations were presented in Table 3.1.

All the military dairy farms were under the control of Directorate of military dairy farms. Feeding, housing and other managerial practices were nearly uniform at all the farms. All practices were in accordance with the standards prescribed by the Directorate of military farms.

Feeding.

The supply of fodder was ensured nearly throughout the year, either as green fodder or as silage. Green fodders like, berseem, lucerne, maize, jowar, oats, turnip, rape or cow pea were usually given. Whereas chopped jowar, maize, bajra and wheat straw were used as dry fodder. The animals were stallfed, but were let loose in open paddocks. The concentrate ration was fed at the time of milking. The extra allowance of concentrate ration was provided to the pregnant animals and first calvers.

Table 3.1: Farm, period and seasonwise frequency distribution of buffaloes

Source	First lactation	Second lactation	Third lactation	Fourth lactation	Fifth lactation	Overall
<i>M</i>	834	835	835	680	494	3678
Ambala F ₁	283	283	283	259	183	1291
Ferozepur F ₂	359	360	360	277	204	1560
Jabalpur F ₃	192	192	192	144	107	827
1968-1972 P ₁	431	329	264	173	95	1292
1973-1977 P ₂	255	282	293	252	189	1271
1978-1982 P ₃	148	224	278	255	210	1115
July-Dec S ₁	672	718	703	542	399	3034
Jan-June S ₂	162	117	132	138	95	644

The calves were allowed to suckle their dams only for the first three days after calving. Thereafter they were weaned and fed whole milk, skim milk and calf starter. The skim milk was fed from second week onwards and skipped by 26th week of age. The feeding schedule were as follows.

Growth ration:

Feeding schedule of the calves from birth to six months

Age (days)	Colostrum (Kg)	Whole milk (Kg)	Skim milk (Kg)	Calf starter (Kg)	Concentrate (Kg)	Feeding times/day
0-3	2.6	-	-	-	-	-
4-7	-	3.5	-	-	-	3
8-14	-	3.5	0.9	0.05	-	2
15-21	-	2.6	1.8	0.10	-	2
22-28	-	2.6	3.1	0.15	-	2
29-30	-	1.8	3.5	0.30	-	2
31-35	-	1.8	3.5	0.45	-	2
36-42	-	1.3	3.1	0.70	-	2
43-49	-	1.3	3.1	0.70	-	2
50-56	-	1.3	3.1	0.90	-	2
57-63	-	1.3	3.1	0.45	0.45	2
64-70	-	0.9	2.6	0.23	0.90	2
71-84	-	0.9	2.6	-	1.35	2
85-112	-	-	2.2	-	1.35	2
113-140	-	-	1.8	-	1.35	2
141-168	-	-	1.3	-	1.35	2
169-182	-	-	0.9	-	1.35	2

Pregnancy ration given to the buffaloes

Period	Category		Remarks
	Young stock (conceiving at the age of 2.5 years)	First calvers	
a) From the date of confirmation of pregnancy or in calf	1 Kg	-	Expected peak yield (EPY) was assumed as
b) 90-60 days before calving	1.5 Kg	1 Kg	9 Kg.
c) 61-30 days before calving	2.0 Kg	16.00 % EPY	
d) 30 days before calving	3.0 Kg	25.00 % EPY	

Production ration given to the buffaloes in milk

Concentrates to milk ratio

1:3	1:2.5	1:2
Upto 9 Kg daily yield	Over 6-9 Kg daily yield	Over 9 Kg daily yield

One Kg ration was given to all first calvers from the date of calving to 4 years of age.

Deduction of concentrates:

Fifty per cent reduction of concentrates from production

ration would be made in the first week and 25 per cent in the second week after calving. Thereafter full ration would be fed without reduction. In case of exceptionally high yielders, the high energy ration would be specially computed and fed.

Housing:

The young calves, heifers, dry stock, down calvers and milking animals were housed separately in separate barns. The milking animals were kept in open paddocks except at the time of milking.

All the enclosures were constructed in such a way, as to ensure protection of the animals from severe or extreme climatic stress. All sheds were provided with good ventilation, lightening and watering arrangements. During hot weather the animals were protected by sprinkling of water. Wallowing facilities were also provided for the comfort of the buffaloes in summer. Cleanliness of the barns were maintained by sweeping and washing the pens regularly twice a day.

Management:

To ensure good health and proper care the herd was divided into, young calves, calves, young stock (heifers), dry stock, pregnant cows, down calvers (animals which were due to calve in 10-15 days) and milking animals and were looked after separately.

Natural service by the good pedigreed buffalo bulls were practiced at all farms. The bulls were let loose along with the females in the open paddocks, both in the morning and evening. The dehorning of buffalo calves was not practiced in any of the farms. Buffaloes were hand milked twice a day at equal intervals. The milk yield was recorded at each milking for each animal. Milk recording starts from the fourth day onwards after calving.

Pedigree sheet and history sheet were maintained for the individual animal. To ensure regular breeding in the herd, fertility checkup, and follow-up actions were undertaken for the whole stock by prompt veterinary service. All the animals were vaccinated against major epizootics viz. Foot and Mouth, Rinderpest, haemorrhagic septicaemia and Black Quarter etc as per schedule. Deworming was also done periodically. All the animals were tested for tuberculosis and Johne's disease and the positive reactors were segregated and culled. The buffaloes were also culled periodically depending upon the productive, fertility and other reproductive problems.

3.2 Materials (Data):

Three thousand six hundred seventy-eight lactations pertaining to first five lactations of 835 buffaloes, which were the progeny of 86 sires formed the materials for the present study. The frequency distribution of buffaloes and their sire groups at different farms, in different lactations were presented in Table 3.2.

Buffaloes having a minimum of 3 complete and normal lactation records, were only included for the study. Lactations preceded by abortions, still births, premature births and also the abnormal lactations like lactations with less than 150 days lactation period were excluded from the study.

Ambala, Ferozepur and Jabalpur farms were coded as F_1 , F_2 , and F_3 respectively.

The records were collected from 1968 to 1982, covering a period of 15 years. The entire duration was divided into 3 periods of 5 years each.

Period 1 (P_1): 1968, 1969, 1970, 1971 and 1972

Period 2 (P_2): 1973, 1974, 1975, 1976 and 1977

Period 3 (P_3): 1978, 1979, 1980, 1981 and 1982

The years were considered according to the year of calving. Depending upon the calving pattern of the buffaloes, each year was further divided into two seasons.

Most calving season (S_1): July to December

Least calving season (S_2): January to June

The actual milk yield given during a lactation period of 300 days or less than that period was considered as the 300 days milk yield. To study the influence of the preceding DP and CI over the other traits of production and reproduction, the DP and CI were included from the second lactation onwards. Hence, though five lactations were analysed only four dry periods and four calving intervals were included in the present study.

The heritability, phenotypic and genetic correlations of age at first calving with other traits were based on 788 half-sib progenies of 72 sires pertaining to first lactation only.

In case of peak yield, 300 days milk yield, lactation milk yield, lactation length and service period, the heritabilities, phenotypic and genetic correlations in the first lactation were based on 788 half-sib progenies of 72 sires. In the second and third lactations they were based on 789 half-sib progenies of 72 sires. In the fourth lactation they were based on 606 half-sib progenies of 61 sires and in the fifth lactation they were based on 368 half-sib progenies of 36 sires. In the pooled data those estimates were based on 3664 half-sib progenies of 85 sires.

The heritability estimates, phenotypic and genetic correlations for dry period and calving interval started from second lactation onwards. In the second and third lactations they were based on 789 half-sib progenies of 72 sires. In the fourth lactation they were based on 606 half-sib progenies of 61 sires and in the fifth lactation they were based on 368 half-sib progenies of 36 sires. In the pooled data the estimates were based on 2823 half-sib progenies of 83 sires.

The analysis for different production and reproduction traits were carried out, lactation wise upto fifth lactation

and also on the pooled data of the five lactations.

The different traits studied were:

- 1) Age at first calving
- 2) Peak yield
- 3) 300 days milk yield
- 4) Total lactation milk yield
- 5) Lactation length ✓
- 6) Service period ✓
- 7) Dry period ✓
- 8) Calving interval ✓
- 9) Genetic and phenotypic correlations among the above traits
- 10) Heritabilities of the above traits

3.3 Methodology used:

As the number of observations in each class was unequal, the different kinds of effects such as farms, periods and seasons can not be separated directly with the ordinary methods of analysis of variance. Hence the least squares method of analysis (Harvey, 1975) was employed. The principle of the technique was to minimise the error sum of squares, sum of squared differences between observed and expected values, called the residual sum of squares.

The following fixed effects mathematical model was employed for analysing the data for non-genetic factors

influencing the production and reproduction traits in buffaloes.

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

Where, Y_{ijkl} = the observations of the character made on l th animal, in the i th farm, j th period and k th season of calving

μ = the population mean common to all observations

F_i = the effect of i th farm ($i = 1 \dots 3$)

P_j = the effect of j th period of calving ($j = 1 \dots 3$)

S_k = the effect of k th season of calving ($k = 1 \dots 2$)

e_{ijkl} = the random method associated with each observation distributed normally and independently with mean '0' and variance σ_e^2

3.3.1 Least squares analysis of data:

The procedure adopted was as follows.

Setting up of normal equations.

From the mathematical model, a system of normal equations were set up and these were presented in Table 3.3 To estimate the 9 unknown constants, 9 normal equations were formed and these were 1 for μ , 3 for farms, 3 for periods and 2 for seasons. These equations were then set up in the form of matrix.

Table 3.3: Set of normal equations

Model:	Y_{ijkl}	=	μ	+	F_i	+	P_j	+	S_k	+	e_{ijkl}
	μ	:	$n \dots$		F_i	:	$n_i \dots$		P_j	:	$n_j \dots$
	F_i	:	$n_i \dots$		F_i	:	$n_i \dots$		P_j	:	$n_j \dots$
	P_j	:	$n_j \dots$		F_i	:	$n_i \dots$		P_j	:	$n_j \dots$
	S_k	:	$n_k \dots$		F_i	:	$n_i \dots$		P_j	:	$n_j \dots$
					S_k	:	$n_k \dots$		P_j	:	$n_j \dots$
									S_k	:	$n_k \dots$
											R_{iM}
											$= Y \dots$
											$= Y_i \dots$
											$= Y_j \dots$
											$= Y_k \dots$

Imposing the restrictions:

Since the equations were not independent, an unique solution could not be obtained. For obtaining the estimates of least squares constants, following constraints or restrictions were imposed. By imposing these restrictions

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

on the estimates of constants, it was possible to compute the F_i , P_j and S_k . 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 the 3rd farm were subtracted from n_{ij} values of all previous columns (two in number). In the row-wise reduction, n_{ij} values in the 3rd row were subtracted from n_{ij} values of all previous rows. The similar procedure was adopted, while imposing the restrictions period-wise and season-wise. Third period and second season were suppressed.

Reduction of RHM (Column vector):

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

Estimation of constants:

The reduced n_{ij} matrix was symmetrical about its main diagonal and was of the dimension 6 x 6, made up of 1 row

and column for μ , 2 for fams, 2 for periods and 1 for season. Similarly reduced RHM was a column vectors of 6 rows. Constants were obtained as follows from the inverse of reduced matrix and RHM's of the equations.

$$\begin{array}{ccc} \text{Reduced n}_{ij} \text{ matrix} & \times & \text{constants} & = & \text{Reduced RHM} \\ 6 \times 6 & & 6 \times 1 & & 6 \times 1 \end{array}$$

$$\text{Constants} = \text{Reduced n}_{ij} \text{ matrix} \times \text{Reduced RHM}$$

The estimates corresponding to the elements that were suppressed while reductions were carried out, were obtained by using following relationships.

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

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

$$S_2 = -(S_1)$$

Least squares analysis of variance:

Computing sum of squares (SS)

1) Total uncorrected sum of squares

$$\sum_i \sum_j \sum_k \sum_l Y_{ijkl}^2 \quad \text{was obtained for each}$$

character by the usual method.

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

$$\text{Error SS} = \sum_i \sum_j \sum_k \sum_l Y_{ijkl}^2 - R \left(\mu, F_i, P_j, S_k \right)$$

where, R was RHM element corresponding to the constants

μ , F_i , P_j and S_k . Sums of squares due to main effects

were obtained by using the following expressions.

$$SS \text{ for the } i\text{th set of main effects} = B_i^1 Z_i^{-1} B_i$$

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

B_i^1 was the transpose of B_i , i.e. row vector.

Z_i^{-1} was 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 SS., error SS and main effects SS, analysis of variance table was set up. The pattern of analysis of variance was shown in Table 3.4.

Table 3.4: Pattern of analysis of variance

Source	d.f.	SS	MSS	'F' value
Farms	$i-1$	$B_i^1 Z_i^{-1} B_i$	SS/df	Farms/Error MSS / MSS
Period	$j-1$	$B_j^1 Z_j^{-1} B_j$	SS/df	Periods/Error MSS / MSS
Season	$k-1$	$B_k^1 Z_k^{-1} B_k$	SS/df	Season/Error MSS / MSS
Error	residual	$\sum_i \sum_j \sum_k \sum_l Y_{ijkl}^2$	SS/df	
		$R(\mu, F_i, P_j, S_k)$		
Total	$n-1$	$\sum_i \sum_j \sum_k \sum_l Y_{ijkl}^2$	SS/df	

The mean sum of squares (MSS) were obtained by dividing the sum of squares of each, by the corresponding d.f. And by dividing the effects (farm, periods, season) MSS with the corresponding error MSS., 'F' values were obtained. for testing the significance of different effects.

Estimation of least squares means and their standard errors:

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

$$\text{Least squares mean for } F_i = \mu + F_i$$

$$\text{Least squares mean for } P_j = \mu + P_j$$

$$\text{Least squares mean for } S_k = \mu + S_k$$

Standard error for least squares means of main effects were obtained by using values of error mean sum of squares and the elements of variance-covariance matrix.

$$\text{SE of } \mu = \sqrt{(C\mu\mu) \sigma_e^2}$$

$$\text{SE } (\mu + a_i) = \sqrt{(C\mu\mu + C_{ii} + 2 C\mu_i) \sigma_e^2}$$

Where,

$C\mu\mu$ = elements of variance-covariance matrix corresponding to μ row and column

C_{ii} = element corresponding to i th effect by row and column

$C\mu_i$ = element in the μ th row and i th column or effect

σ_e^2 = error mean sum of squares

Duncan's Multiple Range Test (DMRT):

After completion of analysis of variance to test the significance of different effects, DMRT as modified by Kramer (1957) was employed to make all pair-wise comparisons with the use of inverse elements and standard deviation for error. The test was performed in the following steps (Harvey, 1975).

- 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 i.e. difference between the two means were estimated.

Where,

\bar{Y}_a = least squares mean for effect (treatment) a.

\bar{Y}_b = least squares mean for effect (treatment) b.

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

was then estimated.

where,

C_{aa} = diagonal element of variance-covariance matrix corresponding to a.

C_{bb} = diagonal element of variance-covariance matrix corresponding to b.

C_{ab} = Non-diagonal element corresponding to ath row and bth column.

4) The value $(\sigma_e Z_{pn}^2)$ was determined.

