GENETIC ANALYSIS OF ECONOMIC TRAITS OF SAHIWAL CATTLE USING ANIMAL MODELS

Thesis

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By

Anil Kumar

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Dedicated

to

My beloved parents
who bore sacrifices and long standing pains
to introduced me the world of language and
to bring me to this stage

And
Critics
Who enlightened my path

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Pantnagar
March, 2003

Anil Kumar
Author

Dr. C.V Singh
Associate Professor
(Genetics and
Animal Breeding)

Department of Genetics and Animal
Breeding,
College of Veterinary and Animal
Sciences,
G.B.Pant University of
Agriculture and Technology,
Pantnagar – 263145
Uttaranchal, INDIA

CERTIFICATE

This is to certify that the thesis entitled **"GENETIC ANALYSIS OF ECONOMIC TRAITS OF SAHIWAL CATTLE USING ANIMAL MODELS"** submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY** with major in **Animal Science (Animal Breeding)** and Minor in **Molecular Biology and Biotechnology** of Post-Graduate Studies, G. B. Pant University of Agriculture & Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Anil Kumar, Id. No. 25875,** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation and source of literature have been duly acknowledged.

(C.V. Singh)
Chairman
Advisory Committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Mr. Anil Kumar, Id. No. 25875,** a candidate for the degree of **DOCTOR OF PHILOSOPHY** with major in **Animal Science (Animal Breeding)** and Minor in **Molecular Biology & Biotechnology** and agree that the thesis entitled **"GENETIC ANALYSIS OF ECONOMIC TRAITS OF SAHIWAL CATTLE USING ANIMAL MODELS",** may be submitted in partial fulfilment of the requirements for the degree.

(C.V. Singh)
Chairman

(Harpal Singh)
Member

(D. Kumar)
Member

(A.K. Gaur)
Member

31.3.03

Head
Department of Genetics and Animal Breeding
(Ex-officio member)

LIST OF ABBREVIATIONS

μ	:	Population Mean
A	:	Relationship Matrix
A^{-1}	:	Inverse of A Matrix
AFC	:	Age at First Calving
AM	:	Animal Model
ANOVA	:	Analysis of Variance
BLUE	:	Best Linear Unbiased Estimation
BLUP	:	Best Linear Unbiased Prediction
C.V.	:	Coefficient Correlation
CC	:	Contemporary Comparison
CT	:	Canonical Transformation
DF	:	Derivative Free
DFREML	:	Derivative Free Restricted Maximum Likelihood
FCI	:	First Calving Interval
FDP	:	First Dry Period
FLL	:	First Lactation Length
FLMY	:	First Lactation Milk Yield
FSP	:	First Service Period
h^2	:	Heritability
HMC	:	Herd Mate Comparison
IAM	:	Individual Animal Model
LSA	:	Least Squares Analysis
LSMLMW	:	Least Squares Means and Maximum Likelihood Method of W.R. Harvey.
MINQUE	:	Minimum Norm Quadratic Unbiased Estimation
MIXMDL	:	Mixed Model
ML	:	Maximum Likelihood
MME	:	Mixed Model Equation
PHS	:	Paternal Halfsibs
RAM	:	Reduced Animal Model
r_e	:	Environmental Correlation
REP	:	Intraclass Correlation
r_g	:	Genotypic Correlation
r_p	:	Phenotypic Correlation
SD	:	Standard Deviation
SDA	:	Simple Daughter Average
SE	:	Standard Error
SRLS	:	Simple Regressed Least Squares

CONTENTS

INTRODUCTION

"Get good counsel before you begin
when you have decided out promptly"

In the Vedic literature the cow, bull and the ox have mentioned more frequently than any other species of animal. Cattle have continued to occupy a special place among man's domestic animals, by reason of veneration, affection and prestige of ownership. Much of this special regard for cattle probably is derived from prehistoric cattle cults, in which, initially, the spirits of slaughtering the wild cattle for worship and later, domestic cattle were given a special place of honor in many religious ceremonies. The pattern of the relationship between man and cattle does indeed suggest a religious origin of domestication. The cattle were domesticated for the first time in South-Central Asia and Asia Minor around 7800 years, ago. Zebus have a history of initially being domesticated by Baluchis, as revealed from depiction of bulls on seals and toys recovered from excavations of Mohenjodaro, which shows the importance of cattle in India since ancient times.

Animal husbandry in India is closely interwoven with agriculture and as a result, it has been, for centuries, a way of life steeped in tradition and handed down from generation to generation. Cattle are the most important livestock in India and play a pivotal role in agrarian economy. There are about 30 known breeds of cattle (Prasad, 2000), which constitute $1/9^{th}$ of the world's cattle breeds. India has a cattle population of 218.80 million, which is 47.85 percent of Asia and 16.32 percent of the world population (FAO, 2000). There has been quantum increase in milk production in recent years after fifties in last century. India produced 17.00 million tones of milk in 1951. This figure rose to 20 million tones in 1960, 23.2 million tones in 1973, 54.0 million tones in 1990 and 86 million tones in 2000 (Hemlatha and Reddy, 2001). This is the most significant achievement in dairy production enterprise after independence. Though, a large number of cattle population existing in India and the per capita availability has increased considerably from 112 gm in the year 1970 to 216 gm in 2001 (Roy, 2002), but it is far away from the recommendation of nutritional expert group of Indian Council of Medical Research. Livestock sector accounts for more than 26 percent to agriculture sector. Contribution of livestock to country's GDP was 5.59 per cent in 2001-02 (Economic survey, 2002-03). The contribution of milk to Indian economy alone was higher than the paddy, wheat and sugarcane in 2001-02 (Economic survey, 2002-03).

India is bestowed with rich domestic animal biodiversity, as evident from the availability of all economically important species of livestock and a large number of breeds/ strains within each of these species. India had some of best breeds of dairy, draught and dual-purpose cattle breeds. These breeds of cattle are essentially the product of long-term natural selection for adaptation to harsh climatic conditions and low management inputs specially feed and health care. Indian breeds of cattle are better adopted to withstand tropical diseases and are more efficient converters of low quality feeds and fodders. The records achieved in all India milk yield competition reveal that genetic material for high producing ability does exist in Indian dairy breeds.

Sahiwal is one of them and comes under the category of best milch breed of Indian sub-continent. They are ponderous in body built and have pendulous dewlap and sheaths, prominent forehead and light color muzzle.

This breed has been evolved out of generations of breeding and adaptability to local environment. Works show that this breed posses good potential for improvement, and there is deterioration in genetic potential during the years.

Maximization of genetic improvement in traits especially of economic importance is the primary objective of breeder and proper selection and utilization of breeding system/design can make desirable genetic improvement. The potential for genetic improvement in a trait largely depends upon genetic variation existing in a population of interest. The variability for a particular trait in a herd of specific population is measured by heritability estimates of trait under given environmental condition. Knowledge of heritability and association among traits and the extent to which genetic variation exists among traits help in deciding the appropriate selection and mating systems/designs.

Thus, the knowledge of genetic properties of traits is the pre requisite in establishing the selection programme or mating designs. Estimation of genetic parameters is synonymous with the estimation of variance components. In this context, variance comprises not only the variance of an observation for a particular trait and individual but also covariance between traits as well as covariance between individuals for the same or different traits.

Estimation of genetic parameters then involves partitioning of observational components, i.e. phenotypic covariance between relatives into causal components such as variances due to additive genetic effects, dominance, epistasis and permanent & temporary environmental effects (Falconer, 1981). This utilizes the known degree of relationship between animal and the resulting expectations of covariance between them.

Traditionally, variance and covariance components are estimated by ANOVA and regression methods and also by Handerson's method I, II and III. But these methods are not appropriate for unbalanced data. The estimates of variance and covariance obtained from these methods are expected to be biased under any selection programme (Robertson, 1977, Meyer and Thompson, 1984). In particular, Henderson's (1953) method III of 'fitting constant' has found extensive use. This approach replaces the SS in balanced ANOVA by quadratic forms involving least squares solutions of effects for which variances are to be estimated. Its widespread application was greatly aided by the availability of a 'general' least-squares computer programme tailored towards application commonly arising in animal breeding (Harvey, 1960 and 1977).

In recent years, advance statistical methods with computer programmes used to estimate variance components have been greatly improved with the development of MINQUE, ML and REML methods, there has been much interest in employing better methods than the ANOVA type estimators. These are all quadratic and are unbiased to selection. The accuracy of estimates of variance components is dependent on the choice of data, methods and models (Misztal, 1992). Animal model is the model of analysis, which includes the additive genetic merit of animals as a random effect and incorporates all information on relationship between animals (Mayer, 1989a).

Today, the need for sire evaluation for their additive genetic ability (breeding value) or transmitting ability to its progeny has been recognized, thus the recognition and promotion of the best genotypes by genetic evaluation is needed. Therefore, accurate, efficient and early evaluation of breeding value of bulls/ sires is of prime importance. The prediction of breeding values constitute 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.

The Best Linear Unbiased Prediction (BLUP) has become the most widely accepted method for genetic evaluation of livestock. Recently, there is a constant thrust to get BLUP evaluating single and multiple traits animal model, depending upon goal of breeding programme (Lin and Lee, 1986, Ducrocque and Besbes, 1993).

In view the above consideration, it was planned to employ derivative free REML and least square method for the analysis of reproduction and production traits in sahiwal. The present study was conducted on sahiwal cattle with the following objectives:

i. to estimate the variance covariance components and genetic parameters for first lactation reproduction and production traits under different procedures,
ii. to compare estimated parameters obtained by different procedures/ methods,
iii. to estimate breeding value of sires by above procedures,
iv. to find rank correlations among sires on the basis of breeding value.

REVIEW OF LITERATURE

"The past can not be changed the future is yet in your power"

A suitable selection and breeding programme is required to obtain the genetic improvement in economic traits of animals. A number of studies have been made on different aspects of dairy cattle breeds. Since the science is progressive and accumulative in nature, thus past and present findings in a particular field are always required for comparison. It is therefore, imperative and essential to review the earlier works in concerned field of study. It may thus be worthwhile to review the literature on each economic character of Sahiwal cattle considered in the present study.

2.1 Statistical methods of estimating genetic and phenotypic parameters:

Fisher (1918) presented a paper on the theory of quantitative genetics, which was the important contribution towards the development of variance development theory. He made the inceptive use of the terms 'variance' and 'analysis of variance'. He developed the analysis of variance method in which sum of squares from analysis of variance (ANOVA) are equated to their expected value.

Eisenhart (1947) was the first who made precise distinction between 'fixed' and 'random' models in his model II, and I respectively. Eisenhart described mixed models in his model III.

Henderson (1953) was the first who published general methods for estimation of variance components from mixed models with unequal subclass numbers. These methods have been widely employed by animal breeders to obtain estimates that are essential for design of selection programmes. Henderson developed two methods, known as method I for a random model and method III for mixed model. Method III turned out to be particularly powerful since it enabled unbiased estimators of variance to be obtained in the presence of confounding, fixed environmental factors. Later Henderson's methods II and III somewhat simpler method for certain mixed models was developed, but with serve restrictions on the model.

Data arising in animal genetics are usually not balanced but methods analogous to the ANOVA have been developed for balanced data. In particular, Henderson's (1953) method III of 'fitting constants' have found extensive use. This approach replaces the sum of squares in the balanced ANOVA by quadratic forms least square solution of effects for which variances are to be estimated. Its, widespread application was greatly aided by the availability of general commonly arising in animal breeding.

In field of animal breeding, this evolution has came, as ANOVA and related methods are based on several assumptions that are commonly violated in typical animal breeding data sets. These assumptions are as:

i. that the data are balanced, i.e. there are equal numbers of individuals in each subclass.

ii. that the data are random sample from an unselected population.

iii. that the data structure confirms to certain standard and stereotypical design, e.g. paternal half sibs or parents off spring, and therefore, only one type of related ness is exploited in the analysis.

However, animal breeding data are typically unbalanced, being from selection experiments or livestock improvement schemes in which animals are continuously culled for poor performance and are related in variety of ways. Hence, estimates from ANOVA and related types of analysis are biased (Shaw, 1987; Meyer, 1989a).

Later it was showed that even without normality ANOVA estimators are minimum variance, quadratic and unbiased. Despite the attractiveness of these properties, ANOVA estimators suffer from one major drawback, i.e. negative estimates of variance components. The ANOVA methods and Henderson's methods do not have general analytical properties that can be used to determine relative optimality of any one application of the general ANOVA method over another and they also lack distributional properties.

Later with the development of MINQUE, ML and REML methods, there has been much interest in employing better methods than the ANOVA type estimators. These were all quadratic, translation invariant, unbiased estimators with no known optimum properties with respect to sampling variance. Over the last decade, statistical methods employed to estimate (co) variance components for continuous traits in most fields, such as animal breeding and population genetics, have generally evolved from analysis of variance (ANOVA) and related type of analysis (general linear model) to maximum likelihood (ML) and related methods (Shaw, 1987; Meyer and Hill, 1992). With the multi trait problems, it has become imperative that more attention was paid to estimation of environmental and genetic covariance matrices for multiple traits. Increase in the power of computers and the developments of specialized algorithms have aided this evolution (Meyer, 1989a and b; Klassen and Smit, 1990).

In contrast to ANOVA, evidence has been accumulating that indicates that ML and REML may have considerable power to eliminate selection bias. Consequently, Henderson (1984) attempted to derive feasible computational strategies for these methods applied to the multiple trait problems. This has resulted in derivation of BLUP method from mixed model equations. In the light of these shortcomings of ANOVA methods, alternative methods like maximum likelihood (ML), restricted maximum likelihood (REML) and minimum norm quadratic unbiased estimation (MINQUE) etc, were considered for estimation of variance components.

2.1.1 Animal model:

The use of ML and REML in animal breeding has brought about change in the random effects fitted in the infinitesimal additive genetic model (Henderson, 1988; Foulley, 1990). In traditional ANOVA and related methods, (co) variance are described in terms of random effect due to a single parent (e.g. sire model) or both parents (sire-dam model), uniquely partitioning the total sum of the squared deviations of the observations from the grand mean into sum of square contributed by each factor in the design (Harville, 1977; Shaw, 1987).

However, over the last decade considerable research efforts have concentrated on the development of specialized and efficient algorithms. This has been closely linked to advances in the genetic evaluation of animals by Best Linear Unbiased prediction (BLUP). However, ML and REML allow the random effect of models to be expressed in terms of the genetic merit or breeding value of animals. These models are called individual animal models (IAM) and incorporate information on relationship between all animals (Meyer, 1989b, 1991). Animal Model (AM) has influenced the use of mixed model methodology in the statistical analysis of animal breeding data considerably. The AM includes a random effect for the additive genetic merit of each animal, both for animals with records and animal, which are parents only, incorporating all known relationship information in the analysis. This requires the inverse of numerator information in the analysis. This requires the inverse of numerator relationship matrix A, which made the AM computationally feasible for large data sets. Kenedy *et al.* (1988) discussed the genetic properties of animal models, outlining how the AM can account for change in genetic means and variance. Thus the AM allows an optimal analysis of data involving multiple generations arising, for instances, from selection experiments (Sorensen and Kennedy, 1986; Kennedy, 1988).

In terms of variance component estimation, the AM had changed thinking from the interpretation of covariances between relatives to a linear model framework where we determine variance directly by fitting corresponding random effects in the model of the analysis. Covariances between random effects for relatives are now taken into account by specifying the variance matrix of random effects accordingly.

With the AM, the additive genetic variance is estimated as the variance of animals' additive genetic merit instead of; for example, four time the variance between sires or twice the covariance between parents and offspring. The basis assumptions of individual animal model (IAM) are:

i. σ^2_e is the same for all observation.

ii. dominance genetic effects are not important and are part of σ^2_p

iii. covariance between animal genetic effect and other random effects in the model are zero,

iv. the relative value of variance must be known, and

v. additive genetic effect can include individual without any observations, and in that case corresponding design matrix contain zero columns for those individuals.

It is intuitively obvious that an IAM is more correct for animal breeding data, since it exploits all know relationship and can therefore account for changes in genetic variance due to both inbreeding and the established linkage disequilibrium (Kennedy and Sorensen, 1988; Henderson, 1990a). Furthermore, the use of an IAM allow more random effects to be fitted, such as maternal and dominance effect, which are known to bias some genetic estimates (Barlow, 1978; Falconver, 1989; Meyer, 1989a; Webb and Bampton, 1990).

The other advantages of animal model are:

i. if data has been collected over many years then the possibility could arise that an individual female animal could appear as one of the measured individuals, but also as the dam of one or more other female animals. Thus, these equations combine information on an animal itself and on its progeny.

ii. In an animal model genetic merit of the female to which sires were mated is also considered whereas the same is ignored while evaluating sires solely on their female progeny, and

iii. If only selected animals were allowed to reproduce then biases due to selection can be avoided by use of numerator relationship matrix.

The major disadvantage of an animal model is the larger order of the equations that need to be solved.

Wiggans and Misztal (1987) opined that the main advantage of an animal model over a sire model is that all additive genetic relationships among animals contribute to an animal's evaluation, which improves the accuracy of evaluation and avoids bias due to non-random mating and female selection. They mentioned the disadvantage that many more equations must be solved, and convergence may be slow because animal equations have off diagonal elements contributed by the relationship matrix.

Meyer and Burnside (1988) mentioned that sire model ignores both the dams of the cow (sire's mate) and relationship between females, and therefore, sire proofs may be biased due to non-random mating or selection of cows. On the other hand, animal model evaluate both the sires and cows simultaneously, animals without records (like sires in dairy cattle) are evaluated from the information on their relatives' records. The animal model takes into account all the relationship, adjusts for the non-random mating, the correlated traits. Canon and Cheshais (1989) enumerated following advantages of animal model:

i. permits the use of all additive genetic relationships among animals as 'a priori' information in animals' evaluation,

ii. the predicted genetic merit of sires is free from bias due to non-random mating since the genetic merit of dams of their progenies is taken in to account, and

iii. the need for grouping is decreased in order to account for genetic trends.

The literatures available have been reviewed under following heads.

i. Mean performance of first lactation reproduction and production traits.

ii. Factors affecting first lactation traits.

iii. Heritability estimates of first lactation traits.

iv. Correlations among the traits.

v. Statistical approaches to estimate genetic and phenotypic parameters.

vi. Relative efficacy of different sire evaluation methods and rank correlation.

2.2 Mean performances of first lactation production and reproduction traits

2.2.1 Age at first calving (AFC)

Age at first calving is one of the most important traits in reproductive life cycle of an animal. Early AFC would result in higher genetic gain per unit of time by decreasing the generation interval. Early age at first calving enable us to complete the progeny testing program as early as possible. The lower age at first calving would result in more number of progenies and lactation in the lifetime of an animal, consequently results in increase in the profits of dairy enterprise.

Averages of age at first calving as reported by various workers in Sahiwal cattle are summarized in Table 2.1. As evident from table, the average AFC ranged from 30.4±0.23 months (Kavitkar *et al.,* 1968) to 1664.39 days (Nandagawali *et al.,* 1996) in Sahiwal.

Tomar *et al.* (1974) observed average value of 35.4 (1062 days) months for AFC in Sahiwal maintained at Chak Ganjaria (Lucknow) while, Kumar and Narain (1979) reported 1112.1 days (912 days) and 37.66 (1129.8 days) months at Chak Ganjaria, Lucknow.

Table 2.1: Average ages at first calving (AFC) along with S.E. in Sahiwal cattle.

No. of observations	Mean ± S.E.	Unit of measurements	References
118	41.1	Months	Singh and Chaudhary (1961)
160	38.45±0.39	Months	Batra and Desai (1964)
76	38	Months	Sundaresan *et al.* (1965b)
114	42	Months	-do-
	37.4± 0.6	Months	Amble and Jain (1967)
	39.2±0.8	Months	-do-
	31.09±0.97	Months	Kavitkar *et al.* (1968)
	30.4±0.23	Months	-do-
	30.9±0.31	Months	-do-
245	39.3±0.39	Months	Kushwaha and Mishra (1969)
456	1155.00	Days	Nagpal and Acharya (1971)
398	38.08±0.39	Months	Gopal and Bhatnagar (1972)
	1464.00	Days	Ahmad and Ahmad (1974)
	35.4	Months	Tomar *et al.* (1974)
	40.4	Months	-do-
	39.0	Months	-do-
	1206.00±6.00	Days	Bhat (1977)
522	1112	Days	Kumar and Narain (1979)
	37.65	Months	-do-
816	1155.00±0.00	Days	Bhatia (1980)
579	38.65±2.69	Months	Chawala and Mishra (1982)
185	1255.00±11.8	Days	Raheja and Bhat (1982)
126	1184.52±14.91	Days	Sharma *et al.* (1982)
865	1180.90	Days	Ganpule and Desai (1983)
580	1176	Days	Bhatnagar *et al.* (1983)
	40.8±1.8	Months	Galina and Arthur (1983)
565	1323.00	Days	Prasad (1983)

590	1322.40	Days	Roy (1983)
338	1281.60±25.8	Days	Rathi (1984)
292	1277.10	Days	Singh (1984)
291	1278.00	Days	Prasad (1986)
	43±0.18	Months	Gandhi and Gurnani (1987)
	37.2	Months	Gurnani *et al.* (1987)
159	1263.90	Days	Kumar (1987)
	45±1.24	Months	Prasad and Manglik (1987)
	41	Months	Bhat and Taneja (1989)
424	1212.83±10.84	Days	Gandhi and Gurnani (1990)
108	1262.76±4.71	Days	Singh and Tomar. (1990)
6000	44.1	Months	Khan *et al.* (1992)
217	1156	Days	Sahota and Gill (1992)
793	1408.68	Days	Kumar (1992)
208	1281.76	Days	Sharma *et al.* (1993)
323	1567.64±20.06	Days	Kuralkar *et al.* (1996)
423	1664.39	Days	Nandagawali *et al.* (1996)
155	40.07	Months	Tomar *et al.* (1996)
1775	1467.62±29.59	Days	Nandagawali *et al.* (1997)
	1564.7±31.6		-do-
50	1138.24±11.92	Days	Singh *et al.* (1998)
	1327.37	Days	Tomar *et al.*(1998)
5200	44.1	Months	Dahlin (1998)
4700	1341.37	Days	Khan *et al.* (1999)
805	1241.25±7.56	Days	Singh (2000)
462	1322.21±7.06	Days	Singh *et al.* (2001)
805	1188.79± 15.95	Days	Singh *et al.* (2001)
95	1107.18	Days	Urade (2001)
1113	1163±18.89	Days	Ahmad *et al.* (2001)

2.2.2 First calving interval (FCI)

Calving interval is the period elapsed between two successive calving and is composed of service period and gestation period. Variation in the calving interval is mostly attributable to the service period because gestation period is the least variable trait. Longer inter calving period increases generation interval, which is unprofitable for dairy industry. First calving interval (FCI) is a trait, which mainly depends on the management and environmental condition of the farm. Regular reproduction in dairy cows with short calving interval is a key feature for rapid multiplication of outstanding genetic material.

