GENETIC EVALUATION OF MURRAH BUFFALOES AT ORGANISED HERDS

Dissertation

Submitted to the Guru Angad Dev Veterinary and Animal Sciences University in partial fulfillment of the requirement for the degree of

DOCTOR OF PHILOSOPHY

in

ANIMAL GENETICS AND BREEDING
(Minor Subject: Animal Biotechnology)

By

Puneet Malhotra
(L-2010-V-01-D)

Department of Animal Genetics and Breeding
College of Veterinary Science

GURU ANGAD DEV VETERINARY AND ANIMAL SCIENCES UNIVERSITY LUDHIANA-141 004

2014

CERTIFICATE - I

This is to certify that the dissertation entitled **"Genetic Evaluation of Murrah Buffaloes at Organised Herds"** submitted for the degree of Ph.D., in the subject of **Animal Genetics and Breeding** (Minor subject: **Animal Biotechnology**) of the Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, is a bonafide research work carried out by **Puneet Malhotra (L-2010-V-01-D)** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

Dr. G.S. Brah
(Major Advisor)
Professor AGB-cum-Director,
School of Animal Biotechnology
Guru Angad Dev Veterinary
and Animal Sciences University,
Ludhiana-141004, India

CERTIFICATE - II

This is to certify that the dissertation entitled **"Genetic Evaluation of Murrah Buffaloes at Organised Herds"** submitted by **Puneet Malhotra (L-2010-V-01-D)** to the Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, in partial fulfillment of the requirements for the degree of Ph.D., in the subject of **Animal Genetics and Breeding** (Minor subject: **Animal Biotechnology**) has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an external examiner.

(Dr. G.S. Brah)
Major Advisor

(Dr. Avtar Singh)
External Examiner
Principal Scientist
Dairy Cattle Breeding
NDRI, Karnal – 132001

(Dr. A.K. Pandey)
Co-Advisor
Principal Scientist
CIRB, Hissar

(Dr. H.S. Sandhu)
Head of the Department

(Dr. S.N.S. Randhawa)
Dean, Postgraduate Studies

ACKNOWLEDGMENT

This work, I must admit has been possible only by the grace and blessings of the Omnipresent, Omniscient and Omnipotent God.

I express my deep sense of gratitude to my major advisor **Dr. G.S. Brah**, Professor Animal Genetics and Breeding-cum-Director, School of Animal Biotechnology, GADVASU, Ludhiana. Without his guidance, steadfast support and stimulation, this work would have been a futile venture. He enlightened me with his erudite and expertise on the subject. Indeed it was a privilege for me to work under such an experienced and humble guide. It goes without saying that this work has been accomplished with his benevolence and generosity.

I am thankful to the members of my Advisory Committee: **Drs. S.P.S. Sangha, Raman Narang** (Dean PGS Nominee) and **Simarjeet Kaur** for their valuable counsel from time to time. I reserve my special thanks to **Dr. C.S. Mukhopadhyay**, also a member of my advisory committee for his help and expertise in statistical analysis of data.

I am highly grateful to **Dr. A.K. Pandey**, Pr. Scientist, CIRB, Hisar and Co-guide for the valuable suggestions and assistance at every stage of the programme. I am highly obliged to Director, CIRB, Hisar for granting permission for the use of research data and other facilities at the institute for this study.

I wish to express my deep sense of gratitude to **Dr. A.K. Srivastva**, Director, NDRI, Karnal for allowing me to use computer facilities at NDRI for statistical analysis of data. I want to convey my heartfelt thanks to **Dr. Avtar Singh**, Pr. Scientist, DCB, Division, NDRI for the deep interest he took in sire evaluation analysis. Sincere thanks are also expressed to **Sardar Gian Singh**, Computer centre, NDRI in understanding the needs of statistical analysis and programming for the statistical analysis of the data.

I convey my sincere thanks to the faculty members / retirees of the University, **Drs. O.S. Parmar, M.P.S. Bakshi, M.L. Mehra, I.S.Bajwa, Ravi Kumar, Parmidner Chawla, A.P.S.Sethi, Ranjana Cheema, R.S. Grewal, S.S. Randhawa, V.S. Malik, Kanchan Sapra, Parmindr Singh, Samita Saini, S.T. Singh, P.P. Dubey, Ashwani Singh, Ranjeet Singh** and **Ajeet Kumar** for their full co-operation.

I am no less grateful to **Dr. S.N.S. Randhawa**, Dean, PGS-cum-Director of Research, GADVASU for his encouragement throughout the course of project.

I am glad to communicate my special thanks to the staff of Dairy Farm, **S/Sh. Gurcharan Singh, Kashmir Singh, R.K. Singla, Sukhwinder**

Singh Yashpal, M.L. Mishra, Sahibdin, Tarsem and **Smt. Baljit Kaur** for creating a congenial atmosphere for study and placing all the available material at my disposal all through the completion of the work.

My very special thanks are due to my friends **Dr. Gagan Bajaj, Dr. Vikas Gupta, Gagan Kamboj, Dr. Nitin Gupta, Abhishek, Gagandeep, Jasdeep, Sarabjot** and **Gagan Dhol** for their invaluable suggestions and pleasant company.

I also feel obliged to **Sh. Ramesh** Kumar and **Gurdeep Singh Maggo** for working day in and day out in computer typing for the timely completion of my manuscript.

I thankfully acknowledge the in-service Ph.D. opportunity received from GADVASU authorities, with the help of which this project is completed.

I will be failing in my duty if I do not give vent to my feelings of indebtedness to my respected late grandmother. I overwhelmingly express my gratitude to my wife for cheerfully bearing all types of inconveniences, wholehearted co-operation and for shouldering greater family responsibilities during the course of investigation. The patience and tolerance shown by my son and daughter at such a tender age in sparing me for my work is praise-worthy. I am no less indebted to my parents and in-laws who have not only kindled the flame of learning in me but also encouraged me at every step to bear this work fruit. I am also grateful to my loving sister for standing by me at every stage of this project. My sister and brother in-laws deserve elixired thanks from me for their untamed and unconditional support during the whole period of my study and for surrounding me, loving me and making my life fun.

All may not have been mentioned but none is forgotten. Needless to say, errors and omission if any are mine.

Place: Ludhiana
Date:

(Puneet Malhotra)

Title of the Thesis	**:**	Genetic Evaluation of Murrah Buffaloes at Organised Herds
Name of the student and Admission No.	**:**	Puneet Malhotra L-2010-V-01-D
Major Subject	**:**	Animal Genetics and Breeding
Minor Subject	**:**	Animal Biotechnology
Name and Designation of Major Advisor	**:**	Dr. G.S. Brah Professor AGB-cum-Director, School of Animal Biotechnology, GADVASU, Ludhiana
Degree to be Awarded	**:**	Doctor of Philosophy (Ph.D.)
Year of award of Degree	**:**	2014
Total Pages of Thesis	**:**	226 + VITA
Name of University	**:**	Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana – 141004

ABSTRACT

The present investigation was undertaken for genetic evaluation of two organised herds of Murrah breed involving 1807 buffaloes for growth, production and reproduction traits. Season had little influence on body weight, gain in weight and relative growth rate. The contribution of periods to total variation was relatively more than that of seasons. Parity of dam generally had significant effect on body weights during first six parities; the effect being most conspicuous for early body weights. Season had significant influence on milk yield, fat%, peak yield and days to reach peak yield. Period of birth/calving had significant influence on some of the traits (AFC, WFC, Peak yield, milk yield per day of lactation length and number of AI per conception). Estimates of heritability for body weights at different ages, monthly gain in weight and relative growth rate varied between 0.11±0.098 and 0.54±0.125; 0.08±0.096 and 0.56±0.126, and 0.06±0.04 and 0.33±0.114 respectively. Higher estimates were obtained for six month body weight, gain in body weight from birth to six months and relative growth rate from birth to six months of age. Higher estimates of heritabilities were obtained for age at first calving (0.76±0.12), weight at first calving (0.45±0.11), 305-day milk yield (0.42±0.11) and fat% (0.61±0.12). Heritability estimates for other first lactation traits were lower: 0.16±0.09 for calf birth weight, 0.12±0.09 for lactation length, 0.22±0.10 for peak yield and 0.16±0.09 for days to reach peak yield. These traits can, therefore, be used either alone or in combination with other traits for selection. Traits related to reproduction had low heritabilities (0.062±0.083 to 0.161±0.095) and were also associated with relatively higher standard errors. Genetic correlations of birth weight with body weight at other ages (except for one-month weight), monthly gain in weight and monthly relative growth rate were low. Genetic correlation among bodyweights and monthly gain in weight were generally desirable partly due to part and whole relationship. The first lactation traits except for PY, Fat % and Fat yield had moderate genetic correlation with AFC. Weight at first calving had moderate genetic correlation with LY, 305 MY, PY, MYLL and Fat yield. Lactation yield had very high genetic correlation with LL, 305 MY, PY, MYLL and Fat yield. Statistical transformation of data to square root and logarithmic scales, in general, decreased the departures from normality of distribution, reduced the heterogeneity of variance among sub classes, and also reduced the relationship between mean and variance. However despite better fulfilment of the assumptions of analysis of variance on transformed scales, the transformation did not result in any appreciable change in the estimates of heritability and their standard errors. Breeding values of the 93 sires for first lactation 305 day or less milk yield averaged to be 1883.4±19.0, 1879.6±7.2 and 1826.5±28.2 kg by LS, BLUP and DFREML methods respectively. Breeding values of 50.5%, 41.9% and 44.1% of the 93 sires by LS, BLUP and DFREML methods was above the average breeding value respectively. The range of breeding values was 847.1 kg, 298.3kg and 1317.2kg for LS, BLUP and DFREML methods respectively. Comparative efficiency of the three sire evaluation methods used in the present study showed BLUP to be the most effective method as it had the lowest error variance, highest coefficient of determination and the lowest coefficient of variation. The LS method ranked second.

Keywords: First lactation traits, growth traits, Murrah buffalo, assumptions of normality, sire evaluation

______________________ _________________________

Signature of Major Advisor Signature of the Student

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

305-MY	305-day milk yield
AFC	Age at first calving
AIN	No. of AI per conception
BLUP	Best linear unbiased prediction
Calf%	Calf-dam weight percent
DFREML	Derivative free restricted maximum likelihood
DRPY	Days to reach peak yield
FAT%	Fat percent in a lactation
FY	Fat yield in a lactation
GP	Gestation period
LL	Lactation length
LS	Least square
LY	Lactation milk yield
MYLL	Milk yield per day of lactation length
PY	Peak yield
Var.	Variance
WAB	Weight of calf at birth
WAC	Weight at calving

CHAPTER I

INTRODUCTION

India is considered as the treasure of world's best buffalo germplasm resources. Buffalo occupies an important place in the dairy industry of India. Buffalo is not only the better source of milk but also provides meat and draught power in India. India has the highest buffalo population (105.1 million) of the world (185.29 million) which is 56.7% of the total (FAO Statistics 2008). Buffalo contributes 53 per cent to the total milk production of India (112 million tons) (Animal Husbandry Statistics 2010). Buffaloes also occupy third place as meat producing animal by contributing about 15 percent towards total meat production of the country. Besides these, buffaloes are a classic work animal of India used for all types of agricultural operations and as a mean of transportation. Buffalo therefore, qualify as a versatile triple purpose (milk, meat and draught) animal.

Murrah is one of the important breeds of buffaloes. This breed has been used for upgrading low milk producing breeds throughout the country. Animals of this breed have also been imported by a number of other countries of Asia, Europe and Africa with the purpose to cross them with their indigenous breeds, and also to raise as a pure breed. Since there is hardly any scope of introducing superior germplasm into this breed, selection is the only tool available for its genetic improvement.

The major thrust in buffaloes breeding programmes in the country is to identify animals of high genetic merit to serve as parents of the next generation. Selection of females is usually based on its first lactation performance while the sires are evaluated on the basis of first lactation 305-days or less milk production of their daughters. Though selection needs to be practiced in both the sexes but, the importance of sire selection far exceeds that of dam selection. Firstly, because the sire has a much greater impact on breed improvement in terms of number of progeny it can leave behind as compared to the female particularly through the use of artificial insemination. Secondly, because only a few sires are needed as replacement as compared to dams, therefore, much more rigorous selection is possible in males. This is so since most of the female progeny born must be kept as replacement for the herd. It is these considerations which emphasizes the need for accurately evaluating and choosing the herd sires. As much as 61% of the genetic gain in dairy cattle results from selection of sires through bulls to breed cows and bulls to breed bulls path. Hence, accurate selection of bulls used in AI programme is of prime importance for long term genetic progress of the population (Robertson and Rendel, 1954). Sire proofs can be effectively utilized in saving male progeny from the best sires and coming from the best dams mated to those sires so chosen. Maximization of genetic improvement in traits especially of economic importance is the primary objective of breeding programme. The potential for genetic improvement of a trait largely depends on the access to genetic variability existing in the population. The variability for a particular trait in a herd of specific population is measured by heritability estimates of trait under given environmental conditions. Knowledge of heritability and the genetic association among traits of economic importance help in deciding the appropriate selection strategy. Estimation of these genetic parameters is based on certain assumptions viz. normality of distribution, homogeneity of variance and lack of relation between mean and variance. Violation of these assumptions affects the estimates of genetic parameters as well as their reliability. The prediction of breeding value constitutes an integral part of most breeding programmes for genetic improvements. The main emphasis in any breeding value estimation or sire evaluation programme is laid on the methods to minimize the environmental variations and work out the relative genetic merit of the animal (Lin and Lee 1986, Ducrocque and Besbes 1993).

Indian Council of Agricultural Research is funding the Network projects for bringing genetic improvement in 7 breeds of buffaloes viz; Murrah, Nili Ravi, Jaffarabadi, Surti, Pandharpuri, Bhadawari and Swamp since 1993 with special emphasis on Murrah. The objective of the projects is to undertake progeny testing for improvement of different breeds of buffaloes at various centres in different parts of the country. The genetic architecture of the net-work herds of Murrah has not been extensively studied so far. Keeping this in view, the present study was planned with the following objectives:

1. To obtain estimates of genetic parameters (heritability and genetic correlations) for different economic traits.
2. To examine the validity of assumption involved in the estimation of genetic parameters and to study the effect of violation of assumptions on the estimates of genetic parameters.
3. To study the efficiency of sire evaluation using three methods viz; least squares (LS), best linear unbiased prediction (BLUP) and derivative free restricted maximum likelihood (DFREML).

CHAPTER II

REVIEW OF LITERATURE

The literature relevant to the objectives of the present investigation had been reviewed under three broad heads averages of various economic traits, estimates of genetic and phenotypic parameters, and breeding value of animals in general and that of bulls in particular. The averages of various economic traits give an idea about the level of performance of a herd while the estimates of genetic and phenotypic parameters (heritability, genetic correlations, and phenotypic correlations) provide a guide to the choice of the most effective selection criterion for the genetic improvement. Estimates of breeding value of bulls are needed for accurate selection of male breeders in order to maximize the rate of genetic progress.

Accordingly, the work done by various workers was reviewed as per objectives of the present study and is presented as under:

2.1 Mean performance, factors affecting and genetic parameters of growth traits

2.2 Mean performance, factors affecting and genetic parameters of first lactation traits

2.3 Sire evaluation methods including their relative efficiencies

2.1 Mean Performance, Factors Affecting and Genetic Parameters of Growth Traits

The growth in buffaloes depends on their genetic makeup and also on their feeding and management. Growth traits are useful in determining prospective value of animals at an early age, if there exist an association between these traits and various other economic traits of the animal. Therefore, the study of body weights and pre-pubertal growth rate in buffaloes is very necessary.

2.1.1 Body Weights

2.1.1.1 Body Weight at Birth

The body weight of new born calf which is one of the first measurable traits is of importance, as it reflects pre-natal growth of the calf. It also determines to some extent, the post-natal growth, survivability and future performance of animal. The average for birth weight of buffalo calves reported by various workers is presented in Table 1.

Table 1: Average body weight of female buffalo calves at birth

N	Weight at birth (kg)	References
251	26.5±	Gudi *et al* 1971)
820	31.22±0.12	Kanaujia (1973)
322	29.42±0.19	Johari (1976)
2400	29.46±0.06	Nautiyal and Bhatt (1977)
746	32.3±0.16	Basu and Rao (1979)
2558	30.2±0.3	Johari and Bhatt (1979a)
2400	30.1±	Nautiyal and Bhatt (1979)
392	28.53±0.34	Yadav *et al* (1982)
477	29.4±6.4	Rao and Murthy (1981)
916	27.72±0.25	Gurung and Johar (1983a)
137	27.09±0.28	Sharma *et al* (1983a)
441	28.31±0.57	Sharma *et al* (1983b)
200	29.31±0.21	Kirmani *et al* (1985)
208	30.5±	Verma and Husain (1985)
628	30.49±0.21	Singh and Basu (1988)
1867	29.85±0.08	Dahama *et al* (1990a)
1646	29.88±0.09	Dahama (1991)
851	23.3±	Kukde and Gire (1992)
197	27.9±0.2	Duc *et al* (1993)
301	30.4±8.4	Rao and Lakshminarayana (1994)
587	26.1-34.0	Jogi and Lakhani (1996)
289	29.58±4.8	Veerapandian *et al (1996)*
424	23.1 ±	Nawale *et al* (1997)
615	34.1±	Kaushish (1997)

The average birth weight of female Murrah calves varied from 23.1 kg (Nawale *et al* 1997) to 34.1 kg (Kaushish 1997).The weighted average of birth weight in Murrah calves was 27.4 kg.

Different workers reported different estimates for heritability of birth weight which are presented in Table 2. Heritability estimates ranged from 0.04 ± 0.07 (Sharma *et al* 1983a) to 0.58±0.13 (Gurung and Johar 1983b) in Murrah buffaloes. The weighted average to heritability of birth weight in Murrah calves was 0.30 and in graded Murrah buffaloes, it was 0.64.

Table 2: Heritability estimates of birth weight in buffaloes

n	Heritability of birth weight	References
731	0.16±0.07	Basu and Rao (1979)
916	0.58±0.13	Gurung and Johar (1983b)
441	0.04±0.07	Sharma *et al* (1983a)
628	0.11±0.12	Singh and Basu (1988)
825	0.53±0.13	Tien and Tripathi (1990)
2466	0.74±0.09	Johari (1976)
2400	0.56±0.09	Nautiyal and Bhat (1979)
201	0.29±0.2	Kirmani *et al* (1984)
1850	0.56±0.08	Dahama *et al* (1990a)

Similarly genetic and phenotypic correlations of birth weight with subsequent body weights and other economic traits as reported by various workers are presented in Table 3.

2.1.1.2 Body weight at 3 months of age

The body weights of buffalo calves at 3 months of age as reported by different workers have been summarized in Table 4.

Table 3: Genetic and phenotypic correlations of birth weight with other traits in buffaloes

Character	Genetic Correlation	Phenotypic Correlation	Reference
Body weight at 3 months age	0.32±0.09	0.23±0.02	Johari and Bhat (1979a)
	0.68±0.06	0.36	Gurung and Johar (1982b)
	-0.002±0.39	0.004	Kirmani *et al* (1984)
Body weight at 6 months age	0.21±0.10	0.11±0.02	Johari and Bhat (1979a)
	0.64±0.07	0.29	Gurung and Johar (1982b)
	0.005±0.33	0.005	Kirmani *et al* (1984)
	-	0.34	Murdia and Chaudhary (1984)
	0.98	0.31	Ansari *et al* (1989)
	-0.07±0.21	0.23±0.04	Tien and Tripathi (1990)
	0.24±0.07	0.14±0.02	Dahama *et al* (1990a)
	-0.13	0.17	Vijai *et al* (1993a)
Body weight ar 12 months age	0.25±0.09	0.11±0.02	Johari and Bhat (1979a)
	0.42±0.10	0.22	Gurung and Johar (1982b)
	-0.009±0.65	-0.004	Kirmani *et al* (1984)
	-	0.31	Murdia and Chaudhary (1984)
	-0.84	0.23	Ansari *et al* (1989)
	0.10±0.28	0.25±0.04	Tien and Tripathi (1990)
	-0.33	0.11	Vijai *et al* (19*93a)*
Body weight at 18 mnths age	0.10±0.13	0.09±0.02	Nautiyal and Bhat (1979)
	0.33±0.11	0.19	Gurung and Johar (1982b)
	-0.01±0.29	-0.01	Kirmani *et al (*1984)
	-	0.38	Murdia and Chaudhary (1984)
	-0.91	0.31	Ansari *et al* (1989)
	0.13±0.26	0.18±0.04	Tien and Tripathi (1990)
	-0.99	0.21	Vijai *et al* (1993a)
Body weight at 24 months age	0.15±0.10	0.06±0.02	Johari and Bhat (1979a)
	0.10±0.13	0.06±0.02	Nautiyal and Bhat (1979)
	0.21±0.11	0.16	Gurung and Johar (1982b)
	-0.01±0.31	-0.01	Kirmani *et al* (1984)
	-	0.21	Murdia and Chaudhary (1984)

Character	Genetic Correlation	Phenotypic Correlation	Reference
	-2.37	0.24	Ansari *et al* (1989)
	-0.19±0.30	0.18±0.04	Tien and Tripathi (1990)
	0.07±0.07	0.02±0.02	Dahama *et al* (1990a)
	-3.44	0.14	Vijai *et al* (1993a)

Table 4: Average body weight of female buffaloes at 3 months of age

N	Weight at 3 months (kg)	Reference
302	77.79±0.86	Johari (1976)
415	68.2±0.58	Basu and Rao (1979)
1295	77.3±0.49	Gurung and Johar (1983b)
301	68.13±1.2	Rao and Lakshminarayana (1994)
615	60.6	Kaushish (1997)
1153	76.6±0.41	Johari (1976)
189	73.8±0.99	Kirmani *et al* (1985)
2400	71.1±0.25	Nautiyal and Bhat (1979)
2358	77.3±1.4	Johari and Bhat (1979a)

Bodyweight at 3 months of age in Murrah buffaloes ranged from 60.6 kg (Kaushish 1997) to 77.7 kg (Johari 1976) with a weighted average of 71.6 kg.

The heritability estimates of bodyweight at 3 months of age in Murrah buffaloes as reported by various workers are summarized in Table 5.

Table 5: Heritability of female buffaloes at 3 months of age

N	Heritabilityof body weight at 3 months of age	Reference
367	0.35±0.17	Basu and Rao (1979)
1295	0.47±0.10	Gurung and Johar (1983b)
2277	0.49±0.08	Johari and Bhat (1979a)
201	0.69±0.29	Kirmani *et al* (1984)

The heritability estimates varied from 0.35 ± 0.17 (Basu and Rao 1979) to 0.69 ± 0.29 in graded Murrah buffaloes (Kirmani *et al* 1984). The weighted average of heritability estimates 0.44 in Murrah and 0.50 in graded Murrah buffaloes. The genetic and phenotypic correlations of body weight at 3 months of age in buffaloes with subsequent body weights are presented in Table 6.

Body weight at 3 months of age had very high genetic and phenotypic correlations with subsequent body weights and as the age advanced the magnitude of correlations decreased (Gurung and Johar 1984). The positive genetic and phenotypic correlations of body weight at 3 months of age with successive body weights suggested that animals having higher body weight at 3 months of age tended to be heavier at later ages

Table 6: Genetic and phenotypic correlations of body weight at 3 months of age in buffaloes

Character	**Genetic Correlation**	**Phenotypic Correlation**	**Reference**
Body weight at 6 months age	0.96±0.01	0.80±0.01	Johari and Bhat (1979a)
	-	0.30	Sharma *et al* (1983a)
	0.99±0.00	0.89±0.00	Gurung and Johar (1984)
	0.04±0.25	0.15	Kirmani *et al* (1984)
Body weight at 12 months age	0.74±0.05	0.57±0.02	Johari and Bhat (1979a)
	-	0.21	Sharma *et al* (1983a)
	0.91±0.01	0.75±0.01	Gurung and Johar (1984)
	0.05±0.22	0.17	Kirmani *et al* (1984)
Body weight at 18 monthsage	-	0.30	Sharma *et al* (1983a)
	0.87±0.02	0.69±0.01	Gurung and Johar (1984)
	0.05±0.22	0.15	Kirmani *et al* (1984)
Body weight at 24 months age	0.61±0.07	0.34±0.02	Johari and Bhat (1979a)
	-	0.21	Sharma *et al* (1983a)
	0.77±0.04	0.62±0.01	Gurung and Johar (1984)
	0.06±0.23	0.16	Kirmani et al (1984)
Body weight at 24 Months age	0.61±0.07	0.34±0.02	Johari and Bhat (1979)
	-	0.21	Sharma *et al* (1983a)
	0.77±0.04	0.62±0.01	Gurung and Johar (1984)
	0.06±0.23	0.16	Kirmani *et al* (1984)

2.1.1.3Body Weight at 6 Months of Age

The average body weight of Murrah females at 6 months of age ranged between 88.2 kg (Kaushish 1997) and 127.1 kg (Johari 1976). The variation in body weight at six months of age may be due to the differences in the climate, feeding and management of herds. The averages for body weight at six months of age in Murrah buffaloes as reported by various workers are presented in Table 7. The weighted average for body weight at 6 months of age in Murrah buffaloes was 113.6 kg.

Table 7: Average body weight of female buffaloes at 6 months of age

N	Weight at 6 months (kg)	Reference
295	127.1 ± 1.43	Johari (1976)
289	104.7 ±1.2	Basu and Rao (1979)
1295	125.6±0.8	Gurung and Johar (1983b)
20	92.6±--	Verma and Husain (1985)
301	101.9±2,5	Rao and Lakshminarayana (1994)
587	116,1 ± --	Jogi and Lakhani (1996)
559	88.2±--	Kaushish (1997)
1114	125.3 ± 0.6	Johari (1976)
2291	127.4± 2.8	Johari and Bhat (1979a)
55	142.1 ± 3.1	Sharma *et al* (1983a)
188	118.9 ± 1.6	Kirmani *et al* (1985)
1646	140.7 ± 0.7	Dahama (1991)

The heritability estimate of body weight at 6months of age in Murrah buffaloes ranged between -1.7 ± 0.15 (Gurung and Johar 1983b) and 0.34 ± 0.12 (Tien and Tripathi 1990). Table 8 shows heritability estimates as reported by different workers for weight at 6 months of age Murrah buffaloes.

Table 8: Heritability of female buffaloes at 6 months of age

N	Heritabilityof body weight at months of age	Reference
252	0.22 ± 0.16	Basu and Rao (1979)
1295	-1.7±0.15	Gurung and Johar (1983b)
569	0.34 ± 0.12	Tein and Tripathi (1990)
2201	0.43 ± 0.07	Johari and Bhat (1979a)
201	1.16± 0.36	Kirmani *et al* (1984)

The genetic and phenotypic correlations of body weights at 6 months of age with subsequent body weights at later ages are presented in Table 9. A perusal of table reveals high genetic and phenotypic correlations among successive body weights and as age advances, the magnitude of these correlations decreases.

Table 9: Genetic and phenotypic correlations of body weight at 6 months of age in buffaloes

Character	Genetic Correlation	Phenotypic Correlation	Reference
Body weight at 12 months age	0.81 ± 0.04	0.68 ± 0.01	Johari and Bhat (1979a)
	-	0.60	Sharma *et al* (1983a)
	0.92 ± 0.01	0.83 ± 0.01	Gurung and Johar (1984)
	0.08 ± 0.42	0.28	Kirmani *et al* (1984)
	0.89	0.62	Murdia and Chaudhary (1984)
	2.63	0.59	Ansari *et al* (1989)
	0.62 ± 0.20	0.68 ± 0.03	Tien and Tripathi (1990)
	0.99	0.62	Vijai *et al* (1993a)
Body weight at 18 months age	-	0.37	Sharma *et al* (1983a)
	0.88±0.02	0.75±0.01	Gurung and Johar (1984)
	0.08±0.19	0.23	Kirmani *et al* (1984)
	0.70	0.53	Murdia and Chaudhary (1984)
	0.84	0.47	Ansari *et al* (1989)
	0.17±0.34	0.48±0.04	Tien and Tripathi (1990)
	1.27	0.42	Vijai *et al* (1993a)
Body weight at 24 monthsage	0.71±0.06	0.41±0.02	Johari and Bhat (1979)
	-	0.29	Sharma *et al* (1983a)
	0.78±0.42	0.66±0.01	Gurung and Johar (1984)
	0.09±0.20	0.22	Kirmani *et al* (1984)
	1.95	0.36	Ansari *et al* (1989)
	0.33±0.33	0.47±0.04	Tien and Tripathi (1990)
	020	0.34	Vijai *et al* (1993a)

2.1.1.4 Body weight at 12 months of age

The averages for body weight at 12 months of age as reported by various workers are summarized in Table 10. The average body weight at 12 months of age in Murrah buffaloes females varied from 139.7 kg (Kaushish 1997) to 217.5 kg (Gurung and Johar 1983b). This variation may be due to different management and feeding practices adopted at different farms. The weighted average for body weight at 12 months of age in Murrah buffaloes was 198.2 kg while it was 219.4 kg in graded Murrah buffaloes.

Table 10: Average body weight of female buffaloes at 12 months of age

n	Weight at 12 months (kg)	Reference
227	212.5±2.5	Johari (1976)
213	185.1±1.9	Basu and Rao (1979)
1295	217.5±1.3	Gurung and Johar (1983b)
301	164.4±4.5	Rao and Lakshminarayana (1994)
587	191.8±--	Jogi and Lakhani (1996)
196	139.7±--	Kaushish (1997)
843	211.0±	Johari (1976)
1672	216.1±4.2	Johari and Bhat (1979a)
49	236.1±5.3	Sharma *et al* (1983a)
177	210.5±4.9	Kirmani *et al* (1985)
1648	227.7±1.1	Dahama (1991)

The heritability estimates for body weight at 12 months of age ranged from 0.18 (Basu and Rao 1979) to 0.78 (Gurung and Johar 1983b). The heritability estimates for body weight at one year of age in Murrah buffaloes as reported in literature are presented in Table 11. The weighted average for heritability at 12 months of age was 0.65 in graded Murrah.

Table 11: Heritability estimates of body weight of buffaloes at 12 months of age

N	Heritabilityof body weight at 18 months of age	Reference
195	0.18±0.18	Basu and Rao (1979)
1295	0.78±0.14	Gurung and Johari (1983b)
538	0.19±0.11	Tien and Tripathi (1990)
1598	0.72±0.11	Johari and Bhat (1979a)
201	0.16±0.19	Kirmani *et al* (1984)

Table 12 presents genetic and phenotypic correlations of body weights at 12 months of age in buffaloes with subsequent body weights at later ages. Table 12 revealed high genetic and phenotypic correlations of 12 months body weight with successive body weights and as age advanced, their correlations tended to decrease. Age at first calving has moderate (Kirmani *et al* 1984) to high (Gurung and Johar 1984), negative genetic and phenotypic correlations with 12 months body weight in buffaloes. It means if body weight is more at 12 months of age, age at first calving will be less in buffaloes. Therefore, animals should be properly fed for increasing body weight at12 months of age.

Table 12: Genetic and phenotypic correlations of body weight at 12 months of age in buffaloes

Character	Genetic Correlation	Phenotypic Correlation	Reference
Body weight at 18 months age	-	0.76	Sharma *et al* (1983a)
	0.97±0.01	0.89±0.01	Gurung and Johar (1984)
	0.12±0.37	0.38	Kirmani *et al* (1984)
	1.09	0.83	Murdia and Chaudhary (1984)
	1.62	0.72	Ansari *et al* (1989)
	0.16±0.36	0.70±0.03	Tien and Tripathi (1990)
	0.80	0.64	Vijay *et al* (1993a)
Body weight at 24 monthsage	0.77±0.04	0.64±0.02	Johari and Bhat (1979a)
	-	0.62	Sharma *et al* (1983a)
	0.90±0.01	0.81±0.01	Gurung and Johar (1984)
	0.12±0.39	0.35	Kirmani *et al* (1984)
	1.09	0.83	Murdia and Chaudhary (1984)
	0.672	0.671	Ansari *et al* (1989)
	0.36±0.33	0.65±0.03	Tien and Tripathi (1990)
	0.26	0.55	Vijai *et al* (1993a)

2.1.1.5 Body Weight at 18 Months of Age

The average body weight at 18 months of age in graded Murrah buffaloes varied from 2629 kg (Kirmani *et al* 1985) to 311.2 kg (Sharma *et al* 1983a). The weighted average for body weight at 18 months of age in graded Murrah buffaloes was 279 kg. Average body weights at 18 months of age in Murrah buffaloes as reported by various workers are presented in Table 13.

Table 13: Average body weight of female buffaloes at 18 months of age

n	Weight at 18 months (kg)	Reference
1290	275.1±1.5	Gurung and Johar (1983b)
2400	279.05±0.09	Nautiyal and Bhat (1977)
2400	279.8±---	Nautiyal and Bhat (1979)
45	311.2±6.4	Sharma *et al* (1983a)
188	262.9±2.9	Kirmani *et al* (1985)

The heritability estimates for body weight at18 months of age in Murrah buffaloes ranged from 0.27 (Tien and Tripathi 1990) to 0.77 (Gurung and Johar 1983b) which indicates high additive genetic variance for this trait in Murrah buffaloes. Weighted average for heritability estimate in Murrah buffaloes was 0.62 Heritability estimates for body weight at 18 months of age as given by various researchers are in Table 14.

Table 14: Heritability estimates of body weight of buffaloes at 18 months of age

N	Heritabilityof body weight at 18 months of age	Reference
1290	0.77±0.01	Gurung and Johar (1983b)
505	0.27±0.12	Tien and Tripathi (1990)
2400	0.38±0.08	Nautiyal and Bhat (1979)
201	1.49±0.37	Kirmani *et al* (1984)

Table 15 presents the genetic and the phenotypic correlations of bodyweight at18 months of age with subsequent body weight at 24 months and weight at first calving and reported by various workers. A perusal of Table 15 revealed that body weight at 18 months of age had high genetic and phenotypic

Table 15: Genetic and phenotypic correlations of body weight at 18 months of age in buffaloes

Character	Genetic Correlation	Phenotypic Correlation	Reference
Body weight at 24 monthsage	0.98±0.00	0.73±0.02	Nautiyal and Bhat (1979)
	-	0.84	Sharma *et al* (1983a)
	0.96±0.07	0.90±0.01	Gurung and Johar (1984)
	0.15±0.18	0.42	Kirmani *et al* (1984)
	1.04	0.87	Murdia and Chaudhary (1984)
	0.72±0.18	0.72±0.03	Tien and Tripathi (1990)
	-0.23	0.89	Vijai *et al* (1993a)
Body weight at first calving	0.29±0.19	0.18±0.03	Nautiyal and Bhat (1979)
	0.54±0.10	0.28±0.03	Gurung and Johar (1984)
	0.05±0.32	0.08	Kirmani et al (1984)
	0.75±0.17	0.33±0.06	Tien and Tripathi (1990)

Correlations with body weight at 12 months and weight at first calving (Gurung and Johar 1984, Tien and Tripathi 1990). It means if animal has high body weight at 18 months of age, it tends to have high body weight at 24 months of age and at calving.

2.1.1.6 Body Weight at 24 Months of Age

The average body weight at 24 months of age in Murrah buffaloes varied from 268.6 kg (Rao and Lakshminarayana 1994) to 336.6 kg (Gurung and Johar 1983b). Weighted average for body weight at 24 months of age in Murrah buffaloes was 320 kg. Similarly in graded Murrah buffaloes, weighted average for body weight at 2 years of age was 341.2 kg. Table 16. presents average body weights at 24 months of age in Murrah buffaloes as reported by various workers.

Table 16: Average body weight of female buffaloes at 24 months of age

n	Weight at 24 months (kg)	Reference
300	326,05±2,8	Johari (1976)
1278	336,6±1,6	Gurung and Johar (1983b)
301	268,6±5.5	Rao and Lakshminarayana (1994)
587	307.2±--	Jogi and Lakhani (1996)
1068	325.9±1.5	Johari (1976)
2400	338.0±1.3	Nautiyal and Bhat (1977)
2255	337.1±4.2	Johari and Bhat (1979a)
2400	337.6±--	Nautiyal and Bhat (1979)
-	372.3±6.5	Sharma *et al* (1983a)
198	321.5±3.5	Kirmani *et al* (1985)
1646	369.4±1.6	Dahama (1991)

Similarly Table 17 presents heritability estimates for body weight at 24 months in buffaloes as reported by researchers. Heritability estimates for body weight at 24 months of age in graded Murrah buffaloes ranged from 0.40 (Nautiyal and Bhat 1979) to 1.3 (Kirmani *et al* 1984) with a weighted average of 0.44. This shows that this trait is highly heritable. Weighted average for heritability of 24 months body weight in Murrah buffaloes was 0.63.

Table 17: Heritability estimates of body weight of buffaloes at 24 months of age

n	Heritabilityof body weight at 24 months of age	Reference
1278	0.81±0.14	Gurung and Johari (1983b)
487	0.18±0.11	Tien and Tripathi (1990)
2170	0.43±0.08	Johari (1976)
2170	0.43±0.07	Johari and Bhat (1979a)
2400	0.40±0.08	Nautiyal and Bhat (1979)
201	1.35±0.37	Kirmani *et al* (1984)

Genetic and phenotypic correlations of body weight at 24 months with weight at first calving in buffaloes were positive and high (Tien and Tripathi 1990,Gurung and Johar 1984), whereas negative and high correlations were reported between the body weight at 24 months of age and the age at first calving (Gurung and Johar 1984). Table 18 represents genetic and phenotypic correlations of body weight at 24 months of age in Murrah buffaloes with body weight at first traits as reported by different researchers.

Table 18: Genetic and phenotypic correlations of body weight at 24 months of age in buffaloes

Character	Genetic Correlation	Phenotypic Correlation	Reference
Body weight at first calving	0.45±0.11	0.20±0.02	Johari and Bhat (1979a)
	0.50±0.15	0.19±0.03	Nautiyal and Bhat (1979)
	0.58±0.09	0.29±0.02	Gurung and Johar (1984)
	-.06±0.34	0.12	Kirmani et al (1984)
	0.73±0.22	0.36±0.06	Tien and Tripathi (1990)

2.1.1.7 Body weight at first calving

The averages for body weights at first calving in different buffalo breeds have been summarized in Table 19.

Table 19: Average body weight of female buffaloes at first calving

N	Weight at first calving (kg)	Reference
936	473.9±2.2	Gurung and Johar (1982c)
241	446.5±3.5	Basu *et al* (1984)
628	476.4±4.2	Singh and Basu (1988)
204	448.9±2.7	Parkash *et al* (1988)
1654	510.6±--	Sethi and Nagarcenkar (1992)
301	441.2±8.4	Rao and Lakshminarayana (1994)
957	470.8±1.9	Yadav *et al* (1996)
90	436.9±5.4	Rao and Rao (1997)
141	429.0±39.8	Rao and Sreemannarayana (1998)
820	518.2±2.1	Kanaujia (1973)
2400	480.7±1.2	Nautiyal and Bhat (1977)
2630	483.5±3.3	Johari and Bhat (1979a)

The average body weight at first calving in Murrah buffaloes was lowest (428.0 kg) as reported by Rao and Sreemannarayana (1998) and highest (510.6 kg) as reported by Sethi and Nagarcenkar (1992). Weighted average for body weight at first calving was 479.9 kg in Murrah buffaloes and 487.2 kg in graded Murrah buffaloes.

The heritability estimates for body weight at first calving as reported by various workers are presented in Tale 20. The heritability estimate for body weight at first calving in Murrah buffaloes ranged between 0.10 (Gokhale and Nagarcenkar 1979) and 0.74 (Tien and Tripathi 1990). The weighted averages for the heritability estimates of body weight at first calving in Murrah buffaloes was 0.35.

Table 20: Heritability estimates of body weight of buffaloes at first calving

N	Heritabilityof body weight at first calving	Reference
2089	0.10±0.06	Gokhale and Nagarcenkar (1979)
241	0.19±0.17	Basu *et al* (1984)
628	0.58±0.15	Singh and Basu (1988)
238	0.74±0.26	Tien and Tripathi (1990)
957	0.73±0.14	Yadav *et al* (1996)
2524	0.23±0.05	Johari and Bhat (1979a)
2400	0.15±0.16	Nautiyal and Bhat (1979)
201	0.38±0.24	Kirmani *et al* (1984)

The genetic and phenotypic correlations of body weight at first calving with other economic traits as reported by researchers have been summarized in Table 21.

Findings of Gurung and Johar (1982c) revealed that body weight at first calving had high and negative genetic correlation with age at first calving and positive correlation with total first lactation milk yield. This means that animal with low age at first calving will have high body weight at first calving and high first lactation milk yield. According to Tien and Tripathi (1990), animals with higher age at first calving will have higher body weights at first calving and will yield more milk in first lactation.

2.1.2 Growth Rate

Growth from birth to 24 months of age in different breeds of buffaloes has been reviewed and presented in Table 22.

Growth During Birth to Three Months of Age

The average monthly growth rate from birth to three months of age ranged from 6.4 kg (Verma and Husain 1985) to 15.9kg (Gurung and Johar 1982a) in Murrah buffalo calves. The unweighted average monthly growth was 11.85g. Nautiyal and Bhat (1977) reported that average absolute growth per month was 14.88 kg in grade female buffaloes during birth to three months of age.

Table 21: Genetic and phenotypic correlations of body weight at first calving in buffaloes

Character	Genetic Correlation	Phenotypic Correlation	Reference
Age at first calving	-0.58±0.12	0.13	Gurung and Johar (1982d)
	0.52±0.37	0.46	Basu *et al* (1984)
	0.25±0.25	0.27±0.06	Tien and Tripathi (1991)
	0.2	0.56	Vijai *et al* (1993b)
	-0.04±0.41	-0.10±0.18	Jahageerdar *et al* (1996)
Total first lactation yield	0.26±0.18	0.15	Gurung and Johar (1982d)
	0.12±0.73	0.03	Kirmani *et al* (1984)
	0.66±0.16	0.58±0.12	Singh and Yadav (1987)
	0.16±0.38	0.37±0.07	Vij and Tiwana (1988)
	0.62±0.19	0.21	Singh and Basu (1988)
	0.60±0.25	0.25±0.02	Singh *et al* (1988)
	0.35±0.24	0.02±0.06	Tien and Tripathi (1991)
305 days lactation yield	0.09±0.42	0.007±0.06	Tien and Tripathi (1991)
	-0.65±0.23	0.22±0.07	Vij and Tiwana (1988)

Table 22: Average monthly growth rate during different months of age

Monthly growth rate (kg) from						References
0-3	**3-6**	**6-12**	**12-18**	**18-24**	**0-6**	
				Months of age		
15.9	16.1	15.3	9.6	10.3	---	Gurung and Johar (1982b)
---	---	15.9	12.5	10.2	19.2	Sharma *et al* (1983a)
6.4	14.0	---	---	---	---	Verma and Husain (1985)
---	---	10.8	13.1	11.4	13.1	Tien and Tripathi (1992)
12.6	11.2	10.4	---	---	11.9	Rao and Lakshminarayana (1994)
---	---	12.6	---	---	14.3	Jogi and Lakhani (1996)
12.5	---	---	---	---	---	Nawale *et al* (1997)

2.1.2.2Growth During Three to Six Months of Age

The average unweighted monthly gain in body weight in Murrah buffaloes was 13.8 kg (Table 22). The daily monthly growth rate ranged between 11.2 (Rao and Lakshminarayana 1994) and 16.1 g (Gurung and Johar 1982a) in Murrah buffaloes Table 22). Nautiyal and Bhat (1977) reported that average absolute growth observed per month during 3 to 5 months of age was 18.44 kg and was maximum in graded Murrah female buffaloes.

2.1.2.3Growth During Six to Twelve Months of Age

The monthly growth rate during six to twelve months of age ranged from 10.8 kg (Tien and Tripathi 1992) to 15.9 kg (Sharma *et al* 1983a) in Murrah buffaloes (Table 22). The average unweighted monthly gain in body weight in Murrah buffaloes was 13.0 kg (Table 22). Nautiyal and Bhat (1977) reported that average absolute growth per month during this period was 15.1 kg in grade buffaloes. Growth during six to twelve months of age is lesser than growth during 3 to 6 months of age and this may be due to inadequate digestive capacity and most milk feeding set back.

2.1.2.4 Growth During Twelve to Eighteen Months of Age

A growth rate of 13.1 kg per month has been reported in Murrah buffaloes by Tien and Tripathi (1992) whereas Gurung and Johar (1982a) reported a growth rate of 9.6 kg per month in Murrah buffaloes (Table 22). The average unweighted daily gain in body weight in Murrah buffaloes was 11.7 kg. Nautiyal and Bhat (1977) reported average absolute growth per month during this period as 10.59 kg in graded female buffaloes.

2.1.2.5 Growth During Eighteen to Twenty four Months of Age

The average monthly growth rate from 18 to 24 months of age in Murrah buffaloes ranged from 10.2 kg (Sharma *et al* 1983a) to 11.4 kg (Tien and Tripathi 1992) (Table 22). The unweighted average of the monthly growth was 10.6 kg in Murrah buffaloes. Average absolute growth per month during 18 to 24 months of age in graded buffaloes was 0.83 kg (Nautiyal and Bhat 1977).

2.1.2.6 Growth During Birth to Six Months of Age

The average growth rate during first 6 months of age (Table 22) ranged from 11.9 kg (Rao and Lakshminarayana 1994) to 19.2 kg (Sharma *et al* 1983a) in Murrah buffaloes. The unweighted average of monthly growth was 14.6 kg in Murrah buffaloes (Table 22).

2.2 Mean performance, factors affecting and genetic parameters of first lactation traits

The least squares means along with their standard errors, non-genetic factors affecting first lactation traits and estimates of genetic parameters thave been reviewed and being discussed as per following details:

2.2.1 Age at First Calving (AFC)

A dairy animal starts repaying the expenditure incurred on it after its first calving only. Therefore, lower age at first calving is desirable for early returns. Lower age at first calving also increases the lifetime production of an animal and reduces the generation internal thereby helping in earlier evaluation of sires and faster genetic improvement.

The AFC ranged from 39.90 months (Bhadula and Desai, 1972) to 55.10 months (Yadav *et al*, 1983) (Table 23). Averages based on large number of observations have been reported as 41.27 months by Goswami and Nair (1965), 44.11 months by Gokhale (1974), 42.52 months by Basavaiah (1978), 42.38 months by Johari and Bhat (1979a), 42.51 months by Reddy (1980), 43.52 months by Dutt and Yadav (1988b), 42.66 months by Singh and Basu (1988), and 45.19 months by Gupta *et al* (1994). Chhikara *et al* (1978), and Jain and Taneja (1982) reported much higher values of 54.64 and 54.47 months in Murrah buffaloes of progeny testing farm, Hisar. The higher values might be due to inclusion of a large number of observations on village purchased buffaloes in their studies.

Table 23: Average age of first calving (AFC) along with SE in Murrah buffaloes

N	Mean ± SE (kg)	Non-genetic factors		References
		Period	Season	
1192	41.27 ± 0.14	NS	NS	Goswami and Nair (1965)
477	40.60 ± 0.22	-	-	Tomar and Desai (1968)
165	49.70 ± 0.54	-	-	Raut and Singh (1971)
217	50.39 ± 0.55			Raut and Singh (1971)
67	44.51 ± 0.68			Singh and Singh (1971)
364	39.90 ± 0.72	*	NS	Bhadula and Desai (1972)
94	41.57 ± 0.81			Gurnani *et al* (1976)
732	43.96 ± 15.52			Basu *et al* (1977)
529	43.60 ± 6.35	-	*	Gudi and Narayanhedkar (1977)
1464	43.09 ± 034			Gurnani and Nagarcenkar (1977)
1468	42.52 ± 0.34	-	-	Basavaiah (1978)
380	54.64 ± 0.48	-	-	Chhikara *et al* (1978)
1464	41.31 ± 10.35			Gokhle and Nagarcenkar (1979)
3250	42.38 ± 1.02	**	NS	Johari and Bhat (1979a)
2465	42.51 ± 0.31	**	**	Reddy (1980)
162	42.12 ± 0.53	-	-	Reddy and Mishra (1980)

N	Mean ± SE (kg)	Non-genetic factors		References
		Period	Season	
323	54.47 ± 1.03	**	NS	Jain and Taneja (1982)
200	42.58 ± 10.05			Basu and Sharma (1982)
804	40.93 ± 12.14	S		Sharma (1982)
392	55.10 ± 20.18			Yadav *et al* (1983)
241	43.80 ± 10.65			Basu *et al* (1984)
222	42.34 ± 3.67			Chaurasia *et al* (1984)
329	48.07 ± 0.33	NS	NS	Khosla *et al* (1984b)
1144	43.29 ± 10.85			Kumar (1984)
627	53.86 ± 61.96			Prakash (1984)
253	52.31 ± 9.60			Thevamanoharan *et al* (1984)
356	43.33 ± 10.05			Tomar (1984)
733	44.93 ± 9.13			Das and Balaine (1985)
210	45.03 ± 13.09			El-Arian (1986)
226	50.58 ± 25.55			Singh and Prakash (1986)
1024	46.01 ± 8.21			Singh and Yadav (1986)
209	43.84 ± 0.37	-	-	El-Arian and Tripathi (1987)
418	43.12 ± 0.33	-	-	El-Arian and Tripathi (1987)
190	45.40 ± 0.52	**	NS	Vij and Tiwana (1987)
1256	43.52 ± 0.60	**	NS	Dutt and Yadav (1988b)
100	46.22 ± 0.51	-	-	Ramesh *et al* (1988)
478	48.84 ± 0.50	**	NS	Sharma and Singh (1990)
628	42.66 ± 0.47	-	-	Singh and Basu (1988)
224	43.98 ± 0.38			Prakash *et al* (1988)
595	53.02 ± 5.10			Shreshtha and Yazman (1990)
412	44.78 ± 0.36	**	**	Gajbhiye and Tripathi (1999)
1030	40.83 ± 16.50			Singh and Rathi (1991)
649	49.27 ± 10.50			Mathur and Mathur (1992)
1654	42.95 ± 8.50			Sethi and Nagarcenkar (1992)
716	45.19 ± 0.53	*	*	Gupta *et al* (1994)

N	Mean ± SE (kg)	Non-genetic factors		References
		Period	Season	
320	50.98 ± 0.43	**	NS	Narula *et al* (1994)
415	43.60 ± 0.34	-	-	Dass (1995)
400	42.58 ± 7.00			Lall (1975)
832	44.36 ± 0.25			Nath (1996)
491	44.09 ± 032			Saha (1998)
701	43.88 ± 0.23	S	NS	Dhara (1994)
1647	42.66 ± 13.98			Dutt and Taneja (1994)
146	51.96 ± 2.27	**	NS	Pundir (1994)
118	40.43 ± 25.55			Shah and Sharma (1994)
1440	47.36 ± 10.04			Singh (1995)
2107	44.90 ± 4.20			Kuralkar and Raheja (1997)
1214	46.37 ± 29.00			Kumar (1998)
916	45.65 ± 0.21			Lathwal (2000)
683	44.30 ± 10.60			Jain and Sadana (2000)
615	52.90 ± 0.41			Sethi *et al* (2001)
518	44.18 ± 0.15			Banik (2001)
1164	42.43 ± 0.33			Dutt *et al* (2001)
396	42.93 ± 8.93	S		Singh (2001)
316	43.83 ±0.55	-	-	Gandhi (2002)
314	53.88 ± .48			Gogoi *et al* (2002)
259	53.96 ± 0.35			Kumar *et al* (2002)
848	46.23 ± 21.70			Rana *et al* (2002)
1312	42.65 ± 10.74	S		Bajetha (2003)
400	53.33 ± 51.00			Pundhir *et al* (2003)
744	50.01 ± 25.50	S		Saini *et al* (2003)
230	50.13 ± 28.22	S		Godara *et al* (2004)
227	50.68 ± 0.28			Sharma *et al* (2004)
115	46.63 ± 1.30			Suresh *et al* (2004)
221	44.90 ± 0.02			Sethi (2005)

N	Mean ± SE (kg)	Non-genetic factors		References
		Period	Season	
1352	40.83 ± 16.53			Dahiya (2006)
105	43.91 ± 24.88			Sachan *et al* (2006)
1200	44.98 ± 0.21	S	S	Wakchaure *et al* (2008)
249	43.57 ± 0.41	S	S	Gupta (2009)
560	43.66 ± 0.86	S	NS	Nawale (2010)
707	45.48 ± 0.13	S	NS	Patil (2011)

Period : The significant effect of period of birth on AFC was reported by Bhadula and Desai (1972), Johari and Bhat (1979a), Reddy (1980), Jain and Taneja (1982), Sharma (1982), Chaurasaia *et al* (1984), Reddy and Taneja (1982), Mishra *et al* (1986), Singh *et al* (1987), Vij and Tiwana (1987), Dutt and Yadav (1988), Sharma and Singh (1990), Gajbhiye and Tripathi (1999), Dhara (1994), Gupta *et al* (1994), Narula *et al* (1994), Pundir (1994), Singh (2001), Bajetha (2003), Saini *et al* (2003), Godara *et al* (2004), Dahiya (2006), Wakchure *et al* (2008), Gupta (2009), Nawale (2010) and Patil (2011).

The non-significant effect of period of birth on AFC was reported by Goswami and Nair (1965), Khosla *et al* (1984b), Ulganathan *et al* (1985), Singh and Yadav (1986), Singh (1995), Kumar (1998), Saha and Sadana (2000), Sule *et al* (2001) and Gogoi *et al* (2002).

Reddy (1980) reported significant effect of year of calving on AFC which he attributed to the varying conditions of climate and differences in availability of feed and fodder over the years.

Jain and Taneja (1982) reported significant effect of period of calving. In general, there was a decline in AFC over the years which was attributed to improved management conditions over the years.

Sharma and Singh (1990) observed significant effect of year of calving on AFC which they attributed to the differences in the availability of inputs and climatic conditions.

Pundir (1994) reported significant effect of period of birth on AFC; an increasing trend in AFC upto 3rd period and thereafter a decline was observed. Similarly, Narula *et al* (1994) reported significant effect of period of calving on AFC. They observed an increase in AFC from period 1 to 2 and thereafter a continuous decline upto the 5th period.

Season: The effect of season of birth was found to be significant on AFC by Gudi and Narayanhedkar (1977),Reddy (1980), Gogoi *et al* (1985),Mishra *et al* (1986), Singh *et al* (1987), Gajbhiye and Tripathi (1999),Sethi and Nagarcenkar (1992), Sahana (1993),Gupta *et al* (1994), Bajetha (2003), Wakchure *et al* (2008) and Gupta (2009).

The non-significant effect of season of birth on AFC was reported by Goswami and Nair (1965), Johari and Bhat (1979a), Jain and Taneja (1982), Chaurasaia *et al* (1984), Khosla *et al* (1984b), Ulganathan *et al* (1985), Singh and Yadav (1986), Vij and Tiwana (1987), Dutt and Yadav (1988b), Sharma and Singh (1990), Sharma (1996), Dhara (1994), Narula *et al* (1994), Pundir (1994),Dass (1995),Nath (1996), Kumar (1998), Saha and Sadana (2000), Singh (2001), Gogoi *et al* (2002), Godara *et al* (2004), Dahiya (2006), Nawale (2010) and Patil (2011).

Goswami and Nair (1965) found non-significant effect of season of birth on AFC. The off-season calvers were reported to have significantly higher AFC when compared to in-season calvers.

Reddy (1980) reported the significant differences among months in his study were due to availability of plenty of good quality fodder for winter calvers whereas in summer, there was scarcity of fodder.

It can therefore be summarized that in most of the studies period/year of birth had significant effect on AFC whereas the effect of season of calving was found non-significant.

2.2.2 305-Dav or Less Milk Yield (305 MY)

Milk yield is the most important trait in dairy animals as it is directly related with the income to a dairyman. Most of the buffaloes complete their lactation within 305 days, and more than 80% of the milk in a lactation of a buffaloes is produced during this period. This trait has also been considered the most important for evaluation and selection of dairy bulls.

The 305 MY ranged between 1355.4 kg (Sharma and Singh, 1990) and 1964.0 kg (Singh *et al*,1990) (Table 24). Average F305MY, based on large number of observations has been reported as 1612.8 kg by Gurnani and Nagarcenkar (1977), 1392.0 kg by Basavaiah (1978), 1753.0 kg by Sreedharan and Nagarcenkar (1978), 1532.1 kg by Patro and Bhat (1979a), 1634.8 kg by Reddy (1980), 1691.0 kg by Kumar (1984), 1964.0 kg by Singh *et al* (1990) and 1457.6 kg Iype and Nagarcenkar (1992).

Period: The significant effect of period of calving on F305MY was reported by Patro and Bhat (1979b), Reddy (1980), Jain and Taneja (1982), Kumar (1984),El-Arian (1986), Gajbhiye (1987), Tomar and Tripathi (1988), Singh *et al* (1990), Iype and Nagarcenkar (1992), Sahana (1993), Dass and Sharma (1994), Dhara (1994), Dass (1995), Nath (1996), Jain and Sadana (1998), Saha (1998), Wakchure *et al* (2008), Gupta (2009) and Patil (2011).

The non-significant effect of period of calving on 305 MY was reported by Sharma and Singh (1990) and Shabade *et al* (1993).

Patro and Bhat (1979b) reported 'that buffaloes calving in most calving season had significantly lower milk yield when compared to those calving in least calving season.

Reddy (1980) reported significant effect of year of calving on 305 MY in Murrah buffaloes. The significant variation between years was attributed to the varying conditions of climate and availability of feed and fodder.

Jain and Taneja (1982) reported significant effect of period of calving on milk yield, but no definite trend was observed over the periods.

El-Arian (1986) observed significant effect of period of calving on 305 MY both for Karnal and Ambala farms. An increasing trend over the periods was observed for both the farms attributable to better mangemental practices followed over the periods.

Singh *et al* (1990) reported significant effect of period and season of calving on first lactation 300-days milk yield. They ascribed the increasing trend observed over the years to extensive use of superior sires.

Season: The significant effect of season of calving on 305 MY was reported by Patro and Bhat (1979b), Reddy (1980), Kumar (1984), El-Arian (1986), Gajbhiye (1987), Hatwar and Chawla (1988), Singh *et al* (1990), Dass and Sharma (1994) and Nath (1996).

The non-significant effect of season of calving on 305 MY was reported by Jain and Taneja (1982), Sharma (1982), Sharma and Singh (1990) Tomar and Tripathi (1988), Iype and Nagarcenkar (1992), Sahana (1993), Shabade *et al* (1993), Dhara (1994), Dass (1995), Jain and Sadana (1998), Saha (1998), Wakchure *et al* (2008), Gupta (2009) and Patil (2011).

Gajbhiye (1987) reported the effect of season was observed to be significant for Karnal farm and non significant for Ambala farm. At Karnal farm the spring season calvers had maximum yield followed by summer and winter season calvers.

El-Arian (1986) observed significant effect of season of calving was attributed to climate and nutritional conditions varying from season to season. The summer calvers produced more milk followed by winter, autum and rainy season calvers, in general, at both the farms.

It can therefore be summarized that in most of the studies the effect of period/year of calving was reported to be significant on 305 MY whereas the effect of season/month was reported to be significant by some workers and non significant by others.

2.2.3 Lactation Length (LL)

The first lactation length in Murrah buffaloes ranged from 267.15 days (Suresh *et al*, 2004) to 373.10 days (Sharma and Singh 1988) with most of the values falling around the average lactation period of 300 days (Table 25). The LL (in days) based on large no. of observations has been reported to be 299 (Gurnani and Nagarcenkar,1977), 300.07 (Gokhle and Nagarcenkar,1979), 291.70 Patro and Bhat (1979a), 301.40 Iype (1980), 310.86 (Kumar,1984), 308.27 (Kumar,1998), 302.10 (Singh,1995),295 (Dutt *et al* ,2001) , 303.74 (Yadav *et al* ,2002), 308.27 (Kumar *et al*, 2003) and 321.21 (Wakchaure, 2007).

Period: The differences in lactation length among various periods reported to be significant by Umrikar and Deshpande (1985b), Vij (1984), Bhalaru and Dhillon (1987), Singh *et al* (1987), Sharma and Singh (1990), Neog *et al* (1993), Sahana (1993), Das and Sharma (1994), Dhara (1994), Dass (1995), Nath (1996), Kumar (1998), Dass and Sadana (2000), Bajetha (2003), Kundu *et al* (2003a), Wakchaure (2007) and Gupta (2009).

The differences in lactation length among various periods reported to be non-significant by El-Arian (1986), Shabade *et al* (1993), Singh (1995), Singh (2001) and Godara *et al* (2004).

Season: The effect of season of calving on LL, reported to be significant by Gurnani *et al* (1976), Basu and Gahi (1978b),Johri and Bhat (1979b), Umrikar and Deshpande (1985a),Singh *et al* (1987), Mohamed *et al* (1993), Nath (1996),Kumar (1998), Dass and Sadana (2000), Godara *et al* (2004) and Pander *et al* (2004).

The effect of season of calving on LL, reported to be non-significant by Kumar and Bhat (1978), Kannaujia and Balaine (1975), Khosla *et al* (1985),Sharma and Singh (1990),Sahana (1993), Shabade *et al* (1993), Das and Sharma (1994), Dhara 1994, Rao *et al* (1994), Dass 1995, Singh (2001),Kundu *et al* (2003b), Sachan *et al* (2006), Wakchaure 2007and Gupta (2009).

2.2.4 Lactation Milk Yield (LY)

The average first lactation milk yield in Murrah buffaloes ranging from 1067.06 kg (Neog *et al* 1993) to 2426.20 kg (Khosla *et al* 1984a) (Table 26). The LY (in kgs) based on large no. of observations has been reported to be 1694.60 (Gurnani and Nagarcenkar, 1977),1540.65 (Gokhle and Nagarcenkar, 1979),1575.80 (Patro and Bhat, 1979a), 1533.30 (Iype, 1980), 1752.85 (Kumar, 1984), 2041 (Singh *et al* ,1990),2040.50 (Singh and Rathi,1991),1621.06 (Dutt and Taneja,1994), 1853 (Kuralkar and Raheja,1997), 1627 (Dutt *et al* ,2001), 1646.09 (Yadav *et al* , 2002) and 1711.74 (Bajetha, 2003). Most of the values ranged for first lactation milk yield between 1500 and 1750 kg.

Period: The differences in first complete lactation milk yield among various periods reported to be significant by Gokhle and Nagarcenkar (1979), Iype (1980),Gurung and Johar (1982a), Sharma (1982), Kumar (1984), Reddy and Taneja (1982), EI-Arian (1986), Dutt and Taneja (1994), Kumar (1998)Dass and Sadana (2000), Singh (2001), Bajetha (2003) and Godara *et al* (2004).

The differences in first complete lactation milk yield among various periods reported to be non-significant by Prakash (1984) and Pander *et al* (2004).

Season : The differences in first complete lactation milk yield among various seasons reported to be significant by Gokhle and Nagarcenkar (1979), Kumar (1984), EI-Arian (1986), Agrawal *et al* (1987), Singh *et aI.* (1987), Neog *et al* (1993), Dutt and Taneja (1994), Dass and Sadana (2000), Sule *et al* (2001),Bajetha (2003), and Godara *et al* (2004).

The differences in first complete lactation milk yield among various seasons reported to be non-significant by Prakash (1984), Kumar (1998), Singh (2001) , Bajetha (2003) in Murrah buffaloes.

2.2.5 Milk Yield per Day of Lactation Length (MYLL)

The trait is important to know the milk producing capacity of animal. The range of the average milk yield per day of first lactation length was 3.73 ± 0.86 (Sharma, 1982) to 8.60 kg/day (Khosla *et al* 1984a) (Table 27).

Period : Significant effect of period of calving on first lactation average daily milk yield was observed by Sharma (1982), Kumar (1984),El-Arian (1986), Hatwar and Chawla (1988), Sahana (1993) and Nath (1996) while non-significant effect was observed by Khosla *et al* (1984a) and Shabade *et al* (1993).

Season: Significant effect of season of calving on first lactation average daily milk yield was observed by Kumar (1984), El-Arian (1986), Hatwar and Chawla (1988) and Nath (1996) while non significant effect of season of calving was observed by Sharma (1982), Khosla *et al* (1984a), Sahana (1993) and Shabade *et al* (1993).

2.2.6 Peak Milk Yield (PY)

This trait gives us the maximum amount of milk given by buffalo in a single day during the lactation. It gives rough idea of milk producing ability of an animal. Various researchers reported peak milk yield in Murrah buffaloes and the same has been presented in Table 28. The range of peak yield observed was from 6.34 kg (Neog *et al* 1993) to 11.35 kg (Khosla *et al* 1985).

2.2.7 Days to Reach Peak Milk Yield (DRPY)

The time taken to reach peak milk yield from date of calving in Murrah buffaloes as reported by different researchers has been presented in Table 29. This trait gives an idea of persistency of milk production as the animal which reaches peak yield in less number of days is expected to be more consistent in milk production. The values of DRPY ranged from 31.45 days (Rao and Rao 1996) to 66.90 days (Raizada *et al* 1971). Rao and Rao (1994) reported that Murrah buffaloes took on an average 32 days to show peak milk yield estimated over different lactations.

2.2.8 Weight at Calving (WAC)

The average figures along with SE for body weight at first calving in Murrah buffaloes (Table 20), ranged from 420.12 ± 2.35 kg (Das and Balaine, 1985) to 503.92 ± 4.55 kg (Singh, 1995).

Period : Significant effect of period of calving on body weight at first calving in Murrah buffaloes was observed by Gokhle and Nagarcenkar (1979), Iype (1980), Gurung and Johar (1982d), Singh (1995) and Dahiya 2006).

However, non-significant effect of period of calving on body weight at first calving in Murrah buffaloes was observed by Kumar (1998) and Bajetha (2003).

Season : Significant effect of season of calving on body weight at first calving in Murrah buffaloes was observed by Gurung and Johar (1982d), and Das and Balaine (1985).

However, the non-significant effect of season of calving on body weight at first calving in Murrah buffaloes was observed by Chaurasia *et al* (1980), Singh (1995), Kumar (1998), Bajetha (2003) and Dahiya (2006).

