

**GENETIC EVALUATION OF HF X GIR HALFBRED SIRES USING  
FERTILITY AND MILK PRODUCTION TRAITS**

by

**Mr. Shinde Onkar Vishnu  
(Reg. No.2016/023)**

**A thesis submitted to the  
MAHATMA PHULE KRISHI VIDYAPEETH  
RAHURI - 413 722, DIST.AHMEDNAGAR  
MAHARSHTRA, INDIA**

In partial fulfillment of the requirements for the degree

of

**DOCTOR OF PHILOSOPHY (AGRICULTURE)**

in

**ANIMAL HUSBANDRY**



**DEPARTMENT OF ANIMAL HUSBANDRY AND DAIRY SCIENCE  
POST GRADUATE INSTITUTE  
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MAHARASHTRA, INDIA  
2021**

## CANDIDATE'S DECLARATION

I hereby declare that this thesis or part

Thereof has not been submitted

by me or other person to any

other University or Institute

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Diploma

Place : MPKV, Rahuri

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Date :    /    / 2021

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This is to certify that the thesis entitled, “**GENETIC EVALUATION OF HF X GIR HALFBRED SIRES USING FERTILITY AND MILK PRODUCTION TRAITS**”, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfilment of the requirement for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **ANIMAL HUSBANDRY**, embodies the results of a piece of bonafide research work carried out by **Mr. SHINDE ONKAR VISHNU** under my guidance and supervision and that 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 have been duly acknowledged.

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Place : M.P.K.V., Rahuri

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## ***ACKNOWLEDGEMENTS***

A journey is easier when you travel together. Interdependence is certainly more valuable than independence. This thesis is the result of three years of work, in which I have been accompanied and supported by many people. It is a pleasant moment for me to express gratitude for all of them.

I personally place my deep sense of heartfelt gratitude, satisfaction and pride to the very polite chairperson of my advisory committee Dr. U.Y. Bhoite, Ex. Professor, Department of Animal Husbandry and Dairy Science, Post Graduate Institute, MPKV, Rahuri. This thesis would not have been possible without his kind support, enthusiasm and inspiration. I am blessed to have such a whole hearted and kind person as my guide for this study, who cared and supported me with lot of patience.

I would like to express the deepest appreciation to Dr. D.K. Kambale, Head, Department of Animal Husbandry and Dairy Science M.P.K.V., Rahuri for providing necessary facilities, helpful criticism, suggestions and encouragement till completion of this venture.

I would also like to place on record my sincere thanks and deep sense of gratitude to the members of advisory committee, Dr. S. D. Mandakmale, Senior Scientist, All India Coordinated Research Project on Sangamneri Goat, Department of Animal Husbandry and Dairy Science M.P.K.V., Rahuri, Dr. D.K. Deokar, Associate Professor, Department of Animal Husbandry and Dairy Science, MPKV, Rahuri and Dr. C.A. Nimbalkar, Associate Professor, Department of Agricultural Economics and Statistics, College of Agriculture Pune, and Dr. U.S. Gaikwad, Assistant Professor, Department of Animal Husbandry and Dairy Science, Pune for their valuable guidance and help during my course of investigation.

I am highly obliged to Dr. Prashantkumar Patil, Hon-Vice Chancellor, MPKV, Rahuri, Dr. A.L. Pharande, Dean, Faculty of Agriculture, M.P.K.V., Rahuri and Dr. P.N. Rasal, Associate Dean. Post Graduate Institute, M.P.K.V., Rahuri for providing necessary facilities and supports during the course of my study in the University.

I again earnestly extend my thanks to Dr. V.S. Lawar, Associate Professor, Department of Animal Husbandry and Dairy Science, MPKV, Rahuri for his co-operation during the research trial and advice given throughout the present study.

I humbly place on record my gratitude to Dr. R.J. Desale, Principal, Agriculture Technology School, Dhule, Late Dr. A.R. Deshmukh, Assistant Professor, Department of Animal Husbandry and Dairy Science and Dr. Y.B. Kandalkar, Senior scientist Network

Project on sheep MPKV, Rahuri for their valuable suggestions and encouragement during the course of study.

I take this opportunity to express gratitude to all of the faculty members of the Department of A.H.D.S Dr. S.S. Jadhav, Dr. R.G. Nimse and Dr. D.R. Birari for their help and support during my study.

Friendship isn't about whom you have known the longest. It's about who came, and never left your side. I have been fortunate to have a good friends who keeps me same through all four years. I greatly value their friendship and I deeply appreciate their belief in me. I would like to express my sincere appreciation to my colleagues, I thanks to my bathmats and seniors Nikhil Raykar, Hrushikesh Bhuikar, Dhananjay Chavan, Pradipkumar Adhale, Raviraj Pawar, Ritesh Patil, Rahul Mali, Farukh Tadvi, Sakharam Pawal, Ranjit Pawar, Uday Pawar, Viswajit Kokare etc. for nice company during Ph.D. study.

I cannot find word to express, heartiest gratitude to my family, my father Shri. Vishnu Shankar Shinde, Mother Sou. Kiran Vishnu Shinde and my wife Sou. Pranita Onkar Shinde for the unceasing encouragement, support and attention, who have always inspired towards success and above all they have given me a moral strength to make myself a successful man.

I am also grateful to Department of Science and Technology, Govt. Of India for providing the financial assistance in the form of INSPIRE fellowship during my Ph.D programme.

I am deeply obliged to all Scientists past and present whose literature has been cited sacrifice, constant encouragement and conciliation have boosted up me towards cherished dreams turning into reality in the form of dissertation.

Lastly I would like to express to my sincere thanks to the Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar for providing me an opportunity to undertake my Ph.D studies in this "Institute of Excellence."

I also place on record, my sense of gratitude to one and all, who directly or indirectly, have lent their hand in this venture.

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**Date :** / /2021

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## LIST OF ABBREVIATIONS

%	: Per cent
*	: Significant at 5 %
**	: Significant at 1 %
5/8 HF x 3/8 SW	: Holstein Friesian x Sahiwal
AFC	: Age at First Calving
AHS	: Animal Husbandry Statistics
AR	: Annual Report
BAH & FS	: Basic Animal Husbandry and Fisheries Statistics
BE	: Breeding efficiency
BFG	: Brown Swiss x Friesian x Gir
BLUP	: Best Linear Unbiased Prediction
BRU	: Bull Rearing Unit
CC	: Contemporary Comparison
CIRC	: Central Institute for Research on Cattle
CV	: Coefficient of variation
DFREML	: Derivative Free Restricted Maximum Likelihood
DMRT	: Duncan's Multiple Range Test
DP	: Dry Period
EBV	: Estimated Breeding Value
ETA	: Estimated Transmitting Ability
FCI	: First Calving Interval
FDP	: First Dry Period
FG	: Friesian x Gir
FJG	: Friesian x Jersey x Gir
FL305DMY	: First Lactation 305 Days or Less Milk Yield
FLL	: First Lactation Length
FLMY	: First Lactation Milk Yield
FSP	: First Service Period
$h^2$	: Heritability
HA	: Herd average
HF x S/T	: Holstein Friesian x Sahiwal / Thrparkar
HF x T	: Holstein Friesian x Tharparkar
HJG	: Holstein x Jersey x Gir
HL	: Herdlife
J x H	: Jersey x Hariana
J x SW	: Jersey Sahiwal
JFG	: Jersey x Friesian x Gir
JG	: Jersey x Gir