The mean performances of first calving interval of Sahiwal cattle as reported by various workers are summarized in Table 2.2. A wide variability was observed in first calving interval and ranged from 392 ± 17 days (Amble and Jain, 1967) to 595.04± 11.98 days (Yadav *et al.,* 1992a) in Sahiwal.

Table 2.2: Average first calving intervals (FCI) along with S.E. in Sahiwal cattle

No. of observations	Mean ±S.E. (days)	References
118	484.4	Singh and Chaudhary (1961)
76	485	Sundareson *et al.* (1965b)
111	465	-do-
115	482	-do-
	392±17	Amble and Jain (1967)
	450±19	-do-
	478.82±15.87	Bhasin and Desai (1967)
245	498.11±124.20	Kushwaha and Mishra (1969)
111	417.87±8.51	Kaul *et al.*(1971)
96	459.35±11.71	-do-
164	421.62±7.45	-do-
	429.2±5.92	Bhat *et al.*(1978)
172	459.6±8.2	Raheja and Bhat (1982)
126	433.73±8.23	Sharma *et al.*(1982)
	425.92±24.62	Chaudhary (1983)
580	473.3	Bhatnagar *et al.* (1983)
	441.42±10.35	Rathi (1989)
	455.55±14.15	Singh (1984)
580	450.5±18.75	Bhatnagar *et al.*(1984)
	448.31±12.31	Suresh Chand and Sharma (1985)
	480.56±0.0	Kumar (1986)
	425.64±92.58	Prasad (1986)
	451.78±24.70	Vij and Basu (1986)
	432.7±18.75	Prasad and Manglik (1987)
	410.8	Gurnani *et al.* (1987)
	475.43±5.71	Gandhi and Gurnani (1988)
	473	Bhat and Taneja (1989)
108	454.37±2.81	Singh and Tomar (1990)
222	595.04±11.98	Yadav *et al.*(1992a)
	486.75±6.43	Yadav *et al.*(1992b)
111	430.49	Sharma *et al.* (1993)
208	467±18	Singh *et al.*(1993b)
159	419.76±5.1	Mishra and Prasad (1994)
271	451	Sahota and Gill (1994)
	490.74±8.32	Sethi *et al.* (1995)
	503.19±7.07	-do-
	433.9	Gandhi *et al.*(1995)
155	423.09	Tomar *et al.*(1995)
815	479.11±4.23	Sethi *et al.*(1997)
209	473±14	Singh *et al.*(1997c)
	469.51±5.02	-do-
50	456.30±12.13	Singh *et al.*(1998)
	503.19±7.07	Tomar *et al.* (1998)
4700	465	Khan *et al.* (1999)
805	518.96±4.30	Singh (2000)
	507±110.02	Ahmad *et al.* (2001)
	492.6±8.18	Singh *et al.* (2001)
462	513.81±5.95	Singh *et al.* (2001)

2.2.3 First service period (FSP)

Age of animal, nutrition, suckling and stimulus exerted by the calf are important factors as they prolong the service period which in turn increase the calving interval and affect lifetime production of an animal.

The mean performance of first service period (FSP) in Sahiwal cattle breeds as reported by several workers are summarized in Table 2.3.

A wide variability in average service period was observed and ranged from 101± 5.5 days (Kavitkar, *et al.,* 1968) to 222.72± 0.05 days (Singh *et al.,* 2001) in Sahiwal.

Table 2.3: Average first service periods (FSP) along with S.E. in Sahiwal cattle.

No. of observations	Mean ±S.E. (Days)	References
-	101±5.5	Kavitkar *et al.* (1968)
-	126.6±3.3	
174	195.54±67.3	Malik and Sindhu (1968)
272	188±5.0	Chopra *et al.*(1973)
	140±5.8	Bhat *et al.*(1978)
	193.3±7.1	Bhatnagar *et al.* (1979)
172	172.9±7.2	Raheja and Bhat (1982)
580	118.9	Bhatnagar *et al.* (1983)
	124.6	Gurnani *et al.* (1987)
	177	Bhat and Taneja (1989)
1982	146.4±2.03	Azhar *et al.* (1990)
108	169.98±3.40	Singh and Tomar (1990)
6000	171.8	Khan *et al.* (1992)
217	174.3	Sahota and Gill (1992)
290	172±14	Singh *et al.* (1993a)
323	216.45±9.06	Kuralkar *et al.* (1996)
230	173±11	Singh *et al.* (1997c)
50	165.12±9.3	Singh *et al.* (1998)
462	222.72±0.05	Singh *et al.* (2001)

2.2.4 First lactation milk yield (FLMY)

Milk production is an important quantitative trait in dairy cattle for economic return. This trait is directly related to the genetic potential of the breed/ herd and the managemental practices being followed. The economics of a dairy enterprise mainly depends upon the milk production. Since this trait determines the economic value of cow, the milk yield is a potential that can be accurately measured and reasonably predicted.

The averages of first lactation milk yield along with S.E. as reported by several workers in Sahiwal cattle are presented in Table 2.4. The values presented in Table 2.4 revealed that average first lactation milk yield ranged from 1162.69 kg. (Taylor *et al.,* 1979) to 2392.39± 38.64 kg (Gandhi and Gurnani, 1988) in Sahiwal cattle.

Table 2.4: Average first lactation milk yields (FLMY) along with S.E. in Sahiwal cattle.

No. of observations	Mean ±S.E. (kg)	References
118	3283 (lbs)	Singh and Chaudhary (1961)
76	2499	Sundareson *et al.*(1965b)
111	2152	-do-
116	2218	-do-
58	1891±89	Amble and Jain (1967)
	1653±139	-do-
245	1400±588.7	Kushwaha and Mishra (1969)
857	1570.49±529.9	Mishra and Kushwaha (1970)
	1596±21	Nagpal and Acharya (1971)
	1647.43	
	2236±34	Gopal and Bhatnagar (1972)
	2138.00	Chopra *et al.* (1973)
	2367±83	Gupta *et al.* (1973)
	1639.3	Tomar *et al.* (1974)
	1799.8	-do-
	2185.00	Usha Anand and Sundaresan (1974)
	1861.70	Taneja *et al.*(1978)
	1611.1±28.5	Bhat *et al.* (1978a)
	2014.90±72.60	Chawla and Mishra (1979)
	1162.69	Taylor *et al.* (1979)
522	1617	Kumar and Narain (1979)
	1711.15	Singh (1979)
	2116.00	Bhatia (1980)
167	1857±113	Tripathi and Bhargava (1981)
108	1595.7±30.6	Sharma and Singh (1981)
343	1436.25	Taneja and Sikka (1981)

928	2058.13±9.25	Ahmad *et al.* (1982)
465	2022.1±38.87	Chawla and Mishra (1982)
580	2106.4±60.3	Bhatnagar *et al.* (1984)
	1789.33±82.55	Rathi (1984)
	1934.86±77.09	Suresh Chand and Sharma (1985)
	1808.1	Prasad and Manglik (1987)
	1880.26±44.5	Sharma *et al.* (1987)
	2392.39±38.64	Gandhi and Gurnani (1988)
	1771	Reddy and Nangercenkar (1988)
	1519.25±121.27	Singh *et al.* (1988)
	1907	Bhat and Taneja (1989)
928	2058.11±9.25	Ahmad *et al.* (1992)
	1502.7±0.0	Khan *et al.* (1992)
	1183.00±31.0	Shaw *et al.* (1992)
222	1608.7±38.3	Yadav *et al.* (1992a)
	1695.88±20.85	Yadav *et al.* (1992b)
108	1508.3	Singh *et al.* (1993b)
290	219±106	Singh *et al.* (1993a)
	2040	Sanota and Gill (1994)
181	1382.35±85.81	Deshmukh *et al.* (1995)
9052	1659.9	Gandhi *et al.* (1995)
323	1501.73±36.6	Kuralkar *et al.* (1996)
290	2518±84	Singh *et al.* (1997c)
5200	1395	Dahlin (1998)
324	1379.19	Deulkar and Kothekar (1999)
805	1643.05±21.55	Singh (2000)
462	1388.78±20.35	Singh *et al.* (2001)

2.2.5 First lactation length (FLL)

Lactation length is also an important production trait, which influence the total milk yield of a lactating animal. Lactation length is the time scale in which milk production function is carried out by the animal. A 300-305 days lactation length is desirable, as longer or shorter lactation length affects the milk yield of animal.

Averages of first lactation length along with S.E. as reported by various workers are summarized in Table2.5. The average first lactation length ranged from 236.18 days (Singh, 1979) to 348.8± 8.1 days (Bhatnagar, 1984) in Sahiwal cattle.

Table 2.5: Average first lactation lengths (FLL) along with S.E. in Sahiwal cattle.

No. of observations	Mean ±S.E. (days)	References
118	264.7	Singh and Chaudhary (1961)
160	295.8±4.7	Batra and Desai (1964)
51	301.75±8.3	Bhasin and Desai (1967)
	305±7	Amble and Jain (1967)
	288±8	-do-
245	297.25±78.53	Kushwaha and Mishra (1969)
857	284.17±70.1	Mishra and Kushwaha (1970)
272	328±5.4	Chopra *et al.* (1973)
	308.00±3.0	Ahmad *et al.* (1974)
	273.7±2.94	Bhat et al. (1978a)
	236.18	Singh (1979)
	288.58	Taylor *et al.* (1979)
322	292	Kumar and Narain (1979)
343	323.18	Taneja and Sikka (1980)
108	281.1±3.9	Sharma and Singh (1981)
	288.4±3.6	Raheja and Bhat (1982)
478	322±4.5	Chawla and Mishra (1982)
126	277.31±4.66	Sharma *et al.* (1982)
	299.00±5.68	Suresh Chand (1982)
580	336	Bhatnagar *et al.* (1983)
	293.4±8.42	Rathi (1984)
	279.9±11.2	Singh (1984)
	348.8±8.1	Bhatnagar (1984)
	315	Gurnani *et al.* (1987)
	304	Reddy and Nagercenkar (1988)
	345.38±4.49	Gandhi *et al.* (1988)
	314	Bhat and Taneja (1989)
	312	Tajane and Rai (1999)
6000	254.7	Khan *et al.* (1992)
222	290±4.45	Yadav *et al.* (1992a)
	280.40±2.30	Yadav *et al.* (1992b)
290	316±8.0	Singh *et al.* (1993a)
108	286.4	Singh *et al.* (1993b)
	299	Sahota Gill (1994)
54	284.89±9.08	Deshmukh *et al.* (1995)
9052	278.3	Gandhi *et al.* (1995)
155	281.2	Tomar *et al.* (1995)
290	309±7	Singh *et al.* (1997c)
44	266.52	Tomar *et al.* (1997)
5200	252	Dahlin (1998)
	334.49	Tomar (1998)
805	332.00±3.83	Singh (2000)
462	274.12±57	Singh *et al.* (2001)

2.2.6 First dry period (FDP)

Dry period is an unproductive phase of an animal, but essential as it plays significant role in regaining the health of an animal. It prepares the animal for next lactation. Longer dry period reduces the effective lifetime production which in turn affects the economics of milk production.

Mean performance along with S.E. of first dry period as reported by various breeders in Sahiwal cattle are presented in Table2.6.

The average values of first dry period varied from 75.3 days (Singh *et al.*, 1993a) to 239.57±5.57 days (Singh *et al.*, 2001) in Sahiwal cattle.

Table 2.6: Average first dry periods (FDP) along with S.E. in Sahiwal cattle.

No. of observations	Mean ±S.E. (days)	References
118	159.73	Singh and Chaudhary (1961)
160	121.2±8	Batra and Desai (1964)
459	89.6±7.1	Kavitkar *et al.*(1968)
	102.6±4.3	-do-
	113.6±10.1	-do-
245	196.12±98.36	Kushwaha and Mishra (1969)
	155.2±5.11	Bhat et al. (1978a)
	156.0±3.2	Bhat *et al.* (1979)
	132.40	Taylar *et al.* (1979)
	170. ±8.3	Raheja and Bhat (1982)
	134.6±4.90	Chawla and Mishra (1982)
126	160.25±7.56	Sharma *et al.* (1982)
500	139.7	Bhatnagar *et al.* (1983)
	96.7	Gurnani *et al.* (1983)
	163.5	Singh *et al.*(1988)
	180.6	Reddy and Nagarcenkar (1990)
271	163.5	Sahota and Gill (1992)
6000	192.4	Khan *et al.* (1992)
290	75.3	Singh *et al.*(1993a)
108	153±13	Singh *et al.* (1993b)
159	137.54±5.65	Mishra and Prasad (1994)
54	147.94±23.35	Deshmukh *et al.* (1995)
155	149.73	Tomar *et al.* (1996)
182	163±11	Singh *et al.* (1997c)
	167.07	Tomar *et al.*(1998)
805	186.20±3.88	Singh (2000)
462	239.57±5.57	Singh *et al.* (2001)

2.3 Factors affecting first lactation production and reproduction traits

Since economic traits in cattle are influenced by genetic and non-genetic factors to a varying degree, the knowledge of these factors on economic traits is a prerequisite for the estimation of genetic and phenotypic parameters used in predicting the breeding values of the animals.

2.3.1 Age at first calving(AFC)

Gahlot, (1990), Kachwaha (1993) and Gahlot *et al.* (2001) reported that age at first calving in Tharparkar cows were significantly influenced by the sires.

Nagpal and Acharya (1971) and Nandagawalis *et al.* (1996) observed that season of calving has no significant effect on age at fist calving in Sahiwal cattle. Singh *et al.* (1990) also reported non-significant effect of season of calving on age at first calving in Sahiwal and its crosses.

Kaul *et al.* (1973) reported significant effect of season on age at first calving in Hariana cattle.

The non-significant effects of season of calving on age at first calving were reported by Umrikar *et al.* (1990), Ulmek and Patel (1993), Mathur and Khosla (1994), Barwe *et al.* (1996) and Bhadoria *et al.* (2002) in Gir cows. Bhatnagar *et al.* (1982), Pannerselvam *et al.* (1990) Vij *et al.* (1992) and Gahlot *et al.* (2001) reported non-significant effect of season of calving on age at first calving in Tharparkar cows.

2.3.2 First calving interval(FCI)

Haque *et al.* (1999) and Aly *et al.* (2000) reported significant ($p<0.05$) effect of sire on first calving interval in Sahiwal and Friesian cows.

Bhat et al. (1978a) observed a significant effect of season of calving on FCI, while in another study the same workers reported non-significant effect of season of calving in Sahiwal. Singh *et al.* (1990) and Sethi *et al.*(1995) also reported non-significant effect of season of calving in Sahiwal and its crosses.

However, Milagrres *et al.* (1988) in Zebu, Garcha and Dev (1994) in Holestian Fresian and Souza et *al.* (1995) in Gir cows observed significant season effects of calving on first calving interval.

2.3.3 First service period(FSP)

Singh and Datt (1963) observed significant effect of season of calving on the first service period.However, Bhat et al. (1978a), Singh *et al.* (1990), Singh *et al.*. (1995) and Kuralkar *et al.*. (1996) observed non-significant effect of season of calving on first service period in Sahiwal and its crosses.

Mathur and Chahal (1997) reported non-significant effect of season of calving on first service period in Hariana cattle. However, they observed that summer season calvers had shortest service period, while longest service period in those calved in rainy season.

2.3.4 First lactation milk yield (FLMY)

Haque *et al.* (1999) reported significant effect of sire on milk yield in Sahiwal and Pabna cattle, whereas, Bangar and Narayankhedkar (1999) reported non-significant effect of sire on first lactation milk yield in Gir cows.

Parmar *et al.* (1982) and Singh *et al.* (1995) observed a significant effect of season of calving on this trait. However, Nagpal and Acharya (1971), Bhat et al. (1978a), Rao *et al.* (1984) and Mishra and Prasad (1994) observed non-significant effect of season of calving on first lactation milk yield in Sahiwal cattle.

Bangar and Naryankhedkar (1999) reported that milk yield in Gir cows was significantly higher in winter calvers than the cows those calved during other seasons. However, Mathur and Khosla (1994) reported non-significant effect of season of calving on first lactation milk yield in Gir cows, while they further reported the cows, which calved in winter, had the best first lactation milk yield than the other seasons.

Mathur and Chahal (1997) and Pandey *et al.* (2001) reported non-significant effects of season of calving on first lactation milk yield in Hariana cows.

2.3.5 First lactation length (FLL)

Haque *et al.* (1999) reported significant effect of sire on lactation length in Sahiwal and Pabna cattle. However, non-significant effect of sire on lactation length was reported by Barbary *et al.* (1999) in pure Friesian cattle.

Das *et al.* (1990), Tekade *et al.* (1994), Kassab (1995), Singh *et al.* (1996) and Mandal *et al.* (2001) reported significant effect of season of calving on FLL, while non-significant effect of season of calving have been observed by Nagpal and Acharya (1971), Bhat et al. (1978a), Rao *et al.* (1984), Deshmukh *et al.* (1995), Singh *et al.* (1995) and Tomar *et al.* (1998) in case of Sahiwal.

Mathur and Chahal (1997) reported significant effect of season of calving on first lactation length in Hariana cattle. However, non-significant effects of season on first lactation period was observed by Pandey *et al.* (2001) in Hariana and Bangar and Narayankhedkar (1999) in Gir cows.

2.3.6 First dry period(FDP)

Pandey *et al.* (2001) reported non-significant effect of sire on first dry period in Hariana cattle.

Sharma and Khan (1989) reported highly significant effect of season of calving on first dry period in Sahiwal cattle. Whereas Bhat (1978) reported non-significant effect of season of calving on first dry period. Similar results were also observed by Chawla and Mishra (1982), Rao *et al.* (1984), Mishra nad Prasad (1994) Deshmukh *et al.* (1995), Singh *et al.* (1995) and Tomar *et al.* (1998) in case of Sahiwal.

However, non-significant effects of season of calving on first dry period were reported by Garcha and Dev (1994) in H.F. and Pandey *et al.* (2001) in Hariana cattle.

2.4 Heritability estimates of first lactation production and reproduction traits

2.4.1 Age at first calving(AFC)

Age at fist calving is the first yard stick of measure the reproduction performance of an animal. The heritability estimates of age at fist calving reported by various worker in diary cattle are presented in Table 2.7.

There is wide variation in the heritability estimates of age at fist calving which ranged from very low estimate 0.003$\pm$ 0.07 (Sethi *et al.,* 1997) to very high estimate i.e. 0.80 $\pm$ 0.10 (Ahmad *et al.,* 1974) in case of Shaiwal.

Table 2.7: Heritability estimates (±S.E.) of age at first calving in Sahiwal cattle.

Heritability ±(S.E.)	References
0.46±0.18	Nagpal and Acharya (1971)
0.136	Gopal and Bhatnagar (1972)
0.80±0.10	Ahamad *et al.* (1974)
0.24±0.11	Tomar *et al.* (1974)
0.14±0.13	Gurnani *et al.* (1976)
0.25±0.11	Taneja *et al.* (1978b)
0.33±0.00	Singh *et al.* (1980)
0.37±0.31	Sharma *et al.* (1982)
0.18±0.04	Gandhi and Gurnani (1987)
0.20±0.06	Singh *et al.*(1990)
0.25±0.05	Khan *et al.* (1992)
0.16±0.11	Yadav *et al.* (1992b)
0.003± 0.07	Sethi *et al.* (1997)
0.10-0.13	Khan *et al.* (1999)
0.62±0.06	Singh *et al.* (2001)

2.4.2 First calving interval(FCI)

The heritability estimates of first calving interval as reported by several workers are presented in Table 2.8. These estimates of first calving interval ranged from very low (0.01± 0.22, Sharma *et al.,* 1982) to medium (0.24 ±0.02, Kumar, 1986). Most of the estimates of heritability value were found very low.