Table 24: Average performance, SE and effect of non genetic factors on first lactation 305-days or less milk yield in Murrah buffalo

N	Mean ± SE (kg)	Non-genetic factors		References
		Period	Season	
1464	1612.8±11.8	-	-	Gurnani and Nagarcenkar (1977)
1392	1392.0±1.8	-	-	Basavaiah (1978)
2138	1532.1±5.7	**	**	Patro and Bhat (1979a,b)
2223	1634.8±3.2	**	**	Reddy (1980)
323	1456.6±58.3	*	NS	Jain and Taneja (1982)
1144	1691.0±8.3	**	*	Kumar (1984)
210	1768.2±9.9	**	*	El-Arian (1986)
599	1747.9±32.0	**	**	El-Arian (1986)
221	1706.7	-	-	Vij and Tiwana (1986a)
396	1526.9±33.9	**	*	Gajbhiye (1987)
445	1635.3±30.5	**	NS	Gajbhiye (1987)
233	1671.42±47.17			Prakash *et al* (1988)

N	Mean ± SE (kg)	Non-genetic factors		References
		Period	Season	
100	1705.2±5.9	-	-	Ramesh *et al* (1988)
478	1355.40±18.96	NS	NS	Sharma and Singh (1990)
628	1707.40±28.50	-	-	Singh and Basu (1988)
318	1413.30±30.70	S	NS	Tomar and Tripathi (1988)
1352	1964.00±38.60	S	S	Singh *et al* (1990)
1926	1457.60±9.10	S	NS	Iype and Nagarcenkar (1992)
424	1785.19±22.19	S	NS	Sahana (1993)
94	1392.20±122.60	NS	NS	Shabade *et al* (1993)
404	1648.00±22.00	S	S	Dass and Sharma (1994)
690	1606.89±23.94	S	NS	Dhara (1994)
628	1752.62±21.22	**	NS	Dass (1995)
628	1784.90±16.70	S	S	Nath (1996)
524	1748.70±26.70	S	NS	Jain and Sadana (1998)
491	1957.58±21.48	S	NS	Saha (1998)
518	1794.87±22.12			Banik (2001)
518	1794.00±22.12	-	-	Banik and Tomar (2002)
571	1644.57±121.08			Taraphder *et al* (2003)
143	1469.19±43.97			Suresh *et al* (2004)
176	1637.60±41.49	-	-	Geetha (2005)
441	1910.53±28.72	-	-	Katneni (2007)
1161	-	S	NS	Wakchaure *et al* (2008)
248	-	S	NS	Gupta (2009)
702	1754.79±28.57	S	NS	Patil (2011)

Table 25: Average performance, SE and effect of non genetic factors first lactation length in Murrah buffalo

N	Mean ± SE (kg)	Non-genetic factors		References
		Period	Season	
696	294.09 ±2.22			Jawarkar and Johar (1975a)
110	283.00 ±6.00			Gurnani *et al* (1976)
1664	299.00 ±1.70			Gurnani and Nagarcenkar (1977)
481	296.12 ±2.77			Singh (1977)
2089	300.07 ±1.18			Gokhle and Nagarcenkar (1979)
2137	291.70 ±4.67			Patro and Bhat (1979b)
1846	301.40 ±1.20			Iype (1980)
200	324.12 ±28.00			Basu and Sharma (1982)
909	287.40 ±9.00			Gurung and Johar (1982b)
392	313.25 ±3.35			Yadav *et al* (1983)
491	285.22 ±2.64			Gogoi *et al* (1984)
1144	310.86 ±3.18			Kumar (1984)
733	297.28 ±2.32			Das and Balaine (1985)
210	325.71 ±7.55			El-Arian (1986)
450	307.07 ±3.94			Gajbhiye (1987)
413	311.33 ±4.25			Gajbhiye (1987)
1214	308.27 ±3.89			Kumar (1998)
478	373.10 ±5.80	S	NS	Sharma and Singh (1990)
628	321.42 ±5.06			Singh and Basu (1988)
595	272.00 ±0.24			Shreshtha and Yazman (1990)
280	294.40 ±5.80			Tein and Tripathi (1991)
649	273.75 ±0.52			Mathur and Mathur (1992)
716	324.02 ±2.54			Raheja (1992a)
105	274.60 ±12.60			Neog *et al* (1993)
424	302.68 ±3.08	S	NS	Sahana (1993)
114	357.90 ±12.99	NS	NS	Shabade *et al* (1993)
404	306.00 ±4.00	S	NS	Dass and Sharma (1994)
683	289.55 ±3.68	S	NS	Dhara (1994)

N	Mean ± SE (kg)	Non-genetic factors		References
		Period	Season	
1647	329.19 ±2.71			Dutt and Taneja (1994)
149	329.40 ±3.90	-	-	Rao and Sreemannarayana (1994)
628	324.99 ±3.36	S	NS	Dass (1995)
1440	302.10 ±3.61			Singh (1995)
-	317.64 ±2.58	S	S	Nath (1996)
2107	341.00 ±1.90			Kuralkar and Raheja (1997)
615	335.50 ±5.10			Sethi and Khatkar (1997)
491	311.51 ±2.89			Saha (1998)
161	290.26 ±0.42			Shrivastava *et al* (1998)
415	313.19 ±2.77			Dass and Sadana (2000)
669	309.01 ±2.41			Lathwal (2000)
518	306.63 ±3.53			Banik (2001)
1164	295.00 ±2.10			Dutt *et al* (2001)
396	305.33 ±3.52			Singh (2001)
259	319.49 ±4.54	-	-	Kumar *et al* (2002)
848	313.00 ±3.19		-	Rana *et al* (2002)
-	319.50 ±4.97	-	-	Sheoron *et al* (2002)
1003	303.74 ±5.92	-	-	Yadav *et al* (2002)
273	310.07 ±2.89			Aziz *et al* (2003)
1214	308.27 ± 3.89			Kumar *et al* (2003)
311	291.52 ±2.53			Kundu *et al* (2003a)
400	342.00 ±16.00			Pundhir *et al* (2003)
230	307.89 ±5.96			Godara *et al* (2004)
337	301.37 ±1.30			Pander *et al* (2004)
624	267.15 ±8.52			Suresh *et al* (2004)
176	278.26 ±3.19	-	-	Geetha (2005)
105	269.69 ±4.87			Sachan *et al* (2006)
441	323.62 ±3.73	-	-	Katneni (2007)
1161	321.21 ±2.25	S	NS	Wakchaure (2007)
248	326.13 ±6.70	S	NS	Gupta (2009)

Table 26: Average first lactation milk yield (LY) along with SE in Murrah buffaloes

No. of observations	Mean ± SE	Author (s)
988	1605.70 ±5.50	Bawa (1975)
696	1557.75 ±11.11	Jawarkar and Johar (1975b)
1464	1694.60 ±4.60	Gurnani and Nagarcenkar (1977)
481	1694.94 ±349.60	Singh (1977)
380	1521.27 ±10.80	Chhikara *et al* (1978)
2089	1540.65 ±9.76	Gokhle and Nagarcenkar (1980)
2137	1575.80 ±36.58	Patro and Bhatt (1979a)
1846	1553.30 ±10.20	Iype (1980)
610	1665.00 ±15.20	Sindhu *et al* (1981)
896	1665.25 ±68.65	Gurung and Johar (1982c)
253	1492.95 ±37.09	Reddy and Mishra (1983)
804	1720.33 ±38.99	Sharma (1982)
269	1661.36 ±56.49	Chakravarty and Rathi (1983)
246	1442.10 ±53.50	Swain and Bhatnagar (1983)
392	1564.86 ±23.69	Yadav *et al* (1983)
329	2426.20 ±19.98	Khosla *et al* (1984a)
1144	1752.85 ±30.90	Kumar (1984)
253	1758.87 ±30.60	Thevamanoharan *et al* (1984)
290	1561.30 ±31.70	Tomar (1984)
733	1587.86 ±17.51	Das and Balaine (1985)
171	1944.15 ±629.84	Asghar (1986)
210	1758.42 ±51.84	El-Arian (1986)
226	1570.00 ±41.89	Singh and Prakash (1986)
478	1654.00 ±4.40	Hatwar and Chawla (1988)
628	1707.37 ±28.51	Singh and Basu (1988)
478	1355.50 ±18.90	Sharma and Singh (1990)

No. of observations	Mean ± SE	Author (s)
1352	2041.00 ±5.20	Singh *et al* (1990)
1030	2040.50 ±51.90	Singh and Rathi (1991)
649	2335.07 ±12.88	Mathur and Mathur (1992)
716	1737.00 ±64.92	Raheja (1992a)
105	1067.06 ±60.10	Neog *et al* (1993)
1647	1621.06 ±43.81	Dutt and Taneja (1994)
2107	1853.00 ±11.50	Kuralkar and Raheja (1997)
615	1693.00 ±29.70	Sethi and Khatkar (1997)
161	1659.37 ±2.99	Shrivastava *et al* (1998)
493	1402.10 ±66.95	Singh and Singh (1999)
415	2067.74 ±23.86	Dass and Sadana (2000)
683	1732.44 ±46.50	Jain and Sadana (1998)
1164	1627.00 ±24.00	Dutt *et al* (2001)
396	1549.29 ±27.29	Singh (2001)
848	1701.00 ±26.40	Rana *et al* (2002)
408	2123.81 ±53.10	Sil *et al* (2002)
1003	1646.09 ±36.62	Yadav *et al* (2002)
273	2357.30 ±10.20	Aziz *et al* (2003)
1312	1711.74 ±20.94	Bajetha (2003)
400	1068.00 ±56.00	Pundhir *et al* (2003)
230	2053.78 ±51.50	Godara *et al* (2004)
337	1944.65 ±26.50	Pander *et al* (2004)
303	2342.47 ±6.70	Sarkar *et al* (2004)
624	1429.17 ±49.67	Suresh *et al* (2004)
458	2033.00 ±37.00	Sethi (2005)
105	1941.00 ±41.00	Sethi (2005)
287	1273.17 ± 15.38	Warade *et al* (2005)

Table 27: Average performance, SE and effect of non-genetic factors on average milk yield per day of lactation in Murrah buffalo (MYLL)

N	Mean ± SE (kg)	Non-genetic factors		References
		Period	Season	
2223	5.68 ±0.07	-	-	Reddy (1980)
804	3.73 ±0.86	S	NS	Sharma (1982)
392	5.20 ±0.62	-	-	Yadav *et al* (1984)
1144	5.65 ±0.08	S	S	Kumar (1984)
1108	8.60	NS	NS	Khosla *et al* (1984a)
210	4.83 ±0.10	S	S	El-Arian (1986)
1823	5.13 ±0.31	-	-	Singh and Yadav (1987)
478	5.43 ±0.07	S	S	Hatwar and Chawla (1988)
605	6.25 ±0.06	S	NS	Sahana (1993)
114	5.07 ±0.17	NS	NS	Shabade *et al* (1993)
149	5.71 ±0.65	-	-	Rao and Sreemannarayana (1994)
-	5.92 ±0.04	S	S	Nath (1996)
-	6.75 ±0.10	-	-	Katneni (2007)
-	7.50	-	-	Annual Report, NDRI (2010)

Table 28: Peak milk yield (kg) in Murrah buffaloes (PY)

No. of observations	Mean ± SE	Author (s)
100	7.50 ±0.15	Rao *et al* (1970)
80	6.90 ±0.16	Rao *et al* (1970)
67	6.67 ±0.40	Raizada *et al* (1971)
409	7.49 ±0.09	Sane *et al* (1972)
1464	8.30 ±0.05	Gurnani and Nagarcenkar (1977)
118	9.18	Garcha and Tiwana (1980)
392	7.78 ±0.24	Yadav *et al* (1983)
206	7.05 ±0.14	Saxena and Tomar (1984)
1108	11.35 ±0.17	Khosla *et al* (1985)
220	10.3	Vij and Tiwana (1986b)
224	8.73 ±0.18	Prakash and Tripathi (1987)
100	9.05 ±0.10	Ramesh *et al* (1988)
135	9.61 ±0.18	Singh *et al* (1990)
399	9.64 ±0.14	Sahana (1993)
105	6.34 ±0.16	Neog *et al* (1993)
369	7.80 ±0.20	Rao and Rao (1994)
628	10.46 ±0.14	Dass (1995)
25	9.25 ±0.21	Shrivastava *et al* (1998)
311	7.61 ±0.11	Kundu *et al* (2003b)
143	10.44 ±0.23	Suresh *et al* (2004)

Table 29: Days to reach peak milk yield in Murrah buffaloes (DRPY)

No. of observations	Mean ± SE	Author (s)
137	66.90 ±12.0	Raizada *et al* (1971)
118	57.18	Garcha and Tiwana (1980)
105	58.30 ±5.50	Neog *et al* (1993)
369	32.00 ±1.00	Rao and Rao (1994)
263	31.45 ±0.76	Rao and Rao (1996)
311	46.77 ±1.77	Kundu *et al* (2003b)
143	35.38 ±1.42	Suresh *et al* (2004)
176	65.25 ±1.71	Geetha (2005)

Table 30: Average weight at first calving (WAC) along with S.E. in buffaloes

No. of observations	Mean ± SE	Author (s)
2400	480.76 ±1.20	Nautiyal and Bhat (1977)
481	500.66 ±2.35	Singh (1977)
2089	477.37 ±1.62	Gokhle and Nagarcenkar (1979)
222	449.37 ±1.68	Chaurasia *et al* (1980)
1044	468.00 ±1.90	Iype (1980)
936	473.93 ±2.24	Gurung and Johar (1982d)
241	446.59 ±3.59	Basu *et al* (1984)
733	420.12 ±2.35	Das and Balaine (1985)
1024	498.47 ±4.40	Singh and Yadav (1988)
204	448.97 ±27.00	Prakash *et al* (1988)
628	476.47 ±4.25	Singh and Basu (1988)
1030	497.00 ±5.00	Singh and Rathi (1991)
1440	503.92 ±4.55	Singh (1995)
1214	501.59 ±4.04	Kumar (1998)
396	500.36 ±3.04	Singh (2001)
1352	497.06 ±5.04	Dahiya (2006)

2.2.9 Farm/Herd affecting first lactation traits

The effect of farm on first lactation traits had been found to be significant by Dass and Sadana (2000) for FLMY and FLP; Gokhle and Nagarcenkar (1979), Singh (1995), Kumar (1998) and Singh (2001) for FLMY and WFC; Iype (1980) for FLMY and WFC; Dutt *et al* (1985), Gogoi *et al* (1985), Singh and Yadav (1986), Dutt and Taneja (1994) and Gogoi *et al* (2002) for AFC; Gurung and Johar (1982c), Das and Balaine (1985), Singh and Yadav (1986), Bajetha (2003) and Dahiya (2006) for WFC.

The farm effect had been observed to be non-significant by Bajetha (2003) for AFC and FLMY, and Pander *et al* (2004) for FLMY and FLP; Chaurasia *et al* (1984), Mishra *et al* (1983), Singh and Yadav (1987), Kumar (1998), and Dahiya (2006) for AFC; Chaurasia *et al* (1985), Singh (1995) and Singh (2001) for FCI; Kannaujia and Balaine (1975) and Sharma and Singh (1990) for FLP; and Chaurasia *et al* (1983), Yadav *et al* 1983) and Narsimharao and Shreemannarayana (1994) for FSP traits in Murrah buffaloes.

2.2.10 Estimates of genetic parameters of first lactation traits

Knowledge about the magnitude of heritability gives an indication about the scope for affecting genetic improvement through selection or culling of animals.

Heritability Estimates

Knowledge of the heritability estimates of economic traits is very essential for planning efficient breeding programmes, the information about the pattern of inheritance of body weights at different ages and various first lactation traits should, therefore, help in assessing the usefulness of these traits in the selection of animals for improving their productivity.

2.2.10.1 Age at First Calving (AFC)

The heritability estimates of AFC observed by various workers have been presented in Table 31. A moderate to high heritability value was reported by Gurung and Johar (1982a) as 0.35 ± 0.09, Basu *et al* (1984) as 0.35 ±0.20, Prakash (1984) as

0.36 ± 0.21, EI-Arian (1986) as 0.31 ± 0.21, Singh and Basu (1988) as 0.43 ± 0.14, Tein and Tripathi (1990) as 0.61 ± 0.29, Dutt and Taneja (1995) as 0.45 ± 0.09, Singh (1995) as 0.57 ± 0.09, Jain and Sadana (1998) as 0.30 ± 0.12, Gogoi *et al* (2002), and Bajetha (2003) as 0.30 ± 0.11 in Murrah buffaloes.

The high heritability value was reported by Kirmani *et al* (1984) as 0.68 ± 0.29, Singh and Prakash (1986) as 0.82 ± 0.10, Tein and Tripathi (1990) as 0.61 ± 0.29, Singh (1995) as 0.57 ± 0.59, Gogoi *et al* (2002) as 0.88 ± 0.44 in Murrah buffaloes. The low heritability was reported by Gokhle and Nagarcenkar (1979) as 0.12 ± 0.06, Sharma (1982) as 0.20 ± 0.10, Kumar (1984) as 0.15 ± 0.06, Raheja (1992) as 0.24 ± 0.16, Dutt and Taneja (1995) as 0.23 ± 0.07, Kumar (1998) as 0.09 ± 0.06, Saha and Sadana (2000) as 0.09 ± 0.12, Thevamanoharan *et al* (2002) 0.04 ± 0.03, Jain and Sadana (2000a) as 0.17 ± 0.07, Singh (2001) as 0.11 ± 0.01, Thevamonoharan *et al* (2002) as 0.003 ± 0.01 and Warade *et al* (2005) as 0.00 in Murrah buffaloes.

2.2.10.2 305 Day or Less Milk Yield (305MY)

The heritability estimates of 305 MY in Murrah were reported to range between 0.02 and 0.54 (Table 32). However, in most of the herds, the heritability estimates were moderate and ranged between 0.14 and 0.38. Gajbhiye (1987) reported low heritability estimates of 0.06 ± 0.11 for buffaloes at Karnal farm. High heritability estimate of 0.54 ± 0.23 was reported by Khan and Johar (1988) for military dairy farms and 0.42 ± 0.016 by Gajbhiye (1987) for military dairy farm, Ambala.

The moderate heritability estimates of F305MY in buffaloes suggested that there is reasonable scope of improvement in this trait. This also suggested the need of progeny testing of the buffalo bulls for increasing the accuracy of sire evaluation. The progeny tested and proven bulls could then be used in a number of herds/farms through artificial insemination.

2.2.10.3 Lactation Length (LL)

The heritability values of FLL as reported by various workers are given in Table 2.10. The heritability estimates for the trait ranged from 0,028 ± 0.11 to 0.42 ± 0.18 in Murrah buffaloes (Table 33).

Most of the workers found low genetic base for the trait first lactation period in Murrah buffaloes (Basavaiah *et al* 1978; Gurung and Johar 1982a; Sharma, 1982; Kumar, 1984; EI-Arian, 1986; Verma and Yadav, 1989; Raheja, 1992a; Raheja, 1993; Dutt and Taneja, 1994; Singh, 1995; Dass and Sadana, 2000; Thevamanoharan *et al,* 2002, and Aziz *et al,* 2003). Yadav *et al* (2002) observed the high heritability value of FLP, whereas Warade *et al* (2005) found a moderate heritability for some traits in Murrah buffaloes.

2.2.10.4 Lactation Milk Yield (LY)

The heritability estimates of FLMY available in the literature have been presented in Table 34. The heritability estimates for the trait ranged from -0.002 ± 0.07 to 0.42 ± 0.12. Jawarkar and Johar (1975b), Basavaiah (1978), Gurung and Johar (1982c), Kumar (1984), Kirmani *et. al.* (1984), Umrikar and Deshpande (1985b), Kandaswamy *et al* (1993), Singh (1995), Sethi and Khatkar (1997), Jain and Sadana (1998), Thevamanoharan *et al* (2000), Jain and Sadana (2000), Singh (2001), Thevamanoharan *et al* (2002), Tonhati *et al* (2004) and Chandra *et al* (2006) reported low heritability of FLMY in Murrah buffaloes. However, Sharma (1982), Mishra *et al* (1983), Dass and. Sadana (2000) and Yadav *et al* (2002) observed moderate heritability of FLMYin the same buffalo breed.

2.2.10.5 Milk Yield per day of Lactation Length (MYLL)

Heritability for First lactation daily milk yield in Murrah Buffalo as available in literature ranged from -0.097 ± 0.124 (EI-Arian, 1986) to 0.39 ± 0.12 (Sharma, 1982) (Table 35).

2.2.10.6 Weight at Calving (WAC)

The estimates of heritability values of WFC ranged from 0.19 ± 0.17 to 0.75 ± 0.27 in Murrah buffaloes (Table 36). Chaurasia *et al* (1980), Basu *et al* (1984), Singh and Yadav (1986), Singh and Singh (1992), Kumar (1998), Singh (2001) and Bajetha (2003) had reported the low heritability value of WFC in Murrah buffaloes. The high heritability was reported by Singh and Basu (1988) as 0.58 ± 0.15 and Tein and Tripathi (1990) as 0.75 ± 0.27 in Murrah buffaloes. However, a moderate heritability was observed by Gurung and Johar (1982d) as 0.35 ± 0.09 and Singh (1995) as 0.33 ± 0.08 in Murrah buffaloes.

Table 31: Heritability estimate for AFC in Murrah buffalo

No. of observation	Method of estimate	Mean ± SE	References
147	ISRD	0.15 ±0.00	Goswami and Nair (1965)
477	PHS	0.24 ±0.13	Tomar and Desai (1968)
279	PHS	0.69 ±0.01	Bhadula and Desai (1972)
2089	PHS	0.12 ±0.06	Gokhle and Nagarcenker (1979)
1677	PHS	0.14 ±0.04	Sreedharan (1976)
1468	PHS	0.26 ±0.07	Basavaiah (1978)
222	PHS	0.28 ±0.10	Chaurasia *et al* (1980)
-	PHS	0.37 ±0.38	Reddy and Mishra (1980)
936	PHS	0.35 ±0.09	Gurung and Johar (1982a)
804	PHS	0.20 ±0.10	Sharma (1982)
241	PHS	0.35 ±0.20	Basu *et al* (1984)
-	PHS	0.34 ±0.09	Chourasia *et al* (1984)
201	PHS	0.68 ±0.29	Kirmani *et al* (1984)
1144	PHS	0.15 ±0.07	Kumar (1984)
627	PHS	0.36 ±0.021	Prakash (1984)
256	PHS	0.26 ±0.014	Dutt *et al* (1985)
210	PHS	0.31 ±0.21	El-Arian (1986)
1024	PHS	0.25 ±0.06	Singh and Yadav (1986)
226	PHS	0.82 ±0.10	Singh and Prakash (1986)
478	PHS	0.14 ±0.12	Hatwar and Chawla (1987)
190	PHS	0.82 ±0.31	Vij and Tiwana (1987)
-	PHS	0.25 ±0.12	Sharma and Singh (1990)
628	PHS	0.14 ±0.12	Singh and Basu (1988)

No. of observation	Method of estimate	Mean ± SE	References
825	PHS	0.62 ±0.29	Tein and Tripathi (1990)
412	PHS	0.55 ±0.19	Gajbhiye and Tripathi (1991)
716	PHS	0.24 ±0.16	Raheja (1992a)
1735	PHS	0.26 ±0.16	Singh and Singh (1992)
-	PHS	0.58 ±0.20	Sahana (1993)
701	PHS	0.03 ±0.14	Dhara (1994)
1647	PHS	0.45 ±0.09	Dutt and Taneja (1994)
320	PHS	0.27 ±0.10	Narula *et al* (1994)
158	PHS	0.36 ±0.26	Dass (1995)
316	PHS	0.42 ±0.09	Dass (1995)
1647	PHS	0.23 ±0.07	Dutt and Taneja (1995)
1440	PHS	0.57 ±0.09	Singh (1995)
-	PHS	0.02 ±0.08	Nath (1996)
874	PHS	0.23 ±0.09	Khan *et al* (1996)
615	PHS	0.17 ±0.08	Sethi *et al* (1996)
2107	PHS	0.20 ±0.05	Kuralkar and Raheja (1997)
683	PHS	0.30 ±0.12	Jain and Sadana (1998)
1214	PHS	0.09 ±0.06	Kumar (1998)
683	PHS	0.17 ±0.07	Jain and Sadana (2000)
415	PHS	0.42 ±0.019	Dass and Sadana (2000)
1361	PHS	0.09 ±0.12	Saha and Sadana (2000)
1229	PHS	0.04 ±0.03	Thevamanoharan *et al* (2000)
1164	PHS	0.37 ±0.10	Dutt *et al* (2001)
396	PHS	0.11 ±0.01	Singh (2001)
314	PHS	0.88 ±0.44	Gogoi *et al* (2002)
-	PHS	0.09 ±0.06	Kumar *et al* (2002)
1322	PHS	0.003 ±0.01	Thevamanoharan *et al* (2002)
1312	PHS	0.30 ±0.11	Bajetha (2003)
287	PHS	0.008 ±0.02	Warade *et al* (2005)
1200	PHS	0.33 ±0.09	Wakchaure *et al* (2008)
249	PHS	0.14 ±0.04	Gupta (2009)

Table 32: Heritability estimate for 305 MY in Murrah buffalo

No. of observation	Method of estimate	Mean ± SE	References
-	PHS	0.14 ±0.11	Khushwaha *et al* (1972)
-	PHS	0.25 ±0.07	Kumar *et al* (1978)
-	PHS	0.42 ±0.12	Sharma (1982)
804	PHS	0.20 ±0.10	Sharma (1982)
-	PHS	0.17 ±0.17	Parkash (1984)
210	PHS	-0.05 ±0.14	El-Arian (1986)
418	PHS	0.24 ±0.14	El-Arian (1986)
343	PHS	0.06 ±0.11	Gajbhiye (1987)
415	PHS	0.41 ±0.16	Gajbhiye (1987)
478	PHS	0.36 ±0.16	Hatwar and Chawla (1987)
-	PHS	0.16 ±0.06	Singh and Yadav (1987)
-	PHS	0.54 ±0.23	Khan and Johar (1988)
478	PHS	0.29 ±0.13	Sharma and Singh (1990)
628	PHS	0.29 ±0.13	Singh and Basu (1988)
825	PHS	0.12 ±0.17	Tein and Tripathi (1990)
-	PHS	0.02 ±0.05	Iype and Nagarcenkar (1992)
404	PHS	0.13 ±0.14	Dass and Sharma (1993)
424	PHS	0.27 ±0.16	Sahana (1993)
690	PHS	0.43 ±0.19	Dhara (1994)
316	PHS	0.38 ±0.18	Dass (1995)
158	PHS	0.21 ±0.22	Dass (1995)
-	PHS	0.15 ±0.09	Nath (1996)
-	PHS	0.18 ±0.07	Kumar *et al* (2002)
1161	PHS	0.65 ±0.12	Wakchaure *et al* (2008)
248	PHS	0.33 ±0.16	Gupta (2009)

Table 33: Heritability estimate for average Lactation Length in Murrah buffalo

No. of observation	Mean ± SE	References
1433	0.06 ±0.05	Basavaiah *et al* (1978)
936	0.05 ±0.06	Gurung and Johar (1982a)
804	0.028 ±0.11	Sharma (1982)
1144	0.04 ±0.05	Kumar (1984)
210	0.20 ±0.19	El-Arian (1986)
268	0.23 ±0.13	Singh and Basu (1988)
602	0.15 ±0.11	Verma and Yadav (1989)
716	0.15 ±0.11	Raheja (1992a)
716	0.08 ±0.04	Raheja (1993)
424	0.21 ±0.16	Sahana (1993)
683	0.28 ±0.11	Dhara (1994)
1647	0.05 ±0.06	Dutt and Taneja (1994)
316	0.05 ±0.13	Dass (1995)
1440	0.14 ±0.06	Singh (1995)
874	0.50 ±0.08	Khan *et al* (1996)
-	-0.03 ±0.09	Nath (1996)
2107	0.10 ±0.04	Kuralkar and Raheja (1997)
615	0.29 ±0.12	Sethi and Khatkar (1997)
1214	0.15 ±0.07	Kumar (1998)
415	0.05 ±0.13	Dass and Sadana (2000)
1229	0.03 ±0.01	Thevamonoharan *et al* (2000)
2107	0.17 ±0.10	Raheja *et al* (2001)
396	0.10 ±0.08	Singh (2001)
132	0.10 ±0.01	Thevamanoharan *et al* (2002)
1003	0.94 ±0.15	Yadav *et al* (2002)
273	0.03 ±0.05	Aziz *et al* (2003)
527	0.23 ±0.14	Sachan *et al* (2005)
287	0.42 ±0.018	Warade *et al* (2005)
1161	0.09 ±0.07	Wakchaure *et al* (2008)
248	0.27 ±0.17	Gupta (2009)

Table 34: The estimates of heritability ± S.E. for Lactation Yield in Murrah buffaloes

No. of observation	Mean ± SE	References
696	-0.02 ±0.07	Jawarkar and Johar (1975b)
1648	0.12 ±0.06	Basavaiah (1978)
896	0.16 ±0.09	Gurung and Johar (1982c)
804	0.42 ±0.12	Sharma (1982)
156	0.35 ±0.10	Mishra *et al* (1983)
201	0.13 ±0.73	Kirmani *et al* (1984)
1144	0.18 ±0.07	Kumar (1984)
678	0.09 ±0.01	Umarikar and Despande (1985b)
716	0.28 ±0.15	Raheja (1992a)
367	0.01 ±0.10	Kandaswamy *et al* (1991)
1647	0.23 ±0.07	Dutt and Taneja (1994)
1440	0.16 ±0.06	Singh (1995)
874	0.27 ±0.07	Khan *et al* (1996)
2107	0.22 ±0.05	Kuralkar and Raheja (1997)
615	0.16 ±0.10	Sethi and Khatkar (1997)
683	0.20 ±0.12	Jain and Sadana (1998)
415	0.35 ±0.18	Dass and Sadana (2000)
683	0.10 ±0.06	Jain and Sadana (2000)
1229	0.17 ±0.00	Thevamanoharan *et al* (2000)
1164	0.32 ±0.09	Dutt *et al* (2001)
2107	0.25 ±0.08	Raheja *et al* (2001)
396	0.18 ±0.04	Singh (2001)
1322	0.10 ±0.01	Thevamanoharan *et al* (2002)
1003	0.40 ±0.11	Yadav *et al* (2002)
273	0.21 ±0.36	Aziz *et al* (2003)
1630	0.14 ±0.00	Tonhati *et al* (2004)
527	0.05 ±0.06	Sachan *et al* (2005)
-	0.15 ±0.12	Chandra *et al* (2006)

Table 35: Heritability estimate for milk yield per day of lactation length in Murrah buffaloes

No. of observation	Method of estimate	Mean ± SE	References
1470	PHS	0.37 ±0.09	Basavaiah (1978)
804	PHS	0.39 ±0.12	Sharma (1982)
1144	PHS	0.27 ±0.08	Kumar (1984)
210	PHS	-0.09 ±0.12	El-Arian (1986)
1024	PHS	0.07 ±0.04	Singh and Yadav (1987)
343	PHS	0.06 ±0.10	Gajbhiye (1987)
316	PHS	0.28 ±0.21	Sahana (1993)
-	PHS	-0.01 ±0.09	Nath (1996)

Table 36: The estimates of heritability ± S.E. for Weight at Calving in Murrah buffaloes

No. of observation	Mean ± SE	References
222	0.28 ±0.10	Chaurasia *et al* (1980)
936	0.35 ±0.09	Gurung and Johar (1982d)
241	0.19 ±0.17	Basu *et al* (1984)
1024	0.24 ±0.06	Singh and Yadav (1986)
268	0.58 ±0.15	Singh and Yadav (1988)
825	0.75 ±0.27	Tein and Tripathi (1990)
1735	0.25 ±0.05	Singh and Singh (1992)
1440	0.33 ±0.08	Singh (1995)
1214	0.28 ±0.08	Kumar (1998)
396	0.29 ±0.15	Singh (2001)
1312	0.28 ±0.10	Bajetha (2003)

4.2.11 Correlations among First Lactation Traits

The genetic and phenotypic correlations among different traits reveal the direction and magnitude of association among them. These are important for planning when improvement in more than one trait is under consideration. The correlations among the traits would indicate how the improvement in one trait would affect the other trait/traits (correlared response). The estimates of genetic and phenotypic correlations among various first lactation traits in Murrah buffaloes are presented in Table 37.

The genetic correlations between AFC and 305MY were reported to be negative in most of the cases and were positive in a few cases. However, the phenotypic correlations were positive and low, and ranged between 0.004 (Gajbhiye, 1987) and 0.320 (Sharma and Singh, 1990). The negative genetic correlations between the two traits reported by Dhindsa (1963), Gokhale (1974), Sharma (1982), EI-Arian (1986), Gajbhiye (1987), and Vij and Tiwana (1988) ranged between -0.021±0.276 and -0.958±0.083 and suggested that the improvement in AFC (lowering of AFC) would be associated with the improvement in F305MY. Therefore, the negative genetic correlation between the two traits was in the desirable direction.

Table 37: Genetic and phenotypic correlation coefficients among first lactation traits in Murrah buffaloes

Trait	Correlation coefficients		No. of observations	References
	Genetic (r_G)	Phenotypic (r_P)		
Age at first calving with :				
305MY	0.56 ± 0.22**	0.11 ± 0.05*		Sahana (1993)
	0.29 ± 0.87	0.15 ± 0.03*		Gupta (2009)
LY	0.31 ±0.87	-0.03 ±0.04	593	Mangurkar and Desai (1981)
	-0.27 ±0.48	-0.01	201	Kiramani *et al* (1984)
	-0.43 ±0.30	0.06 ±0.03	1144	Kumar (1984)
	-0.33 ±0.27	-0.08 ±0.06	280	Gogoi *et al* (1985)

Trait	Correlation coefficients		No. of observations	References
	Genetic (r_G)	Phenotypic (r_P)		
	-0.97 ±0.05	0.04 ±0.06	210	El-Arian (1986)
	0.15 ±0.25	0.10	628	Singh and Basu (1988)
	0.28 ±0.29	0.05 ±0.06	221	Tein and Tripathi (1990)
	-0.13 ±0.06	-0.06 ±0.02	1866	Dhama *et al* (1991)
	0.47 ±0.33	0.28 ±0.21	716	Raheja (1992a)
	-0.20 ±0.26	-0.12 ±0.02	1735	Singh and Singh (1992)
	0.32 ±0.19	0.06	1647	Dutt and Taneja (1994)
	0.05 ±0.03	0.13 ±0.05	1214	Kumar (2000)
	0.21 ±0.20	0.05	2107	Kuralkar and Raheja (1997)
	-0.98 ±0.01	0.11 ±0.06	415	Dass and Sadana (2000)
	-0.05	0.09	683	Jain and Sadana (2000)
	0.74 ±0.01	0.05 ±0.03	396	Singh (2001)
	-0.09 ±0.28	0.02 ±0.03	1312	Bajetha (2003)
LL	-0.39 ±0.57	-0.01 ±0.03	1144	Kumar (1984)
	-0.92 ±0.07	-0.07 ±0.06	280	Gogoi *et al* (1985)
	<-1.0	0.03 ±0.04	418	El-Arian (1986)
	0.32 ±0.09	-0.04	628	Singh and Basu (1988)
	0.15 ±0.15	-0.002 ±0.06	221	Tein and Tripathi (1990)
	-0.11 ±0.19	-0.06 ±0.02	1866	Dhama *et al* (1991)
	-0.28 ±0.45	0.21	716	Raheja (1992a)
	0.35 ±0.24	0.06	2107	Kuralkar and Raheja (1997)
	0.04 ±0.03	-0.22 ±0.05	1214	Kumar (1998)
	-0.50 ±0.55	0.12 ±0.05	415	Dass and Sadana (2000)
	0.61 ± 0.23**	0.08 ± 0.03**		Sahana (1993)
	-0.51 ± 0.87	0.11 ± 0.75		Gupta (2009)
	0.13 ±0.01	0.26 ±0.05	396	Singh (2001)
	0.40 ±0.33	0.04 ±0.03	1312	Bajetha (2003)

Trait	Correlation coefficients		No. of observations	References
	Genetic (r_G)	Phenotypic (r_P)		
WAC	-0.40 ±0.09	0.26 ±0.07	222	Chaurasia *et al* (1980)
	-0.58 ±0.12	0.13	936	Gurung and Johar (1982d)
	0.52 ±0.37	0.46	241	Basu *et al* (1984)
	0.32	-0.09	201	Kirmani *et al* (1984)
	0.15 ±0.23	0.41	628	Singh and Basu (1988)
	0.25 ±0.25	0.27 ±0.06	238	Tein and Tripathi (1990)
	-0.70 ±0.09	-0.20 ±0.02	1735	Singh and Singh (1992)
	0.05 ±0.02	0.17 ±0.003	1214	Kumar (1998)
	-0.26 ±0.01	0.13	396	Singh (2001)
	-0.54 ±0.29	-0.05 ±0.03	1312	Bajetha (2003)
	0.11	0.12	907	Badran *et al* (2005)
MYLL	NE	0.11 ± 0.05*		Gajbhiye (1987)
	0.79 ± 0.13**	0.08 ± 0.05		Sahana (1993)
Lactation Milk Yield with:				
LL	-0.26 ±0.04	0.15	896	Gurung and Johar (1982d)
	0.45 ±0.37	0.67 ±0.02	1144	Kumar (1984)
	0.69 ±0.49	0.58 ±0.04	418	El-Arian (1986)
	0.12 ±0.01	-	411	Khan *et al* (1987)
	0.23 ±0.26	0.38	628	Singh and Basu (1988)
	1.39 ±0.14	0.76 ±0.04	220	Tein and Tripathi (1990)
	0.56 ±0.30	0.61	716	Raheja (1992a)
	>1.00	0.75 ±0.04	415	Dass and Sadana (2000)
	-0.92 ±0.04	0.04 ±0.05	396	Singh (2001)
	1.00	0.42	273	Aziz *et al* (2003)
	0.46 ±0.28	0.48 ±0.02	1312	Bajetha (2003)
	1.00 ±0.90	0.89	815	Roshanfekr (2005)
WAC	0.27 ±0.01	0.16	936	Gurung and Johar (1982d)
	0.12 ±0.73	0.03	201	Kirmani *et al* (1984)

Trait	Correlation coefficients		No. of observations	References
	Genetic (r_G)	Phenotypic (r_P)		
	0.62 ±0.19	0.21	628	Singh and Basu (1988)
	0.35 ±.24	0.02 ±0.06	217	Tein and Tirpathi (1990)
	0.61 ±0.26	0.50 ±0.02	1735	Singh and Singh (1992)
	-0.01 ±0.03	0.39 ±0.001	1214	Kumar (1998)
	>1.00 ±0.03	-0.01 ±0.05	396	Singh (2001)
	0.79 ±0.34	0.01 ±0.03	1312	Bajetha (2003)
Lactation Length with :				
WAC	0.17 ±0.48	0.48	936	Gurung and Johar (1982b)
	-0.15 ±0.26	-0.07	628	Singh and Basu (1988)
	0.80 ±0.74	0.05 ±0.06	217	Tein and Tripathi (1990)
	0.05 ±0.24	0.02 ±0.02	1440	Singh (1995)
	-0.03 ±0.03	0.03 ±0.03	1214	Kumar (1998)
	-0.02 ±0.01	0.41 ±0.04	396	Singh (2001)
	-0.63 ±0.39	-0.03 ±0.03	1312	Bajetha (2003)
305-Day Milk Yield				
AFC	0.21 ± 1.25	0.25 ± 0.09**		Nath (1996)
	NE	0.08		Banik (2001)
	NE	0.22 ± 0.87		Gupta (2009)
MYLL	NE	0.77 ± 0.03		Gajbhiye (1987)
	-0.33 ± 0.42**	0.97 ± 0.01*		Sahana (1993)
LL	0.236 ± 1.119	0.544 ± 0.06**		El-Arian (1986)
	NE	0.70		Banik (2001)
	NE	0.73 ± 0.05**		Gupta (2009)

2.3 Methods of Sire evaluation

Evaluation of sires for their ability to transmit milk production traits to their daughters has gained significant importance due to the fact that high selection intensity could be practiced for bulls. The production and reproduction traits apart from being sex limited are also not highly heritable traits. The genetic improvement in the population through sire selection depends' on the accuracy of selection, selection intensity, genetic variability of the trait, and the generation interval. Most of the work in sire evaluation has been done on cattle population. In this context very limited information is available in the published literature on buffalo population. Though, general principles are almost same and interchangeable between cattle and buffaloes. However, different methods of evaluating sires in cattle and buffaloes have been discussed in the present study.

The available literature on various sires evaluation methods viz., least-squares analysis (LS), best linear unbiased prediction (BLUP) and Derivative free Restricted Maximum Likelihood (DFREML) methods as reported by different workers has been reviewed as under:

2.3.1 Least-Squares Method (LS)

Robertson and Rendel (1954) initially proposed the least-squares procedure for determining the genetic worth of sires. The procedure was based on the principle to minimize the error variance after adjusting the data for various non-genetic or environmental factors.

Cunningham (1965) described the method for obtaining weighted least-squares estimates of sires based on non-orthogonal data of progeny test records, where AI was practiced. He reported that it was possible to classify the sires into different groups much earlier in the young age before the proofs were completed.

Harvey (1987) gave the concept of least-squares analysis for non-orthogonal data. By incorporating site as a random effect in the model of least-squares analysis, the effect of sire can be determined for their genetic merit for effective sire evaluation. The least-squares analysis for estimation of breeding value of sires has widely been used in India by different workers.

Tajane and Rai (1990) used least –squares method for estimation of breeding value of 29 Holstein – Friesian sires and 8 Sahiwal sires based on their 1257

(Holstein – Friesian x Sahiwal)and 519 (Sahiwal x Holstein – Friesian)daughters. Gandhi and Gurnani (1991) estimated breeding value of Sahiwal sires on the basis of first lection 305 –days or less milk yield of Sahiwal daughter maintained at five farms by least – squares technique. Singh *et al* (1992) used the least-squares method for estimation of breeding values of Hariana bulls.

Raheja (1992) used least –square method for estimating the breeding value of Sahiwal sires. Parekh et al. (1994) evaluated Friesian, jersey and brown Swiss based on least – squares method.

Banik (2004) used LSM along with other method (Contemporary comparison) method, SRLS, BLUP AND REML)for evaluation Shiwal sires and reported highly significant rank correlation of LSM with contemporary comparison method (0.91),SRLS (0.98), BLUP (0.85) and REML (0.96). This indicated that the ranking of sires by these method did not alfter significantly.

Mukherjee *et al* (2007) also used LSM along with other method (Contemporary comparison method, SRLS, BLUP and REML)for evaluation of Frieswal sires and reported highly significant rank correlation of LSM with contemporary comparison methods (0.91), BLUP (0.96) and REML (0.91).These indicate that ranking of sires by these method did not differ significantly .

The computational simplicity and readily available computer programs have made this method very useful under Indian conditions.

2.3.2 Best Linear Unbiased Prediction (BLUP)

Henderson (1973, 1975a, b) gave the concept of best liner unbiased prediction (BLUP) method for sire evaluation for mixed model equations. The method combines the feature of least-squares and selection index techniques and was reported to be most powerful and flexible (Henderson, 1974). The BLUP method is unbiased and gives the predicted values nearly equal to expected value of sires with minimum error variance. The methods is also easy to modify if the condition changes. The availability of powerful software for BLUP helped its world wide acceptance for evaluation of genetic merit of sire. Henderson (1973, 1975a) described various criteria that were desirable in a sire evaluation method. BLUP method has the following desirable properties:

- It is unbiased in the sense that the predictor has the expectation as the unknown variable that is known to be predicted (the predictand).
- It minimizes the variable of error of prediction in the class of linear unbiased predictors.
- It maximum the correlation between the predictor and the predictand in the class of linear unbiased predictors.

When the distribution is multivariable normal:

a) It yields the maximum likelihood and the best linear unbiased estimators of the conditional mean of predicted.
b) In the class of linear unbiased predictors, it maximizes the probability of correct pair wise ranking.

Henderson (1975a,b) described the incorporation of numerator relationship matrix which had the benefit of increase in accuracy then earlier evaluation and accounting for genetic and environmental trends.

Henderson (1976) extended the BLUP procedure for multiple traits and on Henderson and Quass (1976) derived method of BLUP for estimating breeding value using multiple traits utilizing individuals's own records as well as large number of relatives of sires with numerator relationship matrix. The records of the relatives are of greatest use when heritabilities, which is the candidate for selection. This was an extension of Henderson's single trait model for evaluating genetic merit of sire.

2.3.3 Restricted Maximum Likelihood Method (REML)

The maximum likelihood method based on estimation of variance and covariance matrix was first proposed by Thompson (1962). Later on Patterson and Thompson (1971) and Thompson (1973) applied restricted maximum likelihood method to animal breeding data by fitting sire model. This requires expected values of second derivatives of likelihood to be evaluated which proved computationally highly demanding for all, but the simplest analyses. Hence, expectation-maximization (EM) type algorithms gained popularity and found widespread use in fitting sire model. Effectively, these algorithms used first derivatives of likelihood function. Except for special cases, however, they require the inverse of matrix of size equal to number of random effects fitted, e.g. number of sires times number of triats, which severely limited the size of analyses feasible.

For analyses under sire model, Graser *et al.* (1987) used derivative free restricted maximum likelihood (DFREML) algorithm for solving the mixed model equations. This only requires factorizing the coefficient matrix of the mixed model equations rather than inverting it, and can be implemented effectively using sparse matrix technique. Moreover, it is readily extendable to animal models including additional random effects and multivariate analyses (Meyer; 1989, 1991 and Meyer *et al* 1989). The multivariate, multidimensional analysis of animal model for evaluating merit of sire was proposed by Meyer and Smith (1996).

Later Smyth (2002) described the procedure of restricted or residual maximum likelihood (REML) for linear models. He also described an explicit algorithm given for REML scoring which yielded the REML scoring together with their standard errors and likelihood values. The algorithms included a Levenberg-Marquardt restricted step modification which ensured the REML likelihood increases at each iteration.

The information on use of DFREML in estimation of variance and covariance components of sire merit in Indian conditions is scanty. Jain (1996) used DFREML method under multiple trait models (two and three traits combination) for estimation of variance and covariance components and heritability estimates of Murrah buffaloes from 683 records maintained at National dairy Research Institute, Karnal. The variance components derived by these models were used in estimating breeding value of sires by BLUP method. He suggested REML method should be used for estimation of genetic parameters and genetic evaluation of bulls. However, this would require information on pedigree and therefore, maintenance of records. He also reported that when the target would be to improve more than one trait, all the traits should be included in the model. However, the traits having very low heritability should not be taken in the model.

Espinosa *et al.* (2001) used data on 2618 records of milk production from 1991 to 1998 to estimate the breeding values in Holstein dairy herd. The variance components were estimated by restricted maximum likelihood method with a derivative-free algorithm. It was concluded that the variance components of this study were reliable for prediction of breeding values of the animals.

2.3.4 Comparison of Effectiveness of Various Method of Sire Evaluation

Kabat and Zerneeki (1980) compared the breeding value of sires for milk yield and fat percent determined by contemporary comparison with least-square and maximum likelihood method. They found the correlation of contemporary comparison with least-square and maximum likelihood methods' were 0.567 and 0.576, respectively for milk production; and 0.353 and 0.371, respectively for milk fat percent. The rank correlation between maximum likelihood and least –squares estimates were 0.999 for both milk yield and fat percent.

Haggar and Dempfle (1981) compared four methods of sire evaluation viz., contemporary comparison, least-squares and two BLUP method for Brown –Swiss bulls. The correlation for the two repeat estimates of the breeding value of bulls were 0.76,0.76,0.83 and 0.80 for four methods, respectively, over sire group and 0.74,0.74,0.80 and 0.78 within sire group.

Gurnani and Nagarcenker (1982) compared Henderson's best linear unibiased predicition (BLUP) with Robertson's contemporary method of sire evaluation using 28 Tharparkar sires having at least 10 daughters per sire. The simple correlation coefficient and rank correlation between these two method were estimated as 0.824 and 0.915, respectively. It was observed that the contemporary comparison was 68.84

per cent as accurate as BLUP method for ranking sire on the basis of their breeding values. They further reported that BLUP method could give higher error of approximation in analyzing the genetic merit of sires. If the number of daughter per sire is small and thus it can give inaccurate estimate of breeding value of sires. They suggested that contemporary method was adequate under Indian conditions.

Cordovi *et al* (1986) estimated breeding values of 157 Holstein–Friesian bulls on the basis of first lactation records of their daughter using' contemporary comparison, least-square and BLUP methods. On comparison, BLUP was found to be least accurate among all the methods.

Gill and Parmar (1988) estimated breeding value of 11 Red Dane bulls on the basis of first lactation 305-days milk yield Red Dane –Sahiwal crossbred daughter by using daughter average, least –square means and BLUP. The rank correlation amongst the three methods were -0.51, -0.28 and 0.71 between daughter average and least –square mean daughter average and BLUP and least –square mean and BLUP, respectively. It was observed that simple daughter average is the most inaccurate method for evaluation of sire's genetic merit.

Kumar and Bhatnagar (1989) estimated the breeding value of 40 Karan Swiss sire based on first lactation milk production records of 355 daughters by using 13 different methods. It was concluded that contemporary comparison was the best for method for estimating genetic merit of sires with lowest error variance.

Tajane and Rai (1990) compared different methods of breeding value of 29 Holstein-Friesian sires and 8 Sahiwal sires based on their 1257 (Holstein –Friesian x Sahiwal) and 519 (Sahiwal X Holstein Friesian) daughters. They utilized herd mate comparison; index corrected for auxiliary traits, least-square, simple regressed least –square and best linear unbiased prediction (BLUP) method and concluded that all the procedures were almost similar for ranking sires of higher merit. It was further reported that least-squares and index corrected for auxiliary traits had lower rank correlation with other methods. The use of BLUP method with complete model including fixed effects of genetic groups and random effects of sires for estimation of breeding value of sires was recommended.

Gandhi and Gurnani (1991) compared the breeding value of Sahiwal sires on the basis of first lactation 305-days or less milk yield of 1500 Sahiwal daughters maintained at five farms. They utilized twelve sire indices by four different methods. I_2 to I_6 were based on unadjusted data and remained (I_7 to I_{12}) was based on adjusted data for farms, periods and both farms and periods. They utilized error variance, coefficient of determination, coefficient of variation and rank correlation methods for estimating accuracy, efficiency and least-squares models were found to be almost equivalent in their accuracy, efficiency and stability. The rank correlations among different methods of sire evaluation were high (0.88 to 1.00) and statistically highly significant ($p < 0.01$).

Raheja (1992b) compared six methods of sire evaluation namely simple daughter average, herd mate comparison, contemporary comparison, ordinary least-squares, regressed least-squares and best linear unbiased prediction (BLUP) for Sahiwal cattle for milk production based on 556 first lactation milk yield and observed that the rank correlation and linear correlation coefficient among sires from different methods ranged from 0.46 to 0.86 and 0.48 to 0.94, respectively. It was recommended that BLUP method for estimation of breeding value of sires was most accurate in comparison to other methods.

Sahana (1996) estimated breeding value of 129 sires based on 1224 first lactation performance of crossbred daughters of Holstein-Friesian bulls by simple daughter average, contemporary comparison, least-squares, simple regressed least-squares and BLUP methods. The contemporary comparison method was observed to have minimum error variance and was reported to be the best method for sire evaluation under organized herds. The relative efficiency of simple daughter average was lowest (13.17%) in comparison to contemporary comparison method. The relative efficiency of least-squares, simple regressed least-squares and BLUP methods to the contemporary comparison was 58.29, 58.34 and 54.81 per cent, respectively. The rank correlation of contemporary comparison with other methods ranged from 0.77 (simple regressed least-squares) to 0.85 (BLUP). All the rank correlations were highly significant ($p < 0.01$).

Jain and Sadana (2000) used the first lactation records of 683 Murrah buffaloes progenies of 84 sires maintained at NDRI, Karnal, for comparing the sire evaluation procedures for the age at first calving (AFC), first lactation 305-day or less milk yield (FLMY)and first service period (FSP). The sires were evaluated using simple daughter average, contemporary comparison, least-squares and BLUP methods. The BLUP evaluations were obtained under the single-trait, two-trait and three-trait individual animal models. The results revealed that while taking a decision regarding method of sire evaluation to be used for sire selection having breeding values, the criterion of rank correlation could be a misleading. The selected sire is likely to give a variable picture. The best linear unbiased prediction method under a multitrait animal model incorporating first lactation milk yield with first service period as a co-variable and age at first calving in the model were found to be more efficient and accurate for the sire selection in Murrah buffaloes than other models.

Tailor *et al* (2000) estimated breeding value of 31 Surti buffalo bulls based on first lactation 305-days milk yield of 507 daughters by 5 sire evaluation methods viz. herd-mate comparison, contemporary comparison, ordinary least-squares, regressed least-squares and BLUP. The accuracy of sire evaluation was judged by the correlation between the actual progeny average for each sire and the estimated breeding value of sires and by rank correlations and coefficients of skewness and kurtosis. Herd-made comparison and contemporary comparison methods had high and significant rank correlations; their correlations with least-squares and BLUP methods were moderate. The rank correlation for two least-squares methods with true sire effects were close to 1 and that for BLUP was lower. BLUP had a lower standard error than other methods. The least –squares and BLUP methods had near perfect normal distribution. The accuracies of ordinary least-square, regressed least – squares, BLUP, contemporary comparison and heard mate comparison were 0.99, 0.97, 0.63, 0.52 and 0.45, respectively. The ordinary least –square method was found the most accurate method of sire evaluation. The recommended that BLUP could be used for evaluating the breeding value of sires.

Gaur *et al.* (2001) estimated the breeding value of Frieswal sires using simple daughter's average, contemporary comparison, least-square and BLUP procedures and computed rank correlations among the values obtained in order to judge the efficiency of the methods. All the rank correlations were greater than 0.86 Rank correlations among sire breeding value estimated from BLUP, LS and CC procedures were near to 1.00 (0.96 to 0.97). They suggested that either of the method employed in the study could be used for the selection of sires for breeding purpose.

Banik (2004) reported that the error variance of the LS was less than the BLUP method of sire evaluation in Sahiwal cattle. The relative efficiency of BLUP in comparison to LS was 0.97. However, the BLUP method of sire evaluation was more stable then LS because of closeness of its coefficient of variation with unadjusted data of first lactation milk yield. As regards accuracy of sire evaluation, the BLUP (R^2 =24.54%) method was found to be more accurate then LS (R^2 =11.07%) based on coefficient of determination (R^2).

Bharti (2004) evaluated the sires by using BLUP and DFREML methods for first lactation traits and toe life time milk yield. She found that BLUP could be a better method for sire evaluation in comparison to DFREML. The rank correlations among method within trait ranged from 0.67 (between BLUP and DFREML for the FSP) to a value of 0.89 (between the FDP and FCI). These correlations were highly significant and indicted that ranking of sires by the above two methods were not much different. However, in "among traits within methods", the ranking of sires had changed, thereby resulting into decreased rank correlation coefficients, which ranged from -0.04 (between FLMY and AFC)to 0.75 (between FCI and FDP) in the case of

DFREML, and -0.09 (between WFC and FDP) to 0.75 (between FDP and FCl) in the case of BLUP method.

Pundhir *et al* (2004) evaluated the Sahiwal sires at Government Livestock Farm, Hissar, utilizing records of 514 cattle and four methods of sire evaluation were used. The methods were – simple daughter average (SD), least-squares (LS), contemporary comparison (CC) and the best linear unbiased prediction (BLUP). The criterion for evaluation of sire was taken as the lactation milk yield of progeny. They measured the accuracy range, the standard error,·the standard deviation, the coefficient of skewness and kurtosis, product moment and the rank correlations for various sire evaluation methods. The BLUP and CC methods were equally good and superior compared to the other two methods. They further concluded that anyone out of the four methods can be effectively used for ranking and selection of the sires for lactation milk yield though preference may be given to BLUP and CC.

Banik and Gandhi (2006) had used the data on 1367 first lactation records of daughters of 81 sires having 5 or more progenies, for the evaluation of sires by three different methods. The methods tested were - least-squares (LS), best linear unbiased prediction (BLUP) and the derivative free restricted maximum, likelihood (DFREML) method. The highest and the lowest overall average breeding value of sires for first lactation on 305-days or less milk yield, was obtained by the BLUP as 1520.72 kg and by the L8 method as 1502.22 kg. The accuracy, efficiency and stability of different sire evaluation methods were compared. The error variance of DFREML method was the least and its coefficient of determination of fitting the model was the highest, thereby, revealing that this method of sire evaluation was not only most efficient but also accurate compared to the other methods. However, the BLUP method was found to be more suitable amongst all the methods that had obtained a coefficient of variation quite near to the unadjusted data. The higher rank correlations between different methods indicated that there was higher degree of similarity in the ranks of sires which ranged from 80-96 percent. However, the

DFREML method seemed to be most efficient sire evaluation method compared to the other methods that suited their data of the study.

Singh (2006) reported that the rank correlations between estimated breeding values (EBVs) for the first lactation 305- days or less milk yield by least –square and BLUP were the highest (0.939 ± 0.001) followed by between SDA and BLUP (0.686 ± 0.001). The rank correlation s of CC and LS with SDA had relatively lower estimates (0.444 and 0.539). The rank correlation of LS and BLUP with CC were found to be negative, thought of lower magnitude. The result revealed a wide variation in the ranking of EBVs by CC in comparison to LS and BLUP. It can be inferred from these result that LS and BLUP methods could be used with greater reliability for evaluation of sires.

Mukherjee *et al* (2007) reported that error variance of the LS was slightly more than the BLUP method of sire evaluation in Frieswal cattle. The relative efficiency of LS in comparison to BLUP was 0.999.

Rana (2008) reported that the rank correlations between estimated breeding values (EBVs) for the first lactation 305- days or milk yield by least –squares and BLUP were the highest (0.939 ± 0.001) followed by between SDA and BLUP (0.686 ± 0.001). The rank correlations of CC and LS with SDA had relatively lower estimates (0.444 and 0.539). The rank correlations of LS and BLUP with CC were found to be negative, thought of lower magnitude. The result revealed a wide variation in the ranking of EBVs by CC in comparison to LS and BLUP. It can be inferred from these result that LS and BLUP methods could be used with greater reliability for evaluation of sires. The error variance of LS methods in 305-days milk yield and predicated 305-days milk yield by ratio and regression methods, using part lactation and 305-days milk yields had lower error variance then the BLUP. Thus on the basis of error variance the LS was considered more efficient then BLUP method. The R^2 value of the LS was relatively then the BLUP in case of actual 305-days milk yields. Therefore, the LS was considered more accurate then BLUP.

From the above literature reviewed on comparison different sire evaluation methods by different workers, it could inferred based on relative efficiency, rank correlation and accuracy that BLUP, LS and CC are comparable and either of the methods can give fairly accurate ranking of sires. However, the BLUP seemed to have an edge over other methods because of having higher efficiency and accuracy of estimated breeding values.

CHAPTER III

MATERIALS AND METHODS

Source of Data

The data pertaining to ancestory, body weight at different ages, production and reproduction traits for the present investigation were collected from the history-cum-pedigree sheets, growth, production and reproduction records, respectively maintained at the Dairy Farm, Deptt. of Animal Genetics and Breeding of Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana under the “All India Co-ordinated Research Project on Buffalo Breeding”. This project was launched in July 1970 with the objective of identification of genetically superior bulls through progeny testing and establishment of elite herd of buffaloes for the production of future sires by Indian Council of Agriculture Research. This project was modified in 1992 as “Network on Buffalo Breeding” with the main objective of identification of genetically superior buffalo bulls using associated herds. The data with respect to required traits were collected over a period of 40 years i.e. from 1973 to 2012 and pertained to 1033 animals. The other herd involved in present study was of CIRB (Central Institute for Research on Buffaloes) Hisar. This institute was established by ICAR in 1987 by transferring the Murrah buffaloes from Government Livestock farm, Hisar. The data with respect to required traits were collected over a period of 25 years i.e. from 1988 to 2012 and pertained to 812 animals.

Breeding stock

As per the technical program of the project, a herd of about 300 Murrah buffaloes was to be maintained for the progeny testing programme. So, in order to have required strength and genetic variability, the buffaloes were purchased from the breeding tract of Murrah, mainly from Rohtak, Sirsa, Hisar and various animal fairs of Punjab and outstanding animals of the individual farmers. Selection and purchasing of the animals was exclusively based on the criteria fixed at ICAR for this project i.e. on the basis of milk yield of three successive milkings, breed characteristics, shape and udder quality characteristics. Once the herd was attained, only a few outstanding buffaloes were purchased from time to time. All the female calves born at the farm were retained till they completed their first lactation record. The male calves from buffaloes giving around 3000 kg or more milk in 305-day lactation length were used for breeding purposes.

Management and feeding of herd

At the dairy farm of GADVASU, the animals were kept in loose housing system housing some covered area. The animals were having free access to feed and water. The following groups of animals were housed separately.

1. Calves upto four months of age
2. Calves over four months upto one year
3. Heifers from 1 to 2 years of age
4. Breeding heifers
5. Pregnant heifers or buffaloes
6. Dry buffaloes
7. Buffaloes in milk (elite animals)
8. Buffaloes in milk (average animals)

The calves were weaned immediately after birth and fed on colostrums for first five days and whole milk from sixth day to sixteen weeks of age. The green fodder and calf starter (CP = 22% and TDN = 75%) consisting of grains, cakes, brans, fish meal, mineral mixture, salt and additives were offered from one month of age onwards. The calves were kept in individual calf pens, usually upto four months of age and were provided adequate protection from adverse weather conditions.

The animals above four months of age were kept in groups in loose housing system and male calves were housed in separate barns. All the animals were bred through artificial insemination. The advanced pregnant animals were segregated to the calving pens at least six weeks before the expected date of calving. Earlier buffaloes were hand milked twice daily but machine milked since 2007 onwards. Body weights were recorded by weighing the animals in the morning before feeding and newly born were weighed before colostrums feeding. The feeding of all the categories of the livestock was done according to the feeding schedule (Appendix I). Berseem and oats during rabi season and sorghum, bajra, maize, cowpea and guara during kharif season were usually given as green fodder whereas wheat bhusa was used as dry fodder. The silage prepared from oats in rabi season and from bajra, sorghum and maize during kharif season was fed during the periods of lean fodder production.

The maintainance and growth ration was fed to the animals in the morning hours once a day while the production ration to the milking cows was again given at the time of milking. Concentrate ration (CP = 18% and TDN 70%) was formulated using cereals, cakes, brans, mineral mixture, salt and additives depending upon season.

The animals at CIRB herd were reared following the similar managemental practices as being followed at GADVASU with few major exceptions of suckling allowed to calves and no weaning was followed. Milk recording was done on weekly basis and on that day calves were not allowed to suckle and allowed to drink milk from bowl.

Recording of Data

The records were collected on the buffalo herd covering a period from 1973 to 2012. Whole of the data recording was divided into four parts and following observations in each part were recorded on buffaloes:

Ancestory

1. Animal number
2. Dam number
3. Sire number
4. Date of birth

Body weight/growth

1. Body weight at birth (kg)
2. Body weight at 1 month age (kg)
3. Body weight at 3 months age (kg)

4. Body weight at 6 months age (kg)
5. Body weight at 12 months age (kg)
6. Body weight at 18 months age (kg)
7. Body weight at 24 months age (kg)
8. Body weight at first calving

Production

1. Date of calving
2. 305-day lactation milk yield (kg)
3. Lactation length in days (days)
4. Lactation milk yield (kg)
5. Peak yield (kg)
6. Date of drying
7. Date of attaining peak yield
8. Fortnightly fat percentage

Reproduction

1. Date of calving
2. Date of successful conception for second lactation
3. Date of second calving
4. No. of services per conception

Derived traits

1. Gestation period (days) (Date of calving – Date of successful conception)
2. Service period (date of 2nd successful conception – Date of first calving)
3. Calving Interval (date of 2nd calving – date of 1st calving)
4. Dry period (date of 2nd calving – date of drying)
5. Calf per cent = (Calf birth weight/Dam wt. at calving) x 100
6. Average fat % (in lactation) (Average of fortnightly fat % over a lactation)
7. Days to reach peak yield (Date of attaining peak yield – Date of calving)
8. Age at first calving (date of first calving – Date of birth)
9. Fat yield (Fat%/100 x Lactation milk yield)

10. Milk yield per day of lactation length (Lactation milk yield/lactation length)

11. Gain in weight/month = $\dfrac{\text{Wt. of final month - Wt. of initial month}}{\text{Difference in months}}$

12. Relative growth rate = $\dfrac{\text{Wt. of final month - Wt. of initial month}}{\text{Difference in months}} \times 100$

Only six traits were available/derived for CIRB herd i.e. Age at first calving, 305-day milk yield, lactation length, lactation yield, peak yield and milk yield per day of lactation length.

Classification of Data

The data on the above mentioned characters were classified as under:

The total period of 40 years was coded into eight periods depending upon the date of birth for age at calving and date of calving for rest of traits. The coding was done as follows:

Code	Period
1	01.01.1973 to 31.12.1977
2	01.01.1978 to 31.12.1982
3	01.01.1983 to 31.12.1987
4	01.01.1988 to 31.12.1992
5	01.01.1993 to 31.12.1997
6	01.01.1998 to 31.12.2002
7	01.01.2003 to 31.12.2007
8	01.01.2008 to 31.12.2012

Further, each year was divided into five seasons depending upon the month of birth and calving. The season were:

Season	Code	Period
Summer	1	16^{th} April – 15^{th} July
Rainy	2	16^{th} July – 15^{th} September
Autumn	3	16^{th} September – 15^{th} November
Winter	4	16^{th} November – 15^{th} February
Spring	5	16^{th} February – 15^{th} April

Standardization of Records

The performance records used for this study were compiled by taking following guidelines so that there was uniformity in the compilation and standardization of these records:

The records of animals of only known pedigree, date of birth and date of calving were included in the study.

Incomplete lactation records due to premature birth, still birth, sickness and death, sale and transfer during the course of lactation have been excluded from this study.

The daily milk yield records during the whole lactation were used for computing the 305-day or less lactation yield and complete lactation yield.

The lactation period was computed as the interval (in days) between the date of calving and the subsequent date of drying-off the cows.

The maximum milk yield recorded on a single day during the course of lactation as was taken as the “peak yield of the animal.

The interval between the date of calving and date on which peak yield was recorded was taken as the number of days to attain peak yield.

While compiling data, milk records of less than 150 days of lactation length or 1000 kg of milk production were considered to be abnormal and were thus deleted.

Statistical analysis of data

The performance of the animals is influenced by various factors. The evaluation of the effect of such factors on the economic trait is, therefore, very essential for identifying significant sources of variation in these traits for deciding the need for adjustment of data for obtaining precise estimates of genetic parameters, for making valid comparisons and for developing efficient management system for optimum productivity. The effects of various environmental factors on growth and first lactation characteristics of Murrah buffaloes were evaluated by analyzing the data using the method of fitting constants as described by Harvey (1990) with the help of LSMCMW(PC-2 version).