JHG	:	Jersey x Holstein x Gir
KF	:	Karan Fries
KS	:	Karan Swiss
LSML	:	Least Squares Maximum Likelihood
LSQ	:	Least Squares Method
MT	:	Multi-trait
MT-AM	:	Multi-trait Animal Model
NID	:	Normally and Independently Distributed
NS	:	Non significant
PDC	:	Project Directorate on Cattle, Meerut
PL	:	Productive life
REML	:	Restricted Maximum Likelihood
$r_g$	:	Genetic correlation
$r_p$	:	Phenotypic correlation
SD	:	Standard deviation
SDAI	:	Simple Daughter Average Index
SE	:	Standard errors
SM-II	:	Smith method II
SP	:	Service Period
SRLS	:	Simple Regressed Least Squares
ST-AM	:	Single Trait Animal Model
ST-SM	:	Single Trait Sire Model
TLL	:	Total Lactation Length
TLMY	:	Total Lactation Milk Yield
TMY	:	Total Milk Yield
TSP	:	Total Service Period
WAETA	:	Weighted Average of Sire's Estimated Transmitting Abilities
$\bar{u}$	:	Overall mean
$\Delta E$	:	Environmental trend
$\Delta G$	:	Genetic trend
$\Delta P$	:	Phenotypic trend

## ABSTRACT

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### GENETIC EVALUATION OF HF x GIR HALFBRED SIRES USING FERTILITY AND MILK PRODUCTION TRAITS

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A candidate for the degree

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**Research Guide** : Dr. U.Y. Bhoite

**Department** : Animal Husbandry and Dairy Science

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The performance record of 403 HF x Gir halfbred daughters of 44 sires maintained during the year 1974 to 2017 at Research Cum-Development Project on Cattle, Mahatma Phule Krishi Vidyapeeth, Rahuri were used to evaluate sires for first lactation and life time traits and to compare the effectiveness of multiple trait animal models over single trait models.

The average least squares means of first lactation for FL300DMY, FLPMY, FLL, FCI, CAFS, IFLS and CACO were  $2780.17 \pm 37.31$  kg, ,  $15.28 \pm 0.16$  kg, ,  $326.77 \pm 1.81$  days,  $408.38 \pm 3.41$  days,  $72.71 \pm 0.85$  days,  $64.22 \pm 2.10$  days  $85.19 \pm 1.90$  days Respectively. The effect of period of calving was significant ( $P < 0.01$ ) on FL300 DMY, FLPMY, FLL and IFLS and non significant on FCI, CAFS and CACO. However, the effects of season of calving and age at first calving group were found to be non significant on first lactation reproduction and production traits. The influence of sire was significant ( $p < 0.01$ ) on FL300 DMY, FLPMY, FLL and CAFS and non significant on FCI, IFLS and CACO.

The heritability estimates of most of the production and reproduction traits were found to be low. The heritability estimates under two traits models were highest ( $0.40 \pm 0.38$ ) in FL300DMY and FCI combination. The highest heritability estimate of FL300DMY among three-trait animal model was observed for FL300DMY, FCI and CACO combination ( $0.27 \pm 0.11$ ).

The genetic correlations of FLPMY ( $0.99 \pm 0.49$ ), AFC ( $0.17 \pm 0.41$ ) and FCI ( $0.19 \pm 0.44$ ) with FL300DMY were positive and significant. The genetic correlation of FLL ( $-0.38 \pm 0.51$ ), CAFS ( $-0.19 \pm 0.44$ ) and CACO ( $-0.00 \pm 0.07$ ) with FL300DMY were Negative and low. The phenotypic correlations of FLPMY ( $0.19 \pm 0.04$ ), FLL ( $0.25 \pm 0.04$ ) and AFC ( $0.05 \pm 0.04$ ) with FL300DMY were positive and significant ( $P \geq 0.05$ ).

The genetic ( $r_g$ ) and phenotypic ( $r_p$ ) correlations of milk production traits (FL300DMY, FLPMY and FLL) with reproduction (AFC, FCI, CAFS, IFLS and CACO) traits were estimated using WOMBAT. It was observed that the estimates of genetic and phenotypic correlations of FL300DMY with FLPMY, FLL, AFC, FCI, CAFS, IFLS and CACO from different multi-trait models in general, changed in magnitude and in certain combinations signs were also changed.

The genetic trends for all the first lactation traits were estimated by Smith (1962) method-II and BLUP method. The overall phenotypic trend estimates of FL300DMY, FLPMY, FLL, AFC, FCI, CAFS, IFLS and CACO were  $-23.03 \pm 2.83$ ,  $-0.03 \pm 0.01$ ,  $-0.05 \pm 0.13$ ,  $6.40 \pm 0.47$ ,  $0.60 \pm 0.24$ ,  $0.06 \pm 0.06$ ,  $0.03 \pm 0.11$  and  $0.10 \pm 0.13$  respectively. The overall genetic trends estimated by Smith-II and BLUP method for FL300DMY were  $-45.64 \pm 16.74$ ,  $-91.71 \pm 20.92$  kg for FLPMY were  $0.54 \pm 0.06$  and  $0.47 \pm 0.05$  for FLL were  $0.18 \pm 11.40$  and  $0.29 \pm 12.60$  days, for AFC be  $-2.12 \pm 14.62$ , and  $-0.13 \pm 11.80$  days for FCI  $3.33 \pm 21.36$  and  $2.12 \pm 27.58$  for CAFS  $-1.87 \pm 2.08$  and  $-1.74 \pm 1.35$  days for IFLS  $-2.68 \pm 3.2$ ,  $-2.62 \pm 3.07$  days and for CACO  $-4.49 \pm 5.69$ ,  $-4.28 \pm 5.12$  days, respectively.

The overall environment trends estimated by Smith-II and BLUP method for FL300DMY were  $-22.603 \pm 20.60$ ,  $-68.68 \pm 18.89$  kg for FLPMY were  $-0.57 \pm 0.08$  and  $-0.50 \pm 0.03$  kg for FLL were  $-0.13 \pm 09.15$  and  $-0.23 \pm 08.25$  days, for AFC be  $8.53 \pm 20.90$  and  $4.27 \pm 16.20$  days for FCI  $3.33 \pm 27.58$  and  $2.12 \pm 27.58$  for CAFS  $1.94 \pm 1.60$  and  $1.80 \pm 1.20$  days for IFLS  $2.71 \pm 3.06$  and  $2.65 \pm 3.07$  days and for CACO  $4.59 \pm 5.11$  and  $4.38 \pm 5.12$  days respectively.