Where,

$$\sigma_e = \sqrt{\text{Error MSS}}$$

Z_{pn}^2 = Significant ($P < 0.05$) studentized range value in Duncan's table (Duncan, 1955) at p and n_2 .

where, p = number of means in the range chosen.

n_2 = number of df for the error.

5) The difference between the pair 'a and b' was considered significant, if the value

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

was found greater than $(\sigma_e Z_{pn}^2)$.

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 element 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.

$$C\mu + F_3 \sqrt{(C\mu\mu + C_{F_3} F_3 + 2(C\mu F_3)) \sigma_e}$$

where,

$C\mu\mu$ = value of variance-covariance matrix corresponding to μ row and column,

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

where,

$$CF_1F_3 = -(C\mu + F_1 + CF_1CF_2)$$

$$CF_2F_3 = -(C\mu + F_2 + CF_2F_1)$$

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

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

Correlation of the data:

Records were corrected for significant effects of farm, period and season for each character using the relationship.

X_{ijkl} = corrected record

Y_{ijkl} = uncorrected record

CF = correction factor

Estimation of genetic and phenotypic parameters:

Heritabilities, genetic and phenotypic correlations of various traits were estimated from the corrected data. From first to fifth lactation, the heritability, phenotypic and genetic correlation estimates were based on the sires, having a minimum of 5 daughters each. And in the pooled data, the estimates were based on the sires, which have got minimum of 10 daughters per sire. Sire variance and covariances were estimated from those sires only.

The following generalised model was used to estimate the components of genetic variances and covariances.

$$Y_{1j} = \mu + S_1 + e_{1j}$$

where,

Y_{1j} = jth observation of 1th sire for a particular character.

μ = overall mean or population mean.

S_1 = effect due to 1th sire common to all its daughters and

e_{1j} = random error, which was NID $(0, \sigma_e^2)$

Assumption,

$$E(S_1) = E(e_{1j}) = 0$$

$$E(S_1)^2 = \sigma_s^2 \text{ and } E(e_{1j})^2 = \sigma_e^2$$

Heritability estimation:

Heritabilities were estimated by paternal half-sib correlation method as outlined by Hazel and Terrill (1945). The estimated sire component of variance was used as an estimate of one fourth of the additive genetic variance.

Table 3.5: Analysis of variance for estimation of heritability

Source	df	SS	MSS	Component
Sires (Between sires)	(S-1)	SS _S	SS _S /(S-1) = MS _S	$\sigma_e^2 + \bar{k} \sigma_s^2$
Error (Progeny within sires)	(N-S)	SS _e	SS _e /(N-S) = MS _e	σ_e^2

where,

S = number of sires

N = total number of progeny

\bar{K} = average number of progeny per sire

$$\sigma_e^2 = \frac{MS_s - MS_e}{\bar{K}}$$

where, \bar{K} was the average number of progeny per sire and was estimated by the following formula.

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

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

The standard error of heritability was estimated by the formula given by Dickerson (1960) as follows:

$$\sigma_s = \sqrt{\frac{2 (MS)_s}{K_{ns}^2} + \frac{(MS)_w}{nw}}$$

where,

$(MS)_s$ = mean squares due to sires

$(MS)_w$ = mean squares due to error

ns = degrees of freedom between sires

nw = degrees of freedom for error

K = coefficient of the sire component

Genetic correlations:

The estimation of genetic correlation coefficient rests on the resemblance between relatives in a manner analogous to the estimation of heritabilities. In case of genetic correlations, 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 cross products of values of the two characters for each individual were summed up and the total sum of products were partitioned according to the source 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 coefficients (r_G) were estimated as follows:

$$r_{G_{ij}} = \frac{\text{Cov. } (S_i \ S_j)}{\sqrt{V_{si} \ V_{sj}}}$$

where,

$\text{Cov } (S_i \ S_j)$ = Component of covariance between sire group for two traits (ij)

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

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

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

$$SE (r_G) = \frac{1-r_G^2}{\sqrt{2}} \sqrt{\frac{SE_{h_1}^2}{h_1^2} + \frac{SE_{h_j}^2}{h_j^2}}$$

Where,

r_G = genetic correlation between the character 1 and j.

h_1^2 and h_j^2 = heritability of characters 1 and j respectively.

Phenotypic correlations:

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

$$r_{P_1 P_j} = \frac{\text{Cov. } T_1 T_j}{\sqrt{(VT_1) (VT_j)}}$$

Where,

$\text{Cov. } T_1 T_j$ = Total component of covariance of ith and jth character.

VT_1, VT_j = Total components of variance of ith and jth characters respectively.

$r_{P_1 P_j}$ = Phenotypic correlation between ith and jth characters.

SE of $r_{P_1 P_j}$ was calculated by the formula given by Panse and Sukatme (1967).

$$SE (r_{P_1 P_j}) = \frac{1-r_{P_1 P_j}^2}{\sqrt{N-2}}$$

Where,

N = Total number of animals.

CHAPTER 4

RESULTS

CHAPTER 4

RESULTS

4.1 Age at first calving:

The overall least squares mean for AFC was estimated to be 1221.30 days (Table 4.01).

The least squares means of AFC was highest for buffaloes at Ambala farm (1257.00 days), followed by Ferozpur (1207.47 days) and lowest in Jabalpur farm (1199.43 days). Duncan's Multiple Range Test (DMRT) revealed a non-significant difference between AFC in Ferozpur and Jabalpur farm. The AFC in Ambala farm differed significantly from rest of the two farms.

The least squares means of AFC in period 1 was highest (1270.66 days), followed by period 2 (1208.08 days) and lowest in period 3 (1185.16 days). DMRT revealed a non-significant difference between the AFC in period 2 and period 3. But the AFC period 1 differed significantly from rest of the two periods.

The least squares means of AFC was highest in buffaloes that calved during season 1 (1222.97 days), than in the buffaloes which calved during seasons 2 (1219.63 days). DMRT revealed a non-significant difference between these two estimates.

Least squares analysis of variance (Table 4.02) revealed that, the AFC was affected highly significantly by the farms and period, while the season of calving, had no significant effect.

The heritability, phenotypic and genetic correlations of AFC with other traits were presented in Table 4.17.

The heritability of AFC was estimated as 0.24 ± 0.03 .

All the genetic correlations of AFC with PY, 300 days milk yield, LMY, LL and SP were found to be non-significant.

There was a highly significant phenotypic correlation of 0.12 between AFC and PY. The correlations with 300 days milk yield and LL were 0.07 and -0.06 respectively. Both the correlations were significant. Whereas the correlations with LMY and SP were non-significant.

4.2 Peak yield:

The overall least squares mean for PY was found to be 9.80 Kg (Table 4.03). The least squares means of PY in the first five lactations were 8.40, 9.73, 10.21, 10.46 and 10.34 Kg respectively. There was a gradual increase of PY upto fourth lactation and declined in the fifth lactation.

The overall least squares means for PY was highest in the Ambala farm (10.10 Kg), followed by Ferozepur farm (9.78 Kg) and lowest in the Jabalpur farm (9.51 Kg). DMRT revealed that, the means of all the farms were significantly different from each other. In all the three farms, the PY gradually increased upto the fourth lactation and then decreased in the fifth lactation.

The overall least squares means for PY was highest in period 3 (10.41 Kg), followed by period 2 (10.09 Kg) and lowest in the period 1 (8.89 Kg). DMRT revealed that, the mean peak yields in all the periods were significantly different from each other. In the period 1 and period 3, the PY gradually increased upto the fourth lactation and then declined in the fifth lactation, but in period 2, there was a gradual increase in PY upto the fifth lactation.

The overall least squares means of PY was higher in buffaloes that calved in season 2 (10.04 Kg), than in buffaloes which calved in season 1 (9.55 Kg). DMRT revealed a significant difference between the two estimates. In the buffaloes that calved during season 1, the PY gradually increased upto the fifth lactation. Whereas in buffaloes which calved during season 2, the PY increased upto the fourth lactation only and decreased in the fifth lactation.

The least squares analysis of variance for PY (Table 4.04) showed that, the overall effect of farms, periods and seasons were highly significant on the PY. When the effects as per lactation wise were considered, the effect of farms on the PY were highly significant in the second and third lactation; significant in the fourth lactation and non-significant in the first and fifth lactations. The effect of periods over the PY were highly significant in all the lactations. The effect of seasons on the PY were highly significant in the first and fourth lactation; significant in the third lactation and non-significant in

the second and fifth lactations.

The heritabilities, phenotypic and genetic correlations of PY with other traits in different lactations were presented in tables 4.17 to 4.22.

The overall heritability of PY was found to be 0.18 ± 0.01 .

The overall genetic correlations of PY with 300 days milk yield, LMY, LL, preceding DP, SP and CI were estimated to be 0.94, 0.93, 0.14, -0.53 and -0.50 respectively. All the correlations were highly significant, except with LL which was inconclusive, associated with large standard error.

The overall phenotypic correlations of PY with 300 days milk yield, LMY, LL, preceding DP, SP and CI were estimated as 0.71, 0.65, -0.04, -0.10, -0.09 and -0.09 respectively. All the correlations were highly significant except, the correlation with the LL which was non-significant.

4.3 300 days milk yield:

The overall least squares mean for 300 days milk yield was found to be 1955.47 Kg (Table 4.05). The least squares means of 300 days milk yield in the first five lactations were calculated as 1754.70, 1971.18, 2015.31, 2044.24 and 2017.23 Kg respectively. There was a gradual increase of 300 days milk yield upto the fourth lactation and decreased in the fifth lactation.

The overall least squares means of 300-days milk yield was highest in the Ferozepur farm (2047.56 Kg), followed by Ambala farm (1991.84 Kg) and lowest in the Jabalpur farm (1827.02 Kg). DMRIT revealed that, the means of

all the farms were significantly different from each other. In Ambala and Ferozpur farm the 300 days milk yield increased upto fourth lactation and decreased in the fifth lactation; while in Jabalpur farm there was a gradual increase upto fifth lactation.

The overall least squares means for 300 days milk yield was highest in period 2 (2057.26 Kg), followed by period 3 (1990.62 Kg) and lowest in period 1 (1818.53 Kg). DMRT revealed that the mean 300 days milk yields in all the periods were significantly different from each other. In period 1 the 300 days milk yield increased upto third lactation and declined in subsequent lactations and in period 2, it increased gradually upto fifth lactation. Whereas in period 3 the 300 days milk yield increased upto fourth lactation and decreased in the fifth lactation.

The overall least squares means of 300 days milk yield was higher in buffaloes which calved during season 2 (1997.36 Kg), than in the buffaloes that calved during season 1 (1913.59 Kg). DMRT revealed a significant difference between the two estimates. In the buffaloes that calved during season 1, the 300 days milk yield gradually increased upto third lactation. Whereas in those buffaloes that calved during season 2, the 300 days milk yield increased upto fourth lactation and declined in the fifth lactation.

The least squares analysis of variance (Table 4.06) revealed that, the overall effect of farms, periods and seasons

were highly significant on the 300 days milk yield. As per lactation wise effects were concerned, the effects of farm were highly significant upto fourth lactation and non-significant on the fifth lactation 300 days milk yield. The effect of periods over the 300 days milk yield were highly significant in all the five lactations. The effect of seasons were highly significant in the third lactation, significant in the second and fifth lactation and non-significant in the first and third lactation.

The heritability, phenotypic and genetic correlations of 300 days milk yield with other traits in different lactations were presented in tables 4.17 to 4.22.

The overall heritability of 300 days milk yield was found to be 0.17 ± 0.01 .

The overall genetic correlations of 300 days milk yield with FY, LMY, LL, preceding DP, SP and CI were estimated as 0.94, 0.99, 0.27, -0.67, -0.16 and -0.47 respectively. All the correlations were highly significant, except the correlation with the preceding SP which was inconclusive associated with large standard error.

The overall phenotypic correlations of 300 days milk yield with FY, LMY, LL, preceding DP, SP and CI were calculated to be 0.71, 0.96, 0.36, -0.07, 0.15 and 0.02 respectively. The correlation with CI was non-significant; the correlation with DP was negative but significant and all other correlations were highly significant.

4.4 Lactation milk yield:

The overall least squares mean for lactation milk yield (LMY) was found to be 2043.07 Kg (Table 4.07). The least squares means of LMY in the first five lactations were 1834.86, 2058.34, 2105.64, 2137.00 and 2110.43 Kg respectively. There was a gradual increase in the LMY upto fourth lactation and decreased in the fifth lactation.

The overall least squares means of LMY was highest in the Ferozpur farm (2138.89 Kg), followed by Ambala (2084.25 Kg) and lowest in the Jabalpur farm (1906.05 Kg). DMRT revealed that, the means of all the farms were significantly different from each other. In Ambala farm the LMY increased gradually upto fourth lactation and declined in the fifth lactation. In the Ferozpur farm the LMY increased only upto third lactation and decreased in the subsequent lactations. Whereas in the Jabalpur farm the LMY increased consistently upto the fifth lactation.

The overall least squares means for LMY was highest in period 2 (2163.18 Kg), followed by period 3 (2066.19 Kg) and lowest in period 1 (1899.83 Kg). DMRT revealed a significant difference between the three means. During the period 1 and period 3 the LMY increased gradually upto fourth lactation and then declined in the fifth lactation. Whereas in the period 2 the LMY increased consistently upto the fifth lactation.

The overall least squares means of LMY was higher in the buffaloes which calved in season 2 (2108.02 Kg), than the

buffaloes which calved in season 1 (1978.12 Kg). DMRT revealed a significant difference between the two estimates. There was a gradual increase in the LMY upto the third lactation followed by a declining trend in the buffaloes which calved in season 1. In case of the buffaloes which calved in season 2, the LMY increased upto fourth lactation and then decreased in the fifth lactation.

The least squares analysis of variance (Table 4.08) revealed a highly significant overall effect of farms, periods and seasons over the LMY. As per the lactation wise effects were concerned, the effects of farm on the LMY were highly significant upto the fourth lactation and non-significant in the fifth lactation. The effect of periods were highly significant in all the five lactations. The effect of seasons were highly significant in the second, fourth and fifth lactations; significant in the third lactation and non-significant in the first lactation.

The heritability, phenotypic and genetic correlations of LMY with other traits were presented in the tables 4.17 to 4.22.

The overall heritability of LMY was estimated to be 0.16 ± 0.01 .

The overall genetic correlations of LMY with PY, 300 days milk yield, LL, preceding DP, SP and CI were found to be 0.93, 0.99, 0.36, -0.68, -0.17 and -0.35 respectively. All the correlations were highly significant, except the

correlation with the preceding SP, which was inconclusive associated with large standard error.

The overall phenotypic correlations of the IMY with PY, 300 days milk yield, LL, preceding DP, SP and CI were 0.65, 0.96, 0.54, -0.06, 0.30 and 0.05 respectively. The correlation with CI was non-significant; the correlation with DP was negative but significant and all other correlations were highly significant.

4.5 Lactation length:

The overall least squares mean for LL was found to be 304.06 days (Table 4.09). The least squares means of LL in the first five lactations were found to be 303.47, 306.86, 302.15, 305.92 and 304.06 days respectively. The lactation lengths were near about the same in all the five lactations studied.

The overall least squares means of LL was highest in the Ferozepur farm (309.61 days), followed by Ambala farm (304.47 days) and lowest in the Jabalpur farm (298.11 days). DMRT revealed that, the means of all the farms were significantly different from each other.