Effect of non-genetic factors

The least squares analysis of variance for non-orthogonal data using the technique described by Harvey (1987) was conducted to study the effect of non genetic factors on performance traits

$$Y_{ijk} = \mu + S_i + P_j + e_{ijk}$$

Where, Y_{ijk}	=	Observation of kth buffalo born/calved in jth season and ith Period
μ	=	Overall population mean
S_i	=	Effect ith season
P_j	=	Effect of jth period
E_{ijk}	=	Random error, assumed to be normally independently distributed with mean zero and constant variance, i.e. NID (0, σ_e^2)

For analysis of growth traits, the effect of parity or lactation number of dam was, in addition to period and season was also included. Similarly, for combined analysis of first lactation traits of GADVASU and CIRB herds, herd effect was also included in the model.

Testing difference between two paired means

The statistical significance of the least squares analysis of difference in LS means between periods, seasons, herds and parity was tested by "F" test (Fisher 1958). The statistical significance of pair-wise differences between means was tested by Duncan's multiple range test, modified by Kramer (1957). In this method, the difference between any two paired means is considered significant if:

$$\left(y_i - y_j\right) = \sqrt{\left(\frac{2}{C^{ii} + C^{jj} C^{ij}}\right)} > \sigma_e Z_p, n_e$$

Where,

$\left(y_i - y_j\right)$	=	Difference between two means
C^{ii}	=	Corresponding iith element of C matrix
C^{jj}	=	Corresponding jjth diagonal element of C matrix

C^{ij}	=	ij^{th} element of C matrix
Z_p, n_e	=	Ducan's Significant Studentized ranges for 5 per cent and 1 per cent level new multiple-range test at n_e degrees of freedom
p	=	Number of paired means in range chosen
σ_e	=	Standard deviation
n_e	=	Error degrees of freedom

Estimation of genetic and phenotypic parameters

Estimation of genetic and phenotypic parameters were obtained by Hendersons method/models II and III. Data were adjusted for significant non-genetic factors to estimate genetic parameters in the present study. Standard methodology was used for estimation of genetic parameters for first/all lactation traits.

Adjustment of data

Prior to estimation of genetic parameters, the data were adjusted for different significant non-genetic factors (season and period). The adjusted records were further used for subsequent analysis.

The data after adjustment for different non-genetic factors were utilized for estimation of different genetic parameters. The heritability, genetic and phenotypic correlations were estimated on those progeny groups which had a minimum of two daughters per sire.

Paternal half-sib correlation (Intra-sire correlation among daughters) method was utilized to estimate heritability of different traits. The Henderson's Model was used:

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

Where

Y_{ij}	=	Adjusted value of j_{th} progeny of i_{th} sire
μ	=	Overall mean
S_i	=	Effect of i_{th} sire
e_{ej}	=	Random error assumed to be distributed normally, and independently with mean zero and constant variance i. e., NID (0, σ_e^2).

The analysis of variance for half sib data with unequal number of daughters under different sires

Analysis of variance

Sauce of	**d.f.**	**SS**	**MS**	**EMS**
Between sires	S – 1	$\sum_{i=1}^{s}\frac{Y_i^2}{n_i}-\frac{Y_.^2}{N}$	MS_s	σ_e^2 + K σ_e^2
Within sires	(N – S)	$\sum Y_{ij}^2-\sum_{i=1}^{s}\frac{Y_i^2}{n_i}$	MS_e	σ_e^2
Total	N – 1			

Where,

S = Number of sires

N = Total number of buffaloes

n_i = Number of the daughters of i[th] sire

The sire component of variance

$$\sigma_s^2=\frac{\{Ms_s-Ms_e\}}{K}$$

Where,

σ_s^2 = The sire component of variance

σ_e^2 = The error component of variance

$$\frac{1}{(S-1)}\left(N-\frac{\sum n_i^2}{N}\right)$$

S = Total number of sires

The intraclass correlation among paternal half sib was determined as:

$$t=\left(\frac{\sigma_s^2}{\sigma_s^2+\sigma_e^2}\right)$$

The heritability was estimated as:

$$h^2=4.t=\frac{4(\sigma_s^2)}{(\sigma_s^2+\sigma_e^2)}$$

The standard error of heritability was estimated by using the following formula as given by Swiger *et al* (1964).

$$S.E\left(h^2\right)=4\sqrt{\frac{\left[2\left(N-1\right)\left(1-t\right)^2\left\{1+\{k-1\}t\right\}^2\right]}{\left\{K^2\left(N-S\right)\left(S-1\right)\right\}}}$$

Where,

N	=	Total number of daughters
S	=	Total number of sires
t	=	Intra class correlation among sizes
K	=	Average number of progeny per sire.

Estimation of genetic and phenotypic correlations

The genetic and phenotypic correlations among different traits were estimated from analysis of variance/covariance using half sib data as suggested by Becker (1975). The genetic correlation was calculated from sire component of variance and covariance.

The model and the procedure of analysis were same as the procedure of estimation of heritability. The analysis of covariance for half-sib data with unequal number of daughters under different sires assumed the following forms:

Analysis of covariance

Sauce of variation	d.f.	SS	MS	EMS
Between sires	S – 1	$\sum_{i=1}^{s}\frac{X_i.Y_{i.}}{n_i}-\frac{X..Y..}{N}$	MCP_s	$\sigma_s^2(xy)$ + K $\sigma_s^2(xy)$
Within sires	(N – S)	$\sum Y_{ij}^2-\sum_i\sum_j X_{ij}\sum_{i=}^{s}\frac{X_iY_j}{n_i}$	MCP_e	$\sigma_s^2(xy)$

The genetic correlation was calculated by using the following formula:

$$Rg(x,y)=\frac{CoV_{s(x,y)}}{\sqrt{\left\{\sigma_{s(x)}^2.\sigma_{s(y)}^2\right\}}}$$

Where,

x,y	=	Two different characters/traits under study
$CoV_{s(x,y)}$	=	Sire components of covariance between trait x and y.
$\sigma^2_{s(x)}$	=	Sire component of variance of trait x
$\sigma^2_{s(y)}$	=	Sire component of variance of trait y

The standard error of genetic correlation (rg) was estimated by using the following formula as given by Robertson (1959).

$$S.E = \frac{1-rg^2}{\sqrt{2}}\sqrt{\frac{SE\left(h^2x\right).SE\left(h^2y\right)}{\left(h^2x\right).\left(h^2y\right)}}$$

Where,

h^2x and h^2y were the heritabilities of traits x and y, respectively.

The phenotypic correlation between trait x and y was estimated using the following formula:

$$R_P\left(x,y\right) = \frac{CoV_{s(x,y)} + CoV_{e(x,y)}}{\sqrt{\left[\sigma_s^2\left(x\right)+\sigma_e^2\left(x\right)\right]\left[\sigma_s^2\left(y\right)+\sigma_e^2\left(y\right)\right]}}$$

Where,

$CoV_{e(x,y)}$	=	The error component of covariance between traits x and y
$CoV_{s(x.y)}$	=	The sire component of covariance between traits x and y
$\sigma_e^2\left(x\right)$	=	The error component of variance for trait x
$\sigma_e^2\left(y\right)$	=	The error component of variance for trait y
$\sigma_s^2\left(x\right)$	=	The sire component of variance for traits x
$\sigma_s^2\left(y\right)$	=	The sire component of variance for traits y

The standard error of phenotypic correlation was obtained as per following formula given by Panse and Sukhatme (1967).

$$S.E.\left(r_p\right) = \frac{\left[1-r_p^2\left(x,y\right)\right]}{\sqrt{N-2}}$$

Where,

$r_p(x, y)$	=	Phenotypic correlation between traits x and y
(N-2)	=	Degree of freedom

The significance of phenotypic correlation was tested by comparing estimated value with the table value given by Snedecor and Cochran (1967) at (N-2) degrees of freedom.

Test of Departures from Normality

Departures were normality of distribution can be categorized in term of skewness and kurtosis. Statistical test used for testing the departure from normality was applied by calculating the coefficients of skewness and kurtosis (Snedecor and Cochran 1967).

Test of skewness: A measure of the amount of skewness in a population is given by the average value of $(x-\mu)^3$ taken over the population. To render this measure independent of the scale on which the data are recorded, it is divided by σ^3. The quantity thus obtained is known as coefficient of skewness. The sample estimate of this coefficient is denoted by g_1. The second and third moments are calculated as follows:

$$m_2 = \frac{\sum\left(x - \bar{x}\right)^2}{n}$$

$$m_3 = \frac{\sum\left(x - \bar{x}\right)^3}{n}$$

Then

$$g_1 = \frac{M_3}{m_2\sqrt{m_2}}$$

Where,

m_2	=	the 2nd moment about the mean
m_3	=	the 3rd moment about the mean

$$\text{S.D. of } g_1 = \sqrt{\frac{6}{n}}$$

Significance of g_1 tested by t-test

Test of Kurtosis : In a population measure of kurtosis is the average value of $(x-\mu)^4$ divided by σ^4.. A sample estimate of coefficient of kurtosis (g_2) is given by:

$$g_2 = b_2 - 3 = \frac{m_4}{m_2^2} - 3$$

Where

$$m_4 \frac{\sum(x - \bar{x})^4}{n}$$ and is referred to as the 4th moment about the mean.

$$\text{S.D. of } g_2 = \sqrt{\frac{24}{n}}$$

Significance of g_2 coefficient was tested by t-test.

Test for Homogeneity of Variance

The homogeneity of variance which is required for pooling variance across groups like season and period was tested by Bartlett's χ^2 test (Snedecor and Cochran 1967). The test criterion M for unequal sample sizes is:

$$M = (2.3026)\left[\left(\sum f_i\right)\log \bar{S}^2 - \sum f_i \log S_i^2\right]$$

Where

f_i	=	the degrees of freedom in ith sample
S_i	=	Variance of the ith sample
$\bar{S}$		Variance pooled over samples and equals $\sum f_i S_i^2 / \sum f_i$
C	=	$1 + \frac{1}{3(a-1)}\left(\sum \frac{1}{f_i} - \frac{1}{\sum f_i}\right)$

Where

a	=	the number of samples
χ^2	=	M/C with (a-1) degrees of freedom

Sire evaluation

The main objective of sire evaluation is to obtain an accurate, efficient and unbiased estimate of breeding values of the bulls, and the ranking them in order of merit so as to choose the bulls of high genetic merit for subsequent improvement of the herd. Different sire evaluation methods have been proposed and used by different workers under different conditions with different accuracies. In the present investigation, the following three methods were used to estimate the breeding value of sires.

1. Least squares technique (LSQ)
2. Best linear unbiased prediction (BLUP)
3. Derivative free restricted maximum likelihood method (DFREML)

The sires having at least five progeny were included in the evaluation of breeding values. A total of 93 sires out of the available were evaluated on the basis of their first lactation 305 day or less milk yield by three different methods.

1. Least squares technique: Robertson and Rendel (1954) first used least squares method for sire evaluation. The least square method discussed by Harvey (1987) was used to estimate the breeding value of bulls. The following model was considered:

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

Y_{ij} = j^{th} dependent single trait of the daughter of i^{th} sire

μ = Population mean

S_i = Effect of i^{th} sire

e_{ij} = Random error, assumed to be normally independently distributed with mean zero and constant variance i.e. NID $(0, \sigma_s^2)$

The index of i^{th} sire was estimated by following formula:

$$I = \mu + S_i$$

Where,

I = Index of i^{th} sire

μ = Population mean

S_i = Least squares constant of i^{th} sire

2. Beast Linear Unbiased Prediction (BLUP): The breeding value of sires was estimated by best linear unbiased prediction (BLUP) method as given by Henderson (1973, 1975a).

The general model of BLUP estimation was considered as follows:

$$Y_{ijk} = X\, h_i + Z\, s_j + e_{ijk}$$

Where,

Y_{ijk}	=	Observation vector of trait with dimension (n x 1)
X	=	Design matrix or incidence matrix for fixed effect with dimension (n x p)
Z	=	Design matrix or incidence matrix for random effect with dimension (n x q)
h_i	=	A vector for fixed effect of dimension (p x 1)
s_i	=	Vector of random effect with mean zero and variance G σ_s^2 with dimension (q x 1)
e_{ijk}	=	Random error vector with dimension (n x 1) with mean zero and variance 1 σ_s^2

The assumes of the model are:

E (y)	=	*Xh*
E (s)	=	*0*
E (e)	=	*0, and*
Var(s)	=	*G* σ_s^2
Var(e)	=	*1* σ_s^2

From the above model the mixed model equations can be written more compactly as follows (Searle *et al* 1992):

$$\begin{bmatrix} \left(XR^{-1}X\right) & \left(XR^{-1}Z\right) \\ \left(ZR^{-1}X\right) & \left(ZR^{-1}Z+G^{-1}\right) \end{bmatrix} \begin{bmatrix} h \\ s \end{bmatrix} = \begin{bmatrix} \left(XR^{-1}Y\right) \\ \left(ZR^{-1}Y\right) \end{bmatrix}$$

Where,

G^{-1} is the diagonal matrix of σ_e^2/σ_s^2 pertaining to sire effect, the σ_e^2 is the error component and σ_s^2 is the sire component of variance.

The above matrix can be written as:

$$A\,B = C \qquad or \qquad B = A^{-1}\,C$$

By solving B, estimates of all the herds and sires was derived. The predicted breeding value of the sire was as follows:

$$S_i = \hat{S}_i + \frac{\sum h_i}{n_i}$$

Where,

S_i = Index of sire

$\hat{S}_i$ = Estimate of sire component from BLUP

h_i = Estimate of i^{th} herd

n^i = Number of herd where the daughters are available.

3. Restricted Maximum Likelihood Method (REML): Restricted maximum likelihood (REML) estimators maximize the likelihood parameters after correcting for the fixed effects. In REML method the loss in degrees of freedom due to correction for fixed effect was taken into account. For REML estimate the data were analyzed by more accurate and advanced derivative free restricted maximum likelihood method (DEREML) programme of Meyer (1993) for evaluation of breeding value sires. This makes a case of REML algorithms using derivatives of the likelihood for multivariate, multidimensional animal model analysis. This is an iteration procedure which starts with a certain set of variance components and stops when the set of variance components which results in the highest likelihood is found in DEREML method, the density function of the multivariate distribution is maximized after correcting all observations first for the fixed effects without taking consideration of the first or second derivatives in the analysis. Single and multiple trait models were used for estimation of different variance and covariance components. In multiple traits two or three traits were considered simultaneously.

Single trait model was considered for estimation of breeding value using DEREML method. For DEREML estimation, following animal model was considered:

$$Y_{ijk} = Xb_i + Zu_i + e_{ijk}$$

Where,

Y_{ijk}	=	K^{th} observation of j^{th} effect of i^{th} fixed effect
bi	=	Vector of observation of fixed effect i.e. Season, Period
u_i	=	Vector of additive genetic effect (Random effect/Sire effect)
X	=	Design matrix/Incident matrix of fixed effect
Z	=	Design in matrix/Incident matrix of random effect
e_{ijk}	=	Vector of residual errors

With *E(y) = Xb* and

The following are the assumptions of the model

	Var (u)	=	G
	Var (e)	=	R
and	Cov (u) $e^{/}$)	=	0

So that, V(y) = $ZGZ^{/}$ + R

The normal distribution of a variable y with mean μ and standard deviation б, the normal distribution of this variable represented as : y-N (μ, $1б^2_{e12}$).

The mathematical distribution of the density function for this normally distributed variable is:

$$f(y)=\frac{1}{\sigma\sqrt{2\pi}}e^{-1/2(y-\mu)^2/\sigma^2}$$

This is known as probability density function (PDF). In case of multivariate, multi dimensional normal distribution PDF follows, y - N(Xb, V). Where, N is the length of y and V is the variance of the parameters. This function f(y) gives the probability of finding a certain ‘y’ such that the parameters are given. The parameters are the means in Xb (“location parameters”) and the variances in V (“dispersion parameters”). Observed data gives probability of having such data for certain parameter value. So the probability density function can be used as a likelihood function.

When the data y is known; the f(y) is a likelihood function which can be maximized in parameters; in other words, find the parameters for which f(y) has highest value has to be found. Instead of maximize f(y),maximize e_{log} of f(y); L(b, V 1 X, y) which is the log likelihood function given as follows:

$$L(b, V \mid X, y) = ½ N \log (2\pi) - ½ (y-Xb)^{/-1})y-Xb)$$

The likelihood function is rewritten after correcting for the fixed effect. This is known as restricted maximum likelihood; secondly it is rewritten in terms of elements that related to mixed model equation. The log of REML likelihood (L) was represented as follows (Harville 1977).

$$\text{Log } L = ½[\text{ Constant} + \log |V| + \log |X^{/} V^{-1} X^{/} | + (y-Xb)^{/} V^{-1}(y-xb)]$$

Where X denotes full rank matrix of sub matrix of X, log L can also be written as follows (Meyer 1989):

$$\text{Log } L = - ½ \ [\text{Constant} + \log |R| + \log |G| + \log |C| + \sqrt{} Py]$$

Where, C is the coefficient matrix in mixed model equation (MME) pertaining to first equation and P is a matrix,

$$P = V^{-1} - V^{/-1} X(X^{/}V^{-1} X)^{-} X^{/}V^{-1}$$

$$= V^{-1} - V^{-1} X^{/}(X^{/}V^{-1}X^{/}V^{-1}$$

Evaluation of the likelihood

1. ***Calculating log 1C1 and $\sqrt{P_y}$ and their derivatives:***

The mixed model matrix (MMM) pertaining to the first equation is:

$$M = \begin{bmatrix} X^{/}R^{-1}X & X^{/}R^{-1}Z & X^{/}R^{-1}Y \\ Z^{/}R^{-1}X & Z^{/}R^{-1}Z+G^{-1} & Z^{/}R^{-1}y \\ Y^{/}R^{-1}X & Y^{/}R^{-1}Z & y^{/}R^{-1}y \end{bmatrix} = \begin{bmatrix} C & r^{/} \\ & \\ r^{/} & r^{/}R^{-1}y \end{bmatrix}$$

Where $r^{/}$ is the vector of right hand side in the MME.

This was done by using Cholesky dedcomposition of the coefficient matrix. The Cholesky decomposition factors a positive definitive matrix into the product of a lower triangular matrix and its transpose. Let L with elements l_{ij} (l_{ij} =0 for j > i) denotes the Cholesky factor of M, i.e. M = $LL^{/}$. Differentiation gives the derivatives of log |C| and √Py as simple function of the diagonal elements of the Cholesky matrix and its derivatives.

2. Calculating log |R| its derivatives

Let y be ordered according to traits within animals and assuming the error covariance between different animals are zero; the log |R| will be

$$\text{Log } |R| = \Sigma N_{w \log}|E_w|$$

Where N_w represents the number of animals having records for combination of the trait w. Differentiation gives the derivatives of log |R|.

3. Calculating log |G| its derivatives:

When a and c are uncorrelated; the T can be partitioned into corresponding block T_A and T_C. Then G =*Diag* {A*T_A; F*T_C}. Thus,

$$\text{Log}|G| = N_A \log|T_A| + N_C| \log|T_C| + q(\log|A|+;pg|G|)$$

Where

A	= Numerator relationship between animals
F	= Identity matrix, describes correlation structure among the level c
T_A	= Diagonal block matrix of Additive genetic between the traits, a
T_C	= Diagonal block matrix of uncorrelated random effect
E	= Residual variance-covariance matrix between the traits
N_A	= Total number of the animals
N_C	= Levels per trait of uncorrelated additional random effect c
*	= Direct product operator

Differentiation of the equation of log|G| gives the derivatives of log |G|.

Maximizing the likelihood

One of the most widely used methods to optimize a non-linear function is the Newton-Raphson (NR) algorithm. As described by Graser *et al* (1987), for single trait method quadratic approximation method was used which requires one dimensional search. For multivariate analysis the value of the step size scaling factor was maximized by using a one dimensional maximization technique (Powell, 1970).

Convergence criteria

The convergence criteria were taken as the variance among the function values; convergence was assumed when this variance was less than 10^{-8}.

By slowing log |C|, √Py, log |R| and; pg |G| and their derivatives different variance, covariance components in animal model the additive genetic value of all the animals were estimated. The breeding value of sires was determined by adjusting the additive genetic value of the sires from the overall population mean.

Criteria for judging effectiveness of various sire evaluation methods

After the sires were evaluated by different procedures, they were ranked as per their genetic merit. The effectiveness of different sire evaluation methods were judged by using the following criteria:

1. Within sire variance or error variance
2. Coefficient of determination
3. Coefficient of variation (%)
4. Rank correlations

1. Within sire variance or error variance

The effectiveness of different sire evaluation methods were judged by within sire variance (error variance). The method giving lowest error variance had higher efficiency and would be most appropriate. The efficiency was measured by the following:

$$\text{Efficiency} = \frac{1}{\text{Error variance}}$$

Relative efficiency (RE) of method II with respect to method I (most efficient method) was calculated by the following equation.

$$\text{RE(E)} = \frac{\text{Error variance of method I}}{\text{Error variance of method II}} \times 100$$

2. Coefficient of determination

The coefficients of determination (R^2-Value) of different methods were estimated for judging the effectiveness of sire evaluation method. The model which showed the highest R^2-value was considered to be the most accurate.

3. Coefficient of variation (%)

The coefficient of variation (CV %) of traits under study from different models of sire evaluation was estimated. In case of ideal adjustment of records, the structure of population as indicated by CV should not alter from the CV of unadjusted data.

4. Rank correlations

After estimation of breeding values of sires, the sires were give rank as per their genetic merit. The Spearman's rank correlation between breeding values of sires derived by various methods was used to judge the effectiveness of different methods. The rank correlation was estimated as per Steel and Torrie (1960).

$$r_s = \frac{6\sum d_i^2}{n(n-1)}$$

Where,

r	=	Rank correlation coefficient
n	=	Number of sires under evaluation
d_i	=	Difference of rank between paired items under two methods.

The significance of rank correlation was tested by t-test as given below:

$$t = r\sqrt{\frac{n-2}{(1-r^2)}}$$

It was compared with t-value with (n-2) degree of freedom.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Mean Performance and Factors Affecting Growth Traits

Body weights during different periods are of importance due to their effect on onset of sexual maturity, survival rate and to some extent due to their effect on reproduction and production. Growth in general is an indicator of an animal's genetic potential under given environmental and managemental conditions. Growth can be characterized by body weights at different ages, increase in body weight for one age to another (absolute gain in weight) and by relative growth rate from one age to another. The least–squares means alongwith their standard errors and coefficients of variations for growth traits categorized on period and season of birth are presented in Tables 38-44. The least-squares analyses of variance for studying the effects of the various non-genetic factors on growth traits are presented in Tables 46 to 47.

4.1.1 Birth Weight

The overall least-squares mean for birth weight was 31.94±0.38kg with a coefficient of variation of 35.0 per cent (Table 38). The overall mean was, in general, higher than those reported by Johari and Bhat (1979a), Nautiyal and Bhat (1979), Verma and Hussain (1985), Singh and Basu (1988), Dahama (1991) and Rao and Lakshminarayana (1994) in Murrah buffaloes. In general, it was within the range of those reported by Kanaujia (1973), Basu and Rao (1979) and Bhardwaj (2002).

Season: The season of birth did not significantly influence the birth weight and accounted for a very small per cent (0.34%) of the variation (Table 45). The average birth weight ranged from 31.5 to 32.6kg over the seasons. However, birth weight was generally higher in spring and winter (32.6 and 32.0kg) as compared to other seasons. The seasonal trend indicated that maximum numbers of calves were born during winter season followed by the rainy season and least number of births were recorded during spring season. Significant influence of season of birth on birth weight was reported by Yadav *et al* (2001) while Thiruvenkadan (2009) and Gupta *et al* (2012) did not find any significant effect.

Table 38: Least-square means (±SE) and coefficients of variation for dam weight, birth weight and calf-dam weight (%)

Effects	N	Dam Wt.(kg)		B Wt. 0(kg)		Calf-dam wt. %	
		Mean±SE	CV(%)	Mean±SE	CV(%)	Mean±SE	CV(%)
Overall μ		551.2±5.31	28.3	31.94±0.38	35.0	5.84±0.08	40.3
Seasons:							
Summer	142	564.3±7.41	15.6	31.58±0.56	21.1	5.65±0.12	25.3
Rainy	220	543.8±6.70	18.3	31.97±0.50	23.2	5.96±0.11	27.4
Autumn	186	549.0±6.98	17.3	31.52±0.52	22.5	5.82±0.11	25.8
Winter	237	548.5±6.42	18.0	32.03±0.47	22.6	5.90±0.10	26.1
Spring	80	550.4±8.42	13.7	32.62±0.64	17.5	5.86±0.14	21.4
Periods:							
1988-92	254	536.4±13.71	40.7	32.14±1.08	53.5	5.97±0.24	64.1
1993-97	227	504.5±11.46	34.2	30.94±0.89	43.3	6.09±0.20	49.5
1998-02	169	541.9±12.12	29.1	32.42±0.95	38.1	6.05±0.21	46.3
2003-07	157	577.7±11.87	25.7	33.57±0.93	34.7	5.90±0.21	44.6
2007-12	58	595.4±19.10	24.4	30.65±1.52	37.8	5.17±0.34	50.1
Parity:							
1	244	474.9±5.98	19.7	29.42±0.44	23.4	6.33±0.09	22.2
2	190	527.1±6.41	16.8	31.45±0.47	20.6	6.03±0.10	22.9
3	116	558.2±7.17	13.8	32.53±0.54	17.9	5.89±0.12	21.9
4	107	575.4±7.34	13.2	32.71±0.55	17.4	5.73±0.12	21.7
5	71	582.9±8.41	12.2	33.24±0.64	16.2	5.72±0.14	20.6
6	56	573.4±9.37	12.2	32.64±0.72	16.5	5.58±0.16	21.5
7	31	572.0±11.40	11.1	32.42±0.89	15.3	5.72±0.20	19.5
8	20	565.1±14.06	11.1	31.30±1.11	15.9	5.53±0.25	20.3
9	16	574.1±15.73	11.0	33.18±1.24	14.9	5.77±0.28	19.4
10	7	543.0±22.94	11.2	31.82±1.83	15.2	5.88±0.42	18.9
11	7	516.9±23.05	11.8	30.67±1.83	15.8	6.05±0.42	18.4

Period: The period of birth also did not significantly influence the birth weight and accounted for a small fraction (0.74%) of the variation (Table 45). The average birth weight ranged between 30.65 and 33.57 kg over the periods with no systematic time trend. Significant influence of period of birth on birth weight was reported by Yadav *et al* (2001) and Thiruvenkadan *et al* (2009) while Gupta *et al* (2012) did not find any significant effect.

Parity: The parity of dam was observed to be highly significant ($p \leq 0.01$) source of variation in the birth weight and accounted for a small (6.52%) of the total variation (Table 45). The average birth weight ranged from 29.42 to 33.24 kg over the different parities of dam. Increasing trend in birth weight was observed up to fifth parity. Significant influence of parity on birth weight was reported by Thiruvenkadan *et al* (2009).

4.1.2 Dam Weight

The overall least-squares mean for dam weight was 551.1±5.31 with a coefficient of variation of 28.33 per cent (Table 38). The overall mean was, in general, higher than those reported by Basu *et al* (1984), Rao and Lakshminarayana (1994), Rao and Rao (1997) and Rao and Sreemannarayana (1998). In general, it was within the range of those reported by Gurung and Johar (1982b) and Singh and Basu (1988).

Season: The season of birth did not significantly influence the dam weight at calving and accounted for a small (0.61%) of the variation (Table 45). The average dam weight ranged from 543.8 to 564.3 kg over the seasons. No systematic trend could be observed over seasons. However, dam weight was observed to be the highest in summer born dams (564.3kg). The non-significant influence of season on dam weight was reported by Bhardwaj (2002) and Gupta *et al* (2012).

Period: The period of birth was observed to be highly significant ($P<0.01$) source of variation in the dam weight and accounted for a small (2.00%) of the variation (Table 45). The average dam weight ranged from 504.5 to 595.4 kg over the periods. No specific trend was observed over periods. Significant influence of period on dam weight was reported by Thiruvenkadan *et al* (2009).

Parity: The parity of dam influenced highly significantly (P<0.01) dam weight and accounted for one fourth (26.28%) of the total variation (Table 45). The average dam weight ranged from 474.9 to 582.9kg over the different parities of dam. Increasing trend in dam weight was observed up to fifth parity of dam. Significant influence of parity of dam on dam weight was reported by Thiruvenkadan *et al* (2009).

4.1.3 Calf-dam Weight (%)

Calf-dam weight (%) is the ratio of calf birth weight to dam weight at calving expressed in percentage. The overall least-squares mean for calf-dam weight (%) was 5.84±0.08 with a coefficient of variation of 40.29 per cent (Table 38).

Seaon: The effect of season of calving on the calf-dam weight (%) was non significant and accounted for a small portion (0.68%) of the variation (Table 45). The average calf-dam weight (%) ranged from 5.65 to 5.96 per cent over the seasons. Calves born during rainy season were having highest calf-dam weight percent of 5.96. This might be attributed to most favorable season for buffaloes. No systematic trend was observed over seasons.

Period: The period of calving did not significantly influence the calf-dam weight (%) and accounted for a small portion (0.51%) of the variation (Table 45). The average calf-dam weight (%) ranged from 5.17 to 6.09 % over the periods. In general a declining trend was observed across the periods.

Parity: The parity of dam was observed to be highly significant (P<0.01) source of variation in the calf-dam weight (%) and accounted for a small (4.38%) of the total variation (Table 45). The average calf-dam weight (%) ranged from 5.53 to 6.33 over the different parities of dam.

4.1.4 One-month Weight

The overall least-squares mean was 42.01±0.44kg with a coefficient of variation of 30.80 per cent indicated a good variability in the trait (Table 39). The calves born with comparatively higher birth weight had shown more gain in weight than calves having lesser birth weight.

Season: The season of calving did not significantly influence the one-month weight and accounted for a small portion (0.95%) of the variation (Table 45). The average one-month weight ranged from 40.97 to 43.23kg over the seasons. No systematic trend was observed over seasons. However, one-month weight was generally highest in spring (43.23kg). Significant influence of season on one-month weight was reported by Basu and Rao (1979) and Kumaravelu *et al* (2004) while Yadav (2001) and Thiruvenkadan *et al* (2009) did not find any significant effect.

Period: The period of calving did not significantly influence the one-month weight and accounted for a small portion (0.82%) of the variation (Table 45). The average one-month weight ranged from 40.07 to 44.30kg over the periods. No systematic trend of change in one-month weight could be observed over periods. Significant influence of period of calving on one-month weight was reported by Yadav (2001) and Thiruvenkadan *et al* (2009) attributed significant effect to variation in management practices and availability of quality fodder over the periods.

Parity: The parity of calving significantly ($P<0.01$) influenced the one-month weight and accounted for a small portion (4.40%) of the variation (Table 45). The average one-month weight ranged from 40.06 to 43.44kg over the periods. Increasing trend of change in one-month weight could be observed up to sixth parity. Significant influence of parity on one-month weight was reported by Thiruvenkadan *et al* (2009).

4.1.5 Three-month Weight

The overall least-squares mean for three-month weight was 63.82±0.72 with a coefficient of variation of 33.18 per cent (Table 39). The overall mean was, in general, higher than those reported by Kaushish (1997) and within range of reported estimate in Murrah buffaloes by Basu and Rao (1979) and Rao and Lakshminarayana (1984) but lesser than reported by Johari (1976), Johari and Bhat (1979a) and Gurung and Johar (1983b).

Table 39: Least-square means(±SE) and coefficients of variation for body weights at 1, 3 and 6 months of age

Effects	N	Body weight at 1 month age (kg)		Body weight at 3 months age (kg)		Body weight at 6 months age (kg)	
		Mean±SE	**CV(%)**	**Mean±SE**	**CV(%)**	**Mean±SE**	**C.V.(%)**
Overall μ	865	42.01±0.44	30.8	63.82±0.72	33.2	97.98±1.32	39.6
Seasons:							
Summer	142	42.03±0.63	17.9	64.24±1.03	19.1	99.12±1.72	20.7
Rainy	220	41.70±0.57	20.3	62.30±0.93	22.1	97.63±1.58	24.0
Autumn	186	40.97±0.59	19.6	63.11±0.97	21.0	98.15±1.64	22.8
Winter	237	42.13±0.54	19.7	63.63±0.88	21.3	95.83±1.53	24.6
Spring	80	43.23±0.72	14.9	65.82±1.18	16.0	99.15±1.92	17.3
Periods:							
1988-92	254	40.07±1.19	47.3	58.70±1.94	52.7	92.80±2.99	51.3
1993-97	227	42.31±0.99	35.2	62.58±1.62	39.0	93.71±2.53	40.7
1998-02	169	41.41±1.05	33.0	64.24±1.71	34.6	95.51±2.66	36.2
2003-07	157	44.30±1.03	29.1	66.72±1.68	31.5	102.13±2.61	32.0
2007-12	58	41.98±1.67	30.3	66.85±2.71	30.9	105.74±4.11	29.6
Parity:							
1	244	40.06±0.50	19.5	62.36±0.82	20.5	97.35±1.45	23.3
2	190	41.42±0.54	18.0	63.37±0.89	19.4	99.40±1.53	21.2
3	116	43.28±0.61	15.2	65.06±0.99	16.4	101.51±1.67	17.7
4	107	42.95±0.62	14.9	65.93±1.02	16.0	102.33±1.71	17.3
5	71	42.67±0.72	14.2	63.04±1.18	15.8	98.99±1.91	16.3
6	56	42.98±0.81	14.1	64.96±1.32	15.2	98.40±2.10	16.0
7	31	42.08±0.99	13.1	65.34±1.61	13.7	101.27±2.52	13.8
8	20	40.83±1.23	13.5	60.15±1.99	14.8	96.02±3.06	14.2
9	16	43.44±1.37	12.6	65.67±2.23	13.6	96.72±3.41	14.1
10	7	41.55±2.01	12.8	62.99±3.26	13.7	92.07±4.92	14.1
11	7	40.87±2.02	13.1	63.13±3.28	13.7	93.66±4.94	13.9

Season: The season of calving did not significantly influence the three-month weight and accounted for a small (0.96%) of the variation (Table 45). The average birth weight ranged from 62.30 to 65.82 kg over the seasons. No systematic trend was observed over seasons. However, birth weight was the highest in spring (65.82kg). Significant influence of season on three-month weight was reported by Basu and Rao (1979) and Kumaravel *et al* (2004) while Yadav *et al* (2001), Bhardwaj (2002), Thiruvenkadan *et al* (2009) and Gupta *et al* (2012) did not find any significant effect.

Period: The period of calving did not significantly influence the three-month weight and accounted for a small (0.89%) of the variation (Table 45). The average birth weight ranged from 58.70 to 66.85 kg over the periods. Increasing trend in three-month weight was observed over period. Significant influence of period on three-month weight was reported by Yadav *et al* (2001), Thiruvenkadan *et al* (2009) and Gupta *et al* (2012) while Bhardwaj (2002) did not find any significant effect.

Parity: The parity of dam was observed to be significant ($P<0.05$) source of variation in the birth weight and accounted for a small (2.29%) of the total variation (Table 45). The average three-month weight ranged from 60.15 to 65.93 kg over the different parities of dam. Increasing trend in three-month weight was observed up to fourth parity. Significant influence of parity on three-month weight was reported by Thiruvenkadan *et al* (2009) while Bhardwaj (2002) did not find any significant effect.

4.1.6 Six-month Weight

The overall least-squares mean was 97.98±1.32kg with a coefficient of variation of 39.62 per cent (Table 39). The overall mean was, in general, higher than those reported by Verma and Hussain (1985), Kaushish (1997) and Bhardwaj (2002) in Murrah buffaloes but lower than those reported by Johari (1976), Sharma *et al* (1983b), Gurung and Johar (1983b) and Dahama (1991). In general, it was within the range of those reported by Basu and Rao (1979) and Rao and Lakshminarayana (1994).

Season: The season of calving did not significantly influence the six-month weight and accounted for a small portion (0.66%) of the variation (Table 45). The season effect did not show any consistent trend. However, six-month weight was generally highest in spring (99.15kg). Significant influence of season on six-month weight was reported by Basu and Rao (1979) and Kumaravel *et al* (2004) while Yadav *et al* (2001), Bhardwaj (2002), Thiruvenkadan *et al* (2009) and Gupta *et al* (2012) did not find any significant effect.

Period: The period of calving did not significantly influence the six-month weight and accounted for a small portion (0.83%) of the variation (Table 45). The average six-month weight ranged from 92.80 to 105.74kg over the periods. Increasing trend of change in six-month weight could be observed over periods. Significant influence of period on six-month weight was reported by Yadav *et al* (2001), Thiruvenkadan *et al* (2009) and Gupta *et al* (2012) while Bhardwaj (2002) did not find any significant effect.

Parity: The parity of calving significantly ($P<0.05$) influenced the six-month weight and accounted for a small portion (1.90%) of the variation (Table 45). The average six-month weight ranged from 92.07 to 102.33kg over the periods. The parity effect did not show any consistent trend. Significant influence of parity on six-month weight was reported by Thiruvenkadan *et al* (2009) while Bhardwaj (2002) did not find any significant effect.

4.1.7 Twelve-month Weight

The overall least-squares mean for twelve-month weight was 171.35±2.05 with a coefficient of variation of 35.19 per cent (Table 40). The overall mean was, in general, higher than those reported by Kaushish (1997) and within range of reported estimates in Murrah buffaloes by Basu and Rao (1979), Rao and Lakshminarayana (1994) and Bhardwaj (2002) but lesser than reported by Sharma *et al* (1983), Gurung and Johar (1983b) and Dahama (1991) and Jogi and Lakhani (1996).

Season: The season of calving significantly ($P<0.05$) influenced the twelve-month weight and accounted for a small (1.28%) of the variation (Table 45). The average twelve-month weight ranged from 166.9 to 176.6 kg over the seasons. No systematic trend was observed over seasons. However, birth weight was the highest in summer (176.6kg). This might be due to calves born in other favourable seasons with highest body weights when reach this stage also show highest weights correspondingly while calves which were in favourable season had lower body weight as they were in unfavourale season earlier and had lower body weight during that season. Significant influence of season on twelve-month weight was reported by Basu and Rao (1979) and Kumaravel *et al* (2004) and Gupta *et al* (2012) while Yadav *et al* (2001), Bhardwaj (2002) and Thiruvenkadan *et al* (2009) did not find any significant effect.

Period: The period of calving was observed to be highly significant (P<0.01) source of variation in the twelve-month and accounted for a small (1.61%) of the variation (Table 45). The average birth weight ranged from 156.9 to 197.0 kg over the periods. Increasing trend in twelve-month weight was observed over periods. The non significant influence of period on twelve-month weight was reported by Yadav *et al* (2001), Bhardwaj (2002), Thiruvenkadan *et al* (2009) and Gupta *et al* (2012).

Parity: The parity of dam did not significantly influence the twelve-month weight and accounted for a small (0.93%) of the total variation (Table 45). The average twelve-month weight ranged from 156.2 to 175.9 kg over the different parities of dam. Increasing trend in twelve-month weight was observed up to fourth parity. Significant influence of parity on twelve-month weight was reported by Thiruvenkadan *et al* (2009) Bhardwaj (2002) did not find any significant effect.

4.1.8 Eighteen-month Weight

The overall least-squares mean was 250.51±3.02kg with a coefficient of variation of 35.46 per cent (Table 40). The overall mean is, in general, lower than those reported by Nautiyal and Bhat (1977), Sharma *et al* (1983a) and Gurung and Johar (1983b) in Murrah buffaloes. In general, it was within the range of those reported by Kirmani *et al* (1985).

Season: The season of calving did not significantly influence the eighteen-month weight and accounted for a small portion (0.32%) of the variation (Table 46). The

Table 40: Least-square means(±SE) and coefficients of variation for body weights at 12, 18 and 24 months of age

Effects	N	Body weight at 12 months age ((kg)		Body weight at 18 months age (kg)		Body weight at 24 months age (kg)	
		Mean±SE	CV(%)	Mean±SE	CV(%)	Mean±SE	C.V.(%)
Overall μ	865	171.3±2.05	35.12	250.5±3.02	35.5	332.2±3.46	30.6
Seasons:							
Summer	142	176.6±2.87	19.4	253.0±3.96	18.6	333.6±4.68	16.7
Rainy	220	171.7±2.59	22.4	249.0±3.63	21.6	335.6±4.26	18.8
Autumn	186	170.5±2.71	21.7	251.5±3.77	20.4	332.8±4.43	18.2
Winter	237	166.9±2.49	23.0	247.6±3.51	21.8	326.7±4.10	19.3
Spring	80	171.0±3.27	17.1	251.5±4.43	15.7	332.8±5.28	14.2
Periods:							
1988-92	254	156.9±5.34	54.2	230.7±6.97	48.1	300.5±8.46	44.9
1993-97	227	164.3±4.46	40.9	243.6±5.88	36.4	329.6±7.10	32.5
1998-02	169	164.2±4.71	37.3	245.9±6.20	32.8	332.3±7.50	29.3
2003-07	157	174.4±4.62	33.2	250.4±6.08	30.4	334.9±7.35	27.5
2007-12	58	197.0±7.44	28.8	282.00±9.60	25.9	363.7±11.72	24.5
Parity:							
1	244	172.4±2.31	20.9	248.1±3.31	20.8	330.6±3.85	18.2
2	190	174.6±2.48	19.6	254.3±3.51	19.0	335.6±4.09	16.8
3	116	175.6±2.78	17.0	252.7±3.85	16.4	331.7±4.54	14.7
4	107	175.7±2.85	16.8	254.0±3.93	16.0	332.1±4.64	14.4
5	71	169.9±3.27	16.2	248.0±4.43	15.0	332.6±5.27	13.3
6	56	175.9±3.64	15.5	259.6±4.88	14.1	344.2±5.84	12.7
7	31	173.1±4.43	14.2	252.5±5.85	12.9	332.6±7.06	11.8
8	20	172.1±5.47	14.2	253.4±7.14	12.6	329.6±8.66	11.7
9	16	168.4±6.12	14.5	251.5±7.95	12.6	334.4±9.68	11.6
10	7	170.8±8.94	13.8	237.6±11.50	12.8	324.3±14.06	11.5
11	7	156.2±8.98	15.2	243.8±11.55	12.5	326.6±14.13	11.4

Average eighteen-month weight ranged from 247.6 to 253.0kg over the seasons. No systematic trend was observed over seasons. However, eighteen-month weight was generally highest in summer (253.0kg). This might be due to calves born in other favourable seasons with highest body weights when reach this stage also show highest weights correspondingly while calves which were in favourable season had lower body weight as they were in unfavourale season earlier and had lower body weight during that season. Significant influence of season on eighteen-month weight was reported by Basu and Rao (1979) and Kumaravel *et al* (2004) and Gupta *et al* (2012) while Yadav *et al* (2001), Bhardwaj (2002) and Thiruvenkadan *et al* (2009) did not find any significant effect.

Period: The period of calving significantly ($P<0.05$) influence the eighteen-month weight and accounted for a small portion (1.49%) of the variation (Table 46). The average eighteen-month weight ranged from 230.7 to 282.0kg over the periods. Increasing trend of change in eighteen-month weight could be observed over periods. The non significant influence of period on eighteen-month weight was reported by Yadav *et al* (2001), Bhardwaj (2002), Thiruvenkadan *et al* (2009) and Gupta *et al* (2012).

Parity: The parity of calving did not significantly influence the eighteen-month weight and accounted for a small portion (1.18%) of the variation (Table 46). The average eighteen-month weight ranged from 237.6 to 254.3kg over the different parities of dam. Increasing trend of change in eighteen-month weight could be observed up to sixth parity. Significant influence of parity on eighten-month weight was reported by Thiruvenkadan *et al* (2009) Bhardwaj (2002) did not find any significant effect.

4.1.9 Twenty fourth-month Weight

The overall least-squares mean for twenty fourth-month weight was 332.21±3.46 with a coefficient of variation of 30.63 per cent (Table 40). The overall mean was, in general, higher than those reported by Rao and Lakshminarayana

(1994) and lower than those reported by Sharma *et al* (1983) and Dahama (1991) in Murrah buffaloes. In general, it was within the range of those reported by Nautiyal and Bhat (1977), Johari and Bhat (1979a) and Gurung and Johar (1983b).

Season: The season of calving did not significantly influence the twenty fourth-month weight and accounted for a small (0.59%) of the variation (Table 46). The average twenty fourth-month weight ranged from 326.7 to 335.6 kg over the seasons. No systematic trend was observed over seasons. However, twenty fourth-month weight was the highest in rainy season (335.6kg). Significant influence of season on twenty fourth-month weight was reported by Basu and Rao (1979) and Kumaravel *et al* (2004) and Gupta *et al* (2012) while Yadav *et al* (2001), Bhardwaj (2002) and Thiruvenkadan *et al* (2009) did not find any significant effect.

Period: The period of calving was observed to be highly significant ($p \leq 0.01$) source of variation in the twenty fourth-month weight and accounted for a small (2.01%) of the variation (Table 46). The average birth weight ranged from 300.5 to 363.7 kg over the periods. Increasing trend was observed over periods. The non significant influence of period on twenty fourth-month weight was reported by Yadav *et al* (2001), Bhardwaj (2002), Thiruvenkadan *et al* (2009) and Gupta *et al* (2012).

Parity: The parity of dam did not significantly influenced twenty fourth-month weight and accounted for a small (0.75%) of the total variation (Table 46). The average birth weight ranged from 324.3 to 344.2kg over the different parities of dam. No consistent trend could be observed in weight over different parities of dam. Significant influence of parity on twenty fourth-month weight was reported by Thiruvenkadan *et al* (2009) while Bhardwaj (2002) did not find any significant effect.

4.1.10 Factors Affecting Monthly Gain in Weight

The least-squares means for various monthly gain in weights for various effects are presented in Tables 45-48 and their analysis of variance is given in Table 46.

4.1.10.1 Monthly Gain in Weight from Birth to One Month of Age

The average monthly gain body weight during first month of life was 10.07±0.34kg (Table 41). The period of birth ($P<0.01$) significantly influenced and season of birth and parity did not significantly influenced growth rate from birth to one month of age (Table 46). Gurung and Johar (1982b) also reported that period of birth had significant ($p<0.01$) effect on growth rate during first month whereas significant effect of season of birth ($p<0.01$) was reported by Rao and Lakshminarayana (1994). Calves born during spring gained weight more rapidly than those born during other seasons.

4.1.10.2 Monthly Gain in Weight from One to Three Month of Age

The average monthly gain body weight during first to three months of life was 10.90±0.25kg (Table 41). The parity, period and season of birth did not significantly influenced growth rate from one to three month of age (Table 46). Gurung and Johar (1982b) also reported that period of birth had significant ($p<0.01$) effect on growth rate during first month whereas significant effect of season of birth ($p<0.01$) was reported by Rao and Lakshminarayana (1994). Calves born during spring gained weight more rapidly than those born during other seasons.

4.1.10.3 Monthly Gain in Weight during Three to Six Months of Age

The calves gained weight at the rate of 11.38±0.29kg per month during three to six months of age (Table 41). The period of birth and parity did not influence the growth of calves but the season of birth significantly ($P<0.05$) influenced the growth rate during three to six months of the age (Table 46). Gurung and Johar (1982b) reported significant ($p<0.01$) effect of period of birth on growth rate during three to six month of age.

4.1.10.4 Monthly Gain in Weight during Six to Twelve Months of Age

The average monthly gain during six to twelve months of age was 12.2±0.39kg (Table 41) and this was more than the gain in weight during birth to one, one to three and three to six months. The daily gain in weight recorded in this

Table 41: Least-square means (±SE) for monthly gain in weight (kg) between 0-1, 1-3, 3-6 and 6-12 months

Effects		**Per month gain in weight between months (Mean±SE)**			
	N	**0-1**	**1-3**	**3-6**	**6-12**
Overall µ	865	10.07±0.34	10.90±0.25	11.38±0.29	12.22±0.27
Seasons:					
Summer	142	10.45±0.49	11.11±0.37	11.62±0.40	12.91±0.39
Rainy	220	9.73±0.44	10.30±0.33	11.77±0.36	12.34±0.35
Autumn	186	9.45±0.46	11.06±0.35	11.68±0.38	12.06±0.37
Winter	237	10.10±0.42	10.75±0.32	10.73±0.35	11.84±0.33
Spring	80	10.60±0.56	11.30±0.43	11.11±0.46	11.97±0.45
Periods:					
1988-92	254	7.92±0.92	9.32±0.72	11.36±0.76	10.68±0.75
1993-97	227	11.36±0.77	10.13±0.60	10.37±0.63	11.76±0.62
1998-02	169	8.98±0.81	11.42±0.63	10.42±0.67	11.45±0.66
2003-07	157	10.73±0.79	11.21±0.62	11.80±0.65	12.04±0.65
2007-12	58	11.34±1.29	12.43±1.01	12.96±1.06	15.20±1.05
Parity:					
1	244	10.64±0.39	11.15±0.29	11.66±0.32	12.51±0.31
2	190	9.98±0.42	10.97±0.32	12.01±0.35	12.53±0.33
3	116	10.76±0.47	10.89±0.36	12.14±0.39	12.35±0.38
4	107	10.23±0.48	11.49±0.37	12.13±0.40	12.23±0.39
5	71	9.43±0.56	10.18±0.43	11.98±0.46	11.81±0.45
6	56	10.34±0.62	10.99±0.48	11.14±0.51	12.91±0.50
7	31	9.67±0.76	11.63±0.60	11.97±0.63	11.96±0.62
8	20	9.54±0.94	9.66±0.74	11.95±0.78	12.67±0.77
9	16	10.20±1.06	11.11±0.83	10.35±0.87	11.95±0.86
10	7	9.76±1.55	10.72±1.22	9.69±1.27	13.12±1.27
11	7	10.20±1.56	11.13±1.23	10.17±1.28	10.43±1.27

study was almost equal to that reported by Jogi and Lakhani (1996) in female Murrah buffaloes but it was lower than that reported by Sharma *et al* (1983) in graded Murrah female buffaloes during six to twelve months of age. The period of birth significantly ($P<0.05$) influenced but season of birth and parity of dam did not influenced the growth rate during this period of life in female buffaloes (Table 46). No consistent trend could be observed for the effect of parity and period of birth.

4.1.10.5 Monthly Gain in Weight during Twelve to Eighteen Months of Age

The average monthly body weight gain in buffalo heifers during twelve to eighteen months of age was 13.2±0.27kg (Table 42). In this period heifers grew faster in comparison to growth in other periods. Similar trend in growth of female Murrah buffaloes has been reported by Tien and Tripathi (1992).The parity, season and period of birth did not significantly influence growth during this period (Table 46). A similar trend of effect of period and season of birth on growth rate during twelve to eighteen months of age had been observed by Gurung and Johar (1982b) and Tien and Tripathi (1992). A systematic trend could not be established for the effect of parity, season and period of birth on growth rate.

4.1.10.6 Monthly Gain in Weight during Eighteen to Twenty four Months of Age

The average growth rate of 13.6±0.25kg per month was recorded in female buffaloes during eighteen to twenty four months of age (Table 42). The per month growth during this period was the highest in comparison to other growth periods. The season and period of birth significantly ($p<0.05$) influence the growth rate during this period but the parity of dam did not influence growth (Table 46). No systematic trend could be observed for effect of parity and period of birth on growth during this period. A smaller gain in weight during this growth phase have been reported by Sharma *et al* (1983) and Tien and Tripathi (1992) in Murrah buffaloes.

4.1.10.7 General remarks on effect of non-genetic factors on growth traits

A perusal of the least-squares means of various traits and the effect of season, period and parity on these factors indicated that season had little effect on body

Table 42: Least-square means (±SE) for monthly gain in weight (kg) between 12-18, 18-24, 0-6 and 6-24 months

Effects	N	Per month gain in weight between months (Mean±SE)			
		12-18	18-24	0-6	6-24
Overall µ	865	13.19±0.27	13.61±0.25	13.01±0.17	13.01±0.17
Seasons:				13.02±0.24	13.02±0.24
Summer	142	12.73±0.37	13.43±0.40	13.20±0.22	13.20±0.22
Rainy	220	12.88±0.34	14.37±0.35	13.03±0.23	13.03±0.23
Autumn	186	13.49±0.35	13.53±0.37	12.82±0.21	12.82±0.21
Winter	237	13.44±0.32	13.18±0.33	12.97±0.27	12.97±0.27
Spring	80	13.41±0.42	13.54±0.47		
Periods:				11.54±0.44	11.54±0.44
1988-92	254	12.30±0.68	11.63±0.80	13.10±0.37	13.10±0.37
1993-97	227	13.21±0.57	14.33±0.66	13.15±0.39	13.15±0.39
1998-02	169	13.60±0.60	14.40±0.70	12.93±0.38	12.93±0.38
2003-07	157	12.67±0.59	14.07±0.69	14.33±0.61	14.33±0.61
2007-12	58	14.16±0.95	13.62±1.13		
Parity:				12.95±0.19	12.95±0.19
1	244	12.60±0.30	13.75±0.30	13.12±0.21	13.12±0.21
2	190	13.29±0.32	13.54±0.33	12.78±0.23	12.78±0.23
3	116	12.85±0.36	13.16±0.38	12.76±0.24	12.76±0.24
4	107	13.04±0.37	13.02±0.40	12.97±0.27	12.97±0.27
5	71	13.00±0.42	14.10±0.47	13.65±0.30	13.65±0.30
6	56	13.95±0.47	14.09±0.53	12.85±0.37	12.85±0.37
7	31	13.23±0.57	13.35±0.66	12.97±0.45	12.97±0.45
8	20	13.55±0.70	12.69±0.82	13.20±0.51	13.20±0.51
9	16	13.85±0.78	13.80±0.92	12.90±0.74	12.90±0.74
10	7	11.13±1.14	14.44±1.36	12.94±0.74	12.94±0.74
11	7	14.60±1.14	13.79±1.37		10.43±1.27

Table 43: Least-square means (±SE) for relative growth rate (kg) during 0-1, 1-3, 3-6, 6-12 months expressed on monthly basis

Effects	**N**	**Per month relative growth rate(%) between months (Mean±SE)**			
		0-1	**1-3**	**3-6**	**6-12**
Overall μ	865	33.07±1.40	26.16±0.68	18.26±0.43	12.59±0.33
Seasons:					
Summer	142	35.56±1.96	26.80±1.03	18.58±0.69	13.20±0.48
Rainy	220	32.41±1.77	24.61±0.91	19.40±0.60	12.81±0.43
Autumn	186	31.72±1.85	27.02±0.96	19.05±0.64	12.37±0.45
Winter	237	32.76±1.70	25.76±0.87	17.24±0.57	12.38±0.41
Spring	80	32.91±2.23	26.62±1.19	17.03±0.81	12.22±0.55
Periods:					
1988-92	254	25.29±3.64	23.87±2.00	19.48±1.39	11.90±0.91
1993-97	227	38.25±3.04	24.18±1.66	16.85±1.14	12.84±0.75
1998-02	169	28.81±3.22	27.80±1.76	16.53±1.22	12.01±0.80
2003-07	157	32.84±3.15	25.09±1.72	18.22±1.19	11.74±0.78
2007-12	58	40.18±5.07	29.88±2.82	20.22±1.97	14.49±1.27
Parity:					
1	244	37.38±1.58	28.48±0.80	19.21±0.52	13.05±0.38
2	190	33.24±1.70	26.92±0.87	19.35±0.57	12.75±0.41
3	116	34.60±1.90	25.39±0.99	18.93±0.66	12.34±0.46
4	107	32.57±1.95	27.19±1.02	18.70±0.68	12.05±0.47
5	71	29.57±2.23	24.07±1.19	19.45±0.81	12.11±0.55
6	56	33.78±2.48	26.39±1.34	17.55±0.91	13.33±0.61
7	31	31.38±3.03	27.66±1.65	18.57±1.14	11.90±0.75
8	20	32.48±3.73	23.65±2.06	20.09±1.43	13.22±0.93
9	16	31.44±4.18	25.66±2.31	15.89±1.61	12.54±1.04
10	7	32.09±6.09	25.28±3.40	16.05±2.37	14.17±1.53
11	7	35.28±6.12	27.10±3.41	17.08±2.39	11.06±1.53

Table 44: Least-square means (±SE) for relative growth rate (kg) during 12-18, 18-24, 0-6, 6-24 months expressed on monthly basis

Effects	N	Per month relative growth rate between months (Mean±SE)			
		12-18	18-24	0-6	6-24
Overall µ	865	7.82±0.61	5.55±0.12	35.41±0.88	13.45±0.25
Seasons:					
Summer	142	7.27±0.24	5.35±0.19	36.88±1.20	13.33±0.34
Rainy	220	7.57±0.21	5.90±0.17	35.63±1.09	13.66±0.31
Autumn	186	8.09±0.23	5.48±0.18	36.29±1.14	13.42±0.32
Winter	237	8.20±0.20	5.46±0.16	33.98±1.05	13.50±0.30
Spring	80	7.96±0.28	5.55±0.23	34.28±1.36	13.34±0.39
Periods:					
1988-92	254	8.04±0.47	5.08±0.39	32.13±2.19	12.76±0.63
1993-97	227	8.12±0.39	6.01±0.32	34.80±1.84	14.28±0.53
1998-02	169	8.37±0.41	6.00±0.34	33.10±1.94	13.81±0.56
2003-07	157	7.42±0.40	5.77±0.33	34.32±1.90	12.77±0.55
2007-12	58	7.15±0.66	4.88±0.55	42.72±3.04	13.62±0.88
Parity:					
1	244	7.39±0.19	5.65±0.15	39.46±0.98	13.51±0.28
2	190	7.71±0.20	5.43±0.16	36.79±1.05	13.40±0.30
3	116	7.37±0.23	5.27±0.19	36.17±1.17	12.76±0.33
4	107	7.55±0.24	5.17±0.19	36.55±1.19	12.64±0.34
5	71	7.72±0.28	5.81±0.22	33.46±1.36	13.32±0.39
6	56	8.01±0.31	5.55±0.25	34.96±1.51	14.06±0.43
7	31	7.77±0.39	5.36±0.32	36.34±1.83	12.87±0.53
8	20	8.09±0.48	5.16±0.40	35.65±2.25	13.78±0.65
9	16	8.42±0.54	5.65±0.45	32.00±2.51	13.83±0.72
10	7	6.45±0.80	6.26±0.66	32.68±3.65	14.06±1.05
11	7	9.55±0.80	5.74±0.66	35.50±3.67	13.70±1.06

Table 45: Least-squares analysis of variance for studying the effect of non-genetic factors on growth traits

Sr. no.	Trait	Sources of variation	df	MS	R^2(%)
1	Dam wt.	Season	4	6280.1	0.62
		Period	4	20457.0**	2.00
		Parity	10	107417.3	26.28
2	B wt. 0	Season	4	16.43	0.34
		Period	4	36.01	0.74
		Parity	10	126.59**	6.52
3	Calf%	Season	4	1.67	0.68
		Period	4	1.25	0.51
		Parity	10	4.26**	4.38
4	B wt.1	Season	4	55.92	0.95
		Period	4	48.08	0.82
		Parity	10	103.28**	4.40
5	B wt.3	Season	4	145.99	0.96
		Period	4	135.32	0.89
		Parity	10	138.76*	2.29
6	B wt.6	Season	4	237.52	0.66
		Period	4	299.85	0.83
		Parity	10	274.64*	1.90
7	B wt.12	Season	4	1469.57*	1.28
		Period	4	1846.37**	1.61
		Parity	10	426.04	0.93

* Signficiant at 5% level ($p \leq 0.05$)

** Signficiant at 1% level ($p \leq 0.01$)

Table 46: Least-squares analysis of variance for studying the effect of non-genetic factors on growth traits

Sr. no.	Trait	Sources of variation	df	MS	R^2(%)
1	B wt.18	Season	4	626.07	0.32
		Period	4	2902.43**	1.49
		Parity	10	921.30	1.18
2	B wt.24	Season	4	1703.70	0.59
		Period	4	5763.52**	2.01
		Parity	10	864.37	0.75
3	G 06	Season	4	7.79	0.83
		Period	4	7.53	0.80
		Parity	10	4.34	1.16
4	G624	Season	4	2.89	0.37
		Period	4	15.01**	1.93
		Parity	10	3.12	1.00
5	RGR 06	Season	4	190.66*	0.98
		Period	4	171.81	0.88
		Parity	10	239.93**	3.06
6	RGR624	Season	4	2.21	0.14
		Period	4	17.39*	1.09
		Parity	10	11.31	1.78

* Signficiant at 5% level ($p \leq 0.05$)
** Signficiant at 1% level ($p \leq 0.01$)

weight, gain in weight and relative growth rate. It accounted for not more than 1.3% of the total variation. Little effect of season implied that herd-management was effective in minimizing the seasonal changes associated with physical environmental factors and feed and fodder availability. Period of calving had significant for some of the traits. But its contribution of total variation for various traits where its effect was significant fell between 1.09 and 2.01%. Period relative to season had slightly more effect on various effects as it extended over forty years. During such a long span of time management practices including nutrition regime change. Additional genetic structure of population also changes due to selection and introduction of animals from outside. There has general improvement in herd performance over time in body weights. Parity of dam generally had significant effect on body weights during first six parities. The effect was most conspicuous for early body weights.

4.2 Mean performance and factors affecting first lactation traits (GADVASU herd)

The least square means along with their standard errors and coefficient of variation (%) for various first lactation traits are presented in Tables 47-51 and their analysis of variance for studying the effect of non-genetic factors like season and period on various first lactation traits are presented in Tables 52-53.

4.2.1 Gestation period

The overall least-squares mean for gestation period was 309.6±0.38 days with little coefficient of variation of 3.46 per cent indicative of very less variability in the trait (Table 47). This trait also supposed to regulate generation interval and in turn response to selection but nothing much can be done in this trait to improve it due to physiological constraints.

Season: The season of calving significantly ($P<0.01$) influenced the gestation period and accounted for a small (3.52%) of the variation (Table 52). The average gestation period ranged from 307.5 to 312.1 days over the seasons. No systematic trend could be observed over seasons. However, gestation period was the highest in spring (312.1days).

Table 47: Least-square means(±SE) and coefficients of variation for gestation period, age at first calving and weight at first calving (GADVASU herd)

Effects	N	Gestation period(days)		Age at first calving(months)		Weight at first calving(kg)	
		Mean±SE	CV(%)	Mean±SE	CV(%)	Mean± SE	CV(%)
Overall μ	1033	309.6±0.33	3.46	45.3±0.41	29.1	465.3±2.66	8.4
Seasons:							
Summer	194	307.7±0.70[a]	3.17	45.2±0.64	19.7	462.8±4.72	14.2
Rainy	221	309.2±0.65[b]	3.12	45.3±0.61	20.0	4614±4.44	14.3
Autumn	202	307.5±0.67[a]	3.10	44.9±0.62	19.6	460.6±4.57	14.1
Winter	279	311.3±0.57[c]	3.06	45.4±0.56	20.6	470.6±4.00	14.2
Spring	137	312.1±0.79[c]	2.96	45.5±0.71	18.3	470.9±5.30	13.2
Periods:							
1973-77	78	305.6±2.05	5.92	33.4±1.69[a]	44.7	418.5±13.15[a]	27.7
1978-82	112	308.9±1.64	5.62	40.8±1.36[b]	35.3	419.2±10.52[a]	26.6
1983-87	166	309.6±1.45	6.03	44.2±1.21[c]	35.2	441.0±9.36[b]	27.3
1988-92	219	310.3±1.45	6.92	48.3±1.21[d]	37.1	436.8±9.38[b]	31.8
1993-97	137	310.3±1.79	6.75	49.1±1.48[d]	35.3	457.9±11.50[b]	29.4
1998-02	139	310.4±1.68	6.38	49.4±1.39[d]	33.2	492.3±10.77[c]	25.8
2003-07	99	309.4±1.90	6.11	45.3±1.57[c]	34.5	518.9±12.19[d]	23.4
2007-12	83	311.9±2.40	7.01	51.6±1.96[e]	34.6	537.9±15.33[d]	26.0

Period: The period of calving did not significantly influence the gestation period and accounted for a small (0.51%) of the variation (Table 52). The average gestation period ranged from 305.6 to 311.9 days over the periods. Increasing trend was observed over periods except for the second last period.

4.2.2 Age at first calving

The overall least-squares mean for age at first calving (AFC) was 45.3±0.41 months with a coefficient of variation of 29.08 per cent (Table 47). The overall mean was, in general, higher than those reported by Sethi and Nagarcenkar (1992), Dass (1995), Lall (1975), Shah and Sharma (1994), Dutt *et al* (2001), Singh (2001), Bajetha (2003), Dahiya (2006), Gupta (2009) and Nawale (2010) and lower than those reported by Shreshtha and Yazman (1990), Mathur and Mathur (1992), Narula *et al* (1994), Pundhir (1994), Sethi *et al* (2001), Gogoi *et al* (2002), Kumar *et al* (2002), Pundhir *et al* (2003), Saini *et al* (2003), Godara *et al* (2004), Sharma *et al* (2004) and Suresh *et al* (2004). In general, it was within the range of those reported by El-Arian (1986), Vij and Tiwana (1987), Gupta *et al* (1994), Lathwal (2000), Sethi (2005), Wakchaure *et al* (2008) and Patil (2011).

Season: The season of birth did not significantly influence the AFC and accounted for a small (0.05%) of the variation (Table 52). The average AFC ranged from 44.9 to 45.5 months over the seasons. No systematic trend could be observed over seasons. However, AFC was observed to be the highest in spring born animals. Significant influence of season on AFC was reported by Gudi and Narayanhedkar (1977), Reddy (1980), Gogoi *et al* (1985), Mishra *et al* (1986), Singh *et al* (1987), Gajbhiye and Tripathi (1991), Sethi and Nagarcenkar (1992), Sahana (1993), Gupta *et al* (1994), Bajetha (2003), Wakchaure *et al* (2008) and Gupta (2009) while Sharma (1990), Dhara (1994), Narula *et al* (1994), Pundir (1994), Dass (1995), Nath (1996), Kumar (1998), Saha and Sadana (2000), Singh (2001), Gogoi *et al* (2002), Godara *et al* (2004), Dahiya (2006), Nawale (2010) and Patil (2011) did not find any significant effect.