The average breeding values of HF x Gir halfbred sires estimated by different single and multi-trait animal models for FL300DMY exhibited variation in estimates which also resulted into variation in percentage of sires having breeding values above or below the average breeding values of sires for a given trait and evaluation methods. The ranges of their breeding values also differed considerably among themselves. The ST-AM was found better among single trait models for FL300DMY because it took account of all existing relationships among the animals. The averages and ranges of their breeding values from different multi-trait animal models for FL300DMY also differed considerably from corresponding estimates of ST-AM. Thus, the different multi-trait animal models should be considered depending upon the traits of the breeding goal and selection criteria.

The single-trait animal model (ST-AM) of sire evaluation for FL300DMY was found superior method than other single trait sire evaluation (LSQ, SRLS and ST-SM) methods based on error variance, relative efficiency and accuracy ( $R^2$ -value). It was observed that single trait animal model (ST-AM) method gave more accurate and precise prediction of breeding values and ranking of animals than other single trait sire evaluation (LSQ, SRLS and ST-SM) methods. The difference among error variance, coefficient of determination ( $R^2$ -value) values of different multi-trait animal models were attributed to the difference in magnitude and direction of genetic and phenotypic correlations of traits included in multi-trait animal models with FL300DMY trait.

However, based on error variance, relative efficiency and coefficient of determination ( $R^2$ -value) the two-trait animal model of trait combination FL300DMY with CAFS was observed better method of sire evaluation than other two-trait animal models. The three-trait animal model of trait combinations FL300DMY, FCI and CAFS had relatively higher efficiency compared to other three-trait models based on error variance.

## 1. INTRODUCTION

India is the largest producer and consumer of milk in the world. The livestock sector globally increasingly important contributor to socio-economic development and food security which provides cheap nutritional food to vast population of India and also generate huge employment opportunities for people in rural areas all-round the year. Dairy business is an important enterprise for livelihood of farmers. Livestock population strengthen the agro-based industries, dairy products, milk plant, fertilizer, pesticides, meat, skin and wool products etc. Hence, livestock plays an important role in Indian economy.

Milk production is a highly complex biological process influenced by animals genetic potential and several other non-genetic factors *viz.*, season of calving, period of calving, age at first calving, lactation order etc. and environmental effects *viz.*, feeding, management, disease control etc.

Crossbreeding programme is quickest way to bring about the improvement in economic traits of dairy cattle. Crossing of non-descript indigenous cattle with exotic dairy breeds *viz.*, Holstein Friesian, Jersey and Brown Swiss for high productivity is the widely adopted policy in India. To generate crossbreds, local cows are crossed with superior exotic dairy breeds having more milk production, higher fat percentage and better adaptability. By crossbreeding, hybrid vigor and additive genetic potential of highly productive exotic breeds are exploited. Thus genetic improvement of livestock by crossbreeding is relatively a worldwide accepted concept for enhancing their growth, reproduction and production performance.

The aim of animal breeding is not only to produce superior individual animals but also to cause a genetic improvement in herd by selecting genetically superior sires and dams as parents for future generations (Bourdon, 1997). Quantitative genetics has a large applicability in animal husbandry. The main goal in animal breeding is to select those Bulls, which can produce offspring with improved phenotypes. In order to establish effective breeding programs it is necessary to know the genetic inheritance of a certain character. The potential for genetic improvement of a trait largely depends upon genetic variation existing in the population of interest. The genetic variability for a

particular trait in a herd or population is measured by heritability of trait under given environmental conditions.

In most breeding programmes attempt is being made to disentangle the genes and environment effects to select animals that have high genetic merit and not those that perform better simply because they are well fed and managed. Thus, the estimation of heritability and evaluation of sires could be one of the best methods to accomplish this aim. The use of an appropriate method for genetic improvement so various methods have been proposed for use in the genetic evaluation of dairy cattle (Kheirabadi *et al.*, 2013). It is expected that genetic evaluation of milk production traits can be done by using a multiple-trait model including reproduction traits. Milk production traits have a moderate heritability and a moderate genetic correlations with reproduction traits (Wall *et al.*, 2003). According to principle of BLUP (Henderson, 1975), the information of milk production traits will give a benefit to accuracy of EBV for reproduction traits (Schaeffer, 1984). Alternatively, a multiple-trait model including milk production will reduce or eliminate the bias (due to indirect selection) in genetic evaluation of reproduction traits by including records upon which selection decisions were made (Pollak *et al.*, 1984; Sorensen and Kennedy *et al.*, 1984).

The effectiveness of sire evaluation is the backbone of any breed improvement programme as the contribution of sire path is higher than the dam path for the overall genetic improvement for a trait (Robertson and Randel, 1954). In addition, very intense selection can be practised in case of males, as few males are required for breeding purpose. Hence, one of the main criteria for enhancing the genetic potential of progenies in a herd is to use proven sires to transmit superior genetic potential for higher milk production.

Milk yield is an important economic trait in livestock species. It represents a major source of income in most dairy enterprises. Economic traits are generally controlled by genetic factors but environmental influences like, year, calving season, age at first calving and parity have significant effects on milk yield. These environmental factors may suppress the animal's true genetic ability and create a bias in the selection of animals. Therefore, these environmental effects have to be taken into account to estimate the genetic factor in milk yield (Djemali and Berger, 1992). The aim of the animal

breeding is not only to produce superior individual animals but also to cause a general improvement in a herd by selecting genetically superior sires and dams as parents for future generations (Bourdon, 1997). Quantitative genetics has a large applicability in animal husbandry. The main goal in animal breeding is to select those cows, which can produce offspring with improved phenotypes. In order to establish effective breeding programs it is necessary to know the genetic inheritance of a certain character. The potential for genetic improvement of a trait largely depends upon genetic variation existing in the population of interest. The genetic variability for a particular trait in a herd or population is measured by heritability of trait under given environmental conditions (Goshu *et al.*, 2014). In practice, there are several traits which influence an animal's actual worth; and a selection strategy focusing only on improvement of a single trait may result in biased genetic progress during selection. Therefore, it is high time to consider reproduction traits also in breeding objective as the reduction in reproduction will affect the overall performance of animals and thereby the profitability of livestock farming. It may also be pointed out that direct selection for reproduction traits may not be efficient because these traits have low heritability values resulting in low accuracy of estimated breeding values and low genetic gain per unit of time. Further, the EBVs of the reproduction traits estimated using a model without combining information of milk production traits may lead to biased selection (Jamrozik *et al.*, 2005).

There are several methods of sire evaluation with a wide range of complexity starting from very simple (simple daughter average) to highly complicated (REML) method. Different methodologies like contemporary comparison, contemporary daughter average index, least squares technique (LSM) and simple regressed least squares technique (SRLS) could be used to evaluate sires for a single trait i.e. milk yield. Henderson (1974) opined that analysis of variance and covariance may give biased components of variance from selected population, whereas, restricted maximum likelihood (REML) estimate can give bias free estimation. Simultaneous attention to reproductive traits in addition to milk production is expected to bring about overall improvement in the index value of a sire. So multi trait criteria of sire evaluation using advance statistical technique like derivative free restricted maximum likelihood

(DFRML) and best linear unbiased prediction (BLUP) would be expected to enhance the accuracy of selection of the bulls.