The overall least squares means for LL was maximum in period 2 (310.14 days), followed by period 1 (303.33 days) and minimum in the period 3 (298.72 days). DMRT revealed a non-significant difference between LL in period 1 and period 3. But the LL in period 2 was significantly different from the other two periods.

The overall least squares means of LL was significantly higher in the buffaloes which calved in season 2 (313.64 days), than in the buffaloes which calved in season 1 (294.49).

The least squares analysis of variance (Table 4.10) revealed that, the overall effect of farms, periods and seasons were highly significant over the LL. When lactation wise effects were considered, the effect of farms were highly significant on the LL. in the first lactation, significant in the second lactation and non-significant in the subsequent third, fourth and fifth lactations. The effect of periods over the LL were highly significant in the fifth lactation, significant in the first and third lactations and nonsignificant in the second and fourth lactations. The effect of seasons on the LL were non-significant in the first lactation, but highly significant in all the subsequent lactations.

The heritabilities, phenotypic and genetic correlations of LL with other traits in different lactations were presented in the tables 4.17 to 4.22.

The overall heritability of LL was estimated as 0.038 ± 0.004 .

The overall genetic correlations of LL with PY, 300 days milk yield, LMY, preceding DP, SP and CI were 0.14, 0.27, 0.36, 0.75, 0.44 and >1 respectively. All the correlations were highly significant, except the correlations with the PY and CI, which were inconclusive, associated with large standard errors.

The overall phenotypic correlations of LL with PY, 300 days milk yield, LMI, preceding DP, SP and CI were found to be -0.04, 0.36, 0.54, 0.04, 0.68 and 0.15 respectively. The correlations with PY and DP were non-significant. All other correlations were highly significant.

4.6 Dry period:

The overall least squares mean for the DP was estimated as 162.74 days (Table 4.11). The least squares means of first four dry periods were 178.09, 167.62, 151.72 and 145.52 days respectively. The first DP was found to be highest, then gradually decreased and became lowest in the fourth DP.

The overall least squares means of DP was maximum in the Ferozepur farm (166.09 days), followed by Ambala farm (165.60) and was minimum in the Jabalpur farm (156.51 days). DMRT showed a non-significant difference in DP, between Ambala and Ferozepur farm, but the DP in Jabalpur farm was significantly different from other two farms. In all the three farms, first DP was highest and fourth was lowest in duration.

The overall least squares means for DP was highest in period 1 (166.76 days), followed by period 3 (161.73 days) and lowest in the period 2 (159.71 days). DMRT revealed a non-significant difference in the dry periods during all the three periods. In all three periods first DP was found to be highest and fourth DP was lowest in length.

The overall least squares means of DP was significantly higher in buffaloes, that calved in season 2 (174.66 days), than those calved in season 1 (150.81 days). In both the seasons, first DP was maximum in duration. But third DP was lowest in buffaloes that calved in season 1, whereas the fourth DP was lowest in buffaloes which calved in season 2.

The least squares analysis of variance (Table 4.12) revealed that, the overall analysis of farms and periods were non-significant and that of seasons were highly significant on the DP. When lactation wise effects were considered, the effect of farms were highly significant on the first DP; significant on the third and fourth DP and non-significant on the second DP. The effect of periods were non-significant on all the four dry periods. The effect of seasons were highly significant over the first, second and third dry periods and non-significant on the fourth DP.

The heritabilities, phenotypic and genetic correlations of DP with other traits in different lactations were presented in tables 4.17 to 4.22

The overall heritability of DPw was estimated to be 0.05 ± 0.01 .

The overall genetic correlations of DP with the CI, succeeding PY, 300 days milk yield, LMY, LL and SP were found to be 0.74, -0.53, -0.67, -0.68, 0.75 and >1 respectively. All the correlations were highly significant.

The overall phenotypic correlations of DP with CI, succeeding PY, 300 days milk yield, LMY, LL and SP were

0.85, -0.10, -0.07, -0.06, 0.04 and 0.12 respectively. The correlations with LL was non-significant; the correlations with 300 days milk yield and LMY were significant and rest of the other correlations were highly significant.

4.7 Service period:

The overall least squares mean for the SP was calculated to be 160.58 days (Table 4.13). The least squares means of SP in the first five lactations were 166.40, 172.57, 156.62, 154.50 and 147.39 days respectively. The SP was found to be highest in the second lactation and declined in the subsequent lactations and was lowest in the fifth lactation.

The overall least squares mean of SP was maximum in the Ferozpur farm (167.31 days), followed by Ambala farm (166.74 days) and minimum in the Jabalpur farm (147.68 days). DMRT revealed a non-significant difference in SP between Ambala and Ferozpur farm, but SP in Jabalpur farm was significantly different from the other two farms. In both the Ambala and Jabalpur farms the SP was highest in the second lactation, whereas in Ferozpur farm it was maximum in the first lactation. In Ambala as well as Ferozpur farm the SP was lowest in the fifth lactation and in Jabalpur farm, it was lowest in the first lactation.

The overall least squares mean of SP was highest in period 1 (167.52 days), followed by period 2 (164.24 days) and lowest in the period 3 (149.97 days). DMRT showed a non-significant difference in the service periods pertaining to period 1 and period 2, but the SP in period 3 was

significantly different from the SP in rest of the two periods. In both the period 1 and period 2 the SP was maximum in the first lactation, followed by a gradual decline and was minimum in the fifth lactation. But in period 3 the SP was highest in the second lactation and lowest in the fifth lactation.

The overall least squares mean of SP was significantly higher in buffaloes that calved in season 2 (188.80 days), than in the buffaloes which calved in season 1 (139.35 days). In the buffaloes which calved during season 1, the SP was maximum in the first lactation, then gradually decreased and reached lowest in the fifth lactation. whereas in the buffaloes that calved in season 2, the SP was highest in the second lactation and lowest in the fifth lactation.

The least squares analysis of variance (Table 4.14) showed that, the overall effect of farms, periods, and seasons were highly significant on the SP. As per the lactation wise effects were concerned, the effect of farms over the SP were highly significant in the first lactation; significant in the third lactation and non-significant in the second, fourth and fifth lactations. The effect of periods over the SP were significant in the first and fifth lactation and non-significant in the second, third and fourth lactations. Whereas the effect of seasons were highly significant over the service periods in all the five lactations.

The heritabilities, phenotypic and genetic correlations of SP with other traits in different lactations were presented in the tables 4.17 to 4.22.

The overall heritability of SP was found to be 0.037 ± 0.004 .

The overall genetic correlations of SP with PY, 300 days milk yield, LMY, LL, preceding DP and CI were estimated as -0.30, -0.16, -0.17, 0.44, >1 and >1 respectively. All the correlations were highly significant, except the correlations with the 300 days milk yield and LMY which were inconclusive, associated with large standard errors.

The overall phenotypic correlations of SP with PY, 300 days milk yield, LMY, LL, preceding DP and CI were -0.09, 0.15, 0.30, 0.68, 0.12 and 0.16 respectively. All the correlations were highly significant.

4.8 Calving interval:

The least squares means of the first four calving intervals (CI) upto the end of five lactations, along with their standard errors were presented in table 4.15. The overall least squares mean of the CI was found to be 465.52 days. The least squares means of first four calving intervals were 482.29, 472.38, 455.21 and 441.39 days respectively. The first CI was found to be highest, then gradually decreased and became lowest in the fourth CI.

The overall least squares means of CI was highest at the Ferozepur farm (472.55 days), followed by Ambala farm (467.78 days) and lowest in the Jabalpur farm (456.23 days).

DMRT revealed that, there was a non-significant difference between the means of Ambala and Ferozepur farms and between the means of Ambala and Jabalpur farms; but the mean CI of Ferozepur farm was significantly high and different from the other two farms. In both the Ambala and Ferozepur farms the first CI was maximum and the fourth CI was minimum in length. Whereas in Jabalpur farm the second CI was highest and third CI was lowest in duration.

The overall least squares means of CI was highest in period 2 (469.19 days), followed by period 1 (465.59 days) and lowest in period 3 (461.77 days). DMRT showed that, there was no significant difference between the CI in the three periods. In all the three periods the first CI was maximum and the fourth CI was minimum in duration.

The overall least squares means of CI was significantly higher in buffaloes which calved in season 2 (483.04 days), than in buffaloes which calved in season 1 (448.00 days). In both seasons the first CI was highest in length. But the third CI was lowest in buffaloes which calved in season 1, whereas the fourth CI was lowest in buffaloes that calved in season 2.

The least squares analysis of variance (Table 4.16) showed that, the overall effect of farms were significant, periods were non-significant and seasons were highly significant on the CI. As per the lactation wise effects were concerned, the effect of farms were highly significant on the first CI only, and on the subsequent calving intervals

the effects were non-significant. The effect of periods were non-significant, on all calving intervals. The effect of seasons were highly significant on the first, second and third calving intervals, but non-significant on the fourth CI.

The heritabilities, phenotypic and genetic correlation of CI with other traits, in different lactations were presented in tables 4.17 to 4.22.

The overall heritability of CI was found to be 0.04 ± 0.01 .

The overall genetic correlations of CI with DP succeeding PY, 300 days milk yield, LMY, LL and SP were estimated as 0.74, -0.50, -0.47, -0.35, >1 and >1 respectively. All the correlations were highly significant, except the correlation with LL, which was inconclusive, associated with large standard error.

The overall phenotypic correlations of CI with DP, succeeding PY, 300 days milk yield, LMY, LL and SP were 0.85, -0.09, 0.02, 0.05, 0.15 and 0.16 respectively. All correlations were highly significant, except the correlations with 300 days milk yield and LMY which were non-significant.

Table 4.01: Least squares means and their standard errors for age at first calving (days)

Source	Code	no. of observations	Mean	S.E.
Overall:	μ	834	1221.30	8.92
Farms:				
Ambala	F ₁	283	1257.00	12.85
Ferozepur	F ₂	359	1207.47 ^a	10.67
Jabalpur	F ₃	192	1199.43 ^a	15.03
Periods:				
1968-1972	P ₁	431	1270.66	9.67
1973-1977	P ₂	255	1208.08 ^a	13.21
1978-1982	P ₃	148	1185.16 ^a	16.26
Seasons:				
July-Dec	S ₁	672	1222.97 ^a	7.77
Jan-June	S ₂	162	1219.63 ^a	15.10

Note: Least squares means with the same superscripts were not significantly different from each other

Table 4.02: Least squares analysis of variance for age at first calving

Source	d.f.	M.S.S.	F
Farm	2	249997.22	7.68**
Period	2	504133.45	15.48**
Season	1	1398.92	0.04
Error	828	32574.29	
Total	833		

** Significant at P/0.01

Table 4.03: Least squares means and their standard errors for peak yield (kg)

Source	Code	1st Lactation			2nd Lactation			3rd Lactation			4th Lactation			5th Lactation			Overall		
		No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.
Overall	M	834	8.40	0.09	835	9.73	0.11	835	10.21	0.11	680	10.46	0.12	494	10.34	0.15	3678	9.80	0.05
Farms:																			
Ambala	F ₁	283	8.47a	0.13	283	10.19	0.15	283	10.77a	0.16	259	10.78a	0.17	183	10.59a	0.22	1291	10.10	0.07
Ferozepur	F ₂	359	8.30a	0.10	360	9.64a	0.14	360	10.45a	0.15	277	10.60a	0.17	204	10.52a	0.21	1560	9.78	0.07
Jabalpur	F ₃	192	8.42a	0.15	192	9.37a	0.18	192	9.42	0.20	144	9.99	0.23	107	9.91a	0.28	827	9.51	0.09
Periods:																			
1968-1972	P ₁	431	7.87	0.10	329	9.00	0.14	264	9.72	0.17	173	9.89	0.20	95	9.55	0.30	1292	8.89	0.07
1983-1977	P ₂	255	8.59a	0.13	282	9.97a	0.15	293	10.35a	0.17	252	10.65a	0.18	189	10.67a	0.22	1271	10.09	0.08
1978-1982	P ₃	148	8.74a	0.16	224	10.23a	0.17	278	10.57a	0.16	255	10.83a	0.18	210	10.79a	0.20	1115	10.41	0.08
Seasons:																			
July-Dec	S ₁	672	8.18	0.08	708	9.55	0.08	703	9.93	0.09	542	10.11	0.11	399	10.14a	0.13	3034	9.55	0.04
Jan-June	S ₂	162	8.61	0.15	117	9.92	0.20	132	10.45	0.20	138	10.80	0.21	95	10.54a	0.26	644	10.04	0.09

Table 4.04: Least squares analysis of variance for peak yield

Source	1st Lactation			2nd Lactation			3rd Lactation			4th Lactation			5th Lactation			Overall		
	d.f.	M.S.S.	F	d.f.	M.S.S.	F	d.f.	M.S.S.	F	d.f.	M.S.S.	F	d.f.	M.S.S.	F	d.f.	M.S.S.	F
Farm	2	2.30	0.72	2	40.40	8.85 ^{***}	2	84.80	15.94 ^{***}	2	21.57	3.81 [*]	2	11.78	1.95	2	82.10	15.16 ^{***}
Period	2	57.63	18.09 ^{***}	2	104.98	22.99 ^{***}	2	42.58	8.01 ^{***}	2	38.26	6.76 ^{***}	2	37.43	6.21 ^{***}	2	666.60	123.05 ^{***}
Season	1	23.46	7.37 ^{***}	1	13.52	2.96	1	24.12	4.53 [*]	1	52.32	9.25 ^{***}	1	11.96	1.98	1	123.52	22.80 ^{***}
Error	828	3.19		829	4.57		829	5.32		674	5.66		488	6.03		3672	5.42	
Total	833			834			834			679			493			3677		

* Significant at P/0.05

** Significant at P/0.01

Table 4.05: Least squares means and their standard errors for 300-day milk yield (kg)

Source	Code	1st Lactation			2nd Lactation			3rd Lactation			4th Lactation			5th Lactation			Overall		
		No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.
Overall	<i>M</i>	834	1754.70	20.13	835	1971.18	23.43	835	2015.31	22.96	680	2044.24	24.71	494	2017.23	30.08	3678	1955.47	10.56
Farms:																			
Ambala	<i>F</i> ₁	283	1766.37	29.00	283	2034.11a	32.25	283	2076.30a	32.62	259	2095.41a	35.32	183	1996.17a	44.15	1291	1991.84	14.96
Ferozepur	<i>F</i> ₂	359	1858.62	24.07	360	2074.22a	30.14	360	2144.24a	30.05	277	2125.38a	34.86	204	2089.49a	42.15	1560	2047.56	13.78
Jabalpur	<i>F</i> ₃	192	1639.11	33.91	192	1805.21	39.01	192	1825.39	40.77	144	1911.94	48.33	107	1966.03a	55.88	827	1827.02	19.10
Periods:																			
1968-1972	<i>P</i> ₁	431	1658.75	21.81	329	1861.48	30.91	264	1937.47a	35.04	173	1933.77	42.75	95	1855.22	59.76	1292	1818.53	15.05
1973-1977	<i>P</i> ₂	255	1848.43	29.81	282	2056.11a	33.17	293	2087.00a	33.96	252	2131.03a	37.57	189	2166.66	43.70	1271	2057.26	15.84
1978-1982	<i>P</i> ₃	148	1756.92	36.70	224	1995.95a	36.00	278	2021.47ab	32.98	255	2067.93a	36.89	210	2029.79	39.90	1115	1990.62	16.23
Seasons:																			
July-Dec	<i>S</i> ₁	672	1752.55a	17.53	718	1926.20	18.27	703	1980.06a	18.43	542	1953.06	22.19	399	1955.10	25.59	3034	1913.59	8.933
Jan-June	<i>S</i> ₂	162	1756.85a	34.08	117	2016.16	42.70	132	2050.56a	41.58	138	2135.43	43.37	95	2079.35	52.56	644	1997.36	18.81