Period: The period of birth was observed to be highly significant (P<0.01) source of variation in AFC and accounted for a small (5.45%) of the variation (Table 52). The average AFC ranged from 33.4 to 51.6 months over the periods. Increasing trend was observed up to sixth period. Significant influence of period on AFC was reported by Gajbhiye and Tripathi (1991), Dhara (1994), Gupta *et al* (1994), Narula *et al* (1994), Pundir (1994), Singh (2001), Bajetha (2003), Saini *et al* (2003), Godara *et al* (2004), Dahiya (2006), Wakchure *et al* (2008), Gupta (2009), Nawale (2010) and Patil (2011) while Goswami and Nair (1965), Khosla *et al* (1984), Ulganathan *et al* (1985), Singh and Yadav (1987b), Singh (1995), Kumar (1998), Saha and Sadana (2000), Sule *et al* (2001) and Gogoi *et al* (2002) did not find any significant effect.

4.2.3 Weight at first calving

The overall least-squares mean for weight at first calving (WFC) was 465.3±2.66kg with coefficient of variation of 18.4 per cent indicative of fair variability in the trait (Table 47). This trait supposed to regulate/significance in maturity of an animal or age at first calving. The overall mean was, in general, higher than those reported by Basu *et al* (1984), Das and Balaine (1985) and Parkash *et al* (1988) and lower than those reported by Nautiyal and Bhat (1977), Singh (1977), Singh and Yadav (1986), Singh and Rathi (1991), Singh (1995), Kumar (1998), Singh (2001) and Dahiya (2006). In general, it was within the range of those reported by Gokhle and Nagarcenkar (1979), Iype (1980), Gurung and Johar (1982) and Singh and Basu (1988).

Season: The season of calving did not significantly influence the WFC and accounted for a small (0.52%) of the variation (Table 52). The average WFC ranged from 460.6 to 470.9kg over the seasons. No systematic trend was observed over seasons. However, WFC was the highest in spring. Significant influence of season on WFC was reported by while Bhardwaj (2002) did not find any significant effect.

Period: The period of calving significantly (P<0.01) influence the WFC and accounted for a small (3.03%) of the variation (Table 52). The average WFC ranged from 418.5 to 537.9kg over the periods. Increasing trend was observed over periods. Significant influence of period on WFC was reported by Yadav (2001) while Bhardwaj (2002) did not find any significant effect.

4.2.4 305-days milk yield:

The overall least-squares mean for 305-days milk yield (305 MY) was 1879.4±18.85kg with coefficient of variation of 32.23 per cent indicative of high variability in the trait (Table 48). This trait considered as an indicator trait for production comparisons and for evaluating the test bulls on their daughter's 305 MY. So, this trait holds a lot of economic importance.

Season: The season of calving significantly ($P<0.05$) influenced the 305 MY and accounted for a small (0.89%) of the variation (Table 52). The average 305 MY ranged from 1793.8 to 1917.1kg over the seasons. No systematic trend was observed over seasons. However, 305 MY was the highest in spring being a favourable season for production as well as reproduction. Significant influence of season on 305 MY was reported by Patro and Bhat (1979b), Reddy (1980), Kumar (1984), El-Arian (1986), Gajbhiye (1987), Hatwar and Chawla (1988), Singh *et al* (1990), Dass and Sharma (1994) and Nath (1996) while Jain and Taneja (1982), Sharma (1982), Sharma and Singh (1988) Tomar and Tripathi (1988), Iype and Nagarcenkar (1992), Sahana (1993), Shabade *et al* (1993), Dhara (1994), Dass (1995), Jain and Sadana (1998), Saha (1998), Wakchure *et al* (2008), Gupta (2009) and Patil (2011) did not find any significant effect.

Period: The period of calving did not significantly influence the 305 MY and accounted for a small (0.51%) of the variation (Table 52). The average 305 MY ranged from 1707.0 to 2079.3kg over the periods. Increasing trend was observed over periods. Significant influence of period on 305 MY was reported by Patro and Bhat (1979b), Reddy (1980), Jain and Taneja (1982), Kumar (1984), El-Arian (1986), Gajbhiye (1987), Tomar and Tripathi (1988), Singh *et al* (1990), Iype and Nagarcenkar (1992), Sahana (1993), Dass and Sharma (1994), Dhara (1994), Dass

Table 48: Least-square means (±SE) and coefficients of variation for calf birth weight, calf weight per cent and 305-day milk yield (GADVASU herd)

Effects	N	Calf birth weight(kg)		Calf weight (%)		305-day milk yield(kg)	
		Mean±SE	CV(%)	Mean±SE		Mean±SE	CV(%)
Overall μ	1033	30.4±0.20	21.2	6.64±0.05	4.2	879.4±18.85	32.2
Seasons:							
Summer	194	30.0±0.41	19.2	6.62±0.10	21.0	1899.5±33.79[b]	24.8
Rainy	221	31.0±0.39	18.7	6.68±0.10	22.2	1884.5±31.75[b]	25.0
Autumn	202	30.2±0.40	18.8	6.58±0.10	21.6	1793.8±32.73[a]	25.9
Winter	279	30.3±0.34	18.7	6.59±0.08	20.3	1902.4±28.56[b]	25.1
Spring	137	30.4±0.47	18.1	6.54±0.12	21.5	1917.1±37.97[b]	23.2
Periods:							
1973-77	78	28.8±1.22	37.4	6.68±0.30	39.7	1707.0±94.61	48.9
1978-82	112	29.8±0.97	34.4	6.85±0.24	37.1	1779.5±75.66	45.0
1983-87	166	30.2±0.86	36.7	6.68±0.21	40.5	1750.6±67.28	49.5
1988-92	219	30.1±0.87	42.7	6.73±0.22	48.4	1757.7±67.49	56.8
1993-97	137	30.6±1.07	40.9	6.45±0.27	49.0	1840.9±82.71	52.6
1998-02	139	31.6±1.00	37.3	6.82±0.25	43.2	2064.5±77.84	44.4
2003-07	99	31.8±1.13	35.3	6.68±0.28	41.7	2055.9±87.76	42.5
2007-12	83	29.9±1.43	43.5	6.26±0.36	52.4	2079.3±110.33	48.3

(1995), Nath (1996), Jain and Sadana (1998), Saha (1998), Wakchure *et al* (2008), Gupta (2009) and Patil (2011) while Sharma and Singh (1988) and Shabade *et al* (1993) did not find any significant effect.

4.2.5 Lactation length

The overall least-squares mean for lactation length (LL) was 357.9±3.16 days with a coefficient of variation of 28.38 per cent (Table 49). The overall mean was, in general, higher than those reported by Sethi and Nagarcenkar (1992), Dass (1995), Lall (1995), Shah and Sharma (1994), Dutt *et al* (2001), Singh (2001), Bajetha (2003), Dahiya (2006), Gupta (2009) and Nawale (2010) and lower than those reported by Shreshtha and Yazman (1990), Mathur and Mathur (1992), Narula *et al* (1994), Pundhir (1994), Sethi *et al* (2001), Gogoi *et al* (2002), Kumar *et al* (2002), Pundhir *et al* (2003), Saini *et al* (2003), Godara *et al* (2004), Sharma *et al* (2004) and Suresh *et al* (2004). In general, it was within the range of those reported by El-Arian (1986), Vij and Tiwana (1987), Gupta *et al* (1994), Lathwal (2000), Sethi (2005), Wakchaure *et al* (2008) and Patil (2011)..

Season: The season of calving did not significantly influence the LL and accounted for a small (0.66%) of the variation (Table 52). The average LL ranged from 345.7 to 371.9 days over the seasons. No systematic trend could be observed over seasons. However, LL was observed to be the highest in spring as considered to be favourable season after fed with flush diet in winter as well as spring. Significant influence of season on LL was reported by by Gurnani *et al* (1976), Basu and Gahi (1978), Johri and Bhat (1979), Umrikar and Deshpande (1985), Singh *et al* (1987), Mohamed *et al* (1993), Nath (1996), Kumar (1998), Dass and Sadana (2000), Godara *et al* (2004) and Pander *et al* (2004) while Kumar and Bhat (1978), Kannaujia and Balaine (1987), Khosla *et al* (1987), Sharma and Singh (1988), Sahana (1993), Shabade *et al* (1993), Das and Sharma (1994), Dhara 1994, Rao *et al* (1994), Dass 1995, Singh (2001), Kundu *et al* (2003), Sachan *et al* (2006), Wakchaure 2007and Gupta (2009) did not find any significant effect.

Period: The period of calving was observed to be non-significant source of variation in LL and accounted for a small (0.28%) of the variation (Table 52). The average LL ranged from 342.2 to 371.4 days over the periods. No consistent trend could be observed in LL over the periods. Significant influence of period on AFC was reported by Umrikar and Deshpande (1985), Vij (1986), Bhalaru and Dhillon (1987), Singh *et al* (1987), Sharma and Singh (1988), Neog *et al* (1993), Sahana (1993), Das and Sharma (1994), Dhara (1994), Dass (1995), Nath (1996), Kumar (1998), Dass and Sadana (2000), Bajetha (2003), Kundu *et al* (2003), Wakchaure (2007) and Gupta (2009) while El-Arian (1986), Shabade *et al* (1993), Singh (1995), Singh (2001) and Godara *et al* (2004) did not find any significant effect.

4.2.6 Lactation milk yield

The overall least-squares mean for first lactation milk yield (FLMY) was 2118.9±26.67 kg with coefficient of variation of 40.45 per cent indicative of high variability in the trait (Table 49). This trait considered as an indicator trait for production comparisons and had a role in reproduction traits. So, this trait holds a lot of economic importance.

Season: The season of calving significantly ($P<0.05$) influenced the FLMY and accounted for a small (0.84%) of the variation (Table 53). The average FLMY ranged from 2002.0 to 2207.5kg over the seasons. No systematic trend was observed over seasons. However, FLMY was the highest in spring being a favourable season for production as well as reproduction. Significant influence of season on 305 MY was reported by Gokhle and Nagarcenkar (1979 a), Kumar (1984), EI-Arian (1986), Agrawal *et al* (1987), Singh et aI. (1987), Neog *et al* (1993), Dutt and Taneja (1994), Dass and Sadana (2000), Sule *et al* (2001), Bajetha (2003), and Godara *et al* (2004) while Prakash (1984), Kumar (1998), Singh (2001), Bajetha (2003) did not find any significant effect.

Period: The period of calving did not significantly influence the FLMY and accounted for a small (0.65%) of the variation (Table 53). The average FLMY ranged

Table 49: Least-square means(±SE) and coefficients of variation for lactation length, lactation yield and milk yield/day of lactation length (GADVASU herd)

Effects	N	Lactation length(days)		Lactation yield(kg)		Milk yield/day of lactation length(kg)	
		Mean±SE	CV(%)	Mean±SE	CV(%)	Mean±SE	CV(%)
Overall μ	1033	357.9±3.16	28.4	2118.9±26.67	40.4	5.94±0.05	27.0
Seasons:							
Summer	194	355.0±6.85	26.9	2122.9±50.57[b]	33.2	5.95±0.09	21.1
Rainy	221	357.0±6.37	26.5	2116.5±47.36[b]	33.3	5.99±0.09	22.3
Autumn	202	345.7±6.60	27.1	2002.0±48.91[a]	34.7	5.83±0.09	21.9
Winter	279	360.1±5.62	26.1	2145.5±42.33[b]	32.9	5.98±0.08	22.3
Spring	137	371.9±7.81	24.6	2207.5±57.12[b]	30.3	5.93±0.10	19.7
Periods:							
1973-77	78	371.4±20.34	48.4	1976.4±144.55	64.6	5.27±0.27[a]	45.2
1978-82	112	367.5±16.19	46.6	2099.2±115.41	58.2	5.66±0.21[b]	39.3
1983-87	166	346.5±14.35	53.4	1947.5±102.50	67.8	5.62±0.19[b]	43.6
1988-92	219	357.5±14.40	59.6	1990.5±102.82	76.4	5.61±0.19[b]	50.1
1993-97	137	368.1±17.74	56.4	2039.1±126.25	72.5	5.63±0.24[b]	49.9
1998-02	139	354.7±16.60	55.2	2254.7±118.21	61.8	6.42±0.22[c]	40.4
2003-07	99	355.5±18.84	52.7	2355.7±134.00	56.6	6.59±0.25[cd]	37.7
2007-12	83	342.2±23.78	63.3	2288.2±168.69	67.2	6.69±0.31[d]	42.2

Table 50: Least-square means(±SE) and coefficients of variation for fat per cent, fat yield in lactation and peak yield (GADVASU herd)

Effects	N	Fat (%)		Fat yield in lactation (kg)		Peak yield (kg)	
		Mean±SE	CV(%)	Mean±SE	CV(%)	Mean±SE	CV(%)
Overall μ	1033	7.13±0.03	13.5	151.3±1.93	41.0	10.46±0.07	21.5
Seasons:							
Summer	194	7.00±0.05[a]	9.9	149.9±3.79	35.2	10.49±0.14[b]	18.6
Rainy	221	7.10±0.05[b]	10.5	150.5±3.54	35.0	10.24±0.13[a]	18.9
Autumn	202	7.23±0.05[c]	9.8	144.7±3.66	36.0	10.20±0.13[a]	18.1
Winter	279	7.22±0.04[c]	9.2	155.1±3.15	33.9	10.92±0.11[c]	16.8
Spring	137	7.09±0.05[b]	8.2	156.4±4.29	32.1	10.46±0.15[b]	16.8
Periods:							
1973-77	78	7.10±0.13	16.2	140.8±10.95	68.7	9.78±0.40[ab]	36.1
1978-82	112	7.13±0.10	14.8	150.3±8.74	61.5	10.47±0.31[bc]	31.3
1983-87	166	7.03±0.09	16.5	137.1±7.75	72.8	10.01±0.28[ab]	36.0
1988-92	219	7.03±0.09	18.9	140.7±7.78	81.8	9.23±0.28[a]	44.9
1993-97	137	7.01±0.11	18.4	142.6±9.56	78.4	10.29±0.34[bc]	38.7
1998-02	139	7.09±0.11	18.3	160.1±8.95	65.9	11.25±0.32[cd]	33.5
2003-07	99	7.33±0.12	16.3	172.2±10.15	58.6	11.03±0.37[cd]	33.4
2007-12	83	7.31±0.15	18.7	166.6±12.79	69.9	11.64±0.46[d]	36.0

Table 51: Least-square means(±SE) and coefficients of variation for days to reach peak yield and number of AI/conception (GADVASU herd)

Effects	N	Days to reach peak yield	Number of AI/conception
		Mean±SE	Mean±SE
Overall μ	1033	50.7±1.00	2.04±0.04
Seasons:			
Summer	194	46.0±2.08[a]	2.05±0.10
Rainy	221	56.0±1.94[b]	2.06±0.10
Autumn	202	54.3±2.01[ab]	1.86±0.10
Winter	279	48.8±1.72[a]	2.20±0.08
Spring	137	48.2±2.37[a]	2.04±0.12
Periods:			
1973-77	78	51.3±6.13	0.78±0.31[a]
1978-82	112	59.7±4.88	1.16±0.25[a]
1983-87	166	55.5±4.33	1.86±0.22[b]
1988-92	219	54.5±4.34	1.82±0.22[b]
1993-97	137	46.4±5.35	2.16±0.27[bc]
1998-02	139	53.1±5.00	3.02±0.26[c]
2003-07	99	46.2±5.68	2.58±0.29[c]
2008-12	83	38.7±7.16	2.97±0.37[c]

Table 52: Least-squares analysis of variance for studying the effect of non-genetic factors on first lactation traits

Sr. No.	Trait	Sources of variation	df	MS	R^2(%)
1	GP	Season	4	679.38*	3.52
		Period	7	66.66	0.51
2	AFC	Season	4	7.47	0.05
		Period	7	469.15**	5.45
3	WAC	Season	4	4361.95	0.52
		Period	7	14471.01**	3.03
4	WAB	Season	4	22.57	0.34
		Period	7	16.85	0.45
5	Calf %	Season	4	3.25	0.79
		Period	7	0.94	0.40
6	305d MY	Season	4	375063.3*	0.89
		Period	7	223568.5	0.92
7	LL	Season	4	12107.2	0.67
		Period	7	2901.0	0.28

* Signficiant at 5% level ($p \leq 0.05$)
** Signficiant at 1% level ($p \leq 0.01$)

Table 53: Least-squares analysis of variance for studying the effect of non-genetic factors on first lactation traits

Sr. No.	Trait	Sources of variation	df	MS	R^2(%)
1	LY	Season	4	803184.6*	0.84
		Period	7	355608.0	0.65
2	Fat %	Season	4	1.53**	1.80
		Period	7	0.22	0.47
3	PY	Season	4	16.68**	2.28
		Period	7	11.10**	2.66
4	DRPY	Season	4	28796**	1.70
		Period	7	765.32	0.79
5	MYLL	Season	4	0.674	0.20
		Period	7	2.778*	1.45
6	Fat yield	Season	4	344155.6	7.68
		Period	7	256443.5	10.02
7	AI no.	Season	4	2.81	0.64
		Period	7	6.08**	2.43

* Signficiant at 5% level ($p \leq 0.05$)
** Signficiant at 1% level ($p \leq 0.01$)

from 1947.5 to 2355.7kg over the periods. No consistent trend could be observed over periods. Significant influence of period on FLMY was reported by by Gokhle and Nagarcenkar (1979), Iype (1980), Gurung and Johar (1982), Sharma (1982), Kumar (1984), Reddy and Taneja (1984), EI-Arian (1986), Dutt and Taneja (1994), Kumar (1998) Dass and Sadana (2000), Singh (2001), Bajetha (2003) and Godara *et al* (2004) while Prakash (1984) and Pander *et al* (2004) did not find any significant effect.

4.2.7 General remarks on effect of non-genetic factors on first lactation traits

A perusal of the least-squares means of various first lactation traits and the effect of season and period on these factors indicated that season had non-significant effect on various first lactation traits except for milk production, fat%, peak yield and days to reach peak yield. The contribution to total variation for various traits where its effect was significant fell between 0.84 and 3.52%. Little effect of season implied that herd-management was effective in minimizing the seasonal changes associated with physical environmental factors and feed and fodder availability. Period of calving had significant influence on some of the traits (AFC, WFC, Peak yield, milk yield per day of lactation length and number of AI per conception). But its contribution of total variation for various traits where its effect was significant fell between 1.45 and 5.45%. Period relative to season had slightly more effect on various effects as it extended over forty years. During such a long span of time management practices including nutrition regime change. Additional genetic structure of population also changes due to selection and introduction of animals from outside. There has general improvement in herd performance over time in weight at first calving, 305-days milk yield and milk production per day of lactation length. But, at the same time there has been considerable increase in age at first calving and number of artificial inseminations required per conception. This indicated the poor reproductive management of the herd, as both traits directly indicated the reproductive status of the herd which must be decreased for overall improvement of the herd.

4.3 Mean performance and factors affecting first lactation traits (CIRB herd)

The least square means along with their standard errors and coefficient of variation (%) for various first lactation traits are presented in Tables 54-55 and their analysis of variance for studying the effect of non-genetic factors like season and period on various first lactation traits are presented in Tables 56.

4.3.1 Age at first calving

The overall least-squares mean for age at first calving (AFC) was 46.4±0.58 months with a coefficient of variation of 34.8 per cent (Table 54). The overall mean was, in general, higher than those reported by Sethi and Nagarcenkar (1992), Dass (1995), Lall (1975), Shah and Sharma (1994), Dutt *et al* (2001), Singh (2001), Bajetha (2003), Dahiya (2006), Gupta (2009) and Nawale (2010) and lower than those reported by Shreshtha and Yazman (1990), Mathur and Mathur (1992), Narula *et al* (1994), Pundhir (1994), Sethi *et al* (2001), Gogoi *et al* (2002), Kumar *et al* (2002), Pundhir *et al* (2003), Saini *et al* (2003), Godara *et al* (2004), Sharma *et al* (2004) and Suresh *et al* (2004). In general, it was within the range of those reported by El-Arian (1986), Vij and Tiwana (1987), Gupta *et al* (1994), Lathwal (2000), Sethi (2005), Wakchaure *et al* (2008) and Patil (2011)..

Season: The season of birth did not significantly influence the AFC and accounted for a small (0.06%) of the variation (Table 56). The average AFC ranged from 45.2 to 47.2 months over the seasons. No systematic trend could be observed over seasons. However, AFC was observed to be the lowest in spring born animals. Significant influence of season on AFC was reported by Gudi and Narayanhedkar (1977), Reddy (1980), Gogoi *et al* (1985), Mishra *et al* (1986), Singh *et al* (1987), Gajbhiye and Tripathi (1991), Sethi and Nagarcenkar (1992), Sahana (1993), Gupta *et al* (1994), Bajetha (2003), Wakchaure *et al* (2008) and Gupta (2009) while Sharma

Table 54: Least-square means(±SE) and coefficients of variation for age at first calving, 305 days milk yield and lactation milk yield(CIRB herd)

Effects	N	Age at first cavling(months)		305 days milk yield(kg)		Lactation milk yield(kg)	
		Mean±SE	CV(%)	Mean±SE	CV(%)	Mean±SE	CV(%)
Overall μ	774	46.4±0.58	34.8	1644.9±22.37	37.8	1794.8±28.49	4.2
Seasons:							
Summer	81	45.7±0.91	17.9	1608.5±49.21	27.5	1762.9±66.07	33.7
Rainy	223	45.8±0.68	22.2	1658.3±31.85	28.7	1805.6±41.98	34.7
Autumn	221	47.2±0.69	21.7	1615.6±32.39	29.8	1772.8±42.74	35.8
Winter	197	47.2±0.70	20.8	1635.4±33.34	28.6	1789.9±44.07	34.6
Spring	52	45.2±1.04	16.6	1706.6±58.25	24.6	1842.9±78.49	30.7
Periods:							
1988-92	48	34.8±1.93[a]	38.4	1318.7±116.5[a]	61.2	1468.4±158.0[b]	74.5
1993-97	86	38.9±1.30[ab]	30.9	1366.8±75.67[a]	51.3	1357.0±102.3[a]	69.9
1997-02	217	46.3±1.03[bc]	32.8	1681.8±57.83[b]	50.6	1773.2±77.91[c]	64.7
2003-07	285	54.2±1.15[c]	35.8	1861.2±65.73[c]	59.6	2046.2±88.75[d]	73.2
2008-12	138	57.6±1.40[c]	28.5	1995.8±82.40[d]	48.5	2329.3±111.5[e]	56.3

(1990), Dhara (1994), Narula *et al* (1994), Pundir (1994), Dass (1995), Nath (1996), Kumar (1998), Saha and Sadana (2000), Singh (2001), Gogoi *et al* (2002), Godara *et al* (2004), Dahiya (2006), Nawale (2010) and Patil (2011) did not find any significant effect.

Period: The period of birth was observed to be highly significant (P<0.01) source of variation in AFC and accounted for a small (6.13%) of the variation (Table 56). The average AFC ranged from 34.8 to 57.6 months over the periods. Increasing trend was observed over the periods. Significant influence of period on AFC was reported by Gajbhiye and Tripathi (1991), Dhara (1994), Gupta *et al* (1994), Narula *et al* (1994), Pundir (1994), Singh (2001), Bajetha (2003), Saini *et al* (2003), Godara *et al* (2004), Dahiya (2006), Wakchure *et al* (2008), Gupta (2009), Nawale (2010) and Patil (2011) while Goswami and Nair (1965), Khosla *et al* (1984), Ulganathan *et al* (1985), Singh and Yadav (1987b), Singh (1995), Kumar (1998), Saha and Sadana (2000), Sule *et al* (2001) and Gogoi *et al* (2002) did not find any significant effect.

4.3.2 305-days milk yield

The overall least-squares mean for 305-days milk yield (305 MY) was 1644.9±22.37kg with coefficient of variation of 37.8 per cent indicative of high variability in the trait (Table 54). This trait considered as an indicator trait for production comparisons and for evaluating the test bulls on their daughter's 305 MY. So, this trait holds a lot of economic importance.

Season: The season of calving significantly (P<0.05) influenced the 305 MY and accounted for a small (0.83%) of the variation (Table 56). The average 305 MY ranged from 1615.6 to1706.6kg over the seasons. No systematic trend was observed over seasons. However, 305 MYwas the highest in spring being a favourable season for production as well as reproduction. Significant influence of season on 305 MY was reported by Patro and Bhat (1979), Reddy (1980), Kumar (1984), El-Arian (1986), Gajbhiye (1987), Hatwar and Chawla (1988), Singh *et al* (1990), Dass and Sharma (1994) and Nath (1996) while Jain and Taneja (1982), Sharma (1982), Sharma and Singh (1988) Tomar and Tripathi (1988), Iype and Nagarcenkar (1992), Sahana (1993), Shabade *et al* (1993), Dhara (1994), Dass (1995), Jain and Sadana (1998), Saha (1998), Wakchure *et al* (2008), Gupta (2009) and Patil (2011) did not find any significant effect.

Period: The period of calving significantly (P<0.05) influenced the 305 MY and accounted for a small (1.51%) of the variation (Table 56). The average 305 MY ranged from 1318.7 to 1995.8kg over the periods. Increasing trend was observed over periods. Significant influence of period on 305 MY was reported by Patro and Bhat (1979), Reddy (1980), Jain and Taneja (1982), Kumar (1984), El-Arian (1986), Gajbhiye (1987), Tomar and Tripathi (1988), Singh *et al* (1990), Iype and Nagarcenkar (1992), Sahana (1993), Dass and Sharma (1994), Dhara (1994), Dass (1995), Nath (1996), Jain and Sadana (1998), Saha (1998), Wakchure *et al* (2008), Gupta (2009) and Patil (2011) while Sharma and Singh (1988) and Shabade *et al* (1993) did not find any significant effect.

4.3.3 Lactation length

The overall least-squares mean for lactation length (LL) was 334.5±3.56 days with a coefficient of variation of 29.6 per cent (Table 55). The overall mean was, in general, higher than those reported by Sethi and Nagarcenkar (1992), Dass (1995), Lall (1995), Shah and Sharma (1994), Dutt *et al* (2001), Singh (2001), Bajetha (2003), Dahiya (2006), Gupta (2009) and Nawale (2010) and lower than those reported by Shreshtha and Yazman (1990), Mathur and Mathur (1992), Narula *et al* (1994), Pundhir (1994), Sethi *et al* (2001), Gogoi *et al* (2002), Kumar *et al* (2002), Pundhir *et al* (2003), Saini *et al* (2003), Godara *et al* (2004), Sharma *et al* (2004) and Suresh *et al* (2004). In general, it was within the range of those reported by El-Arian (1986), Vij and Tiwana (1987), Gupta *et al* (1994), Lathwal (2000), Sethi (2005), Wakchaure *et al* (2008) and Patil (2011)..

Season: The season of calving did not significantly influence the LL and accounted for a small (0.66%) of the variation (Table 56). The average LL ranged from 329.3 to

Table 55: Least-square means(±SE) and coefficients of variation for lactation length, peak yield and milk yield/day of lactation length (CIRB herd)

Effects	N	Lactation length(days)		Peak yield(kg)		Milk yield/day of lactation length(kg)	
		Mean±SE	CV(%)	Mean±SE	CV(%)	Mean±SE	CV(%)
Overall μ	774	334.5±3.56	29.6	7.60±0.10	36.6	5.39±0.07	36.1
Seasons:							
Summer	81	333.0±9.02	24.4	7.61±0.20	23.6	5.30±0.13	22.1
Rainy	223	329.3±5.57	25.3	7.79±0.13	24.9	5.53±0.09	24.3
Autumn	221	335.6±5.68	25.2	7.36±0.13	26.3	5.29±0.09	25.3
Winter	197	336.7±5.88	24.5	7.61±0.14	25.8	5.32±0.09	23.7
Spring	52	337.7±10.78	23.0	7.60±0.23	21.8	5.50±0.15	19.7
Periods:							
1988-92	48	358.5±21.91[bc]	42.3	6.68±0.45[a]	46.7	4.07±0.30[a]	51.1
1993-97	86	295.8±14.13[a]	44.3	6.81±0.30[a]	40.8	4.74±0.20[a]	39.1
1997-02	217	309.2±10.69[a]	50.9	7.59±0.23[b]	44.6	5.76±0.15[b]	38.4
2003-07	285	331.9±12.22[b]	62.1	8.24±0.26[c]	53.3	6.17±0.17[c]	46.5
2008-12	138	376.9±15.42[c]	48.1	8.65±0.32[c]	43.5	6.20±0.22[c]	41.7

Table 56: Least-squares analysis of variance for studying the effect of non-genetic factors on economic traits (CIRB herd)

Trait	Sources of variation	df	MS	R^2(%)
AFC	Season	4	45.02	0.43
	Period	4	148.08*	1.41
305 MY	Season	4	127653.3	0.39
	Period	4	461736.0*	1.42
LL	Season	4	6137.4	0.55
	Period	4	11873.1	1.06
LY	Season	4	250140.5	0.42
	Period	4	756656.7*	1.27
PY	Season	4	2.93	0.56
	Period	4	10.10*	1.94
MYLL	Season	4	2.61	1.12
	Period	4	1.51	0.65

* Signficiant at 5% level ($p \leq 0.05$)
** Signficiant at 1% level ($p \leq 0.01$)

337.7 days over the seasons. No systematic trend could be observed over seasons. However, LL was observed to be the highest in spring as considered to be favourable season after fed with flush diet in winter as well as spring. Significant influence of season on LL was reported by by Gurnani *et al* (1976), Basu and Gahi (1978), Johri and Bhat (1979), Umrikar and Deshpande (1985), Singh *et al* (1987), Mohamed *et al* (1993), Nath (1996), Kumar (1998), Dass and Sadana (2000), Godara *et al* (2004) and Pander *et al* (2004) while Kumar and Bhat (1978), Kannaujia and Balaine (1987), Khosla *et al* (1987), Sharma and Singh (1988), Sahana (1993), Shabade *et al* (1993), Das and Sharma (1994), Dhara 1994, Narsimharao *et al* (1994), Dass 1995, Singh (2001), Kundu *et al* (2003), Sachan *et al* (2006), Wakchaure 2007and Gupta (2009) did not find any significant effect.

Period: The period of calving was observed to be non-significant source of variation in lactation length (LL) and accounted for a small (0.26%) of the variation. The average LL ranged from 295.8 to 376.9 days over the periods (Table 56). No consistent trend could be observed in LL over the periods. Significant influence of period on AFC was reported by Umrikar and Deshpande (1985), Vij (1986), Bhalaru and Dhillon (1987), Singh *et al* (1987), Sharma and Singh (1988), Neog *et al* (1993), Sahana (1993), Das and Sharma (1994), Dhara (1994), Dass (1995), Nath (1996), Kumar (1998), Dass and Sadana (2000), Bajetha (2003), Kundu *et al* (2003), Wakchaure (2007) and Gupta (2009) while El-Arian (1986), Shabade *et al* (1993), Singh (1995), Singh (2001) and Godara *et al* (2004) did not find any significant effect.

4.3.4 Lactation milk yield

The overall least-squares mean for first lactation milk yield (FLMY) was 1794.8±28.5kg with coefficient of variation of 44.2 per cent indicative of high variability in the trait (Table 54). This trait considered as an indicator trait for production comparisons and had a role in reproduction traits. So, this trait holds a lot of economic importance.

Season: The season of calving significantly ($P<0.05$) influenced the FLMY and accounted for a small (1.23%) of the variation (Table 56). The average FLMY ranged from 1762.9 to 1842.9kg over the seasons. No systematic trend was observed over seasons. However, FLMY was the highest in spring being a favourable season for production as well as reproduction. Significant influence of season on 305 MY was reported by Gokhle and Nagarcenkar (1979 a), Kumar (1984), EI-Arian (1986), Agrawal *et al* (1987), Singh et aI. (1987), Neog *et al* (1993), Dutt and Taneja (1994), Dass and Sadana (2000), Sule *et al* (2001), Bajetha (2003), and Godara *et al* (2004) while Prakash (1984), Kumar (1998), Singh (2001), Bajetha (2003) did not find any significant effect.

Period: The period of calving did not significantly influence the FLMY and accounted for a small (0.75%) of the variation (Table 56). The average FLMY ranged from 1357.0 to 2329.3kg over the periods. Increasing trend was observed over periods. Significant influence of period on FLMY was reported by Gokhle and Nagarcenkar (1979), Iype (1980), Gurung and Johar (1982), Sharma (1982), Kumar (1984), Reddy and Taneja (1984), EI-Arian (1986), Dutt and Taneja (1994), Kumar (1998) Dass and Sadana (2000), Singh (2001), Bajetha (2003) and Godara *et al* (2004) while Prakash (1984) and Pander *et al* (2004) did not find any significant effect.

4.5 Mean performance and factors affecting first lactation traits (GADVASU and CIRB herd)

The least square means along with their standard errors and coefficient of variation (%) for various first lactation traits for pooled data of both herds are presented in Tables 57-58 and their analysis of variance for studying the effect of non-genetic factors like season and period on various first lactation traits are presented in Tables 59.

4.5.1 Age at first calving (AFC)

The overall least-squares mean for age at first calving (AFC) was 47.6±0.20 months with a coefficient of variation of 15.7 per cent (Table 57). The overall mean was, in general, higher than those reported by Sethi and Nagarcenkar (1992), Dass (1995), Lall (1995), Shah and Sharma (1994), Dutt *et al* (2001), Singh (2001), Bajetha (2003), Dahiya (2006), Gupta (2009) and Nawale (2010) and lower than those reported by Shreshtha and Yazman (1990), Mathur and Mathur (1992), Narula *et al* (1994), Pundhir (1994), Sethi *et al* (2001), Gogoi *et al* (2002), Kumar *et al* (2002), Pundhir *et al* (2003), Saini *et al* (2003), Godara *et al* (2004), Sharma *et al* (2004) and Suresh *et al* (2004). In general, it was within the range of those reported by El-Arian (1986), Vij and Tiwana (1987), Gupta *et al* (1994), Lathwal (2000), Sethi (2005), Wakchaure *et al* (2008) and Patil (2011)..

Herd: The herd had highly significant ($P<0.01$) influence on AFC and accounted for fair portion (13.2%) of the variation.

Table 57: Least-square means(±SE) and coefficients of variation for age at first calving, 305 day milk yield and lactation milk yield (GADVASU and CIRB herds pooled)

	N	Age at first calving (months)		305 day milk yield(kg)		Lactation milk yield(kg)	
		Mean±SE	CV(%)	Mean±SE	CV(%)	Mean±SE	CV(%)
Overall μ	1388	47.6±0.20	15.7	1808.4±11.28	23.2	2014.3±16.42	30.4
Herds:							
GADVASU	614	44.4±0.30[a]	16.7	1899.5±16.48[b]	21.5	2142.9±24.01[b]	27.7
CIRB	774	50.7±0.30[b]	16.5	1717.3±16.31[a]	26.5	1885.8±23.76[a]	35.1
Seasons:							
Summer	209	47.3±0.49[a]	15.0	1788.9±26.94	21.8	1989.0±39.26	28.5
Rainy	341	47.1±0.39[a]	15.3	1822.9±21.55	21.8	2009.6±31.40	28.8
Autumn	324	47.8±0.40[ab]	15.1	1762.2±21.93	22.4	1955.1±31.96	29.4
Winter	369	48.1±0.37[b]	14.8	1818.3±20.24	21.4	2026.6±29.49	27.9
Spring	145	47.6±0.59[ab]	14.9	1849.7±32.38	21.1	2091.4±47.19	27.2
Periods:							
1988-92	255	50.1±0.46[d]	14.7	1604.5±25.57[a]	25.4	1790.9±37.26[a]	33.2
1993-97	219	49.0±0.48[c]	14.5	1753.4±26.69[b]	22.5	1944.9±38.89[b]	29.6
1997-02	337	45.9±0.40[a]	16.0	1847.9±21.83[c]	21.7	2043.5±31.81[c]	28.6
2003-07	366	45.9±0.39[a]	16.3	1790.5±21.42[b]	22.9	1991.0±31.21[bc]	30.0
2008-12	211	47.0±0.49[b]	15.1	2041.6±27.10[d]	19.3	2301.4±39.49[d]	24.9

Season: The season of birth significantly influence the AFC and accounted for a small (0.56%) of the variation (Table 59). The average AFC ranged from 47.1 to 48.1 months over the seasons. No systematic trend could be observed over seasons. However, AFC was observed to be the lowest in animals born during rainy season. Significant influence of season on AFC was reported by Gudi and Narayanhedkar (1977), Reddy (1980), Gogoi *et al* (1985), Mishra *et al* (1986), Singh *et al* (1987), Gajbhiye and Tripathi (1991), Sethi and Nagarcenkar (1992), Sahana (1993), Gupta *et al* (1994), Bajetha (2003), Wakchaure *et al* (2008) and Gupta (2009) while Sharma (1990), Dhara (1994), Narula *et al* (1994), Pundir (1994), Dass (1995), Nath (1996), Kumar (1998), Saha and Sadana (2000), Singh (2001), Gogoi *et al* (2002), Godara *et al* (2004), Dahiya (2006), Nawale (2010) and Patil (2011) did not find any significant effect.

Period: The period of birth was observed to be highly significant ($P<0.01$) source of variation in AFC and accounted for a small (4.37%) of the variation (Table 59). The average AFC ranged from 45.9 to 50.1 months over the periods. AFC was observed to be the lowest during third and fourth periods. Significant influence of period on AFC was reported by Gajbhiye and Tripathi (1991), Dhara (1994), Gupta *et al* (1994), Narula *et al* (1994), Pundir (1994), Singh (2001), Bajetha (2003), Saini *et al* (2003), Godara *et al* (2004), Dahiya (2006), Wakchure *et al* (2008), Gupta (2009), Nawale (2010) and Patil (2011) while Goswami and Nair (1965), Khosla *et al* (1984), Ulganathan *et al* (1985), Singh and Yadav (1987b), Singh (1995), Kumar (1998), Saha and Sadana (2000), Sule *et al* (2001) and Gogoi *et al* (2002) did not find any significant effect.

4.5.2 305-days milk yield (305 MY)

The overall least-squares mean for 305-days milk yield (305 MY) was 1808.4±11.28kg with coefficient of variation of 23.2 per cent indicative of high variability in the trait (Table 57). This trait considered as an indicator trait for production comparisons and for evaluating the test bulls on their daughter's 305 MY. So, this trait holds a lot of economic importance.

Herd: The herd had highly significant (P<0.01) influence on 305 MY and accounted for low portion (4.6%) of the variation.

Season: The season of calving significantly (P<0.05) influenced the 305 MY and accounted for a small (0.30%) of the variation (Table 59). The average 305 MY ranged from 1762.2 to1849.7kg over the seasons. No systematic trend was observed over seasons. However, 305 MYwas the highest in spring calved animals, it being a favourable season for production as well as reproduction. Significant influence of season on 305 MY was reported by Patro and Bhat (1979), Reddy (1980), Kumar (1984), El-Arian (1986), Gajbhiye (1987), Hatwar and Chawla (1988), Singh *et al* (1990), Dass and Sharma (1994) and Nath (1996) while Jain and Taneja (1982), Sharma (1982), Sharma and Singh (1988) Tomar and Tripathi (1988), Iype and Nagarcenkar (1992), Sahana (1993), Shabade *et al* (1993), Dhara (1994), Dass (1995), Jain and Sadana (1998), Saha (1998), Wakchure *et al* (2008), Gupta (2009) and Patil (2011) did not find any significant effect.

Period: The period of calving had highly significant (P<0.05) influence on the 305 MY and accounted for a small (4.45%) of the variation (Table 59). The average 305 MY ranged from 1604.5 to 2041.6kg over the periods. Increasing trend was observed over periods. Significant influence of period on 305 MY was reported by Patro and Bhat (1979), Reddy (1980), Jain and Taneja (1982), Kumar (1984), El-Arian (1986), Gajbhiye (1987), Tomar and Tripathi (1988), Singh *et al* (1990), Iype and Nagarcenkar (1992), Sahana (1993), Dass and Sharma (1994), Dhara (1994), Dass (1995), Nath (1996), Jain and Sadana (1998), Saha (1998), Wakchure *et al* (2008), Gupta (2009) and Patil (2011) while Sharma and Singh (1988) and Shabade *et al* (1993) did not find any significant effect.

4.5.3 Lactation length

The overall least-squares mean for lactation length (LL) was 346.4±2.25 days with a coefficient of variation of 24.2 per cent (Table 57). The overall mean was, in general, higher than those reported by Sethi and Nagarcenkar (1992), Dass (1995), Lall (1995), Shah and Sharma (1994), Dutt *et al* (2001), Singh (2001), Bajetha

(2003), Dahiya (2006), Gupta (2009) and Nawale (2010) and lower than those reported by Shreshtha and Yazman (1990), Mathur and Mathur (1992), Narula *et al* (1994), Pundhir (1994), Sethi *et al* (2001), Gogoi *et al* (2002), Kumar *et al* (2002), Pundhir *et al* (2003), Saini *et al* (2003), Godara *et al* (2004), Sharma *et al* (2004) and Suresh *et al* (2004). In general, it was within the range of those reported by El-Arian (1986), Vij and Tiwana (1987), Gupta *et al* (1994), Lathwal (2000), Sethi (2005), Wakchaure *et al* (2008) and Patil (2011)..

Herd: The herd had highly significant (P<0.01) influence on LL and accounted for low portion (2.31%) of the variation.

Season: The season of calving did not significantly influence the LL and accounted for a small (0.51%) of the variation respectively (Table 59). The average LL ranged from 341.0 to 357.7 days over the seasons. No systematic trend could be observed over seasons. However, LL was observed to be the highest in spring calved animals as this season considered to be favourable season after being fed with flush diet in winter as well as spring. Significant influence of season on LL was reported by by Gurnani *et al* (1976), Basu and Gahi (1978), Johri and Bhat (1979), Umrikar and Deshpande (1985), Singh *et al* (1987), Mohamed *et al* (1993), Nath (1996), Kumar (1998), Dass and Sadana (2000), Godara *et al* (2004) and Pander *et al* (2004) while Kumar and Bhat (1978), Kannaujia and Balaine (1987), Khosla *et al* (1987), Sharma and Singh (1988), Sahana (1993), Shabade *et al* (1993), Das and Sharma (1994), Dhara 1994, Narsimharao *et al* (1994), Dass 1995, Singh (2001), Kundu *et al* (2003), Sachan *et al* (2006), Wakchaure 2007and Gupta (2009) did not find any significant effect.

Period: The period of calving was observed to be non-significant source of variation in lactation length (LL) and accounted for a small (0.61%) of the variation. The average LL ranged from 335.7 to 355.0 days over the periods (Table 59). The declining trend observed in LL over the periods except the last period where it had increased. Significant influence of period on AFC was reported by Umrikar and Deshpande (1985), Vij (1986), Bhalaru and Dhillon (1987), Singh *et al* (1987), Sharma and Singh (1988), Neog *et al* (1993), Sahana (1993), Das and Sharma (1994), Dhara (1994), Dass (1995), Nath (1996), Kumar (1998), Dass and Sadana (2000), Bajetha (2003), Kundu *et al* (2003), Wakchaure (2007) and Gupta (2009) while El-Arian (1986), Shabade *et al* (1993), Singh (1995), Singh (2001) and Godara *et al* (2004) did not find any significant effect.

4.5.4 Lactation milk yield (LY)

The overall least-squares mean for first lactation milk yield (LY) was 2014.3±16.4kg with coefficient of variation of 30.4 per cent indicative of high variability in the trait (Table 58). This trait considered as an indicator trait for production comparisons and had a role in reproduction traits. So, this trait holds a lot of economic importance.

Herd: The herd had highly significant (P<0.01) influence on LY and accounted for low portion (4.63%) of the variation.

Season: The season of calving did not significantly influence the LY and accounted for a small (0.41%) of the variation (Table 59). The average LY ranged from 1955.1 to 2091.4kg over the seasons. No systematic trend was observed over seasons. However, LY was the highest for animals calved during spring and it considered to be favourable season for production as well as reproduction. Significant influence of season on LY was reported by Gokhle and Nagarcenkar (1979 a), Kumar (1984), EI-Arian (1986), Agrawal *et al* (1987), Singh et aI. (1987), Neog *et al* (1993), Dutt and Taneja (1994), Dass and Sadana (2000), Sule *et al* (2001), Bajetha (2003), and Godara *et al* (2004) while Prakash (1984), Kumar (1998), Singh (2001), Bajetha (2003) did not find any significant effect.

Period: The period of calving had highly significant (P<0.01) influence on the LY and accounted for a small (3.39%) of the variation (Table 59). The average LY ranged from 1790.9 to 2301.4kg over the periods. Increasing trend was observed over periods. Significant influence of period on FLMY was reported by Gokhle and Nagarcenkar (1979), Iype (1980), Gurung and Johar (1982), Sharma (1982), Kumar (1984), Reddy and Taneja (1984), EI-Arian (1986), Dutt and Taneja (1994), Kumar

Table 58: Least-square means(±SE) and coefficients of variation for lactation length, peak yield and milk yield/day of lactation milk yield (GADVASU and CIRB herds pooled)

	N	Lactation length(days)		Peak yield(kg)		Milk yield/day of lactation length (kg)	
		Mean±SE	CV(%)	Mean±SE	CV(%)	Mean±SE	CV(%)
Overall µ	1388	346.42±2.25	.2	9.06±0.05	20.6	5.82±0.03	19.2
Herds:							
GADVASU	614	356.86±3.29[b]	22.8	10.29±0.07[b]	16.8	6.02±0.04[b]	16.4
CIRB	774	335.98±3.25[a]	26.9	7.84±0.07[a]	24.9	5.63±0.04[a]	19.8
Seasons:							
Summer	209	343.34±5.37	22.6	9.00±0.11[b]	17.7	5.77±0.07	17.5
Rainy	341	341.43±4.30	23.3	9.07±0.09[bc]	18.3	5.91±0.06	18.7
Autumn	324	341.05±4.37	23.1	8.80±0.09[a]	18.4	5.75±0.06	18.8
Winter	369	348.58±4.03	22.2	9.28±0.08[c]	16.6	5.82±0.05	16.5
Spring	145	357.68±6.46	21.7	9.18±0.13[bc]	17.0	5.87±0.09	18.5
Periods:							
1988-92	255	352.69±5.10	23.1	8.41±0.10[a]	19.0	5.12±0.07[a]	21.8
1993-97	219	347.54±5.32	22.6	8.97±0.11[bc]	18.1	5.59±0.07[ab]	18.5
1997-02	337	341.13±4.35	23.4	9.22±0.09[c]	17.9	5.99±0.06[b]	18.4
2003-07	366	335.72±4.27	24.3	8.80±0.09[b]	19.6	5.93±0.06[b]	19.4
2008-12	211	355.00±5.40	22.1	9.92±0.11[d]	16.1	6.51±0.07[c]	15.6

(1998) Dass and Sadana (2000), Singh (2001), Bajetha (2003) and Godara *et al* (2004) while Prakash (1984) and Pander *et al* (2004) did not find any significant effect.

4.5.5 Peak yield (PY)

The overall least-squares mean for peak yield (PY) was 9.06±0.05kg with coefficient of variation of 20.6 per cent indicative of moderate variability in the trait (Table 58). This trait considered as an indicator trait for production comparisons. So, this trait holds a lot of economic importance.

Herd: The herd had highly significant (P<0.01) influence on PY and accounted for high portion (32.18%) of the variation.

Season: The season of calving had significant (P<0.05) influence on the PY and accounted for a small (0.49%) of the variation (Table 59). The average PY ranged from 8.80 to 9.28kg over the seasons. No systematic trend was observed over seasons. However, PY was the highest for animals calved during winter, as it considered to be favourable season for production as well as reproduction because of availability of high quality leguminous fodder. Significant influence of season on PY was reported by Gokhle and Nagarcenkar (1979 a), Kumar (1984), EI-Arian (1986), Agrawal *et al* (1987), Singh et aI. (1987), Neog *et al* (1993), Dutt and Taneja (1994), Dass and Sadana (2000), Sule *et al* (2001), Bajetha (2003), and Godara *et al* (2004) while Prakash (1984), Kumar (1998), Singh (2001), Bajetha (2003) did not find any significant effect.

Period: The period of calving had highly significant (P<0.01) influence on the PY and accounted for a small (1.88%) of the variation (Table 59). The average PY ranged from 8.41 to 9.92kg over the periods. No consistent trend could be observed over periods. Significant influence of period on PY was reported by Gokhle and Nagarcenkar (1979), Iype (1980), Gurung and Johar (1982), Sharma (1982), Kumar (1984), Reddy and Taneja (1984), EI-Arian (1986), Dutt and Taneja (1994), Kumar (1998) Dass and Sadana (2000), Singh (2001), Bajetha (2003) and Godara *et al* (2004) while Prakash (1984) and Pander *et al* (2004) did not find any significant effect.

Table 59: Least-squares analysis of variance for studying the effect of non-genetic factors on economic traits (GADVASU and CIRB pooled)

Trait	Sources of variation	df	MS	R^2(%)
AFC	Season	4	123.4*	0.56
	Period	4	960.1**	4.37
	Herd	1	11612.04**	13.21
305 MY	Season	4	194897.1	0.30
	Period	4	2863384.8**	4.45
	Herd	1	11845422.0**	4.60
LL	Season	4	11721.9	0.51
	Period	4	13985.0	0.61
	Herd	1	210212.0**	2.31
LY	Season	4	537272.2	0.41
	Period	4	4462299.0**	3.39
	Herd	1	24324860.0**	4.63
PY	Season	4	7.34*	0.49
	Period	4	28.1**	1.88
	Herd	1	1918.9**	32.18
MYLL	Season	4	0.781	0.16
	Period	4	31.3**	6.44
	Herd	1	45.3**	2.33

* Signficiant at 5% level ($p \leq 0.05$)
** Signficiant at 1% level ($p \leq 0.01$)

4.5.6 Milk yield per day of lactation length (MYLL)

The overall least-squares mean for milk yield per day of lactation length (MYLL) was 5.82±0.03kg with coefficient of variation of 19.2 per cent indicative of moderate variability in the trait (Table 58). This trait considered as an indicator trait for production comparisons. So, this trait holds a lot of economic importance.

Herd: The herd had highly significant (P<0.01) influence on MYLL and accounted for small portion (2.33%) of the variation.

Season: The season of calving did not significantly influence the MYLL and accounted for a small portion (0.16%) of the variation (Table 59). The average MYLL ranged from 5.75 to 5.91kg over the seasons. No systematic trend was observed over seasons. Significant influence of season on PY was reported by Gokhle and Nagarcenkar (1979 a), Kumar (1984), EI-Arian (1986), Agrawal *et al* (1987), Singh et aI. (1987), Neog *et al* (1993), Dutt and Taneja (1994), Dass and Sadana (2000), Sule *et al* (2001), Bajetha (2003), and Godara *et al* (2004) while Prakash (1984), Kumar (1998), Singh (2001), Bajetha (2003) did not find any significant effect.

Period: The period of calving had highly significant (P<0.01) influence on the MYLL and accounted for a small (6.44%) of the variation (Table 59). The average MYLL ranged from 5.12 to 6.51kg over the periods. Increasing trend was observed over periods. Significant influence of period on MYLL was reported by Gokhle and Nagarcenkar (1979), Iype (1980), Gurung and Johar (1982), Sharma (1982), Kumar (1984), Reddy and Taneja (1984), EI-Arian (1986), Dutt and Taneja (1994), Kumar (1998) Dass and Sadana (2000), Singh (2001), Bajetha (2003) and Godara *et al* (2004) while Prakash (1984) and Pander *et al* (2004) did not find any significant effect.

4.5.7 General remarks on effect of non-genetic factors on first lactation traits

A perusal of the least-squares means of various lactation traits and the effect of season, period and herd on these factors indicated that season had non-significant effect on various first lactation traits except for age at first calving and peak yield. The contribution to total variation for various traits where its effect was significant fell between 0.49 and 0.56%. Little effect of season implied that herd-management was effective in minimizing the seasonal changes associated with physical environmental factors and feed and fodder availability. Period of calving had significant influence on all of the traits under study except for the lactation length where it had non-significant effect. But its contribution of total variation for various traits where its effect was significant fell between 1.88 and 6.44%. Period relative to season had slightly more effect on various effects as it extended over twenty five years. During such a long span of time management practices including nutrition regime change. Additional genetic structure of population also changes due to selection and introduction of animals from outside. There has general improvement in herd performance over time in peak yield and milk production per day of lactation length. Herd had significant influence on all of the traits under study indicating significant differences in performance among two herds.

4.6 Estimates of Genetic and Phenotypic Parameters

The estimates of heritability, and the magnitude and type (direction) of genetic association among economic traits are the most important genetic parameters needed for the designing a breeding plan to bring about genetic improvement in overall productivity of the herd. Phenotypic and environmental associations among these traits are required for efficient flock/herd management system so as that genetic potential can be fully realized.

4.6.1 Heritability Estimates of Body weights and Growth

The estimates of heritability of body weight at different ages, the corresponding gain in weight and the relative growth rates along with their standard errors are presented in Table 60.

Birth weight: Heritability of birth weight was estimated to be 0.197±0.104. Estimates of similar magnitude were reported by Basu and Rao (1979) and Kirmani *et al* (1984), Johari (1976), Nautiyal and Bhat (1979), Dahama *et al* (1990) and Tien and Tripathi (1990). However, Chowdhary and Barhal (1979), Sharma *et al* (1983) and Singh and Basu (1988) reported lower estimates..

Calf-dam weight (%): The heritabililty of calf-dam weight was lower (0.110±0.098) than of birth weight. This indicated that birth weight was influenced by maternal effects while calf weight expressed as percentage of dam weight became independent of contribution of dam’s weight (maternal influences).

Table 60: Heritability ± SE estimates for growth traits (GADVASU herd)

Sr.No.	Traits	h^2 ± S.E.
1.	Birth weight (B wt 0)	0.197±0.104
2.	Calf-dam weight %	0.110±0.098
3.	Body weight at 1 m (B wt 1)	0.263±0.109
4.	Body weight at 3 m (B wt 3)	0.236±0.108
5.	Body weight at 6 m (B wt 6)	0.536±0.125
6.	Body weight at 12 m (B wt 12)	0.304±0.112
7.	Body weight at 18 m (B wt 18)	0.481±0.122
8.	Body weight at 24 m (B wt 24)	0.389±0.117
9.	Monthly gain in weight 0-1 m age(G 01 m)	0.287±0.111
10.	Monthly gain in weight 1-3 m age(G 13 m)	0.166±0.103
11.	Monthly gain in weight 3-6 m age(G 36 m)	0.275±0.110
12.	Monthly gain in weight 0-6 m age(G 06 m)	0.561±0.126
13.	Monthly gain in weight 6-12 m age(G 612 m)	0.214±0.107
14.	Monthly gain in weight 12-18 m age(G 1218 m)	0.390±0.117
15.	Monthly gain in weight 18-24 m age(G 1824 m)	0.081±0.096
16.	Monthly gain in weight 6-24 m age(G 624 m)	0.333±0.114
17.	Monthly relative growth rate 0-1m age(RG 01 m)	0.227±0.107
18.	Monthly relative growth rate 1-3m age(RG 13 m)	0.174±0.104
19.	Monthly relative growth rate 3-6m age(RG 36 m)	0.056±0.04
20.	Monthly relative growth rate 0-6m age(RG 06 m)	0.335±0.115
21.	Monthly relative growth rate 6-12m age(RG 612 m)	0.236±0.108
22.	Monthly relative growth rate 12-18m age(RG 1218 m)	0.178±0.103
22.	Monthly relative growth rate 18-24m age(RG 1824 m)	0.087±0.096
23.	Monthly relative growth rate 6-24m age(RG 624 m)	0.332±0.114

Body weight at other ages: Heritability of one month body weight was 0.363±0.109 which was higher than that of birth weight and calf-dam per cent (Table 60).

Heritability of three month weight was 0.236±0.108, which was close to those reported by Basu and Rao (1979). Estimates of higher magnitude were reported by Johari and Bhat (1979b), Gurung and Johar (1983b) and Kirmani *et al* (1984).

Heritability of six-month weight was higher (0.536±0.125) than of corresponding estimates at other ages. Estimate of similar magnitude was also reported by Johari and Bhat (1979b) while estimates of lower magnitude were reported by Basu and Rao (979) and Tien and Tripathi (1990).

Heritability of twelve-month weight was estimated to be 0.304±0.112. Estimates of lower magnitude were reported by Basu and Rao (1979), Kirmani *et al* (1984) and Tien and Tripathi (1990) while Johari and Bhat (1979a) and Gurung and Johar (1983b) reported higher estimates.

Heritability of eighteen-month weight was 0.481±0.122 which was close to the estimates reported by Nautiyal and Bhat (1979). Estimates of higher magnitude were reported by Gurung and Johar (1983b) and Kirmani *et al* (1984).Estimate of lower magnitude was reported by Tien and Tripathi (1990).

Heritability of twenty four-month weight was 0.389±0.117 which was close to the estimates reported by Johari (1976), Johari and Bhat (1979b) and Nautiyal and Bhat (1979). Estimates of higher magnitude than that of present study were reported by Gurung and Johar (1983b) and Kirmani *et al* (1984).

Gain in weight: Heritabilities of gain in weight at different age intervals were generally moderately high, and varied between 0.08±0.096 and 0.561±0.126. There was no consistent trend over different age intervals. Heritability estimates of gain in weight were, in general, fairly similar to body weights at different ages.

Relative growth rate: Relative growth rate expresses the gain in weight independent of the initial weight. Heritability estimates of relative growth rate ranged between 0.056±0.04 and 0.33±0.11. Heritability of relative growth rates was quite similar to those of corresponding estimates of gain in weight. This implied that the type and magnitude of gene action for relative growth was same as that for gain in weight and body weights.

General remarks on heritabilities of body weight and growth : The estimates of heritability for body weights at different ages, monthly gain in weight and relative growth rate ranged between 0.11 and 0.54, 0.08 and 0.56, and 0.06 and 0.33 respectively. Higher estimates were obtained for six month body weight, gain in body weight from birth to six months and relative growth rate from birth to six months of age. These results indicated that the magnitude of additive genetic variance in the first six months was higher than that in the later periods. Environmental variation during the post calfhood (beyond six months of age) period increases, thereby decreasing the magnitude of heritability.

A perusal heritability estimates indicated that a fairly large proportion of the phenotypic variation in body weights and growth upto six months of age was of genetic origin. Early growth can, therefore, be improved through selection.

4.6.2 Heritability of First Lactation Traits (GADVASU herd)

Half-sib heritability estimates for various first lactation traits are presented in Table 61.

Gestation period: The estimate of heritability for first gestation period was quite low (0.161±0.095) and proportionately carried large standard error.

Age at first calving: Estimate of heritability of age at first calving was 0.761±0.125. Estimates of similar magnitude were reported by Bhadula and Desai (1972), Kirmani *et al* (1984), Singh and Parkash (1986), Vij and Tiwana (1987), Tien and Tripathi (1990) and Gogoi *et al*. (2002). However, low estimates for AFC were reported by Raheja (1992), Singh and Singh (1992), Sahana (1993), Dutt and Taneja (1994), Narula *et al* (1994), Dass (1995), Singh (1995), Khan *et al* (1996), Jain and Sadana (1998), Das and Sadana (2000), Dutt *et al* (2001), Bajetha (2003), Wakchaure *et al* (2008) and Gupta (2009), Nath (1996), Kumar (1998), Saha and

Table 61: Heritability estimates for various first lactation traits (GADVASU herd)

Sr.No	Trait	
1.	GP	0.161±0.095
2.	AFC	0.761±0.125
3.	WAC	0.454±0.112
4.	WAW	0.157±0.095
5.	Calf %	0.127±0.093
6.	305 MY	0.4217±0.110
7.	LL	0.125±0.090
8.	LY	0.364±0.114
9.	MY/LL	0.291±0.103
10.	Fat%	0.611±0.119
11.	Fat yield	0.280±0.106
12.	PY	0.225±0.099
13.	DRPY	0.163±0.095
14.	AI No.	0.062±0.083

Sadana (2000), Thevamanoharan *et al* (2000) and Kumar *et al* (2002). The high value of heritability of this trait coupled with relatively lower standard error indicated that the trait was highly influenced by additive genetic variance; and as such it can be easily improved through selection based on animals own performance.

Weight at calving: The estimate of heritabililty for weight at first calving was 0.454± 0.112. Estimates of similar magnitude were reported by Gurung and Johar (1982), Singh and Yadav (1988) and Singh (1995). However, higher estimate were reported by Tein and Tripathi (1990). Chaurasia et a (1980), Basu *et al* (1984), Singh and Yadva (1986), Singh and Singh (1992), Kumar (1998), Singh (2001) and Bajetha (2003) reported lower estimates. By virtue of the high heritability of weight at calving, the trait can be improved through individual selection.

Weight at birth: The heritability of weight at birth was 0.157 ± 0.095 which was fairly close to the estimates reported by Basu and Rao (1979) and Singh and Basu (1988). However, higher estimates were reported by Gurung and Johar (1983), Tein and Tripathi (1990), Johari (1976), Nautiyal and Bhat (1979) and Kirmani *et al* (1984). Sharma *et al* (1983), however, reported lower estimates. The low value of heritability of this implied that the trait was more influenced by environmental factors and its improvement in this trait could be done by better breeding, feeding and management practices.

Calf-dam weight (%) : The estimate of heritability for calf-dam weight (%) was low (0.127±0.093) which indicated that improvement in this trait could be done by better managemental practices as trait was more influenced by environmental factors (Table 61).

305-day milk yield: The estimate of heritability for 305-day milk yield was 0.427±0.110. Estimates of similar magnitude were reported by Sharma (1982), Gajbhiye (1987), Dhara (1994) and Dass (1995). However, high heritability estimates for this trait were reported by Khan and Johar (1988) and Wakchaure *et al* (2008) and low heritability estimates for this trait were reported by Kumar *et al* (1978), Hatwar and Basu (1988), Tein and Tripathi (1990), Dass and Sharma (1993), Sahana (1993), Dass (1995), Nath (1996), Kumar *et al* (2002) and Gupta (2009). The high heritability of the trait indicated the existence of high genetic variability, and in turn high scope of improvement in this trait through selection.

Lactation length: The estimate of heritability for first lactation length (LL) was 0.125±0.090. Estimates of similar magnitude were reported by Verma and Yadav (1989), Reheja (1992), Singh (1995), Kumar (1998), Reheja *et al* (2001), Singh (2001) and Thevamanoharan *et al* (2002). However, high heritability estimates for this trait were reported by Singh and Basu (1988), Sahana (1993), Dharr ((1994), Khan *et al* (1996), Sethi and Khatkar (1997), Yadav *et al* (2002), Warade *et al* (2005) and Gupta (2009) and low heritability estimates for this trait were reported by Kumar (1984), Reheja (1993), Dutt and Taneja (1994), Dass ((1995), Dass and Sadan (2000), Thevamonaharan *et al* (2000), Aziz *et al* (2003) and Wakchaure *et al* (2008). The low value of heritability implied that the trait could be improved through better managemental practices.

Lactation milk yield: The estimate of heritabililty for first lactation milk yield (LY) was 0.364±0.114. Estimates of similar magnitude were also reported by Sharma (1992), Mishra *et al* (1983), Dass and Sadana (2000), Dutta *et al* (2001) and Yadav *et al* (2002). However, low heritability estimates for FLY were reported by Kirmani *et al* (1994), Kumar (1984), Raheja (1992), Dutt and Taneja (1994), Khan *et al* (1997) and Kuralkar and Reheja (1997), Sethi and Khatkar (1997), Jain and Sadana (1998) (2000), Thevamanoharan *et al* (2000, 2002). Singh (2001), Tonhart *et al* (2004) and Chandra *et al* (2005).

Milk yield per day of lactation length: The estimate of heritability for milk yield per day of lactation length (MYLL) was 0.291±0.103 (Table 61). Estimates of similar magnitude were reported by Kumar (1984) and Sahana (1993). Higher estimates of heritability for MYLL were reported by Basavaiah (1978) and Sharma (1982) were reported by Basavaiah (1978) and Sharma (1982) lower estimates of heritability for MYLL were reported by Gajbhiye (1987), Singh and Yadav (1987) and Nath ((1996).

General remarks on heritabilities of first lactation traits: The estimates of heritability for different first lactation traits were within the range of those reported in literature. In general, the traits related to reproduction had low heritabilities and were also associated with relatively higher standard errors which made the estimates not to differ significantly from zero. Traits related to milk production viz. 305 day milk yield, lactation milk yield, lactation length were moderately heritable. The size of standard error was quite low. Total yield of fat, age at first calving, weight at first calving, had higher heritabilities than production traits.

Baring the number of inseminations, gestation period, lactation length and days to reach peak yield, all other traits had sufficient genetic variability to warrant effectiveness of selection for their improvement. The most important trait influencing economic return viz. 305 day milk yield and complete lactation yield had moderate heritabilities and can therefore be easily improved through individual selection. Being sex limited, selection in males can be effected through progeny testing.

Higher estimates of heritability's were obtained for age at first calving, weight at first calving, 305-days milk yield and fat% in a lactation. The magnitude of additive genetic variance for these traits was higher than those of other traits (calf birth weight, lactation length, peak yield and days to reach peak yield. These traits can, therefore, be used either alone or in combination with other traits as a selection criterion for improving the age and weight at puberty in both males and females. This in turn will help in reducing age at first calving in females and age of first semen donation in males.

4.6.3 Estimates of Heritability (CIRB herd)

Estimates of heritability (half-sib), obtained using model II of Henderson (Henderson 1953) for first lactation traits are presented in Table 62. The estimates of heritability for AFC, 305 MY, LL, LY, PY and MYLL were 0.357, 0.246, 0.074, 0.200, 0.378 and 0.398 respectively. Estimates of similar magnitude for AFC were reported by El-Arian and Tripathi (1987), Dass and Sadana (2000), Dutt *et al* (2001) and Wakchaure *et al* (2008).

Table 62: Heritability ± SE estimates for various first lactation traits (CIRB herd)

Traits	h^2 ± S.E.
Age at first calving	0.357±0.120
305-day milk yield	0.246±0.118
Lactation length	0.074±0.097
Lactation milk yield	0.200±0.112
Peak yield	0.378±0.132
Milk yield per day of lactation length	0.398±0.134

Heritability of lactation length was very low and also associated with relatively higher standard errors which made the estimate not to differ significantly from zero. Estimates of similar magnitude had previously been reported for lactation length in Murrah buffaloes (Gurung and Johar (1982), Raheja (1993), Dutt and Taneja (1994), Dass and Sadana (2000) and Wakchaure *et al* (2008).

4.6.4 Estimates of Heritability (GADVASU and CIRB herd pooled)

Traits related to milk production viz. 305 MY, LY, PY and MYLL had moderate to high heritability (0.200 to 0.398) (Table 63). Estimates of similar magnitude were also reported for 305 MY by El-Arian and Tripathi (1987), Sahana and Sadana (1998), various first lactation traits were reported by Vij and Tiwana (1987), Tien and Tripathi (1990) and Gogoi *et al*. (2002), for LY by Dutt and Taneja (1994), Kuralkar and Raheja (1997), Jain and Sadana (1998) and Aziz *et al* (2003) and for MYLL by Sharma and Basu (1986). The size of standard errors was also low. The high value of heritability of AFC, PY and MYLL coupled with relatively lower standard error indicated that these traits had sizeable amount of additive genetic variance to warrant the effectiveness of selection for their improvement.