Table 2.8 : Heritability estimates (±S.E.) of first calving interval in Sahiwal cattle.

Heritability ±(S.E.)	References
0.01±0.15	Sandhu (1968)
0.01±0.22	Sharma *et al.*(1982)
0.10±0.07	Rathi (1984)
0.24±0.02	Kumar (1986)
0.06±0.03	Reddy and Nagercenkar (1989)
0.18±0.09	-do-
0.05±0.04	-do-
0.08±0.06	-do-
0.02±0.03	-do-
0.21±0.06	Singh *et al.*(1990)
0.18± 0.05	Khan *et al.*(1992)
0.03-0.07	Khan *et al.* (1999)
0.08±0.07	Singh (2000)
0.07±0.07	-do-
0.19±0.07	Singh *et al.* (2000)
0.11±0.04	-do-

2.4.3 First service period (FSP)

First service period (FSP) is one of the managemental traits, which is non-heritable from one generation to another; because of this, estimates of heritability regarding first service period were found non-significant (Chopra *et al.,* 1973; Taneja and Bhat, 1971 and Reddy and Nagercenkar, 1989). The heritability estimates as reported by various workers are summarized in Table 2.9.

The heritability estimates for first service period ranged from 0.03±0.03 (Reddy and Nagercenkar, 1989) to 0.2± 0.08 (Singh, 2000) in Sahiwal.

Table 2.9: Heritability estimates (±S.E.) of first service period in Sahiwal cattle.

Heritability ±(S.E.)	References
0.09±0.20	Chopra *et al.* (1973)
0.09±0.10	Taneja and Bhat (1971)
0.07±0.04	Reddy and Nagercenkar (1989)
0.18±0.11	-do-
0.08±0.07	-do-
0.15±0.07	-do-
0.03±0.03	-do-
0.18±0.05	Khan *et al.* (1992)
0.27±0.08	Singh *et al.* (2000)
0.15±0.04	-do-
0.20±0.08	Singh (2000)

2.4.4 First lactation milk yield (FLMY)

Heritability estimates along with S.E. for first lactation milk yield (FLMY) as reported by several workers are presented in Table 2.10 The values of heritability varied form 0.013±0.2 (Javed *et al.,* 2001) to 0.51± 0.21 (Khanna and Bhat, 1971) in Sahiwal.

Most of the estimates of heritability of first lactation milk yield as observed by various workers were found form medium to moderate. However, Nagpal and Acharya (1971), Gurnani *et al.,* (1976), Gandhi and Gurnani

(1995), Dahlin *et al.* (1998), Singh (2000) and Javed *et al.* (2001) reported lower estimates of heritability for the first lactation milk yield.

Table 2.10: Heritability estimates (±S.E.) of first lactation milk yield (FLMY) in Sahiwal cattle.

Heritability (±S.E.)	References
0.51±0.21	Khanna and Bhatt (1971)
0.15±0.14	Nagpal and Acharya (1971)
0.43	Chopra *et al.* (1973)
0.58±0.56	-do-
0.31±0.19	Tomar *et al.* (1974)
0.14±0.14	Gurnani *et al.* (1976)
0.41±0.14	Taneja *et al.* (1978b)
0.45±0.22	Singh (1979)
0.43±0.03	Bhatia (1980)
0.28±0.07	Singh *et al.* (1980)
0.38±0.33	Sharma and Singh (1981)
0.19±0.04	Gandhi and Gurnani (1987)
0.20	Gandhi and Gurnani (1988)
0.16±0.04	Khan *et al.* (1992)
0.30±0.15	Yadav *et al.* (1992b)
0.177	Gandhi and Gurnani (1995)
0.14±0.017	Dahlin (1998)
0.34±0.09	Singh *et al.* (2000)
0.18±0.04	-do-
0.10±0.07	Singh (2000)
0.06±0.06	-do-
0.013±0.022	Javed *et al.* (2001)

2.4.5 First lactation length (FLL)

The heritability estimates for first lactation length (FLL) along with S.E. as reported by several workers are summarized in Table-2.11. The estimates of heritability are ranging from 0.32 (Singh *et al.* 1994 and Singhal *et al.* 1994) to 0.67±0.26 (Chopra *et al.*,1973) in Sahiwal.

Table 2.11: Heritability estimates (±S.E.) of first lactation length (FLL) in Sahiwal cattle.

Heritability (±S.E.)	References
0.67±0.26	Chopra *et al.* (1973)
0.37±0.12	Ahmad and Ahamad (1974)
0.16±0.10	Taneja *et al.* (1978b)
0.21±0.12	Singh (1979)
0.38±0.33	Sharma and Singh (1981)
0.12±0.26	Sharma *et al.* (1982)
0.11±0.01	Singh (1984)
0.18±0.06	Rathi (1984)

0.07	Gandhi and Gurnani (1988)
0.12±0.04	Reddy and Nagercenker (1989)
0.37±0.12	-do-
0.09±0.05	-do-
0.19±0.07	-do-
0.09±0.04	-do-
0.23±0.13	Yadav *et al.* (1992b)
0.10±0.03	Khan *et al.* (1992)
0.032	Singh *et al.* (1994)
0.032	Singhal *et al.* (1994)
0.31±0.09	Singh *et al.* (2000)
0.05±0.04	Singh *et al.* (2000)
0.08±0.06	Singh (2000)
0.09±0.07	-do-

2.4.6 First dry period(FDP)

First dry period (FDP) is being non-productive period of the animal after first calving to next lactation and is a part of calving interval. The heritability estimates of first dry period along with S.E. as reported by several workers are summarized in Table 2.12

The heritability estimates for first dry period ranged from 0.01±0.05 (Singh, 2000) to 0.17±0.11 (Taneja *et al.,* 1978b). Most of the heritability estimates are very low as reported by Gandhi and Gurnani (1987), Singh *et al.* (1993b), Sethi *et al.* (1998), Singh (2002) in case of Sahiwal.

Table 2.12: Heritability estimates (± S.E.) of first dry period (FDP) in Sahiwal cattle.

Heritability (±S.E.)	References
0.17±0.11	Taneja *et al.* (1978b)
0.06±0.3	Gandhi and Gurnani (1987)
0.07	Gandhi and Gurnani (1988)
0.05±0.04	Reddy and Nagercenkar (1989)
0.11±0.07	-do-
0.10±0.04	-do-
0.12±0.04	Khan *et al.* (1992)
0.02±0.02	Singh *et al.*(1993b)
0.02±0.05	Sethi *et al.* (1998)
0.09±0.06	Singh *et al.* (2000)
0.04±0.03	-do-
0.02±0.06	Singh (2000)
0.01±0.05	-do-
0.028±0.03	Javed *et al.* (2001)

2.5 Comparison among heritability estimates

Raheja (1992) revealed that heritability estimates obtained under maximum likelihood method for first, second and third lactation milk yield were lower and had small standard error as compared to LS method.

Koots *et al.* (1994a) reported significant effect of differents methods of estimatation on heritability estimates.

Snyman *et al.* (1995) observed that the differences in higher/lower estimates of heritability could partly be explained through the use of different models of analysis.It seemed that the more detailed animal model yielded higher heritability than the simpler sire model.

Jain and Sadana (1998) reported that though the heritability estiamtes under REML method were found lower than the estimates obtained under LS method, but the former were more reliable as they had smaller standard error of variance.

Pander and Yadav (1998) observed that restricted maximum likelihood (REML) using animal model is the best method for estimation of genetic parameters from small data sets.

2.6 Correlation coefficients among first lactation reproduction and production traits

Though the estimates of genetic and phenotypic correlations are consistent in magnitude and direction, however some broad trends can be established on the basis of available literature. The genetic and phenotypic correlations among reproduction and production traits observed by various workers in dairy cattle are summarized in Table 2.13.

The genetic and phenotypic correlations of FCI with FSP, FDP, and FLL were reported positive and high in case of Sahiwal, while the genetic correlation of FCI with FLMY in case Sahiwal was reported negative (Table 2.13).

Table 2.13: Genetic and phenotypic correlation coefficients among first lactation reproduction and production traits in Sahiwal and other purebred cattle.

Traits	Genetic group	Correlation coefficient Genetic	Phenotypic	References
		AFC		
FCI	Sahiwal	0.02+0.4	-0.025+0.01	Singh *et al.*(1990)
		0.01	-	Gandhi and Gurnani (1990)
		Low	-	Khan *et al.* (1999)
		0.26+0.36	0.06+0.03	Singh (2000)
	Ongole	-0.28+0.25	0.07+0.06	Ramalu and Sidhu (1995)
	Hariana	0.47+0.40	0.17+0.04	Dalal *et al.*(2001)
FSP	Sahiwal	0.230+0.34	0.05+0.03	Singh (2000)
	Ongole	-0.27+0.01	0.06+0.07	Ramalu and Sidhu (1995)
		0.03+0.06	-	Singh *et al.* (1990)
	Hariana	0.41+0.38	0.18+0.04	Dalal *et al.* (2002)
FLMY	Sahiwal	0.01+0.05	0.58+0.02	Nagpal and Acharya (1970)
		0.30	0.03	Taneja *et al.*(1978)
		0.38	0.13	Taneja *et al.* (1978a)
		-0.43+0.69	0.01	Singh *et al.*(1980)
		-0.97+0.0	-	Rathi (1980)
		1.0+0.00	0.18+0.09	Suresh Chand and Sharma (1985)
		0.58+0.0	0.02+00.07	Kumar (1987)
		-0.18+0.20	0.08+0.08	
		-0.34	-	Singhal *et al.* (1994)
		0.54+0.3	0.18+0.03	Singh (2000)
	Hariana	-0.58+0.54	0.12+0.04	Dalal *et al.* (2002)
FLL	Sahiwal	0.46	0.10	Taneja *et al.* (1978a)
		-0.06	-	Gandhi and Gurnani (1990)
		Negative	-	Singh *et al.* (1999)
		-0.137+0.36	0.052+0.035	Singh (2000)
	Ongole	0.48+0.15	0.12+0.06	Venkatashwaralu *et al.* (1972)
	Hariana	0.21+0.47	0.11+0.04	Dalal *et al.* (2002)
FDP	Sahiwal	0.27+0.25	0.01	Singh *et al.* (1980)
		-	0.29	Chaudhary (1983)
		-0.61+0.01	-	Rathi (1984)
		-1.12+0.02	0.01+0.09	Suresh Chand and Sharma (1985)
		Positive		Singh *et al.* (1999)
		0.83+1.14	0.03+0.03	Singh (2000)
	Ongole	0.14+0.28	-0.03+0.07	Ramalu and Sidhu (1995)
		1.14+0.05	0.11+0.06	Venkatashwaralu *et al.* (1972)
	Hariana	0.40+0.48	0.13+0.04	Dalal *et al.* (2002)
		FCI		
FSP	Sahiwal	0.99±0.009	0.99±0.009	Singh (2000)
		0.99±001	0.99±0.001	Singh (2000)
	Ongole	0.83±0.02	0.78±0.03	Ramalu and Sidhu (1995)

	Hariana	0.99±0.01	0.97±0.01	Dalal *et al.* (2002)
FLMY	Sahiwal	-	0.31	Singhal *et al.*(1994)
		-0.464±0.48	0.35±0.03	Singh (2000)
		-0.761±0.58	0.34±0.03	Singh (2000)
		-0.05±0.05	0.25±0.46	Singh *et al.* (1980)
		0.03±0.0	0.25±0.0	Suresh Chand and Sharma (1985)
		-0.62±0.49	0.10±0.08	Kumar (1986)
		0.13±0.06	0.03±0.10	Prasad (1986)
		0.47	-	Gandhi and Gurnani (1990)
	Hariana	0.73±0.47	0.32±0.04	Dalal *et al.*(2002)
FLL	Sahiwal	0.57	-	Gandhi and Gurnani (1990)
		-	0.47	Singhal *et al.*(1994)
		0.92±0.33	0.54±0.04	Singh (2000)
		0.915±0.33	0.53±0.02	Singh (2000)
	Hariana	0.71±0.31	0.50±0.03	Dalal *et al.* (2002)
FDP	Sahiwal	0.78±0.58	0.03±0.03	Singh (2000)
		0.69±0.69	0.713±0.01	Singh (2000)
	Ongole	0.52±0.17	0.75±0.03	Ramalu and Sidhu (1995)
	Hariana	0.89±0.16	0.78±0.02	Dalal *et al.* (2002)
			FSP	
FLMY	Sahiwal	-0.39±0.4	0.35±0.03	Singh (2000)
		-0.63±0.56	0.35±0.03	Singh (2000)
	Hariana	0.84±0.42	0.34±0.04	Dalal *et al.* (2002)
FLL	Sahiwal	0.95±0.3	0.53±0.03	Singh (2000)
		0.93±0.32	0.53±0.02	Singh (2000)
FDP	Sahiwal	0.73±0.58	0.71±0.02	Singh (2000)
		0.65±0.69	0.71±0.02	Singh (2000)
	Ongole	0.28±0.01	0.36±0.06	Ramalu and Sidhu (1995)
	Hariana	0.80±0.25	0.53±0.03	Dalal *et al.* (2002)
			FLMY	
FLL	Sahiwal	0.08±0.62	0.68±0.01	Singh *et al.* (1980)
		0.38±0.17		Sharma and Singh (1981)
		-0.35±0.25	0.35±0.07	Sharma *et al.* (1987)
		0.72		Gandhi and Gumani (1990)
		0.65	0.75	Singh *et al.* (1994)
		0.73±0.03	0.95±0.00	Singh *et al.* (1997a)
		-0.14±0.59	0.72±0.01	Singh (2000)
		-0.16±0.7	0.73±0.01	Singh (2000)
	Hariana	0.843±0.018	0.886±0.095	Pandey *et al.* (2001)
		0.73±0.32	0.70±0.03	Dalal *et al.* (2002)
FDP	Sahiwal	-0.68±0.17	-0.16±0.04	Singh *et al.*(1980)
		-0.95±0.02		Rathi (1984)
			Negative	Singh *et al.* (1999)
		-0.78±1.5	-0.19±0.03	Singh (2000)
		-1.46±1.03	-0.20±0.03	
	Hariana	0.54±0.37	-0.10±0.04	Dalal *et al.* (2002)
			FLL	
FDP	Sahiwal	-1.10±0.09	-0.17±0.04	Singh *et al.* (1980)
			-0.45±0.07	Rathi (1984)
			Negative	Singh *et al.*(1999)
		0.48±0.42	-0.20±0.03	Singh (2000)
		0.34±1.4	-0.20±0.03	Singh (2000)
	Hariana	0.24+0.60	-0.10±0.04	Dalal *et al.* (2002)

2.7 Breeding value estimation

In order to make rapid genetic progress in performances through selection for traits of economic importance, selected animals must be chosen for their superior breeding value (Dalton, 1985; Bichard, 1988; Dempfle, 1988; Falconer, 1989; Nicholas, 1993). There are many sources of information, on which individuals breeding values can be estimated. These include individual performance, family performance and the combined performances of individual and family weighted appropriately after correlation for known environmental effects. Falconer (1989) and Nicholas (1993) documented the conditions under which the use of these different sources of information were appropriate. A point worth highlighting is that when heritability is low, combining individual and family performances, appropriately weighted, provides the maximum response to selection.

Traditionally, in the absence of random mating, the breeding values are estimated as the individual or progeny deviation form contemporary performance within an environment (Dalton, 1985; Falconer, 1989 and Nicholas, 1993) after adjusting for most identifiable environmental sources, viz birth rank, rearing rank, age of dam and age of the individual. Estimation of breeding value would be biased from traditional method in selected population. Recently, best linear unbiased prediction (BLUP) developed by Henderson (1949; 1973), is better method (Henderson, 1973, 1980; Kennedy, 1981; Falconer, 1989; Nicholas, 1993), particularly, when IAM has been employed for the analysis. The model of analysis under BLUP takes into account the fixed effects and relatedness between animals, therefore, breeding value estimated from this methods are less biased (Falconer, 1989; Henderson, 1973, 1990b and Nicholas, 1993).

2.7.1Relative efficacy of different sire evaluation method

In dairy cattle sire evaluation based on milk yield is most widely used criteria for estimating the genetic merit of a sire. However, other first lactation traits like peak yield, first lactation milk yield as well as reproduction traits like age at first calving, calving interval etc. also included in sire evaluation programme,.

Lush (1933) was the first who discussed different sire indices and recommended equal parent index to be best as it was simple for field use. Robertson and Rendel (1954) found that daughter's average index and contemporary comparison methods were suitable in sire evaluation for random mating and nonrandom mating.

Jain and Malhotra (1971) carried out a study on relative merit of eleven methods for estimating breeding values of dairy sire on the single herd basis. In two methods, only daughter's production was considered, in another three, daughter's and dam's records were used and in rest six, the information of daughters were used. Their contemporaries, with or without records of their dam, were utilized to get the breeding values of sires. They found that the I=A+1/2 heritability q (D-CD) could be the most efficient for dairy sire evaluation, when dam's records are not available otherwise index I=A=1/2 heritability Q (D-CD)-b (M-CM) could be the best.

Chander and Gurnani (1976) carried out the sire evaluations by nine different methods in Tharparker cattle. They suggested that index

I=A+2nheritability/4+(n-1)n^2 (D-CD)-b (M-CM) was the most efficient when the heritability was below 0.3, but in case of high heritability (i.e.>0.3), the index I=A+n/n+12 [(D-CD)-b (M-CM) was found to be most efficient.

Harvey (1979) compared the accuracy of SRLS with Henderson's BLUP procedure. He found that BLUP method of sire evaluation was 1-7% more efficient than SRLS, when usual assumptions were met.

Four methods of Holstein sires evaluation viz., simple daughter average, corrected daughter average, contemporary comparison and least squares methods for non-orthogonal data, were corporated by Rao (1979). He found that corrected daughter average index gave lowest standard error closely followed by simple daughter average index, cc and least square methods.

Parekh and Pande (1982) compared five methods of sire evaluation namely, predicted difference unadjusted data, predicted difference on adjusted data, LS, SRLS and BLUP method. They suggested that LS was the most accurate in crossbred progeny of H.F. and Jersey sires for milk production.

Different sire evaluation methods for Sahiwal and H.F. bulls were analyzed by Tajne and Rai (1990). The BLUP procedure was found most superior in appraisal of genetic merit of Sahiwal and Friesian sires for milk yield.

Gandhi and Gurnani (1992) studied 37 Sahiwal bulls on the basis of 305 days milk production and various production efficiency traits over lactation. They found that the selection of bulls on the basis of production efficiency traits would bring more genetic improvement in herd, because of high heritability and favourable correlation with lactation traits.

Raheja (1992)reported least squares (LS) method to be more accurate than best linear unbiased prediction (BLUP) method.

Singh *et al.* (1992) compared BLUP, LS, SRLS and CC methods for ranking of Hariana sires for part lactation milk yield. The BLUP method was considered to be more appropriate method than others, due to its sound theoretical properties and lesser prediction error variance.

Parekh *et al.* (1994) studied LS, PD, SRLS and BLUP procedure for evaluation of HF sires using two models viz., model one and model two. Not much differences were observed in ranking under two models. They observed that under model 1, BLUP was most suitable while under model 2, LS, SRLS and PD were more appropriate methods for ranking the sires.

Pundir and Raheja (1994) used multi trait BLUP procedure for estimating breeding values of Sahiwal sires for first lactation and lifetime performance traits. The rank and product moment correlation ranged between 0.22 to 0.91 and 0.21 to 0.84, respectively, between first lactation and life time performance traits. They evaluated the Hariana and Sahiwal sires for first lactation and lifetime productivity. They applied multi-traits best linear unbiased prediction (BLUP) procedure to estimate the breeding value of sires for different first lactation and life time traits. Multi trait mixed animal model included the year season of calving fixed effect and sire genetic group as random effect. They found t hat rank of sire for different traits were found almost similar for 4-5 per cent of top sires for first lactation and life time traits.

Further they suggested t hat sire should be selected on the basis of first lactation traits and selection or evaluation of dairy sires for lifetime could be used as additional criteria.

Gokhale and Mangurkar (1995) were used five methods (SDA, HMC, CC, LS ands LBUP) for sire evaluation in Holstein crossbreds. They evaluated the sires on the basis of 305 day lactation milk yield. They reported that sire which ranked superiors by HMC, CC and BLUP methods, was ranked second by SDA and LS methods. Since rank correlation and simple product moment correlation under CC and BLJP method were highly correlated, they revealed that BLUP and / or CC methods can well be used for evaluation of sires under field conditions.

Kuralkar *et al.* (1995) compared five models of BLUP for evaluating 323 progeny of 23 Sahiwal bulls on the basis of first lactation milk yield. The model one (BLUP) was more efficient than other models which includes fixed effects of herd (farm), season, year and sires as random effects. The rank correlation among models ranged form 0.64 to 1.00. He evaluated sire using different non-genetic fixed effects in BLUP models for first lactation milk yield in Sahiwal. For this they used five best linear unbiased prediction (BLUP) models. Model I included fixed effects of herd (Farm), season, year and random effect of sires. Years were grouped into period in model 2. Age at first calving in model 3 and preceding service period in model 4. In model 5 they included both the traits. The BLUP model 1 was found more efficient than the other models because standard errors of prediction in model 1 were lower.