Note: Least squares means with same superscripts were not significantly different from each other

Table 4.06: Least squares analysis of variance for 300-day's milk yield

Source	1st Lactation		2nd Lactation		3rd Lactation		4th Lactation		5th Lactation		Overall	
	d.f.	M.S.S. F	d.f.	M.S.S. F	d.f.	M.S.S. F	d.f.	M.S.S. F	d.f.	M.S.S. F	d.f.	M.S.S. F
Farm	2	2826030.50	2	3967558.40	2	4995571.80	2	1685017.90	2	601139.00	2	11078081.00
		17.04 ^{**}		18.79 ^{**}		22.31 ^{**}		6.72 ^{**}		2.48		49.51 ^{**}
Period	2	2675354.80	2	2520336.50	2	1188774.20	2	1486099.40	2	2280995.40	2	15864016.00
		16.14 ^{**}		11.94 ^{**}		5.31 ^{**}		5.93 ^{**}		9.43 ^{**}		70.90 ^{**}
Season	1	2326.51	1	807056.27	1	548551.38	1	3619920.10	1	1161822.30	1	3725760.20
		0.01		3.83 [#]		2.45		14.43 ^{**}		4.80 [*]		16.65 ^{**}
Error	828	165813.32	829	211137.03	829	223933.37	674	250803.77	488	242001.97	3672	223739.59
Total	833		834		834		679		493		3677	

* Significant at P/0.05

** Significant at P/0.01

Table 4.07: Least squares means and their standard errors for lactation milk yield (kg)

Source	Code	1st lactation		2nd lactation		3rd lactation		4th lactation		5th lactation		Overall							
		No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.			
Overall:	M	834	1834.86	22.75	835	2058.34	25.95	835	2105.64	25.65	680	2137.00	27.54	494	2110.43	33.00	3678	2043.07	11.72
Farms:																			
	Ambala	283	1848.25	32.76	283	2124.22a	35.72	283	2171.61a	36.44	259	2204.00a	39.36	183	2084.30a	48.45	1291	2084.25	16.60
	Ferozepur	359	1952.94	27.20	360	2165.10a	33.38	360	2238.15a	33.58	277	2212.24a	38.85	204	2185.01a	46.25	1560	2138.89	15.29
	Jabalpur	192	1703.45	38.31	192	1885.70	43.20	192	1907.16	45.56	144	1994.77	53.86	107	2061.99a	61.31	827	1906.05	21.19
Periods:																			
	1968-1972	431	1726.59	24.65	329	1949.58	34.24	264	2016.51a	39.16	173	2023.51	47.64	95	1950.44a	65.57	1292	1899.83	16.70
	1973-1977	255	1959.43	33.68	282	2151.67a	36.75	293	2198.17	37.94	252	2233.27a	41.87	189	2280.19	47.95	1271	2163.18	17.58
	1978-1982	148	1818.62	41.46	224	2073.76a	39.87	278	2102.23a	36.86	255	2154.24a	41.11	210	2100.68a	43.78	1115	2066.19	18.01
Seasons:																			
	July-Dec	672	1822.28a	19.81	718	1988.28	20.33	703	2047.67	20.59	542	2018.27	24.73	399	2009.71	28.08	3034	1978.12	9.91
	Jan-June	162	1847.48a	38.51	117	2128.39	47.29	132	2163.60	46.47	138	2255.74	48.33	95	2211.16	57.67	644	2108.02	20.88

Table 4.08: Least squares analysis of variance for lactation milk yield

Source	1st Lactation		2nd Lactation		3rd Lactation		4th Lactation		5th Lactation		Overall							
	d.f.	M.S.S.	F	d.f.	M.S.S.	F	d.f.	M.S.S.	F	d.f.	M.S.S.	F						
Farm	2	3649977.90	17.24 ^{**}	2	4286418.10	16.55 ^{**}	2	5401176.00	19.32 ^{**}	2	1873483.20	6.02 ^{**}	2	653230.85	2.24 ^{**}	2	12388007.00	44.96 ^{**}
Period	2	3991066.20	18.85 ^{**}	2	2642994.70	10.20 ^{**}	2	1789368.60	6.40 ^{**}	2	1670215.80	5.36 ^{**}	2	2857107.60	9.81 ^{**}	2	18673323.00	67.77 ^{**}
Season	1	80060.53	0.38	1	1957641.50	7.56 ^{**}	1	1483266.80	5.31 [*]	1	6131094.80	19.69 ^{**}	1	3054250.80	10.48 ^{**}	1	6959018.90	32.51 ^{**}
Error	828	211713.95		829	259025.27		829	279609.00		674	311442.88		488	291375.54		3672	275560.71	
Total	833			834			834			679			493			3677		

* Significant at P/0.05

** Significant at P/0.01

Table 4.09: Least squares means and their standard errors for lactation length (days)

Source	Code	1st lactation			2nd lactation			3rd lactation			4th lactation			5th lactation			Overall		
		No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.
Overall	M	834	303.47	2.73	835	306.86	2.93	835	302.15	2.83	680	305.92	2.99	494	304.06	3.57	3678	304.06	1.29
Farms:																			
Ambala	F ₁	283	306.41a	3.94	283	305.72a	4.04	283	302.39a	4.01	259	307.16a	4.28	183	298.14a	5.23	1291	304.47	1.83
Ferozepur	F ₂	359	312.03a	3.27	360	314.80a	3.77	360	307.66a	3.70	277	306.94a	4.22	204	304.71a	5.00	1560	309.61	1.69
Jabalpur	F ₃	192	291.97	4.60	192	300.05a	4.89	192	296.39a	5.02	144	303.65a	5.85	107	309.34a	6.62	827	298.11	2.34
Periods:																			
1968-1972	P ₁	431	301.45a	2.96	329	306.86a	3.87	264	298.38a	3.31	173	305.55a	5.18	95	300.30ab	7.08	1292	303.33a	1.85
1973-1977	P ₂	255	310.66	4.05	282	310.40a	4.16	293	310.48	4.18	252	308.37a	4.55	189	315.36a	5.18	1271	310.14	1.94
1978-1982	P ₃	148	298.31a	4.98	224	303.31a	4.51	278	297.60a	4.06	255	303.84a	4.47	210	296.53b	4.73	1115	298.72a	1.99
Seasons:																			
July-Dec	S ₁	672	300.35a	2.38	718	293.78	2.29	703	294.55	2.27	542	292.00	2.69	399	289.33	3.03	3034	294.49	1.10
Jan-June	S ₂	162	306.59a	4.63	117	319.93	5.35	132	309.75	5.12	138	319.83	5.25	95	318.80	6.23	644	313.64	2.13

Table 4.10: Least squares analysis of variance for lactation length

Source	1st Lactation	2nd Lactation	3rd Lactation	4th Lactation	5th Lactation	Overall
	d.f. M.S.S. F	d.f. M.S.S. F	d.f. M.S.S. F	d.f. M.S.S. F	d.f. M.S.S. F	d.f. M.S.S. F
Farm	2 23414.53 7.66 ^{**}	2 13297.05 44.02 [*]	2 6580.00 1.94	2 479.47 0.13	2 3714.44	2 31292.16 9.30 ^{**}
Period	2 9080.27 2.98 [*]	2 3080.53 0.93	2 13312.05 3.93 [*]	2 1271.52 0.35	2 17771.06	2 38634.17 11.48 ^{**}
Season	1 4909.78 1.61	1 68195.24 20.59 ^{**}	1 25479.73 7.51 ^{**}	1 84147.94 22.87 ^{**}	1 65353.58	1 194815.53 57.91 ^{**}
Error	828 3055.35	829 3311.87	829 3391.29	674 3679.78	488 3400.15	3672 3364.40
Total	833	834	834	679	493	3677

* Significant at P/0.05

** Significant at P/0.01

Table 4.11: Least squares means and their standard errors for dry period (days)

Source	Code	1st dry period			2nd dry period			3rd dry period			4th dry period			Overall		
		No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.
Overall:	M	835	178.09	4.37	835	167.62	4.32	680	151.72	3.69	494	145.52	4.35	2844	162.74	2.12
Farms:																
Ambala	F ₁	283	173.99a	6.01	283	166.69a	6.13	259	161.70a	5.28	183	153.48a	6.38	1008	165.60a	2.99
Ferozpur	F ₂	360	193.05	5.62	360	170.79a	5.65	277	145.89b	5.21	204	136.18b	6.09	1201	166.09a	2.84
Jabalpur	F ₃	192	167.23a	7.27	192	165.40a	7.67	144	147.57ab	7.22	107	146.90ab	8.07	635	156.51	3.85
Periods:																
1968-1972	P ₁	329	183.84a	5.76	264	168.56a	6.59	173	149.59a	6.39	95	139.98a	8.64	861	166.76a	3.30
1973-1977	P ₂	282	177.52a	6.18	293	163.95a	6.38	252	150.38a	5.61	189	145.59a	6.32	1016	159.71a	3.13
1978-1982	P ₃	224	172.91a	6.71	278	170.36a	6.20	255	155.19a	5.51	210	150.99a	5.77	967	161.73a	3.10
Seasons:																
JULY-Dec	S ₁	718	162.45	3.40	703	153.36	3.46	542	138.27	3.32	399	139.05a	3.70	2362	150.81	1.76
Jan-June	S ₂	117	193.73	7.96	132	181.89	7.82	138	165.17	6.48	95	151.99a	7.59	482	174.66	3.81

Table 4.12: Least squares analysis of variance for dry period

Source	1st dry period		2nd dry period		3rd dry period		4th dry period		Overall						
	d.f.	M.S.S.	F	d.f.	M.S.S.	F	d.f.	M.S.S.	F	d.f.	M.S.S.	F			
Farm	2	46298.04	6.31**	2	2013.14	0.25	2	17802.34	3.18*	2	14600.50	2.90*	2	16674.18	2.43
Period	2	7350.87	1.00	2	2952.40	0.37	2	1950.24	0.35	2	3468.05	0.69	2	9265.25	1.35
Season	1	97543.79	13.30**	1	89821.89	11.35**	1	78290.76	13.99**	1	12596.22	2.49	1	22646.64	33.10**
Error	829	7333.71		829	7917.64		674	5596.35		488	5053.28		2838	6848.04	
Total	834			834			679			493			2843		

* Significant at P/0.05

** Significant at P/0.01

Table 4.13: Least squares means and their standard errors for service period (days)

Source	Code	1st Lactation		2nd Lactation		3rd Lactation		4th Lactation		5th Lactation		Overall					
		No. of observations	Mean	No. of observations	Mean	No. of observations	Mean	No. of observations	Mean	No. of observations	Mean	No. of observations	Mean	S.E.			
Overall:	M	834	166.40	835	172.57	835	156.62	5.30	680	154.50	4.98	494	147.39	5.60	3678	160.58	2.42
Farms:																	
Ambala	F ₁	283	168.19	283	172.29a	283	169.67a	7.52	259	161.19a	7.12	183	149.22a	8.23	1291	166.74a	3.43
Ferozpur	F ₂	359	189.19	360	183.18a	360	154.05ab	6.93	277	148.30a	7.03	204	142.00a	7.85	1560	167.31a	3.16
Jabalpur	F ₃	192	141.81	192	162.22a	192	146.15b	9.41	144	154.03a	9.74	107	150.94a	10.41	827	147.68	4.37
Periods:																	
1968-1972	P ₁	431	176.42a	329	174.51a	264	152.98a	8.08	173	154.10a	8.62	95	145.04ab	11.13	1292	167.52a	3.45
1973-1977	P ₂	255	174.59a	282	167.42a	293	164.63a	7.83	252	161.13a	7.57	189	160.94a	8.14	1271	164.24a	3.63
1978-1982	P ₃	148	148.17	244	175.76a	278	152.26a	7.61	255	148.28a	7.44	210	136.18b	7.43	1115	149.97	3.72
Seasons:																	
JULY-DEC	S ₁	672	148.41	718	136.57	703	131.69	4.25	542	122.46	4.47	399	112.44	4.77	3034	132.35	2.05
JAN-JUNE	S ₂	162	184.38	117	208.56	132	181.55	9.59	138	186.55	8.74	95	182.34	9.79	644	188.80	4.31

Table 4.14: Least squares analysis of variance for service period

Source	1st Lactation			2nd Lactation			3rd Lactation			4th Lactation			5th Lactation			Overall		
	d.f	M.S.S.	F	d.f	M.S.S.	F	d.f	M.S.S.	F	d.f	M.S.S.	F	d.f	M.S.S.	F	d.f	M.S.S.	F
Farm	2	132615.44	10.29**	2	24869.14	1.94	2	31839.85	2.87*	2	11049.27	1.08	2	3391.14	0.40	2	98574.38	8.40**
Period	2	45458.07	3.53*	2	5070.54	0.40	2	12289.55	1.03	2	10238.07	1.01	2	30116.17	3.59*	2	97740.10	8.33**
Season	1	163107.04	12.65**	1	516799.56	40.39**	1	274353.14	23.03**	1	446243.29	43.78**	1	367716.65	43.78**	1	1691471.20	144.09**
Error	828	12892.91		829	12795.81		829	11914.60		674	10191.94		488	8400.12		3672	11739.28	
Total	833			834			834			679			493			3677		

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

Table 4.15: Least squares means and their standard errors for calving interval (days)

Source	Code	1st calving interval			2nd calving interval			3rd calving interval			4th calving interval			Overall		
		No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.	No. of observations	Mean	S.E.
Overall:	U	835	482.29	5.82	835	472.38	5.67	680	455.21	5.19	494	441.39	6.26	2844	465.52	2.87
Farms:																
Ambala	F1	283	480.80a	8.01	283	469.81a	8.06	259	462.97a	7.42	183	444.54a	9.18	1008	467.78ab	4.05
Ferozepur	F2	360	504.48	7.48	360	478.46a	7.42	277	453.14a	7.32	204	427.43a	8.77	1201	472.55a	3.85
Jabalpur	F3	192	461.60a	9.68	192	468.87a	10.07	144	449.52a	10.16	107	452.21a	11.62	635	456.23b	5.21
Periods:																
1968-1972	P1	329	483.74a	7.67	264	470.48a	8.66	173	444.62a	8.98	95	426.47a	12.43	861	465.59a	4.47
1973-1977	P2	282	487.48a	8.24	293	479.04a	8.39	252	461.92a	7.89	189	446.04a	9.09	1016	469.19a	4.24
1978-1982	P3	224	475.67a	8.94	278	467.61a	8.15	255	459.09a	7.75	210	451.67a	8.30	967	461.77a	4.19
Seasons:																
JULY-Dec	S1	718	464.09	4.53	703	451.70	4.55	542	430.60	4.66	399	431.42a	5.32	2362	448.00	2.38
Jan-June	S2	117	500.50	10.60	132	493.06	10.27	138	479.82	9.11	95	451.36a	10.93	482	483.04	5.16