Table 63: Heritability ± SE estimates for various economic traits (GADVASU and CIRB herds pooled)

Sr. No.	Traits	h^2 ± S.E.
1	Age at first calving	0.311±0.086
2	305-day milk yield	0.311±0.092
3	Lactation length	0.115±0.074
4	Lactation milk yield	0.259±0.087
5	Peak yield	0.473±0.094
6	Milk yield per day of lactation length	0.418±0.100

4.7 Correlations among body weights and growth rates

The estimates of genetic, phenotypic and environmental correlations among body weights and growth rates along with their standard errors are given in Table 64. The various correlations among growth traits ranged from low to high. All correlations were significant and in desirable directions except a few ones.

4.7.1 Birth weight with other weights

Correlations presented in table 64 revealed that birth weight had positive genetic relationship with body weights at three months, six months and twelve months of age whereas

Table 64: Heritability and correlations among growth traits

	Bw0	Bw1	Bw3	Bw6	Bw12	Bw18	Bw24	G06	G624	Rg06	Rg624
Bw0	**0.20±0.10**	.67(.69)	.39 (.44)	.26 (.33)	.13(.11)	.29(.10)	.10(.21)	-.10 (-.18)	.01(.12)	-.66 (-.75)	-.18 (-.12)
Bw1	.64±.20	**0.26±0.11**	.67(.64)	.44(.33)	.26(.15)	.21(-.02)	.16 (-.001)	.20(-.03)	.001 (-.11)	-.26 (-.48)	-.30 (-.26)
Bw3	.25±.30	.79±.14	**0.24±0.11**	.66(.45)	.30(.11)	.26(.063)	.17(.001)	.53(.24)	-.066 (-.15)	.13 (-.13)	-.48 (-.37)
Bw6	.22±.24	.64±.16	.99±.09	**0.54±0.12**	.54(.41)	.44(.17)	.35(.20)	.93(.87)	-.003 (-.097)	.49(.27)	-.65 (-.61)
Bw12	.21±.33	.53±.24	.72±.21	.73±.12	**0.30±0.11**	.81(.78)	.67(.55)	.50(.41)	.52(.41)	.27(.12)	.04(.11)
Bw18	-.02±.29	.60±.20	.66±.22	.65±.12	.90±.063	**0.48±0.12**	.83(.70)	.42(.09)	.71(.65)	.23 (-.04)	.24(.41)
Bw24	-.14±.28	.47±.23	.57±.22	.49±.15	.92±.094	.97±.04	**0.39±0.12**	.33(.12)	.93(.95)	.14(-.12)	.47(.62)
G06	.02±.26	.56±.20	.97±.12	.98±.01	.68±.14	.67±.12	.57±.16	**0.56±0.13**	-.009 (-.163)	.75(.67)	-.61 (-.58)
G624	-.26±.30	.23±.27	.15±.30	.12±.21	.73±.16	.81±.08	.91±.04	.19±.21	**0.33±0.11**	-.011 (-.162)	-.32 (-.21)
Rg06	-.50±.45	.17±.28	.63±.23	.73±.12	.54±.20	.55±.17	.57±.22	.85±.07	.28±.25	**0.33±0.11**	-.32 (-.21)
Rg624	-.33±.33	-.39±.31	-.72±.37	-.72±.30	-.08±.24	.06±.20	.25±.20	-.67±.28	.60±.15	-.50±.27	**0.33±0.11**

Figures along diagonal indicate heritability estimates
Figures on upper side of diagonal indicate phenotypic correlation and in parentheses environmental correlation
Figures on lower side of diagonal indicate genetic correlation

there was negative genetic correlation between birth weight and body weights of eighteen months, twenty four months and growth rate from six to twenty four months and monthly relative growth rates from birth to six months and from six month to twenty four months. These correlations had high standard errors. This may be due to small number of observations used in the data.

Phenotypic correlations of birth weight with other body weights at other stages were high to low with progress of age and had negative phenotypic correlation with various growth rates. Similar trend was observed for environmental correlations.

4.7.2 One-month weight with other weights

The genetic correlations of one month body weight were very high and positive with adjacent body weights and declined with advancing age. One-month body weight had negative genetic correlation (-0.39±0.31) with relative growth rate from birth to six month of age. The phenotypic correlations of body weight at one month of age were also positive with subsequent body weights except for relative growth rates. A similar trend of genetic and phenotypic correlations of body weight at one month of age with subsequent body weights and gain in weight were reported by Gurung and Johar (1984) and Johari and Bhat (1979).

4.7.3 Three-month weight with other weights

The genetic correlations of three month body weight were very high and positive with adjacent body weights and declined with advancing age. Three month body weight had negative genetic correlation (-0.72±0.37) with relative growth rate per month for period from six to twenty four months. The phenotypic correlations of body weight at three months of age were also positive with subsequent body weights and gain in body weight per month. A similar trend of genetic and phenotypic correlations of body weight at three months of age with subsequent body weights were reported by Johari and Bhat (1979), Gurung and Johar (1984), Yadav *et al* (2007), Thiruvenkadan *et al* (2009) and Gupta *et al* (2012).

4.7.4 Six-month Weight with Other Weights

The genetic correlation of body weight at six months of age with body weights at twelve months, eighteen months, twenty four months of age and gain in weight at various stages were high and positive while the genetic correlation of six months body weight was negative and high with relative monthly growth rate for period from six to twenty four months of age (-0.72±0.30). Similar trend was observed in case of phenotypic correlations of body weight of six months of age with body weights at twelve months, eighteen months, twenty four months while negative correlations were observed with monthly gain in weight and relative growth rate for period from six to twenty four months of age. A similar trend of environmental correlations of six-month weight with other weights, monthly gain in weights and monthly relative growth rates was observed. A similar trend for genetic and phenotypic correlations of body weight at six months with subsequent body weights at twelve, eighteen and twenty four months and gain in weights were observed by Johari and Bhat (1979), Gurung and Johar (1984), Yadav *et al* (2007), Thiruvenkadan *et al* (2009) and Gupta *et al* (2012).

4.7.5 Twelve-month Weight with Other Weights

Table 64 also revealed high and positive genetic correlations of body weight at twelve month of age with body weights at eighteen months, twenty four months of age and with monthly gain in weight. A negative genetic correlation of twelve month body weight with monthly relative growth rate for period from six to twenty four months of age was observed. A similar trend was observed for phenotypic correlation of twelve months body weight with body weights at eighteen months, twenty four months of age, monthly gain in weight and monthly relative growth rate. Environmental correlations of twelve month body weight with other weights showed the similar trend. Gurung and Johar (1984), Yadav *et al* (2007), Thiruvenkadan *et al* (2009) and Gupta *et al* (2012) also reported positive and high genetic and phenotypic correlations of bodyweight at twelve months of age with body weights at eighteen months, twenty four months of age and gain in weight at various stages.

4.7.6 Eighteen-month Weight with Other Weights

A perusal of Table 64 revealed that body weight at eighteen months of age had positive and high genetic (0.97±0.04), phenotypic (0.83) and environmental (0.70) correlation with twenty four month body weight in Murrah buffaloes. Almost similar genetic correlation between body weight at eighteen months of age and weight at twenty four months of age was reported by Tien and Tripathi (1990), Thiruvenkadan *et al* (2009) and Gupta *et al* (2012). Body weight at eighteen months of age showed positive genetic and phenotypic correlation with monthly gain in weight and relative growth rate.

4.7.7 Twenty-month Weight with other Weights

The body weight at twenty four months of age had high positive genetic, phenotypic and environmental correlations with monthly gain in weight and relative growth rate for period from six to twenty four months of age (Table 64). Negative environmental correlation of twenty four-month weight was observed for monthly relative growth rate from birth to six months of age.

4.7.8 Monthly Gain in Weights

The monthly gain in weights from birth to six month and six to twenty four months of age had positive genetic correlation with monthly relative growth from birth to six month but negative with period of six to twenty four month of age (Table 64). However, phenotypic and environmental correlation among the two gains in weight traits was observed to be negative. The genetic, phenotypic and environmental correlation among two relative growth rate traits was observed to be negative.

4.7.9 General Remarks on Correlations among Growth Traits

In view of the low genetic correlation of birth weight with most body weight at other ages (except for one-month weight) monthly growth rate and monthly relative growth rate do not appear to be good criteria for selection for faster post calf hood growth rate. A perusal of the estimates of genetic correlation among the bodyweights and the growth rates indicated a desirable genetic association among them, except for the undesirable relationship of some body weights with monthly growth rates. Since six-month weight was more heritable than the birth weight, is also free from maternal effects and because of its favourable genetic association with post calf hood weights and growth rates, selection of calves on the basis of the six-month body weight should prove handy for early selection of young bulls for breeding. Moreover, information about the dam's current half lactation also becomes available by this time to take a final decision about the choice of the future bulls for breeding for bringing about genetic improvement in the overall productivity of the herd.

A perusal of the phenotypic correlations presented in indicated the existence of low to high degree of desirable association among growth traits except for the correlations of body weights with post calf hood monthly growth rates and monthly relative growth rates. The lowest correlation was between birth weight and eighteen-month weight and negative with monthly growth rates. The correlations between adjacent body weights were higher than those between non-adjacent body weights, probably due to greater similarity of environmental and managemental conditions between adjacent records. These phenotypic correlations indicate that the body weight at a given age played an important role in determining the body weights at subsequent ages, emphasizing the need for efficient feeding management system for ensuring better growth throughout the growing period of the calves.

The negative environmental correlations of initial body weights with later months body weights and their respective monthly growth rates indicated that the environmental and managemental conditions responsible for faster early months growth rate and higher weight at six months age did not influence the post calf hood growth rate in the same direction, indicating the need for adopting different feeding and management practices during the calf hood and post calf hood periods.

4.8 Correlations among various First Lactation Traits (GADVASU herd)

The genetic, phenotypic and environmental correlations among different traits are given in Table 65. Above the diagonal are phenotypic and in parenthesis are environmental correlations whereas below the diagonal are the genetic correlations.

4.8.1 Association of Age at First Calving with: Other Traits

Lactation milk yield: The genetic correlation of age at first calving and first lactation total milk yield was moderate and significant (0.34 ± 0.19). Similar finding was reported by Mangurkar and Desai (1981) and Dutt and Taneja (1994). However, Raheja (1992) and Singh (2001) reported high and positive genetic correlation while Kiramani *et al* (1984) and Singh (1992) reported high but negative genetic correlation between these two traits.

The phenotypic and environmental correlation of age at first calving and first lactation total milk yield was small and significant (0.07 and 0.04). Most of the workers (Kumar, 1984; El-Arian, 1986; Tein and Tripathi, 1990; Dutt and Taneja, 1994; Kuralkar and Raheja, 1997; Jain and Sadana, 2000 and Singh, 2001) reported small and significant phenotypic correlation between these two traits. Raheja (1992a), Kumar (1995) and Dass and Sadana (2000) reported high and positive phenotypic correlation, while Gogoi *et* al (1985), Dhama *et al* (1991) and Singh and Singh (1992) reported negative phenotypic correlation between these two traits.

First lactation 305 days or less milk yield: The genetic correlation between age at first calving and first lactation 305 days or less milk yield was moderate, positive and significant (0.32 ± 0.18). Similar but non-significant genetic correlation between these traits was observed by Gupta (2009), while higher estimate of this parameter was reported by Sahana (1993).

The phenotypic and environmental correlation between age at first calving and first lactation 305 days or less milk yield was small and non-significant (0.11 and 0.08). Similar finding was reported by Sahana (1993). However, Gupta (2009) reported higher phenotypic correlation between these two traits.

Table 65: Correlations among first lactation traits (GADVASU herd)

	AFC	WFC	LY	LL	305MY	FAT%	PY	DRPY	MYLL	F YIELD
AFC		.39(.44)	.07(.04)	.03(.05)	.11(.08)	.08(.66)	.12(.16)	.01(-.14)	.09(-.11)	.10(.11)
WFC	.40±.13		.21(.13)	.003 (-.006)	.29(.24)	.17(.56)	.33(.28)	-.03(.005)	.32(.14)	.24(.25)
LY	.34±.19	.35±.22		.76(.75)	.89(.86)	.03(.38)	.55(.52)	.04(.04)	.54(.39)	.96(.98)
LL	.29±.29	.04±.36	.94±.16		.48(.41)	.11(.32)	.16(.14)	-.02(-.04)	-.10(-.28)	.76(.73)
305 MY	.32±.18	.40±.20	.97±.03	.93±.37		-.01(.39)	.67(.64)	.08(.07)	.77(.67)	.84(.84)
FAT%	-.24±.15	-.32±.18	-.45±.21	-.44±.38	-.43±.20		-.01(-.03)	-.03(-.09)	-.08(.11)	.29(.52)
PY	.13±.24	.46±.21	.65±.18	.37±.50	.79±.12	.07±.24		.04(.11)	.65(.61)	.53(.47)
DRPY	.29±.28	-.06±.28	.06±.35	.05±.53	.14±.34	.06±.26	-.27±.37		.11(.14)	.03(.03)
MYLL	.39±.22	.59±.18	.87±.13	.65±.50	.93±.07	-.49±.22	.77±.17	-.23±.33		.47(.36)
F YIELD	.10±.21	.23±.22	.91±.03	.95±.16	.87±.06	.002±.21	.70±.20	.02±.39	.84±.19	

Figures along diagonal indicate heritability estimates
Figures on upper side of diagonal indicate phenotypic correlation and in parentheses environmental correlation
Figures on lower side of diagonal indicate genetic correlation

First lactation length: The genetic correlation between age at first calving and first lactation length was moderate and non-significant (0.29 ± 0.29). The non-significant genetic correlation between these two traits was observed by Raheja (1992a), Dass and Sadana (2000), Gupta (2009) and Singh (2001).

The phenotypic and environmental correlation between age at first calving and first lactation length was near to zero and non-significant (0.03 and 0.05). Near to zero and non-significant phenotypic correlation between these two traits was also reported by El-Arian (1986), Singh and Basu (1988) and Bajetha (2003). Much higher estimate of this parameter was reported by Raheja (1992a), Dass and Sadana (2000) and Singh (2001).

4.8.2 Association of First Lactation Total Milk Yield with Other Traits

First lactation 305 days or less milk yield: The genetic correlation between first lactation total milk yield and first lactation 305 days or less milk yield was close to one (0.97±0.03). Banik (2001) and Gupta (2009) observed the genetic correlation between these two traits to be non-estimatable while moderate estimate for this parameter was reported by El-Arian (1986).

The phenotypic and environmental correlation between first lactation total milk yield and first lactation 305 days or less milk yield was high (0.48 and 0.41) and statistically highly significant ($p < 0.01$). El-Arian (1986) reported similar estimate but higher estimates were reported by Banik (2001) and Gupta (2009).

First lactation length: The genetic correlation between first lactation total milk yield and first lactation length was very high and significant (0.94 ± 0.16). Kumar (1984), El-Arian (1986), Raheja (1992a), Bajetha (2003) and Roshanfekr (2005) also reported very high and significant genetic correlation between these two traits while low and non-significant estimates was observed by Khan *et al* (1987) and Singh and Basu (1988). Estimates of more than one were observed by Tein and Tripathi (1990), Dass and Sadana (2000) and Aziz *et al* (2003).

The phenotypic and environmental correlation between first lactation total milk yield and first lactation length were high (0.76 and 0.75) and highly significant ($p < 0.01$). Similar observations were reported by Kumar (1984), El-Arian (1986), Tein and Tripathi (1990), Raheja (1992a), Dass and Sadana (2000) and Roshanfekr (2005) while quite low and non-significant estimates were reported by Gurung and Johar (1982d) and Singh (2001).

4.8.3 Association of First Lactation 305 days or Less Milk Yield with Other Traits

First lactation length: The genetic correlation between first lactation 305 days or less milk yield and first lactation length was very high, positive and significant (0.93 ± 0.37). Banik (2001) and Gupta (2009) observed the genetic correlation between these two traits to be non-estimatable while low estimate for this parameter was reported by El-Arian (1986).

The phenotypic and environmental correlation between first lactation 305 days or less milk yield with first lactation length was high and positive (0.48 and 0.41) and highly significant ($p < 0.01$). Higher estimates of phenotypic correlation between these two traits were observed by El-Arian (1986), Banik (2001) and Gupta (2009).

4.9 Correlations among Various First Lactation Traits (CIRB herd)

The estimates of genotypic, phenotypic and environmental correlations of various first lactation traits are presented in Table 66. AFC had negative genetic correlation with all the five traits in the study. Similar findings were also observed by Gurung and Johar (1982), Chourasia *et al* (1985), Dass and Sadana (2000) and Yadav *et al* (2007). While positive phenotypic and environmental correlations of AFC with their traits were there but they were also of low magnitude. 305 MY also had negative genetic correlation with LL but very high genetic, phenotypic and environmental correlations with LY and PY were observed.

4.10 Correlations among Various First Lactation Traits (GADVASU and CIRB herds pooled)

Genetic correlations of AFC were observed to be significantly negative with 305 MY, PY and MYLL (Table 67). Similar negative correlations were also reported

Table 66: Correlations among first lactation traits (CIRB herd)

	AFC	305 MY	LY	LL	PY	MYLL
AFC		0.0177 (0.236)	0.175 (0.221)	0.179 (0.199)	0.200 (0.280)	0.187 (0.257)
305 MY	-0.607±0.184		0.925 (0.925)	0.559 (0.602)	0.788 (0.773)	0.778 (0.762)
LY	-0.501±0.242	0.930±0.054		0.762 (0.791)	0.702 (0.684)	0.625 (0.608)
LL	-0.222±0.447	-0.699±0.295	-0.150±0.624		0.364 (0.377)	0.045 (0.087)
PY	-0.609±0.149	0.989±0.006	1.026±0.017	0.314±0.804		0.731 (0.728)
MYLL	-0.506±0.172	1.016±0.009	0.886±0.066	-0.864±0.115	0.756±0.0104	

Figures along diagonal indicate heritability estimates
Figures on upper side of diagonal indicate phenotypic correlation and in parentheses environmental correlation
Figures on lower side of diagonal indicate genetic correlation

Table 67: Correlations among first lactation traits (GADVASU and CIRB herds pooled)

	AFC	305 MY	LY	LL	PY	MYLL
AFC		0.154 (0.183)	0.142 (0.151)	0.123 (0.119)	0.174 (0.219)	0.143 (0.184)
305 MY	-0.194±0.190		0.917 (0.915)	0.538 (0.567)	0.744 (0.724)	0.771 (0.757)
LY	0.015±0.217	0.951±0.021		0.770 (0.789)	0.633 (0.606)	0.607 (0.589)
LL	0.272±0.396	-0.012±.301	0.370±0.286		0.0284 (0.283)	0.022 (0.036)
PY	-0.247±0.156	0.950±.017	0.964±0.013	0.416±0.259		0.706 (0.0693)
MYLL	-0.283±0.162	0.935±.022	0.834±0.061	-0.258±0.303	0.0810±0.052	

Figures along diagonal indicate heritability estimates
Figures on upper side of diagonal indicate phenotypic correlation and in parentheses environmental correlation
Figures on lower side of diagonal indicate genetic correlation

by Gurung and Johar (1982) and Chourasia *et al*. (1985). AFC has non-significant correlation with LY and positive correlation with LL. The phenotypic correlations of AFC with MY, LL, LY, PY and MYLL were positive and low. Similar trend was observed for environmental correlations.

Genetic correlations of 305 MY were observed to be positive and high with LY, PY and MYLL while negative genetic correlation was observed with LL whereas El-Arian (1986) reported positive genetic correlation of 305 MY with LL. The phenotypic correlations of 305 MY with other traits were in range of 0.538 and 0.917. Similar findings were also reported by Gajbhiye (1987), Sahana (1993) and Gupta (2009)

The estimate of genetic correlations of LY observed to be significant and positive with LL, PY and MYLL. Similar findings were also reported by Kumar (1984) and Bajetha (2003).

Significant positive genetic correlation of LL was observed with PY and significant negative correlation was observed with MYLL.

Significant and high positive genetic correlations of PY were observed with MYLL which indicated more milk yield per day of lactation length in animals of with higher peak yield.

4.11 Comparison of Heritability by Two Statistical Models

Accuracy of genetic evaluation depends on the heritability estimate of the trait of interest. The magnitude of heritability provides an idea about the scope for effectiveness of genetic improvement through selection. Hence, accurate and precise estimates of heritability are one of the prerequisites for genetic improvement. Estimates of genetic parameters for various first lactation traits were obtained both by Model 2 and 3 (Henderson, 1953). The model 2 performance records were adjusted for fixed effects (season period) were adjusted where there significant influence on trait was observed and then using random effect ANOVA for sires. Model 3 involved simultaneous consideration of fixed (season and period) and random (sires) effects. The heritability estimates obtained by two models for first lactation traits are presented in Table 68.

Table 68: Comparison of heritability estimates

Trait	Model	Sire variance	Error variance	F value.	h^2±S.E.	't' value
GP	II	87.473	69.332	1.262	0.176±0.094	1.872
	III	85.585	69.692	1.228	0.161±0.095	1.695
AFC	II	85.050	49.070	1.733	0.457±0.111	4.117
	III	103.764	45.493	2.281	0.761±0.125	6.088
WAC	II	4383.156	2876.696	1.524	0.337±0.104	3.240
	III	4775.600	2811.118	1.699	0.454±0.112	4.053
WAB	II	30.443	24.635	1.236	0.159±0.093	1.710
	III	30.244	24.677	1.226	0.159±0.095	1.674
CALF%	II	1.770	1.546	1.145	0.099±0.089	1.112
	III	1.820	1.544	1.179	0127±0.093	1.366
LY	II	477652.697	345380.322	1.383	0.252±0.099	2.545
	III	503598.844	342344.348	1.471	0.318±0.104	3.058
305 MY	II	226297.015	148066.659	1.528	0.340±0.104	3.269
	III	240897.184	145813.047	1.652	0.427±0.110	3.882
LL	II	8034.004	6838.866	1.175	0.119±0.090	1.322
	III	7934.589	6851.859	1.158	0.113±0.092	1.228
FAT%	II	0.534	0.278	1.917	0.556±0.116	4.793
	III	0.550	0.277	1.982	0.611±0.119	5.134
PY	II	3.303	2.566	1.287	0.192±0.095	2.021
	III	3.414	2.576	1.325	0.225±0.099	2.273
DRPY	II	746.142	616.654	1.210	0.142±0.092	1.543
	III	764.205	620.700	1.231	0.163±0.095	1.716
MY/LL	II	1.662	1.202	1.383	0.252±0.099	2.545
	III	1.714	1.200	1.428	0.291±0.103	2.825
FAT YIELD	II	263601.463	197613.342	1.334	0.222±0.097	2.289
	III	271730.450	197179.162	1.378	0.259±0.101	2.564
AI No	II	1.533	1.679	0.913	-ve	-
	III	1.730	1.645	1.052	0.038±0.086	0.442

Gestation period: Estimate for sire variance was higher for model 2 (87.473) than for model 3 (85.585) which indicated that model 2 accounted for larger additive genetic variation in comparison to model 3. Consequently the estimates of heritability were higher for model 2 (0.176±0.094) than model 3 (0.161±0.095) with same magnitude of standard error. The estimated 't' value for heritability by model 2 was larger indicating the estimate to be considerably more reliable than of model 3. This made the heritability estimate to be more reliable.

Age at first calving: Estimate for sire variance was higher for model 3 (103.764) than model 2 (85.05). The estimates of heritability by model 3 was higher (0.761±0.125) than of model 2 (0.457±0.111) with similar magnitude of standard error. The estimated 't' value for h^2 by model 3 was much larger indicating the estimate to be considerably more reliable than of model 2. The estimated 't' value for heritability by model 3 provided a more reliable estimate of heritability.

Weight at first calving: Estimate for sire variance was higher for model 3 (4775.60) than model 2 (4383.10). The estimates of heritability by model 3 was higher (0.454±0.112) than of model 2 (0.337±0.104) with similar magnitude of standard error. The estimated 't' value for h^2 by model 3 was much larger indicating the estimate to be considerably more reliable than of model 2. The estimated 't' value for heritability by model 3 provided a more reliable estimate of heritability.

Weight at birth: Estimate for sire variance was higher for model 2 (30.443) than for model 3 (30.244) which indicated that model 2 accounted for larger additive genetic variation in comparison to model 3. Consequently the estimates of heritability were higher for model 2 (0.159±0.093) than model 3 (0.159±0.095) with same magnitude of standard error. The estimated 't' value for heritability by model 2 was larger indicating the estimate to be little more reliable than of model 3. This made the heritability estimate to be more reliable.

Calf-dam weight %: Estimate for sire variance was higher for model 3 (1.820) than model 2 (1.770). The estimates of heritability by model 3 was higher (0.127±0.093) than of model 2 (0.099±0.089) with similar magnitude of standard error. The estimated ‘t’ value for h^2 by model 3 was much larger indicating the estimate to be little more reliable than of model 2. The estimated ‘t’ value for heritability by model 3 provided a more reliable estimate of heritability.

Lactation yield: Estimate for sire variance was higher for model 3 (503598.8) than model 2 (477652.7). The estimates of heritability by model 3 was higher (0.318±0.104) than of model 2 (0.252±0.099) with similar magnitude of standard error. The estimated ‘t’ value for h^2 by model 3 was much larger indicating the estimate to be little more reliable than of model 2. The estimated ‘t’ value for heritability by model 3 provided a more reliable estimate of heritability.

305-days milk yield: Estimate for sire variance was higher for model 3 (240897.2) than model 2 (226297.01). The estimates of heritability by model 3 was higher (0.340±0.104) than of model 2 (0.318±0.104) with similar magnitude of standard error. The estimated ‘t’ value for h^2 by model 3 was much larger indicating the estimate to be little more reliable than of model 2. The estimated ‘t’ value for heritability by model 3 provided a more reliable estimate of heritability.

Lactation length: Estimate for sire variance was higher for model 2 (8034.0) than for model 3 (7934.6) which indicated that model 2 accounted for larger additive genetic variation in comparison to model 3. Consequently the estimates of heritability were higher for model 2 (0.119±0.090) than model 3 (0.113±0.092) with same magnitude of standard error. The estimated ‘t’ value for heritability by model 2 was larger indicating the estimate to be considerably more reliable than of model 3. This made the heritability estimate to be more reliable.

Fat %: Estimate for sire variance was higher for model 3 (0.550) than model 2 (0.534). The estimates of heritability by model 3 was higher (0.611±0.119) than of model 2 (0.556±0.116) with similar magnitude of standard error. The estimated ‘t’ value for h^2 by model 3 was much larger indicating the estimate to be considerably more reliable than of model 2. The estimated ‘t’ value for heritability by model 3 provided a more reliable estimate of heritability.

Peak yield: Estimate for sire variance was higher for model 3 (3.414) than model 2 (3.303). The estimates of heritability by model 3 was higher (0.225±0.99) than of model 2 (0.192±0.095) with similar magnitude of standard error. The estimated 't' value for h^2 by model 3 was much larger indicating the estimate to be little more reliable than of model 2. The estimated 't' value for heritability by model 3 provided a more reliable estimate of heritability.

Days to reach peak yield: Estimate for sire variance was higher for model 3 (764.2) than model 2 (746.1). The estimates of heritability by model 3 was higher (0.163±0.95) than of model 2 (0.142±0.92) with similar magnitude of standard error. The estimated 't' value for h^2 by model 3 was much larger indicating the estimate to be little more reliable than of model 2. The estimated 't' value for heritability by model 3 provided a more reliable estimate of heritability.

Milk yield per day of lactation length: Estimate for sire variance was higher for model 3 (1.714) than model 2 (1.662). The estimates of heritability by model 3 was higher (0.291±0.103) than of model 2 (0.252±0.099) with similar magnitude of standard error. The estimated 't' value for h^2 by model 3 was much larger indicating the estimate to be little more reliable than of model 2. The estimated 't' value for heritability by model 3 provided a more reliable estimate of heritability.

Fat yield: Estimate for sire variance was higher for model 3 (2717.3) than model 2 (2636.01). The estimates of heritability by model 3 was higher (0.259±0.101) than of model 2 (0.222±0.097) with similar magnitude of standard error. The estimated 't' value for h^2 by model 3 was much larger indicating the estimate to be little more reliable than of model 2. The estimated 't' value for heritability by model 3 provided a more reliable estimate of heritability.

Number of AI per conception: Estimate for sire variance was higher for model 3 (1.73) than model 2 (1.53). The estimates of heritability by model 3 was higher (0.038±0.086) while negative estimate was observed in model 2. So the heritability estimate by model 3 considered to be reliable.

An overall perusal of the comparison of estimates by the two models indicated that barring GP, WAB< LL and MYLL, the estimates by model 3 were higher and proportionality carried smaller standard errors, thereby making the heritability estimates to be more reliable. Not only this model 3 did not yield a negative estimated while model 2 did.

4.12 Testing of Assumptions in Estimation of Genetic Parameters

The technique of ANOVA which is widely used for estimation of genetic parameters is based on certain assumptions viz. normality of distribution, absence of relation between mean and variance, and homogeneity of variance among sub-classes. The second objective of the investigation was to test whether or not these basic assumptions of ANOVA are fulfilled for the main traits under investigations; and if not, to examine the effect of commonly used statistical transformations for the accomplishment of the assumptions, and finally to study the effect of transformation on estimates of heritability.

4.12.1 Normality of distribution

The estimates of skewness (G_1) and kurtosis (G_2) along with their estimated‘t’ values, which help in quantifying the departures from normality, pertaining to the distribution of various first lactation traits are presented in Tables 69-70. The actual distributions of different traits are depicted in Figs. 1 to 7.

Gestation period: The estimate of skewness (G_1) for gestation period (GP) was negative and non-significant. The frequency distributions of the trait as shown in Fig. 1 also clearly depicts the asymmetry. The deviations from normality were in the form of negative skewness and positive kurtosis.

A comparison of skewness and kurtosis coefficients for GP on the original, square root and logarithmic scales showed that transformation resulted in considerable increase in the asymmetry of distribution. The estimated ’t’ values for G_1 and G_2 were –15.4 and -18.7 on the original scale, -16.4 and 20.1 on the square root scale and -17.4 and 21.5 on logarithmic scale respectively. The coefficient of

Table 69: Distribution statistics of first lactation traits of original and transformed data: (n=1033)

Trait	Scale	G_1	t_1	G_2	t_2	CV %
GP	Original	-1.177	-15.440	2.854	18.728	2.82
	Sqrt	-1.251	-16.415	3.57	20.056	1.414
	Log	-1.326	-17.396	3.273	21.473	0.497
AFC	Original	0.578**	7.589	0.026	0.170	17.08
	Sqrt	0.373**	4.899	-0.225	-1.475	8.45
	Log	0.170	2.238	-0.363	-2.381	4.400
WAC	Original	0.452**	5.931	0.659	4.322	12.97
	Sqrt	0.227*	.985	0.367	2.405	6.46
	Log	0.008	0.112	0.252	1.654	2.105
WAB	Original	-0.386	-5.064	0.210	1.379	16.65
	Sqrt	-0.683	-8.961	0.780	5.116	8.619
	Log	-1.024	-13.432	1.784	11.705	5.287
CALF%	Original	0.197*	2.592	0.417	2.739	19.01
	Sqrt	-0.154	-2.018	0.483	3.168	9.64
	Log	-0.537	-7.048	1.040	6.823	10.488
LY	Original	0.766**	10.049	0.803	5.270	30.02
	Sqrt	0.361**	4.744	-0.079	-0.521	14.87
	Log	-0.006	-0.074	-0.404	-2.654	3.90
305 MY	Original	0.260**	3.41	-0.302	-1.979	22.77
	Sqrt	-0.011	-0.152	-0.437	-2.865	11.51
	Log	-0.281	-3.693	-0.381	-2.499	3.11

SE of G_1 = 0.076

SE of G_2 = 0.152

* Signficiant at 5% level ($p \leq 0.05$)

** Signficiant at 1% level ($p \leq 0.01$)

Table 70: Distribution statistics of first lactation traits of original and transformed data: (n=1033)

Trait	Scale	G_1	t_1	G_2	t_2	CV %
LL	Original	0.571**	7.499	0.371	2.433	23.53
	Sqrt	0.222	2.919	0.076	0.501	11.73
	Log	-0.146	-1.914	0.192	1.262	4.03
FAT%	Original	0.313**	4.108	0.283	1.857	8.68
	Sqrt	0.171	2.245	0.237	1.556	4.33
	Log	0.026	0.345	0.265	1.740	4.42
PY	Original	0.315**	4.129	0.050	0.329	17.01
	Sqrt	0.072	0.942	-0.088	-0.579	8.53
	Log	-0.175	-2.294	-0.019	-0.127	7.39
DRPY	Original	0.443**	5.810	-0.624	-4.094	49.74
	Sqrt	-0.030	-0.397	-0.772	-5.066	26.43
	Log	-0.597	-7.83	-0.169	-1.110	15.00
MY/LL	Original	0.500**	6.563	0.327	2.145	20.48
	Sqrt	0.207*	2.712	-0.045	-0.295	10.21
	Log	-0.078	-1.029	-0.148	-0.971	11.68
Fat yield	Original	0.931**	12.211	1.314	8.625	32.31
	Sqrt	0.461	6.051	0.178	1.171	15.89
	Log	0.03	0.407	-0.229	-1.505	3.30
AI No.	Original	1.210**	15.876	0.695	4.561	63.22
	Sqrt	0.808**	10.609	-0.421	-2.763	30.50
	Log	1.187**	15.573	0.61	4.060	0.27

SE of G_1 = 0.076

SE of G_2 = 0.152

* Signficiant at 5% level ($p \leq 0.05$)

** Signficiant at 1% level ($p \leq 0.01$)

variation on the original scale was 2.82%. Transformation of data resulted in considerable reduction in the coefficients of variation. The percentage decreases in coefficients of variation relative to the original scale were 49.8 and 82.4. Fig. 1 also shows that transformation increased the spread of values. None of the two transformations were effective in eliminating the deviations from normality for gestation period.

Age at first calving: Age at first calving was characterised by significantly positive skewness. A comparison of skewness and kurtosis coefficients for AFC on the original, square root and logarithmic scales showed that transformation resulted in considerable decrease in the asymmetry of distribution but the estimated ‘t’ values of G_1 were 7.59, 4.89 and 2.23 and G_2 were 0.17, -1.47 and -2.38 on original, square root and logarithmic scales respectively. However, the transformation led to increased departures from normality in the form of negative kurtosis.

The coefficient of variation on the original scale was 17.1%. The transformation of data resulted in considerable reduction in the coefficients of variation. Fig. 1 also shows that transformation reduced the spread of values. Although transformation markedly reduced the deviations from normality but the estimates on square root and logarithmic scales still remained significant.

Weight at calving: The estimate of skewness (G_1) for weight at first calving (WFC) was positive and highly significant. The frequency distributions of the trait as shown in Fig. 2 also depicted the asymmetry. The deviations from normality were in the form of positive skewness and positive kurtosis.

A comparison of skewness and kurtosis coefficients for WFC on the original, square root and logarithmic scales showed that transformation resulted in considerable decrease in the asymmetry of distribution. The estimated ’t’ values of G_1 and G_2 were 5.3 and 4.32 on the original scale, and 2.98 and 2.40 on the square root scale and 0.11 and 1.65 on logarithmic scale respectively. The coefficient of variation on the original scale was 12.9%. Transformation of data resulted in considerable reduction in the coefficients of variation. The percentage decreases in coefficients of variation relative to the original scale were 50.2 and 83.8. Fig. 2 also shows that transformation reduced the spread of values. Logarithmic transformation was highly effective in eliminating the deviations from normality.

Calf weight at birth: The estimate of skewness (G_1) for calf weight at birth was negative and non-significant. The frequency distributions of the trait as shown in Fig. 2 also clearly depict the asymmetry. The deviations from normality were in the form of negative skewness and positive kurtosis.

A comparison of skewness and kurtosis coefficients for calf weight at birth on the original, square root and logarithmic scales showed that transformation increased the asymmetry of distribution by increasing both skewness and kurtosis. The estimated 't' values of G_1 and G_2 were -0.39 and 0.21 on the original scale, -0.68 and 0.78 on the square root scale and -1.02 and 1.78 on logarithmic scale respectively. The coefficient of variation on the original scale was 16.6%. Transformation of data resulted in considerable reduction in the coefficients of variation. The percentage decreases in coefficients of variation relative to the original scale were 48.2 and 68.2. Fig. 2 also shows that transformation increased the spread of values. None of the two transformations were effective in eliminating the deviations from normality for calf weight at birth.

Calf-dam weight (%): The estimate of skewness (G_1) for calf-dam weight per cent was positive and significant. The frequency distributions of the trait as shown in Fig. 3 also clearly depict the asymmetry. The deviations from normality were in the form of positive skewness and positive kurtosis.

A comparison of skewness and kurtosis coefficients for calf-dam weight per cent on the original, square root and logarithmic scales showed that transformation increased the asymmetry of distribution by increasing both skewness in negative and kurtosis in positive direction. The estimated 't' values of G_1 and G_2 were 2.59 and 2.74 on the original scale, -2.02 and 3.17 on the square root scale and -7.05 and 6.82

on logarithmic scale respectively. The coefficient of variation on the original scale was 19.0%. Transformation of data resulted in considerable reduction in the coefficients of variation. The percentage decreases in coefficients of variation relative to the original scale were 49.3 and 44.8. Fig. 3 also shows that transformation increased the spread of values. None of the two transformations were effective in eliminating the deviations from normality for calf-dam weight percent.

Lactation yield: The estimates of skewness (G_1) for first lactation yield were highly significant (Table 69). The frequency distributions of the trait as shown in Fig. 3 depicts the asymmetry. The deviations from normality were in the form of positive skewness and positive kurtosis.

A comparison of skewness and kurtosis coefficients for FLY on the original, square root and logarithmic scales showed that transformation resulted in considerable decrease in the asymmetry of distribution. The estimated‘t’ values of G_1 and G_2 were 10.05 and 5.27 on the original scale, and 4.74 and -0.52 on the square root scale and -0.07 and -2.65 on logarithmic scale respectively. The coefficient of variation on the original scale was 17.1%. Transformation of data resulted in considerable reduction in the coefficients of variation (Table 69). Fig. 3 also shows that transformation reduced the spread of values. Although the transformation markedly reduced the deviations from normality but significant positive skewness and significant negative kurtosis on square root and logarithmic scales respectively predicted.

305-days milk yield: The estimate of skewness (G_1) for 305-days milk yield was positive and highly significant. The frequency distributions of the trait as shown in Fig. 4 also clearly depict the asymmetry. The deviations from normality were in the form of positive skewness and negative kurtosis.

A comparison of skewness and kurtosis coefficients for 305-days milk yield on the original, square root and logarithmic scales showed that transformation increased the asymmetry of distribution by increasing both skewness and kurtosis in negative direction. The estimated‘t’ values of G_1 and G_2 were 0.26 and -0.30 on the original scale, -0.011 and -0.44 on the square root scale and -0.28 and -0.38 on logarithmic scale respectively. The coefficient of variation on the original scale was 22.8%. Transformation of data resulted in considerable reduction in the coefficients of variation. The percentage decreases in coefficients of variation relative to the original scale were 49.4 and 86.3. Fig. 4 also shows that transformation increased the spread of values. None of the two transformations were effective in eliminating the deviations from normality for 305-days milk yield.

Lactation length: The estimates of skewness (G_1) and kurtosis (G_2) for lactation length were positive and highly significant. The frequency distributions of the trait as shown in Fig. 4 also clearly depict the asymmetry. The deviations from normality were in the form of positive skewness and positive kurtosis.

A comparison of skewness and kurtosis coefficients for lactation length on the original, square root and logarithmic scales showed that only square root transformation decreased the asymmetry of distribution by decreasing both skewness and kurtosis. The estimated‘t’ values of G_1 and G_2 were 7.49 and 2.43 on the original scale, 2.92 and 0.50 on the square root scale and -1.91 and 1.26 on logarithmic scale respectively. The coefficient of variation on the original scale was 23.5%. Transformation of data resulted in considerable reduction in the coefficients of variation. The percentage decreases in coefficients of variation relative to the original scale were 50.1 and 82.9. Fig. 4 also shows that transformation decreased the spread of values. Square root transformation was highly effective in eliminating the deviations from normality for lactation length while logarithmic transformation increased the asymmetry by increasing skewness in negative direction.

Fat %: The estimates of skewness (G_1) for fat % were highly significant (Table 70). The frequency distributions of the trait as shown in Fig. 5 clearly depict the asymmetry. The deviations from normality were in the form of positive skewness and positive kurtosis.

A comparison of skewness and kurtosis coefficients for fat % on the original, square root and logarithmic scales showed that transformation resulted in considerable decrease in the asymmetry of distribution (Table 70). The estimated't' values of G_1 and G_2 were 4.11 and 1.86 on the original scale, and 2.24 and 1.56 on the square root scale and 0.34 and 1.74 on logarithmic scale respectively. Percentage reductions in the magnitude of skewness on the transformed scales relative to the original scale were 45.3 and 91.6. The corresponding figures for kurtosis were 16.2 and 6.30%. The coefficient of variation on the original scale was 17.1%. This suggests that relative to the mean, the fat % values were not widely scattered. This was also evident from Fig. 6. The transformation of data resulted in considerable reduction in the coefficients of variation (Table 70). Fig. 5 also shows that transformation reduced the spread of values. The transformation markedly reduced the deviations from normality and the estimates on both scales became non-significant.

Peak yield: The estimate of skewness (G_1) for peak yield was positive and highly significant. The frequency distributions of the trait as shown in Fig. 5 also clearly depict the asymmetry. The deviations from normality were in the form of positive skewness and positive kurtosis.

A comparison of skewness and kurtosis coefficients for lactation length on the original, square root and logarithmic scales showed that transformation decreased the asymmetry of distribution by decreasing both skewness and kurtosis. The estimated't' values of G_1 and G_2 were 4.13 and 0.33 on the original scale, 0.94 and -0.58 on the square root scale and -2.29 and -0.13 on logarithmic scale respectively. The coefficient of variation on the original scale was 17.01%. Transformation of data resulted in considerable reduction in the coefficients of variation. The percentage decreases in coefficients of variation relative to the original scale were 49.8 and 56.5. Fig. 5 also shows that transformation decreased the spread of values. Square root transformations was highly effective in eliminating the deviations from normality for peak yield while logarithmic transformation increased the asymmetry by increasing skewness in negative direction.

Days to reach peak yield: The estimate of skewness (G_1) for days to reach peak yield was positive and highly significant. The frequency distributions of the trait as shown in Fig. 6 also clearly depict the asymmetry. The deviations from normality were in the form of positive skewness and negative kurtosis.

A comparison of skewness and kurtosis coefficients for days to reach peak yield on the original, square root and logarithmic scales showed that transformation increased the asymmetry of distribution by increasing both skewness and kurtosis in negative direction. The estimated'tʼ values of G_1 and G_2 were 5.81 and -4.09 on the original scale, -0.40 and -5.07 on the square root scale and -7.83 and -1.11 on logarithmic scale respectively. The coefficient of variation on the original scale was 49.7%. Transformation of data resulted in considerable reduction in the coefficients of variation. The percentage decreases in coefficients of variation relative to the original scale were 46.9 and 69.8. Fig. 6 also shows that transformation increased the spread of values. None of the two transformations were effective in eliminating the deviations from normality for days to reach peak yield.

Milk yield per day of lactation length: The estimate of skewness (G_1) for milk yield per day of lactation length was positive and highly significant. The frequency distributions of the trait as shown in Fig. 6 also clearly depict the asymmetry. The deviations from normality were in the form of positive skewness and positive kurtosis.

A comparison of skewness and kurtosis coefficients for milk yield per day of lactation length on the original, square root and logarithmic scales showed that only square root transformation decreased the asymmetry of distribution by decreasing both skewness and kurtosis. The estimated'tʼ values of G_1 and G_2 were 6.56 and 2.14 on the original scale, 2.71 and -0.29 on the square root scale and -1.03 and -0.97 on logarithmic scale respectively. The coefficient of variation on the original scale was

20.5%. Transformation of data resulted in considerable reduction in the coefficients of variation. The percentage decreases in coefficients of variation relative to the original scale were 50.1 and 42.9. Fig. 6 also shows that transformation decreased the spread of values. Square root transformations was highly effective in eliminating the deviations from normality for milk yield per day of lactation length while logarithmic transformation increased the asymmetry by increasing skewness and kurtosis in negative direction.

Fat yield: The estimates of skewness (G_1) for first lactation fat yield were highly significant (Table 70). The frequency distributions of the trait as shown in Fig. 7 clearly depict the asymmetry. The deviations from normality were in the form of positive skewness and positive kurtosis.

A comparison of skewness and kurtosis coefficients for fat yield on the original, square root and logarithmic scales showed that transformation resulted in considerable decrease in the asymmetry of distribution (Table 70). The estimated't' values of G_1 and G_2 were 12.21 and 8.62 on the original scale, and 6.05 and 1.17 on the square root scale and 0.41 and -1.50 on logarithmic scale respectively. The coefficient of variation on the original scale was 32.3%. This suggests that relative to the mean, the fat yield values were not widely scattered. This was also evident from Fig. 7. The transformation of data resulted in considerable reduction in the coefficients of variation (Table 70). Fig. 7 also shows that transformation reduced the spread of values. The transformation markedly reduced the deviations from normality and the estimates on both scales became non-significant.

General comments on normality of distributiion

The overall results for testing for the normality of distribution showed that none of the traits conformed to normality. Departures mostly existed in the form of kurtosis. Transformation of data resulted in larger reduction in coefficient of variability for all traits, and it was also effective in reducing the departures from normality for most of the traits though the coefficients of G_1 and G_2 continued to be significant. For some traits viz. weight at birth, calf-dam weight per cent, 305 day milk yield and days to reach peak yield, data transformation increased the departures from normality or change the direction of skewness and kurtosis. The general inference from estimates of skewness and kurtosis is that variability in all the variables depicted departures from normality and the traditional transformations did not completely eliminate these departures.

4.12.2 Homogeneity of variance

Bartlett's X^2 values for testing the homogeneity of variance among seasons and periods for various traits are shown in Table 71 and 72 .

Gestation period: Gestation period showed homogeneity of variance among seasons on original as well as on the square root and logarithmic transformed scales. However significant heterogeneity on original, square root as well as on logarithmic transformed scale was observed among periods. The transformation was unable to eliminate the heterogeneity and the values continued to be significant among periods.

Age at first calving: Age at first calving showed homogeneity of variance among seasons on original but the square root and logarithmic transformed scales showed significant heterogeneity. Among periods the age at first calving showed highly significant heterogeneity of variances on original, square root as well as on logarithmic transformed scale. The transformation, however, was unable to reduce the heterogeneity and the values continued to be highly significant among periods.

Weight at calving: Weight at calving showed homogeneity of variance among seasons for original as well as for square root and logarithmic transformed scales. Among periods the weight at calving showed significant homogeneity of variances on original, square root as well as on logarithmic transformed scale. The transformation, however, was able to increase the magnitude of homogeneity.

Weight at birth: Weight at birth showed homogeneity of variance among seasons on original as well as the square root and logarithmic transformed scales. Among periods the weight at birth showed highly significant heterogeneity of variances on

Table 71: Homogeneity of variance of season-wise F value (GADVASU herd)

Trait	Season		
	Original	SQR T	LOG T
GP	0.278 (p=0.893)	0.301 (p=0.878)	0.328 (p=0.859)
AFC	2.245 (p=0.062)	2.548 (p=0.038)	2.860 (P=0.023)
WAC	1.536 (p=0.190)	1.415 (p=0.227)	1.297 (p=0.269)
WAB	0.542 (p=0.705)	0.527 (p=0.716)	0.565 (p=0.688)
Calf %	0.629 (p=0.642)	0.493 (p=0.741)	0.405 (p=0.805)
LL	1.788 (p=0.129)	2.098 (p=0.079)	2.486 (p=0.042)
LY	0.371 (p=0.829)	0.223 (p=0.926)	0.154 (p=0.961)
305 MY	0.337 (p=0.853)	0.253 (p=0.908)	0.241 (p=0.915)
PY	1.273 (p=0.279)	0.793 (p=0.530)	0.527 (p=0.716)
DRPY	9.346 (p=0.000)	5.408 (p=0.000)	3.210 (p=0.012)
MY/LL	2.446 (p=0.045)	2.381 (p=0.050)	2.356 (p=0.052)
Fat yield	0.313 (p=0.870)	0.201 p=0.938)	0.276 (p=0.893)
Fat %	0.392 (p=0.814)	0.520 (p=0.721)	0.698 (p=0.594)
AI No	4.166 (p=0.002)	2.362 (p=0.052)	4.069 (p=0.003)

Table 72: Homogeneity of variance of period-wise F value (GADVASU herd)

Trait	Period		
	Original	**SQR T**	**LOG T**
GP	2.129 (p=0.038)	2.209 (p=0.31)	2.292 (p=0.025)
AFC	4.899 (p=0.000)	4.645 (p=0.000)	4.749 p=0.000)
WAC	0.879 (p=0.523)	0.382 (p=0.913)	0.159 (p=0.993)
WAB	2.717 (p=0.009)	2.650 (p=0.010)	2.663\ (p=0.010)
Calf %	0.834 (p=0.559)	0.860 (p=0.538)	0.993 (p=0.435)
LL	5.161 (p=0.000)	4.952 (p=0.000)	4.604 (p=0.000)
LY	4.093 (p=0.000)	2.600 (p=0.012)	1.548 (p=0.147)
305 MY	3.520 (p=0.001)	2.222 (p=0.030)	1.536 (p=0.151)
PY	3.904 (p=0.000)	2.750 (p=0.008)	1.919 (p=0.063)
DRPY	0.551 (p=0.796)	0.536 (p=0.808)	1.064 (p=0.384)
MY/LL	3.025 (p=0.004)	2.000 (p=0.052)	1.407 (p=0.199)
Fat yield	5.216 (p=0.000)	2.766 (p=0.007)	1.291 (p=0.251)
Fat %	9.029 (p=0.000)	8.922 (p=0.000)	8.910 (p=0.000)
AI No	8.307 (p=0.000)	4.921 (p=0.000)	8.135 (p=0.000)

original, square root as well as on logarithmic transformed scale. The transformation, however, was able to reduce the magnitude of heterogeneity to some extent and the values continued to be significant among periods.

Calf-dam weight (%): Calf-dam weight (%) showed significant homogeneity of variance among seasons on the original square root and logarithmic transformed scales. Among periods the calf-dam weight (%) showed significant homogeneity of variances on original, square root as well as on logarithmic transformed scale. The transformation, however, was able to increase the magnitude of homogeneity and the values continued to be significant among periods.

Lactation length showed homogeneity of variance among seasons for original as well as on square root and logarithmic transformed scales. Among periods the lactation length showed highly significant heterogeneity of variances on original, square root as well as on logarithmic transformed scale. The transformation, however, was able to reduce the magnitude of heterogeneity to some extent and the values continued to be highly significant among periods.

Lactation yield: Lactation yield showed homogeneity of variance among seasons for original as well as on square root and logarithmic transformed scales. Among periods the lactation yield showed highly significant heterogeneity of variances on original and significant heterogeneity of variance on square root transformed scale. However, logarithmic transformation was able to reduce the magnitude of heterogeneity and lead the values to be non-significant among periods.

305-days milk yield: 305-days milk yield showed homogeneity of variance among seasons for original as well as on square root and logarithmic transformed scales. Among periods the 305-days milk yield showed highly significant heterogeneity of variances on original, significant on square root transformed scale and non-significant on logarithmic transformed scale. So, logarithmic transformation was able to reduce the magnitude of heterogeneity and made variances non-significant among periods on transformed scale.

Peak yield: Peak yield showed homogeneity of variance among seasons for original as well as on square root and logarithmic transformed scales. Among periods the peak yield showed highly significant heterogeneity of variances on original as well as on square root transformed scale and non-significant on logarithmic transformed scale. So, logarithmic transformation was able to reduce the magnitude of heterogeneity and made variances non-significant among periods on transformed scale.

Days to reach peak yield: Days to reach peak yield showed highly significant heterogeneity of variance among seasons for original as well as on square root and significant on logarithmic transformed scales. So, logarithmic transformed scale was able to decrease the magnitude of heterogeneity of variances and made them significant from highly significant. Among periods the days to reach peak yield showed highly significant homogeneity of variances on original, square root as well as on transformed scale.

Milk yield per day of lactation length: Milk yield per day of lactation length showed significant heterogeneity of variance among seasons for original as well as on square root transformed scale. However, logarithmic transformed scales were able to make the variances significant homogeneous among seasons. Among periods the milk yield per day of lactation length showed highly significant heterogeneity of variances on original scale. However, square root and logarithmic transformed scale were able to reduce the magnitude of heterogeneity and made variances non-significant among periods on transformed scale.

Fat yield: Fat yield showed homogeneity of variance among seasons for original as well as on square root and logarithmic transformed scales. Among periods the fat yield showed highly significant heterogeneity of variances on original as well as on square root transformed scale and non-significant on logarithmic transformed scale. So, logarithmic transformation was able to reduce the magnitude of heterogeneity and made variances non-significant among periods on logarithmic transformed scale.

Fat (%): Fat (%) showed homogeneity of variance among seasons for original as well as on square root and logarithmic transformed scales. Among periods the fat (%) showed highly significant heterogeneity of variances on original as well as on square root and logarithmic transformed scales. So, both transformations were unable to reduce the magnitude of heterogeneity and to make the variances non-significant among periods on transformed scales.

Number of services per conception: Number of services per conception showed highly significant heterogeneity of variance among seasons for original as well as on logarithmic transformed scale. However, square root transformation was able to reduce the heterogeneity of variances among seasons and made them non-significant on transformed scale. Among periods number of services per conception showed highly significant heterogeneity of variances on original as well as on square root and logarithmic transformed scales. So, both transformations were unable to reduce the magnitude of heterogeneity to make variances non-significant among periods on transformed scale.

General Remarks on homogeneity of variance

The transformation of data is statistically expected to remove the heterogeneity of variance. However, for some of the traits (AFC, LL, MYLL and number of AI per conception) transformed scale exhibited high degree of heterogeneity of variance among seasons. The heterogeneity of variance for AFC, WAB, LL, Fat % and number of AI per conception was higher for periods and remain significant even after tranformation. Among the various traits, traits related to production had the highest heterogeneity of variance in comparison to rest of traits.

For the estimation of various genetic and phenotypic parameters in animals, the data is adjusted for season and period effects. However, high degree of heterogeneity of variance observed among seasons and periods for various first lactation traits would indicate that the pooling of variance under such circumstance is statistically unjustified. The effect of the heterogeneity per se on the estimates of various genetic parameters in terms of direction and magnitude is not known. However, it would be one of the several causes for the wide variation observed in the estimates of various genetic parameters over years as well as for the low precision of the estimates.

4.12.3 Relation between mean and variance

For studying the relation between mean and variance, these statistics were obtained for different seasons, periods and across 93 sire-families. The estimates of regression of variance on mean, and the correlation between these two statistics are presented in Fig. 8 to 28 both on the original as well as the transformed scales for seasons, periods and sire families.

Gestation period: A strong, negative and significant correlation between mean and variance was found for gestation period. The correlation coefficient was -0.44 for seasons, -0.83 for periods and -0.59 for sire families. The transformation of gestation period to square root and logarithmic scale resulted in increase of the relation to a certain degree in negative direction. The correlation coefficients on original scale increased to -0.51, -0.57, -0.60 and -0.83, -0.84, -0.62 on the square root and logarithmic scale for seasons, periods and sire families respectively. Nonetheless the correlation coefficients continued to be highly significant ($p<0.01$). Similarly, strong, negative and significant regression between mean and variance was found for gestation period. The transformation of gestation period to square root and logarithmic scale resulted in decrease of the relation to a certain degree but still remained in negative direction.

Age at first calving: A strong, negative and significant correlation between mean and variance was found for age at first calving (AFC) for seasons and positive for periods and sire families. The correlation coefficient was -0.66 for seasons, 0.39 for periods and 0.27 for sire families. The transformation of AFC to square root and logarithmic scale resulted in increase of the relation to a certain degree in negative direction for seasons and decrease in relation between mean and variance for periods and for sire families. The correlation coefficient increased to -0.75 and -0.80 for seasons, decreased to 0.14 and -0.12 for periods and also decreased to 0.15 and 0.015 for sire families on transformed scales. Nonetheless the correlation coefficients continued to be highly significant ($p<0.01$) for seasons only and became non-significant for periods and sire families. Similarly, strong, negative and significant regression between mean and variance was found for AFC for seasons and positive for periods and sire families. The transformation of AFC to square root and logarithmic scale resulted in decrease of the dependence to a certain degree but still remained in negative direction for seasons and reduced to non-significant for periods and sire families.

Weight at calving: A strong, positive and significant correlation between mean and variance was found for weight at calving (WAC) for both seasons and periods and moderate, positive and significant for sire families. The correlation coefficient was 0.75 for seasons, 0.89 for periods and 0.25 for sire families. The transformation of WAC to square root and logarithmic scale resulted in decrease of the relation to a certain degree but still remained significant for seasons and periods and non-significant for sire families. The correlation coefficients decreased to 0.70, 0.62 and 0.80, 0.58 and 0.15, 0.04 on the square root and logarithmic scale for seasons, periods and sire families respectively. Similarly, strong, positive and significant regression between mean and variance was found for WAC. The transformation of WAC to square root and logarithmic scale resulted in decrease of the relation but still remained significant on square root and non-significant on logarithmic scale.

Weight of calf at birth: A moderate, negative and significant correlation between mean and variance was found for seasons and sire families and very high, positive and significant correlation was observed for periods for weight of calf at birth (WAB). The correlation coefficients were -0.12, -0.26 and 0.12 for seasons, sire families and periods respectively. The transformation of WAB to square root and logarithmic scale resulted in increase of the relation to a certain degree in negative direction for seasons, sire families and decrease in relation in periods. The correlation coefficient of -0.12 increased to -0.30 and -0.40, coefficient of -0.26 increased to -0.45 and -0.58 and coefficient of 0.12 for periods decreased to 0.020 and -0.070 on the square root and logarithmic scale for seasons, sire families and periods, respectively. The correlation coefficients continued to be highly significant ($p<0.01$) for season and sire families while became non-significant for periods. A weak, negative and non-significant regression between mean and variance was found for WAB for seasons, high, negative and significant regression for sire families and high, positive and significant regression was observed for periods. The transformation of WAB to square root and logarithmic scale resulted in increase of the dependence to a certain degree for seasons, decreased to certain degree for sire families and decreased to non-significant for periods.

Calf-dam weight (%) : A strong, positive and significant correlation between mean and variance was found for calf weight per cent for seasons and sire families while weak and negative relation exited for periods. The correlation coefficient was 0.56 for seasons which had decreased to 0.32 and 0.08, correlation coefficient of 0.15 for sire families decreased to -0.09 and -0.33 and -0.12 for periods which increased to -0.38 and -0.52 in the negative direction on transformation of data to square root and logarithmic scale respectively. Similarly, strong, positive and significant regression between mean and variance was found for calf weight per cent for seasons, sire families and negative non-significant relation existed for periods. The transformation of calf weight per cent to square root resulted in decrease in relation to non-significant for seasons, sire families and periods and logarithmic scale resulted in decrease of the relation to non-significant for seasons but increased in negative direction and remained significant for periods and sire families.

Lactation milk yield: A strong, negative and significant correlation between mean and variance was found for lactation milk yield (LY) for seasons and positive for periods and sire families. The correlation coefficient was -0.31 for seasons, 0.85 for periods and 0.44 for sire families. The transformation of LY to square root and logarithmic scale resulted in increase of the relation to a certain degree in negative direction for seasons and decrease in relation between mean and variance for periods and sire families. On transformation correlation coefficients of -0.31 increased to -0.52 and -0.73 for seasons, correlation coefficient of 0.85 decreased to 0.70 and 0.41 on transformed scale for periods and correlation coefficient of 0.44 decreased to 0.24 and -0.003 for sire families on the square root and logarithmic scale respectively. Nonetheless the correlation coefficients continued to be highly significant ($p<0.01$) for seasons and periods and non-significant for sire families on logarithmic scale. Similarly, strong, negative and significant regression between mean and variance was found for LY for seasons and high and positive for periods and sire families. The transformation of LY to square root and logarithmic scale resulted in decrease of the relation to a certain degree but still remained in negative direction for seasons and reduced to non-significant for periods and sire families on logarithmic scale.

Lactation length: A strong, negative and significant correlation between mean and variance was found for lactation length (LL) for seasons and positive for periods and sire families. The correlation coefficient was -0.74 for seasons, 0.26 for periods and 0.40 for sire families. The transformation of LL to square root and logarithmic scale resulted in increase of the relation to a certain degree in negative direction for seasons and decrease in relation between mean and variance for periods and sire families. The correlation coefficients of -0.74 increased to -0.79 and -0.81 on the square root and logarithmic scale for seasons, correlation coefficient of 0.26 decreased to 0.01 and -0.25 on transformed scale for periods and coefficient of 0.40 decreased to 0.19 and -0.05 on transformed scale for sire families. Nonetheless the correlation coefficients continued to be highly significant ($p<0.01$) for seasons only and became non-significant for periods on square root scale and remained significant and negative on logarithmic scale and vice-versa for sire families. Similarly, strong, negative and significant regression between mean and variance was found for LL for seasons and positive for periods and sire families. The transformation of LL to square root and logarithmic scale resulted in decrease of the relation but still remained in negative direction for seasons and reduced to non-significant for periods and sire families.

305-days milk yield: A weak, positive and non-significant correlation between mean and variance was found for 305-days milk yield (305 MY) for seasons and strong, positive and significant for periods and sire families. The correlation coefficient was 0.07 for seasons, 0.63 for periods and 0.25 for sire families. The transformation of 305 MY to square root and logarithmic scale resulted in decrease of the relation to a certain degree in negative direction for seasons and decrease in relation between mean and variance for periods and sire families. The correlation coefficients of 0.07 decreased to -0.0006 and -0.08 on the square root and logarithmic scale for seasons, correlation coefficient of 0.63 decreased to 0.47 and 0.20 on transformed scale for periods and coefficient of 0.25 decreased to 0.053 and -0.14 for sire families. Nonetheless the correlation coefficients continued to be highly significant ($p<0.01$) for periods only and continue to be non-significant and became negative for seasons and sire families on transformed scales. Similarly, strong, positive and significant regression between mean and variance was found for 305 MY for seasons, periods and sire families. The transformation of 305 MY to square root and logarithmic scale resulted in decrease of the relation in negative direction and became non-significant for seasons and reduced to non-significant for periods and sire families on logarithmic scale.

Fat per cent: A strong, negative and significant correlation between mean and variance was found for fat per cent (Fat %) for seasons and positive for periods and sire families. The correlation coefficient was -0.46 for seasons, 0.34 for periods and 0.22 for sire families. The transformation of fat % to square root and logarithmic scale resulted in increase of the relation to a certain degree in negative direction for seasons and decrease in relation between mean and variance for periods and sire families. The correlation coefficients of -0.46 increased to -0.61 and -0.69 on the square root and logarithmic scale for seasons, correlation coefficient of 0.34 decreased to 0.24 and 0.14 on transformed scale for periods and coefficient of 0.22 decreased to 0.14 and 0.06 for sire families. Nonetheless the correlation coefficients continued to be highly significant ($p<0.01$) for seasons and periods and non-significant for sire families. Similarly, weak, negative and significant regression between mean and variance was found for fat % for seasons and positive for periods and sire families. The transformation of fat % to square root and logarithmic scale resulted in decrease of the relation to a certain degree but still remained in negative direction for seasons and reduced to non-significant for seasons, periods and sire families.

Peak yield: A strong, positive and significant correlation between mean and variance was found for peak yield (PY) for both seasons and periods and moderate for sire families. The correlation coefficient was 0.69 for seasons, 0.85 for periods and 0.23 for sire families. The transformation of PY to square root and logarithmic scale resulted in decrease of the relation to a certain degree but still remained significant for seasons and periods while non-significant for sire families. The correlation coefficients of 0.69, 0.85 and 0.23 decreased to 0.48, 0.18 and 0.79, 0.70 and 0.075, -0.074 on the square root and logarithmic scale for seasons and periods, respectively. Nonetheless the correlation coefficients continued to be highly significant ($p<0.01$) for seasons and periods while non-significant for sire families. Similarly, strong, positive and significant regression between mean and variance was found for PY. The transformation of PY to square root and logarithmic scale resulted in decrease of the relation and became non- significant on square root and logarithmic scale.

Days to reach peak yield: A strong, positive and significant correlation between mean and variance was found for days to reach peak yield (DRPY) for both seasons and periods. The correlation coefficient was 0.80 for seasons and 0.48 for periods. The transformation of DRPY resulted in decrease of the relation to a certain degree but still remained significant for square root transformation and became non-significant in logarithmic transformation for seasons. While transformation for periods resulted in reduction of relation to negative magnitude. The correlation coefficients of 0.80 and 0.48 decreased to 0.58, 0.085 and -0.14, -0.56 on the square root and logarithmic scale for seasons and periods, respectively. Similarly, strong, positive and significant regression between mean and variance was found for DRPY. The transformation of DRPY resulted in decrease of the relation on square root and became non- significant logarithmic scale for seasons and vice-versa for periods.

Milk yield per day of lactation length: A strong, positive and significant correlation between mean and variance was found for milk yield per day of lactation length (MYLL) for both seasons and periods. The correlation coefficient was 0.58 for seasons and 0.76 for periods. The transformation of MYLL to square root and logarithmic scale resulted in decrease of the relation to a certain degree but still remained significant. The correlation coefficients of 0.58 and 0.76 decreased to 0.51, 0.41 and 0.62, 0.36 on the square root and logarithmic scale for seasons and periods, respectively. Similarly, strong, positive and significant regression between mean and variance was found for MYLL. The transformation of MYLL to square root and logarithmic scale resulted in decrease of the relation to certain degree for seasons and became non- significant on square root and logarithmic scale for periods respectively.