Thus they concluded that the BLUP including the fixed effect of year and the random effect of sire are recommended

Singh and Parekh (1995) evaluated sire for 305 days first lactation milk yield in 2-breed progeny. They used five different methods of sire evaluation viz,HMC, PD, LS, SRLS and BLUP. They reported that ranking of sire by LS, PD and SRLS was positive for all 21 sires out of 44 tested, while HMC and BLUP estimated 24 and 22 sires positive, respectively. They observed positive and significant rank correlations under all the five methods, and also concluded that SRLS can be used as best method for sire evaluation.

Gaur and Raheja (1996) evaluated the Sahiwal sires for part and first lactation 300 days milk yields. Breeding values of sires were estimated by best linear unbiased prediction (BLUP) procedure using a model containing year of calving, season of calving and sire genetic group as fixed effects, sire within sire genetic group as random effect and age at first calving as covariable. They reported that accuracy of estimates of breeding values of sires for 300 days milk yield was higher than accuracy of sires breeding values for part yield, however, further they suggested that selection of sires based on 150 days milk yield of daughters with reasonable accuracy can be made to reduce the time required to take selection decision.

Gaur and Raheja (1996) further evaluated the sires on the basis of peak yield, lactation length and lactation yield under LS and BLUP methods. They observed that there was not much difference in ranking of sires for all 3 traits. They reported low product moment and rank correlations between LS and BLUP for lactation length, while both product moment and rank correlations among estimates for peak yield and lactation yield ere high (0.83 to 0.88). Finally, they concluded that due to complexity of BLUP procedure, the simple leasts squares constants of sires would be better for genetic evaluation of sires.

Thakur (1997) compared four methods (BLUP, LS, SRLS, and CC) to evaluate Jersey sires. The BLUP was categorized more appropriate followed by SRLS/ LS and CC methods.

Sahana and Gurnani (1999) evaluated the Karanfries sire on the basis of lactation milk yield trait. The rank correlation between breeding values estimated using auxiliary traits were high i.e. varied from 0.77-0.78.

Dhaka and Raheja (2000) used DLS, RLS and BLUP procedures to evaluate the Sahiwal bulls. They observed estimates of breeding value obtained from RLS showed perfect normal distribution followed by BLUP. Further, RLS has the minimum standard error followed by BLUP and OLS methods. But due to cost of computations and relative computational difficulties they suggested BLUP is the best method.

Sahana and Gurnani (2000) used first lactation performance records of Karan Fries cows to examine the efficiency, accuracy and repeatability of 5 sire evaluation methods viz., SDA, CC, LSQ, SRLS, and BLUP. The CC method was observed to be most efficient sire evaluation method and SDA the least efficient. Though BLUP method was considered to be most efficient method, had lower efficiency than CC method under Indian farm condition, due to small data size. The rank correlation of CC method with other 4 methods ranged between 0.77 with SRLS and 0.85 with BLUP.

Singh (2000) compared three methods (BLUP, LS, SRLS) to evaluate the Sahiwal bulls. The sound theoretical properties of BLUP categorized as most suitable followed by SRLS and LS method for ranking of Sahiwal bulls. He further observed maximum rank correlation between LS and SRLS method (0.991) on the basis of different trait where as minimum correlation was estimated between LS-BLUP and SRLS-BLUP method (0.634) indicating maximum and minimum, respectively, between these methods.

He also reported rank correlation between FLPY and F300 (0.983 to 0.920), between FLPY and FLMY (0.737 to 0.779) and between F 300 and FLMY (0.815 to 0.857) by different methods of sire evaluation and found similarities between traits for sire evaluation. Further, he suggested that sire should be selected on the basis of FLPY.

Gaur *et al.* (2001) carried out a study to estimate the sire solutions using SDA, CC, LS and BLUP procedures. They suggested that either of the methods can be used for the selection of sires for breeding purpose to improve total lactation milk yield. However, due to complexity of BLUP, LS and CC can be used in practice for genetic evaluation of sires.

MATERIALS AND METHODS

*"Use all methods analytical,
bring every detail into play planning to
the critical cause the team to win their way"*

3.1 Source of experimental data:

Data in present study were recorded over a period of 26 years (1975-2001), from pedigree sheet of 875 Sahiwal cattle, maintained at State Livestock cum Agriculture Farm, Chak Ganjaria, Lucknow (U.P.). The cows were progenies of 57 sires.

The farm was established in 1959 near Gusaiganj of district Lucknow, Uttar Pradesh. It is located about 15 km. away from Lucknow on Lucknow-Varanasi road. The records available on farm were examined and scrutinized carefully. Lactation records which were considered abnormal on account of systematic disorders, abortion and death of calf during lactation and records below 150 days of lactation yield, were omitted from the present study.

3.2 History of Sahiwal cattle:

Sahiwal is one of the best dairy breeds of Indian sub-continent. The breeding tract of this breed was Montgomary district of United India, now in Pakistan. Professional herdsman called "Junglies" once kept them in large herd. However, with the introduction of irrigation to the region they began to be kept in smaller numbers by the farmers of the region, who used them as draft and dairy animals.

This breed is known for tick-resistant, heat-tolerant and noted for its high resistance to parasites, both internal and external. Due to their heat tolerance and high milk production they have been exported to other Asian countries as well as Africa and the Caribbean. As oxen they are generally docile and lethargic, making them more useful for slow work. The color can range from reddish brown to the more prominent red with varying amounts of white patches on the neck, and the underline. In males the color darkens towards the extremities such as the head, legs and tails.

The Sahiwal is the heaviest milker of all Zebu breeds and display a well-developed udder. Sahiwal are noted for their hardiness under unfavorable climatic conditions.

3.3 Management of the herd:

The Department of Animal Husbandry, U.P. provides necessary guidelines regarding managemental practices and feeding schedules of animal's time to time, to be followed.

It is found/ noticed that uniform feeding of animals as per prescribed schedule was rarely met due to administrative, financial and other reasons. The proportion and quality of different items of feeds were also variable as per their availability in different seasons and years.

The disease control means were also prescribed by the Department of Animal Husbandry, U.P. The vaccination against R.P., H.S. and F.M.D. were followed regularly; dewarming schedule was also practiced regularly.

The weaning system was practiced in Sahiwal herd. Approximately one teat was left for suckling to the calves. The milking has practiced two times in a day; 4.30 A.M. and 4.30 PM. and each cows milk has recorded daily. Complete stripping of cows were practiced, thrice in a month to estimate the test yield as well as record peak yield on 1, 11, 21 day of every month.

3.4 Recording of observations:

The observations pertaining to lactation records of the animals were recorded from history/pedigrees sheets available at farm. The information on the following items were recorded.

1. Animal No.
2. Sire No.
3. Dam No.
4. Date of birth.
5. Date of first calving.
6. Date of second calving.
7. Date of first service.
8. Date of second service.
9. Date of first drying.
10. First lactation length.
11. First lactation milk yield.

3.4.1 Traits considered:

All the 875 cattle were recorded for the following traits:

1. Age at first calving (AFC)
2. First calving interval (FCI)
3. First service period (FSP)

4. First lactation milk yield (FLMY)
5. First dry period (FDP)
6. First lactation length (FLL)

3.5 Classification of data:

The data were classified according to season of calving. Generally Uttar Pradesh is categorized under sub-tropical continental climatic condition. However, the middle plain of U.P. in which the farm is situated (as regard to microclimatic conditions) categorized under normal humid tropical area, with 80-90 cm average annaul rainfall. The lowest temperature recorded in January averaging 12-15^{0}C, whereas the highest temperature recorded in June with average temperature of 44-45^{0}C. The distribution of rainfall is also varying sharply. Overall climatic condition varies sharply, 70 % of the rainfall belongs to threes months July, August, September of the year. The four seasons based on the climatic conditions (Relative humidity, temperature, rainfall etc.) were classified:

Duration of months	Season	Code
1. December, January, February (Humid with low temperature)	Winter	1
2. March, April, May (High temperature and low humidity)	Summer	2
3. June, July, August (High temperature and high humidity)	Rainy	3
4. September, October, November (Moderate temperature)	Autumn	4

3.6 Statistical Analyses

Least-squares analysis (LSA) and derivative-free Restricted Maximum Likelihood (DFREML) methods were used for the estimation of genetic and phenotypic parameters and variance-covariance components.

3.6.1 Least-squares analysis of variance (LSA) method

The LSMLMW and MIXMDL package of Harvey (1990) under different models were carried out for the analysis. Two models were considered to examine the effect of genetic and non-genetic factors on various first lactation reproduction and production traits.

3.6.1.1 Model 2

This model considered was from Harvey (1990), which consists of one set of cross-classified non-interacting random effect. All six traits were analyzed simultaneously with the following statistical model :

$$y_{ijk} = \mu + S_i + C_j + e_{ijk}$$

where,

y_{ijk} is observation on k^{th} progeny of i^{th} sire in j^{th} season,

μ is the overall mean,

S_i is random effect of i^{th} sire (i = 1,2, ..., 57),

C_j is the fixed effect of the j^{th} season (j=1,2,3,4),and

e_{ijk} is the random error which is normally and independently distributed with mean 0 and variance σ^2_e.

The analysis computed with the mixed model least-squares program utilizes the Method 3 of Henderson (1953).

3.6.1.2 Model 8

This model considered was from Harvey (1990). The model was fitted on all the traits and the traits were analyzed separately. The general formulation of the mixed model fitted on the observation, comprised the following:

$$y_{ij} = \mu + C + e_{ij}$$

where,

y_{ij} is observation on i^{th} progeny i^{th} season,

μ is the overall mean,

C_i is the fixed effect of the i^{th} season (j=1,2,3,4),and

e_{ij} is the random error which is normally and independently distributed with mean 0 and variance σ^2_e.

The formulation of the model in matrix notation was as follows:

$$y = I\mu + Xb + Za + e$$

where,

I is the column vector of one's,

μ is an overall mean,

b is a column vector of fixed effect,

a is a column vector of random effect,

Z is an incidence matrix of 0′ s and I's,

X is an incidence matrix of 0′ s, I's & - I's and X-$\overline{X}$ values for the discrete effects, and

e is a column vector of the random errors.

In this model only random effect was considered. Henderson's mixed model equations were used by MIXMDL program of Harvey (1990) to estimate Best Linear Unbiased Predictions (BLUP) of random effect, Best Linear Unbiased Estimates (BLUE) of the fixed effect and the MINQUE estimates of variance component. In this analysis, MINQUE estimates of the variance components are computed and the REML option was used to obtain restricted maximum likelihood estimates of variance components from iterative MINQUE.

Mixed model equations were:

$$\begin{bmatrix} N & 1'Z & 1'X \\ Z'1 & Z'Z + k A^{-1} & Z'X \\ X'1 & X'Z & X'X \end{bmatrix} \begin{bmatrix} \hat{\mu} \\ \hat{a} \\ \hat{b} \end{bmatrix} = \begin{bmatrix} y. \\ Z'y \\ X'y \end{bmatrix}$$

where,

$k = (1 - REP) / REP = \sigma^2_e / \sigma^2_a$,

A^{-1} = an inverse of the relationship matrix, and

REP = intra-class correlation

Now let the inverse segment for the random set of effects ($Z'Z + k A^{-1}$ section) from the inverse of the coefficient matrix be designed as Caa.

MINQUE estimates of variance components:

The MINQUE quadratics form, from Henderson (1984) was:

$$Q_1 = \hat{a}' A^{-1} \hat{a}$$
$$Q_2 = \hat{e}'\hat{e}$$

where, $\hat{e} = y - X\hat{b} - Z\hat{a}$

and

$$E(Q_1) = E(\hat{a}' A^{-1} \hat{a}) = tr\,[A^{-1}\,Var\,(\hat{a})] = T_{11}\,\sigma^2_a + T_{12}\sigma^2_e$$

$$T_{11} = s - 2k\,tr\,(A^{-1}\,Caa) + k^2\,tr\,(A^{-1}Caa\,A^{-1}Caa\,)$$

$$T_{12} = tr\,(A^{-1}Caa\,) - k\,tr\,(A^{-1}Caa\,A^{-1}Caa\,)$$

$$E(Q_2) = E\,(\hat{e}'\,\hat{e}) = tr\,[\,Var\,(e)] = T_{21}\,\sigma^2_a + T_{22}\,\sigma^2_e$$

$$T_{21} = k^2\,T_{12}$$

$$T_{22} = N - p - s + k^2\,tr\,(A^{-1}Caa\,A^{-1}Caa\,)$$

The MINQUE equations were:

$$\begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \cdot \begin{bmatrix} \sigma^2_a \\ \sigma^2_e \end{bmatrix} = \begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix}$$

where,

tr = trace,

s = number of random classes,

N = total number of observations, and

p = number of degrees of freedom for fixed effects including one for μ.

The sum of squares of solutions to the MME (mixed model equations) with the expectations calculated from the inverse of the coefficient matrix for the MME could be used to obtain MINQUE estimates of variance components. Iterative MINQUE with normality was the same as REML.

3.6.1.3 Estimation of parameters

The estimates of h^2 and genetic, phenotypic and environmental correlations were computed from sire components of variance and covariance using LSMLMW and MIXMDL computer program PC-2 (Harvey, 1990). Estimates of heritabilites and all correlations were based upon variance and covariance components using the method of paternal half-sibs correlations. The theoretical expectations and causal components for variances and covariances among families used in this study are shown in Table3.1.

Table 3.1: Simultaneous equations to estimate causal components of variance from observed family variances under model 2 and 8

Observed family components	Statistical model used	Causal components							
		Additive			Dominance			σ^2_{EC}	σ^2_e
		σ^2_{AD}	σ^2_{AM}	σ^2_{ADAM}	σ^2_{DD}	σ^2_{DM}	σ^2_{DDDM}		
$\sigma^2_{s(PHS)}$	Model 2	1/4	0	0	0	0	0	0	0
$\sigma^2_{w(PHS)}$	Model 2	0	0	0	0	0	0	0	¾
$\sigma^2_{s(PHS)}$	Model 8	1/4	0	0	0	0	0	0	0
$\sigma^2_{w(PHS)}$	Model 8	0	0	0	0	0	0	0	¾

where, σ^2_{AD} additive direct, σ^2_{AM} additive maternal, σ^2_{ADAM} additive direct maternal, σ^2_{DD} dominance direct, σ^2_{DM} dominance maternal , σ^2_{DDDM} dominance direct maternal, $_{PHS}$ paternal half sibs, σ^2_{EC} permanent maternal environmental, and $\sigma^2 e$ random environmental.

3.6.1.3.1 Estimation of heritability:

3.6.1.3.1.1 under model 2

The heritability for the traits under study were computed by the paternal half-sib correlation method. The expected mean squares (EMS) for various effects were:

ANOVA Table

S.V	D.F	M.S	E(MS)
Between sire	s-1	MS_s	$\sigma^2_e + k_1 \sigma^2_s$
Between season	c-1	MS_c	$\sigma^2_e + kk_2\sigma^2_c$
Error	N-s-c-y+2	MS_e	σ^2_e
Total	N-1		

The components of variance were estimated as follows:

$$\hat{\sigma}^2_e = MS_e$$

$$\hat{\sigma}^2_s = (MS_s - MS_e)/k_1$$

and $$k_1 = \frac{1}{s-1}[N - \frac{\sum_{i=1}^{s} n_i^2}{N}]$$

$$h^2 = \frac{[(1-NR1)\hat{\sigma}^2_s]}{[((1-NW)/NR1) * \hat{\sigma}^2_s + \hat{\sigma}^2_e]}$$

where,

$\hat{\sigma}^2_s$ is cross classified sire variance component estimate,

$\hat{\sigma}^2_e$ is error variance estimate,

NR1 is the decimal percentage of additive genetic variance in σ^2s. NR1 is between variance component and is equal to 0.25, and

NW is the decimal percentage of additive genetic variance in σ^2e in random mating population. NW is within variance component and is equal to 0.75.

3.6.1.3.1.2 under model 8

The heritability estimated under Model 2 analysis was divided by 4 and then the value obtained was used as intra-class correlation in REP option for respective trait in Model 8 analysis. This method also used paternal half-sib correlations method to estimate the h^2. Therefore, the intra-class correlation was estimated by using VAR (A) and VAR (E), estimated under MINQUE, and then this correlation value was multiplied by 4 to obtain h^2.

$$t = \hat{\sigma}^2_s / (\hat{\sigma}^2_s + \hat{\sigma}^2_e)$$

$$h^2 = 4t$$

where,

t is intra-class correlation among half sibs,

$\hat{\sigma}^2_s$ is the between sire component of variance, and

$\hat{\sigma}^2_e$ is the within sire component of variance or error variance.

3.6.1.3.2 Estimation of correlations

$$r_g(hh') = \frac{\mathrm{Cov}_s(hh')}{\sqrt{\hat{\sigma}^2_s(h) \times \hat{\sigma}^2_s(h')}}$$

$$r_e(hh') = \frac{\hat{\sigma}_e(hh') - [(NW/NR1)\ \hat{\sigma}_s(hh')]}{\sqrt{[\hat{\sigma}^2_e(h) - (NW/NR1)\hat{\sigma}^2_s(h)][\hat{\sigma}^2_e(h') - (NW/NR1)\hat{\sigma}^2_s(h')]}}$$

$$r_p(hh') = \frac{\hat{\sigma}_e(hh') + \{[(1\text{-NW}) / \text{NR1}]\ \hat{\sigma}_s(hh')\}}{\sqrt{[\hat{\sigma}_e^2(h) + ((1-NW)/NR1)\hat{\sigma}_s^2(h)][\hat{\sigma}_e^2(h') + ((1-NW)/NR1)\hat{\sigma}_s^2(h')]}}$$

where,

Cov_s is sire or family covariance,

h refers to h^{th} trait and h' refers to another trait respectively,

$\hat{\sigma}^2_s$ refers among variance or covariance components, and

$\hat{\sigma}^2_e$ refers within variance or covariance components.

3.6.1.3.3 Estimation of standard error

The standard error of h^2 was estimated using the formula of Swiger *et al.* (1964) which is as follows:

$$S.E\ (h^2) = \frac{4\ \sqrt{2(N-1)(1-t)^2(1+(k-1)t)^2}}{\sqrt{k^2(N-s)(s-1)}}$$

where,

t is intra-class correlation,

s is the number of sires,

N is the total number of observations, and

k is the average number of progenies per sire.

The standard error of genetic correlation was estimated by the formula as given by Robertson (1959):

$$S.E\ (r_g) = \frac{1-r_g^2}{\sqrt{2}} \times \frac{\sqrt{S.E(h_x^2) \times S.E(h_y^2)}}{\sqrt{h_x^2 \times h_y^2}}$$

where,

h^2_x and h^2_y are the h^2 estimates of trait x and y, respectively,

S.E is the standard error, and

r_g is genetic correlation.

The standard error of phenotypic correlation was estimated by the formula as given by Panse and Sukhatme (1967):

$$S.E\ (r_p) = \frac{\sqrt{1 - r^2_{p(xy)}}}{\sqrt{N-2}}$$

where,

$r_{p(xy)}$ is the phenotypic correlation between trait x and trait y, and

N is the total number of observations.

The significance of phenotypic correlation was tested from the Table of Snedecor and Cochran (1967) at (N-2) degrees of freedom.

3.6.2 Restricted Maximum Likelihood (REML) method

For REML estimation of variance components, data were analyzed by derivative free Restricted Maximum Likelihood (DFREML) program of Meyer (1998) under univariate animal model. Derivative free restricted maximum likelihood (DFREML) was described by Smith and Graser (1986) and Meyer (1989b). The program attempts to locate the likelihood function (L) without using information from derivative of L. The derivative free algorithm, for use in REML (co)variance component estimation in animal or reduced animal model, does not require matrix inversion, instead it uses dimensional search involving the variant part of the log likelihood to find the maximum of the function. Computational strategies used and problems associated with this kind of analysis have been discussed by Meyer (1992a. 1993a).

Variances components were estimated by REML using a derivative free algorithm, fitting an animal model throughout and incorporating all available pedigree information (Meyer, 1989, 1991, and 1998). Variance matrices were estimated by derivative free REML (Smith and Gracer, 1986; Gracer *et al.*, 1987) and popularized by Meyer (1988, 1989 and 1991). The single trait DFREML program developed by Meyer (1998) was used. Heritability estimates were subsequently obtained by using the derivative-free REML procedure (DFREML) of Meyer (1998) using animal model. The heritability was categorized as direct in animal model where only a direct effect was fitted. The model includes all animals, even without records, but as parents in the base population. It, therefore, take all information into account for the estimation of variance components (Sorenson and Kennedy, 1986). Full pedigree were available, but parents with only a single link to one offspring were treated as unknown, as they did not contribute any information and unnecessarily increased the number of effects in the analysis (Meyer, 1994).

3.6.2.1 Single trait model

In univariate analysis, age at first calving (AFC), first calving interval(FCI),first service period (FSP),first lactation milk yield(FLMY), first lactation length(FLL) and first dry period (FDP) were analyzed separately.

The same model was fitted on all six traits. The general formulation of the mixed model fitted on the observations, comprised the following:

$$y_{ijk} = \mu + A_i + C_j + + e_{ijk}$$

where,

y_{ijk} is the observation on k^{th} trait of i^{th} animal in j^{th} season,

μ is the overall mean,

A_i is random effect of i^{th} animal (i = 1,2, ..., 875),

C_j is the fixed effect of the j^{th} season (j=1,2,3,4),and

e_{ijkl} is the random error which is normally and independently distributed with mean 0 and variance σ^2_e.