Table 4.16: Least squares analysis of variance for calving interval

Source	1st calving interval			2nd calving interval			3rd calving interval			4th calving interval			Overall		
	d.f.	M.S.S.	F	d.f.	M.S.S.	F	d.f.	M.S.S.	F	d.f.	M.S.S.	F	d.f.	M.S.S.	F
Farm	2	106554.28	8.19 ^{**}	2	7666.40	0.56	2	9149.45	0.83	2	22121.09	2.11	2	44049.66	3.51 ^{**}
Period	2	8855.41	0.68	2	9464.54	0.69	2	11515.16	1.04	2	15242.76	1.46	2	13457.57	1.07
Season	1	132172.91	10.16 ^{***}	1	188726.72	13.81 ^{***}	1	262459.30	23.71 ^{***}	1	29928.92	2.86	1	488913.44	38.89 ^{***}
Error	829	13009.81		829	13663.88		674	11069.49		488	10470.64		2838	12572.30	
Total	834			834			679			493			2843		

* Significant at P/0.05

** Significant at P/0.01

Table 4.17: Heritabilities phenotypic and genetic correlations among first lactation traits in buffaloes

Trait	Age at first calving	Peak yield	300-days milk yield	Lactation milk yield	Lactation length	Service period
Age at calving	0.24 ± 0.03	0.12 ± 0.04	0.07 ± 0.04	0.05 ± 0.04	-0.06 ± 0.04	-0.03 ± 0.04
Peak yield	-0.20 ± 0.25	0.33 ± 0.04	0.67 ± 0.03	0.58 ± 0.03	-0.07 ± 0.04	-0.07 ± 0.04
300-days milk yield	0.13 ± 0.31	0.66 ± 0.16	0.19 ± 0.03	0.95 ± 0.03	0.37 ± 0.03	0.20 ± 0.04
Lactation milk yield	0.06 ± 0.33	0.76 ± 0.13	0.95 ± 0.04	0.16 ± 0.03	0.56 ± 0.03	0.38 ± 0.03
Lactation length	-0.01 ± 0.52	-0.28 ± 0.42	0.52 ± 0.40	0.45 ± 0.47	0.06 ± 0.03	0.67 ± 0.03
Service period	≤1	0.11 ± 0.60	0.98 ± 0.03	0.78 ± 0.30	0.75 ± 0.53	0.03 ± 0.03

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

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

Table 4.18: Heritabilities, phenotypic and genetic correlations among second lactation traits in buffaloes

Trait	Peak yield	300-days milk yield	Lactation milk yield	Lactation length	Dry period	Service period	Calving interval
Peak yield	0.18 ± 0.03	0.72 ^{**} ± 0.03	0.65 ^{**} ± 0.03	-0.03 ± 0.04	-0.08 ^{**} ± 0.04	-0.07 [*] ± 0.04	-0.05 ± 0.04
300-days milk yield	0.85 ^{**} ± 0.09	0.22 ± 0.03	0.96 ^{**} ± 0.01	0.36 ^{**} ± 0.03	-0.06 [*] ± 0.04	0.16 ± 0.04	0.06 ± 0.04
Lactation milk yield	0.78 ^{**} ± 0.13	0.999 ^{**} ± 0.001	0.19 ± 0.03	0.53 ^{**} ± 0.03	-0.06 [*] ± 0.04	0.30 ^{**} ± 0.03	0.07 [*] ± 0.04
Lactation length	-0.20 ± 0.43	0.13 ± 0.41	0.22 ± 0.41	-0.10 ± 0.03	-0.03 ± 0.04	0.68 ^{**} ± 0.03	0.09 ^{**} ± 0.04
Dry period	-1.00 ^{**} ± 0.01	-0.64 ^{**} ± 0.58	-0.63 ^{**} ± 0.62	>1	0.02 ± 0.03	0.04 ± 0.04	0.87 ^{**} ± 0.02
Service period	-0.79 ^{**} ± 0.16	-0.17 ± 0.38	-0.16 ± 0.40	0.75 ^{**} ± 0.23	>1	0.11 ± 0.03	0.05 ± 0.04
Calving interval	-0.94 ^{**} ± 0.09	-0.51 ± 0.54	-0.43 ± 0.62	>1 ^{**}	0.48 ± 1.78	>1	0.03 ± 0.03

Table 4.19: Heritabilities, phenotypic and genetic correlations among third lactation traits in buffaloes

Trait	Peak yield	300-days milk yield	Lactation milk yield	Lactation length	Dry period	Service period	Calving interval
Peak yield	0.07 ± 0.03	0.70 ^{**} ± 0.03	0.62 ^{**} ± 0.03	0.01 ± 0.04	-0.05 ± 0.04	-0.02 ± 0.04	-0.06 [*] ± 0.04
300-days milk yield	0.90 ^{**} ± 0.35	0.01 ± 0.03	0.94 ^{**} ± 0.01	0.41 ^{**} ± 0.03	-0.06 ^{**} ± 0.04	0.20 ^{**} ± 0.03	0.01 ± 0.04
Lactation milk yield	0.58 ^{**} ± 0.50	0.31 ± 1.59	0.07 ± 0.03	0.59 ^{**} ± 0.03	-0.03 ± 0.04	0.34 ^{**} ± 0.03	0.05 ± 0.04
Lactation length	0.15 ± 0.72	0.83 ^{**} ± 0.54	0.90 ^{**} ± 0.14	0.07 ± 0.03	0.05 ± 0.04	0.66 ^{**} ± 0.03	0.14 ^{**} ± 0.04
Dry period	L ⁻¹	L ⁻¹	L ⁻¹	L ⁻¹	0.10 ± 0.03	0.10 ± 0.04	0.85 ^{**} ± 0.02
Service period	-0.10 ± 0.77	0.32 ± 1.65	0.56 ^{**} ± 0.53	>1 ^{**}	L ⁻¹	0.07 ± 0.03	0.13 ± 0.04
Calving interval	-0.74 ^{**} ± 0.29	L ⁻¹	L ⁻¹	L ⁻¹	0.94 ^{**} ± 0.06	L ⁻¹	0.10 ± 0.03

Table 4.20: Heritabilities, phenotypic and genetic correlations among fourth lactation traits in buffaloes

Traits	Peak yield	300-days milk yield	Lactation milk yield	Lactation length	Dry period	Service period	Calving interval
Peak yield	-0.07 ± 0.03	0.71 ^{**} ± 0.03	0.65 ^{**} ± 0.03	0.002 ± 0.040	-0.08 ± 0.04 ^{**}	-0.08 ± 0.04 ^{**}	-0.09 ± 0.04 ^{**}
300-days milk yield	-0.40 ± 0.80	-0.04 ± 0.03	0.96 ^{**} ± 0.01	0.38 ^{**} ± 0.04	-0.08 ± 0.04 ^{**}	0.14 ± 0.04 ^{**}	-0.01 ± 0.04
Lactation milk yield	-0.35 ± 0.70	-0.96 ^{**} ± 0.10	-0.05 ± 0.03	0.56 ^{**} ± 0.03	-0.07 ± 0.04 ^{**}	0.28 ± 0.04 ^{**}	0.02 ± 0.04
Lactation length	-0.28 ± 0.47	-0.76 ^{**} ± 0.17	-0.88 ^{**} ± 0.10	-0.11 ± 0.03	0.03 ± 0.04	0.68 ± 0.03 ^{**}	0.15 ± 0.04 ^{**}
Dry period	-0.98 ^{**} ± 0.02	0.30 ± 0.78	0.16 ± 0.70	0.30 ± 0.42	-0.08 ± 0.03	0.16 ± 0.04 ^{**}	0.84 ± 0.02 ^{**}
Service period	-0.81 ^{**} ± 0.20	-0.65 ^{**} ± 0.21	-0.85 ^{**} ± 0.10	-0.97 ^{**} ± 0.02	0.99 ± 0.02 ^{**}	-0.10 ± 0.03	0.20 ± 0.04 ^{**}
Calving interval	-0.81 ^{**} ± 0.45	-0.30 ± 1.60	-0.36 ± 1.29	-0.37 ± 0.82	≤ 1	> 1 ^{**}	0.03 ± 0.03

Table 4.21: Heritabilities, phenotypic and genetic correlations among fifth lactation traits in buffaloes

Traits	Peak yield	300-days milk yield	Lactation milk yield	Lactation length	Dry period	Service period	Calving interval
Peak yield	0.13 ± 0.05	0.71 ^{**} ± 0.04	0.66 ^{**} ± 0.04	-0.003 ± 0.052	-0.13 ^{**} ± 0.05	-0.03 ± 0.05	-0.09 ^{**} ± 0.05
300-days milk yield	0.67 ^{**} ± 0.46	-0.06 ± 0.04	0.96 ^{**} ± 0.01	0.37 ^{**} ± 0.04	-0.10 ^{**} ± 0.05	0.16 ^{**} ± 0.05	0.01 ± 0.05
Lactation milk yield	0.04 ± 0.51	-0.997 ^{**} ± 0.003	-0.13 ± 0.04	0.55 ^{**} ± 0.04	-0.09 ^{**} ± 0.05	0.32 ^{**} ± 0.04	0.06 [*] ± 0.05
Lactation length	≤1	≤1	≤1	0.08 ± 0.05	0.07 [*] ± 0.05	0.66 ^{**} ± 0.04	0.23 ^{**} ± 0.05
Dry period	-0.54 ± 1.22	-0.53 ± 0.68	-0.66 ^{**} ± 0.42	>1	0.05 ± 0.05	0.28 ^{**} ± 0.05	0.79 ^{**} ± 0.03
Service period	≤1	-0.66 ^{**} ± 0.32	-0.51 ^{**} ± 0.32	0.98 ^{**} ± 0.04	>1 ^{**}	0.16 ± 0.05	0.38 ^{**} ± 0.04
Calving interval	≤1	≤1	-0.78 ^{**} ± 0.22	>1 ^{**}	-0.10 ± 2.46	0.91 ^{**} ± 0.10	-0.02 ± 0.04

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

Table 4.22: Heritabilities, phenotypic and genetic correlations of different traits in pooled data of buffaloes

Traits	Peak yield	300-days milk yield	Lactation milk yield	Lactation length	Dry period	Service period	Calving interval
Peak yield	0.18 ± 0.01	0.71 ± 0.01	0.65 ± 0.01	-0.04 ± 0.02	-0.10 ± 0.02	-0.09 ± 0.02	-0.09 ± 0.02
300-days milk yield	0.94 ± 0.02	0.17 ± 0.01	0.96 ± 0.01	0.36 ± 0.02	-0.07 ± 0.02	0.15 ± 0.02	0.02 ± 0.02
Lactation milk yield	0.93 ± 0.02	0.99 ± 0.002	0.16 ± 0.01	0.54 ± 0.02	-0.06 ± 0.02	0.30 ± 0.02	0.05 ± 0.02
Lactation length	0.14 ± 0.24	0.27 ± 0.23	0.36 ± 0.22	0.038 ± 0.004	0.04 ± 0.02	0.68 ± 0.01	0.15 ± 0.02
Dry period	-0.53 ± 0.18	-0.67 ± 0.14	-0.68 ± 0.15	0.75 ± 0.32	0.05 ± 0.01	0.12 ± 0.02	0.85 ± 0.01
Service period	-0.30 ± 0.22	-0.16 ± 0.24	-0.17 ± 0.25	0.44 ± 0.31	>1	0.037 ± 0.004	0.16 ± 0.02
Calving interval	-0.50 ± 0.20	-0.47 ± 0.22	-0.35 ± 0.26	>1	0.74 ± 0.19	>1	0.04 ± 0.01

CHAPTER 5

DISCUSSION

CHAPTER 5

DISCUSSION

5.1 Character means:

The overall least squares means obtained for different traits were briefly described as follows.

The mean AFC was found to be 1221.30 days (40.71 months). The AFC has an appreciable influence on lifetime production of milk and longevity. Early AFC reduces the cost of raising heifers to productive stage, increases lifetime production and thereby enhancing the overall economy of buffalo farming. The present estimate of AFC was similar to the reports of Krishnamacharyulu et al. (1973), Gurung et al. (1976 a), Bhat (1978) and Basu et al. (1979).

The overall PY was estimated as 9.80 Kg. The mean peak yields in the first five lactations were 8.40, 9.73, 10.21, 10.46 and 10.34 Kg respectively. The increase in PY along with increase in 300 days milk yield and LMY upto the fourth lactation might be due to development of body systems and mammary glands, reaching the stage of physiological, lactational maturity coupled with the increased functioning of the active secretory tissue of the udder in the fourth lactation. The present results of PY was similar to the findings of Singh and Tiwana (1981).

The overall 300 days milk yield was found to be 1955.47 Kg. The mean 300 days milk yield in the first five lactations were 1754.70, 1971.18, 2015.31, 2044.24 and

2017.23 Kg respectively. The 300 days milk yield increased consistently upto the fourth lactation, in accordance with the PY. Similar trend in 300 days milk yield during first five lactations was reported by Patro and Bhat (1979 b). The present overall 300 days milk yield was higher than, the findings of Nagarcenkar (1978), Basu et al. (1979) and Reddy and Taneja (1980 b) in Murrah buffaloes.

In the present study the overall LMY was estimated as 2043.07 Kg. The mean LMY in first five lactations were 1834.86, 2058.34, 2105.64, 2137.00 and 2110.43 Kg respectively. Similar to the PY and 300 days milk yield, the LMY also increased upto the fourth lactation indicating the attainment of the lactational maturity, and decreased in the fifth lactation. These results showed that the buffaloes were more persistent in milk production only upto the fourth lactation. Similar trend in LMY during first five lactations was observed by Chhikara et al. (1978) and Patro and Bhat (1979 b) in Murrah buffaloes. The overall LMY appeared to be lower than the findings of Arora et al. (1962) in Murrah buffaloes and higher than the reports of Khanna and Kanuja (1981) in Murrah grades.

The overall LL was found to be 304.06 days. The lactation length in the first five lactations were 303.47, 306.86, 302.15, 305.92 and 304.06 days respectively. The lactation lengths were almost the same in all the five lactations. It revealed managerial practice in the military farms to dry the buffaloes on completing the

300 days LL. Though the LL was one of the important traits having a major impact on the milk yield, its effect on the overall LMY was almost the same in all the lactations. The present LL in the first five lactations were slightly higher than reported by Basu *et al.* (1979) and Patro and Bhat (1979 b) in Murrah buffaloes. The overall LL was similar to the findings of Raut *et al.* (1974), Basu *et al.* (1976) and Reddy and Taneja (1980 b) in Murrah buffaloes. Since the overall LL obtained in the present estimate was quite close to the ideal LL of 300 days no efforts were needed to alter it.

The overall DP was 162.74 days. The mean dry periods in the first four lactations were 178.09, 167.62, 151.72 and 145.52 days respectively. The first DP was found to be longest; as the buffaloes were in the growing phase of their life, they probably required more rest in the early part of their life and hence, the first DP was longest in duration. The DP being the unproductive period it curtails the profits of the dairy farmer, hence it must be reduced to the optimum length. The present overall DP was in agreement with Khanna and Kanujia (1981). The present estimate of 163 days DP was rather high and should be brought down to around 100 days by adapting package of managerial practices so as to make the buffaloes more economic.