Fat yield: A positive and significant correlation between mean and variance was found for fat yield (FY) for seasons and sire families and high, positive and significant for periods. The correlation coefficient was 0.29 for seasons, 0.95 for periods and 0.49 for sire families. The transformation of FY to square root and logarithmic scale resulted in decrease of the relation to negative magnitude for seasons whereas relation decreases to a certain degree but still remained significant for periods. The correlation coefficients decreased to -0.09, -0.45 and 0.84, 0.45 and 0.27, -0.016 on the square root and logarithmic scale for seasons, periods and sire families respectively. Similarly, strong, positive and significant regression between mean and variance was found for FY. The transformation of FY to square root resulted in decrease of the relation to great degree for seasons and periods. whereas became non- significant on logarithmic scale for seasons and periods while decreased to non-significant for sire families on transformation for both scales.

AI number: A strong, positive and significant correlation between mean and variance was found for AI number for both seasons and periods. The correlation coefficient was 0.96 for seasons and 0.84 for periods. The transformation of AI number to square root and logarithmic scale resulted in decrease of the relation to a certain degree but still remained significant for both seasons and periods. The correlation coefficients decreased to 0.92, 0.96 and 0.75, 0.83 on the square root and logarithmic scale for seasons and periods, respectively. Nonetheless the correlation coefficients continued to be highly significant ($p<0.01$). Similarly, strong, positive and significant regression between mean and variance was found for AI number. The transformation of AI number to square root scale resulted in decrease of the relation but remain significant both for seasons and periods. Whereas logarithmic scale resulted in decrease of the relation and became non-significant both for seasons and periods.

A review of the literature did not show any attempt on examination of the relations between mean and variance. The results of this investigation, however, indicated that mean and variance depicted a strong relationship for weight at calving, lactation milk yield, peak yield, days to reach peak yield, fat yield and number of services per conception.. Transformation of data to square root and logarithmic scales generally led to decrease in the magnitude of relationship between two statistics. In contrast, other first lactation traits showed lesser dependence of variance on mean.

4.12.4 Effect of transformation on Heritability estimates

The heritability estimates were worked out for data adjusted for non-genetic factors viz. seasons and periods of various first lactation traits. Heritability estimates from transformed data (square root and logarithmic scale transformation) were also obtained to study the effect of transformation on the estimates of heritability (Table 73 and 74).

Gestation period: The F-value and heritability estimates corresponding to GP were 1.228 and 0.161±0.095 respectively on original scale. On transformation there was marginal increase in values of estimates (F=1.233 and heritability=0.164±0.095) on logarithmic scale only but they were non-significantly different from original estimates.

Age at first calving: The F-value and heritability estimates corresponding to AFC were 2.281 and 0.761±0.125 respectively on original scale. On transformation there was marginal increase in values of estimates (F=2.343, 2.398 and heritability =0.790±0.126, 0.817±0.127) on both scales but they were non-significantly different from original estimates.

Weight at calving: The F-value and heritability estimates corresponding to WAC were 1.699 and 0.454±0.112 respectively. On transformation there was marginal decrease in values of estimates (F=1.674, 1.646 and heritability=0.440±0.111, 0.424±0.110) on both scales of transformation but they were non-significantly different from original estimates.

Weight at birth: The F-value and heritability estimates corresponding to WAB were 1.226 and 0.159±0.095 respectively on original scale. On transformation there was marginal increase in values of estimates (F=1.238, 1.250 and heritability=0.167± 0.095, 0.176±0.096) on both scales only but they were non-significantly different from original estimates.

Lactation milk yield: The F-value and heritability estimates corresponding to LY were 1.471 and 0.318±0.104 respectively on original scale. On transformation there was marginal increase in values of estimates (F=1.518, 1.559 and heritability=0.347± 0.106, 0.372±0.107) on both scales only but they were non-significantly different from original estimates.

Table 73: Effect of transformation of heritability

Trait	Scale	Sire variance	Error variance	F value	h^2±S.E
GP	ORIG	85.585	69.692	1.228	0.161±0.095
	SQRT	0.070	0.057	1.229	0.161±0.095
	LOG T	0.009	0.0007	1.233	0.164±0.095
AFC	ORIG	103.64	45.493	2.281	0.761±0.125
	SQRT	0.557	0.238	2.343	0.790±0.126
	LOG T	0.048	0.020	2.398	0.817±0.127
WAC	ORIG	4775.600	2811.118	1.699	0.454±0.112
	SQRT	2.535	1.515	1.674	0.440±0.111
	LOG T	0.022	0.013	1.646	0.424±0.110
WAB	ORIG	30.244	24.677	1.226	0.159±0.095
	SQRT	0.267	0.215	1.238	0.167±0.095
	LOG T	0.039	0.031	1.250	0.176±0.096
CALF%	ORIG	1.820	1.544	1.179	0.127±0.093
	SQRT	0.070	0.059	1.193	0.136±0.093
	LOG T	0.045	0.037	1.205	0.145±0.094
LY	ORIG	503598.844	342344,348	1,471	0.318±0.104
	SQRT	59.190	38.988	1.518	0.347±0.106
	LOG T	0.117	0.075	1.559	0.372±0.107
305 MY	ORIG	240897.184	145813.047	1.652	0.427±0.110
	SQRT	32.856	19.805	1.659	0.431±0.111
	LOG T	0.074	0.044	1.664	0.434±0.111

Table 74: Effect of transformation of heritability

Trait	Scale	Sire variance	Error variance	F value	h^2±S.E
LL	ORIG	7934.589	6851.859	1.158	0.113±0.092
	SQRT	5.469	4.705	1.163	0.116±0.092
	LOG T	0.063	0.054	1.166	0.118±0.092
FAT%	ORIG	0.550	0.277	1.982	0.611±0.119
	SQRT	0.019	0.010	1.956	0.597±0.119
	LOG T	0.074	0.044	1.664	0.575±0.0118
PY	ORIG	3.414	2.576	1.325	0.225±0.099
	SQRT	0.083	0.062	1.337	0.233±0.099
	LOG T	0.033	0.024	1.350	0.241±0.100
DRPY	ORIG	764.205	620.700	1.231	0.163±0.095
	SQRT	3.932	3.165	1.242	0.170±0.095
	LOG T	0.383	0.305	1.256	0.179±0.096
MY/LL	ORIG	1.714	1.200	1.428	0.291±0.103
	SQRT	0.071	0.050	1.427	0.290±0.103
	LOG T	0.049	0.035	1.417	0.284±0.102
Fat yield	ORIG	2717.304	1971.792	1.378	0.259±0.101
	SQRT	4.367	3.106	1.406	0.277±0.102
	LOG T	0.120	0.084	1.430	0.292±0.086
AI No.	ORIG	1.730	1.645	1.052	0.038±0.086
	SQRT	0.179	0.169	1.058	0.042±0.087
	LOG T	0.340	0.319	1.063	0.046±0.087

305-days milk yield: The F-value and heritability estimates corresponding to 305 MY were 1.652 and 0.427±0.110 respectively on original scale. On transformation there was marginal increase in values of estimates (F=1.659, 1.664 and heritability= 0.431±0.111, 0.434±0.111) on both scales only but they were non-significantly different from original estimates.

The transformation on square root and logarithmic scale did not result in any appreciable change in the estimates of F-value and in heritability and their standard errors. The estimates of heritability on transformed scale remain of similar magnitude as that of original scale for GP, 305 MY, LL, PY, DRPY, MYLL and number of AI per conception. The estimates of heritability increased on transformed scale for AFC, WAB, Calf-dam weight %, LY and Fat yield while estimates for WAC and Fat% had decreased on transformed scale.

It is apparent from the discussion that though the transformation of data to square root and logarithmic scales, in general, decreased the departures from normality of distribution, reduced the heterogeneity of variance among sub classes, and also reduced the relationship between mean and variance. However despite better fulfilment of the assumptions of analysis of variance on transformed scales, the transformation did not result in any appreciable change in the estimates of heritability and their standard errors. It can therefore be concluded that analysis of variance as used for estimation of heritability for the type of the data used in the present investigation is a robust technique. However empirical transformations as suggested by Box and Cox (1964) can be tried for data transformation so that better fit of the data to the assumptions of ANOVA may be accomplished.

4.13 Sire Evaluation

Breeding values of the Murrah buffaloes sires maintained at GADVASU herd were estimated for first lactation 305 days or less milk yield by three different methods viz. least squares (LS), best linear unbiased prediction (BLUP) and derivative free restricted maximum likelihood method (DFREML). Sires having at least five progeny with first lactation milk yield records were considered in this study. The overall average of breeding values of sires for first lactation 305 days or less milk yield and the range of breeding values obtained by different methods are presented in Table.

The breeding value estimates of 93 Murrah buffalo sires along with their ranks by the three methods are presented in Table 75. As higher milk yield is desirable, the bull with highest breeding value for this trait was ranked first.

Table 75: Average breeding value for 305 Days or less milk yield by different methods of sire evaluation

Sire	No. of dau	BV LS	LS Rank	BV Blup	BLUP Rank	BV DfReml	DfReml Rank
1	13	1912.8	42	1919.3	28	1712.6	59
2	13	1780	67	1920.6	26	2149.7	14
3	10	1890.8	46	1933.6	21	2197.2	10
4	13	1829.8	58	1826	71	1690.1	65
5	11	2233.4	4	1857.9	50	1666	67
8	8	2020.1	18	1819.1	75	1658.6	68
9	20	2091.2	13	1830.1	69	1605.8	74
10	5	1876.9	50	1954.3	19	2076.4	18
14	5	1436.9	93	1907.5	31	1967	28
15	11	1712.8	76	1830.5	67	1627.7	72
17	33	1905.9	44	1892.9	36	1700.4	63
18	5	2005.9	19	2019.8	3	2502.7	2
22	11	1583.4	89	1842.8	62	1779.4	50
23	5	2234.2	3	1868.9	46	1711.2	61
24	8	2100.7	12	1911	30	1881.5	35
27	5	1977	28	1816.4	78	1535	81
28	7	1987	27	1915.7	29	1956.8	29
29	10	1796.5	64	1903.6	32	1993.9	25
30	5	2284	1	1899.6	34	1988.6	26
32	11	1913.8	41	1775.4	90	1481.5	86
35	14	2079.2	14	1935.6	20	2004.7	22
40	8	1853	54	1803.2	83	1751.5	56
41	7	1841.6	55	2012.5	4	2206.2	8

Sire	No. of dau	BV LS	LS Rank	BV Blup	BLUP Rank	BV DfReml	DfReml Rank
42	5	1787.4	65	2004.2	5	2268.1	6
45	6	2046.2	17	1993.4	6	2158.9	13
46	5	2054.9	16	1849.1	56	1823.5	42
47	27	2164.6	8	1876.7	41	1927.9	31
49	5	2003.8	22	1829.2	70	1656.3	69
50	10	1719.9	75	1964	15	2183.2	12
51	5	2182.8	6	1954.7	18	2053.6	19
52	5	1605.1	88	1868.5	47	1691	64
54	9	1798	63	1838	64	1589.3	77
55	6	1709.5	78	1779.5	89	1225.8	92
60	5	2207	5	1978.9	10	2105.8	15
69	5	1483.8	92	1845.1	59	1844.8	40
70	7	1886.7	47	1811.2	81	1538.8	80
74	5	1779.2	68	1879.4	40	1859.9	38
75	9	1608.7	87	1978.5	11	2219.4	7
76	7	1832.2	57	1806.6	82	1467.6	89
77	7	1656.7	82	1815.2	79	1593	76
78	5	1767.6	71	1968	13	2081.4	17
96	19	1835.8	56	1846.9	58	1488.4	85
97	8	1953.2	33	1852.7	54	1768.9	52
98	13	1945.1	37	1932	22	1849.2	39
99	8	2000.8	24	1812.2	80	1601.5	75
100	8	2004.6	20	1843	61	1797.6	46
101	8	1612.9	86	1897.7	35	1936.8	30
102	7	1756.5	72	1920.4	27	1925.4	32
103	5	1929.3	40	1795	85	1555	79
106	7	1968	31	1988.5	8	1901.9	34
107	12	1964.1	32	1831.8	66	1752.5	55
108	5	1950.5	34	1929.6	23	2083.3	16
109	5	1701.2	80	1800.7	84	1445.4	90
110	7	1634.9	85	1993	7	2436.5	3
113	17	1948.2	35	1764.4	91	1186.2	93
114	6	1751.5	73	1871	45	1647	71
115	5	1864.3	51	1837.6	65	1614.5	73

Sire	No. of dau	BV LS	LS Rank	BV Blup	BLUP Rank	BV DfReml	DfReml Rank
117	15	1854.7	53	1821.4	72	1803.4	45
119	22	1878.8	48	1757	93	1268.4	91
120	14	1815.5	59	1888.3	37	1793.3	47
121	7	1934.7	39	1855	52	1758	54
122	11	2077.2	15	1927.9	25	1999.4	24
123	11	2004.1	21	1955.5	17	2201.4	9
125	19	1811.7	60	1821	73	1707.9	62
132	10	2126.9	11	1852.4	55	1723.6	57
135	6	1710.9	77	1871.3	44	1763	53
140	5	1993.1	25	1880.4	39	1779.1	51
141	7	1767.9	70	2033.3	2	2503.4	1
148	5	1987.5	26	1760.9	92	1470.1	88
149	5	1948.2	36	1984.6	9	2330	5
151	5	1973.2	30	1841.4	63	1839.7	41
156	5	2152.4	9	1819	76	1578.5	78
157	7	1907	43	1858.7	49	1677.5	66
158	5	1641.9	84	1849.1	57	1914.6	33
160	5	1940.5	38	1862	48	1784.7	49
161	6	1491.8	91	1819.6	74	1712.1	60
162	7	1701	81	1843.1	60	1723	58
163	8	2136.6	10	1784.1	88	1502.3	84
166	6	1642.5	83	1928.2	24	2010.6	21
167	7	1561.1	90	1900.3	33	1975.6	27
175	15	1798.4	62	1789.2	87	1518.5	82
188	5	1877.2	49	1793.8	86	1477.5	87
189	6	1856.4	52	1857.7	51	1807.7	43
191	6	1732.1	74	1976.7	12	2037.1	20
195	6	2170.5	7	2055.3	1	2373.8	4
196	8	1905.7	45	1883.9	38	1876.6	37
202	5	1707.8	79	1816.9	77	1513.6	83
231	5	2003.2	23	1875.9	42	1880.4	36
232	5	1973.3	29	1875.3	43	1803.9	44
233	6	2244.5	2	1852.7	53	1790.6	48
235	5	1804.9	61	1830.2	68	1647.1	70
237	7	1783.4	66	1965.8	14	2191.2	11
238	6	1778	69	1960	16	2002.7	23

4.13.1 Least squares method

The average breeding value by LS method was 1883.4 kg (Table 76 and 77). The breeding value of 47 sires out of 93 sires (50.5%) was above average breeding value, while the remaining 46 sires (49.5%) had breeding value below the average breeding value. The highest breeding value was observed to be 2284kg (Sire No.30), which was 21.3 per cent higher than the average breeding value, whereas the lowest breeding value was observed as 1436.9 kg (Sire No. 14), which was 23.7 per cent lower than the average breeding value. The difference in breeding value of the highest and lowest ranking bull was between 847.1 kg.

The number of sires having breeding value 20 per cent and higher than the overall average breeding value was 1 (1.07%). There were 7, 15 and 28 sires out of total 93 sires (7.53, 16.13 and 30.11%, respectively) whose breeding values were 15, 10 and 5 per cent and more than the overall average breeding value.

4.12.2 Best Linear Unbiased Prediction method (BLUP)

The average breeding value was 1879.6 kg (Table 76 and 77). The breeding value of 39 sires out of 93 sires (41.9%) was above average breeding value, while 54 sires (58.1%) were having breeding values below the average breeding value. The highest breeding value was observed as 2055.3kg (Sire No.195), which was 9.35 per cent higher than the average breeding value, whereas the lowest breeding value was observed as 1757kg (Sire No. 119), which was 6.52 per cent lower than the average breeding value. The difference of breeding values between the upper and lower estimates was 298.3 kg.

The number of sires having breeding value 5 per cent and higher than the overall average breeding value was 12 (12.9%). However, no sires were having breeding value 10% and above the average breeding value.

4.13.3 Derivative free restricted maximum likelihood method (DFREML)

The evaluation of breeding values of sires by DFREML method gave the average breeding value for first lactation 305 days or less milk yield as 1826.5kg (Table 76 and 77). The breeding value of 41 sires out of 93 sires (44.1%) was above

Table 76: Average breeding value estimates for first 305-days or less milk yield by different methods of sire evaluation

Sire evaluation method	Average BV	Number of sires above BV	Number of sires below BV	Maximum BV	Minimum BV	Range of BV
LS	1883.4	47	46	2284	1436.9	847.1
BLUP	1879.6	39	54	2055.3	1757	298.3
DFREML	1826.5	41	52	2503.4	1186.2	1317.2

Table 77: Descriptive statistics of breeding value estimates by various methods of sire elevation

	Mean	SE	SD	G_1	t_1	G_2	t_2
LS	1883.4	18.98	183.01	-0.051	0.2	-0.251	0.49
BLUP	1879.6	7.18	69.27	0.472	1.86	-0.542	1.07
DFREML	1826.5	28.22	272.18	0.293	1.15	0.040	0.08

average breeding value, while 52 sires (55.9%) were having breeding values below the average breeding value. The highest breeding value was observed as 2503.4kg (Sire No.141), which was 37.1 per cent higher than the average breeding value, whereas the lowest breeding value was observed as 1186.2 kg (Sire No. 113), which was 35.1 per cent lower than the average breeding value. The difference of breeding values between the upper and lower estimates was 1317.2 kg.

The number of sires having breeding value 20 per cent and higher than the overall average breeding value were 10 (10.75%). There were 15, 21 and 32 sires out of total 93 sires (16.13, 22.58 and 34.41%, respectively) whose breeding values were 15, 10 and 5 per cent and more than the overall average breeding value.

4.14 Comparison of Different Methods of Sire Evaluation

The relative efficiency of different sire evaluation methods was evaluated by error variance, coefficient of determination and coefficient of variation.

4.14.1 Error Variance

The error variance is one of the criteria of judging effectiveness of different methods of sire evaluation. An efficient method of sire evaluation must have minimum error variance. The error variance of three sire evaluation methods along with their relative efficiency are presented in Table 78. Error variance for BLUP was lowest (144269.32kg^2) and, therefore, it was considered to be most efficient out of the three sire evaluation methods used in the present study. The LS was second in order efficient on the basis of this criterion. Maximum error variance (148433.85kg^2) was found in DFREML method.

The relative efficiency (%) of different methods were estimated in comparison to most efficient method i.e. BLUP. Compared to BLUP, the least squares method, and DFREML methods were 97.50 and 97.19%, respectively. Results of present study are in agreement with those obtained by Dempfle (1977), Harvey (1987), Haggar and Dempfle (1981), Danell (1982), Mityut'Ko (1988) and Anacker and Diett (1990), who observed that BLUP method was most efficient than conventional CC, LSQ and SRLS method in western countries. Kumar and

Bhatnagar (1989), Singh (1992) and Sahana (1996) revealed that contemporary comparison method was more efficient than least squares, simple regressed least squares and BLUP methods. Sahana and Gurnani (1999) reported the relative efficiency was highest in SRLS (58.34%) followed by LSQ (58.29%) and lastly BLUP (54, 81%) in comparison with CC method of sire evaluation. On the contrary, the LSQ method was most efficient as reported by Tajane and Rai (1990) and Deb *et al* (1998).

Table 78: Comparative efficacy of different sire evaluation methods

Method	Error variance (kg^2)	Relative efficiency (%)	R^2-Value (%)	CV (%)
LS	147969.33	97.50	18.16	9.72
BLUP	144269.32	100	19.30	3.68
DFREML	148433.85	97.19	17.63	14.90

4.14.2 Coefficient of Determination

The coefficients of determination (R^2-value) for fitting different models were estimated to judge the effectiveness of sire evaluation methods. Higher the R^2-value, higher is the accuracy of fitting the model. The BLUP method showed the highest coefficient of determination (19.30%) as compared to other methods. LS (18.16%) was observed to be second best method, after BLUP method for estimating the breeding values of sires.

4.14.3 Coefficient of Variation (%)

The coefficient of variation (%) for breeding value estimates by different methods were 9.72, 3.68 and 14.90, respectively for LS, BLUP and DFREML (Table 80). The lowest CV was observed for BLUP and followed by LS. These findings depicted that BLUP method was most efficient method. Whereas, Gandhi and Gurnani (1991) reported BLUP method to be least stable method of sire evaluation.

4.14.4 Rank correlation

Accuracy of different methods of sire evocation was estimated by coefficient of rank correlation of breeding values of sires estimated by various methods (Table

79). All the estimated rank correlation were very high ranging from 0.80 (LS with BLUP) to 0.92 (BLUP with DFREML). The highest estimate of rank correlation indicated almost similar ranking of bulls from these methods.

Table 79: Rank correlation among various methods of sire evaluation

Method	**LS**	**BLUP**	**DFREML**
LS	1.0	0.80	0.81
BLUP		1.0	0.92
DFREML			1.0

On the basis of comparison of error values, R^2 value and CV (%), the BLUP method was observed to be the best while DFREML to be the least efficient.

CHAPTER V

SUMMARY AND CONCLUSIONS

Murrah is one of the important breeds of buffaloes. This breed has been used for upgrading low milk producing breeds throughout the country. Animals of this breed have also been imported by a number of other countries of Asia, Europe and Africa with the purpose to cross them with their indigenous breeds, and also to raise as purebreds. Since there is hardly any scope of introducing superior germplasm into this breed, selection is the only tool available for genetic enhancement of its performance in the country. The present study was undertaken on two organised herds of Murrah with the objectives to obtain estimates of genetic parameters (heritability and genetic correlations) of economically important traits, to examine the validity of assumption involved in the estimation of genetic parameters and to study the effect of violation of assumptions on the estimates of genetic parameters, and to study the efficiency of sire evaluation by three methods viz. Least squares (LS), Best linear unbiased prediction (BLUP) and Derivative free restricted maximum likelihood (DFREML).

Performance records of 1033 Murrah buffaloes pertaining to a herd of Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana (GADVASU) and 774 Murrah buffaloes pertaining to a herd of Central Institute for Research on Buffaloes, Hisar (CIRB) were utilized for the present investigation. Performance records on growth, reproduction and production traits viz. gestation period (GP), age at first calving (AFC), weight at first calving (WAC), weight of calf at birth (WAB), calf-dam weight %, 305-day milk yield (305 MY), lactation milk yield (LY), lactation length (LL), peak yield (PY), days to reach peak yield (DRPY), fat %, fat yield (FY), milk yield per day of lactation length (MYLL) and number of AI per conception (No. AI) of GADVASU herd, which spanned over a period of forty years (1973-2012), were divided into eight periods of five-year duration each. Information on only six traits viz. AFC, 305 MY, LY, LL, PY and MYLL was available from CIRB herd. Records of CIRB, distributed over of 25 years (1988 to 2012), were divided into five equal periods of five years each. Each year for both the herds was divided into five seasons viz. summer, rainy, autumn, winter and spring according to date of birth for gestation period, age at first calving and weight at first calving and date of calving for rest of the traits. Records with the history of abnormal lactation (less than 150 days) due to abortion, premature birth and incomplete lactation due to death or disposal of buffaloes were excluded from the analysis.

Season, period and herd were considered as fixed effects for examining their effect on the traits under study. Least squares analysis for unequal sub-class numbers as described by Harvey (1987) was used for studying the effect of the non-genetic factors on different traits. Estimates of heritability, and genetic and phenotypic correlations among different traits were estimated by paternal half-sib analysis of variance and covariance on season- and period- adjusted records (Model 2 of Harvey, 1987). Normality of distribution was tested by obtaining the estimates of skewness and kurtosis. Homogeneity of variance among sub groups viz. seasons, periods and sire families, was tested by Bartlett's test. Relation between means and variances (of seasons, periods and sire families) was tested by correlation and regression coefficients. Effect of standard statistical transformations viz. square root, logarithmic and arc sine (for %) on the fulfilling the assumptions of ANOVA, and on the estimates of heritability was studied. Heritability estimates obtained by model 2 of Harvey were also compared with those obtained by Model 3(Henderson, 1953) which included season and period as fixed, and sire as random effects. Breeding values of sires for first 305 days or less milk yield was obtained by Least squares (LS), Best linear unbiased prediction (BLUP) and Derivative free restricted maximum likelihood (DFREML) methods. Efficiency of the three sire evaluation methods was judged by comparing their error variances, coefficients of determination and variation.

Least-squares analysis of variance for effect of season, period and parity on various growth traits indicated that season, in general, had little effect on body weight, monthly gain in weight and relative growth rate where it accounted for less than 1.3% of the total variation. Herd-management was thus effective in minimizing the seasonal changes associated with physical environmental factors, and feed and fodder availability. Period of calving had significant influence on some of the growth traits, but its contribution to total variation fell between 1.09 and 2.01% only. However, period relative to season had slightly more effect on various growth traits as it spanned over forty years. During such a long time span, management practices including nutrition regime change. Additionally, genetic structure of population also undergoes change due to selection and introduction of outside animals. Parity of dam generally exerted significant effect on body weights during the first six parities; the effect being most conspicuous for early body weights.

Least-squares ANOVA for the effect of season and period on first lactation traits indicated that season had non-significant influence on AFC, WAB, calf-dam weight %, LL, MYLL, Fat yield and number of AI per conception but its effect on milk production, fat%, peak yield and days to reach peak yield was significant. Period of calving had significant influence on AFC, WFC, Peak yield, milk yield per day of lactation length and number of AI per conception. There has been improvement over time in weight at first calving, 305-days milk yield and milk production per day of lactation length. At the same time however, there has been considerable increase in age at first calving and number of artificial inseminations required per conception. This could be due to poor reproductive management of the herd, as both traits are integral component of reproduction, and their heritabilities are low.

Estimates of heritability for body weights at different ages, monthly gain in weight and relative growth rate varied between 0.11±0.098 and 0.54±0.125; 0.08±0.096 and 0.56±0.126, and 0.06±0.04 and 0.33±0.114 respectively. Higher estimates were obtained for six month body weight, gain in body weight from birth to six months and relative growth rate from birth to six months of age. Environmental variation during the post calfhood (beyond six months of age) period usually increases, thereby decreasing the magnitude of heritability. Since the estimates of heritability were generally moderate for body weights and gain in weight upto six months of age, early growth can, therefore, be improved through appropriate forms of selection.

Higher estimates of heritabilities were obtained for age at first calving (0.76±0.12), weight at first calving (0.45±0.11), 305-days milk yield (0.42±0.11) and fat% (0.61±0.12). Heritability estimates for other first lactation traits were lower: 0.16±0.09 for calf birth weight, 0.12±0.09 for lactation length, 0.22±0.10 for peak yield and 0.16±0.09 for days to reach peak yield. These traits can, therefore, be used either alone or in combination with other traits for selection. Traits related to reproduction had low heritabilities (0.062±0.083 to 0.161±0.095) and were also associated with relatively higher standard errors which made the estimates not to differ significantly from zero.

Baring the number of inseminations, gestation period, lactation length and days to reach peak yield, all other traits had sufficient genetic variability to warrant effectiveness of selection for their improvement. The most important trait influencing economic returns viz. 305 day milk yield and complete lactation yield had moderate heritabilities and can hence be easily improved through individual selection. Being sex limited, selection in males can be effected through progeny testing.

Genetic correlations of birth weight with body weight at other ages (except for one-month weight), monthly gain in weight and monthly relative growth rate were low. Genetic correlation among bodyweights and monthly gain in weight were generally desirable partly due to part and whole relationship. Heritability of six-month weight being more than of birth weight, and the trait is also free from maternal effects. Its genetic correlation with post calf hood weights, gain in weights and growth rates is also favourable. Selection of calves on the basis of the six-month body weight can therefore be used for early selection of young bulls. The first lactation traits except for PY, Fat % and Fat yield had moderate genetic correlation with AFC. WFC had moderate genetic correlation with LY, 305 MY, PY, MYLL and Fat yield. LY had very high genetic correlation with LL, 305 MY, PY, MYLL and Fat yield. Tests for normality of distribution showed that none of the first lactation traits conformed to normality. Departures mostly existed in the form of skewness and kurtosis. Transformation of data resulted in larger reduction in coefficient of variability for all traits. Transformation was also effective in reducing the departures from normality for most of the traits though the coefficients of G_1 and G_2 continued to be significant. For some traits viz. weight at birth, calf-dam weight per cent, 305 day milk yield and days to reach peak yield, statistical transformation increased the departures from normality or changed the direction of skewness and kurtosis. The general inference from estimates of skewness and kurtosis is that most traits exhibited departures from normality, and the traditional transformations did not completely eliminate these departures.

Estimation of genetic and phenotypic parameters in animals involves adjustment of performance records for season and period effects, and then pooling of data over seasons and periods. High degree of heterogeneity of variance was observed among seasons and periods for various first lactation traits which indicated that the pooling of variances under such circumstances is statistically unjustified. The effect of heterogeneity *per se* on the estimates of various genetic parameters in terms of direction and magnitude is not known. However, it could be one of the several causes for the wide variation observed in the estimates of various genetic parameters by different workers as well as for the low precision of estimates.

Statistical transformation of data is expected to remove the heterogeneity of variance. However, for some of the traits (AFC, LL, MYLL and number of AI per conception) the transformed scale exhibited high degree of heterogeneity of variance among seasons. Heterogeneity of variance for AFC, WAB, LL, Fat % and number of AI per conception was higher for periods and remained significant even after transformation. Of the various traits, traits related to production had higher heterogeneity of variance in comparison to rest of traits.

Means and variances depicted a strong relationship for weight at calving, lactation milk yield, peak yield, days to reach peak yield, fat yield and number of services per conception. Transformation of data to square root and logarithmic scales generally led to decrease in the magnitude of relationship between the two statistics. In contrast to this, other first lactation traits showed lesser dependence of variance on mean.

Data transformation to square root and logarithmic scales did not result in any appreciable change in the estimates of heritability and their standard errors. The estimates of heritability on transformed scale remained of similar magnitude as that of original scale for GP, 305 MY, LL, PY, DRPY, MYLL and number of AI per conception. The estimates of heritability increased on transformed scale for AFC, WAB, Calf-dam weight %, LY and Fat yield while estimates for WAC and Fat% decreased on transformed scale.

The general inference from transformation of data to square root and logarithmic scales being that transformation, in general, decreased the departures from normality, reduced the heterogeneity of variance among sub-classes, and also reduced the relationship between mean and variance. However despite better fulfilment of the assumptions of analysis of variance on transformed scales, transformation did not result in any appreciable change in the estimates of heritability and their standard errors. Analysis of variance as used for estimation of heritability is thus a robust technique at least for the type of data used herein.

Breeding values of the 93 sires for first lactation 305 day or less milk yield averaged to be 1883.4±19.0, 1879.6±7.2 and 1826.5±28.2 kg by LS, BLUP and DFREML methods respectively. Breeding values of 50.5%, 41.9% and 44.1% of the 93 sires by LS, BLUP and DFREML methods was above the average breeding value respectively. The range of breeding values was 847.1 kg, 298.3kg and 1317.2kg for LS, BLUP and DFREML methods respectively.

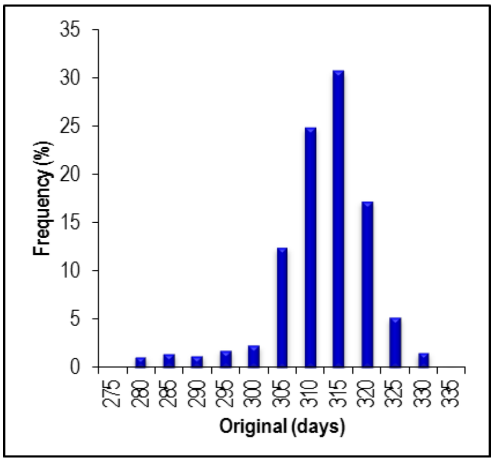
Comparison of efficiency of sire evaluation by three methods used in the present study showed BLUP to be the most effective method as it showed the lowest error variance, highest coefficient of determination and the lowest coefficient of variation. The LS method ranked second after BLUP.

Based on the overall results of the present study, the following conclusions have been drawn:

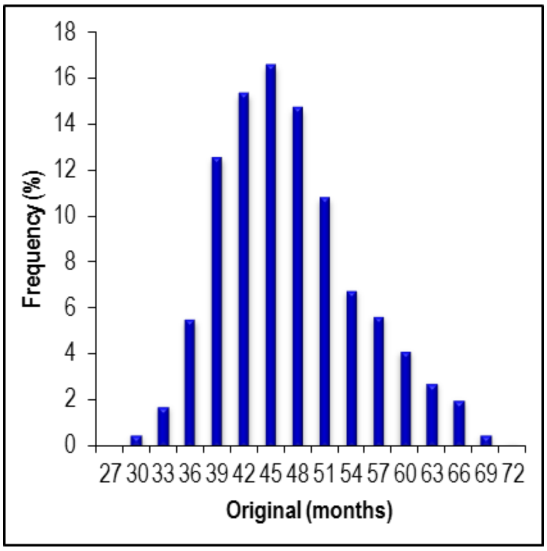
- Season in general had low effect on growth traits but relatively higher effect on first lactation production traits. But its contribution to total variation was fairly low which implied herd management, if appropriately made, can eliminate the contribution of this non-genetic source of variability to performance. This will in effect improve the accuracy of estimation of genetic parameters and of genetic evaluation in general.

- Period of birth/calving exerted significant influence on some of the traits (AFC, WFC, Peak yield, milk yield per day of lactation length and number of AI per conception). In general, production traits improved over time while reproductive traits declined. Appropriate measures thus need to be taken to check the decline in the reproductive status of the herds.
- Most of the growth and production traits had sufficient genetic variability to warrant effectiveness of selection for their improvement.
- Statistical transformation though generally made the data to satisfy the assumption of estimation of genetic parameters but its effect on heritability was small showing ANOVA to be a robust technique.
- Of the three sire evaluation methods used in the present study, BLUP was found to be most effective.

estation period



Age at first calving



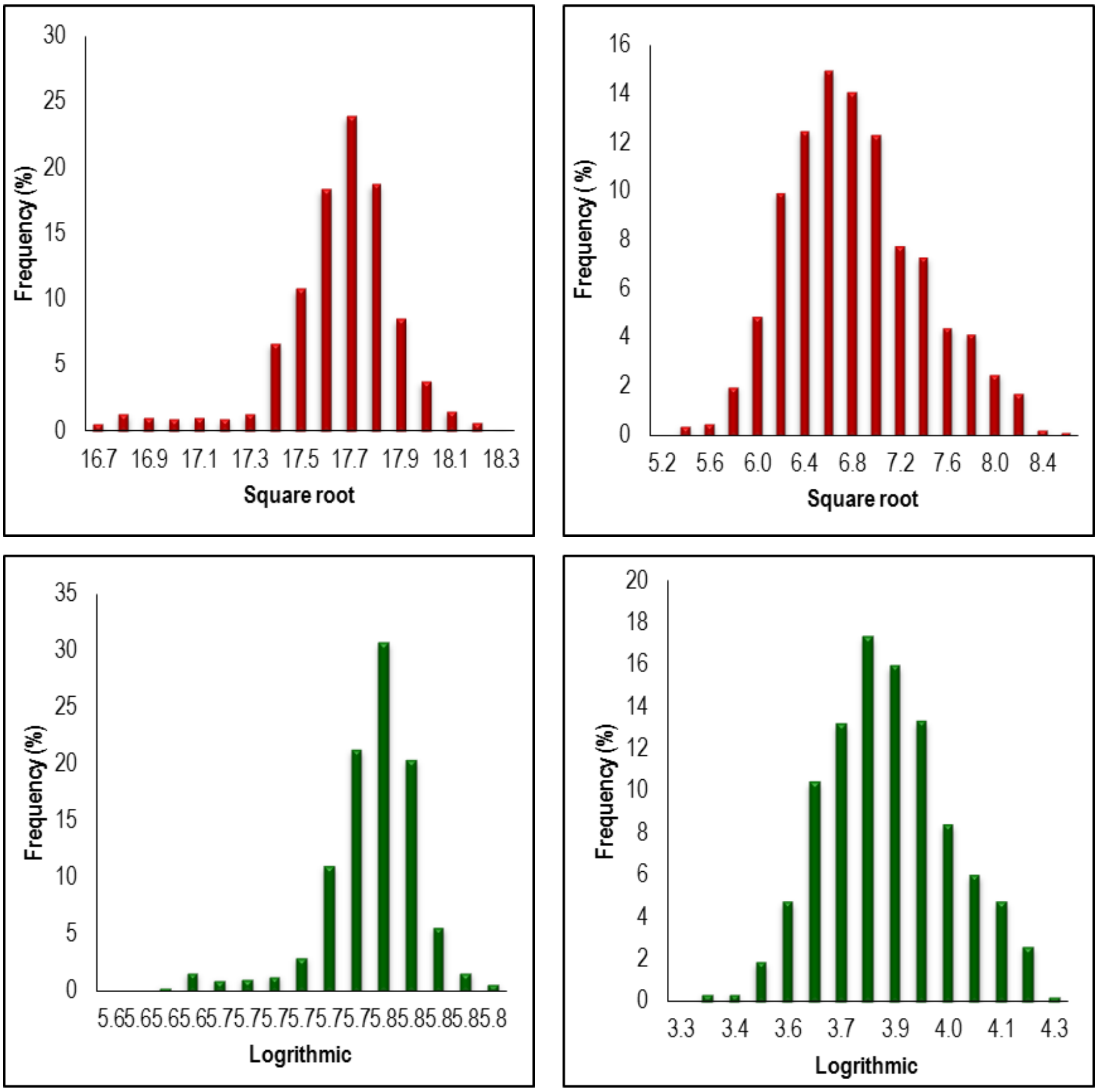


Fig. 1: Frequency distribution of gestation period and age at first calving on original and transformed scales

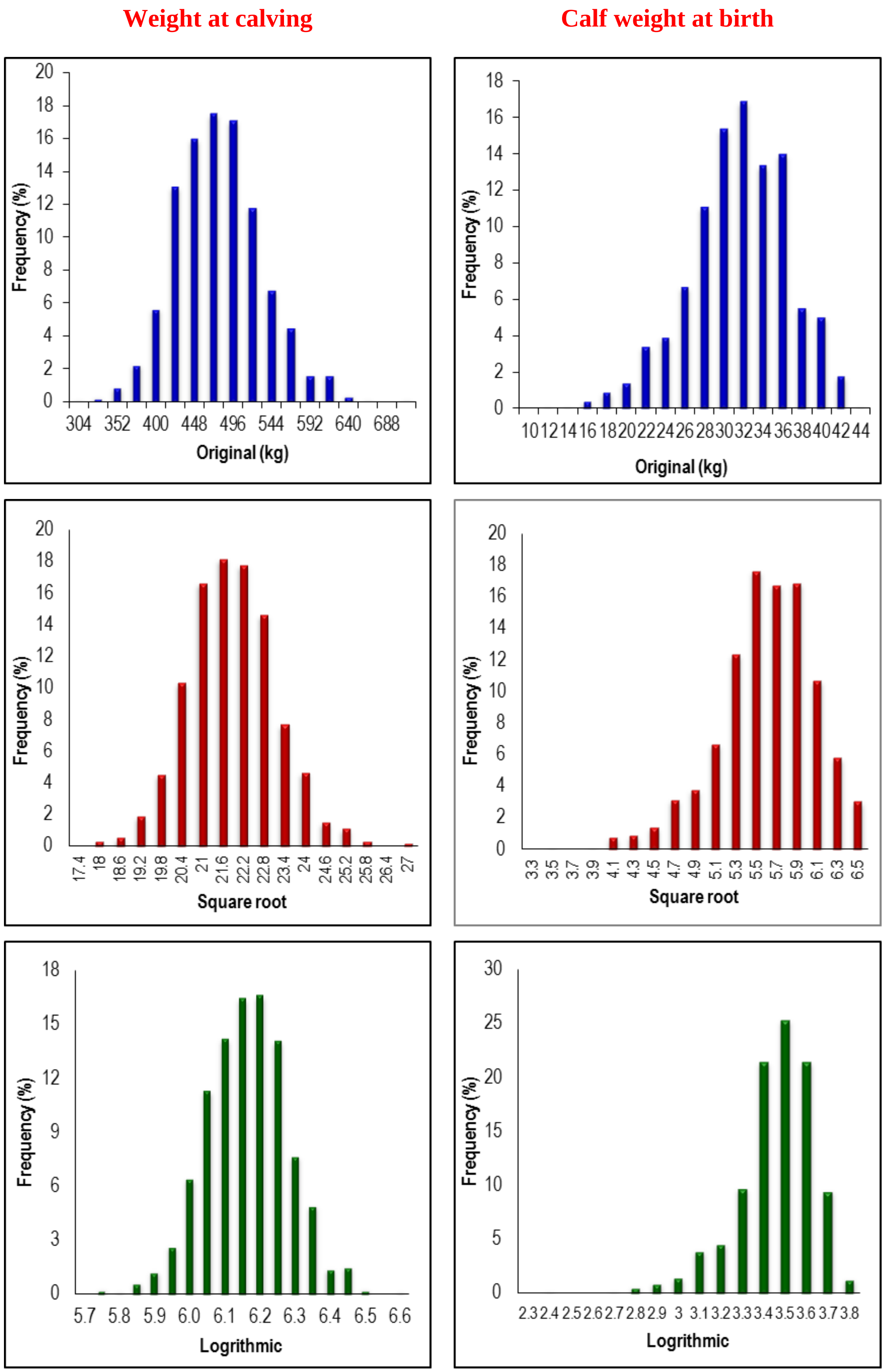


Fig. 2: Frequency distribution of weight at calving and weight at birth on original and transformed scales

Calf-dam weight (%) **Lactation yield**

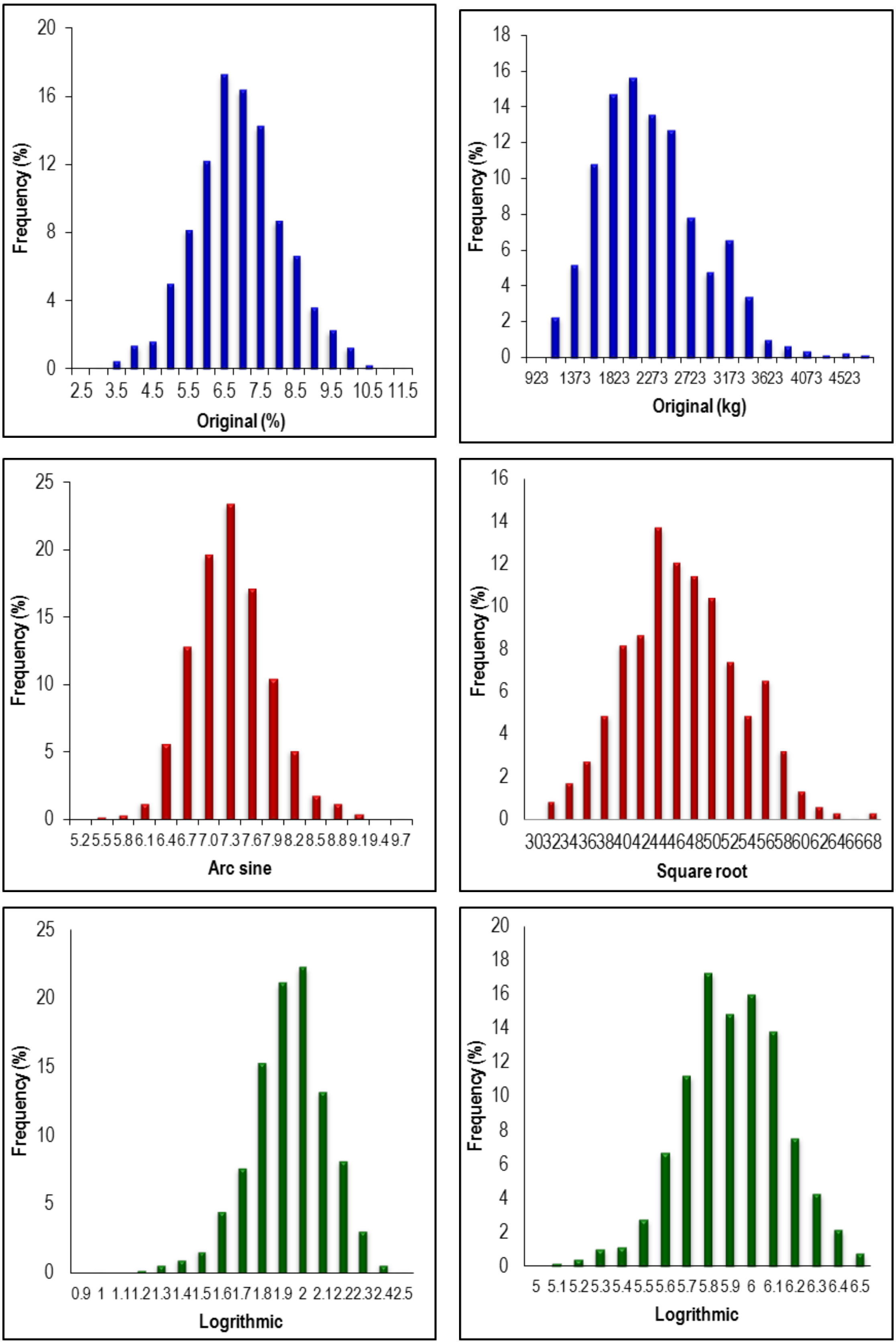


Fig. 3: Frequency distribution of calf-dam weight (%) and lactation yield on original and transformed scales

305 day milk yield **Lactation length**

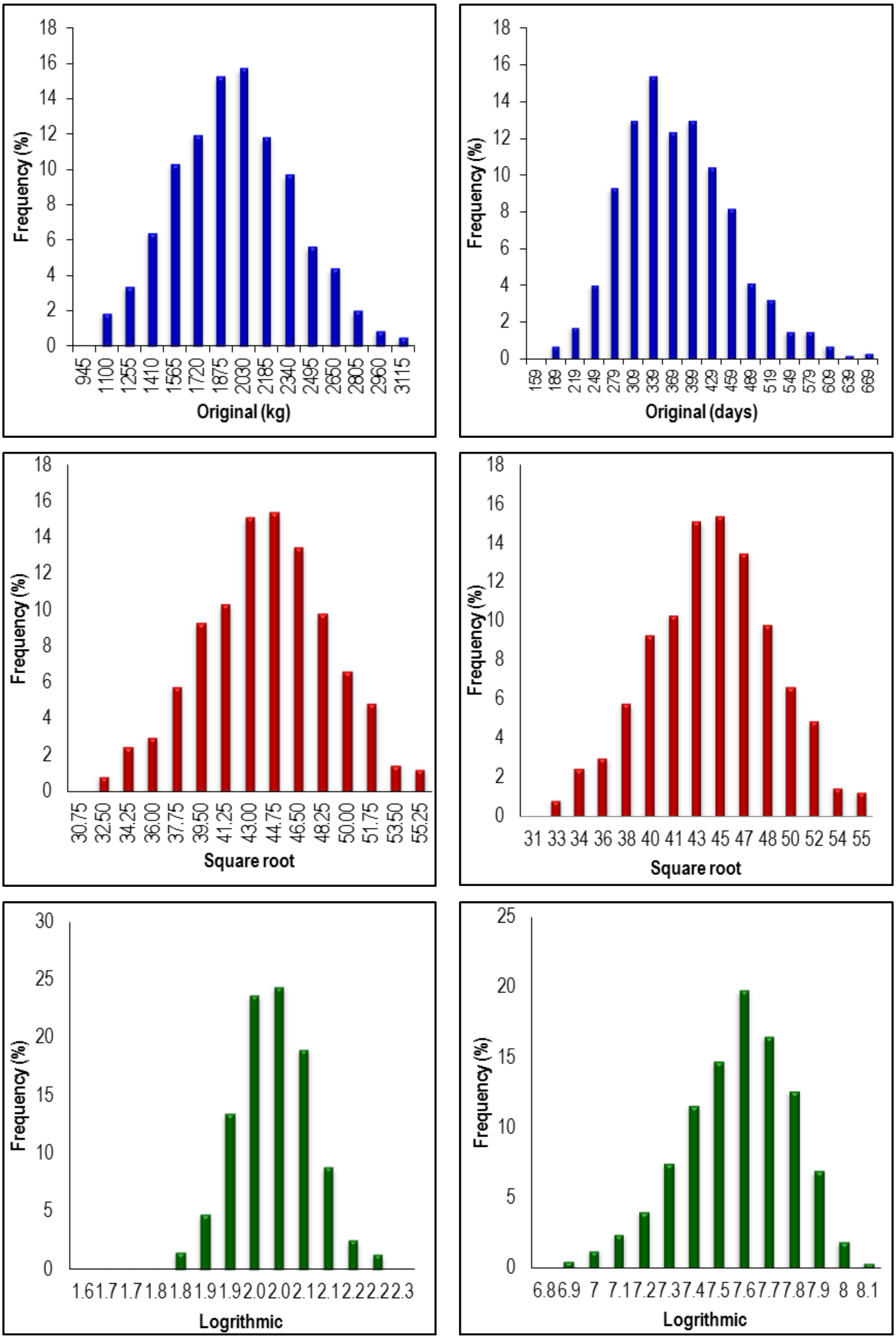


Fig. 4: Frequency distribution of 305 day milk yield and lactation length on original and transformed scales

Fat (%) **Peak yield**

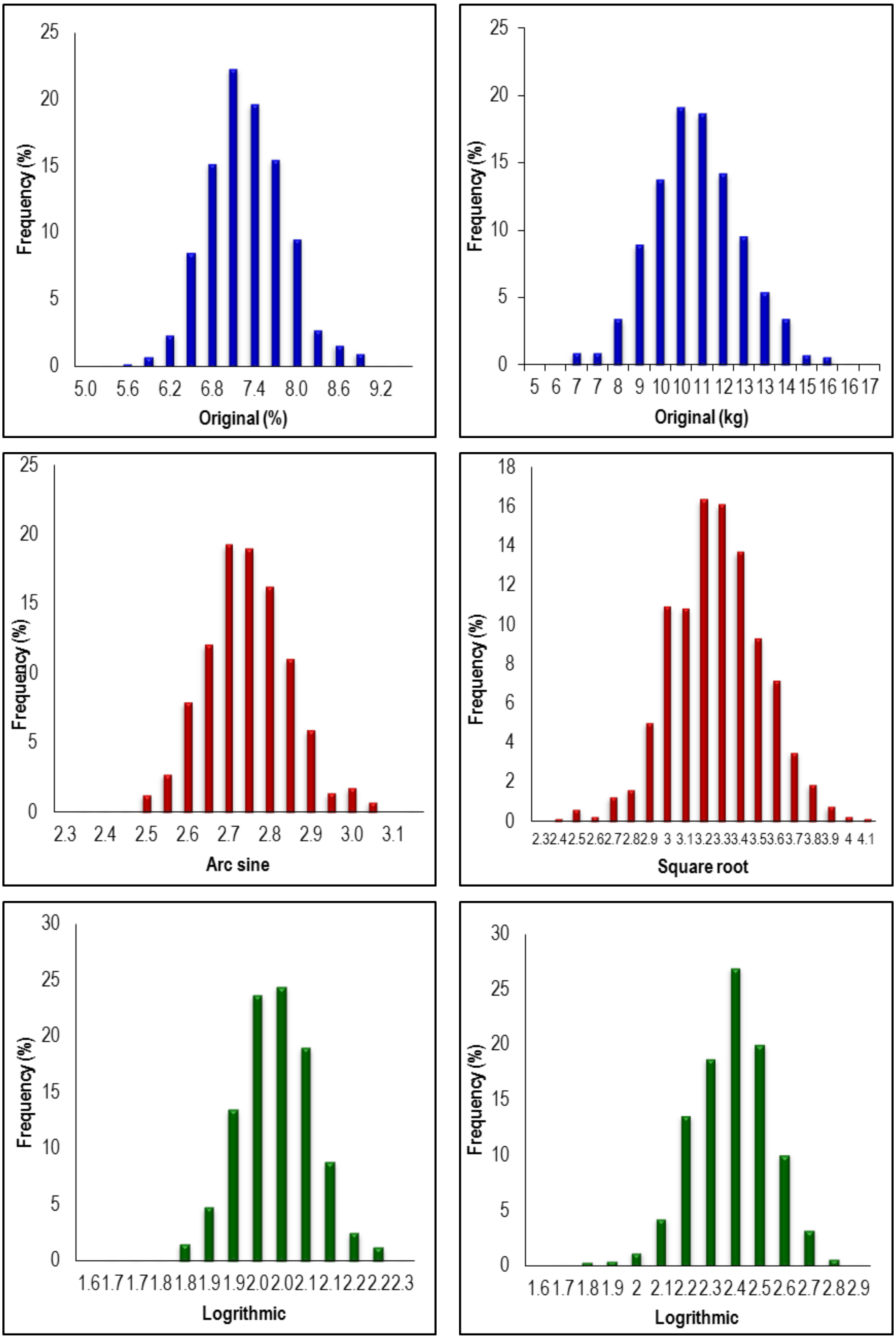


Fig. 5: Frequency distribution of fat (%) and peak yield on original and transformed scales

Days to reach peak yield **Milk yield per day of lactation length**

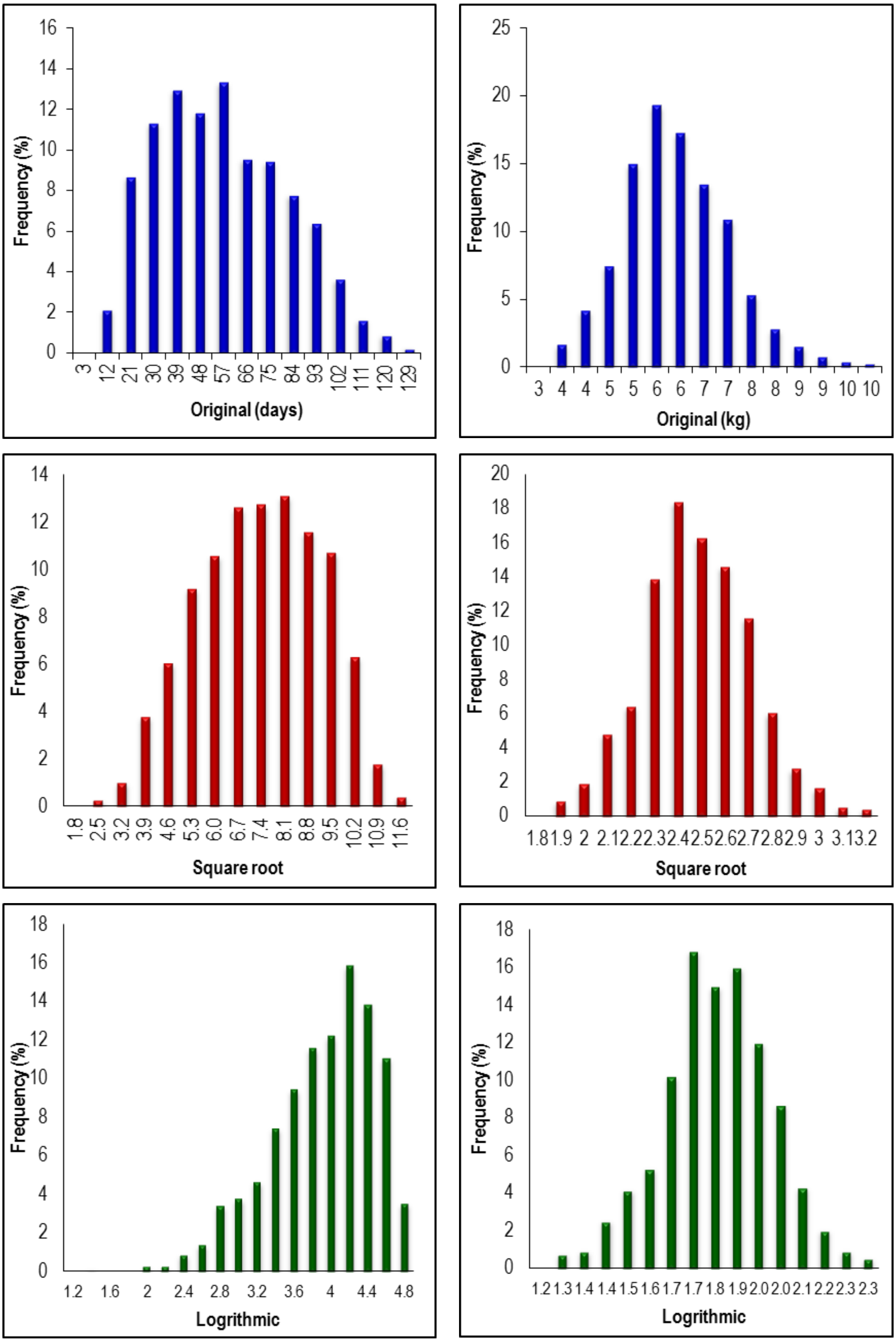


Fig. 6: Frequency distribution of days to reach peak yield and milk yield per day of lactation length on original and transformed scales

Fat yield

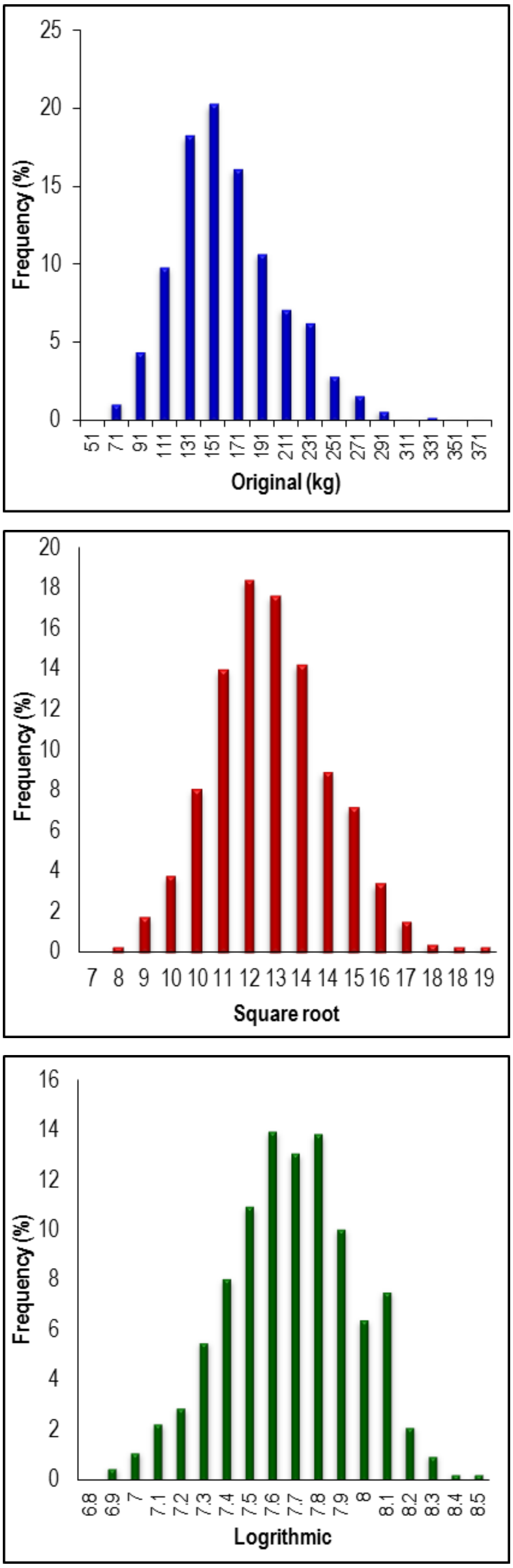


Fig. 7: Frequency distribution of fat yield on original and transformed scales

Gestation period **Age at first calving**

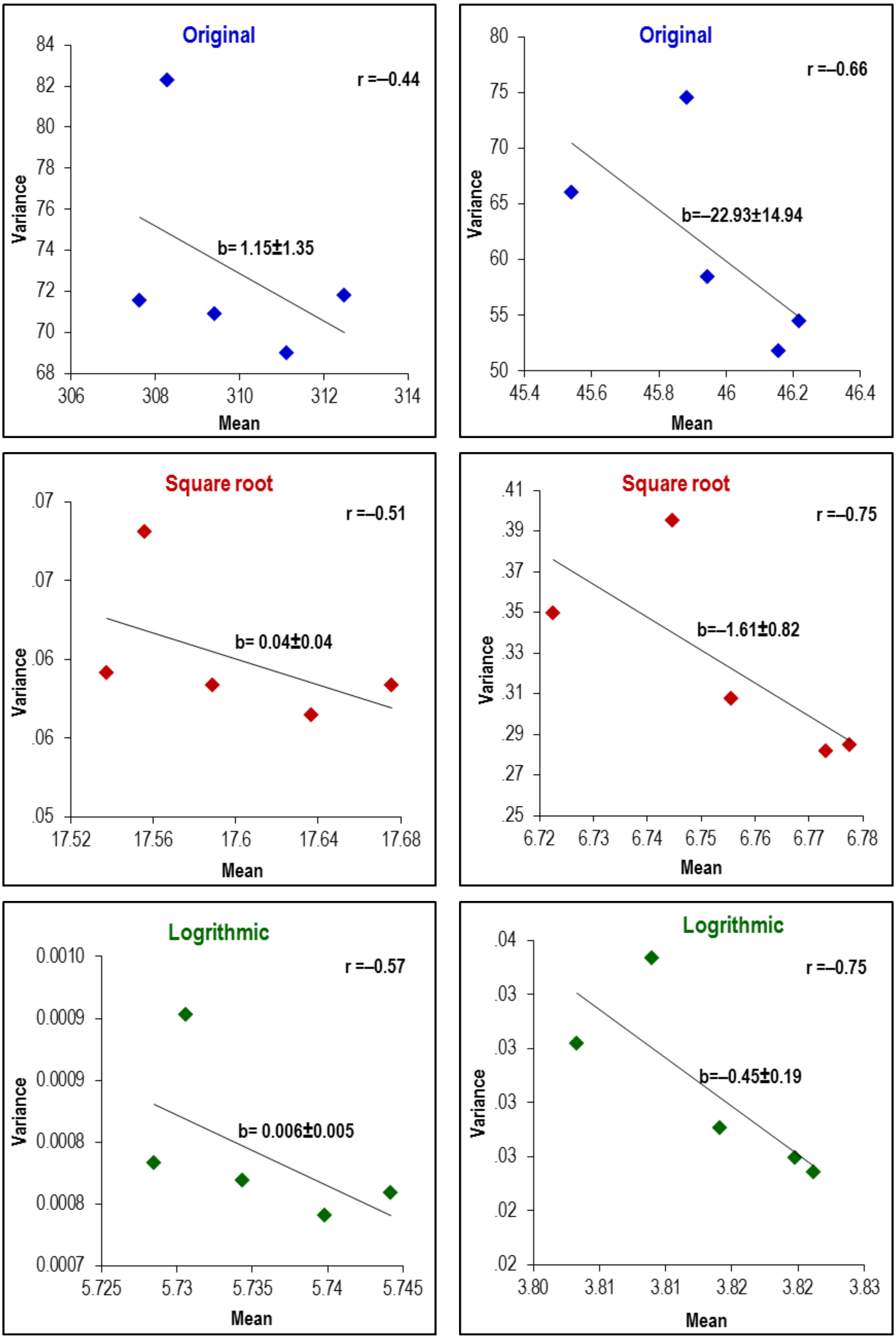


Fig. 8: Relation between mean and variance for gestation period and age at first calving on original and transformed scales (Season wise)

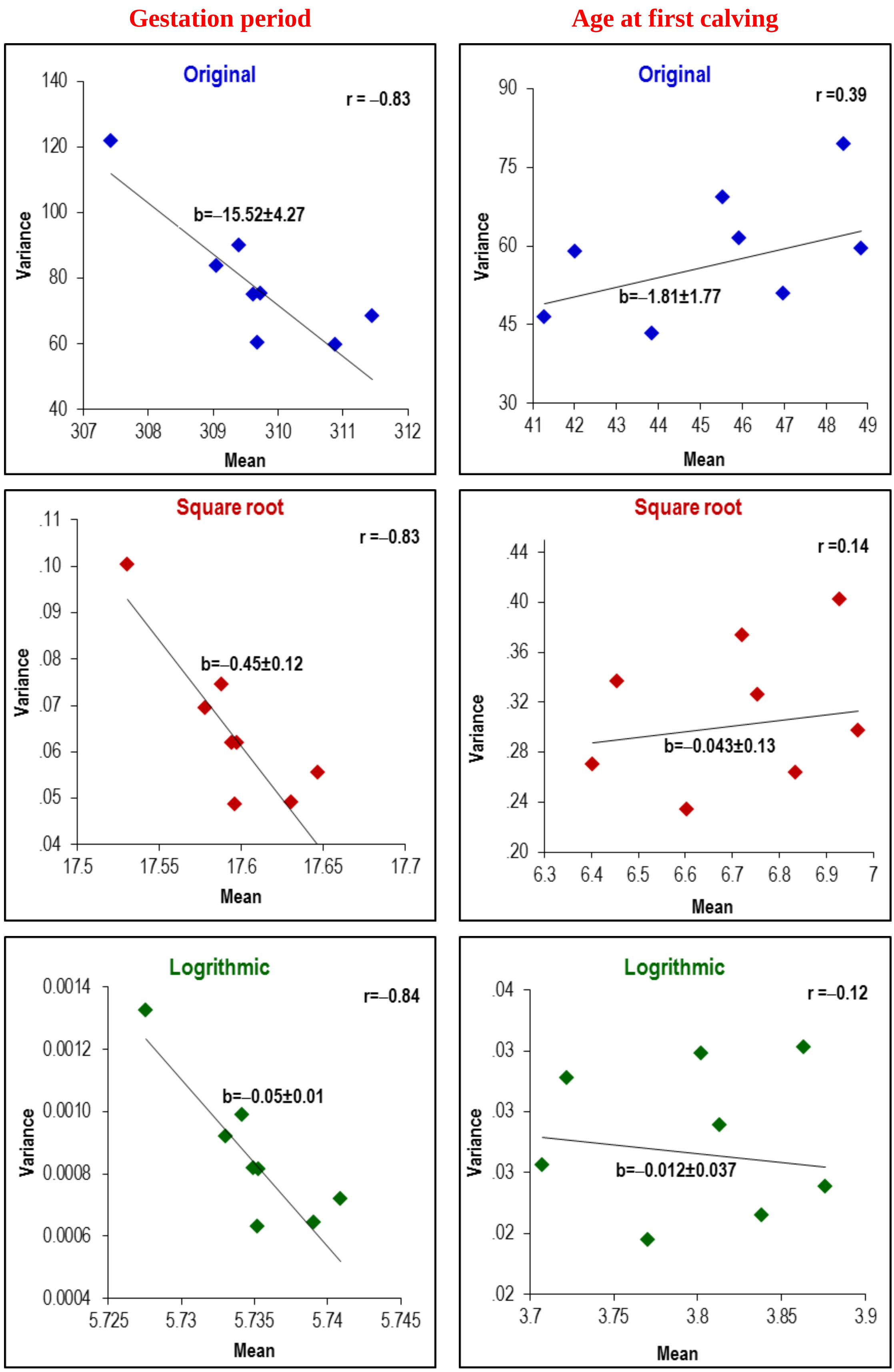


Fig. 9: Relation between mean and variance for gestation period and age at first calving on original and transformed scales (Period wise)