The formulation of general single trait animal model, in matrix notation, is:

$$y = Xf + Za + e$$

where,

y is a vector of N x 1 records (i = 1,2,3,4),
f is a vector of fixed environmental effect of season(1,2). No covariable was taken here,
a is a vector of breeding values for additive direct genetic effects fitted which is random,

X is a $N \times NF$ design matrix for fixed effects with column ranks $N \times F^*$,

Z is a $N \times NR$ design matrix for random animal effects, where Z = I,
and e is a vector of N random residual errors.

Assumptions of the model were:

$$E[y] = Xf$$

$$E[a] = E[e] = 0$$

with variances,

$$Var(a) = A\,\sigma^2_a = G$$

$$Var(e) = I\,\sigma^2_e = R$$

$$Cov(a, e') = 0$$

$$Var(y) = ZAZ'\,\sigma^2_a + I\,\sigma^2_e = ZGZ' + R = V$$

where,

A is numerator relationship matrix,

σ^2_a is direct additive genetic variance,

σ^2_e is residual variance, and

I represents identity matrix.

All the covariances were assumed to be nill. This was the simple animal model fitting animals' direct additive genetic effect only (i.e., ignoring any maternal effects). Additionally, inbreeding was excluded from vector f but included in A. Starting values for h^2 given was taken from estimate of model 8 of least-squares analysis. The left-hand bracket was given as 0.1 and right hand as 0.5.

3.6.2.3 Evaluating the Likelihood

Assuming the above model in which y has a multivariate normal distribution with mean Xb and variance V, the log of the likelihood function (L) to be maximized is then (Meyer, 1993):

$$\log L = -\frac{1}{2}[const + \log|V| + \log|X^{*\prime}V^{-1}X^{*}| + (y - X\hat{b})'V^{-1}(y - X\hat{b})]$$

where,

X^* (of order N x NF^*) denotes a full column rank sub-matrix of X, and

$X^* = X^0$

Alternatively, the log likelihood can be expressed as a function of covariance matrices of the random effects in the model of analysis (Harville, 1977 and Searle, 1979):

$$-2\log L = const + \log|R| + \log|G| + \log|C| + y'Py$$

where,

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

$= V^{-1} - V^{-1}X^*(X^{*\prime}V^{-1}X^*)^{-1}X^{*\prime}V^{-1}$

R is the residual covariance matrix associated with random effects,

C is the coefficient matrix of the general mixed model equations, and

$y'Py$ is a generalized residual sum of squares.

Maximum likelihood estimation consists of obtaining the parameters (i.e. variance components) that maximize the likelihood function (L). Maximizing likelihood function is same as maximizing the log L or minimizing the -2log L.

3.6.2.4 Calculation of $\log|C|$ and $y'Py$

These two terms viz., $\log|C|$ and $y'Py$, require 'factorization' of the coefficient matrix of the MME. The factorization was done by Cholesky decomposition (Boldman & Van Vleck, 1991). Coefficient matrix (C) can be decomposed in to the product of a lower triangular matrix (L ={l_{ij}} with l_{ij} = 0 for j>i) and its transpose.

$$LL' = C$$

C, to be decomposed, should be positive definite and of full rank.

then, $\log|C| = 2 \sum_{i=1}^{NR+NF^*} l_{ii}$

Therefore, the determinant of a triangular matrix is simply the product of its diagonal elements. Solutions for fixed and random effects fitted are obtained by solving the two triangular systems by simple forward/backward substitutions, i.e. Lv = r and L'w = v;

where, r is the vector of RHS in the MME.

The solutions are used to determined $y'Py$ as (Harville, 1977):

$$y'Py = y'R^{-1}y - y'R^{-}X^{*}\hat{b}^{*} - y'R^{-1}Z\hat{a}$$

3.6.2.5 Calculation of $\log|R|$

$$\log|R| = \sum_{w=1}^{W} Nw \log|Ew|$$

where,

R is block diagonal for animal when cov(ee') = 0,

W is the possible combinations of traits recorded,

N*w* represents number of animals having records for combinations of traits *w*,

E*w* is the sub-matrix of variance-covariance matrix for the trait *w* (*w*<=q),

Obtained by deleting rows and columns pertaining to missing records.

3.6.2.6 Calculation of $\log|G|$

$$\log|G| = NA\log|T| + q\log|A|$$

where,

G = T × A

T is the additive genetic covariance matrix between traits, of size q × q,

NA is the total number of animals,

q is the number of traits,

A is the numerator relationship matrix between animals, and

× is the direct matrix product.

$\log|A|$ does not depend on the parameters to be estimated and is not required in order to maximize log L.

3.6.2.7 Univariate analyses

For this analysis, R = σ^2_E I and the error variance can be estimated directly from the residual sum of squares as:

$$\sigma^2_E = y'Py \; / \; (N\text{-}r(X))$$

Hence the likelihood can be maximized with respect to remaining parameters expressed as a function of the original variances and σ^2_E, i.e. the dimension of the search is reduced by one (Graser *et al.*, 1987; Meyer, 1989b).

3.6.2.8 Maximizing the likelihood

In DFREML, the quadratic approximation, as described by Graser *et al.* (1987), method was used for single trait models, which required one-dimensional search. They compared AI-REML with other methods and in their example found it to reach convergence five times faster than with a derivative free algorithm and 15 times faster than with an expectation-maximization algorithm. The algorithm is a Newton method that uses first and second derivatives to find estimates of genetic parameters that maximize the likelihood function. Solutions for fixed and random effects (generalized least squares) are presented and discussed. The program does not, however, present individual predicted breeding values of animals.

3.6.2.9 Convergence criteria

The convergence criterion was the variance of the likelihood function values. The convergence criterion was taken as the variance among the function values; convergence was assumed when this variance was less than less than 10^{-8}. In other words, convergence was considered to be obtained when mean squared differences between (co)variances matrices in consecutive rounds was 10^{-8}. Iterations were assumed to have converged when the differences in the variance of successive log likelihood was less than 10^{-8}. A value of 10^{-8} gives a good accuracy of estimation.

3.6.2.10 Global Maximization

After convergence, it was again verified that the maximization attained is global and not local. This was done by researching the parameter space within the range of 10% of the values obtained at convergence in the previous run.

3.6.2.11 Standard error of the estimates

The standard errors of the genetic parameters for single trait models were estimated as described by Meyer (1989b). Approximate standard errors of the estimated variance components were obtained by an approach similar to that of Smith and Graser (1986). Standard errors for correlations were calculated as described by Falconer and Mackay (1996).

3.7 Sire Evaluation

Sires with a minimum of four progenies were considered for analysis and sire evaluation. Solutions obtained after analyzing the data with Model 8 (taking only sires as random effect) and with univariate REML using animal model (taking animals with and without records as random effects) were BLUP values. On the basis of these BLUP values animals were ranked.

The Spearman's rank correlation between BLUP values, obtained by above methods, was worked out (Steel and Torrie, 1980) as follows:

$$r = 1 - \frac{6\sum_i d_i^2}{(n-1)n(n+1)}$$

where,

r is the rank correlation,

n is the number of sires,

d_i is the difference between rank of the sire ranked by two methods.

The significance of the rank correlation was tested by student's t-test as:

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

with n-2 degrees of freedom.

RESULTS AND DISCUSSION

"Research is very good;
the meaning is certainly plain,
results are still quite absurd, it literally means search again"

Chapter 4 **RESULTS AND DISCUSSION**

The reproductive and productive traits of first lactation records were studied and analyzed in the present investigation. The characteristics of data structure are summarized in Table 4.1. The results of the present study have been presented and discussed under different headings to conform the objectives of the study.

Table 4.1: Characteristics of data for all the traits.

Particulars	No. of observations
No. of records	875
No. of years	26
No. of base animals	410
No. of animals with records	875
No. of animals with unknown sires	0
No. of sires with progeny records	57
No. of dams with progeny records	358
No. of grand sires with progeny records	48
No. of grand dams with progeny records	103

4.1 Mean performances

4.1.1 General means

General means for age at first calving (AFC), first calving interval (FCI), first service period (FSP), first lactation milk yield (FLMY), first lactation length (FLL) and first dry period (FDP) along with their standard deviation (S.D.) has been presented in Table 4.2. The phenotypic means of AFC, FCI, FSP, FLMY, FLL and FDP were 1297.13 days, 520.44 days, 202.39 days, 1554.86 kg, 313.67 days and 206.76 days, respectively.

Table 4.2: General means (± S.D.) for AFC, FCI, FSP, FLMY, FLL and FDP in Sahiwal cattle.

S.No.	Traits	Means	S.D.
1	AFC (days)	1297.13	173.37
2	FCI (days)	520.44	126.36
3	FSP (days)	202.39	8.55
4	FLMY (kg)	1554.86	577.23
5	FLL (days)	313.67	84.31
6	FDP (days)	206.76	98.54

4.1.2 Least squares means (±S.E.)

The least squares means along with S.E., estimated by model 2, model 8 of LSA and univariate animal model of REML for different traits have been presented in Tables 4.3, 4.4 and 4.5, respectively and the least squares means (±S.E.) for different traits under different models has been summarized in Table 4.6.

4.1.2.1 Age at first calving (AFC)

The least squares means (±S.E.) of AFC estimated by model 2, model 8 and univariate animal model were found to be 1297.43±10.55days, 1296.48±9.61 days and 1297.13 days, respectively. The least squares means estimated by model 8 was slightly lower than the means estimated by model 2 and univariate animal model. The least squares means of AFC in the present study were near to the values, those reported by Rathi (1984), Gandhi and Gurnani (1987) and Sharma *et al.* (1993) in Sahiwal Cattle.

However, lower values than the present study were reported by Singh and Chaudhary (1961), Batra and Desai (1964), Sundaresan *et al.* (1965b) Kavitkar *et al.* (1968), Kushwaha and Mishra (1969), Nagpal and Acharya (1971), Bhat (1977), Chawla and Mishra (1982), Ganpule and Desai (1983), Roy (1983), Galina and Arthur (1983), Bhatnagar *et al.* (1983), Gurnani *et al.* (1987), Bhat and Taneja (1989), Sahota and Gill (1992), Singh *et al.* (2001), Urade (2001) and Ahmad *et al.*(2001), in Sahiwal. However, Ahmad and Ahmad (1974), Prasad (1983), Prasad and Manglik (1987), Khan *et al.*(1996, 1997), Dahlin (1998), Khan *et al.*(1999) and Singh *et al.*(2001) reported higher mean values of AFC in Sahiwal than those reported in present study. The differences within breed in AFC as reported by several workers attributed due to managemental practices applied at different farms.

These mean values indicating that there is need to improve the physiological functions related to reproductive and feed conversion efficiency which will result in early puberty. The early puberty can be achieved by providing better nutrition, health and managemental practices.

4.1.2.2 First calving interval (FCI)

The least squares means of FCI estimated by model 2 model 8 and univariate model were found to be 520.±7.49 days, 515.98±6.76 days, 516.76 days as shown in Tables 4.3, 4.4 and 4.5, respectively. The mean estimated under model 8 was slightly lower than the value estimated under model 2.

Table 4.3: Least squares means (±S.E.) for AFC, FCI, FSP,FLMY, FLL and FDP model 2 of LSA in Sahiwal cattle.

S.No.	Particulars	No. of observations	Least squares means ±S.E.					
			AFC (days)	FCI(days)	FSP (days)	FLMY(kg)	FLL (days)	FDP (days)
1	Overall mean (N)	875	1297.43±10.55	520.18±7.49	202.40±0.36	1552.48±26.00	313.76±5.48	206.42±4.71
2.	Season of calving							
	1 (Winter)	173	1330.30±16.11	523.03±11.65	202.52±0.72	1505.45±49.35	314.28±8.04	208.75±8.53
	2 (Summer)	231	1293.59±14.52	507.78±10.46	202.74±0.62	1534.09±43.09	314.47±7.30	193.31±7.49
	3 (Rainy)	172	1268.91±16.33	522.20±10.81	202.15±0.73	1592.50±50.18	313.49±8.14	208.71±8.66
	4 (Autumn)	299	1296.90±13.63	527.70±9.80	202.21±0.57	1577.86±39.51	312.81±6.89	214.89±6.89

Table 4.4: Least squares means (±S.E.) for AFC, FCI, FSP, FLMY, FLL and FDP under model 8 in Sahiwal cattle.

S.No.	Particulars	No. of observations	Least squares means ±S.E.					
			AFC (days)	FCI(days)	FSP (days)	FLMY(kg)	FLL (days)	FDP (days)
1	Overall means (N)	875	1296.48±9.61	515.98±6.76	203.42±0.34	1556.50±25.29	312.45±4.85	204.24±4.52
2.	Season of calving							
	1 (Winter)	173	1324.79±15.38	517.66±11.05	203.53±0.68	1506.01±47.43	312.04±7.56	206.58±8.20
	2 (Summer)	231	1290.25±13.55	503.75±9.70	203.91±0.59	1546.01±41.06	313.37±6.69	190.83±7.11
	3 (Rainy)	172	1273.06±15.29	520.30±10.99	203.21±0.68	1599.94±47.19	312.99±7.52	208.46±8.15
	4 (Autumn)	299	1297.83±12.58	522.21±8.98	203.03±0.53	1573.66±37.19	311.40±6.24	211.11±6.48

Table 4.5: Least squares means (±S.E.) for AFC, FCI, FSP, FLMY, FLL and FDP under univariate animal model of REML in Sahiwal cattle.

S.No.	Particulars	No. of observations	Least squares means ±S.E.					
			AFC (days)	FCI (days)	FSP (days)	FLMY (kg)	FLL (days)	FDP (days)
1	Overall mean (N)	875	1297.13	516.76	202.39	1548.01	313.87	206.76
2.	Season of calving							
	1 (Winter)	173	1322.33	518.42	202.52	1506.13	312.97	210.02
	2 (Summer)	231	1288.45	509.17	202.93	1545.64	315.12	192.62
	3 (Rainy)	172	1281.27	522.37	202.26	1600.92	315.74	212.09
	4 (Autumn)	299	1298.37	519.02	201.90	1543.64	311.77	212.74

These estimates were found to be higher than those reported by Bhasin and Desai (1967), Kaul *et al.* (1971), Bhat *et al.* (1978), Sharma *et al.* (1982), Chaudhary (1983), Rathi (1984), Suresh Chand and Sharma (1985), Prasad (1986), Gurnani *et al.* (1987), Singh *et al.* (1996), Mishra and Prasad (1994), Tomar *et al.* (1996), Singh *et al.* (1998) and Singh *et al.* (2001) in Sahiwal cattle.

However, results of present study are in close agreement with the findings of Singh (2000) and Singh *et al.* (2001). Whereas, higher mean value was reported by Yadav *et al.* (1992a) in Sahiwal.

The differences among results for FCI as reported by various workers and estimate obtained in present study might be attributed due to the different managemental practices applied at different farms/herds.

4.1.2.3 First service period (FSP)

The least squares means of first service period were estimated as 202.40±0.36 days, 203.42±0.34 days, and 202.39 days, respectively, under model 2, model 8 and univariate animal models. The mean value estimated under model 8 was found to be slightly higher than those estimated under model 2 and univariate animal model.

The lower mean values estimated than the findings were reported by Kavitkar *et al.* (1981) Chopra *et al.*(1973), Bhat *et al.* (1978), Raheja and Bhat (1982), Bhatnagar *et al.* (1983), Gurnani *et al.*(1987), Azhar *et al.* (1990), Khan *et al.*(1992), Sahota and Gill (1992), Singh *et al.* (1997c) and Singh *et al.* (1998) in Sahiwal cattle. However, higher values for first service period have been reported by Kuralkar *et al.* (1996) and Singh *et al.* (2001) in Sahiwal than the values estimated in present study. These differences might be due to differences in managemenetal practices under different environmental conditions at different farms/herds.

4.1.2.4 First lactation milk yield (FLMY)

The least squares means of FLMY under model 2, model 8 and univariate animal model were found as 1552.48±26.00 kg, 1556.50±25.29 kg and 1548.01 kg, respectively, as shown in Tables 4.3, 4.4 and 4.5.

These values were found to be higher than those reported by Kushwaha and Mishra (1969), Tomar *et al.* (1974), Taylor *et al.* (1979), Taneja and Sikka (1981), Singh *et al.* (1988), Shaw *et al.* (1992), Kuralkar *et al.* (1996), Dahlin (1998), Deulkar and Kathekar (1999) and Singh *et al.* (2001) in Sahiwal.

Higher mean values than the present study for FLMY were estimated by Singh and Chaudhary (1961), Amble and Jain (1967), Nagpal and Acharya (1970), Chopra *et al.* (1973), Tomar *et al.* (1974), Usha Anand and Sundaresan (1974), Taneja *et al.*(1978), Bhat *et al.* (1978), Chawla and Mishra (1979), Kumar and Narain (1979), Singh (1979), Bhatia (1980), Tripathi and Bhargava (1981), Sharma and Singh (1981), Ahmad *et al.* (1982), Chawla and Mishra (1982), Bhatnagar *et al.* (1984), Rathi (1984), Suresh Chand and Sharma (1985), Sharma *et al.* (1987), Prasad and Manglik (1987), Gandhi and Gurnani (1988), Reddy and Nangercenkar (1988), Bhat and Taneja (1989), Ahmad *et al.* (1992), Yadav *et al.* (1992a,b), Singh *et al.*

(1993a), Sanota and Gill (1994), Gandhi *et al.* (1995), and Singh (2000) in Sahiwal. However, Sundaresan *et al.* (1965b), Gopal and Bhatnagar (1972), Gupta *et al.* (1973) and Singh *et al.* (1997c) reported much higher values for FLMY than the values estimated in present study.

4.1.2.5 First lactation length (FLL)

The least squares means of FLL estimated by model 2 and model 8 and univariate animal models were found to be 313.76±5.48 days, 312.45±4.85 days and 313.87 days, respectively (Tables 4.3, 4.4 and 4.5). The mean estimated by model 8 was slightly lower than the means estimated by model 2 and univariate animal model.

These estimates of FLL were in close agreement with the findings of Ahmad and Ahamad (1974), Gurnani *et al.* (1987), Bhat and Taneja (1989), Tajane and Rai (1990), Singh *et al.* (1993a) and Singh *et al.* (1997c), whereas, lower values of FLL have been reported by Singh and Chaudhary (1961), Batra and Desai (1964), Mishra and Kushwaha (1970), Bhat *et al.* (1978, 1979), Singh (1979), Kumar and Narain (1979), Sharma and Singh (1981), Sharma *et al.* (1982), Singh (1984), Khan *et al.* (1992) Yadav *et al.* (1992a, b), Gandhi *et al.* (1995) and Singh *et al.* (2001) in Sahiwal.

However, higher means than the present study were observed by Chopra *et al.* (1973), Taneja and Sikka (1981), Chawla and Mishra (1982), Bhatnagar *et al.* (1983), Bhatnagar (1984), Gandhi *et al.* (1988), Tomar *et al.*(1998) and Singh (2000) in Sahiwal cattle.

The differences among Sahiwal cattle for the first lactation lengths as reported by various workers might be due to different managemental practices applied at different farms/herds.

4.1.2.6 First day period (FDP)

The least squares means (±S.E.) estimated by model 2 and 8 and univariate animal models for FDP have been presented in Tables 4.3, 4.4 and 4.5 and reported as 206.42±4.71 days 204.24±4.52 days and 206.76 and respectively. The least squares means estimated by model 2 and univariate animal models were found to be slightly higher than the value estimated under model 8.

Singh *et al.* (2001) reported higher mean values for FDP than the values estimated in present study. However, lower mean values for FDP than the present study were reported by Singh and Chaudhary (1961), Batra of Desai (1964), Kavitkar *et al.*(1968), Kushwaha and Mishra (1969), Bhat *et al.* (1978), Bhat *et al.* (1979), Tayalar *et al.* (1979), Raheja and Bhat (1982), Chawla and Mishra (1982), Sharma *et al.* (1982), Bhatnagar *et al.* (1983), Gurnani *et al.* (1983), Singh *et al.*(1988), Reddy and Nagarcenkar (1990), Sahota and Gill (1992), Khan *et al.* (1992), Singh *et al.*(1993a), Singh *et al.* (1993b), Mishra and Prasad (1994), Deshmukh *et al.* (1995), Tomar *et al.* (1996), Singh *et al.* (1997c), Tomar (1998) and Singh (2000) in Sahiwal cattle.

These wide ranges in FDP of different herds of sahiwal cattle might be due to the differences in managemetnal practices followed at different farms.

Table 4.6: Least squares means (±) obtained under different methods.

Models	Traits					
	AFC (days)	FCI (days)	FSP (days)	FLMY (kg)	FLL (days)	FDP (days)
Model 2	1297.43±10.55	520.18±7.49	202.40±0.36	1552.48±26.00	313.76±5.48	206.42±4.71
Model 8	1296.48±9.61	515.98±6.76	203.42±0.34	1556.50±25.29	312.45±4.85	204.24±4.52
Univariate animal model	1297.13	516.76	202.39	1548.01	313.87	206.76

4.1.3 Coefficient of variation (C.V.%)

The coefficients of variation (c.v.%), for different traits measured under model 2, 8 and univariate animal models, have been presented in Table 4.7. The coefficients of variation were found almost similar for different traits under model 2, model 8 and univariate animal models except for FCI.

Table 4.7: Coefficient of variation (C.V.%) for AFC, FCI, FSP, FLMY, FLL and FDP under model 2, model 8 of LSA and univariate animal model of REML in Sahiwal cattle.