The overall SP in the present study was 160.58 days. The mean service periods in the first five lactations were 166.40, 172.57, 156.62, 154.50 and 147.39 days respectively.

The second SP was found to be highest in length. Environmental factors greatly influence the reproductive behaviour and efficiency in buffaloes. The SP was more under the control of management than the hereditary factors. The SP exerts a pronounced effect on LL. For economic reasons, prolonging the SP, so as to increase the LL was not desirable, as it may temporarily increase the milk yield in a particular lactation, but the overall lifetime production would be reduced by reduction in the calf crops of the animal. The SP had got highly significant positive phenotypic correlation with the preceding CI and hence the highest SP was recorded in the second lactation due to the longest preceding CI in the first lactation. The present overall SP was higher than the reports of Goswami and Kumar (1968) and Swain (1980) and lower than the findings of Reddy and Taneja (1980 b) in Murrah buffaloes. The overall SP of 160 days was on the higher side and all managerial efforts were needed to bring it down to around 90 days.

The overall CI was found to be 465.52 days. The mean first four calving intervals were 482.29, 472.38, 455.21 and 441.39 days respectively. First CI was longest in duration. The CI was found to be mostly influenced by the DP, SP and LL and was more under the control of managerial effects, rather than genetic effects. The longest first CI might be due to the longest DP in the first lactation. Similar trend in the first four calving

intervals were reported by Basu et al. (1979) in Murrah buffaloes. The present overall CI was in agreement with reports of Guddi et al. (1969), Kanujia (1978) Roy et al. (1981) and Sastry et al. (1982). However it appeared to be lower than the findings of Bhatnagar et al. (1961) and Reddy and Taneja (1980 b). It was higher than the reports of Kanujia et al. (1975 b), Singh et al. (1976) and Swain (1980) in Murrah buffaloes.

5.2 Effect of farms:

The overall effect of farms were found to be highly significant on AFC, PY, 300 days milk yield, LMY, LL and SP; significant on the CI and non-significant on the DP.

The AFC was highest at Ambala farm and lowest at Jabalpur farm. The increased AFC at Ambala might be due to climatological factors and other managerial practices adopted in raising the heifers. Increase in AFC would also increase the milk yield, because buffaloes that calved at later age would have better developed body and mammary tissue than those calved at an early age. But the overall assessment for higher AFC was not advantageous, as the buffaloes that attain early maturity and calve early were the ones, that would prove more economical as they complete more lactations, with lesser calving intervals, giving more lifetime milk yield, than the late maturing ones. The significantly higher AFC at Ambala farm, than at Ferozepur and Jabalpur farms, perhaps resulted in the correspondingly higher peak yield at Ambala farm.

Both the 300 days milk yield and LMY was highest at Ferozepur, followed by Ambala and was lowest at Jabalpur farm. Higher milk yield at Ambala was perhaps due to the higher AFC on that farm. The LL was highest at Ferozepur farm, which was followed by Ambala and Jabalpur farms. Higher milk yields at Ferozepur and Ambala farms were not only due to higher AFC and longer lactation lengths, but might be due to the better managerial practices and due to the presence of genetically high yielding stock. Unlike in other two farms, at Jabalpur farm there was a steady increase of both 300 days milk yield and LMY upto the fifth lactation. As the AFC at Jabalpur farm was lowest, the animals at that farm required more time to reach the stage of physiological lactational maturity, than the animals at the other two farms; and hence the milk yield at Jabalpur farm increased consistently upto the fifth lactation.

The overall effect of farms on the DP was found to be non-significant. However, the DP was maximum at Ferozepur farm, followed by Ambala and Jabalpur farms.

The overall SP was maximum at the Ferozepur farm and minimum at the Jabalpur farm. The significantly lower SP at the Jabalpur farm resulted in the significantly shorter CI.

5.3 Effect of periods:

The overall effect of periods were found to be highly significant on all the traits, except on the DP and CI where the effects were non-significant.

The significant decrease in AFC (1270.66 to 1185.16 days) and SP (167.52 to 149.97 days) and significant increase in the FY (8.89 to 10.41 Kg) from the period 1 to period 3, revealed an overall improvement brought about by the improvement in managerial practices followed by the military farms over the years.

Both the 300 days milk yield and LMY (2057.26 and 2163.18 Kg) were found to be highest in period 2, followed by period 3 (1990.62 and 2066.19 Kg) and lowest in the period 1 (1818.53 and 1899.83 Kg). It showed that there was an increase in the milk yield from period 1 to period 2, but again the milk yield decreased in period 3. The highest milk yield in period 2, which decreased in period 3 was due to the highest LL (310.14 days) in the period 2, and significantly lowered LL (298.72 days) in period 3. The production differences in periods might be also due to variations in the climate, managerial practices, changes in herd size and also due to the introduction of animals with different genetic potentials.

Periods had non-significant effect on the DP and CI. The dry periods and calving intervals were practically similar in all the three periods. However, the DP appeared to be longest in period 1 (166.76 days), followed by period 3 (161.73 days) and shortest in period 2 (159.71 days). The influence of DP was reflected in the milk yields in the corresponding periods. Decrease in the DP from period 1 to period 2 revealed the overall improvement in the managerial

practices. Though there was a non-significant difference, the CI was also found to be highest in period 2 (469.19 days), which was followed by period 1 (465.59 days) and lowest in period 3 (461.77 days). In all the 3 periods, the first CI was longest, probably due to longer DP required by the buffaloes in the first lactation, since they were in the growing phase.

5.4 Effect of seasons:

The overall effects of season of calving were found to be highly significant on all the traits except on the AFC.

Season of calving had no significant effect on the AFC in buffaloes. The AFC was practically similar in both the seasons of calving. Similar results were reported by Bhullar (1975) and Reddy and Mishra (1980 a).

The PY, 300 days milk yield, LMY, LL, DP, SP and CI were significantly higher in the buffaloes which calved in season 2 (least calving season), than in the buffaloes that calved in season 1 (most calving season). Similar findings were reported by Goswami and Nair (1965 a), Kanujia et al. (1975 b), Dharmeswar Das (1978), Patro and Bhat (1979 b) and Singh and Tiwana (1981).

Increase in the PY, milk yield and LL in the buffaloes which calved in season 2, might be due to the abundant availability of good quality leguminous green fodders during their advance stage of pregnancy before calving and also after calving from January to April. Highest SP and DP in the buffaloes that calved in season 2 might be due to

the unfavourable climatic conditions, like high ambient temperature, increased solar radiation and decreased quality of fodders in summer.

5.5 Genetic correlations:

The genetic correlations of AFC with LMY and SP were very low and non-significant. The correlations with PY was negative and with 300 days milk yield the correlation was positive but both were inconclusive as they were associated with high standard errors. The correlations of AFC with LL and SP were in agreement with the findings of Mohan (1977).

The overall genetic correlations of PY with 300 days milk yield and LMY were positive and highly significant; with preceding DP, SP and CI the correlations were negative and highly significant. While the correlation of PY with LL was inconclusive associated with high standard error. Similar correlations between PY and 300 days milk yield were reported by Dninsa (1963) and Cheema and Basu (1983). The correlation with LMY was in agreement with the results of Tomar and Desai (1967) and Mangurkar and Desai (1981).

The overall genetic correlations of 300 days milk yield with LMY and LL were positive and highly significant, and the correlations with preceding DP and CI were negative and highly significant. Whereas the correlation with the preceding SP was negative and inconclusive, as it was associated with large standard error. Similar correlations of 300 days milk yield with LMY and LL was reported by Patro and Bhat (1979 a).

The overall genetic correlation of LMY with LL was positive and highly significant and the correlations with preceding DP and CI were negative and highly significant. Whereas, the correlation between LMY and preceding SP was negative and inconclusive, as it was associated with high standard error. The correlation between LMY and LL was in agreement with the findings of Patro and Bhat (1979 a) and Gurung and Johar (1982 a). Similar correlations of LMY with DP was observed by Bhat (1978).

The overall genetic correlations of LL with the preceding DP and SP were positive and highly significant. But the correlation between LL and preceding CI was positive and non-significant, as it was associated with high standard error. Similar correlation between LL and preceding DP was obtained by Reddy and Taneja (1980 b).

The overall genetic correlation of the preceding DP with the SP was found to be positive and highly significant. Similarly the genetic correlation between DP and CI was also positive and highly significant.

The overall genetic correlation of SP with the preceding CI was estimated to be positive and highly significant.

The highly significant and positive genetic correlations among all the production traits indicated that on the genetic plane they were the same traits and there were no inherent antagonisms among them. Improvement in one trait could bring about genetic improvement in the other correlated traits.

Since the heritabilities of the traits other than production, such as LL, DP, SP and CI were almost zero, the genetic correlations were of no practical value.

5.6 Phenotypic correlations:

The phenotypic correlation of AFC with PY was positive and highly significant, with 300 days milk yield positive and significant, with LL negative but significant, and the correlations with LMY and SP were non-significant. The correlation of AFC with PY was in agreement with Dhinsa (1963) and Tomar and Desai (1968); Correlation with 300 days milk yield was similar to Dhinsa (1963) and Reddy and Taneja (1980 b). The correlation with SP was similar to the findings of Mohan (1977), Bhat (1978) and Swain (1980).

The overall phenotypic correlations of PY with 300 days milk yield and LMY were positive and highly significant, while the correlations with preceding DP, SP and CI were negative but highly significant. The correlation with LL was negative and non-significant. The present correlation of PY with 300 days milk yield was similar to the observations of Dhinsa (1963), Tomar and Desai (1967) and Cheema and Basu (1983). The correlation with LMY was in agreement with Tomar and Desai (1967), Garcha and Tiwana (1981) and Mangurkar and Desai (1981). The correlation with the preceding DP was slightly higher in the present study than the findings of Apparao (1978) in Murrah buffaloes.

The overall phenotypic correlations of 300 days milk yield with LMY, LL and preceding SP were positive and

highly significant, whereas the correlation with preceding DP was negative but significant and the correlation with preceding CI was found to be non-significant. The correlation of 300 days milk yield with LMY was similar to the results of Apparao (1978) and the correlations with LL and SP were in agreement with the findings of Basu and Ghai (1978 b) and Reddy and Taneja (1980 b). The phenotypic correlations of 300 days milk yield with LMY and LL in all the first five lactations were totally in agreement with the results of Patro and Bhat (1979a).

The overall phenotypic correlations of LM¹ with LL and preceding SP were positive and highly significant, whereas the correlation with the preceding DP was negative but significant and the correlation with preceding CI was non-significant. The present correlation with LL was similar to the results of Gill and Dev (1970), Basu (1978) and Garcha and Tiwana (1981) in Murrah buffaloes. The correlation with preceding DP was in agreement with result of Ohri and Prakash (1969). The correlations with SP were similar to the findings of Gill and Dev (1970), Apparao (1978) and Basu (1978) in Murrah buffaloes. The highly significant and positive genetic and phenotypic correlations among PY, 300 days milk yield and LMY indicated that those traits were perhaps controlled by the same set of genes and selection based on peak yield which was known quite early in the lactation, could bring about positive correlated response in the 300 days milk yield and LMY.

In the present study the overall phenotypic correlations of LL with the preceding SP and CI were positive and highly significant and the correlation with preceding DP was non-significant. The correlation with SP was in agreement with the findings of Gill and Dev (1970), Singh et al. (1972) and Basu and Ghal (1981) in Murrah buffaloes.

The overall phenotypic correlations of preceding DP with SP and between DP and CI were positive and highly significant. Similar correlations with SP were reported by Singh et al. (1972) in Murrah buffaloes. The correlations of DP with CI was in agreement with the findings of Gill and Dev (1970), Reddy and Taneja (1980 b) and Basu and Ghal (1981) in Murrah buffaloes.

The overall phenotypic correlations of SP with CI was found to be positive and highly significant. The present correlation was slightly lesser in magnitude to that of the findings of Gill and Dev (1970), Basu et al. (1978 a), Reddy and Taneja (1980b) and Sastry et al. (1982).

The highly significant and positive phenotypic correlations among DP, SP were the components of CI. Thus the relationship between them was also justifiable for the highly significant and positive phenotypic correlations among LL, SP and CI.

5.7 Heritability:

The heritabilities in the present study were estimated by the paternal half-sib correlation method from the corrected data.

In the present study the overall heritability estimates for AFC, FY, 300 days milk yield, LMY, LL, DP, SP and CI were found to be 0.24, 0.18, 0.17, 0.16, 0.04, 0.05, 0.04 and 0.04 respectively.

Low heritability estimates of LL, DP, SP and CI indicated that, sire difference with respect to transmitting ability for those traits were insignificant and selection for these traits would not yield the desired results. They could be improved only by the efficient and judicious managerial practices.

There was an increase in the heritability estimates for all the traits under study (except AFC) from the first to second lactation and then declined in the subsequent lactations. The increase in the heritability from first to second lactation was mainly due to increased genetic variance. The possible reasons for differences in genetic variances in the first and second lactations might be either due to differences in the degree of expression of genes responsible for those traits in different lactations or those traits in different lactations might have been influenced by different number of genes (Butcher and Freeman, 1968). Thus, those traits might be different genetically in various lactations and hence the heritabilities for the same traits were different in various lactations.

However, the difference in the number of sires, the number of progeny per sire and the variation in the individual records within the half-sib groups at different

lactations, might have contributed towards the differences in heritability estimates in the present study.

There were a few negative heritability estimates in the third, fourth and fifth lactations. Those negative heritabilities indicated that, there were high individual variations in the data, which exceeded the variation between half-sib groups.

CHAPTER 6

SUMMARY

CHAPTER 6

SUMMARY

Data pertaining to first five lactations of 835 buffaloes maintained at Ambala, Ferozepur and Jabalpur military dairy farms from 1968 to 1982 were studied. Total 3678 lactations were analysed.

The different traits studied in the present investigation were:

1. Age at first calving
2. Peak yield
3. 300-days milk yield
4. Lactation milk yield
5. Lactation length
6. Dry period
7. Service period
8. Calving interval

The overall least squares means for AFC, PY, 300 days milk yield, LMY, LL, DP, SP and CI were found to be 1221.30 days, 9.80 Kg, 1955.47 Kg, 2043.07 Kg, 304.06 days, 162.74 days, 160.58 days and 465.52 days, respectively.

The overall PL, 300 days milk yield and LMY increased gradually upto the fourth lactation, indicating the attainment of the lactational maturity by the fourth lactation. There was an increase in the milk yield consistently even upto the fifth lactation in early calvers, revealing that, younger first calvers take more time to reach the physiological

lactational maturity, than the aged first calvers.

In the present study the overall lactation length was almost the same in first five lactations. It revealed that, the managemental practices followed at military dairy farms were ideal to maintain 300 days LL.

The first dry period was found to be longest and it decreased gradually in the subsequent lactations. Since the animals were in the growing phase, probably they required more lactational rest and hence, the first DP might be longest than the subsequent ones. Similar to the dry periods, the first CI was highest in length and it gradually decreased in the subsequent lactations.

The early age at first calving, shorter service periods indicating high level of fertility, resulted in smallest calving intervals at Jabalpur farm. But the milk production was also lowest due to shortest lactation lengths and perhaps due to low genetic potentiality of the buffaloes.