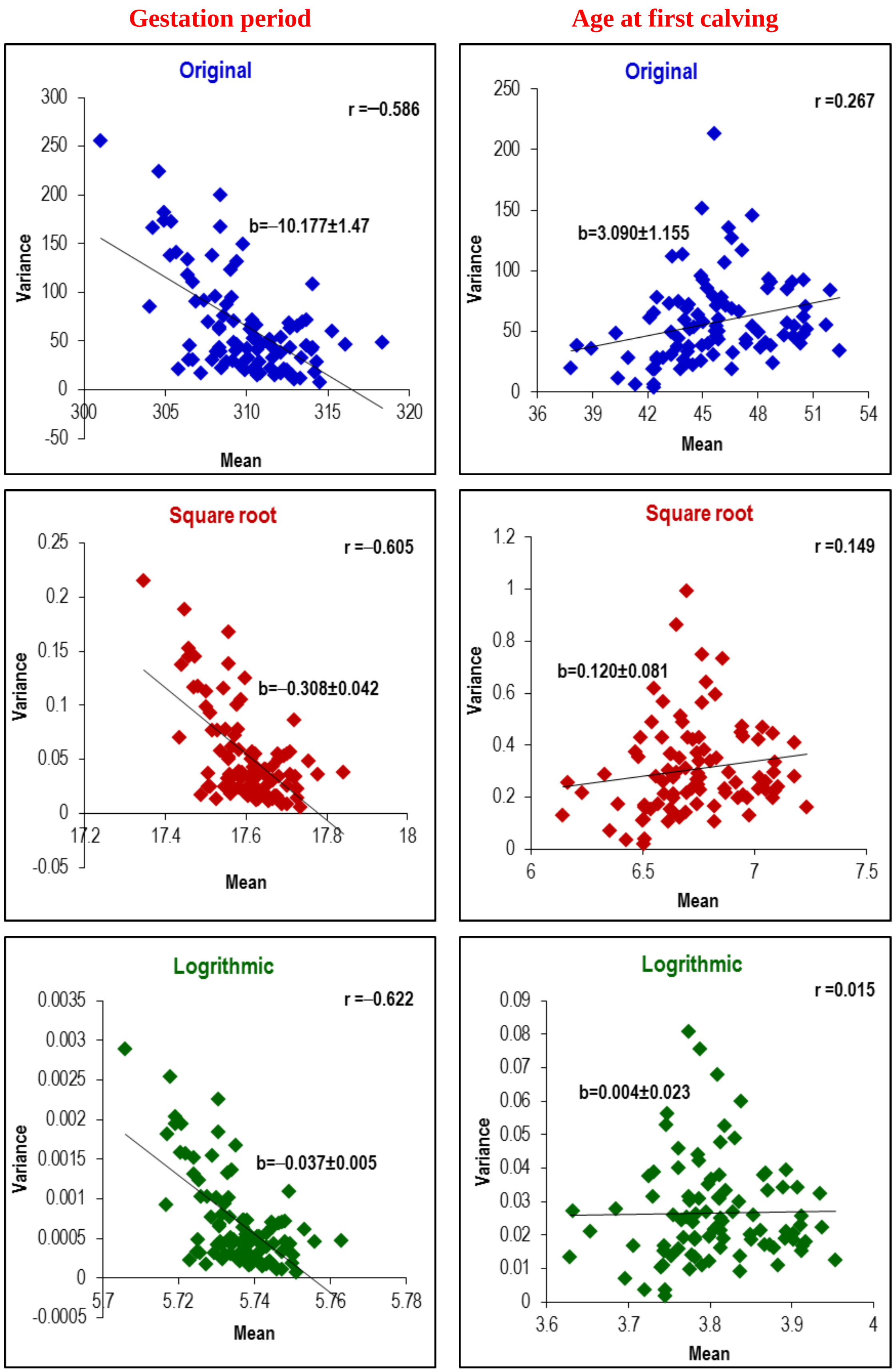


Fig. 10: Relation between mean and variance for gestation period and age at first calving on original and transformed scales (Sire wise)

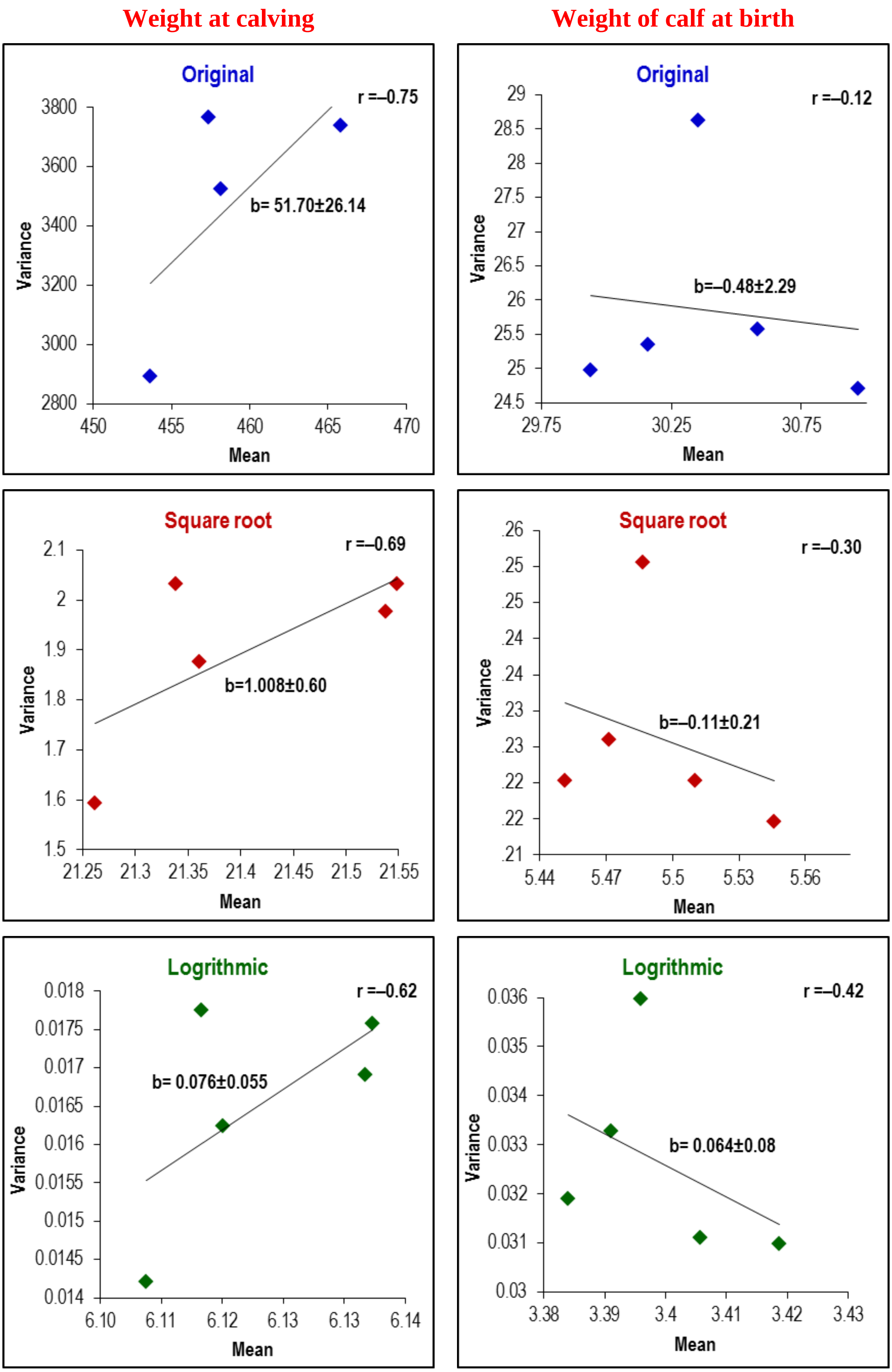


Fig. 11: Relation between mean and variance for weight at calving and weigh of calf at birth on original and transformed scales (Season wise)

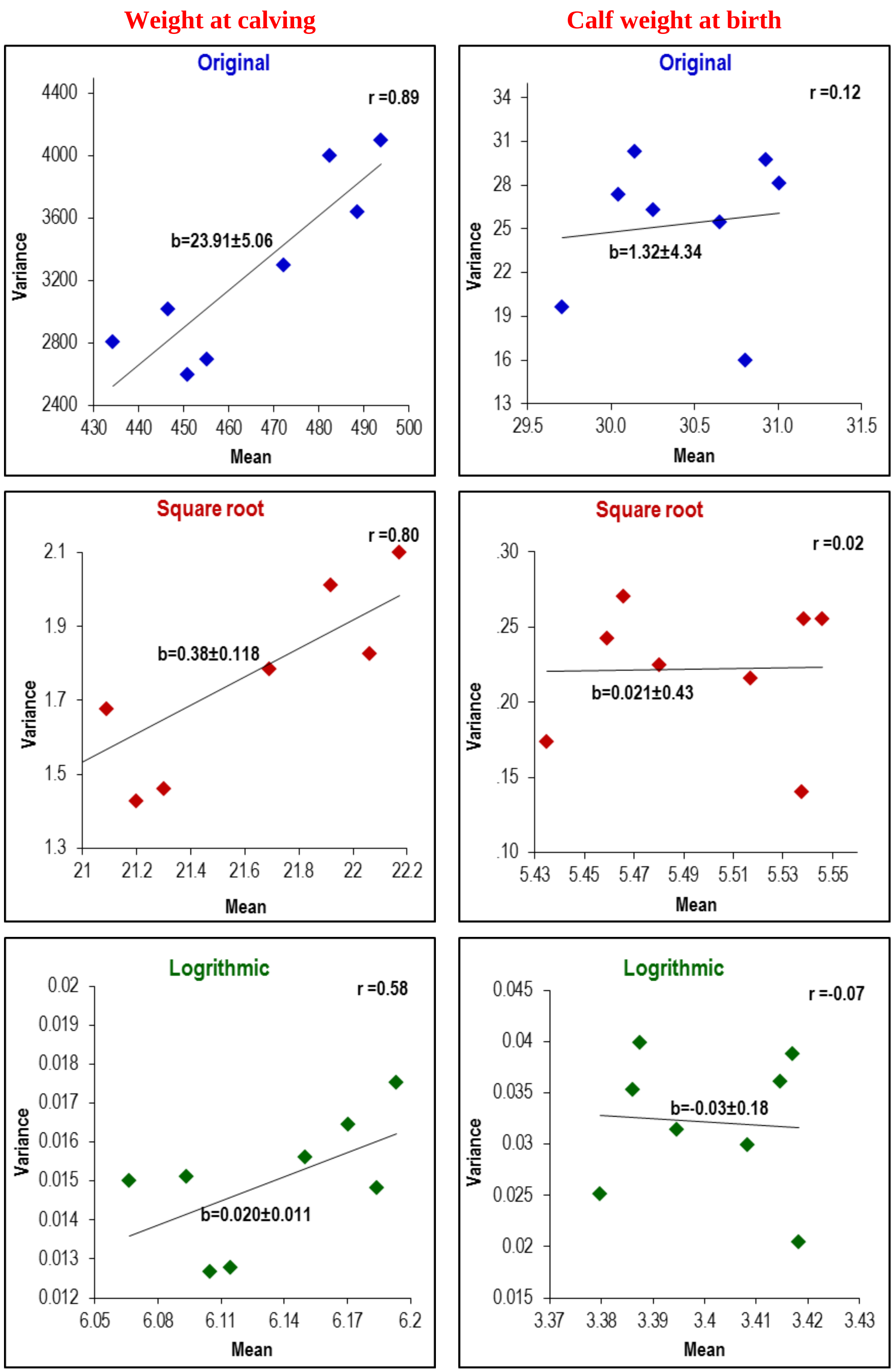


Fig. 12: Relation between mean and variance for weight at calving and calf weight at birth on original and transformed scales (Period wise)

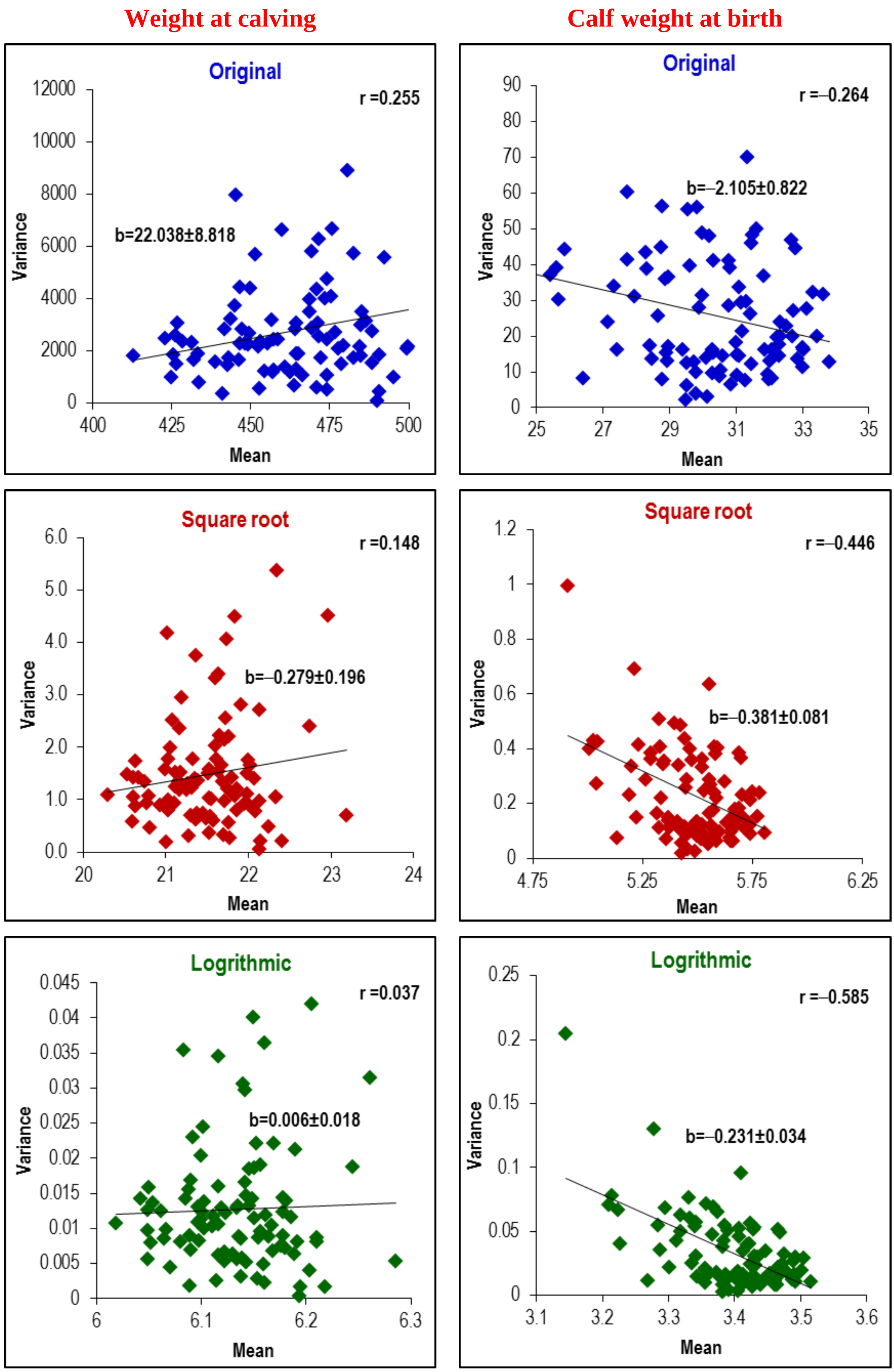


Fig. 13: Relation between mean and variance for weight at calving and calf weight at birth on original and transformed scales (Sire wise)

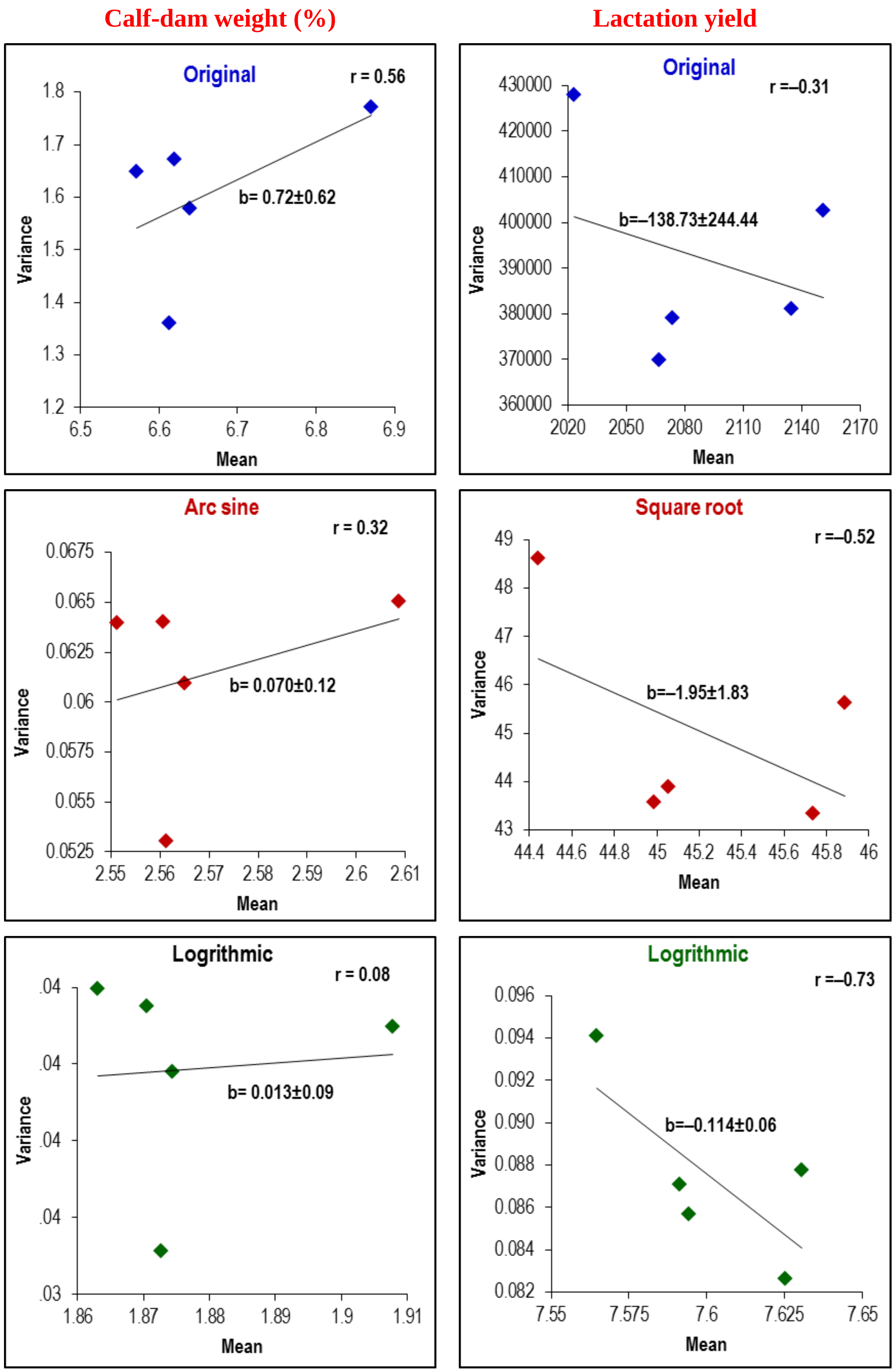


Fig. 14: Relation between mean and variance for calf-dam weight and lactation yield on original and transformed scales (Season wise)

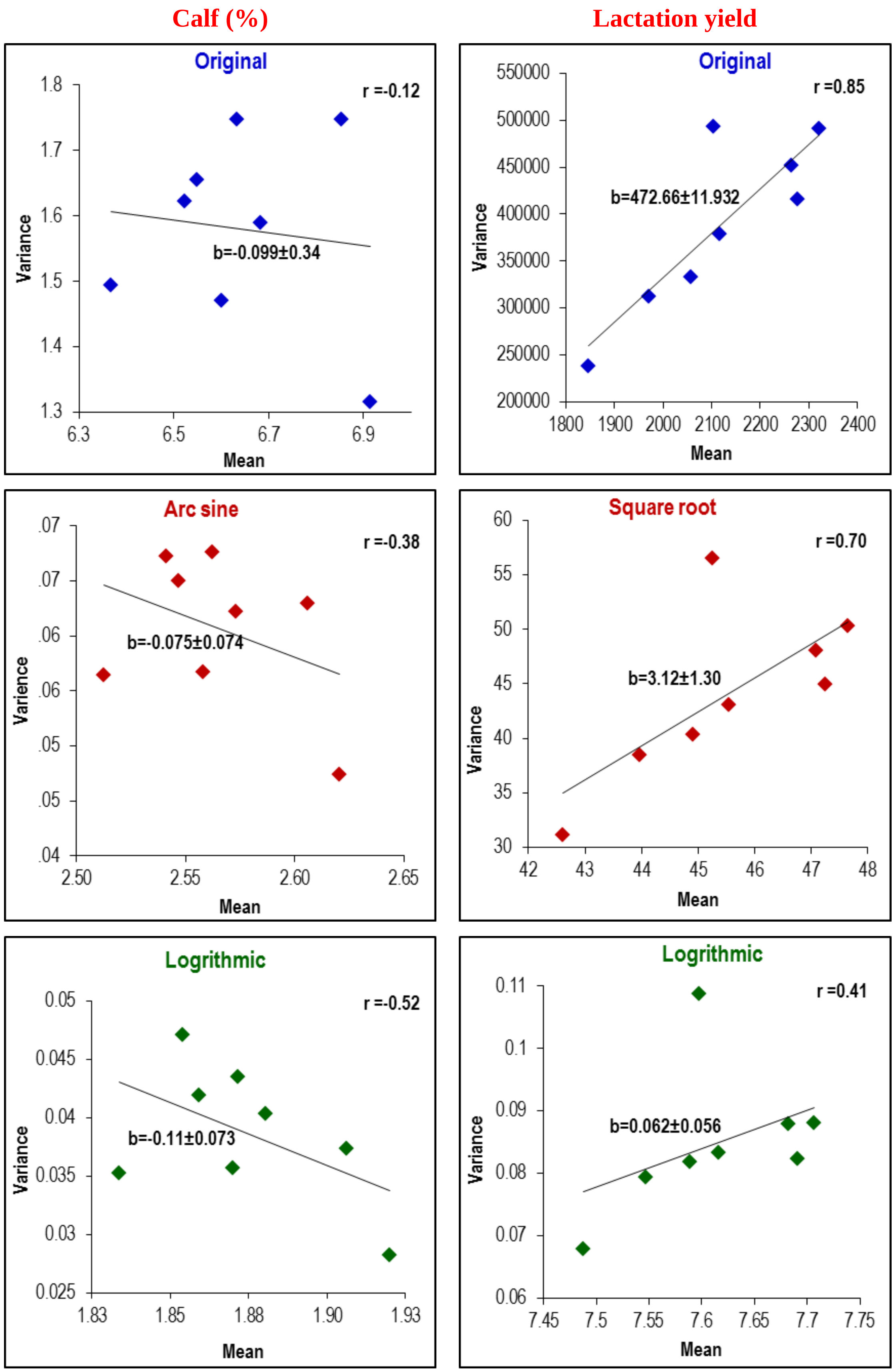


Fig. 15: Relation between mean and variance for calf (%) and lactation yield on original and transformed scales (Period wise)

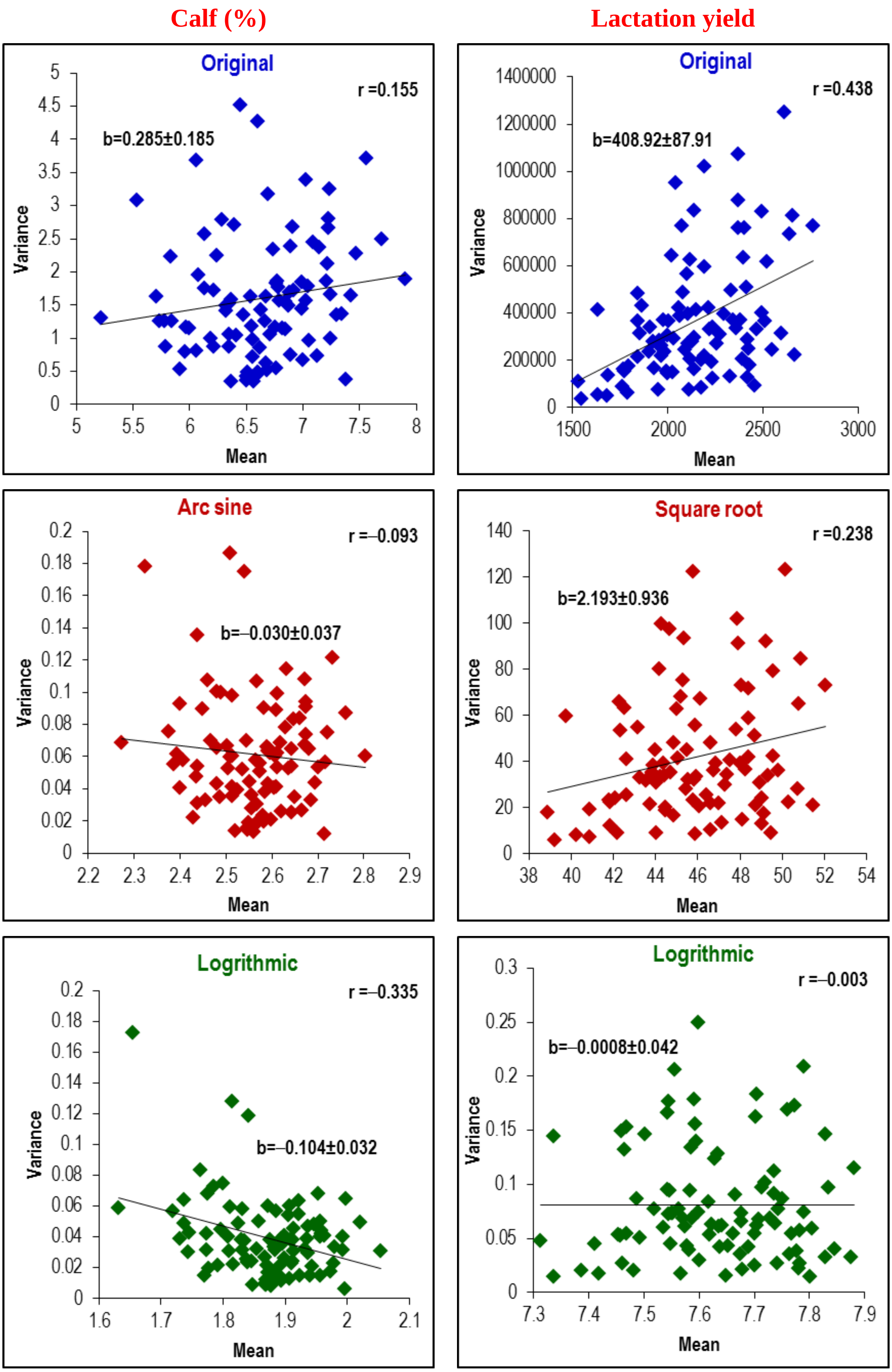


Fig. 16: Relation between mean and variance for calf (%) and lactation yield on original and transformed scales (Sire wise)

Lactation length 305 day milk yield

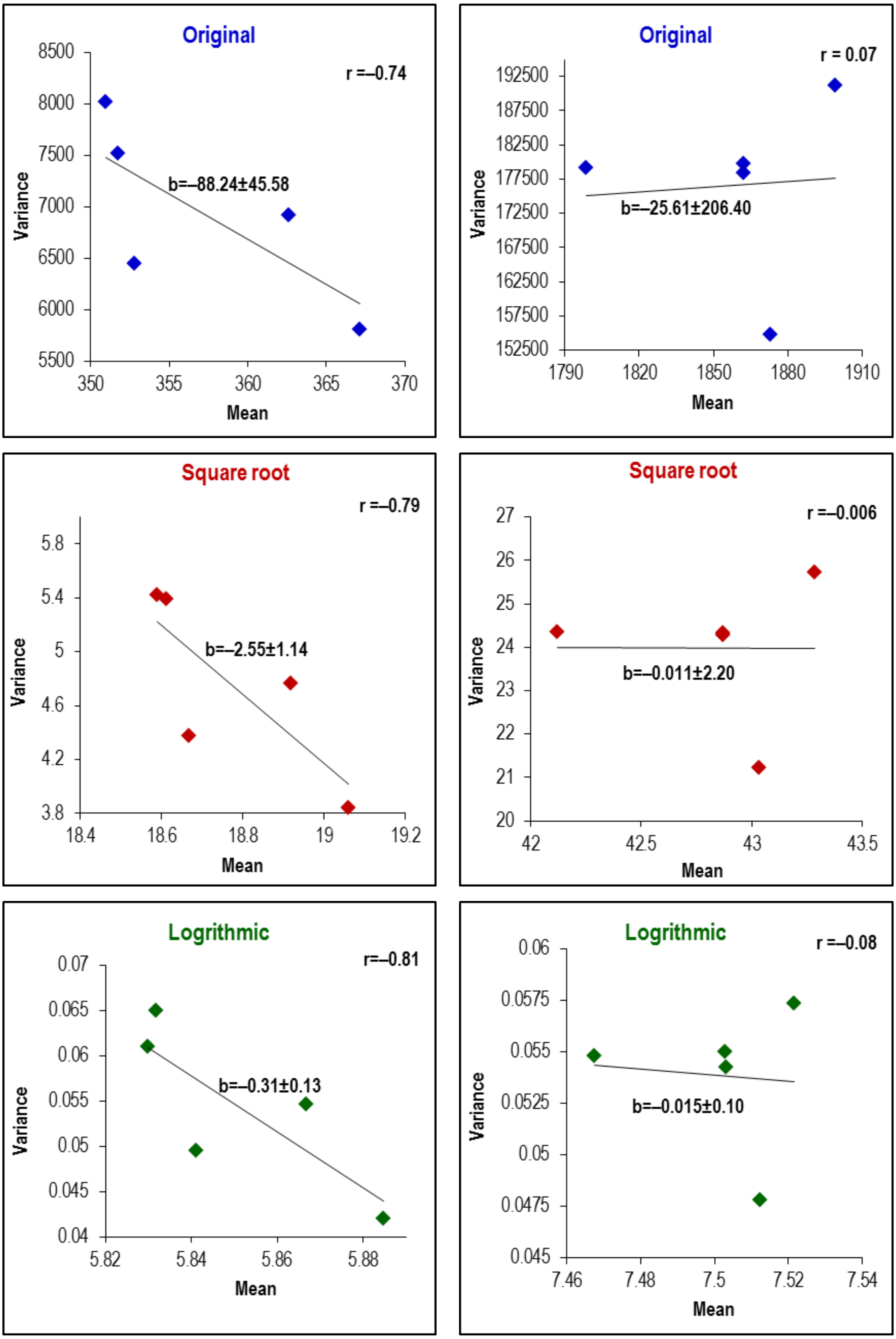


Fig. 17: Relation between mean and variance for lactation length and 305 milk yield on original and transformed scales (Season wise)

Lactation length 305 day milk yield

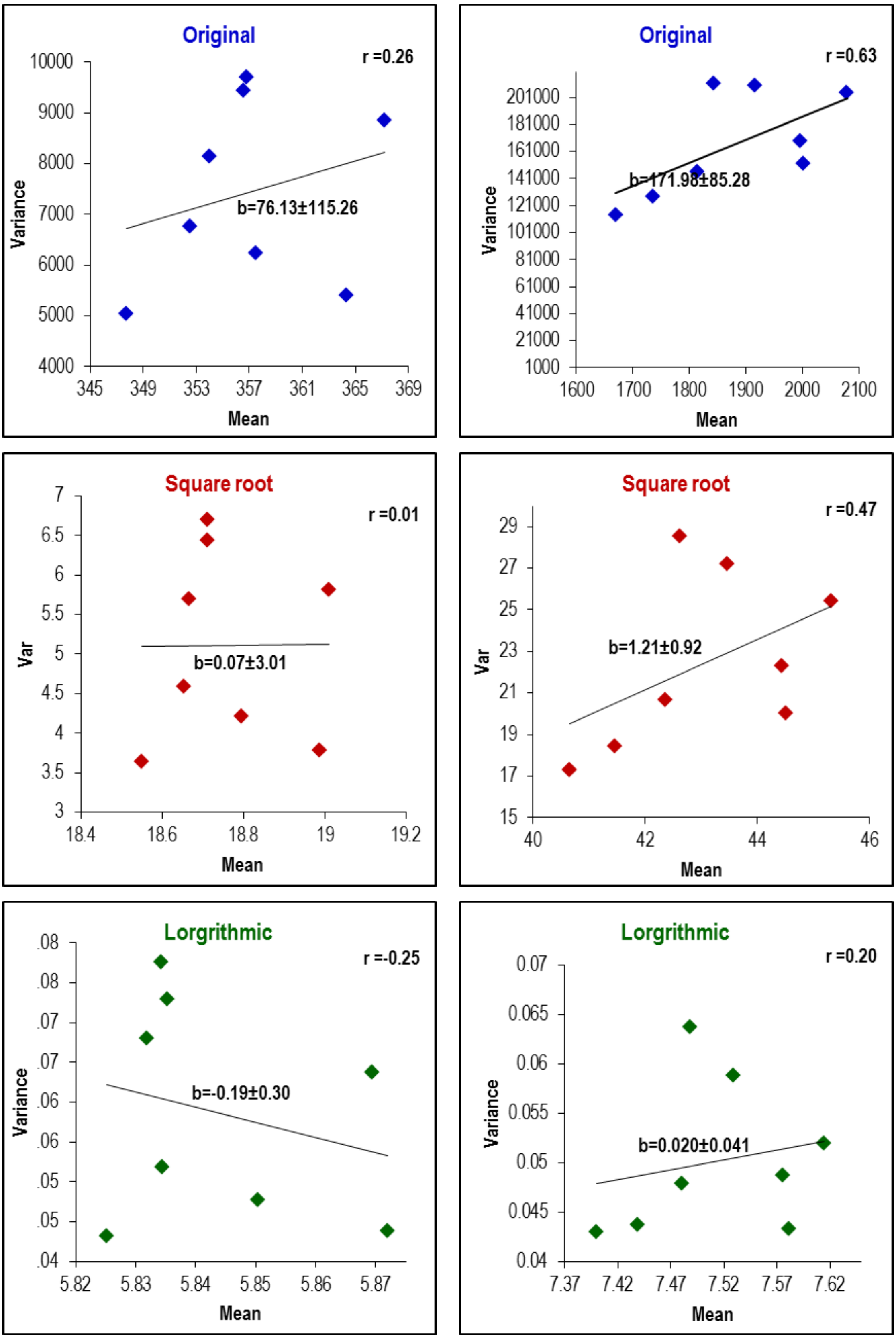


Fig. 18: Relation between mean and variance for lactation length and 305 day milk yield on original and transformed scales (Period wise)

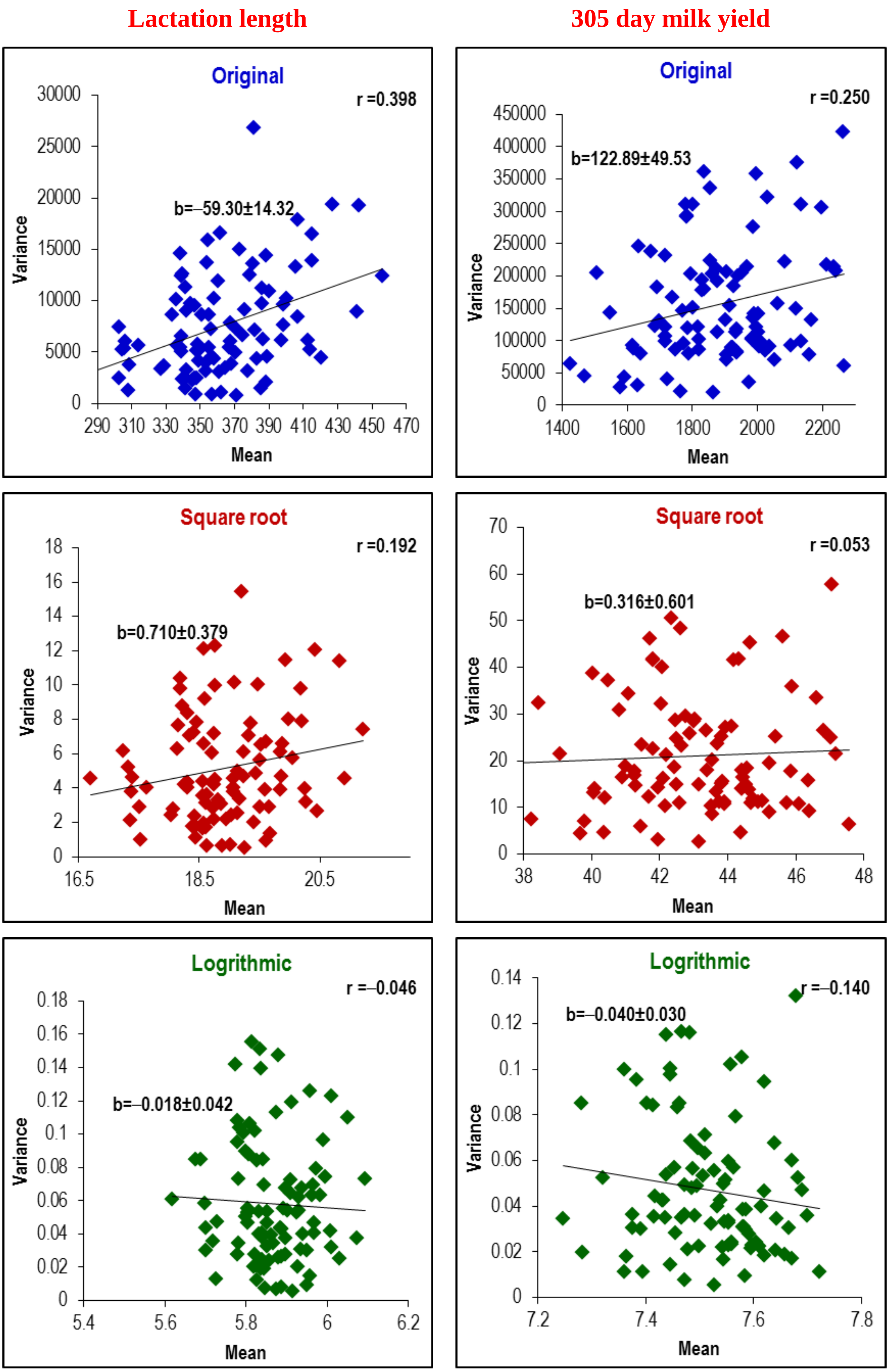


Fig. 19: Relation between mean and variance for lactation length and 305 day milk yield on original and transformed scales (Sire wise)

Fat (%) **Peak yield**

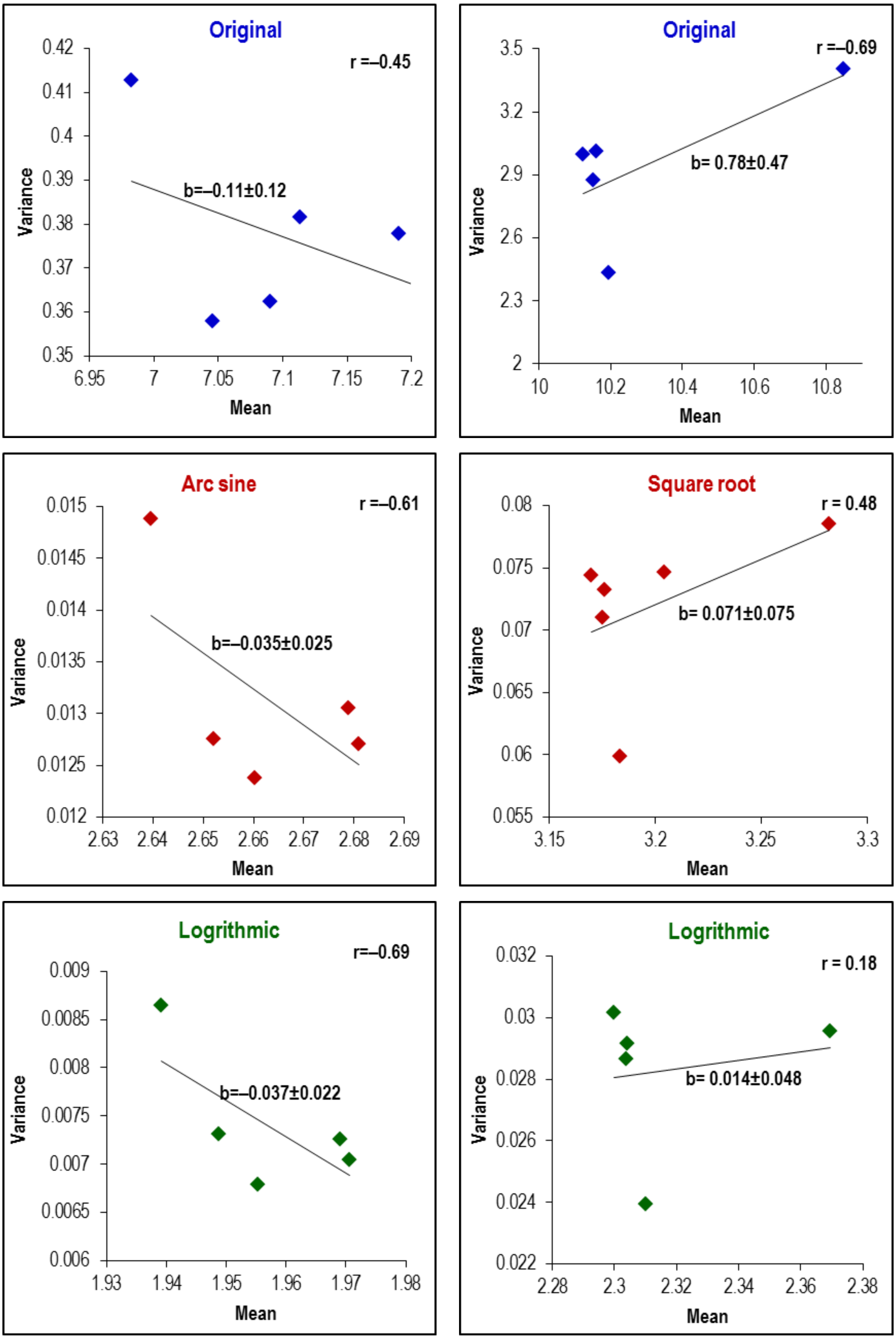


Fig. 20: Relation between mean and variance for fat (%) and peak yield on original and transformed scales (Season wise)

Fat (%) **Peak yield**

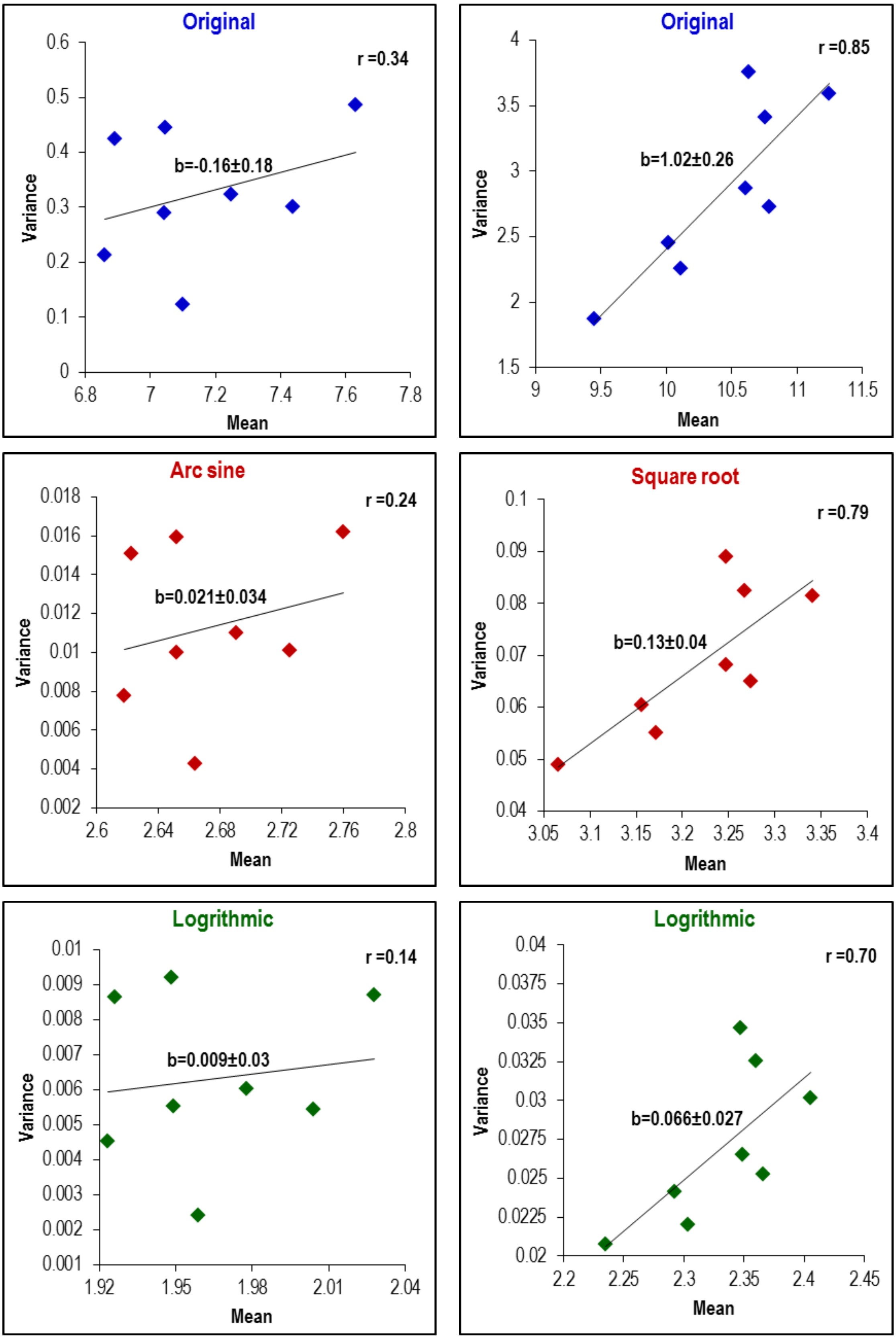


Fig. 21: Relation between mean and variance for fat (%) and peak yield on original and transformed scales (Period wise)

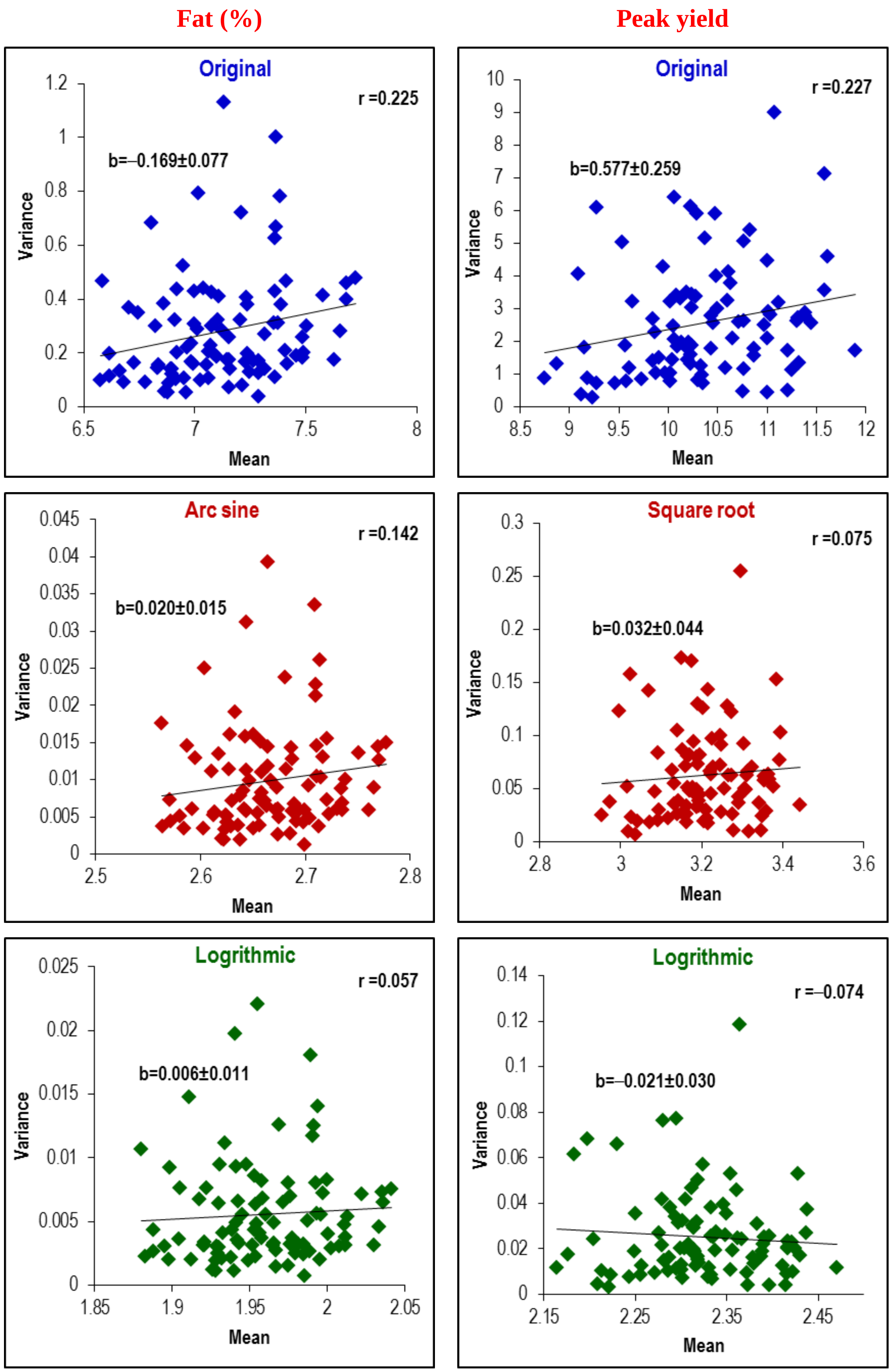


Fig. 22: Relation between mean and variance for fat (%) and peak yield on original and transformed scales (Sire wise)

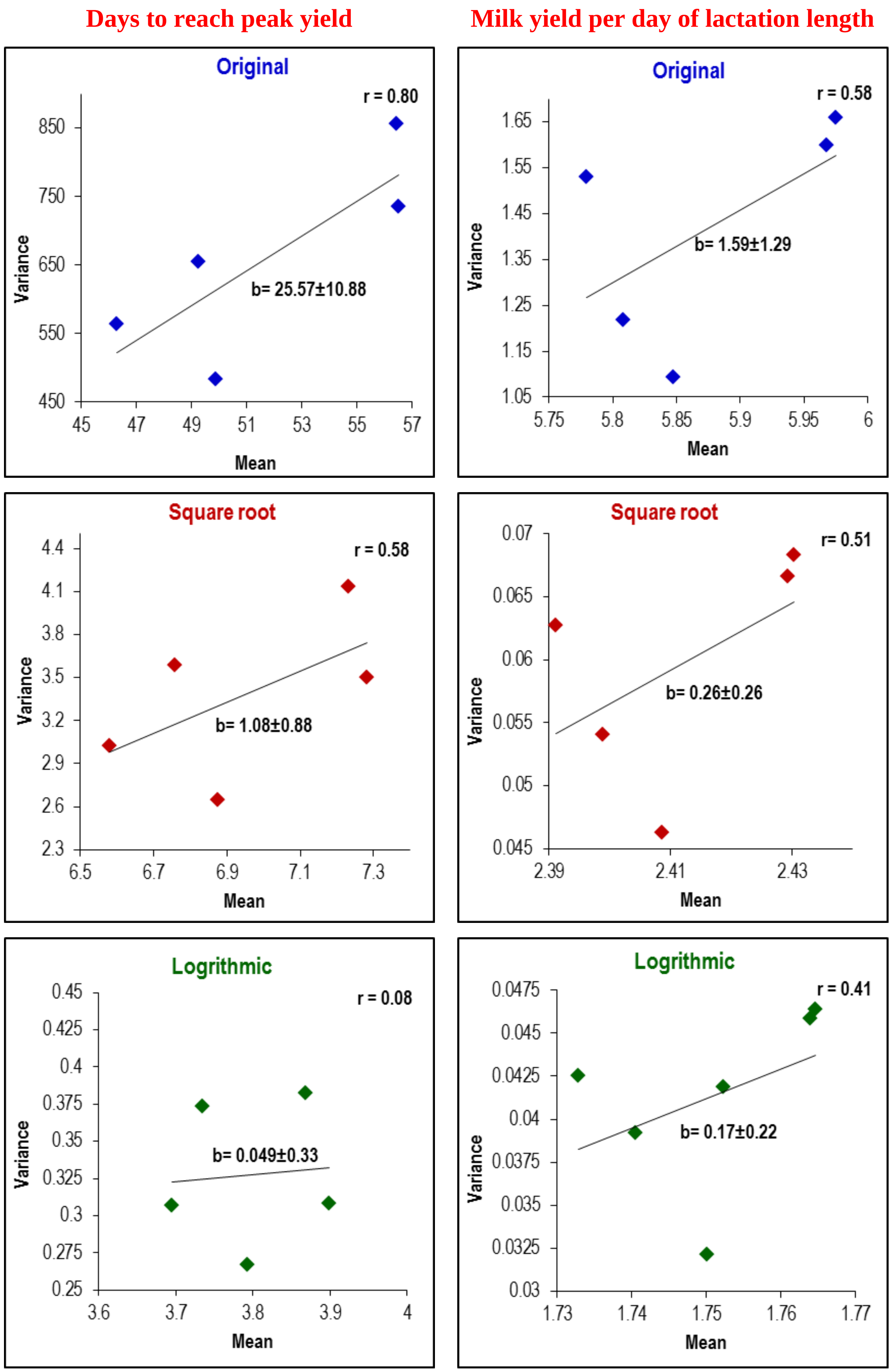


Fig. 23: Relation between mean and variance for days to reach peak yield and milk yield per day of lactation length on original and transformed scales (Season wise)

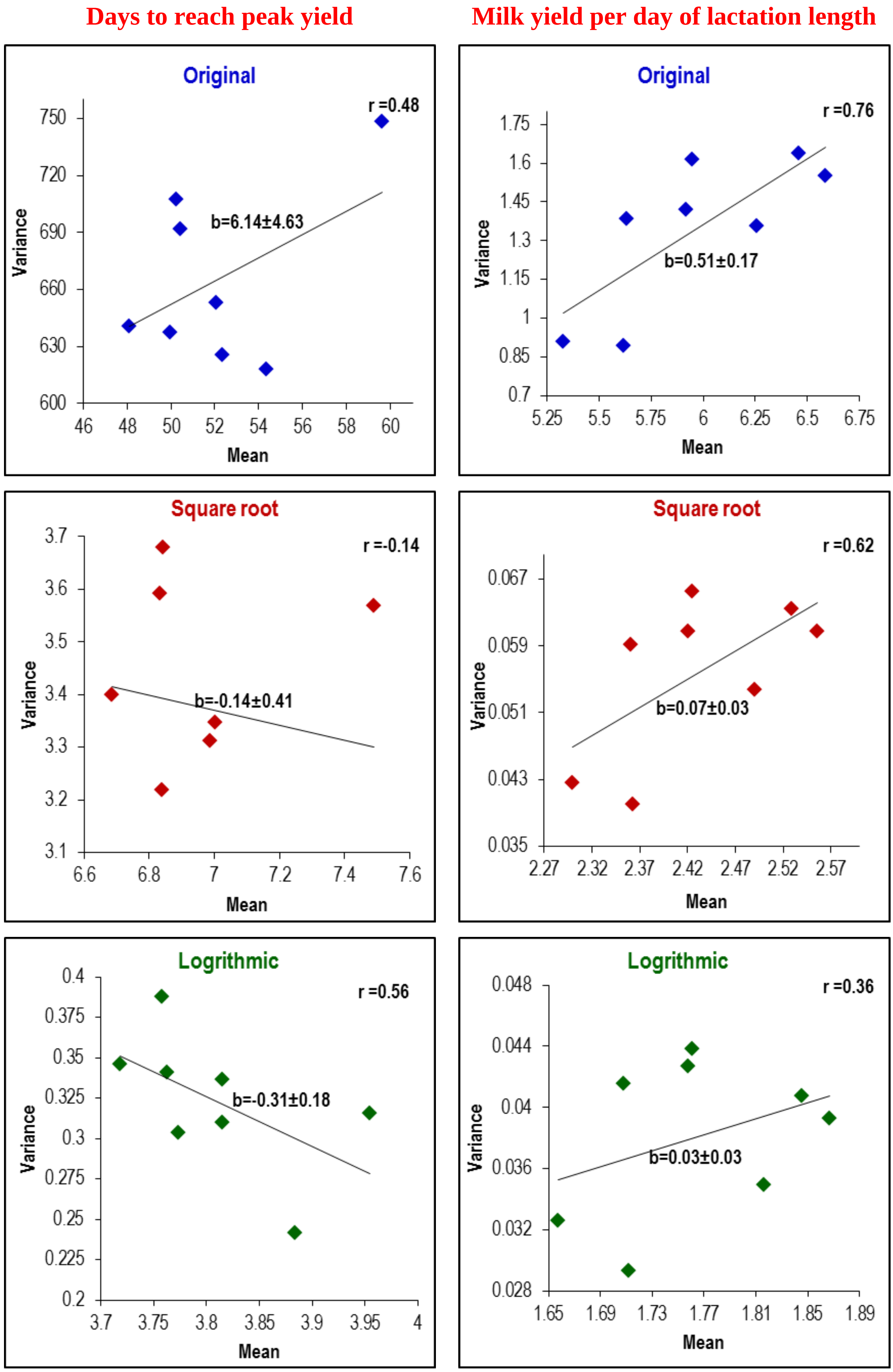


Fig. 24: Relation between mean and variance for day to reach peak yield and milk yield per day of lactation length on original and transformed scales (Period wise)

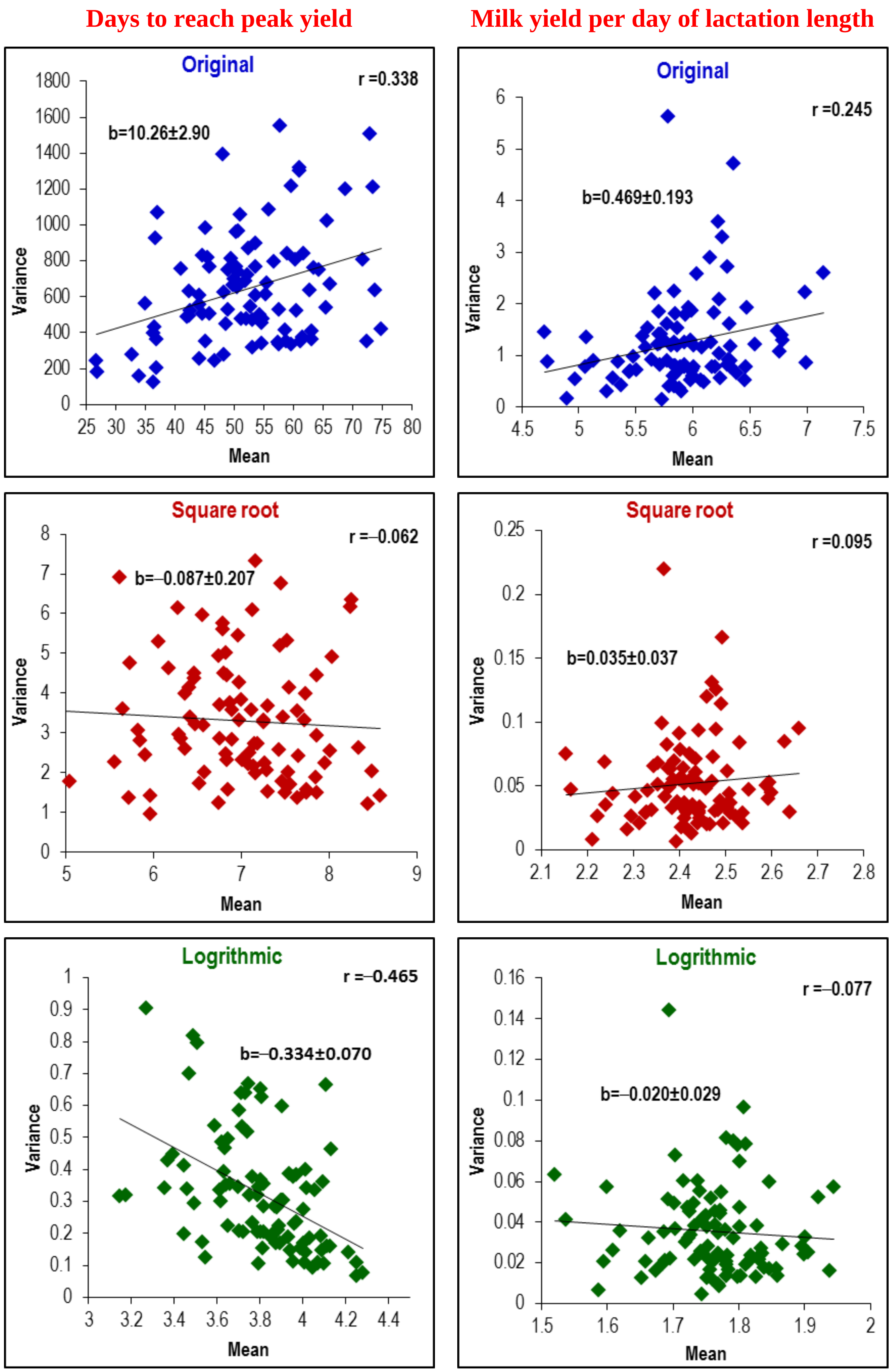


Fig. 25: Relation between mean and variance for days to reach peak yield and milk yield per day of lactation length on original and transformed scales (Sire wise)

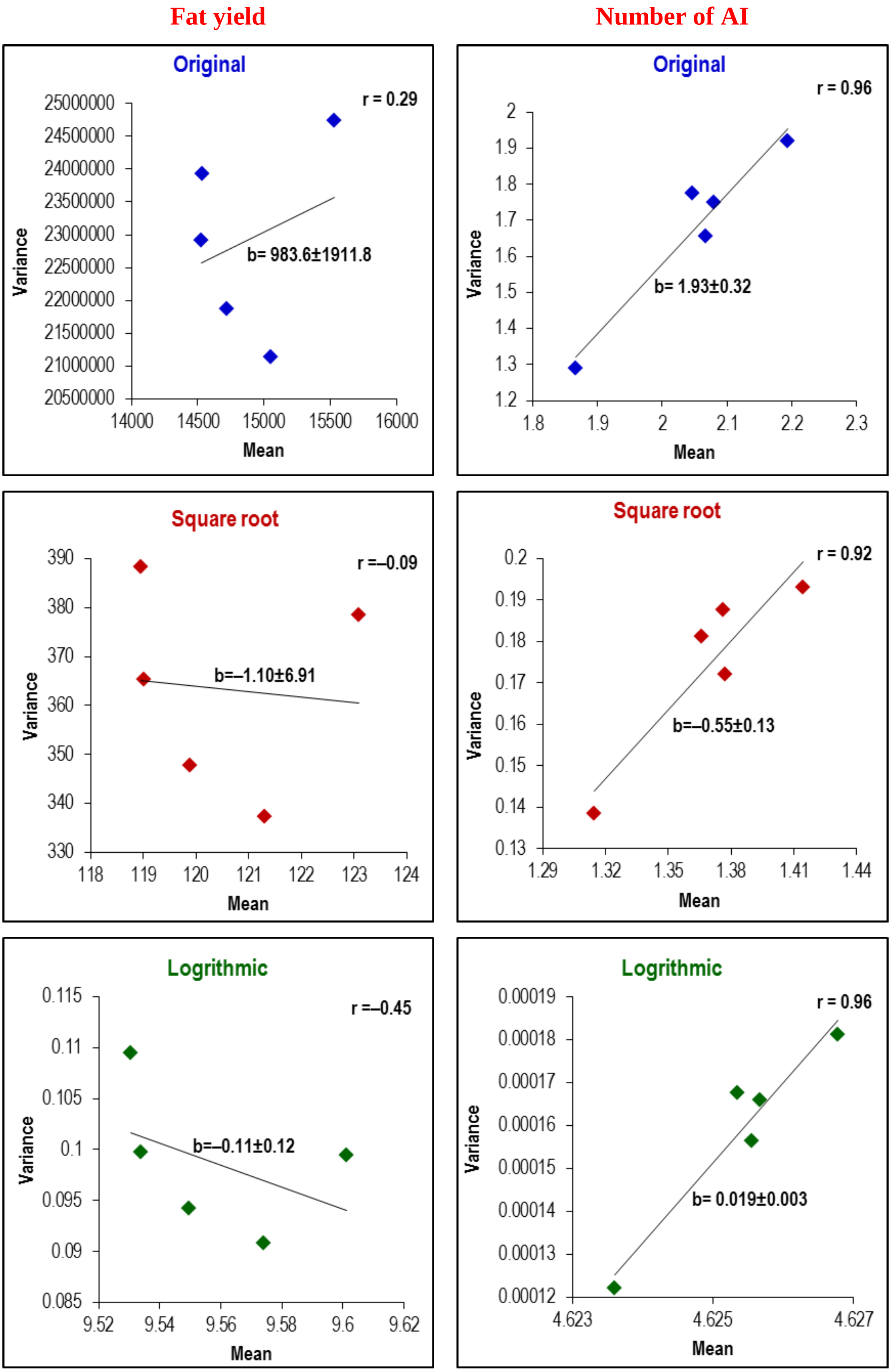


Fig. 26: Relation between mean and variance for fat yield and number of AI on original and transformed scales (Season wise)