In India, the majority of the studies have been conducted investigating the associations among the reproduction traits and production traits using single trait models and very few studies have been carried out using multi-trait model approach. Moreover, the animal breeder is also interested in improvement of lifetime production and reproduction of dairy cows for overall profitability. Further, decline in reproduction performance is likely to have a negative effect on herd life or stability of the animals, as lifetime milk production will lower.

Therefore, the present investigation entitled “Genetic evaluation of sires of HF x Gir halfbred using fertility and milk production traits” is proposed, with the following objectives.

1. To study fertility and milk production traits of HF x Gir halfbred.
2. To study effect of genetic and non-genetic factors on traits under study.
3. To determine association between fertility and milk production traits.
4. To evaluate sires on the basis of fertility and milk production traits using single and multi-trait models.

## 2. REVIEW OF LITERATURE

Crossbreeding of Indian cattle with exotic breeds like Holstein Friesian, Jersey and Brown Swiss has made significant progress in the rural economy of India. It has also played a major role in the improvement of milk production as well as reproductive performance of zebu cattle. The ultimate goal in animal breeding is to rank the animals according to their genetic merit for the desired characters and to use them efficiently in breeding programme. The aim of cattle breeding in India was to evolve a new strain of dairy cattle, which would have higher growth rate with better reproductive and productive performance. The several research reports available on first lactation, lifetime production traits and sire evaluation particularly on halfbreds, triple crosses and interse are briefly reviewed as per the objectives of the present study under the following headings.

- 2.1 Average Performance and Factors Affecting First Lactation Performance Traits
- 2.2 Estimates of Phenotypic and Genetic Correlations Among Milk Production and Reproduction Traits
- 2.3 Single Trait and Multiple Trait Models
- 2.4 Genetic and Phenotypic Trends
- 2.5 Sire Evaluation
- 2.6 Comparison of Sire Evaluation Methods

### **2.1 Average Performance and Factors Affecting First Lactation Performance Traits**

The literature available on average performance and factors affecting age at first calving (AFC), first lactation milk yield (FLTMY), first lactation 300/305-days or less lactation milk yield (FL 300 DMY), first service period or days open (CAFS), first lactation length (FLL), first dry period (FDP), interval between first and last service (IFLS) and first calving interval (FCI) have been reviewed in this chapter.

#### **2.1.1 Age at first calving**

Age at first calving (AFC) of dairy cattle is an important trait which decides the productive herd life and lifetime milk production of an animal. Optimum age at first calving minimizes the cost of raising the heifers, shortens the generation interval,

facilitates the breeders to get more number of offspring records to evaluate the breeding bulls at an early age thereby increasing the intensity of selection and genetic gain per unit of time.

Perusal of the various reports revealed that age at first calving ranged between  $949.32 \pm 5.47$  (Rathi, 2015) to  $1427.74 \pm 5.44$  (Jadhav, 1990). The published reports of estimated average AFC in various exotic and zebu crosses along with effect of sire, season and period of birth are summarized in Table 2.1.

**Table 2.1 Least squares means and factors affecting age at first calving in different crossbred cattle**

Breed group	Mean $\pm$ SE	Non genetic factors		Sire	Reference
		Period of birth	Season of birth		
HF x SW	$1427.74 \pm 5.44$	S	S	S	Jadhav (1990)
HF x SW	$1100 \pm 31.30$	NS	NS	-	Rana (1991)
KF	$977.97 \pm 9.86$	S	NS	-	Arora and Sharma (1983)
HF x SW	$965.26 \pm 14.54$	S	S	S	Jadhav and Khan (1996)
KF	$1009.40 \pm 13.53$	S	NS	S	Saha (2001)
HF x Deoni	$1308.75 \pm 176.44$	-	-	-	Thombre <i>et al.</i> (2002)
5/8 HF x 3/8 SW	$1070.68 \pm 14.06$	S	S	S	Akhtar <i>et al.</i> (2003)
Frieswal	$972.37 \pm 3.60$	S	NS	-	Mukharjee (2005)
Crossbred Sahiwal	$1321.82 \pm 10.83$	NS	S	-	Dubey and Singh (2005)
Frieswal	$29.72 \pm 0.45$ (months)	S	NS	S	Singh <i>et al.</i> (2014)
Frieswal	$949.32 \pm 5.47$	S	S	-	Rathi (2015)
Phule Triveni	$985.41 \pm 1.93$	S	NS	S	Ambhore <i>et al.</i> (2017)

S = Significant

NS = Non significant

#### a. Effect of period of birth

The significant influence of period of birth on age at first calving was reported by Bhoite (1996) in FG, JG, FJG, JFG and BFG two and three breed crosses, Singh (1995), Panja (1997), Sivakumar (1998), Sahana and Gurnani (2000), Saha (2001) and Divya (2012) in Karan Fries cattle Whereas, the effect of period of birth on age at first calving was observed non-significant by Sinha (1999) and Nehra (2011) in Karan Fries cattle.

Review of literature revealed a wide variation in different breed groups for AFC across different periods, seasons, age groups and sires at different locations because

of genetic variability across the herds in genetic constitution and diverse environmental factors operating at different farms.

**b. Effect of season of birth**

The difference due to season of birth in age at first calving was reported to be significant in different crossbred cows by Akhtar *et al.* (2003), PDC-AR (2003-04) and Dubey and Singh(2005).Whereas, the non-significant effect of season of birth on age at first calving was reported by Kale (1984) and Kulkarni (1985) in Gir crossbreds, Bhoite (1996) in JG, FG, FJG, JFG and BFG, Mukharjee (2005) in Frieswal and Divya (2012) in Karan Fries cattle.

**c. Effect of sire**

The effect of sire on age at first calving was found to be significant as reported by Jadhav (1990), Panja (1997) and Saha (2001) in Karan Fries cattle at NDRI farm. In other Holstein crosses, the effect of sire on age at first calving was reported to be significant by Akhtar *et al.* (2003), Singh *et al.* (2014) and Ambhore *et al.* (2017) in Frieswal and Phule Triveni cattle respectively.

**d. Heritability estimates**

The heritability estimate of AFC ranged from  $0.17 \pm 0.09$  (Saha, 2001) to  $0.43 \pm 0.13$  (Nehra, 2011) in Karan Fries cattle and  $0.10 \pm 0.02$  (PDC-AR, 2003-04) to  $0.23 \pm 0.04$  (Mukharjee, 2005) in Frieswal cattle.

**2.1.2 First lactation 300 days milk yield**

The FL300DMY is the most important economic trait of the dairy animals. Table 2.3 reveals a wide variation in different breed groups for FL300DMY across different periods, seasons, age groups and sires at different locations because of variability in genetic constitution and environmental factors operating at different farms. The FL300DMY varies from  $2470 \pm 20$  kg (Saha, 2001) to  $3292.61 \pm 53.6$  (Rathi, 2015).

**Table 2.2 Least squares means and factors affecting first lactation 300 days milk yield in different crossbred cattle**

Breed group	Mean $\pm$ SE	Effect			Sire	Reference
		Period of calving	Season of calving	AFC		
KF	2470 $\pm$ 20	S	S	S	-	Saha (2001)
KF	3173 $\pm$ 82	NS	S	-	-	Singh and Gurnani (2004)
Frieswal	2805 $\pm$ 18	S	S	S	S	Mukharjee (2005)

Table 2.2 contd....