Comparatively higher age at first calving, with longest service periods lead to longest calving intervals and with longest lactation lengths produced highest milk yields at Ferozepur farm.

There was a significant decrease in A/C, SP and DP along with significant increase in the peak yields from period 1 to 3, and lactation milk yield from period 1 to 2. It revealed the improvement brought over in the

efficient managerial practices followed at the military dairy farms.

There was a significant increase in the milk yield and LL in the buffaloes which calved in least calving season, than those calved in most calving season. It might be due to plenty availability of good, palatable and nutritious leguminous green fodders during advanced stages of pregnancy and also after calving from January to April.

With the increased milk yield, there was also a significant increase in the SP, CI and DP in the buffaloes, that calved in least calving season, than those calved in most calving season. It might be due to the unfavourable, adverse climatic conditions like high ambient temperature and increased solar radiation and decreased quality and quantity of green fodders during summer months.

It could be concluded that by adopting controlled breeding programme in buffaloes more number of calvings could be achieved during least calving season. Thus the milk production in the buffaloes and especially the milk production during the summer months could be increased, for maintaining uniform supply of milk throughout the year leading to better dairy economy.

The data was corrected for the significant effects of farm, period and season. The genetic and phenotypic correlations and heritabilities were estimated from the same data.

There were positive and highly significant genetic correlations among FY, 300 days milk yield and LMY.

The 300 days milk yield was highly correlated to LL and LMY. The LL had highly significant and positive correlations with preceding DP and SP. Similarly positive correlation trend were observed between SP and preceding DP and CI.

The phenotypic correlations were almost same to that of genetic correlations, except the correlation between preceding DP and LL, which was non-significant. In addition, there were highly significant positive correlations of FY, 300 days milk yield and LL with AFC, SP and preceding CI respectively.

The overall heritabilities for AFC, FY, 300 days milk yield, LMY, LL, DP, SP and CI were 0.24, 0.18, 0.17, 0.16, 0.04, 0.05, 0.04 and 0.04 respectively.

Since the heritabilities of LL, DP, SP and CI were negligible, the genetic correlations among them were of no practical value. Genetically as well as phenotypically, the correlations among FY, 300 days milk yield and LMY were positive and highly significant. The highly significant genetic and phenotypic correlations among the production traits, which were moderately heritable, indicated the possibility of selection on the basis of peak yield. The peak yield was known quite early in the lactation and might prove effective in bringing about a positive correlated response to increase the milk yield in buffaloes.

LITERATURE CITED

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- Abdul-Aziz, A.S. and Hamed, M.K. (1981) The effect region, season and year of calving on complete milk records of Egyptian buffaloes. Egyptian J. Anim. Prod. 19:227-231. (Fide Anim. Breed. Abstr. 50:6015).
- Agarwala, O.P. (1962) Certain factors of reproduction and production in a water buffalo herd. Indian J. Dairy Sci. 15:45-51.
- Ahmad, M., Chaudhary, R.A. and Khan, B.B. (1981) Effect of month and season of calving on the length of subsequent calving intervals in Nili-Havi buffaloes. Anim. Reproduction Sci. 3:301-306. (Fide Anim. Breed. Abstr. 49:5133).
- Alim, K.A. (1967) Repeatability of milk yield and length of lactation of the milking buffalo in Egypt. Trop. Agric. Trin. 44:159-163. (Fide Anim. Breed. Abstr. 35:3372).
- Alim, K.A. (1978) The productive performance of Egyptian buffalo in a dairy herd. World Rev. Anim. Prod. 14:57-64. (Fide Anim. Breed. Abstr. 47:601).
- Ambalkar, S.S. (1980) Effect of season of calving on the length of service period in Nagpuri buffaloes. Livestock Advisor. 2:9-10.
- Amble, V.K., Gopalan, R., Malnotra, J.C. and Mehrotra, P.C. (1970) Some vital statistics and genetic parameters of Indian buffaloes at Military Dairy Farms. Indian J. Anim. Sci. 40:377-388.
- Apparao, A. (1978) The reproductive efficiency of Murrah buffaloes in relation to growth and production. M.Sc. Thesis submitted to Kurukshetra University, Kurukshetra.

- Arora, S.P., Bajpai, L.D. and Muley, A.R. (1962) Influence of dry period on milk yield and effect of season on lactation yield and lactation days of Murrah buffaloes. *J. Vet. Anim. Husband. Res. (Mhow, M.P.)* 5:51-53.
- Basu, S.B. (1978) Milk production in Murrah buffaloes. XX Intr. Dairy Congr. Vol. E. Paris, France, Congrulat (22). (*Fide Anim. Breed. Abstr.* 47:1198).
- Basu, S.B., Bhatnagar, D.S., Sundaresan, D., Gurnani, M., Nagarcenkar, R., Sharma and Sharma, P.A. (1979) Murrah buffaloes at N.D.R.I. N.D.R.I. Karnal, Publication 154.
- Basu, S.B., Bhoserekar, M., Goswami, S.L. and Sharma, P.A. (1978 a) sources of variation affecting reproductive performance of Murrah buffaloes. *Indian J. Dairy Sci.* 31:294-296.
- Basu, S.B. and Ghal, A.S. (1978 b) Studies on milk production in Murrah buffaloes. *Indian J. Anim. Sci.* 48:593-596.
- Basu, S.B. and Ghal, A.S. (1978 c) A Note on the lactation length in Murrah buffaloes. *Indian J. Anim. Sci.* 48:906-909.
- Basu, S.B. and Ghal, A.S. (1981) Genetic and non-genetic sources of variation in dry period of Murrah buffaloes. *Indian J. Anim. Sci.* 51:150-152.
- Basu, S.B., Sharma, P.A. and Nagarcenkar, R. (1976) Selective breeding in Murrah buffaloes for economic traits. Annual Report. N.D.R.I. Karnal. pp. 193-197.
- Basu, S.B., Sharma, P.A. and Nagarcenkar, R. (1977) Selective breeding in Murrah buffaloes. Annual Report. N.D.R.I. Karnal. pp. 205-209.
- Bawa, K.S. and Dhillon, J.S. (1980) Estimation of genetic parameters of first, second and third lactation records in buffaloes. *Indian J. Dairy Sci.* 33:144-145.

- Belorkar, P.M., Khire, D.W., Kadu, M.S. and Kalkini, A.S. (1977) Studies on the effect of service period on lactational yield, lactation period and dry period in Nagpuri (Berari) buffaloes. *Indian vet. J.* 54:384-388.
- Bhalari, S.S. and Dhillon, J.S. (1978) Estimates of phenotypic and genetic parameters of some measures efficiency of milk production. *J. Agric. Sci.* 91:181-183 (*Fide Anim. Breed. Abstr.* 46:5874).
- Bhat, P.N. (1978) Genetic parameters of milk production and scope of increasing milk production in buffaloes Vis-a-Vis Cattle. Proceeding of FAO/ICLDA/Govt of India seminar on "Buffalo Reproduction and A.I." held at N.D.R.I. Karnal.
- Bhatnagar, V.K., Lohia, K.L. and Monga, O.P. (1961) Effect of month of calving on milk yield, lactation length and calving interval in Murrah buffaloes. *Indian J. Dairy Sci.* 14:102-103.
- Bhullar, M.S. (1975) Factors affecting the accuracy of progeny testing in buffaloes. *Thesis Abstracts* 1:242-243.
- Butcher, D.A. and Freeman, A.E. (1968) Heritabilities and repeatabilities of milk and milk fat production by lactations. *J. Dairy Sci.* 51:1387-1391.
- Cady, R.A., Shan, S.K., Schermerhorn, E.C. and McDowell, R.E. (1983) Factors affecting performance of Nili-Ravi buffaloes in Pakistan. *J. Dairy Sci.* 66:578-586.
- Chakravorty, A.K. (1983) Progeny testing of Murrah bulls for efficient milk production. *Thesis Abstracts.* 9:146-147.

- Chaudhary, R.A. and Akmea, W. (1978) Buffalo breeds of Pakistan and programmes for their improvement. Proceedings of FAO/SIDA/Govt of India seminar on "Buffalo Reproduction and AI", held at N.D.R.I. Karnal.
- Chaudhary, I.A. and Shaw, A.O. (1965) Production traits of Pakistani buffaloes. Pakistan J. Sci. 17:252-258. (Fide Anim. Breed. Abstr. 35:3381).
- Cheema, J.S. and Basu, S.B. (1983) Usefulness of some components of the lactation curve for selection in Murrah buffaloes. Animal Production 36:277-283 (Fide Dairy Sci. Abstr. 45:3177).
- Chhikara, B.S., Balaine, D.S., Chaudhary, S.R. and Chopra, S.C. (1978) Performance levels and culling patterns in Murrah buffalo herd. Indian J. Dairy Sci. 31:292-293.
- Chothani, A.A. (1978) Buffalo productivity in relation to milk requirement in the country. Proceedings of the Indo-Soviet symposium on "Buffalo-Breeding", held at NBDB, Anand.
- Chowdhary, M.S. and Chaudhary, A.L. (1981) Studies on peak yield and days to attain peak yield in Mehsana and Surti buffaloes. Indian vet. J. 58:203-207.
- Cockrill, W.R. (1981) The water buffalo - a review. British Vet. J. 137:8-16.
- Dave, B.K. and Taylor, C.M. (1969) Relationship of age, body weight at first calving and first lactation yield in buffaloes. J.N.K.V.V. Res. J. 3:80-84 (Fide Anim. Breed. Abstr. 39:3185).
- Dave, B.K. and Taylor, C.M. (1971) Some observations on the peak yield of Indian water buffaloes. Indian vet. J. 48:246-251.

- Dev, D.S. and Tiwana, M.S. (1978) Selection programmes in buffaloes in the past and the present. Proceedings of the Indo-Soviet symposium on " Buffalo Breeding", held at NDDB., Anand.
- Dharmeshwar, Das. (1978) Age and weight effects and lifetime performance of Haryana cattle and buffaloes. Ph.D. Thesis submitted to Haryana Agri. University, Hissar.
- Dhinsa, H.S. (1963) Inheritance of some economic characters in buffaloes. Indian vet. J. 40:352-361.
- Dickerson, G.L. (1960) Techniques for research in quantitative animal genetics. Techniques and Procedures in animal production research. American Society of Anim. Prod. Publication, Beltrville, Maryland, U.S.A. 57
- Duncan, David, B. (1955) Multiple range and multiple F tests. Biometrics 11:1-42.
- Dutt, M., Singh, S.P. and Desai, R.N. (1965 a) Significance of age at first calving and 305 day first lactation yield in relation to lifetime production, longevity and production life in Murrah buffaloes. Indian vet. J. 42:28-39.
- Dutt, M., Singh, S.P. and Desai, R.N. (1965) Prediction equations for milk yields in Murrah buffaloes. Indian vet. J. 42:506-512.
- El-Shekn, A.S. and Mohammed, A.A. (1967) The reproductive performance of the Egyptian buffalo. J. Anim. Prod. U.A.R. 5:99-117. (Fide Anim. Breed. Abstr. 37:276).
- Eltawil, B., Monkhtar, S.A., Galal, E.S.L. and Khismn, E.S. (1976) Factors affecting the production and composition of Egyptian buffalo milk. Trop. Anim. Health Prod. 8:115-121. (Fide Anim. Breed. Abstr. 44:5586).
- F A O Production year book (1980) FAO of the United Nations, Rome : 34

- Garcna, D.S. and Tiwana, M.S. (1981) A note on the repeatability of persistency of milk yield and some other economic traits in buffaloes. *Indian J. Anim. Sci.* 51:103-104.
- Gill, G.S. and Dev, D.S. (1970) Studies on some economic traits in a herd of Murrah buffaloes. *Indian J. Anim. Prod.* 1:168-175.
- Gokhale, S.B. and Nagarcenkar, R. (1979) Relationship of age and weight on first calving with monthly cumulative, monthly first lactation milk yield in Murrah buffaloes. *Indian J. Anim. Gen. breed.* 1:78-81.
- Gokhale, S.B. (1981) Inheritance of part lactations and their use in selection among Murrah buffaloes. *Inesis Abstracts.* 7:128-129.
- Goswami, S.B. and Kumar, S. (1967) Effect of potentiality of milk production of the Murrah buffaloes on their calving intervals of different lactations. *Indian J. Vet. Sci. and A.H.* 37:16-25.
- Goswami, S.B. and Kumar, S. (1968) Influence of season and off season of calving and average daily milk yield of the Indian water buffaloes on their fertility. *Indian J. Dairy Sci.* 21:27-36.
- Goswami, S.B. and Nair, A.P. (1965 a) Studies on off-season calving of the Indian water buffaloes II. *Indian J. Dairy Sci.* 18:104-108.
- Goswami, S.B. and Nair, A.P. (1965 b) Effect of season and "off-season" of calving of buffaloes (*Bubalus bubalis*) on their first lactation milk yield and length. *Indian J. Vet. Sci. and A.H.* 35:239-244.
- Gudal, A.K., Sohani, A.D. and Kukade, S.V. (1969) Observations on reproductive characters in Murrah buffaloes at Aarey Milk Colony - Bombay. *Indian vet. J.* 46:416-420.

- Gupta, L.A., Sastry, N.S.H., Yadav, R.S. and Jaiswal, U.C. (1981) Observations on calving interval of Murrah buffaloes belonging to a medium sized herd. Haryana Agril Univ. J. Res. 11:129-135.
- Gumani, M. and Nagarcenkar, R. (1971) Evaluation and breeding performance of buffaloes and estimation of genetic and phenotypic parameters. Annual Report. N.D.R.I. Karnal. pp. 48-50.
- Gumani, M., Nagarcenkar, R. and Gupta, S.K. (1976a) Performance in different lactations and repeatability of economic characters in Murrah buffaloes. Indian J. Dairy Sci. 29:117-120.
- Gumani, M., Nagarcenkar, R., Gupta, S.K. and Amarjit Singh (1976b) Seasonality of calving and its influence on economic characters in Murrah buffaloes. Indian J. Dairy Sci. 29:173-178.
- Gurung, B.S. and Johar, K.S. (1982a) Studies on factors affecting first lactation yield in Murrah buffaloes. Indian vet. J. 59:521-526.
- Gurung, B.S. and Johar, K.S. (1982 b) Note on factors affecting first lactation period in Murrah buffaloes. Indian J. Anim. Sci. 52:431-432.
- Gurung, B.S. and Johar, K.S. (1982c) Studies on body weight at first calving and its relationship with reproductive and productive traits in Murrah buffaloes. Indian vet. J. 59:939-943.
- Harvey, Walter, R. (1975) Least squares analysis of data with unequal sub-class numbers. Agricultural Research Service - H4. United States Department of Agriculture, Washington D.C. Reprinted, Feb. 1975.