S.No.	Traits	Coefficient of variation		
		Model 2	Model 8	Univariate
1	AFC	12.78	12.74	13.85
2	FCI	23.25	23.21	17.59
3	FSP	2.96	2.97	3.00
4	FLMY	36.57	36.54	33.57
5	FLL	25.37	25.37	26.78
6	FDP	46.70	46.50	48.39

4.1.3.1 Age at first calving (AFC)

The coefficients of variation (c.v.%) in AFC were found as 12.78, 12.74 per cent and 13.05 per cent under model 8 and univariate animal models, respectively (Table 4.7). These values are almost similar and showing moderate estimates, indicating that tere is scope for selection, in order to get an early calving. AFC may further reduced by an efficient management and feeding of young growing heifers at early growth phase. Better growth at early age may lead to early calving.

4.1.3.2 First calving interval (FCI)

The coefficients of variation (Table 4.7) for FCI were reported as 23.25 under model 2, 23.21 per cent under model 8 and 17.59 per cent under univariate animal model.

Since, longer calving interval has been reported in present study, the efforts should be made to reduce the FCI by 3 months in these animals. Longer calving interval is counter productive and could be controlled by reducing service period and dry period and this can be achieved by better managemaent practices as sufficient variability exists in the herd for FCI.

4.1.3.3 First service period (FSP)

The coefficients of variation (c.v. %) for FSP under model 2, model 8 and univariate animal models were found to be 2.96, 2.97 per cent and 3.00 per cent, respectively (Table 4.7). These values are almost similar. The lower values of coefficients of variation showing that there is very small variation in the herd for FSP and a fair amount of uniformity in FSP is existed in the herd. The reduced service period can only get through proper managemental and feeding practices.

4.1.3.4 First lactation milk yield (FLMY)

The coefficients of variation (c.v.%) for FLMY under model 2, 8 and univariate models have been estimated as 36.57 per cent, 36.54 percent and 33.57 per cent, respectively (Table 4.7).

The values for coefficients of variation reported under different models were found to be almost similar. The moderate values of coefficients of variation under different models for FLMY showing that there is large variation for this trait among the animals in the herd and there is chance of improvement in this trait through selection, better managemental and feeding practices at farm.

4.1.3.5 First lactation length (FLL)

The coefficients of variation (c.v. %) for FLL were found to be as 25.37 per cent, 25.37 percent and 26.78 per cent under model 2, 8 and univariate animal models, respectively (Table 4.7). There is not much differences among coefficients of variation observed under three methods/ models.

These values of coefficients of variation for FLL indicated the presence of variation among the animals in the herd and this trait could be improved through better animal husbandry practices for obtaining the higher milk production.

4.1.3.6 First dry period (FDP)

The coefficients of variation for FDP under model 2, model 8 and univariate models were found to be as 46.70 percent, 46.56 per cent and 48.39 per cent, respectively (Table 4.7). The value obtained under three different models showing not much difference among them.

There is variability (46.70 to 48.39 per cent) available within this trait, thus this trait inviting more attention. This trait need to be reduced by at least 100 days which can be only possible through by reducing the service period by providing/applying the efficient management practices at farm.

4.1.4 Coefficient of multiple determinations (R^2)

The coefficient of multiple determination (R^2) (Table 4.8) obtained under model 8 were 0.095, 0.090, 0.021, 0.035, 0.112 and 0.049, respectively, for AFC, FCI, FSP, FLMY, FLL and FDP. The coefficient of multiple determinations in the present study indicated that variability in the population and genetic potentiality of the animals at this farm only can improve through the introduction of the new germ plasm of Sahiwal cattle from outside of the herd. There is no literature available for the comparison of present study.

Table 4.8: Coefficient of multiple determination (R^2) for AFC, FCI, FPS, FLMY, FLL and FDP under model 8 of LSA in Sahiwal cattle.

S.No.	Traits	R^2
1.	AFC	0.095
2.	FCI	0.090
3.	FSP	0.021
4.	FLMY	0.035
5.	FLL	0.112
6.	FDP	0.049

4.2 Factors affecting first lactation production and reproduction traits

4.2.1 Sire effect

The random effect of sires had highly significant (p<0.01) effect on AFC, FCI, FLMY, FLL, FDP, except FSP (p<0.05), under model 2 (Table 4.9).

Gahlot, R.S. (1990), Kachwaha (1993), Gahlot *et al.* (2001) in Tharparkar and Singh in Sahiwal cattle, also observed that age at first calving significantly influenced by the sires.

Significant effect of sires on first calving interval was observed by Haque *et al.* (1999) and Aly *et al.* (2000) in Sahiwal and Friesian cows, respectively, which are in agreement of present findings.

In present study it was found sires significantly influenced that first lactation milk yield, which is supported by the findings of Haque *et al.* (1999)

Table 4.9: Analysis of variance of AFC, FSP, FLMY, FLL and FDP under model 2 of LSA.

S.No.	Source of variation	D.F.	Mean squares					
			AFC (days)	FCI (days)	FSP (days)	FLMY (kg)	FLL (days)	FDP (days)
1	Sire	56	69150.35**	35154.31*	94.63**	476503.32*	18355.86*	15170.20*
2.	Season	3	89927.64**	16103.51	14.89	262873.98	129.74	18630.16
3	Error	815	27274.69	14644.06	71.80	323573.56	6358.83	9293.03

* (P<0.01) ** (P<0.05)

Table 4.10: Analysis of variance of AFC, FCI, FSP, FLMY, FLL and FDP under model 8 of LSA.

S.No.	Source of variation	D.F.	Mean squares					
			AFC (days)	FCI (days)	FSP (days)	FLMY (kg)	FLL (days)	FDP (days)
1.	Season	3	71665.55**	15606.51	35.53	273480.23	181.35	19053.79
2	Error	871	27305.78	14585.04	71.89	322800.29	6334.16	9266.28

** (P<0.05)

in Sahiwal and Pabna cattle. However, Bangar and Narayankhedkar (1999) reported non-significant effect of sire on milk yield in Gir cows.'

Haque *et al.* (1999) reported significant effect of sire on lactation length in Sahiwal and Pabna cattle, which support the findings observed in present study.

Significant effect of sires was observed on first dry period, while Pandey *et al.* (2001) reported non-significant effect of sire on first dry period in Hariana cattle.

The significant effect of sires on all the traits indicated that superior sires could be used effectively for the improvement of these traits.

4.2.2 Season effect

The effects of season of calving were not significant on all the traits except age at first calving under model 2 and model 8 (Tables 4.9 and 4.10, respectively). Although it was expected that differences in physical environment would have an effect. Season, therefore, did not have large influence, as the animals at this farm were raised on cultivated fodder, where green fodder were available round the year and supplementation was done with concentrate mixture.

The significant effect of season on age at first calving was observed in present study. The cow who calved in rainy season attained early age at first calving followed by those, calved in summer, autumn and winter season. Similar observations were reported under model 2 and model 8.

Kaul *et al.* (1973) also reported significant effect of season on age at first calving in Hariana cattle.

However, Nagpal and Acharya (1971), Singh *et al.* (1990) in Sahiwal, Umrikar *et al.* (1990) Ulmek and Patel (1993), Mathur and Khosla (1994), Barwe *et al.* (1995, 1996) and Bhadoria *et al.* (2002) in Gir cows and Bhatnagar *et al.* (1982), Pannerselvam *et al.*(1990), Vij *et al.* (1992) and Gahlot *et al.* (2001) in Tharparkar cows reported non-significant effect of season on age at first calving.

Season of calving was not found to influence the first calving interval under model 2 and model 8. However, cows calved in summer had short calving interval than those calved in autumn. The findings of Bhat *et al.* (1978) in Sahiwal, Singh *et al.* (1990) and Sethi *et al.* (1995) in Sahiwal and its crosses are in agreement of present findings.

However, Milagres *et al.* (1988c) in Zebu, Garcha and Dev (1994) in H.F. and Souza *et al.* (1995) in Gir cows observed significant effect of season of calving on first calving interval.

Non-significant effect of season of calving on first service period in present study, was in agreement with the findings of Bhat *et al.* (1978), Singh *et al.*(1990), Singh *et al.* (1995), Kuralkar *et al.* (1996) in Sahiwal and its cross, Mathur and Chahal (1997) in Hariana cattle.

First lactation milk yield was also not influenced by season of calving. However, rainy season contributed to higher milk yield and winter season contributed lower, under both models (model 2 and model 8). Non-significant effect of season of calving on first lactation milk yield in present study was supported by the findings of Nagpal and Acharya (1971), Bhat *et al.* (1978), Rao *et al.* (1984), Mishra and Prasad (1994) in Sahiwal, Barbary *et al.* (1999)

in H.F., Mathur and Khosla (1994) in Gir and Mathur and Chahal (1997) in Hariana. However, Parmar *et al.* (1982), Singh *et al.* (1995) and Bangar and Naryan Khedkar (1999) observed significant effect of season of first lactation milk yield.

First lactation length was not found significantly influenced by season under model 2 and model 8. Similar findings were also observed by Nagpal and Acharya (1971), Bhat *et al.* (1978), Rao *et al.* (1984), Deshmukh *et al.* (1995), Singh *et al.* (1995), Tomar *et al.* (1998) in Sahiwal, Pandey *et al.* (2001) in Hariana and Bangar and Narayankhedkar (1999) in Gir cows. However, Das *et al.* (1990). Tekade *et al.* (1994) Kasab (1995), Singh *et al.* (1996), Mandal *et al.* (2001) and Mathur and Chahal (1997) reported significant effects of season of calving on first lactation length.

Non-significant effect of season of calving on first dry period was supported by findings of Bhat (1978), Chawla and Mishra (1982), Rao *et al.* (1984). Mishra and Prasad (1994), Deshmukh *et al.* (1995), Singh *et al.* (1995) in H.F. and Pandey *et al.* (2001) in Hariana cattle. However, Sharma and Khan (1989) reported highly significant effect of season of calving on first dry period.

4.3 Estimation of genetic and phenotypic parameters

The method of least squares analysis (LSA) of variance based on paternal half-sib correlation has widely been used in India for estimating the covariance components for animal breeding data. However, Henderson (1986) opined the ANOVA and ANOVA based methods might give biased estimates when data have resulted from selected population. As an alternative, REML with animal model is the method of choice by virtue of its "built in" statistical properties of consistency, efficiency and being asymptotically unbiased. Smith and Graser (1986) reported that REML method also has the small simple properties of unbiasedness. The small, unbalanced data spread over a number of years, use din the present study.

Variance and covariance components were estimated under model 2 and model 8 of Harvey (1990) package. These models of LSA included the fixed effect of season and random effect of sire. A single trait animal model was also used on the same data to obtain the estimates of variance and covariance component by REML method, using DFREML package of Meyer (1998).

The observed between and within sire variances for traits under model 2 and 8 of LSA have been summarized in Table 4.11. Sires, under model 2 of LSA, accounted for 9.30, 8.52, 2.07, 3.05, 11.15 and 4.04 per cent of total variation for AFC, FCI, FSP, FLMY, FLL and FDP, respectively. The corresponding values, under model 8 were found as 9.59, 8.50, 1.99 3.31, 11.05 and 4.31 respectively (Table 4.10). The sire had accounted more variation for AFC, FCI, and FLL under both models of LSA. The sire variation under model 2 and model 8 for all the traits were observed almost similar. The variance and covariance matrices for AFC, FCI, FSP, FLMY, FLL and FDP estimated under under model 2 have been presented in Table 4.12.

Table 4.11: Observed between and within sire variances for various traits under model 2 and 8 of LSA (expressed as percentage of phenotypic variation).

Observed family components	Model used	Traits											
		AFC		FCI		FSP		FLMY		FLL		FDP	
		AFC	Per cent	FCI	Per cent	FSP	Per cent	FLMY	Per cent	FLL	Per cent	FDP	Per cent
σ^2_s(PHS)	Model 2	2785.99	9.30	1364.55	8.52	1.52	2.07	10174.43	3.05	798.16	11.15	391.01	4.04
σ^2_w(PHS)	Model 2	27274.69	90.73	14644.07	91.48	71.00	97.92	323573.56	96.95	6358.82	88.84	9293.03	95.96
σ^2_s(PHS)	Model 8	2898.49	9.59	1354.97	8.50	1.46	1.99	11048.29	3.31	786.82	11.05	418.47	4.31
σ^2_w(PHS)	Model 8	27305.71	90.41	14584.84	91.49	71.89	98.01	322799.66	96.69	6334.19	88.95	9266.24	95.48

Table 4.12: **Variance and covariance matrices of AFC, FCI, FSP, FLMY, FLL and FDP under model 2 of LSA in Sahiwal cattle.**

Traits		AFC	FCI	FSP	FLMY	FLL	FDP
AFC	A^a	11143.96					
	E^b	27274.69					
	P^c	30060.68					
FCI	A^a	1734.372	5458.2				
	E^b	2686.355	14644.07				
	P^c	3119.948	16008.62				
FSP	A^a	-37.608	12.884	6.08			
	E^b	38.078	-48.475	71.80			
	P^c	28.676	-45.254	73.32			
FLMY	A^a	12286.26	10732.28	-0.620	40697.72		
	E^b	-1699.431	21435.293	-126.722	323573.57		
	P^c	1372.134	24118.363	-126.877	333747.99		
FLL	A^a	2466.776	3543.408	-33.816	10327.264	3192.64	
	E^b	230.723	5854.931	-16.103	24403.466	6358.83	
	P^p	847.417	6740.783	-24.557	26985.282	7156.98	
FDP	A^a	-732.404	1914.784	46.7	405.016	350.748	1564.04
	E^b	2455.632	8789.136	-32.372	-2968.172	-503.896	9293.03
	P^c	2272.53	9267.832	-20.697	-2866.98	-416.209	9684.04

Where, A^a : additive genetic variances (dagonal) covariances (below diagonal)
E^b : environmental variances (diagonal) and covariances (below diagonal)
P^c :phenotypic variances (diagonal) and covariances (below diagonal)

4.3.1 Heritability estimates

Heritability is the most important concept in the application of genetics to animal breeding, as it is the property of a population, trait and environmental condition prevailing. The knowledge of heritability estimates of economic traits is essential for formulating various genetic improvement programs and predicting response to selection. Heritability estimates express the reliability of phenotypic value as a guide to the breeding value, and also used to describe the amount of the superiority of parents above their contemporaries for a given traits which on an average is passed on to the offspring. The heritability estimated under model 2, model 8 of LSA and univariate animal model of REML have been presented in Tables 4.13, 4.14 and 4.15.

4.3.1.1 Age of first calving(AFC)

The h^2 estimated for AFC were found to be 0.371, 0.384 and 0.721 under model 2, model 8 of LSA and univariate animal model REML, respectively, in Sahiwal cattle. The h^2 estimates from model 2 and 8 were almost similar for AFC. The univariate animal model of REML method estimated higher h^2 than the LSA methods. Because of its desirable properties, the univariate animal model estimator was considered to be more appropriate than that of LSA methods. The above differences observed among h^2 estimates may be due to the different methods applied in the present study. The medium to high heritability estimates with relatively moderate coefficient of variation value under different methods suggested that AFC alone would be appropriate trait for evaluation of animals as estimates indicated presence of additive genetic variance. Therefore, the AFC may be considered in combination with other important traits for better evaluation of animals in herds.

The heritability estimates reported by Singh (1979) and Sharma *et al.* (1982) for AFC in Sahiwal cattle were similar to that of the estimated in the present study. Lower estimates of heritability for AFC were reported by Gopal and Bhatnagar (1972), Tomar *et al.* (1974), Gurnani *et al.* (1976), Taneja *et al.* (1978b), Gandhi and Gurnani (1987). Kumar (1987) Khan *et al.* (1992), Yadav *et al.* (1992b), Jahav and Khan (1996), Sethi *et al.* (1997) and Khan *et al.* (1999). However, Singh *et al.*(1980), Singhal *et al.* (1994) Singh (2000) and Singh *et al.* (2001) reported higher estimates of heritability for AFC than the estimates in the present study.

4.3.1.2 First calving interval (FCI)

The h^2 estimated by three ways for FCI were found to be as 0.341, 0.340 and 0.311(Tables 4.13,4.14 and 4.15). The model 2 (0.341) and model 8 (0.340) had almost similar estimates of h^2 for FCI. The h^2 estimated under univariate REML for FCI was found to be slightly lower (0.311) than estimated under LSA methods, but the former was more reliable.

The h^2 estimates obtained under different models were found to be higher than the values reported by Sandhu (1968), Sharma *et al.*(1982), Rathi (1984), Kumar (1986), Reddy and Nagercenkar (1989), Singh *et al.*(1990), Khan *et al.*(1992), Khan *et al.* (1999), Singh (2000), and Singh *et al.* (2000)in Sahiwal

Table 4.14: Estimates of heritability and variance components for various traits in Sahiwal cattle under model 8 of LSA.

S.No.	Traits	Heritability	Variance components			
			σ^2_p	σ^2_a	σ^2_s	σ^2_e
1	AFC	0.384	30204.2	11593.96	2898.49	27305.71
2	FCI	0.340	15939.81	5419.88	1354.97	14584.84
3	FSP	0.079	73.35	5.84	1.46	71.89
4	FLMY	0.132	333847.95	44193.16	11048.29	322799.66
5	FLL	0.442	7121.01	3147.28	786.82	6334.19
6	FDP	0.173	9704.71	1673.88	418.47	9286.24

Table 4.14: Estimates of heritability and variance components for various traits in Sahiwal cattle under model 8 of LSA.

S.No.	Traits	Heritability	Variance components			
			σ^2_p	σ^2_a	σ^2_s	σ^2_e
1	AFC	0.384	30204.2	11593.96	2898.49	27305.71
2	FCI	0.340	15939.81	5419.88	1354.97	14584.84
3	FSP	0.079	73.35	5.84	1.46	71.89
4	FLMY	0.132	333847.95	44193.16	11048.29	322799.66
5	FLL	0.442	7121.01	3147.28	786.82	6334.19
6	FDP	0.173	9704.71	1673.88	418.47	9286.24

Table 4.15: Estimates of heritability and variance components for various traits in Sahiwal cattle under univariate animal model of REML.

S.No.	Traits	Heritability ± S.E.	Variance components		
			σ^2_p	σ^2_a	σ^2_e
1	AFC	0.721	32302.95	23303.74	8999.20
2	FCI	0.311	6120.58	1903.63	4216.95
3	FSP	0.127	73.58	9.37	64.20
4	FLMY	0.174	270034.58	46954.50	223080.08
5	FLL	0.232	7056.46	1635.70	5420.76
6	FDP	0.383	10013.96	3830.89	6183.07

The moderate values/ estimates of heritability for FCI with medium value of coefficients of variation suggested that there is chance of selection of animals for FCI as sufficient amount of additive genetic variability exists in the herd and calving interval could be reduced upto optimal level.

4.3.1.3 First service period (FSP)

The heritability estimates under three methods for FSP ranged from 0.079 (model 2) to 0.127 (univariate animal model), which have been presented in Tables 4.13, 4.14 and 4.15.

Model 2 (0.083) and model 8 (0.079) estimated almost similar heritabilities value. The results suggested that the variation present for first service period in the could be attributed due to the environmental factors like variation in management practices, availability of feed and fodder etc. These values were in close agreement with those reported by Taneja and Bhat (1971) Chopra *et al.* (1973), and Reddy and Nagercenkar (1989). However, higher values than the present study were reported by Khan *et al.* (1992) and Singh *et al.* (2000).

The lower estimates of h^2 with lower value of coefficients of variation for FSP revealing that all the variations in FSP present are due to only non-genetic causes viz., managemental, nutritional and season.

4.3.1.4 First lactation milk yield (FLMY)

The h2 estimates for FLMY ranged from 0.122 (model 2) to 0.174 (univariate animal model) as revealed from Tables 4.13, 4.14 and 4.15. The h^2 estimates under model 2 and model 8 were found similar. The heritability estimated under univariate animal model was slightly higher than the LSA methods.

Nagpal and Acharya (1971) Gurnani *et al.* (1976),Gandhi and Gurnani (1987), Khan *et al.* (1993), Gandhi and Gurnani (1995) and Dhalin *et al.* (1998) in Sahiwal had reported values of h^2 within the range as reported in present study for FLMY. Khanna and Bhatt (1971), Chopra *et al.* (1973), Tomar *et al.* (1974), Taneja *et al.* (1978), Singh (1979), Bhatia (1980), Sharma and Singh (`1981), Yadav *et al.*(1992b) and Singh *et al.* (2000) reported higher estimates of heritability for FLMY, whereas lower h^2 were reported by Singh (2000) and Javed *et al.* (2001) in Sahiwal.

Heritability Estimates, under all the three methods, indicated that the traits are lowly heritable. These estimates are clearly suggesting that there is not much chances of response to selection, when selection would apply on this trait. The low magnitude of heritability estimates for this trait might be due to increased influence of the non-permanent factors on the trait.

4.3.1.5 First lactation length (FLL)

The estimates of h^2 for FLL under model 2, model 8 and univariate animal model were found to be 0.446, 0.442 and 0.232, respectively (Tables 4.13, 4.14 and 4.15). Model 2(0.446) and model 8(0.442) estimated almost similar values of heritability. The h^2 estimate reported under univariate animal model was found lower than those reported under model 2 and model 8.