Breed group	Mean $\pm$ SE	Effect			Sire	Reference
		Period of calving	Season of calving	AFC		
KF	3068 $\pm$ 22	S	S	-	-	Kokate (2009)
KF	3076 $\pm$ 22	-	NS	-	-	Rashia (2010)
KF	3243 $\pm$ 47	NS	NS	S	S	Nehra (2011)
Phule Triveni	2623 $\pm$ 20	S	NS	NS	-	Shelke (2012)
Phule Triveni	2897 $\pm$ 26	S	S	NS	NS	Pol <i>et al.</i> (2013)
Frieswal	3292.61 $\pm$ 53.6	S	NS	S	-	Rathi (2015)
Phule Triveni	2646.77 $\pm$ 39.30	S	NS	S	S	Ambhore <i>et al.</i> (2017)

S = Significant

NS = Non significant

Table 2.3 Heritability estimates of first lactation production traits

Breed/trait	FLMY	F300 MY	FLL	Reference
KF	0.31 $\pm$ 0.088	0.46 $\pm$ 0.10	0.13 $\pm$ 0.06	Sahana (1996)
KF	0.26 $\pm$ 0.05	0.21 $\pm$ 0.16	0.09 $\pm$ 0.01	Panja (1997)
KF	0.32 $\pm$ 0.08	0.41 $\pm$ 0.13	0.13 $\pm$ 0.07	Sahana and Gurnani (2000)
Frieswal	0.16 $\pm$ 0.04	0.20 $\pm$ 0.04	0.11 $\pm$ 0.03	Mukharjee (2005)
Frieswal	0.35 $\pm$ 0.11	-	0.04 $\pm$ 0.06	Kumar (2007)
KF	0.41 $\pm$ 0.13	0.48 $\pm$ 0.14	0.19 $\pm$ 0.11	Nehra <i>et al.</i> (2012)
KF	0.24 $\pm$ 0.07	0.39 $\pm$ 0.09	0.13 $\pm$ 0.06	Dash (2014)
Phule Triveni	0.35 $\pm$ 0.16	0.32 $\pm$ 0.15	0.07 $\pm$ 0.11	Ambhore <i>et al.</i> (2017)

Table 2.4 Heritability estimates of different first lactation reproduction traits

Breed/trait	AFC	FSP	FCI	Reference
KF	0.36 $\pm$ 0.19	0.046 $\pm$ 0.14	0.017 $\pm$ 0.13	Panja (1997)
KF	0.17 $\pm$ 0.99	0.16 $\pm$ 0.75	0.35 $\pm$ 0.10	Saha (2001)
Frieswal	0.23 $\pm$ 0.04	0.06 $\pm$ 0.03	0.06 $\pm$ 0.03	Mukharjee (2005)
KF	0.43 $\pm$ 0.13	-	0.12	Nehra (2011)
KF	0.36 $\pm$ 0.08	0.18 $\pm$ 0.09	0.12 $\pm$ 0.07	Dash (2014)
Phule Triveni	0.48 $\pm$ 0.19	0.25 $\pm$ 0.17	0.28 $\pm$ 0.17	Ambhore <i>et al.</i> (2017)
KF	0.22 $\pm$ 0.07	0.038 $\pm$ 0.06	-	Sahana (1996)

#### a. Effect of period of calving

The significant effect of period of calving on first lactation 300/305 days milk yield in crossbred cattle was observed by Chavan (1995) in FG and *interse* of FG half-bred, Mhasade (2010) in FG, Chavan (2010) in HF x Girhalfbred, Singh (1995), Sivakumar (1998), Sahana and Gurnani (2000), Saha (2001), Singh *et al.* (2005) and Kokate (2009) in Karan Fries cattle.

Whereas, the non-significant effect of period of calving on first lactation 300 days milk yield was noticed by Panja (1997); Singh and Gurnani (2004); Nehra (2011) and Divya (2012) in Karan Fries cattle.

**b. Effect of season of calving**

The significant influence of season of calving on first lactation 300 days milk yield was reported by Saha (2001), Singh and Gurnani (2004), Mishra and Joshi (2004), Singh *et al.* (2008), Singh *et al.* (2005), in Karan Fries cattle and Ambhore *et al.* (2017) in Phule Triveni cows.

The non-significant effect of season of calving on first lactation 300 days milk yield was reported by different research workers in different breeds as Nehra (2011) in Karan fries and their *interse*, Patond (2009) in Jersey, Rashia (2010) and Nehra (2011) in Karan Fries, Bhadauria and Katpatal (2003) in HF x Sahiwal, Mhasade (2010) in FG, Talape (2010) in Jersey, Garudkar (2011) and Shelke (2012) in Phule Triveni synthetic cows.

**c. Effect of age at first calving groups**

Significant effect of age at first calving group on first lactation 300 days milk yield was observed by PDC-AR (2003-04), Mukharjee (2005) in Karan Fries cattle and Ambhore *et al.* (2017) in Phule Triveni cows.

The non-significant effect of age at first calving group on first lactation 300 days milk yield was noticed in different crossbred cattle by Mandakmale *et al.* (2002), Garudkar (2011) and Shelke (2012) in Phule Triveni synthetic cows while in Karan Fries cattle by Panja (1995) and Divya (2012).

**d. Effect of sire**

The variation due to sire in FL305DMY was found to be significant by Singh (1995); Nehra (2011) and Divya (2012) in Karan Fries cattle. In other Holstein crosses, the effect of sire on FL305DMY was reported to be significant by Mukharjee (2005) in Frieswal and Ambhore *et al.* (2017) in Phule Triveni cattle whereas, Rao *et al.* (2000) found its effect to be non-significant.

## **Heritability estimates**

The heritability estimate for FL 300 DMY ranged from  $0.20 \pm 0.04$  (Mukharjee, 2005) to  $0.48 \pm 0.14$  (Nehra *et al.*, 2012). The heritability estimates for FL 300 DMY in different genetic groups have been presented in Table 2.4.

### **2.1.3 Interval between first calving and conception (CACO)**

The service period (SP) is an indicator of breeding efficiency and reproductive management practices followed in the herd. For any dairy cattle breeding programme, optimum service period is always desirable. Very short service period is not conducive for proper involution of uterus for a cow after calving, while long SP will result in prolonged inter calving period, increased generation interval and increased management cost.

The average CAFS in different crossbreds ranged between  $124 \pm 4$  days (Panja, 1997) and  $164.51 \pm 2.51$  days (Mukharjee, 2005).

The reports in the literature have been summarized in Table 2.6.

#### **a. Effect of period of calving**

The significant effect of period of calving on CACO was reported by Panja (1997) in Karan Fries, Mhasade (2010) in FG crossbreds, Rathi (2015) in Frieswal cows.

Whereas, non-significant influence of period of calving on CACO was observed by Talape (2010) in Jersey crossbreds Mhasade (2010) in FG crossbred and Ambhore *et al.* (2017) in Phule Triveni cattle.