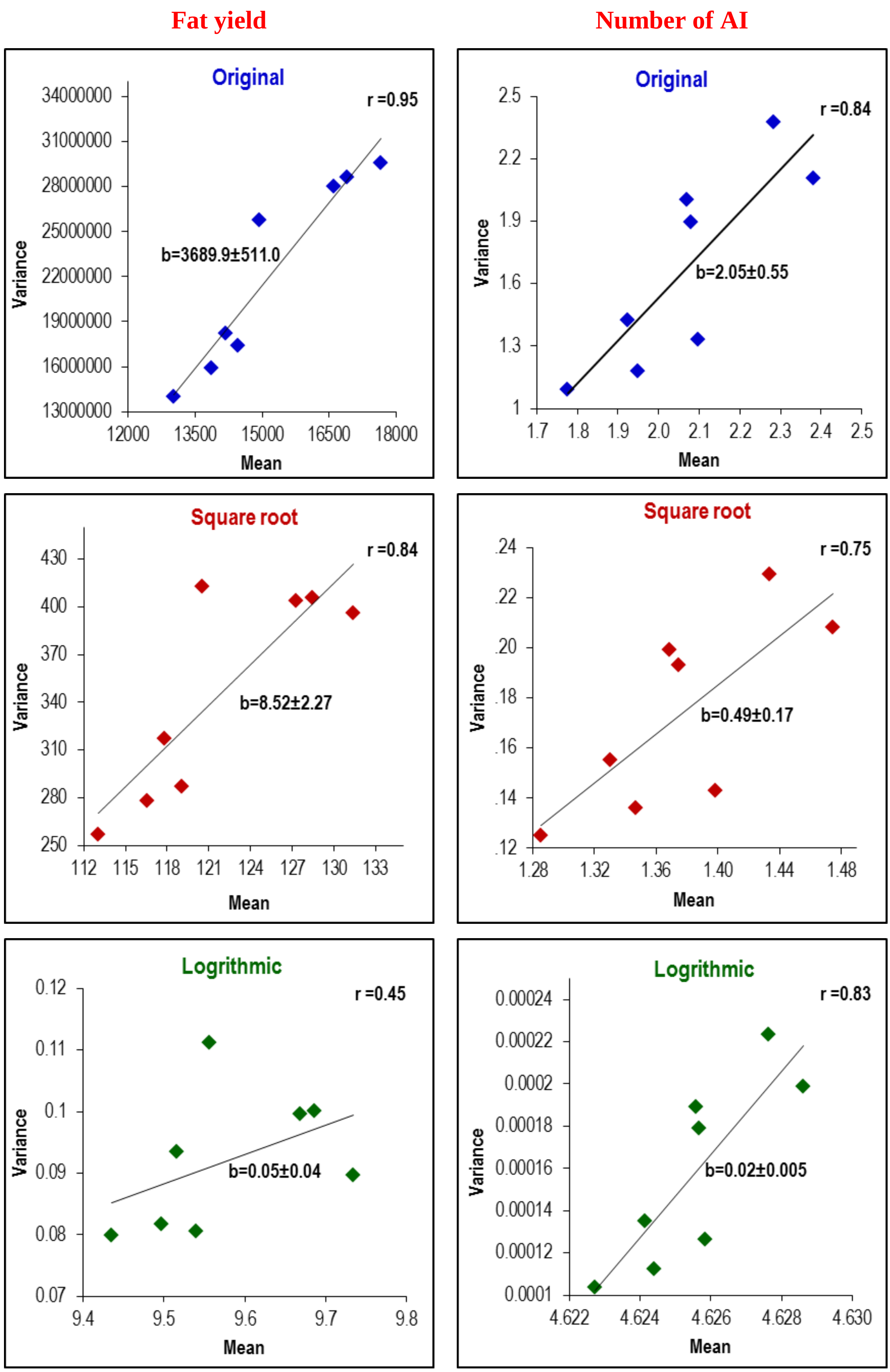


Fig. 27: Relation between mean and variance for fat yield and number of AI on original and transformed scales (Period wise)

Fat yield

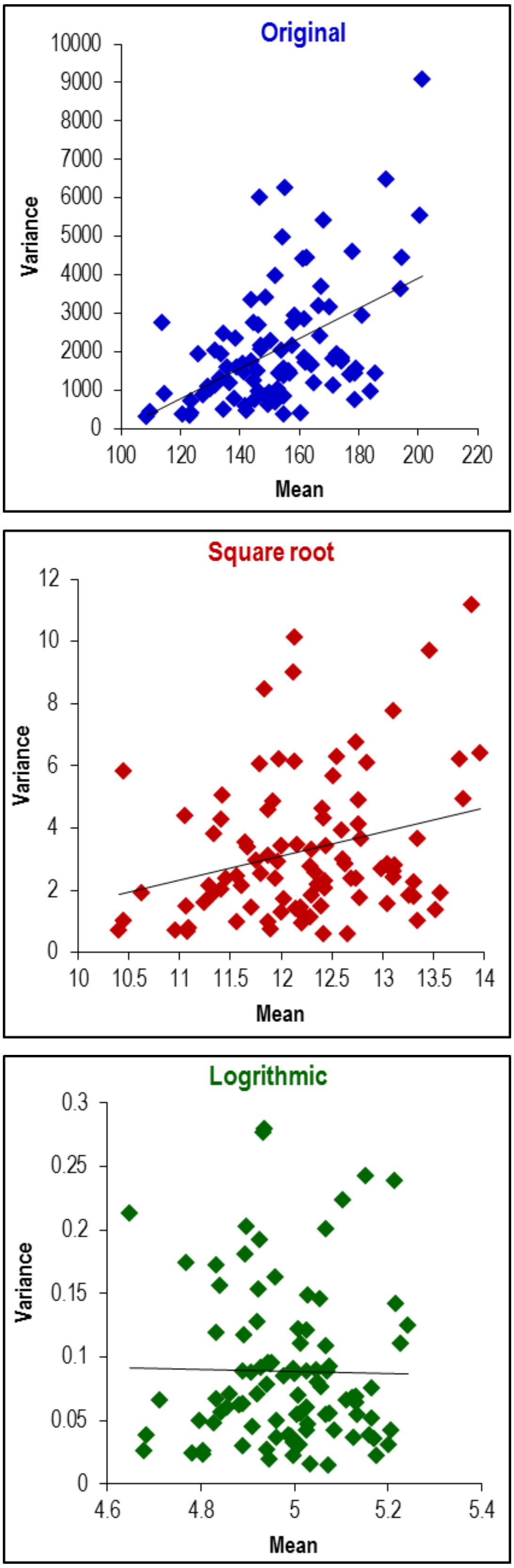


Fig. 28: Relation between mean and variance for fat yield on original and transformed scales (Sire wise)

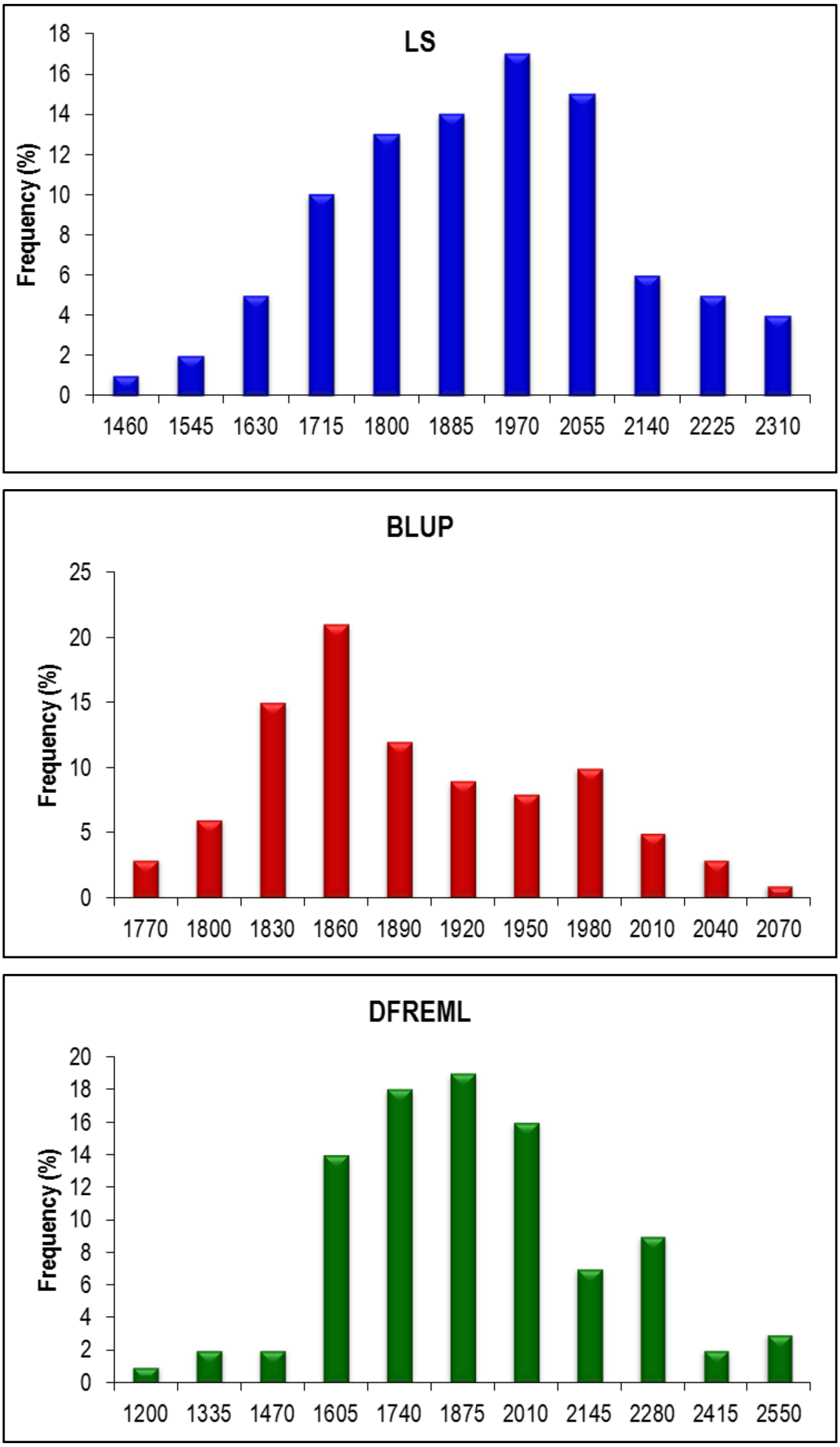


Fig. 29: Frequency distribution of breeding values for 305-day milk yield using various methods of sire evaluation

REFERENCES

Agrawal S B, Patel R K and Sharma K N S. 1987. Estimations of performance characteristics of Murrah buffaloes under village conditions. *Indian Journal of Dairy Sciences* **40**: 200-04.

Anacker G and Diett G. 1990. Predication of breeding value of progeny tested dairy bull sin the GErmnay Democratic republic by means of BLUP method. *Tierzucht* **44**(4): 157-59.

Animal Husbandry Statistics. 2010. Department of Animal Husbandry Dairying & Fisheries, Ministry of Agriculture, Government of India.

Annual Reprot. 2009-2010. National Dairy Research Institute, Karnal, India.

Ansari A K, Jain L S and Tailor S P. 1989. Estimation of heritability and correlation for body weights at different ages in medium-sized buffaloes. *Indian Journal of Animal Sciences* **59**: 1329-30.

Asghar A A. 1986. Studies required for progeny tested bulls to improve buffalo milk production in Punjab. *3rd Annual report.* Livestock Prod. Res. Inst. Bahadurnagar, Okara, Pakistan.

Aziz M A, Owen J B, Azhar S A, Mahdy A E and Shafie O M. 2003. Genetic and phenotypic variations of lactation length and total milk yield of Pakistan buffaloes. *Alexandria Journal of Agricultural Research* **48**: 11-22.

Badran A E, El-Barbary A, Bedeir L and Shafie O M. 2005. Inbreeding, genetic and environmental effects on the milk production traits in Egyptian buffaloes. *Buffalo Journal* **21**: 89-95.

Bahlaru S S and Dhillon J S. 1987. Studies on first lactation length in buffaloes. *Asian Journal of Dairy Research* **6**: 1-6.

Bajetha G. 2003. 'Genetic studies on some economic traits on Murrah buffaloes.' M.Sc. Thesis, GBPUA&T, Pantnagar.

Banik S and Gandhi R S. 2006. Animal model versus conventional methods of sire evaluation in Sahiwal cattle. *Asian Australian Journal of Animal Sciences* **19**(9): 1225-28.

Banik S and Tomar S S. 2002. Path analysis of 305-days milk yield in Murrah buffaloes. *Indian Journal of Dairy Sciences* **55**: 346-49.

Banik S. 2001. 'Direct and indirect effect of different characters on milk production of Murrah buffaloes – A path analysis'. M.Sc. Thesis, NDRI, Karnal, Haryana, India.

Banik S. 2004. 'Sire evaluation in Sahiwal cattle'. Ph.D. Dissertation, NDRI, Karnal, India.

Basavaiah P, Sharma K M S and Nagarcenkar R. 1978. Studies on lactation cerve in Murrah buffaloes. XX International Dairy Congress, Volume E, Paris, France Congrilait, 19-21 (*Animal Breeding Abstracts*) **47**: 1148.

Basavaiah P. 1978. ‘Genetic studies of lactation curve and its use in sire evaluation in Murrah buffaloes’. Ph.D. Dissertation, Panjab University, Chandigarh.

Basu S B and Ghai A S. 1978a. Studies on milk production in Murrah buffaloes. *Indian Journal of Animal Sciences* **48**: 593-96.

Basu S B and Ghai A S. 1978b. A note on the lactation length of Murrah buffaloes. *Indian Journal of Animal Sciences* **48**: 908-09.

Basu S B and Rao M K. 1979. Growth pattern in Murrah buffalo calves. *Indian Veterinary Journal* **56**: 570-74.

Basu S B and Sharma P A. 1982. Crossbreeding in buffaloes. A Review of Agro-Animal Sciences and Health. pp. 465-66.

Basu S B, Sharma P A and Nagarcenkar R. 1977. Selective breeding in Murrah buffaloes for economic characters. Annual Report, NDRI, Karnal, India, pp. 205-09.

Basu S B, Tomar O S and Ghai A S. 1979. Growth pattern in Murrah buffalo calves. *Indian Veterinary Journal* **56**: 570-74.

Basu S B, Tomar O S and Ghai A S. 1984. Genetic studies on sexual maturity traits of buffalo heifers. *Indian Journal of Animal Science* **54**: 14-18.

Bawa K S. 1975. ‘Heritabilities and genetic correlations among first, second and third lactation records in buffaloes’. M.Sc. Thesis, P.A.U. Ludhiana, India.

Becker W A. 1975. *Manual of Quantitative Genetics*. 3rd edn. Pub. Program in Genetics, Washington State University, Washington, USA.

Bhadula S K and Desai R N. 1972. Genetic studies on productive efficiency of early calvers in Murrah buffaloes. *Indian Journal of Animal Production* **3**: 66-73.

Bharati. 2004. ‘Genetic studies on some economic traits using animal model and construction of selection indices’. Ph.D. Dissertation, GB Pant University of Agriculture and Technology, Pantnagar.

Bhardwaj B . 2002. ‘Studies on growth rates in buffaloes’. M.V.Sc. Thesis, Punjab Agricultural University, Ludhiana.

Box G E P and Cox D R. 1964. An analysis of transformations. *Journal of the Royal Statistical Society, Series B,* **26**: 211-52.

Chakravarty A K and Rathi S S. 1983. Effect of set of sires and season of calving on efficiency of milk production in Murrah buffaloes under progeny testing programme. National symposium on Breeding Livestock for economic efficiency and second annual conference of Indian Society of Animal Breeding and Genetics, HAU, Hissar, 11-13 March, pp. 146.

Chandra K, Sharma R C and Kumar S. 2006. Inheritance of persistency of milk production in Murrah buffaloes. In: National Symposium on Conservation and Improvement of Animal Genetic Resources under Low Input System, 9-10 Feb., 2006, p. 172.

Chaurasia S K, Dhingra M M and Gurung B S. 1980. Factors affecting body weight at first calving and its relationship with age at first calving in Murrah buffaloes. *Indian Journal of Heredity* **12**: 17-18.

Chaurasia S K, Dhingra M M and Gurung B S. 1984. Studies on age at first calving and its correlation with some of the reproductive traits in Murrah buffaloes. *Indian Veterinary Journal* **61**: 222-26.

Chaurasia S K, Gurung B S and Dhingra M M. 1985. Studies on first service period and its correlation with reproductive traits in Murrah buffaloes. *Livestock Advisor* **8**: 23-26.

Chhikara B S, Balaine D S, Chaudhary S R and Chopra S C. 1978. Performance levels and culling patterns in Murrah buffalo herd. *Indian Journal of Dairy Science* **31**: 292-93.

Chourasia S K, Dhingra M M and Gurung B S. 1984. Studies on age at first calving and its correlation with some of the reproductive traits in Murrah buffaloes. *Indian Veterinary Journal* **61**: 222-26.

Chowdhary M S and Barhat N K. 1979. A note on inheritance of birth weight in Indian buffaloes. *Indian Journal of Animal Sciences* **49**: 222-24.

Cordovi J, Gurerra D and Menendez A. 1986. A study of evaluation of Holstein Friesian bulls. *Revista de Reproduction Animal* **12**: 17.

Cunningham E P. 1965. The evaluation of sires from progeny test data. *Animal Production* **7**: 221-31.

Dahama R S, Malik P S and Singh B. 1990a. Genetic analysis of birth weight in buffaloes. *Indian Veterinary Journal* **67**: 934-38.

Dahama R S. 1991. Factors affecting body weights in buffaloes. *Indian Veterinary Medical Journal* **15**: 34-37.

Danell B. 1982. Evaluation of sires on first lactation yield of Swedish dairy cattle. *Dissertation Abstract International* **43**: 33.

Das D and Balaine D S. 1985. Productive performance of Indian buffaloes. *Buffalo Bulletin* **4**: 63-66.

Dass G and Sadana D K. 2000. Inheritance of some economic traits in Murrah buffaloes. *Indian Journal of Animal Research* **34**(1): 46-48.

Dass G and Sharma R C. 1993. Genetic parameters of first lactation traits in Murrah buffalo. *Journal of Dairying Food and Home Science* **12**: 120-24.

Dass G and Sharma R C. 1994. Factors affecting milk production in Murrah buffaloes. *Indian Journal of Animal Research* **28**: 61-64.

Dass G. 1995. 'Studies on prediction of lactation yield on test day values in buffaloes'. Ph.D. Dissertation, NDRI Deemed University, Karanal, India.

Deb S M, Guranni M and Chacko C T. 1998. Comparison of sire evaluation methods under field conditions. *Indian Journal of Dairy Science* **51**: 210-15.

Dempfle L. 1977. Comparison of several sire evaluation methods in dairy cattle breeding. *Livestock Production Science* **4**(2): 129-39.

Deshpande K S and Umrikar U D. 1986. Factors affecting lifetime production in Murrah buffaloes. *Indian Journal of Dairy Science* **39**: 478-80.

Dhama R S, Malik P S and Singh B. 1991. Genetic analysis of age at first calving in Indian buffaloes. *Indian Veterinary Medical Journal* **15**:280-84.

Dhara S K. 1994. 'Prediction of breeding of milk production by multiple regression and principal component analysis in Murrah buffaloes'. M.Sc. Thesis, NDRI Deemed University, Karnal, India.

Dhinsa H S. 1963. Inheritance of some economic characters in Murrah buffaloes. *Indian Veterinary Journal* **40**: 352-61.

Duc N V, Verma R P, Thin C X and Tien N Q. 1993. Factors influencing the birth weight of Murrah calves in Vietnam. *Indian Journal Dairy Science* **46**: 540-42.

Ducrocq V and Besbes B. 1993. Solution of multiple trait animal models with missing data on some traits. *Journal of Animal Breeding and Genetics* **110**: 81-92.

Dutt G and Yadav M C. 1988a. Evaluation of the productive performance of Murrah buffaloes. *Indian Journal of Dairy Sciences* **41**: 8-11.

Dutt G and Yadav M C. 1988b. Evaluation of the reproductive performance of Murrah buffaloes. *Indian Journal of Dairy Science* **41**: 8-11.

Dutt G, Yadav M C and Singh C V. 1985. Factors affecting age at first calving in Nili and Murrah buffaloes. *Livestock Adviser* **10**: 51-53.

Dutt T and Taneja V K. 1994. Phenotypic and genetic parameters of age at first calving, first lactation milk yield and some measures of efficiency of production in Murrah buffaloes. *Indian Journal of Animal Science* **64**: 966-68.

Dutt T and Taneja V K. 1995. Genetic studies on first lactation length, first dry period and first calving interval in Murrah buffaloes. *Indian Journal of Animal Science* **65**: 339-40.

Dutt T, Bhushan B and Kumar S. 2001. First lactation and life time performance traits in Murrah buffaloes. *Indian Journal of Animal Science* **71**(5): 483-84.

El-Arain. 1986. 'Genetic analysis of Murrah buffalo herds'. Ph.D. Dissertation, Kurukshetra University, Kurukshetra, India.

El-Arian M N S and Tripathi V N. 1987. Genetic and phenotypic trends in productive and reproductive traits of Murrah buffalo. *Buffalo Journal* **3**: 141-46.

Espinosa A P, Rodriguez A F, Jimenez C J, Espinoza V J L and Nunez D R. 2001. Genetic evaluation of Holstein dairy herd in Baja California Sur utilizing an animal model with repeated measurements. *Agrociencia* **35**: 347-53.

FAO Statistics. 2008. Food and Agriculture Organization of the United Nations, Rome.

Fisher R A. 1958. *Statistical methods for research workers*. 13th edition Hanfer, New York, pp. 138.

Gajbhiye P U and Tripathi V N. 1991. Factors affecting peak yield and days to attain peak yield in Murrah buffaloes. *Asian Journal of Dairy Science* **10**(3): 166-68.

Gajbhiye P U and Tripathi V N. 1999. Effect of season, period and age at first calving on first lactation traits in Murrah buffaloes. *Indian Journal of Dairy Science* **52**: 199-203.

Gajbhiye P U. 1987. 'Evolving restricted indices for selection of buffaloes'. Ph.D. Dissertation, Kurukshetra University, Kurukshetra, Haryana.

Gandhi R S and Gurnani M. 1991. Accuracy of different methods of sire evaluation in Sahiwal cattle. *Indian Veterinary Journal* **68**: 659-62.

Gandhi R S. 2002. Evolving multi-trait criteria in Murrah buffaloes. *Buffalo Journal.* **2**: 183-92.

Garcha D S and Tiwana M S. 1980. Effect of some environmental and physiological factors on persistency of milk yield in buffaloes. *Indian Journal of Dairy Science* **50**: 612-15.

Gaur G K and Raheja K L. 1996. Comparison of sire evaluation procedures and relationship between estimates of sires' breeding values for production traits in sahiwal. *Indian Journal of Animal Science* **66**: 735-37.

Gaur G K, Tripathi V N, Mukherjee S and Chaudhary V K. 2001. Efficiency of sire evaluation procedure in Frieswal Cattle. *Indian Journal of Veterinary Research* **10**: 1-6.

Geetha E. 2005. 'Studies on breeding values for persistency in Murrah buffaloes'. M.Sc. Thesis, NDRI, Karnal, Haryana, India.

Gill G S and Parmar O S. 1988. Genetic merit of Red Dane bull used in crossbreeding project. *Indian Journal of Animal Sciences* **58**: 811-13.

Godara P. 1989. 'Studies on projection of milk production level from progressive records in Murrah buffaloes'. M.V.Sc. Thesis, Haryana Agricultural University, Hisar, India.

Gogoi P K, Das D, Goswami R N, Nahardeka N and Das G C. 2002. Studies on age at first calving in Murrah and Surti buffaloes maintained in Assam. *Indian Veterinary Journal* **79**(8): 854-55.

Gogoi P K, Johar K S and Singh A. 1984. A note on lactation period in Murrah buffaloes. *Indian Veterinary Medicine Journal* **8**: 192-93.

Gogoi P K, Johar K S and Singh A. 1985. Genetic analysis of milk yield in Murrah buffaloes. *Indian Veterinary Medicine Journal* **62**: 970-75.

Gogoi P K, Johar K S and Singh A. 1986. Factors affecting dry period in Murrah buffaloes. *Indian Veterinary Medicine Journal* **63**: 340-41.

Gokhale S B and Nagarcenkar R. 1979. Relationship of age and weight on first calving with monthly and cumulative monthly first lactation milk yield in Murrah buffaloes. *Indian Journal of Animal Genetics and Breeding* **1**: 78-81.

Gokhale S B and Nagarcenkar R. 1980. First lactation partial records in relation to lifetime production in Murrah buffaloes. *Indian Journal of Animal Science* **50**(6): 928-31.

Gokhale S B. 1974. 'Inheritance of part lactation and their use in selection among Murrah buffaloes'. Ph.D. Dissertation, Agra University, Agra, India.

Goswami S B and Nair A P. 1965. Influence of inheritance, season and period of birth and body weight at birth of the Murrah buffaloes on the age of first calving. *Indian Journal of Dairy Sciences* **18**: 137-40.

Graser H U, Smich S P and Tier B. 1987. A derivative-free approach for estimating variance components in animal models by restricted maximum likelihood. *Journal of Animal Sciences* **64**: 1362-70.

Gudi A K and Narayankhedker S G. 1977. Effect of different environmental factors on age at first calving in buffaloes at Aarey Milk Colony, Bombay-65. *Indian Veterinary Journal* **54**: 33-35.

Gudi A K, Sohoni A D and Tatke M B. 1971. Studies of some factors influencing birth weight of Murrah buffalo calves. *Indian Journal of Animal Sciences* **41**: 1120-22.

Gupta B D, Kaushik S N and Mishra R R. 1994. Study on reproduction efficiency parameters of Murrah buffaloes. *Indian Journal of Dairy Science* **47**(4): 257-64.

Gupta J P, Sachdeva G K, Gandhi R S and Chakarvarty A K. 2012. Non-genetic factors influencing growth and production performance in Murrah buffaloes. *Indian Journal of Dairy Science* **65**(3): 239-41.

Gupta J P. 2009. 'Evolving selection criteria using growth and production traits in Murrah buffaloes'. M.V.Sc. Thesis, NDRI, Karnal, India.

Gurnani M and Nagarcenkar R. 1977. Measurement of genetic change in economic traits of dairy animals. *Annual Report NDRI Karnal*, pp. 106-08.

Gurnani M and Nagarcenkar R. 1982. Comparison of breeding value of sires by Henderson's BLUP and Robertson's method in 2nd World Congress on applied to Livestock Production, 4-8 October, 1982, Madrid Spain Ed. Garsi (1982): (*Animal Breeding Abstracts* **51**: 1459).

Gurnani M, Nagarcenkar R and Gupta S K. 1976. Performance of different lactation and repeatability of economic characters in Murrah buffaloes. *Indian Journal of Dairy Science* **29**: 117-20.

Gurung B S and Johar K S. 1982a. Note on the correlation between birth weight and economic traits in Murrah buffaloes. *Indian Journal of Animal Sciences* **52**: 254-56.

Gurung B S and Johar K S. 1982b. Studies on growth measures in Murrah buffaloes. *Indian Veterinary Journal* **59**: 292-97.

Gurung B S and Johar K S. 1982c. Studies on factors affecting first lactation yield in Murrah buffalos. *Indian Veterinary Journal* **59**: 521-26.

Gurung B S and Johar K S. 1983a. Effect of genetic and non-genetic factors on birth weight of Murrah buffalo calves. *Indian Veterinary Journal* **60**: 205-09.

Gurung B S and Johar K S. 1983b. Genetic architecture of body weights in Murrah buffaloes. *Indian Veterinary Journal* **60**: 365-70.

Gurung B S and Johar K S. 1984. Studies on relationship between different growth, productive and reproductive traits in Murrah buffaloes. *Indian Veterinary Journal* **61**: 137-42.

Gurung S B and Johar K S. 1982. Studies on body weight at first calving and its relationship with productive and reproductive traits in Murrah buffaloes. *Indian Veterinary Journal* **59**: 939-43.

Haggar C and Dempfle L. 1981. What can be gained by the BLUP procedure under various circumstances? Paper 32nd Annual Meeting of the European Association for Animal Production. **6**: 6.

Harvey W R. 1987. Mixed model least square and maximum likehood computer programme PGI-1 version.

Harvey W R. 1990. Users guide for mixed model Least Square and Maximum Likelihood Computer Porgram (PC-2 version) USDA-ARS.

Harville D A. 1977. Maximum likelihood approaches to variance component estimation and to related problems. *Journal of American Association* **72**: 320-40.

Hatwar R K and Chawla D S. 1987. Heritability estimates of various first lactation traits obtained by using adjusted and unadjusted records in Murrah buffaloes. *Asian Journal of Dairy Research* **6**: 169-70.

Hatwar R K and Chawla D S. 1988. Least square means of various first lactation traits and milk constituents of Murrah buffaloes. *Indian Journal of Animal Science* **58**: 988-90.

Henderson C R and Quass R L. 1976. Multiple trait evaluation using relatives' records. *Journal of Animal Sciences.* **43**: 1188-97.

Henderson C R. 1953. Estimation of variance and covariance components. *Biometrics* **9**: 226-52.

Henderson C R. 1973. Sire evaluation and genetic trend. *Proceedings of Animal Breeding and Genetics Symposium* in honour of Dr. J.L. Lush, ASAS and ADSA Champaign, Illinois, pp. 10-41.

Henderson C R. 1974. General flexibility of linear model techniques for sire elevation. *Journal of Dairy Science* **57**: 963-72.

Henderson C R. 1975a. Use of relationship among sires to increase accuracy of sire evaluation. *Journal of Dairy Science* **58**: 1731-38.

Henderson C R. 1975b. Use of all relatives in intra herd prediction of breeding values and producing abilities. *Journal of Dairy Science* **58**: 1910-16.

Henderson C R. 1976. Multitrait sire evaluation using the relationship matrix. *Journal of Dairy Science* **59**(4): 769-74.

Iype S and Nagarcenkar R. 1992. Influence of non-genetic factors on part and 300 days first lactation milk yield in Murrah buffaloes. *Journal of Dairying Food and Home Science* **11**: 50-54.

Iype S. 1980. First lactation milk yield. First lactation period and weight at first calving in Murrah buffaloes. *Kerala Veterinary Science* **11**: 15-19.

Jahageerdar S, Govin daiah M G and Jayashankar M R. 1996. Genetic studies on maturity traits in buffaloes. *Indian Journal of Animal Sciences* **66**: 54-58.

Jain A and Sadana D K. 1998. Effect of genetic and non-genetic factors on first lactation traits in Murrah buffaloes using alternate models. *Indian Journal of Animal Science* **68**: 950-53.

Jain A and Sadana D K. 2000. Heritability estimation under single and multi-trait animal models in Murrah buffaloes. *Asian-Australian Journal of Animal Science* **13**: 575-79.

Jain A and Taneja V K. 1982. Effect of non-genetic factors on reproduction and production traits in Murrah buffaloes. *Asian Journal of Dairy Science* **1**: 123-29.

Jain A. 1996. 'Sire evaluation under multiple traits models in Murrah buffaloes'. Ph.D. Dissertation, NDRI, Karnal, India.

Jain J P and Malhotra J C. 1971. Comparative study of different methods of indexing sires'. *Indian Journal of Animal Science* **41**: 1101-08.

Jawarkar K V and Johar K S. 1975a. Studies on the effect of period and sequence of lactation on the lactation period of Murrah buffaloes. *Indian Journal of Animal Sciences* **45**: 1-3.

Jawarkar K V and Johar K S. 1975b. A genetic study on milk yield in Murrah buffaloes. *Indian Veterinary Journal* 426-30.

Jogi S and Lakhani G P. 1996. Study of body weights, rate of gain and mortality percentage in Murrah buffalo calves. *Buffalo Bulletin* **15**: 51.

Johri D C and Bhat P N. 1979a. Effect of genetic and non-genetic factors on body weight in buffaloes. *Indian Journal of Animal Sciences* **49**: 597-603.

Johri D C and Bhat P N. 1979b. Effect of genetic and non-genetic factors on production traits in buffaloes. *Indian Journal of Animal Science* **49**: 984-91.

Johri D C. 1976. Evaluation of Indian buffaloes (1) Growth. *Indian Veterinary Journal* **53**: 943-47.

Kabat S and Zarneeki A. 1980. Estimating breeding value of bulls using least squares and maximum likelihood methods. *Proceedings of 31st Annual Meeting, European Association for Animal Production*.

Kanaujia A S and Balaine D S. 1975. Factors affecting some production traits in Indian buffaloes. *Indian Journal of Dairy Science* **28**: 57-61.

Kanaujia A S. 1973. Genetic and economic investigations in buffaloes (*Bubalus bubalis*). Ph.D. Dissertation, Haryana Agricultural University, Hissar, India.

Kandaswamy N, Ulaganathan V and Krishnan A R. 1991. Genetic analysis of milk yield per day of age at second calving in Murrah buffaloes. *Indian Journal of Dairy Science* **44**: 519-21.

Kandaswmy N, Logiathaan V V and Krishan A R. 1993. Non-genetic factors affecting calving interval and dry period of Murrah buffaloes. *Buffalo Bulletin* **12**:63-65.

Katneni V K. 2007. 'Studies on genetic persistency of milk production in Murrah buffaloes'. Ph.D. Dissertation, NDRI, Karnal, India.

Kaushish S K. 1997. Factors affecting body weight of Murrah calves. *Indian Journal of Animal Sciences* **67**: 1117-18.

Khan F H and Johar K S. 1988. Cumulative part production records as an aid to selection in Murrah buffaloes. *Indian Journal of Dairy Sciences* **41**: 346-50.

Khan M A, Mohinddin G and Javed K . 1996. Inheritance of some performance traits in buffaloes. Proc. 2nd ABA congress, October 9-12, Manila, Philippines.

Khan M Q, Ali S Z and Pingle S S. 1987. Effect of month of calving on total lactational yield in Murrah buffaloes. *Livestock Advisor* **8**: 5-7.

Khosla S K, Gill G S, Parmer O S and Malhotra P K. 1985. Factors affecting peak yield and yield per day of lactation in buffaloes field conditions. *Journal of Research PAU* **22**: 747-52.

Khosla S K, Gill S S and Malhotra P K. 1984a. Effect of non genetic factors on lactation yield in herd book registered Murrah buffaloes under village conditions. *Indian Journal of Animal Science* **54**: 1-5.

Khosla S K, Gill S S and Malhotra P K. 1984b. Effect of some non-genetic factors on age at calving and service period in herd book registered Murrah buffaloes under village conditions. *Indian Journal of Animal Science* **54**: 407-12.

Khushwaha G S, Basi S B and Sengar O P S. 1972. Inheritance of part lactations in Murrah buffaloes. *Indian Journal of Dairy Sciences* **48**: 353-56.

Kirmani S M S, Rao G N and Sarma P L N. 1984. Heritability estimates and phenotypic and genetic correlations of body weights at different ages and first lactation traits in graded Murrah buffaloes. *Indian Veterinary Journal* **61**: 410-13.

Kirmani S M S, Rao G N and Sarma P L N. 1985. A note on the body weights from birth to two years of age in Grade Murrah buffaloes. *Indian Veterinary Journal* **62**: 619-21.

Kramer C Y. 1957. Extension of multiple range tests to group correlated adjusted means. *Biometrics* **13**: 13-18.

Kukde A H and Gire P D. 1992. Economic traits of cow and buffalo milk production: A comparison. *Livestock Advisor* **17**: 10-17.

Kumar A and Bhatnagar D S. 1989. Estimation of sire index by different methods and its efficiency in Karan Swiss herd of cattle. *Indian Journal of Animal Sciences* **59**: 731-32.

Kumar A, Rana Z S, Dhaka S S, Dalal D S, Singh S and Sethi R K. 2002. Test day yield and lactation parameters of Murrah buffaloes. *Proceedings of Seventh WCGALP*, Montpellier, pp: 1-3.

Kumar B. 1984. 'Index and method of sire evaluation in buffaloes'. Ph.D. Dissertation, Kurukshetra University, Kurukshetra, Haryana.

Kumar D, Singh H, Kumar D and Singh C V. 2003. Non-genetic factors affecting some production and reproduction traits in Murrah buffaloes. *Indian Journal of Animal Research* **37**(1): 24-27.

Kumar D. 1998. 'Construction of multi trait selection indices in Murrah buffaloes'. Ph.D. Dissertation, GBPAU&T, Pantnagar.

Kumar R and Bhat P N. 1978. Effect of non-genetic factors on lactation length in Indian buffaloes. *Indian Journal of Animal Science* **48**: 559-62.

Kumar R, Bhat P N and Garg R C. 1978. Inheritance of various segment of lactation curve of Indian buffaloes. *Indian Journal of Dairy Science* **48**: 652-55.

Kumaravelu N, Sivakumar T, Nisha P R and Gopi H. 2004. Studies on some factors affecting birth weight in buffalo calves. *Cheiron* **33**: 51-53.

Kundu S, Pandey R S and Singh S K. 2003a. Non-genetic factors affecting some reproductive traits in Murrah buffaloes. *Indian Journal of Animal Science* **73**(8): 928-29.

Kundu S, Pandey R S and Singh S K. 2003b. Studies on some persistency traits in Murrah buffaloes. *Indian Journal of Animal Research* **37**(1): 28-31.

Kuralkar S V and Raheja K L. 1997. Estimation of genetic and phenotypic trends for first lactation traits in Murrah buffaloes. *Indian Journal of Animal Science* **67**(8): 695-97.

Lall H K. 1975. Study of economic characters in Murrah buffaloes. *Indian Veterinary Journal* **52**: 337-44.

Lathwal S S. 2000. 'Optimum levels of economic traits for maximizing profit function in Murrah buffaloes'. Ph.D. Dissertation, NDRI, Karnal, Haryana, India.

Lin C Y and Lee A J. 1986. Sequential estimation of genetic and phenotypic parameters in multiple trait mixed model analysis. *Journal of Dairy Science* **69**: 2696-2703.

Mangukar B R and Desai R N. 1981. Inter relationship between heiferhood body weight and first lactation performance in buffaloes. *Indian Veterinary Journal* **58**: 199-202.

Mathur A K and Mathur B S. 1992. Murrah buffaloes in their breeding tract. *Indian Journal of Animal Sciences* **62**: 961-72.

Meyer K and Smith S P. 1996. Restricted Maximum Likelihood estimation for animal models using derivatives of the likelihood. *Genetics Selection Evaluation* **28**: 23-49.

Meyer K, Graser H U and Hammond K. 1989. Estimates of genetic parameters for first lactation test day production of Australian Black and White cows. *Livestock Production Science* **21**: 177-99.

Meyer K. 1989. Restricted Maximum Likelihood to estimate variance components for animal models with several random effects using a derivative-free algorithm. *Genetics Selection Evolution* **21**: 317-40.

Meyer K. 1991. Estimating variance and covariances for multivariate animal models by Restricted Maximum Likelihood. *Genetics Selection Evolution* **23**: 63-83.

Meyer K. 1993. Derivative Free Restricted Maximum Likelihood Programme. User Notes.

Mishra R C, Kushwaha N S and Singh R. 1983. Studies on the influence of environmental factors upon lactation milk yield in Murrah and Bhadawari buffaloes. *Indian Veterinary Medicine Journal* **7**: 135-39.

Mishra R C, Kushwaha N S and Singh R. 1986. Study on age at first calving in Murrah buffaloes and Bhadawari buffaloes. *Animal Breeding Abstracts* **55**: 221.

Mityuk'Ko V I. 1988. Evaluation of bulls by contemporary comparisons, modified contemporary comparison and BLUP. *Byulleten Vsesoyuznyi Nauchno Issledovatel Suki Institut Razvedeniya I Genetiki Selskokhozyaistvennykh Zhivotnykh* **101**: 8-10.

Mohamed M, Kawthar A M and Khatbb A S. 1993. Genetic relationship of age and weight at first calving with first lactation milk yield in Egyptian buffaloes. *Buffalo Bulletin* **12**: 38-46.

Mukherjee S, Joshi B K and Gaur G K. 2007. Comparison of sire evaluation methods in Friewal cattle. *Indian Journal of Animal Sciences* **77**: 773-76.

Murdia C K and Chaudhary A L. 1984. Genetic studies on body weights in light breeds of buffaloes. *Indian Journal of Animal Science* **54**: 6-10.

Narula H K, Chhikara B S, Kanaujia A S and Saini A. 1994. Factors affecting some economic traits of production in Murrah buffaloes. *Journal of Dairying Foods and Home Science* **13**: 98-102.

Nath M. 1996. 'Evaluation of breeding value in Murrah buffaloes by various methods'. M.V.Sc. Thesis, NDRI, Karnal, India.

Nautiyal L P and Bhat P N. 1977. Growth curve in Indian buffaloes. *Indian Journal of Animal Sciences* **47**: 517-20.

Nautiyal L P and Bhat P N. 1979. Effect of various factors on body weights in Indian buffaloes. *Indian Journal of Animal Sciences* **49**: 979-83.

Nawale K G, Deshmuke A M, Atkare V G, Gampawar A S and Deshmukh A B. 1997. Studies on the growth rate of purnathadi buffalo calves from birth to thirteen weeks. *Indian Veterinary Journal* **74**: 587-89.

Nawale V S. 2010. 'Development of optimum model for prediction and assessment of breeding efficiency in Murrah buffaloes'. M.V.Sc. Thesis, NDRI, Karnal, India.

Neog P K, Das D and Goswami R N. 1993. First lactation traits of Murrah buffaloes under the farm conditions of Assam. *Indian Veterinary Journal* **70**: 232-35.

Pander B L, Dhaka S S and Singh S. 2004. Factors affecting performance traits of third lactation in Indian buffaloes. *Proceedings of National Symposium on Livestock Biodiversity vis-à-vis Resource Exploitation* at NBAGR, Karnal, during February 11-12, 2004, p. 162.

Panse V G and Sukhatme P V. 1967. *Statistical Methods for Agricultural Workers.* IARI, New Delhi.

Parekh H B, Singh U K and Rao K C. 1994. Comparative study of different sire evaluation procedures under two models using crossbred progeny. *Indian Journal of Animal Science* **64**: 1070-74.

Patil C S. 2011. 'Genetic evaluation of fertility in Murrah buffalo'. M.V.Sc. Thesis, NDRI, Karnal, India.

Patro B N and Bhat P N. 1979a. Inheritance on production traits in buffaloes. *Indian Journal of Animal Science* **49**: 10-14.

Patro B N and Bhat P N. 1979b. Effect of some non genetic factors on production traits in Indian buffaloes. *Indian Journal of Animal Science* **49**: 91-98.

Patterson C D and Thompson R. 1971. Recovery of inter-block information when block sizes are unequal. *Biometrika* **58**: 545-54.

Powell M J D. 1970. A survey of numerical methods for unconstrained optimization. *Siam Reviews* **12**: 79-97.

Prakash A and Tripathi V N. 1987. Genetic study of peak yield in Murrah buffaloes. *Indian Journal of Dairy Science* **40**: 45-48.

Prakash A, Tripathi V N and Tomar S S. 1988. Relative importance of age and weight at calving on milk production in Murrah buffaloes. *Indian Journal of Dairy Science* **41**: 129-31.

Prakash A. 1984. 'Performance evaluation of Murrah buffalo herd'. M.Sc. Thesis, Kurukshetra University, Kurukshetra, Haryana, India.

Pundir R K, Malik R P S and Prakash B. 2004. Comparison of different sire evaluation methods in Sahiwal cattle. *Indian Journal of Animal Sciences* **74**: 229-31.

Pundir R K, Navani N K, Jain P K, Pande D P and Kumar S. 2003. A study on status, performance and molecular characterization of buffaloes. *Buffalo Journal.* **19**: 71-82.

Pundir R K. 1994. Estimation of environmental effects on first lactation traits in Murrah buffaloes by maximum likelihood. *Journal of Dairying, Food and Home Science* **13**: 77-82.

Raheja K L, Vinayak A K and Kalra S. 2001. Comparison of four methods of variance components estimation for heritability of economic traits in Murrah buffaloes. *Indian Journal of Animal Sciences* **71**: 146-49.

Raheja K L. 1992a. Selection free estimates of genetic parameters of production and reproduction traits of first lactations in Murrah buffaloes. *Indian Journal of Animal Science* **62**: 149-54.

Raheja K L. 1992b. Comparison of progeny testing of Sahiwal sires' by different methods of sires-evaluation. *Indian Journal of Dairy Science* **45**: 64-69.

Raheja K L. 1993. Restricted maximum likelihood estimates of genetic parameters of first three lactation traits in Murrah buffaloes. *Indian Journal of Dairy Sciences* **46**: 147-54.

Raizada B C, Singh D S and Tiwari R B L. 1971. The Effect of season on the lactation performance of buffalo cows. *Indian Journal of Animal Science* **41**: 315-20.

Ramesh J, Krishnamurthy G M and Narasaiah Naidu K. 1988. Prediction of milk production in Murrah buffaloes from performance records up to first service period. *Proceedings II World Buffalo Congress.* pp. 110-13.

Rana J. 2008. 'Genetic evaluation of Murrah buffalo sires based on part lactation and test day milk yield records'. Ph.D. Dissertation, Choudhary Charan Singh University, Meerut, India.

Rana Z S, Dalal D S, Sangwan M L and Malik C P. 2002. Performance status of Murrah buffaloes for first lactation traits – a review. *Proceedings of the 7th World Congress on Genetics Applied to Livestock Production* at CCS Haryana Agricultural University, Hissar, during August, 2002, pp. 0-3.

Rao A V N and Lakshminarayana K. 1994. Growth rate of female Murrah calves in Andhra Pradesh. *Indian Veterinary Journal* **71**: 928-29.

Rao A V N and Rao H R M. 1994. Peak yield as related to lactation traits in Murrah buffaloes. *Indian Veterinary Journal* **71**(12): 1207-09.

Rao A V N and Rao H R M. 1996. Effect of service period, dry period and sex of calf on peak yield in Murrah buffaloes. *Indian Veterinary Journal* **73**(12): 1296-97.

Rao A V N and Rao H R M. 1997. Life time production performance of Murrah buffaloes. *Indian Veterinary Journal* **74**: 906-07.

Rao A V N and Sreemannarayana O. 1994. The relationship between calving to conception interval and milk production in Murrah buffaloes. *Indian Veterinary Journal* **71**: 619-20.

Rao A V N and Sreemannarayana O. 1998. Weight at first calving as related to some fertility and production traits in Murrah buffaloes. *Indian Veterinary Journal* **75**: 756-57.

Rao A V N, Lakshminarayana K and Shreemannarayaha O. 1994. Effect of season of birth on age at first calving and first lactation in Murrah buffaloes. *Indian Veterinary Journal* **71**: 747-48.

Rao D S K and Murthy A K. 1981. A study on the economic traits in Murrah buffaloes – (1) Birth weight (2) secondary sex ratio (3) Mortality rate and (4) Age at first calving and its correlation to birth weight. *Indian Veterinary Journal* **58**: 124-28.

Rao T P, Singh B P and Dutta M. 1970. Studies on lactation curves and association of certain production traits in Murrah buffaloes. *Indian Journal of Animal Science* **40**: 246-51.

Raut KC and Singh S. 1971. Classification and productivity of milch animals. *Indian Journal of Animal Science* **41**: 1-6.

Reddy C E and Taneja V K. 1982. Genetic trends for 300 day first lactation milk yield in Murrah buffaloes. In 2nd World Congress on Genetics Applied to Livestock Production 4th – 8th October, 1982, 7. Symposia (1) Madrid, Spain.

Reddy C E. 1980. 'Genetic analysis of breeding records of buffaloes'. Ph.D. Dissertation, Kurukshetra University, Kurukshetra, Haryana.

Reddy K M and Mishra R R. 1980. Effect of age at first calving on lactation components and calving distribution in Murrah buffaloes. *Indian Journal of Dairy Science* **33**: 347-50.

Reddy K M and Mishra R R. 1983. A comparative study of different methods of prediction of lactation yield from part yield in Murrah buffaloes. *Indian Journal of Dairy Science* **36**(3): 224-49.

Robertson A and Rendel J M. 1954. The performance of heifers got by artificial insemination. *Journal of Agriculture Sciences* **44**: 184-92.

Robertson A. 1959. The sampling variance of the genetic correlation coefficient. *Biometrics.* **15**: 469-85.

Roshanfekr H. 2005. Genetic relationship of age and weight at first calving with first lactation milk yield in buffaloes. *Indian Journal of Animal Sciences* **75**: 812-16.

Sachan C B, Kushwaha B P and Kundu S S. 2006. Production performance of Bhadawari buffaloes at organized herd. In: National Symposium on Conservative and Improvement of Animal Genetic Resources Under Low Input System, 9-10 Feb., 2006, p. 138.

Saha S and Sadana D K. 2000. Effect of genetic and non genetic factors on reproductive traits in Murrah buffaloes. *Indian Journal of Animal Management* **16**: 51-53.

Saha S. 1998. 'Studies on breeding efficiency in buffaloes'. M.Sc. Thesis, NDRI, Karnal, Haryana, India.

Sahana G and Gurnani M. 1999. Efficacy of auxiliary traits in estimation of breeding value of sires for milk production. *Asian Australian Journal of Animal Science* **12**: 511-14.

Sahana G and Sadana D K. 1998. Evaluation of the production performance of Murrah buffaloes. *Indian Journal of Dairy Science* **51**(2): 115-20.

Sahana G. 1993. 'Association between productive and reproductive traits in Murrah buffaloes'. M.Sc. Thesis, NDRI, Karnal, Haryana, India.

Sahana G. 1996. 'Effectiveness of sire evaluation methods for milk production along with auxiliary traits vis-à-vis other methods in crossbred cattle'. Ph.D. Dissertations, National Dairy Institute, Deemed University, Karnal, India.

Saini M S, Pander B L, Yadav R S, Grewal S S and Singh N. 2003. Reproductive performance of Murrah buffaloes. *Indian Journal of Animal Reproduction*. **24**: 22-23.

Sane D D, Khanna R S, Bajpai L D and Bhat P N. 1972. Effect of month and season of calving, lactation number, lactation length, dry period, age and weight at first calving on milk yield and peak yield in Murrah buffaloes. *Indian Journal of Animal Production* **3**: 22-29.

Sarkar U, Gupta A K, Mohanty T K, Raina V S and Prasad S. 2004. Genetic and non-genetic factors affecting milk yield and milk constituents in Murrah buffaloes. *J Dairying Foods and Home Science* **25**(2): 125-28.

Saxena S K and Tomar N S. 1984. Phenotypic studies on milk production in first four lactations of Murrah buffaloes. *Indian Veterinary Journal* **6**: 218-21.

Searle S R, Casella G and McCulloch C E. 1992. *Variance Components.* John Wiley and Songs, Inc., New York.

Sethi R K and Khatkar M S. 1997. Genetic parameters of production traits in Murrah buffaloes. *Indian Journal of Animal Science* **67**: 141-42.

Sethi R K and Nagarcenkar R. 1992. Effect of non-genetic factors on production and reproduction traits in Murrah buffaloes. *Indian Journal of Animal Science* **62**: 1212-15.

Sethi R K, Khatkar M S and Tripathi V N. 1996. Age at first calving in Murrah buffaloes. *Proceedings of the Second Asian Buffalo Association Congress*, Hissar, p. 392-95.

Sethi R K. 2001. Buffalo Breeds of India. Proc. of Fourth Asian Buffalo Congress, New Delhi, India, 25 to 28 Feb.

Sethi R. 2005. Improvement of buffalo for milk, meat and drought: A review. *Indian Journal of Animal Sciences* **75**: 327-34.

Shabade N S, Jagtap D Z and Behla N D. 1993. Factors affecting production and production efficiency traits of first lactation in Murrah buffaloes. *Indian Journal of Animal Science* **63**: 1212-13.

Shah D and Sharma K N S. 1994. Production and reproduction performance of bovine in Bulandsahar district of Uttar Pradesh. *Indian Journal of Animal Sciences* **64**: 178-85.

Sharma A. 1982. 'Breeding and selection methods for maximizing profit function in buffaloes'. Ph.D. Dissertation, Kurukshetra University, Kurukshetra, Haryana.

Sharma D B, Singh C S P and Mishra H R. 1983a. Growth rate in the buffaloes. *Indian Veterinary Journal* **60**: 1017-18.

Sharma K C, Goel R, Kumar S and Singh H N. 2004. Conservation of indigenous germplasm-Bhadwari buffalo: Study on reproduction performance. *Proceedings of National Symposium on Livestock Biodiversity vis-à-vis Resource Exploitation* at NBAGR, Karnal, during February 11-12, 2004, p. 155.

Sharma K C, Tomar N S and Mishra B S. 1983b. Studies on the birth weight of Hariana, Murrah and Hariana x Holstein-Friesian calves. *Indian Veterinary Journal* **60**: 550-54.

Sharma R C and Singh B P. 1990. Genetic studies on Murrah buffaloes in livestock farms in Uttar Pradesh. *Proceedings II World Buffalo Congress* held at New Delhi, India, 12-16 Dec, 1988.

Sharma R C. 1996. 'A study on selection indices based on different approaches for genetic improvement in buffaloes'. Ph.D. Dissertation, HAU, Hisar, India.

Shreshtha N R and Yazman J A. 1990. Performance of Murrah and native x Murrah cross buffaloes in Nepal. Genetics and Breeding, Digestive Physiology and Nutrition, 28-33. *Animal Breeding Abstract* **58**: 1094.

Shrivastava A K, Singh C S P and Verma S K. 1998. Effect of non-genetic factors on production traits in buffaloes of unorganized farming system. *Indian Veterinary Journal* **75**(3): 228-52.

Sil B K, Jana D N, Samanta R, Dhara K C and Gosh N. 2002. Effect of calving pattern on standard lactational yield of crossbred cow. *Journal of Interacademicia* **6**: 196-201.

Sindhu M S, Pal R N and Agarwal C K. 1981. Studies on the effect of lactation number and stage of lactation on some production characters of Murrah buffaloes. *HAUJ Research* **11**: 440-42.

Singh B B and Singh B P. 1971. Comparative study of lifetime economics of Haryana cows vs. Murrah buffaloes. *Indian Veterinary Journal* **48**: 485-89.

Singh B P, Kumar V and Chauhan V P S. 1992. Comparison of different methods of sire evaluation. *Indian Journal of Animal Science* **62**(8): 749-53.

Singh B, Singh C V and Yadav M C. 1988. Genetic studies on some economic traits in Nili-Ravi buffaloes. *Indian Veterinary Journal* **65**: 599-602.

Singh C V and Prakash B. 1986. Genetics of production traits and their use for construction of selection index in Murrah buffaloes. *Asian Journal of Dairy Research* **5**: 212-14.

Singh C V and Singh R V. 1992. Incorporation of productive and reproductive traits for the maximization of genetic gain. *Indian Veterinary Science* **69**:1104-06.

Singh C V and Yadav M C. 1986. Estimation of genetic and non-genetic parameters affecting reproduction traits in Indian buffaloes. *Indian Journal of Dairy Research* **5**: 171-74.

Singh C V and Yadav M C. 1987. Non-genetic factors affecting daily milk yield in Murrah buffaloes. *Indian Journal of Animal Science* **57**(1): 56-58.

Singh C V and Yadav M C. 1988. Effect of genetic and non-genetic factors on lifetime production traits in Indian buffaloes. *Indian Veterinary Journal* **65**: 555-58.

Singh C V, Singh R V and Singh Y P. 1987. Effect of some non-genetic factors on economic traits in Nili-Ravi buffaloes. *Indian Journal of Animal Science* **57**: 891-94.

Singh D and Basu S B. 1988. Genetic parameters of first lactation traits in Murrah buffaloes. *Indian Veterinary Journal* **65**: 593-98.

Singh G. 1995. ‘Genetic improvement in quantitative traits through restricted selection indices in Murrah buffaloes’. Ph.D. Dissertations, Dr. B.R. Ambedkar University, Agra, India.

Singh H P. 1977. 'Studies on genetic and environmental trends for economic traits in buffaloes'. Ph. D. Dissertation, GBPAU&T, Pantnagar, India.

Singh P K and Singh B P. 1999. Efficacy of different methods in genetic evaluation of Murrah sires. *Indian Journal of Animal Sciences* **69**: 1044-47.

Singh R. 1992. 'Genetic evaluation of Sahiwal bulls on the basis of daughter's multiple traits under selection'. M.Sc. Thesis, NDRI, Karnal, India.

Singh S and Rathi S S. 1991. Relationship among various reproduction and production efficiency traits in Murrah buffaloes. *International Journal of Tropical Agriculture* **8**: 93-99.

Singh S K. 2001. 'Genetic studies on economic traits and prediction of life time milk yield in Murrah buffaloes'. M.Sc. Thesis, GBPAU&T, Pantnagar.

Singh S S, Rathi S S and Sangwan M L. 1990. Environmental variances affecting production efficiency in Murrah buffaloes. *Buffalo Journal* **6**: 105-12.

Smyth K S. 2002. An efficient algorithm for REML in Heteroscedastic Regression. *Journal of Graphical Computational Statistics* **11**.

Snedecor G W and Cochran W G. 1967. *Statistical Methods,* 6th Edn. Oxford and IBH Publishing Co., New Delhi, India.

Sreedharan S and Nagarcenkar R. 1978. Relation of body size measures to production efficiency in Murrah buffaloes. Brief Communication 20th International Dairy Conference, Paris, pp. 5.

Sreedharan S. 1976. 'Inheritance of body size measures in relation to production efficiency in buffaloes'. Ph.D. Dissertation, Punjab Agricultural University, Ludhiana, India.

Steel R G D and Torrie J H. 1960. *Principles and Procedures of Statistics.* 2nd edn, McGraw Hill Book Co., Inc. New York, Toronto, London.

Sule S R, Taparia A L, Jain L S and Tailor S P. 2001. Reproductive status of buffaloes maintained under sub-humid conditions of Rajasthan. *Indian Veterinary Journal* **78**: 1049-51.

Suresh R, Bidarkar D K, Gupta B R, Sudhakar Rao B and Sudhakar K. 2004. Production and reproduction performance of Murrah buffaloes. *Indian Journal of Animal Science* **74**(8): 854-57.

Swain S N and Bhatnagar D S. 1983. Relationship and productive traits in Murrah buffaloes. *Indian Journal of Dairy Science* **36**: 382-86.

Swiger L A, Harvey W R, Everson D O and Gregory K E. 1964. The variance of intraclass correlation involving groups with one observations. *Biometrics* **20**: 818-26.

Tailor S P, Banerjee A K and Yadav S B S. 2000. Comparison of different methods of sire evaluation. *Indian Journal of Animal Sciences* **70**: 73-74.

Tajane K R and Rai A V. 1990. Efficiency of sire evaluation methods to improve milk yield of Sahiwal x Holstein Friesian cattle. *Indian Journal of Animal Sciences* **60**: 183-91.

Taraphder S, Tomar S S and Gupta A K. 2003. Incidence of abnormal calvings and their effect on milk production of Murrah buffaloes. *Indian Journal of Animal Science* **73**(10): 1187-88.

Thevamanoharan K, Pilakaratve N and Coonewardene L A. 1984. Analysis of milk production in an upgrading programme among buffaloes in Sri Lanka. *World Review Animal Production* **20**: 27-31.

Thevamanoharan K, Vandepitte W and Mohiuddin G. 2002. Heritability estimates for various performance traits of Nili-Ravi buffaloes. *Proceedings of 7th World Congress on Genetics Applied to Livestock Production*, Montpellier, France, August, 2002. p. 1-4.

Thevamanoharan K, Vandepitte W, Mohiuddin G and Shafique M. 2000. Genetics, phenotypic and residual correlations between various performance traits of buffaloes. *Buffalo Bulletin* **19**: 80-86.

Thiruvenkadan A K, Panneerselvam S and Rajendran R. 2009. Non-genetic and genetic factors influencing growth performance in Murrah buffaloes. *South African Journal of Animal Sciences* **39**(1): 102-06.

Thompson R. 1973. Estimation of variance and covariance components with an application when records are subject to culling. *Biometrics* **29**:527-50.

Thompson W R Jr. 1962. The problem of genetic estimates of variance components. *Annual Mathematics Statistics* **33**: 273-89.

Tien N Q and Tripathi V N. 1990. Genetic parameters of body weight at different ages and first lactation traits in Murrah buffalo heifers. *Indian Veterinary Journal* **67**: 821-25.

Tien N Q and Tripathi V N. 1991. Effect of age and weight at first calving on first lactation production in Murrah buffalo. *Buffalo Bulletin* **10**: 3-7.

Tien N Q and Tripathi V N. 1992. Effect of dam's parity, mouth and year of birth and systems of rearing on growth rate of Murrah buffalo heifers. *Indian Journal of Dairy Science* **45**: 568-69.

Tomar S P S and Desai R S. 1968. Genetic relationship of age at first calving and first lactation in buffaloes on military farms in north. *Indian Journal of Animal Health* **7**: 189-93.

Tomar S S and Tripathi V N. 1988. Incidence and association among certain reproductive problems in Murrah buffaloes. *Indian Journal of Dairy Science* **47**(12): 1050-52.

Tomar S S. 1984. Variation due to age of dam in the productivity of female progeny. *Indian Veterinary Journal* **61**: 49-53.

Tonhati H, Munoz M F C, Duarte J M C, Reichert R H, Oliveira J A and Lima A L F. 2004. Estimates of correlation factors for lactation length and genetic parameters for milk yield in buffaloes. *Arquivo Brasibiro de Medicina Veterrinaria-e-Zootecnia* **56**: 251-57.

Ulaganthan V, Ramchandaran B V, Krishan A R and Chandrasekaran S K. 1985. Factors influencing first lactation yield, age at first calving, service period and lactation length in Murrah buffaloes. *Cherion* **14**: 31-33.

Umrikar U D and Deshpande K S. 1985a. Factors affecting milk yield per day of calving interval and productive life in Murrah buffaloes. *Indian Journal of Animal Science* **55**: 782-85.

Umrikar U D and Deshpande K S. 1985b. Studies on lactation milk yield in Murrah buffaloes. *Cherion* **14**: 151-52.

Veerapandian C, Chandran N Daniel Joy, Jayarajan S and Kathaperumal V. 1996. Pattern of calving and birth weight in Murrah buffaloes in an organized farm. *Indian Veterinary Journal* **73**: 450-51.

Verma D N and Hasain K Q. 1985. Study of growth rate and birth weight of Haryana and Murrah buffalo calves. *Indian Veterinary Journal* **62**: 316-20.

Verma K and Yadav M C. 1989. Genetic studies on dry period in Nili buffaloes. *Indian Journal of Dairy Science* **42**: 627-29.

Vij P K and Tiwana M S. 1986a. Phenotypic and genetic parameters of some production traits in buffaloes. *Indian Veterinary Journal* **63**(10): 838-45.

Vij P K and Tiwana M S. 1986b. Phenotypic and genetic trends in some economic traits in buffaloes. *Indian Journal of Dairy Science* **39**(9): 328-29.

Vij P K and Tiwana M S. 1987. Phenotypic and genetic parameters of reproduction traits in buffaloes. *Asian Journal of Dairy Research* **6**(3): 159-66.

Vij P K and Tiwana M S. 1988. A note on evaluation of buffalo sires. *Indian Journal of Dairy Science* **41**(4): 500-01.

Vij P K. 1984. Genetic analysis of a closed herd of buffaloes. Ph.D. Dissertation, PAU, Ludhiana, India.

Vijai R G, Jain L S and Tailor S P. 1993a. Body weights and their genetic and phenotypic parameters in Surti and Mehsana buffaloes. *Indian Journal of Animal Science* **63**: 52-55.

Vijai R G, Jain L S, Tailor S P and Pathodia O P. 1993b. Age and weight at first calving and its association with reproductive traits in medium-sized buffaloes. *Indian Veterinary Journal* **70**: 1018-21.

Wakchaure R S, Sachdeva G K and Gandhi R S. 2008. Comparison of heritability estimates from time sires and least squares adjustments in Murrah buffaloes. *Indian Journal of Animal Sciences* **78**: 1159-61.

Wakchaure R S. 2007. 'Estimation of correction factors using time series analysis in Murrah buffaloes'. M.V.Sc. Thesis, NDRI, Karnal, India.

Warade S D, Patil S L, Ali S Z and Kularlkar S V. 2005. Productive and reproductive genetic traits of buffaloes in Maharastra state. *Indian Journal of Veterinary Research* **14**: 25-28.

Yadav B S, Khan F H and Yadav M C. 1996. Genetic studies on body weight at first calving in Murrah buffaloes. *Indian Veterinary Journal* **73**: 362-64.

Yadav B S, Sharna J S and Dutta O M. 1984. Projection of lactation milk yield from part record in crossbred dairy cows. *Journal of Dairy Research* **51**: 525-30.

Yadav B S, Yadav M C, Khan F H and Singh A. 2002. Murrah buffaloes. II. First lactation yield and first lactation period. *Buffalo Bulletin* **21**(3): 51-54.

Yadav B S, Yadav M C, Singh A and Khan F H. 2001. Murrah buffaloes – 1. Birth Weight. *Buffalo Bulletin* **20**: 29-31.

Yadav K N, Rathi S S, Ram S and Singh R. 1983. Estimates of genetic and phenotypic trends in Murrah buffaloes under progeny testing programme. *Indian Journal of Dairy Science* **36**: 330-32.

Yadav K N, Rathi S S, Shri Ram and Singh R. 1982. Estimates of genetic and phenotypic trends in Murrah buffaloes. *Indian Journal of Dairy Science* **35**: 604-06.

VITA

Name of the student	:	Puneet Malhotra
Father's name	:	Dr. S.K. Malhotra
Mother's name	:	Smt. Jasbir Malhotra
Nationality	:	Indian
Date of birth	:	29.10.1977
Permanent home address	:	H.No. 3257/1, Nai Abadi, Sirhind - 140406, Distt. Fatehgarh Sahib (Punjab)

EDUCATIONAL QUALIFICATION

Bachelor degree	:	B.V. Sc & A.H.
University	:	Punjab Agricultural University, Ludhiana
Year of award	:	2001
OGPA/OCPA/% marks	:	7.16/10.00
Master's degree	:	M.V.Sc. (Animal Breeding and Genetics)
University	:	Punjab Agricultural University, Ludhiana
Year of award	:	2003
OGPA/OCPA/% marks	:	8.13/10.00
Title of Thesis	:	Genetic and Non-Genetic factors affecting mortality and culling in crossbred cattle
Ph.D.	:	Animal Genetics and Breeding
OCPA /% marks	:	7.47/10.00
Awards/Distinctions/ Fellowships/Scholarship	:	University Merit Certificate in M.V.Sc.