Chopra *et al.* (1973) reported higher value of h^2 for AFC than the values reported under the models studied. However, estimates of heritability for FLL in present study were well within the range of heritability estimates as reported by Ahmad *et al.* (1974), Reddy and Nagercenkar (1989), Yadav *et al.* (1992b) and Singh *et al.* (2000). Lower h^2 than those estimated in present study, were reported by Taneja *et al.* (1992), Singh *et al.* (1994), Singhal *et al.* (1994) and Singh (2000) in Sahiwal.

The medium value of h^2 for FLL indicating that additive genetic variability for the traits is existing and selection for the lactation length of 305 days should be practiced.

4.3.1.6 First dry period (FDP)

The h^2 estimates for FDP under three models ranged from 0.162(model 2) to 0.383(univariate animal model), as presented in Tables 4.13, 4.14 and 4.15. Model 2(0.162) and Model 8(0.173) of LSA estimated almost similar values of heritability. The h^2 estimate reported under univariate animal model of REML was found higher than those reported under model 2 and model 8 of LSA.

Similar results of heritability for FDP were obtained by Taneja *et al.* (1978b). However lower estimates of heritability for FDP than the present study were reported by Gandhi and Gurnani (1987), Gandhi and Gurnani (1988), Reddy and Nagercenkar (1989), Khan *et al.* (1992), Singh *et al.*(1993b), Sethi *et al.* (1998), Singh *et al.* (2000), Singh (2000) and Javed *et al.* (2001) in Sahiwal cattle.

The low magnitude of h^2 clearly indicated that this trait is influnced by the environmental factors and this trait can be improve by better feeding and managemental practices.

4.3.2 Comparison among heritability estimates

Estimates of heritability for different traits under study, in model 2, model 8 and univariate animal model have been presented in Table 4.16.

Table 4.16: Comparison among heritability (±S.E.) estimates obtained under different methods.

Observed family components	Traits					
	AFC	FCI	FSP	FLMY	FLL	FDP
Model 2	0.371	0.341	0.083	0.122	0.446	0.162
Model 8	0.384	0.340	0.079	0.132	0.442	0.173
Univariate animal model	0.721	0.311	0.127	0.174	0.232	0.383

First lactation length held the highest h^2 estimates (0.446) followed by AFC (0.371), FCI (0.341), FDP (0.162), FLMY (0.122) and FSP (0.083) under model 2. Heritability estimated under model 8 also displayed the similar tendency as h^2 estimated under model 2. The results clearly revealed that the heritabilities estimated under both models of least squares analysis were found almost similar or near to similar value.

However, the higher h^2 values were estimated under univariate animal model were found for AFC (0.721) followed by FDP (0.383), FCI (0.311), FLL (0.232), FLMY (0.174) and FSP (0.127).

The estimated h^2 under model 2 and model 8 of LSA using paternal half sibs were found consistent and stable between both models but differ from those obtained with univariate animal model of REML.

The h^2 estimated under univariate animal model of REML for AFC, FSP, FLMY and FDP were found to be higher than estimated under model 2 and model 8 of LSA, except for FCI and FLL. The lower h^2 estimates for AFC, FSP, FLMY and FDP under model 2 and model 8 than univariate animal model revealed that univariate animal model of REML method of variance components was more efficient than the LS ANOVA methods. This can be attributed due to the well-known properties of efficiency and sufficiency of the REML method as this method utilizes all the known relationship under an animal model. On the other hand, the efficiency of the model decreased as LSA methods used in present study did not account all relationships between/ among animals.

The results in the present study showed that different estimates of h^2 could also be due to application of different estimation procedures with same/ different models. The differences observed under different models could be due to model effect and factors considered under different models. Koots *et al.* (1994a) and Snyman *et al.* (1995) observed significant effect of different methods in estimation of h^2. Restricted maximum likelihood (REML) using animal model is the best method for estimation of genetic parameters from small data sets(Pander and Yadav,1998).

Since h^2 values for different traits under model 2 and model 8 were estimated using paternal half sibs information, therefore, there was no maternal information included. Such type of paternal half sibs estimates of h^2 might be reduced due to selection of sires. Koots *et al.* (1994a) also observed reduction in h^2 estimates, based on paternal half sibs methods, due to selection of sires.

However, Jain and Sadana (1998) reported that though the h^2 estiamtes under REML method were found lower than the estimates obtained under LS method, but the farmer were more reliable as they had smaller standard error of variance.

The results obtained by Raheja (1992) revealed that h^2 estimates obtained under maximum likelihood method for first, second and third lactation milk yield were lower and had small standard error as compare to LS method. He also observed that standard error h^2 estimate is an obvious criterion for comparing the precision but not the bias for the estimation procedure. Therefore, the results of the present investigation indicated or revealed that the univariate REML method was more efficient for estimation of variance components. Because of its desirable properties the univariate REML estimator was consider to be more appropriate than that of LSA methods. The above differences observed in the values of heritability from LSA methods and univariate animal model of REML alarms that an inappropriate value of heritability may result in hicorrect prediction of breeding values of bulls and the response to selection.

4.4 Genetic and phenotypic correlation among reproductive and productive traits

Hazel (1943) was the first who introduced the concept of genetic correlation into animal breeding theory. The genes that control the expression of one quantitative trait may influence the expression of other traits due to biochemical and physiochemical relationships among various life processes.

Genetic correlation between two traits is the correlation genetic effects that influence the two traits and it is arise due to pleiotropy and linkage.

The estimates of gentic, phenotypic and environmental correlations among the various traits computed from different components of variance and covariance under model 2 are presented in Table 4.17.

4.4.1Age at first calving with others

The genetic correlation of AFC with FCI estimated by model 2 was found to be positive i.e. 0.222±0.21 in Sahiwal cattle, corresponding environmental and phenotypic correlations between these two traits were also observed positive but small in magnitude (0.098 and 0.142, respectively).

Similar findings for genetic correlation between these traits were also reported by Singh *et al.* (1990), Gandhi and Gurnani (1990) and Khan *et al.* (1999) in Sahiwal. However, higher genetic correlation between these two traits were also reported by Dalal *et al.* (2001) in Hariana cattle and Singh (2000) in Sahiwal cattle. Ramalu and Sidhu (1995) reported negative genetic correlation between AFC and FCI in Ongole cattle.

Positive and small phenotypic correlation between AFC and FCI were reported by Singh (2000) in Sahiwal, Ramalu and Sidhu (1995) in Ongole and Dalal *et al.* (2002) in Hariana cattle. However, negative trend in phenotypic phenotypic was obtained by Singh *et al.* (1990) in Sahiwal cattle.

The positive and lower genetic and phenotypic correlation between AFC and FCI indicated that selection at early age at first calving could simultaneously result in short first calving interval. Present results revealed

Table 4.17: Genetic phenotypic and environmental correlations among first lactation reproduction and production traits under model 2 of least squares analysis. (LSA).

Traits		AFC	FCI	FSP	FLMY	FLL
FCI	r_g	0.222±0.21**				
	r_e	0.098				
	r_p	0.142				
FSP	r_g	-0.145±0.35	0.071±0.36			
	r_e	0.059	-0.069			
	r_p	0.019	-0.042			
FLMY	r_g	0.577±0.29**	0.720±0.23*	-0.001±0.049		
	r_e	-0.147	0.241	-0.028		
	r_p	0.014	0.330	-0.026		
FLL	r_g	0.414±0.193*	0.849±0.08*	-0.243±0.34	0.906±0.15*	
	r_e	-0.187	0.494	0.018	0.49	
	r_p	0.058	0.630	-0.034	0.552	
FDP	r_g	-0.175±0.27	0.655±0.16*	0.479±0.45**	0.051±0.37	0.157±0.27
	r_e	0.242	0.794	-0.091	-0.067	-0.135
	r_p	0.133±	0.744	-0.025	-0.050	-0.050

* (P<0.01) ** (P<0.05)

that both traits are governed by same set of genes. The lower magnitude of genetic and phenotypic association between these traits clearly indicated that these traits were controlled by environmental factors. Better health and management practices at farm would improve the AFC, which would also reduce the FCI.

The genetic, environmental and phenotypic correlations between AFC and FSP were found to be as –0.145±0.35, 0.059 and 0.019, respectively. The genetic correlation between these two traits was negative and non-significant, while phenotypic and environmental correlations were found to be small and positive.

Singh (2000) reported positive and moderate genetic correlation between these two traits in Sahiwal cattle, while Ramalu and Sidhu (1995) observed negative association between these two traits in Ongole. Dalal *et al.* (2002) reported higher positive association between these two traits in Hariana cattle.

Singh (2000) also reported small positive phenotypic correlation between these two traits in Sahiwal and similar results was also reported by Dalal *et al.* (2002) in Hariana cattle.

The genetic, environmental and phenotypic correlations of AFC with FLMY were found to be as 0.577±0.29, –0.147 and 0.014, respectively.

Similar trends of genetic correlation were reported by Kumar (1987) and Singh (2000) Surech Chand and Sharma (1985) reported higher genetic correlation between AFC and FLMY than the results of present study.

However, Nagpal and Acharya (1970) reported very small genetic correlation between these two traits, while Singh *et al.* (1980), Rathi (1980), Sharma *et al.* (1987) Singhal *et al.* (1994) reported negative association between AFC and FLMY.

Nagpal and Acharya (1970) reported higher positive phenotypic association between AFC and FLMY. However, Taneja *et al.* (1978), Singh *et al.* (1980), Kumar (1987) and Sharma *et al.* (1987) reported lower amount of association between these two traits.

Evidently, the sire had capacity to transmit early age at first calving with higher milk yield. Estimate of genetic correlation between AFC and FLL (0.414±0.193) was highly positive and significant. Generally positive genetic correlation between AFC and FLL was inferred from the positive phenotypic response in AFC and both traits are affected by same set of genes.

The estimate of phenotypic correlation between AFC and FLL was positive and low (0.058) in magnitude. The positive phenotypic correlation between these two traits showed the existence of positive association and indicated that increase AFC is associated with increase in FLL. The result of the present study are in close agreement with the findings of Taneja et al.(1978a) in Sahiwal and Venkatashwaralu et al.(1972) in Ongole cattle. However, Gandhi and Gurnani(1990) Singh et al.(1999) and Singh (2000) reported negative trend in genetic associations between these two traits.

Singh (2000) reported similar findings for phenotypic association between AFC and FLL, while lower and positive between these traits were observed by Taneja *et al.* (1978a) in Sahiwal, Venkatashwaralu *et al.* (1972) in Ongole and Dalal *et al.* (2002) in Hariana.

The environmental correlation between AFC and FLL was negative. The results of the present study are in close agreement with the findings of Taneja *et al.* (1978a) in Sahiwal and Vekatashwaraiu *et al.* (1972) in Ongole cattle. However, Gandhi and Gurnani (1990), Singh *et al.* (1999) and Singh (2000)) reported negative trend in genetic association between these two traits.

The genetic, environmental and phenotypic correlation between AFC and FDP were found to be -0.175 ± 0.27, 0.242 and 0.133, respectively.

Genetic association between AFC and FDP was found to be negative and non-significant. However, negative genetic association between these two traits were also observed by Rathi (1984) and Suresh chand and Sharma (1985) in Sahiwal cattle, while Singh *et al* (1980), Singh *et al* (1999) and Singh (2000) observed positive association between these two traits.

Phenotypic association between AFC and FDP was found to be as 0.133. Dalal *et al.* (2002) observed similar magnitude of phenotypic association between these two traits in Hariana cattle. However, lower to medium positive phenotypic association between these two traits were observed by Singh *et al* (1980), Chaudhary (1983), Suresh Chand and Sharma (1985) and Singh (2000) in Sahiwal and Venkatashwaralu *et al* (1972) in Ongole cattle, while Ramalu and Sidhu (1995) reported negative association between these two traits.

4.4.2 FCI with other traits

The genetic, environmental and phenotypic correlation between FCI and FSP were found to be as 0.071±0.36, –0.069 and -0.042, respectively, under model 2 (Table 4.17).

The genetic correlation between these two traits under present study was very low and non-significant. Singh (2000) in Sahiwal, Ramalu and Sidhu (1995) in ongole and Dalal *et al* (2002) in Hariana cattle were reported higher and positive correlations between these two traits.

The negative phenotypic correlation (-0.042) between FCI and FSP was observed in present study, while Singh (2000) in Sahiwal, Ramalu and Sidhu (1995) in Ongole and Dalal *et al* (2002) in Hariana cattle reported positive association between FCI and FSP.

The negative phenotypic and environmental correlations are an indication of non-significant environmental factors affecting the relationship between FCI and FSP.

The genetic, environmental and phenotypic correlations of FCI with FLMY were found to be as 0.720±0.23, 0.241 and 0.330, respectively, presented in Table 4.17.

Similar magnitude for genetic association was observed by Dalal *et al* (2002) in Hariana cattle. However, lower values were reported by Prasad (1986) and Gandhi and Gurnani (1990), while Singh *et al.* (1980), Kumar (1986) and Singh (2000) reported negative trend of genetic association between FCI and FLMY.

Singhal *et al.* (1994) and Singh (2000) observed almost similar magnitude of phenotypic association between FCI and FLMY in Sahiwal cattle and Dalal *et al.* (2002) in Hariana cattle. However, Prasad (1986) and Kumar (1986) observed lower magnitude of phenotypic association between these two traits in Sahiwal cattle.

These correlations indicated that animals with long first calving interval lactated more milk during their first lactation on phenotypic scale due to genetic and non-genetic reasons as evident from the sign and magnitude of genetic and environmental correlations. This implies when selection is made for increased milk yield could cause a correlated increase in FCI.

Genetic, environmental and phenotypic correlations of FCI with FLL were found to be as 0.849±0.08, -0.494 and 0.630, respectively (Table 4.17) under model 2.

Similar results have also been reported by Gandhi and Gurnani (1990), Singhal *et al.* (1994) and Singh (2000) in Sahial and Dalal *et al.* (2002) in Hariana cattle.

The correlations estimated in present study indicated that FCI and FLL were not antagonistic characters affected by same set of genes. These correlations indicated that cows with longer time interval between two successive calving would results in longer lactation length on phenotypic scale due to both genetic and environmental causes.

The genetic, phenotypic and environmental correlations between FCI and FDP were found to be as 0.655±0.16 0.744 and 0.794, respectively under model 2 of LSA. Almost similar findings for genetic and phenotypic association between these two traits were reported by Singh (2000) in Sahiwal, Ramalu and Sidhu (1995) in Ongole and Dalal *et al.* (2002) in Hariana cattle.

These correlations indicated that cows with longer dry period had taken longer time interval between two successive calving on phenotypic scale due to both genetic and environmental causes. This suggested that both the traits were controlled by similar genetic environmental conditions.

4.4.3 FSP with other traits

The present study has shown that the genetic, environmental and phenotypic correlations between FSP and FLMY were found as–0.001±0.49, –0.028 and -0.042, respectively (Table 4.17).

Singh (2000) similar results was reported for in Sahiwal cattle, while Dalal *et al.* (2002) observed highly positive correlation between these two traits.

The phenotypic correlation between these two traits was also found very low with negative trend, while Singh (2000) in Sahiwal and Dalal *et al.* (2002) in Hariana cattle observed highly positive association between FSP and FLMY.

Though the estimate of genetic association between FSP and FLMY was found to be negative and non-significant but the trends found in genetic, phenotypic and environmental association were in desirable direction.

The genetic, environmental and phenotypic correlations between FSP with FLL were found to be as –0.0243±0.34, 0.018 and -0.034, respectively, under model 2 of LSA (Table 4.17).

The value reported for genetic correlation between FSP and FLL was found negative and non-significant. Phenotypic association was also found in negative trend, while Singh (2000) reported highly positive genetic as well as phenotypic correlations between these two traits.

The genetic, phenotypic and environmental correlations between FSP and FDP were found to be as 0.479±0.45, -0.025 and –0.091, respectively, (Table 4.17).

Singh (2000) and Dalal *et al.* (2002) reported higher positive genetic association than the present study between these two in Sahiwal and Hariana cattle, while Ramalu and Sidhu (1995) reported lower than the estimate of present study in Ongole cattle.

Negative and small environmental and phenotypic correlations found between FSP and FDP, in present study, while Singh (2000) in Sahiwal, Ramalu and Sidhu (1995) in Ongole and Dalal *et al.* (2002) in Hariana cattle were reported positive phenotypic correlations.

4.4.4 FLMY with other traits

The genetic, environmental and phenotypic correlations between FLMY and FLL were positive and relatively high, as 0.906±0.15, 0.49 and 0.552, respectively under model 2 of LSA (Table 4.17).

The estimate of genetic correlation between these two traits is of general interest in selection for these characters in Sahiwal cattle.

The values of genetic correlation between these two traits as reported by Singh *et al.* (1980), Sharma and Singh (1981), Gandhi and Gurnani (1990), Singh *et al.* (1994) and Singh *et al.* (1997a) were lower than those estimated in present study. However, Sharma *et al.* (1987) and Singh (2000) reported negative trend between these two traits in Sahiwal cattle.

Singh *et al.* (1980) Singh *et al.* (1994), Singh *et al.* (1997a) and Singh (2000) observed highly positive phenotypic association between these two traits. Similar findings were also observed by Pandey *et al.* (2001) and Dalal *et al.* (2002) in Hariana cattle.

The correlations estimated under study indicated that FLMY and FLL are genetically correlated, so that selection for FLMY might result increase in genetic merit for the other traits. The differences inn the sign and magnitude of correlations obtained by several workers and in present study, might be due to the sampling variations and different genetic makeup of herds.

The genetic, environmental and phenotypic correlations between FLMY and FDP were found to be as 0.051±0.37, –0.067 and -0.050, respectively.

The genetic association between these two traits was found to be non-significant and positive, while Singh *et al.* (1980), Rathi (1984) and Singh (2000) reported negative trend in genetic association between these two traits.

Similar trend as observed in present study for phenotypic association between these two traits were also observed by Singh *et al.* (1980), Singh *et al.* (1999) and Singh (2000) in Sahiwal, Dalal *et al.* (2002) also observed Similar trend in Hariana cattle.

4.4.5 FLL with FDP

The genetic correlation between FLL and FDP was found to be positive and non-significant (0.157±0.27) under model 2 of LSA. Similar trend were also observed by Singh (2000) in Sahiwal and Dalal *et al.* (2002) in Hariana cattle.

The phenotypic correlation between FLL and FDP was found as –0.050 (Table 4.17). Similar results also reported by Rathi (1984), Singh *et al.* (1999) and Singh (2000) in Sahiwal and Dalal *et al.* (2002) in Hariana cattle.

In general, the genetic correlations estimated in the present study were mostly higher than their phenotypic counter parts in all the traits. Large differences between genetic and phenotypic correlations tend to occur only when the genetic correlation was estimated with low precision. The magnitude of genetic correlations among all the traits in general were higher than the environmental correlations which indicates that phenotypic correlations among these traits were more due to genetic cause.

4.5 Sire evaluation

4.5.1 Relative efficacy of different methods in evaluation of Sahiwal sires

The spectacular improvement in production capacity in dairy cattle could be achieved from selection of sires. Selection of sires based on their accurately predicated breeding value is of paramount importance. Prediction of breeding value depends upon the methods of sire evaluation used.

As per the objectives, the sires have been ranked on the basis of breeding value obtained under LS procedure (BLUP 1) and REML procedure (BLUP 2). The breeding values and list of ten top ranking sires have been summarized in Table 4.18 to 4.21. BLUP 1 procedure had included the season as fixed effect while BLUP 2 procedure using a mixed model containing season of calving as fixed effect and sire as random effect. These methods were based on progeny testing. BLUP 2 procedure was based on an animal model, which utilized information from all known relationships. The sires were sorted out on the basis of the solutions obtained for all the animals and used for comparison.

The raw means estimated by the different methods were found same, therefore, the breeding values taken as deviation of sires value from the raw mean. These have been presented and discussed for the sire evaluation and comparison under BLUP 1 and BLUP 2 methods.

A total of 57 sires were evaluated, for AFC, FCI and FLMY in sahiwal cattle. The information on sire evaluation viz., percent of sire with positive and negative effects, sire effect for the top ranking and bottom ranking sires and per cent superiority/inferiority of top/bottom under BLUP 1 and BLUP 2 have been presented in Table 4.18 to 4.21.

4.5.1.1 Age at first calving

The estimated general mean of AFC (1297.13 days) has been used for LS and BLUP in Sahiwal cows. Less than half of the sires (47.36%) were

Table 4.18: Range of solutions for breeding values for AFC, FCI and FLMY under BLUP 1 procedure in Sahiwal cattle.

S.No.	Traits	Best sire			Worst sire			% of sire	
		AFC			FCI			FLMY	
		Sire code	Value	% of mean	Sire code	Value	% of mean	+ effect	- effect
1.	AFC	1015	-95.712	-7.38	1026	82.81	6.38	47.36	52.63
2.	FCI	1008	-60.78	-11.68	1020	69.45	13.34	50.87	49.13
3.	FLMY	1026	103.99	6.68	1041	-167.49	-10.77	56.14	43.86

Table 4.19: Range of solutions for breeding values for AFC, FCI and FLMY under BLUP 2 procedure in Sahiwal cattle.