#### **b. Effect of season of calving**

Significant effect of season of calving on CACO was found by Mukharjee (2005) in Frieswal, Singh (2013) in KF and Mhasade (2010) in FG crossbreds.

Whereas, non-significant difference due to season of calving in CACO was reported by Bhoite (1996) and Kamble (2003) in Gir crossbreds, Jadhav (2009) in HF x Girhalfbreds, Divya (2012) in KF and Ambhore *et al.* (2017) in Phule Triveni cattle.

#### **c. Effect of age at first calving groups**

The significant effect of age at first calving group on CACO was noticed by Mukharjee (2005) and Rathi (2015) in Frieswal cattle. Whereas, non significant effect

of age at first calving groups on CACO was reported by Panja (1997), Saha (2001) and Singh (2013) in KF cattle.

#### d. Effect of sire

The effect of sire on CACO was found to be non significant by Singh (1995), Panja (1997), Saha (2001), Singh (2013) in KF cattle and Ambhore *et al.* (2017) in Phule Triveni cattle.

#### Heritability estimates

The heritability estimates of CACO varied from  $0.046 \pm 0.14$  (Panja, 1997) in Karan Fries to  $0.25 \pm 0.17$  (Ambhore *et al.*, 2017) in Phule Triveni cattle.

#### 2.1.4 First lactation length (FLL)

Lactation length of different breeds of cattle reported by various researchers has been summarized in Table 2.7. The first lactation length in different crossbred cattle ranges between  $307.49 \pm 1.51$  (Rathi, 2015) to  $359.92 \pm 4.33$  (Nehra, 2011).

**Table 2.5 Least squares means and factors affecting first lactation length in different crossbred cattle**

Breed group	Mean $\pm$ SE	Effect			Sire	Reference
		Period	Season	AFC		
FJG	326 $\pm$ 3	S	S	-	-	Bhoite (1996)
KF	344 $\pm$ 6	S	S	S	-	Sahana and Gurnani (2000)
KF	315.25 $\pm$ 10.10	NS	NS	NS	-	Saha (2001)
5/8 HF x 3/8 S	321.03 $\pm$ 2.15	NS	NS	-	-	Akhtar <i>et al.</i> (2003)
Gir crossbred	346 $\pm$ 2	S	NS	-	NS	Deokar (2003)
Frieswal	343.57 $\pm$ 2.59	S	S	NS	-	PDC AR (2003-04)
Frieswal	324.12 $\pm$ 1.50	S	S	S	-	Mukharjee (2005)
Phule Triveni	315 $\pm$ 7	S	S	-	NS	Zol <i>et al.</i> (2009)
KF	315.25 $\pm$ 10.10	NS	NS	-	-	Saha <i>et al.</i> (2010)
KF	359.92 $\pm$ 4.33	S	NS	NS	-	Nehra (2011)
Frieswal	307.49 $\pm$ 1.51	S	NS	S	-	Rathi (2015)
Phule Triveni	331.03 $\pm$ 3.01	S	NS	S	NS	Ambhore <i>et al.</i> (2017)

S = Significant

NS = Non significant

**a. Effect of period of calving**

The significant effect of period of calving on first lactation length was observed by Mukharjee (2005) and Rathi (2015) in Frieswal cows, Zol *et al.* (2009) in Phule Triveni crossbred cows, Nehra (2011) in Karan Swiss, Kamble (2003) in Gir crossbred and Mhasade (2010) in FG crossbred.

The non-significant influence of period of calving on first lactation length of different crossbred cows was reported by Saha *et al.* (2010) in Karan Fries, Patond (2009) in Jersey and Chavan (2010) in HF x Gir halfbred.

**b. Effect of season of calving**

Bhoite (1996) studied the performance of halfbreds of Gir crosses and reported significant effect of season of calving on first lactation length.

The non-significant effect of season of calving on first lactation length was reported by Akhtar *et al.* (2003) in 5/8 HF x 3/8 S, Talape (2010) in Jersey crossbred cows, Mhasade (2010) in FG crossbred cows and Rathi (2015) in Frieswal cows.

**c. Effect of age at first calving groups**

The significant effect of age at first calving group on first lactation length was reported by Jadhav (1991) in HF x SW crossbred. Mandakmale *et al.* (2002) in Phule Triveni cows, Sivakumar (1998) and Sahana and Gurnani (2000) in Karan Fries cattle.

The non-significant variation due to age at first calving groups in first lactation length was reported by Nikam (2010) in Phule Triveni cows, Gatchearle *et al.* (2009) in HF x Deoni crossbred cows, Mhasade (2010) in FG crossbred cows and Nehra (2011) in Karan Fries cattle.

**d. Effect of sire**

Hedge *et al.* (2009) revealed that effect of sire on first lactation length was significant ( $P < 0.01$ ) in Sahiwal x Jersey crossbred cows. Whereas, Ambhore *et al.* (2017) reported that the influence of sire was non-significant on lactation length in Phule Triveni cattle.

**Heritability estimates**

The heritability estimates of first lactation length in triple crossbred cattle was  $0.07 \pm 0.11$  (Ambhore *et al.*, 2017) in Phule Triveni cattle whereas, in Karan Fries crossbred it was  $0.19 \pm 0.11$  (Nehra *et al.*, 2012).

### 2.1.5 Peak milk yield

Peak milk yield observed by various authors in different breeds and crossbreds are presented in table.

**Table 2.6 Average peak milk yield in different breeds of cattle**

<b>Breed</b>	<b>PY ( kg)</b>	<b>Author</b>
Crossbred with 5/8 HF inheritance	12.04 ± 0.40	Bhutia <i>et al.</i> (1988)
HF x Sahiwal	15.70 ± 1.03	Garcha <i>et al.</i> (1989)
FG	20.27 ± 0.18	Patil (1989)
Jersey	11.99 ± 0.25	Bhadouria <i>et al.</i> (1990)
HF × Deoni	10.48 ± 0.22	Krishna <i>et al.</i> (1991)
BFG	17.45 ± 1.08	Jebale (1994)
IBFG	13.68 ± 0.92	Jebale (1994)
Tharparkar	10.60 ± 0.40	Tomar and Pandey (1995)
Gir	10.04 ± 0.10	Nanavati and Qureshi (1996)
FJG	15.06 ± 0.15	Gawari (1999)
BFG	15.15 ± 0.22	Gawari (1999)
JFG	14.60 ± 0.30	Gawari (1999)
FH	15.23 ± 0.21	Singh <i>et al.</i> (2000)
JH	13.27 ± 0.30	Singh <i>et al.</i> (2000)
FBH	13.41 ± 0.33	Singh <i>et al.</i> (2000)
BFH	14.46 ± 0.39	Singh <i>et al.</i> (2000)
FJH	14.50 ± 0.37	Singh <i>et al.</i> (2000)
JFH	14.78 ± 0.39	Singh <i>et al.</i> (2000)
Jersey	13.10 ± 0.37	Patond (2009)
HF x Sahiwal	13.30 ± 0.35	Shubha Lakshmi <i>et al.</i> (2009)
Phule Triveni	12.94 ± 0.31	Garudkar (2011)
Phule Triveni	13.92 ± 0.31	Shelke (2012)
Gir Triple cross cow	15.17 ± 0.12	Patond (2013)

**a. Effect of period of calving**

Gill *et al.* (1970) reported that the period of calving had significant ( $P < 0.01$ ) effect on peak milk yield in Haryana cows. The contributions of periods to the variability in peak milk yield were 10.83 and 6.69 per cent for first lactation and the production up to 5 lactations.