- Hazel, L.N., Baker, M.L. and Reinmiller, C.E. (1943) Genetic and environmental correlations between growth rates of pigs at different ages. *J. Anim. Sci.* 2:118-128.
- Hazel, L.N. and Ferrill, C.E. (1945) Heritability of weaning weight and staple length in range Rambouillet lambs. *J. Anim. Sci.* 4:347-358.
- Indian Agricultural Research (Statistics) Institute, New Delhi. (1964) Statistical analysis of buffalo breeding data available at military dairy farms. *Status New letter and Austr. New Delhi* 13:11-12.
- Isnaq, S.M. and Shah, S.K. (1975) Comparative performance of buffaloes and Samwal cows as dairy animals. *Agriculture Pakistan* 26:75-88. (Fide *Anim. Breed. Abstr.* 46:5848).
- Iqbaluddin, Singh, B.P. and Dutt, M. (1970) Association of part yield of first lactation and age at first calving with complete lactation yield in Murrah buffaloes. *Indian J. Anim. Health.* 9:163-169.
- Jawarkar, K.V. and Johar, K.S. (1974) A genetic study on dry period of Murrah buffaloes. *J.N.K.V.V. Res. J.* 6:98-101.
- Jawarkar, K.V. and Johar, K.S. (1975a) Studies on effect of period and sequence of lactations on the lactation period of Murrah buffaloes. *Indian J. Anim. Sci.* 45:1-3.
- Jawarkar, K.V. and Johar, K.S. (1975 b) A genetic study on milk yield of Murrah buffaloes. *Indian Vet. J.* 52: 426-430.
- Johari, D.C. and Bhat, P.N. (1979a) Effect of genetic and non-genetic factors on reproductive traits in Indian buffaloes. *Indian J. Anim. Sci.* 49:1-16.

- Jonari, D.C. and Bhat, P.N. (1979b) Effect of genetic and non-genetic factors on production traits in buffaloes. *Indian J. Anim. Sci.* 49:984-991.
- Kanujia, A.S. (1978) Genetic and economic investigations in buffaloes (*Bubalus bubalis*). Thesis Abstracts. 4: 281-283.
- Kanujia, A.S. and Balaine, D.S. (1975 a) Factors affecting some productive traits in Indian buffaloes. *Indian J. Dairy Sci.* 28:57-62.
- Kanujia, A.S., Balaine, D.S. and Rath, S.S. (1974) Factors affecting some economic traits of reproduction in Indian buffaloes. *Indian J. Dairy Sci.* 27:264-270.
- Kanujia, A.S., Balaine, D.S. and Rath, S.S. (1975 b) Effect of some environmental and physiological factors on reproduction and production traits in Indian buffaloes. *Maryana Agric. Univ. J. Res.* 5:179-187.
- Khanna, A.S. and Kanujia, A.S. (1981) Influence of preceding dry period on lactation yield in buffalo. *Agricultural Science Digest, India* 1:252-254 (Fide *Dairy Sci. Abstr.* 45:5371).
- Khire, D.W., Kadu, M.S., Belorkar, P.M., Thatte, V.R. and Kalkini, A.S. (1977) Breeding efficiency and producing ability of milk in Nagpuri (Berari) buffaloes. *Indian J. Anim. Sci.* 47:85-87.
- Khire, D.W., Deshmukh, S.N., Singh, S.N., Thatte, V.R., Amin, M.M. and Desai, R.T. (1983) Some economic characters in Nagpuri buffaloes. *Indian J. Anim. Sci.* 53:413.
- Khushin, S.S., El-Issaway, H.F. and Afifi, M.A. (1963) Milk yield in a herd of Egyptian buffaloes as affected by service period, calving interval and dry period. *J. Anim. Prod. U.A.R.* 3:145-168 (Fide *Anim. Breed. Abstr.* 33:3238).

- Kohli, M.L. and Malik, D.D. (1960) The effect of service period on total milk production and lactation length in Murrah buffaloes. *Indian J. Dairy Sci.* 13:105-111.
- Kramer Clyde Young. (1957) Extension of multiple range tests to group correlated adjusted means. *Biometrics.* 13:13-18.
- Krisnamacharyulu, E. and Prabhu, S.S. (1973) A study on the age at first calving in Murrah buffaloes. *Indian J. Anim. Prod.* 4:182.
- Kumar, R. and Bhat, P.N. (1978 a) Effect of non-genetic factors on lactation length in Indian buffaloes. *Indian J. Anim. Sci.* 48:559-562.
- Kumar, R. and Bhat, P.N. (1978 b) Effect of some non-genetic sources of variation on milk yield in Indian buffaloes. *Indian J. Anim. Sci.* 48:639-642.
- Lal, H.A. (1975) Study of economic characters in Murrah buffaloes. *Indian vet. J.* 52:337-344.
- Luktuke, S.N. and Roy, D.J. (1964) Studies on post-partum estrus in Murrah buffaloes. *Indian J. Vet. Sci. and A.H.* 34:166-170.
- Mahadevan, P. (1960) Some genetic parameters of the water buffalo. *Emp. J. Exp. Agric.* 28:99-103. (Fide *Dairy Sci. Abstr.* 22:2409).
- Malossini, F. and Pilla, A.M. (1963) Estimation of repeatability and heritability of production in buffaloes. *Annali Sper. Agr. N.S.* 17:455-470 (Fide *Anim. Breed. Abstr.* 34:1137).
- M ngurkar, B.R. and Desai, R.N. (1981) Interrelationship between netler hood body weights and first lactation performance in buffaloes. *Indian vet. J.* 58:199-202.
- Mohan, D.K. (1977) Genetic studies on some of the reproductive traits in Murrah buffaloes. *Thesis Abstracts.* 3:255-256.

- Nagarckenkar, R. (1978) Riverine buffaloes of India and possibilities of genetic improvement Vis-A-Vis cattle. Proceedings of FAO/SIDA/Govt of India seminar on "Buffalo Reproduction and A.I", held at NDRI, Karnal.
- Naidu, K.N. (1983) Effect of season of calving on the subsequent reproductive behaviour in buffaloes. Indian vet. J. 60:34-37.
- Onri, S.P. and Prakash, A. (1969) Performance of Murrah buffaloes in arid zone. I. Effect of length of dry period on successive lactation yield. Indian vet. J. 46:311-315.
- Panse, V.G. and Sukhatme, P.V. (1967) Statistical methods for Agricultural workers. Published by ICAR, Krishna Bhavan, New Delhi.
- Patro, B.N. and Bhat, P.N. (1979 a) Inheritance of production traits in buffaloes. Indian J. Anim. Sci. 49:10-14.
- Patro, B.N. and Bhat, P.N. (1979 b) Effect of some non-genetic factors on production traits in Indian buffaloes. Indian J. Anim. Sci. 49:91-97.
- Peeva, T.S. (1977) Age at first calving and its effect on body weight and dairy performance of Bulgarian buffaloes and their F₁ crosses with Murrah. Zhivotnov '' dnl Nauka. 14:26-35. (Fide Anim. Breed. Abstr. 46:2715).
- Peeva, T.S. (1979) Dairy performance correction factors for calving season and age. Zhivotnov dnl Nauka 16:20-25. (Fide Anim. Breed. Abstr. 49:1204).
- Polikhronov, D. (1965) The effect of service period on the milk production and lactation of buffaloes in Bulgaria. Zhivot. Nauk. 2:537-544 (Fide Anim. Breed. Abstr. 34:1173).

- Polikhronov, D., Peeva, T.S. and Boikovski, S. (1977 a)
The relationship of body weight with milk production of buffaloes born in Bulgaria. *Zhivotnov'' dni Nauki* 14:28-32 (Fide Anim. Breed. Abstr. 48:781).
- Polikhronov, D., Peeva, T.S. and Boikovski, S. (1977 b) The effect of dry period duration on milk production of Murran and Bulgarian buffalo cows and crossbreds of the two breeds. *Zhivotnov'' dni Nauki* 14:28-32. (Fide Anim. Breed. Abstr. 48:7186).
- Polikhronov, D., Peeva, T.S. and Boikovski, S. (1977 c)
The duration of successive lactations and its effect on milk production of Bulgarian-bred buffaloes. *Zhivotnov'' dni Nauki* 14:39-42 (Fide Anim. breed. Abstr. 48:7187).
- Porwal, M.L., Singh, M.P. and Karandikar, G.W. (1981) Studies on reproductive performance of Murran buffaloes. *Indian vet. J.* 58:295-299.
- Raju, V.R. (1969) Some factors causing variation in the production traits of Murrah buffaloes. M.Sc.(Vety). Thesis submitted to the Andhra Pradesh Agril university, Hyderabad.
- Rao, M.K. and Nagarcenkar, R. (1977) Potentialities of the buffalo. *World Review of Anim. Prod.* 13:53-62.
- Rao, B.H., Patel, U.G. and Tomar, S.S. (1973) Seasonal trend in reproductive behaviour of Surti buffaloes II. Service period and post-partum oestrus interval. *Indian vet. J.* 50:413-417.
- Rao, I.P., Singh, B.P. and Mahesh, Dutt. (1970) Studies on lactation curves and association of certain production traits in Murrah buffaloes. *Indian J. Anim. Sci.* 40: 246-251.

- Rathu, S.S., Singh, D. and Acharya, R.M. (1971) Phenotypic and genetic parameters of some economic traits in Indian buffaloes. *Indian J. Anim. Prod.* 2:1-6.
- Raut, K.C. and Singh, S. (1978) Population structure and some production traits of buffaloes in rural areas (of Krishna delta in AP). *Indian J. Anim. Sci.* 48: 331-334.
- Raut, K.C., Singh, S. and Chaudhary, M.L. (1974) Some factors influencing the production of buffalo milk. *Indian J. Anim. Sci.* 44:713-716.
- Razada, B.C. and Pandey, M.D. (1981) Buffalo reproduction 2. Breeding of, off-season and normal season calvers. *Indian J. Anim. Sci.* 51:164-168.
- Report of the National Commission of Agriculture Part VII. (1976) Published by the Ministry of Agriculture and Irrigation Government of India.
- Reddy, K.M. and Mishra, R.R. (1980 a) Effect of age at first calving on first lactation components and calving distribution in Murrah buffaloes. *Indian J. Dairy Sci.* 33: 347-350.
- Reddy, K.M. and Mishra, R.R. (1982) A study on lactation components in Murrah buffaloes. *Indian vet. J.* 59: 375-381.
- Reddy, C.M. and Taneja, V.K. (1980 b) Genetic analysis of breeding records of buffaloes. Annual Report NDRI, Karnal pp 157-160.
- Robertson, A. (1959) The sampling variance of the genetic correlation coefficients. *Biometrics.* 15:469-485.
- Roychowdhury, P.N. (1970) Effect of service period on the milk production and lactation length of buffaloes in Italy. *Zenthl. Vet. Med. Reihe. A.* 17: 213-215. (vide *Anim. Breed. Abstr.* 39:1581).

- Roychoudhury, P.N. and Cesarini, R.B. (1969a) Influence of length of preceding dry period on subsequent lactation performance of Italian buffaloes. *Indian vet. J.* 46: 685-687.
- Roy, D.K., Choudhary, R.A. and Jøhar, K.S. (1981) Effect of season, parity and period on calving interval of Murrah buffalo. *Livestock Adviser* 6:42-45.
- Roychoudhury, P.N. and Succi, G. (1969 b) Effect of the month of calving on the length of service period in Italian buffaloes. *Indian vet. J.* 46:1059-1062.
- Sane, D.D., Khanna, R.S., Bajpai, L.D. and Bhat, P.M. (1972a) Effect of month and season of calving, lactation numbers, lactation length, dry period, age and weight of first calving on milk yield and peak yield in Murrah buffaloes. *Indian J. Anim. Prod.* 3:22-29.
- Sane, D.D., Khanna, S.S., Bajpai, L.D. and Bhat, P.M. (1972b) Studies on Murrah buffaloes (*Bubalus bubalis*) II. Genetic analysis of milk yield and peak yield. *Indian J. Anim. Prod.* 3:61-65.
- Sasanna, I. and Nagarcenkar, R. (1978) Evaluation of Murrah buffalo sires on the basis of part lactation yields. Annual Report, NDRI, Karnal. pp. 140-141.
- Sastry, N.S.R., Juneja, I.J., Yadav, R.S. and Gupta, I.R. (1982) Studies on components of calving interval of Murrah buffaloes. *Maryana Agri. Univ. J. Res.* 12:6-12.
- Searle, S.R. (1961) Phenotypic, genetic and environmental correlations. *Biometrics.* 17:474-480.
- Sharma, R.C. and Singh, B.P. (1981) Factors affecting the lifetime milk production in Unadawari buffaloes. *Indian vet. J.* 58:47-52.
- Singh, R.P. (1966) A study of production upto 10 years of age in buffaloes maintained at military farms. *Indian vet. J.* 43:986-992.

- Singh, S.B. and Desai, R.N. (1962) Production characters of Bhadawari buffalo cows. Indian vet. J. 39:332-343.
- Singh, V. and Desai, R.N. (1978) Production performance of Murrah buffaloes in relation to their calving trend. Indian J. Anim. Sci. 48:334-339.
- Singh, H.P. and Singh, R. (1977) Statistical studies of some economic traits of Indian buffaloes. Indian vet. J. 54:823-833.
- Singh, G., Taneja, V.K., Bajpai, L.D. and Bhat, P.N. (1972) Studies in Murrah buffaloes IV. service period. Indian J. Anim. Prod. 3:159-164.
- Singh, G., Taneja, V.K., Bajpai, L.D. and Bhat, P.N. (1976) Studies in Murrah buffaloes (Lubalis)- calving interval. Indian J. Anim. Prod. 7:19-23.
- Singh, G. and Tiwana, M.S. (1981) Some factors affecting the peak yield in buffaloes. Indian J. Dairy Sci. 34:116-118.
- Breedharan, S. and Nagarcenkar, R. (1973) Inheritance of body size and its relationship with production efficiency in buffaloes. Annual Report, NDRI, Karnal. pp. 102.
- Swain, Sacchindranata (1980) Studies on certain productive and reproductive traits, with special reference to service period in Murrah buffaloes. M.Sc. Thesis submitted to Kurukshetra University, Kurukshetra.
- Tomar, S.P.S. and Desai, R.N. (1967) Inheritance and genetic correlations of peak yield with milk production and lactation period in buffaloes on military farm. Indian vet. J. 44:308-314.
- Tomar, S.P.S. and Desai (1968) Genetic relationship of age at first calving with first lactation yield in buffaloes on military farms in North. Indian J. Anim. Health. 7:189-197.

- Tomar, N.S. and Tomar, S.P.S. (1960) A study of calving season in Murrah buffaloes. Indian vet. J. 37: 445-452.
- Vankov, K. and Peeva, T.S. (1979) Phenotypic and genetic parameters of selection characters in buffaloes. I. Variability of milk production and body weight. Zhivotnov'ni Nauki 16:25-34 (Fide Anim. Breed. Abstr. 49:1210).
- Venkataratnam, G. and Venkalah, D. (1964) Some observations on the production characters of Murrah buffaloes. II. Season of calving. Indian vet. J. 41:507-512.
- Venkalah, D. and Anantakrishnan, C.P. (1964) Influence of length of preceding dry period on the subsequent lactation performance of Murrah buffaloes. Indian J. Dairy Sci. 17:87-88.
- Venkalah, D. and Anantakrishnan, C.P. (1966) Effect of season of calving on the length of service period in Murrah buffaloes. Indian J. Dairy Sci. 19:1-3.
- Yadav, K.N. (1980) Appraisal of genetic and environmental responses in different economic traits of Murrah buffaloes under progeny testing programme. Thesis Abstracts. 6:264-266.