S.No.	Traits	Best sire			Worst sire			No. of sire with	
		AFC			FCI			FLMY	
		Sire code	Value	% of mean	Sire code	Value	% of mean	+ effect	- effect
1.	AFC	1049	-242.22	-18.67	1026	187.65	14.46	52.63	47.37
2.	FCI	1008	-83.33	-16.02	1020	72.46	13.93	54.38	44.62
3.	FLMY	1001	264.51	17.01	1041	-368.04	-23.07	52.63	47.37

found to be superior to the population mean under BLUP 1 procedure. The corresponding value under BLUP 2 was found to be higher (52.63%).

Breeding values of AFC have been found in the range of –95.71 t o 82.81 and –242.22 to 187.65, respectively, under BLUP 1 and BLUP 2. The range of sire effects was found much wider in BLUP 1 than the BLUP 2.

Best sires contributed –7.38 per cent and –18.67 per cent to general mean, respectively, under BLUP 1 and BLUP 2. Whereas, Corresponding values of worst sires contribution have been found 6.38 per cent and 14.46 per cent, under BLUP 1 and BLUP 2 procedure, respectively. BLUP 2 had shown maximum value in terms of superiority / inferiority.

The upper limits of breeding values for AFC have been found form –95.71 days (BLUP 1) to –242.22 days (BLUP 2), whereas lower limit reduced from 82.81 (BLUP 1) to 187.65 days (BLUP 2). The upper and lower limits of sire effect under BLUP 1 found to be below half of the BLUP 2 procedure.

4.5.1.2 First calving interval

An average estimated value of 520.44 days for FCI in Sahiwal has been found under present study. This value was used in BLUP 1 and BLUP 2 for sire evaluation. More than half of the sires (50.87%) were found superior to the population mean under BLUP 1 procedure for FCI. The corresponding value under BLUP 2 was found to be as 54.38 per cent.

The range of breeding values for FCI were found from –60.78 to 69.45 and –83.33 to 72.46 under BLUP 1 and BLUP 2 procedures, respectively.

Best/superior sires contributed –11.68 per cent and –16.02 per cent to the average FCI in population, respectively under BLUP 1 and BLUP 2 procedures. The corresponding values of worst sires contribution have been found 13.34 per cent and 13.93 per cent, under two different procedures. Therefore, BLUP 2 had shown maximum value in term of superiority / or inferiority.

The upper limit of breeding values for FCI has been found from –60.78 days (BLUP 1) to –83.33 days (BLUP 2), whereas lower limit ranged from 69.45 days (BLUP 1) to 79.46 days (BLUP 2). The upper and lower limits of breeding values under BLUP 1 procedure were found higher than those found under BLUP 2.

4.5.1.3 First lactation milk yield

The general mean for FLMY estimated under study was found to be as 1554.86 kg. This mean was used under BLUP 1 and BLUP 2 procedure for sire evaluation for FLMY.

More than half of the sires (56.14 percent) were found to be superior to the population mean as BLUP 1 procedure, whereas 52.63 per cent sires were found superior to population mean under BLUP 2 procedure.

Breeding values for FLMY have been found in the range of –167.49 to 103.99 under BLUP 1 and –368.04 to 264.51 under BLUP 2 procedure. The range of breeding values was found higher in BLUP 2 than the BLUP 2 procedures.

Best sire contributed 6.68 percent (BLUP 1) and 17.01 percent (BLUP 2) to the general mean. The corresponding values for the worst sires contribution to the population mean were found as –10.77 per cent and –23.67 per cent under BLUP 1 and BLUP 2, respectively.

The upper limits of breeding values for FLMY have been found 103.99 kg (BLUP 1) to 264.51 kg (BLUP 2) whereas lower limits reduced from 167.49 kg to –368.04 kg, respectively, under BLUP1 and BLUP 2 procedures. The upper and lower limits of breeding values under BLUP 1 were found to be less than half of the BLUP 2 procedure.

It is observed that maximum ranges of breeding values for AFC, FCI and FLMY were reported under BLUP 2. The distribution/ ranking of top 10 sires for genetic merit estimated by BLUP 1 and BLUP 2 procedures are presented in Table 4.20 and 4.21, respectively. These tables revealed that more than 60 per cent of sires have been ranked under top 10 sires for corresponding traits under different models.

It is observed from the results that maximum range of sire's breeding values for AFC, FCI and FLMY were reported under BLUP 2 procedure. Ranking of sires by BLUP 1 and BLUP 2 were positive for 27 and 30 sires out of 57 evaluated, for AFC. 29 and 31 sires out of 57 were evaluated for positive performance for FCI under BLUP 1 and BLUP 2 procedure, respectively, whereas, 32 and 30 sires out of 57 sires for FLMY were found with positive performance under BLUP 1 and BLUP 2 procedures.

The distribution/ranking of top 10 sires on the basis of their breeding value estimated by BLUP 1 and BLUP 2 procedures have been presented in Tables 4.20 and 4.21, respectively. The higher percentage of superior sires to population mean for AFC and FCI the traits were observed under BLUP 1 than the BLUP 2 procedures. This might be due to no fitting of sire effect in

Table 4.20: Ranking of top 10 sires for AFC, FCI and FLMY under BLUP 1 procedure in Sahiwal cattle.

Ranks	Traits					
	AFC		FCI		FLMY	
	Sire	Value	Sire	Value	Sire	Value
1.	264	-95.71	198	-60.78	442	103.99
2.	518	-77.48	596	-48.36	179	94.18
3.	1050	-67.75	771	-44.89	1208	90.96
4.	305	-57.69	1033	-42.17	208	77.11
5.	262	-53.01	1050	-40.04	149	72.52
6.	79	-52.17	611	-36.48	262	70.52
7.	403	-50.48	1060	-34.57	282	65.86
8.	Gulab	-48.12	494	-31.99	270	57.69
9.	494	-43.43	518	-20.81	252	56.31
10.	203	-43.33	79	-20.51	329	47.35

Table 4.21: Ranking of top 10 sires for AFC, FCI and FLMY under BLUP 2 procedure in Sahiwal cattle.

Ranks	Traits					
	AFC		FCI		FLMY	
	Sire	Value	Sire	Value	Sire	Value
1.	518	-242.22	198	-83.33	179	264.50
2.	264	-182.81	596	-62.16	442	257.55
3.	1050	-178.98	1050	-53.52	1208	234.16
4.	305	-172.78	1060	-47.09	149	193.97
5.	403	-159.61	1033	-45.72	208	181.44
6.	397	-144.24	494	-45.12	262	128.90
7.	494	-133.55	771	-44.91	252	115.66
8.	1237	-124.11	611	-44.63	625	109.98
9.	79	-118.66	509	-33.05	282	109.69
10.	262	-111.99	518	-29.11	1090	105.37

the BLUP 1. In BLUP 2 procedure sires were sorted out from the animal solutions and than ranked on the basis of breeding values.

These findings are in close agreement with the findings of. Harvey (1979), Tajne and Rai (1990), Raheja (1992), Singh *et al.* (1992), Gokhale and Mangurkar (1995), Thakur (1997), Dhaka and Raheja (2000), Singh (2000), Sahana and Gurnani (2000) and Gaur *et al.* (2001), who also reported BLUP as best procedure for the sire evaluation.

However, Parekh and Pandey (1982), Singh and Parekh (1995) and Gaur and Raheja (1996) observed that LS was the best procedure for sire evaluation in comparison to other procedure.

Since, BLUP 1 procedure had included the season as fixed effect while BLUP 2 procedure using a mixed model containing season of calving as fixed effect and sire as random effect and the results reveled that the range of breeding values, percentage sires superior to population mean and superiority of best sire were more under BLUP 2 than the BLUP 1 procedure, the BLUP 2 procedure should be used to evaluate the sires.

4.5.2 Rank correlation

All 57 sires were ranked on the basis of the solution obtained under BLUP 1 and BLUP 2 using animal models for AFC, FCI and FLL. The rank correlation coefficients for "among methods within traits" and "among traits within method" are presented in Table 4.22.

Rank correlations for the traits between methods were highly significant. Rank correlations between methods were in the range of 0.916 to 0.973. Rank correlations were above 0.90 for all the traits when sires were ranked under BLUP 1 and BLUP 2. Therefore, ranking under these two procedures was almost same.

Table 22: Rank correlation coefficients between BLUP 1 and BLUP 2.

Traits		BLUP 1		
		AFC	FCI	FLMY
BLUP 2	AFC	**0.973**	0.279	0.208
	FCI	0.251	**0.973**	0.518
	FLMY	0.234	0.469	**0.916**

Figures on diagonal are "among method within traits" rank correlation coefficients.
Above diagonal values are among traits within method rank correlation coefficient under model 8 and
Below diagonals are among traits within method rank correlation coefficient under univariate animal model.

The rank correlations "among traits within methods" were low than "among methods within trait". In "among traits with in method" the ranking of sires changed resulting into decreased rank correlation coefficients. With in the method, the rank correlation ranged from 0.279 (between AFC and FCI) to 0.518 (between FCI and FLMY) under BLUP 1, while in BLUP 2 ranged from 0.251 (between AFC and FCJ)) to 0.469 (between FCI and FLMY). In general, FCI had highest rank correlations with FLMY in both methods, ranging from 0.469 in BLUP 2 to 0.518 BLUP 1. This might be due to high genetic correlation between FCI and FLMY.

SUMMARY AND CONCLUSION

"Summing of results provide further leads to prosperity"

SUMMARY AND CONCLUSION

The data for the present study were collected from the pedigree records of 875 Sahiwal cattle spread over 26 years from 1975 to 2001. The animals were maintained at State Livestock cum Agriculture Farm, Chak Ganjaria, Lucknow (U.P.). The traits studied were age at first calving (AFC), first calving interval (FCI), first service period (FSP), first lactation milk yield (FLMY), first lactation length (FLL) and first dry period (FDP).

Lactation records below 150 days of lactation yield were omitted from the present study. The sires having less than four progenies had deleted from analysis. The data were subjected to LSMLMW and MIXMDL package of Harvey (1990) and Derivative free REML package of Meyer (1998). Same models were fitted to taking season as fixed and sire as a random effect.

The phenotypic mean of AFC, FCI, FSP, FLMY, FLL and FDP were 1297.13 days, 520.44 days, 202.39 days, 1554.86 kg, 313.67 days and 206.76 days, respectively.

The least squares means (±S.E.) were 1297.43±10.55 days, 520.18±7.49 days, 202.40±0.36 days, 1552.48±26.00 kg, 313.76±5.48 days and 206.42±4.71 days, respectively, under model 2, 1296.48±9.61 days, 515.98±6.76 days, 203.42±0.34 days, 1556.50±25.29 kg, 312.45±4.85 days and 204.24±4.52 days respectively, under model 8 and 1297.13 days, 516.76 days, 202.39 days, 1548.01 kg, 313.87 days and 206.76 days under univariate animal model of REML, respectively, for AFC, FCI, FSP, FLMY, FLL and FDP. Univariate animal model of REML analysis has estimated slightly higher coefficients of variation for all the traits except for FCI and FLMY than model 2 and model 8 analyses.

The fixed effect of season had non-significant effect on all the traits except for AFC ($p<0.05$) under model 2 and model 9. The random effect of sires had highly significant effect ($p<0.01$) on all the traits except FSP ($P<0.05$) under model 2 analysis. The sire had more variation for FCI, FsP and FLL under model 2 and for AFC, FLMY and FDP under model 8.

The coefficients of multiple determinations under model 8 were 9.50, 9.00, 2.10, 3.50, 11.20 and 4.90 percent, respectively, for AFC, FCI, FSP, FLMY, FLL and FDP. The higher values of coefficient of variation for AFC, FCI and FLL indicated that there is need for applying intense selection pressure for these traits.

Additive (direct), phenotypic and environmental variances were estimated under model 2, 8 and univariate animal model. The phenotypic and environmental variances estimated under model 2 and 8 analysis were found almost similar for corresponding traits. Univariate REML analysis had higher value of phenotypic and environmental variances for AFC than those of model 2 and 8.

Additive (direct) variances estimated from univariate animal model were higher than estimates of model 2 and model 8 for AFC, FSP, FLMY and FDP.

The heritability estimates for AFC were 0.371, 0.384 and 0.721, respectively, under model 2, model 8 and univariate animal model.

The heritability estimates for FCI under model 2, model 8 and univariate animal model were 0.341, 0.340 and 0.311, respectively. These values were almost similar among all three models.

The heritability estimates FSP and FLMY were found very low under all the models applied.

The heritability estimated by three methods for FLL were found 0.496, 0.442 and 0.232 under model 2, model 8 and univariate animal model, respectively. The heritability estimates obtained under model 2 and 8 were found almost similar while the heritability estimate under univariate animal model was low.

The heritability estimates for FDP were 0.162, 0.173 and 0.383, respectively, under model 2, model 8 and univariate animal model. The heritability estimated under univariate animal model was found higher than those estimated under model 2 and model 8.

The differences occurred in heritability estimates under different model analysis could be due to applying the different estimation procedures and could be due to the model effects as different models were used in present study. The univariate REML method was found to be the more efficient method as it utilized all the known relationship under an animal model.

AFC, FLMY and FDP shared negative correlation between coefficients of variation and heritability estimates under model 2, model 8 and univariate animal model, while FCI, FLL and FSP had positive correlation between coefficients of variation and heritability estimates under all models.

Genetic correlations of AFC with FCI, FLMY and FLL were found positive (0.222±0.21, 0.577±0.29 and 0.414±0.193) and significant. The genetic correlation of AFC with FSP and FDP were found negative and non-significant. The magnitude and trend of genetic correlation of AFC with FCI, FLMY and FLL in present study revealed that selection at early age at first calving would result higher milk yield at shorter lactation length.

The phenotypic correlations of AFC with FCI, FSP, FLMY, FLL and FDP were found positive and small whereas, environmental correlations of AFC with FCI, FSP, FDP were found positive and negative with FLMY and FLL.

Genetic correlations of FCI with FLMY FLL and FDP were found positive and significant, except with FSP.

The phenotypic and environmental correlations of FCI with FLMY, FLL and FDP were positive and moderate to high except in case of FSP in which magnitudes of these were found negative.

The genetic correlations of FSP with all other traits were observed negative and non-significant, however, with FDP it was found positive, and significant, which revealed that longer FSP would result in longer FDP.

The phenotypic and environmental correlations of FSP with all other traits were found in negative trend and low in magnitude.

The genetic, phenotypic and environmental correlations of FLMY with FLL were found highly significant which is of general interest in selection for these characters in Sahiwal. However, the corresponding values of FLMY with FSP were found non-significant and in negative trend.

The genetic correlation of FLL with FDP was found non-positive. Phenotypic and environmental correlations between these two traits were low and negative.

In general, the genetic correlations tend to be slightly higher than their phenotypic counterparts in all the traits.

The heritability estimate of AFC and its genetic and phenotypic correlation with other traits under present study indicated that selection on the basis of AFC would be effective for the improvement of other traits.

Breeding values of sires were obtained/ estimated by best linear unbiased prediction under model 8 of LSA (BLUP 1) and under univariate animal model of REML (BLUP 2) for sire evaluation. Since the raw means estimated under different methods were same, breeding values were taken as deviation from the raw means. A total of 57 sires were evaluated for AFC, FCI and FLMY. Less than half of the sire (47.36percent) were found superior to the population mean for AFC under BLUP 1 whereas, corresponding value was found 52.63 per cent under BLUP 2. There were 27 sires (BLUP 1) and 30 sires (BLUP 2) out of total 57 found with positive performance of AFC.

About 50 per cent sires were found superior to the population mean for FCI (BLUP 1), whereas, corresponding value under BLUP 2 was 54.38 per cent. 29 and 31 sires out of 57 sires were evaluated with positive performance for FCI under BLUP 1 and BLUP 2, respectively.

More than half of the sires (56.15percent) were found superior to the population mean for FLMY under BLUP 1 and 52.63 per cent under BLUP 2. 32 sires under BLUP 1 and 30 sires under BLUP 2 out of 57 sires were found with positive performance for FLMY.

Results revealed that range of breeding values, number of superior sires to population mean and higher values of superior sire were more under BLUP 2. Since, this procedure (BLUP 2) was based on univariate animal model of REML, BLUP 2, procedure could be used to evaluate the sires.

The rank correlations "among traits within methods" were low than "among methods within trait". In "among traits with in method" the ranking of sires changed resulting into decreased rank correlation coefficients. With in the method, the rank correlation ranged from 0.279 (between AFC and FCI) to 0.518 (between FCI and FLMY) under model 8, while in univariate animal model ranged from 0.251 (between AFC and FCJ)) to 0.469 (between FCI and FLMY). In general, FCI had highest rank correlations with FLMY in both methods, ranging from 0.469 in univariate animal model to 0.518 model 8. This might be due to high genetic correlation between FCI and FLMY.

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VITA

Name	:	*ANIL KUMAR*
Date of Birth	:	2^{nd} October, 1976
Place of Birth	:	Pantnagar, Uttaranchal
1992	:	Passed High School Examination from Pantnagar Intermediate College, Pantnagar (U.P.Board, Allahabad)
1994	:	Passed Intermediate Examination from Pantnagar Intermediate College, Pantnagar (U.P.Board, Allahabad).
1998	:	Passed B.Sc. (Z.B.C.) degree form Govt. Raza P.G. College, Rampur, (M.J.P., Rohilkhand University, Bareilly).
2000	:	Successfully completed M.Sc. Ag. (Animal Breeding) degree from G.B. Pant University of Agriculture and Technology, Pantnagar.
		During M.Sc. Ag. Programme, author was recipient of "Graduate Teaching/Research Assistantship".
2001	:	Joined Ph.D .degree programme in Animal Science (Animal Breeding) with minor Molecular Biology and Biotechnology in G.B. Pant University of Agriculture and Technology, Pantnagar.
	:	During Ph.D. Degree Programme, author was recipient of 'University Fellowship".

Present address
Anil Kumar
S/O Shri Shyam Sunder
H.No. VI/1621
Pantnagar
Distt. U.S.Nagar (Uttaranchal)
Pin:263145

Permanent Address
S/o Shri Shyam Sunder
Vill. :Belhi
P.O.: Tarkulwa
Distt.: Deoria
(U.P.)

ABSTRACT

Name	: Anil Kumar	**Id.No.**	: 25875
Semester and Year of Admission	: II, 2000-2001	**Degree**	: Ph.D
Major	: Animal Science (Animal Breeding)	**Department**	: Genetics and Animal Breeding
Minor	: Molecular Biology and Biotechnology		

Topic: "GENETIC ANALYSIS OF ECONOMIC TRAITS OF SAHIWAL CATTLE USING ANIMAL MODELS"

Advisor: Dr. C.V. Singh

Data consisting of 875 Sahiwal cattle, maintained at, State Livestock cum Agriculture Farm, Chak Ganjaria, Lucknow (U.P.), over the period of 26 (1975-2001). The data were subjected to LSMLMW and MIXMDL package of Harvey (1990) and derivative free REML package of Mayer (1990). Season of calving had taken as fixed effect and sire as random effect in different models.

The least squares means were found 1297.43±10.55 days, 520.18±7.49 days, 202.40± 0.36 days, 1552.48±26.00 kg, 313.76±5.48 days and 206.42±4.71 days, respectively, under model 2 of LSA and 1296.48±9.61 days, 515.98±6.76 days, 203.42±0.34 days 1556.50±25.29 kg, 312.45±4.85 days and 204.24±4.52 days, respectively, under model 8 of LSA. The least squares means under univariate animal model of REML were found 1297.13 days, 516.76 days, 202.39 days, 1548.01 kg, 313.87 days and 206.76 days for AFC, FCI, FSP, FLMY, FLL and FDP respectively. The slightly differences observed among least squares means estimated under LSA and univariate animal models. The coefficient of variation for all the traits were found almost similar or near to similar in all the models.

The sires had highly significant ($p<0.01$) effects on all the traits under model 2 except on FSP ($p<0.05$). The differences among sire variation had occurred under model 2 and model 8. Season had non-significant effect on all the traits except on AFC ($p<0.05$) under both models of LSA. The coefficient of multiple determination (R^2) were found 9.50, 9.00, 2.10, 3.50, 11.20 and 4.90 per cent for AFC, FCI, FSP, FLMY, FLL and FDP, respectively, under model 8.

The h^2 estimated under model 2, model 8 and univariate animal model of REML were 0.371 0.384 and 0.721, respectively, for AFC, 0.341, 0.340 and 0.311, respectively, for FCI, 0.083, 0.079 and 0.127, respectively, for FSP, 0.122, 0.132 and 0.174, respectively, for FLMY, 0.446, 0.442 and 0.232, respectively, for FLL and 0.162, 0.173 and 0.383, respectively, for FDP. The difference occurred among h^2 estimates under different models could be due to applying the different estimation procedures with same/ different models or could be due to model effect in different models. Genetic correlations estimated under present study were found higher than their phenotypic counter parts in all the traits. Genetic correlations of AFC with FDI, FLMY and FLL, FCI with FLMY, FLL and FDP, FSP with FDP and that of FLMY with FLL were found positive and significant. 47.38, 50.87 and 56.14 per cent sires were found best under BLUP 1 for AFC, FCI and FLMY, respectively. However, corresponding values under BLUP 2 were 52.63, 54.38 and 52.63 for AFC, FCI and FLMY. The superiority of best sire was higher in BLUP 2 than the BLUP 1 for all the traits. The rank correlations for AFC, FCI and FLMY between BLUP 1 and BLUP 2 were found higher and significant.

(C.V. Singh)
Advisor

(Anil Kumar)
Author