Garcha *et al.* (1989) observed significant ( $P < 0.01$ ) effect of period of calving on peak milk yield in HF  $\times$  Sahiwal cows. Maximum peak milk yield ( $18.4 \pm 1.17$  kg) was recorded during year 1980 and minimum ( $14.2 \pm 0.87$  kg) in 1983.

Singh *et al.* (1989) noticed that period of calving significantly ( $P < 0.01$ ) influenced peak milk yield in FH, BH, JH crossbred cows.

Patil (1989) in HF  $\times$  Gir halfbred and Jebale (1994) in BFG cows showed that period of calving had non-significant effect on peak milk yield.

Gawari (1999) observed that period of calving had significant ( $P < 0.01$ ) effect on peak milk yield in FJG, BFG and JFG triple cross cows. The peak milk yield of cows calved during  $P_2$  ( $17.22 \pm 0.18$ ) was significantly higher than  $P_1$ ,  $P_3$ ,  $P_4$  and  $P_5$ . The peak milk yield exhibited decreasing trend from  $P_2$  to  $P_5$ , which were distinctly different from each other.

Singh *et al.* (2000) worked on 1221 records of 407 crossbred cows of seven genetic groups with half (one exotic breed) and three-fourth (two exotic breeds) inheritance involving HF, BS and J crosses with Haryana cows, maintained at CCS Haryana Agricultural University Farm, Hissar from 1970 to 1987 and reported that period of calving had significant ( $P < 0.01$ ) effect on the peak milk yield.

Kulkarni (2001) showed that period of calving had significant ( $P < 0.01$ ) influence on the peak milk yield in Red Sindhi cows. The peak milk yield of cows calved during  $P_1$  ( $9.20 \pm 0.25$ ) was significantly higher than cows calved in other periods. The peak yield exhibited decreasing trend from  $P_1$  to  $P_5$ .

Patond (2009) worked on data of 251 Jersey cows maintained at Bull Mother Farm, Tathawade, Pune over a period of 10 years (1996-2005) and noted that period of calving had significant ( $P < 0.01$ ) variation in peak milk yield. The peak milk yield of cows calved during  $P_2$  ( $14.04 \pm 0.32$  kg) was significantly higher than cows calved in rest of the periods.

Garudkar (2011) noted that period of calving had significant ( $P < 0.01$ ) influence on peak milk yield in Phule Triveni synthetic cows. The mean peak milk yield of cows calved during  $P_3$  was significantly higher ( $14.79 \pm 0.40$  kg) than cows calved in other periods which were at par with each other.

Shelke (2012) reported non-significant variation due to period of calving in peak milk yield of Phule Triveni synthetic cows.

Patond (2013) observed that effect of period of calving on peak milk yield in Gir triple cross cows was significant ( $P < 0.01$ ). The peak milk yield of cows calved during  $P_1$  ( $16.16 \pm 0.21$  kg) and  $P_2$  ( $15.85 \pm 0.15$  kg) was significantly higher than cows calved in  $P_3$  ( $14.47 \pm 0.16$  kg),  $P_4$  ( $14.41 \pm 0.21$  kg) and  $P_5$  ( $13.92 \pm 0.34$  kg) which were at par with each other.

#### **b. Effect of season of calving**

Singh *et al.* (1989) observed that season of calving had significant ( $P < 0.01$ ) effect on the peak milk yield in all lactations in FH, BH and JH halfbred. The peak milk yield was significantly lower during rainy season when the climate is very hot and humid at Izatnagar. Autumn calvers had also equally low peak milk yield as compared to those calving in other seasons.

Dhangar and Patel (1993) reported that season of calving had non-significant effect on peak milk yield in HF  $\times$  Haryana halfbred cows.

Tomar and Pandey (1995) worked on 463 normal lactation records comprising 164 Tharparkar, 156 HF  $\times$  Tharparkar, 48 BS  $\times$  Tharparkar and 95 Jersey  $\times$  Tharparkar cows, maintained at NDRI, Karnal (Haryana) and revealed that season of calving had significant ( $P < 0.01$ ) effect on peak milk yield.

Gawari (1999) reported that season of calving had significant ( $P < 0.01$ ) influence on peak milk yield in FJG, BFG and JFG triple crossbred cows. The peak milk yield was significantly higher in cows calved in winter season ( $15.27 \pm 0.16$  kg) than cows calved in rainy season ( $14.21 \pm 0.16$  kg).

Singh *et al.* (2000) noted that season of calving had non-significant effect on peak milk yield in Haryana crosses with HF, BS and Jersey.

Kulkarni (2001) observed that season of calving had significant ( $P < 0.01$ ) effect on peak milk yield in Red Sindhi cows. The cows calved during winter season had

significantly higher peak milk yield ( $8.89 \pm 0.28$  kg) than those calved during rainy season ( $8.15 \pm 0.58$  kg).

Kumar and Singh (2004) observed that season of calving had significant ( $P < 0.01$ ) effect on peak milk yield in Karan Fries cows. The winter calvers had significantly higher peak milk yield ( $20.27 \pm 0.38$  kg) than autumn calvers ( $18.28 \pm 0.45$  kg) and rainy season calvers ( $15.32 \pm 0.45$  kg).

Patond (2009) in Jersey cows, Garudkar (2011) and Shelke (2012) in Phule Triveni synthetic cows and Patond (2013) in Gir triple cross noticed that season of calving had non-significant effect on the peak milk yield.

### c. Effect of age at first calving

Gill *et al.* (1970) worked on 521 first lactation records and 1008 repeated lactation records up to 5<sup>th</sup> lactation in Haryana cows. The data for this investigation were obtained from an experimental Haryana herd, maintained at Govt. Livestock Farm, Hissar, from 1945 to 1965. They observed that age at first calving had non-significant effect on peak milk yield.

Gupta and Johar (1981) reported that age at first calving had significant ( $P < 0.01$ ) influence on the peak milk yield in Tharparkar and Friesian crosses.

Gawari (1999) observed that age at first calving had significant ( $P < 0.01$ ) effect on peak milk yield in FJG, BFG and JFG triple cross cows. The cows calved in early age ( $A_1$  group) had significantly lower PMY ( $14.52 \pm 0.16$  kg) than those calved in  $A_3$  group ( $15.2 \pm 0.18$  kg). The PMY increased as the AFC of cows increased.

Kulkarni (2001) noted that age at first calving had significant ( $P < 0.01$ ) influence on the peak milk yield in Red Sindhi cows. The cows calved at 56 to 60 months had highest peak milk yield ( $9.82 \pm 0.57$  kg) and those calved at 61 months and above age had lowest peak milk yield ( $7.79 \pm 1.30$  kg). The peak milk yield of 56 to 60 month AFC group was significantly higher than all other groups. The peak milk yield of cows exhibited increasing trend from  $A_3$  to  $A_5$  group.

Patond (2009) in Jersey cows, Garudkar (2011) and Shelke (2012) in Phule Triveni synthetic cows, showed that age at first calving had non-significant effect on peak milk yield.

Patond (2013) recorded that in Gir triple cross cows the influence of age at first calving on peak milk yield was significant ( $P < 0.05$ ). The cows of  $A_3$  group ( $15.54 \pm 0.19$  kg) had significantly higher peak milk yield than cows of  $A_2$  group ( $14.92 \pm 0.19$  kg). The difference in peak milk yield between cows of  $A_1$  and  $A_3$  group was at par with each other.

#### d. Effect of sire

Patond (2013) noticed in Gir triple crossbred cows that the effect of sire on peak milk yield was significant ( $P < 0.01$ ). The highest mean of peak milk yield was observed in cows of sire  $B_3$  ( $17.62 \pm 0.46$  kg) and lowest in cows of sire  $B_{18}$  ( $12.94 \pm 0.58$  kg).

### 2.1.6 Interval between first and last service (IFLS)

#### a. Effect of period of calving

The significant effect of period of calving on interval between first and last service was observed by Akhtar *et al.* (2003) in 5/8 HF x 3/8 SW and Mukharjee (2005) in Frieswal.

**Table 2.7 Least squares means and factors affecting Interval between first and last service (days) in different crossbred cattle**

Breed group	Mean $\pm$ SE	Non genetic factors			Sire	Reference
		Period	Season	AFC		
KF	$64.47 \pm 1.46$	NS	NS	NS	NS	Panja (1997)
KF	$81.72 \pm 5.96$	NS	NS	NS	S	Saha (2001)
5/8 HF x 3/8 SW	$65.31 \pm 2.69$	S	S	-	S	Akhtar <i>et al.</i> (2003)
KF	$75.00 \pm 6.00$	NS	NS	-	-	Singh and Gurnani (2004)
Frieswal	$115.64 \pm 1.86$	S	S	S	NS	Mukharjee (2005)
KF	$80.72 \pm 5.96$	NS	S	-	-	Saha <i>et al.</i> (2010)
Frieswal	$127.17 \pm 5.66$	S	S	NS	-	Rathi (2015)

S = Significant

NS = Non significant

Whereas, the non-significant effect of period of calving on Interval between first and last service was reported by Singh and Gurnani (2004), Saha *et al.* (2010) in Karan Fries cows and Kamble (2003) in FG, FJG, JFG and BFG triple crosses of Gir cattle.

**b. Effect of season of calving**

The significant effect of season of calving on interval between first and last service was observed by Akhtar *et al.* (2003) in 5/8 HF x 3/8 SW, Saha *et al.* (2010) in Karan Fries and Rathi (2015) in Frieswal cattle. Whereas, the non-significant effect of season of calving on first lactation dry period was reported by Singh and Gurnani (2004) in Karan Fries .

**c. Effect of age at first calving**

The significant effect of age at first calving group on interval between first and last service was observed by Mukharjee (2005) in Frieswal cows. Whereas, the non significant of age at first calving group was reported by Panja (1997), Saha (2001) in KF cattle.

**d. Effect of sire**

Saha (2001) and Akhtar *et al.* (2003) revealed that difference due to sire in first and last service was significant ( $P < 0.01$ ) in Karan Fries and 5/8 HF x 3/8 SW cattle. Whereas, Panja (1997) in Karan Fries and Mukharjee (2005) in Frieswal reported that the influence of sire was non-significant.

**Heritability estimates**

Deshmukh *et al.* (2003) reported 0.20 heritability for interval between first and last service in Holstein Friesian x Gir crossbreds. Komatwar *et al.* (2009) noticed the heritability in HF x Sahiwal crossbreds as  $0.12 \pm 0.006$  and Mukharjee (2005) estimated the heritability for interval between first and last service was  $0.06 \pm 0.03$  in Frieswal cows. This low heritability estimates suggested that this trait was largely influenced by non-genetic factors and further improvement in trait can be brought by improving management practices.

**2.1.7 First calving interval**

Too long calving interval reduces genetic progress, whereas too short calving interval leads to decrease in milk yield both in current and in successive lactations. Thus, calving interval is an important economic trait to the dairyman and particularly for improving the reproductive performances of the animal. For efficient breeding, cow should calve every year. For the rapid multiplication of the outstanding genetic material through various breeding plans, reproduction in dairy cows with regular

shorter calving interval is a key feature. Animals having shorter calving intervals are known for better economic gains, because of greater lifetime milk yield as well as gain in the number of offspring are always welcomed.

The average first calving interval in crossbred cattle as reported in literature ranged from  $386.62 \pm 2.59$  days in HF x Sahiwal (Akhtar *et al.*, 2003) to  $435.31 \pm 2.69$  days in Frieswal cattle (Mukharjee, 2005) and the values are presented in Table 2.8.

**Table 2.8 Least squares means and factors affecting first calving interval (days) in different crossbred cattle**

Breed group	Mean $\pm$ SE	Non genetic factors			Sire	Reference
		Period	Season	AFC		
KF	$405 \pm 4$	NS	S	NS	NS	Panja (1997)
FJG	$413 \pm 6.27$	-	-	-	-	Bhoite <i>et al.</i> (1999)
KF	$423 \pm 13$	NS	S	NS	NS	Saha (2001)
5/8 HF x 3/8 SW	$386 \pm 7$	NS	S	-	NS	Akhtar <i>et al.</i> (2003)
5/8 HF x 3/8 SW	$393 \pm 3$	NS	S	-	NS	Akhtar <i>et al.</i> (2003)
Frieswal	$421 \pm 10$	S	S	-	NS	Mukharjee (2005)
Phule Triveni	$438 \pm 6.05$	-	-	-	-	Deokar <i>et al.</i> (2008)
KF	$328 \pm 5$	S	NS	NS	NS	Nehra (2011)
Frieswal	$432.92 \pm 3.92$	S	NS	S	-	Rathi (2015)
Phule Triveni	$430.32 \pm 4.01$	S	NS	NS	NS	Ambhore <i>et al.</i> (2017)

**a. Effect of period of calving**

The significant ( $P < 0.01$ ) variation due to period of calving in first lactation calving interval was observed by Singh (1991) in Karan Fries, Zol *et al.* (2009) in Phule Triveni cattle, Mukharjee (2005) and Rathi (2015) in Frieswal cows. While, the non-significant effect of period of calving on first lactation calving interval was reported by Bhoite (1999) in two and three breed crosses of HF, Jersey, Brown Swiss with Gir cows, Akhtar *et al.* (2003) in 5/8 HF x 3/8 SW and Mhasade (2010) in FG crossbred.

**b. Effect of season of calving**

The significant variation due to of season of calving in first calving interval was reported by Singh (1991), Panja (1997), in KF, Akhtar *et al.* (2003) in 5/8 HF x 3/8 SW crossbred.

Whereas, the non-significant effect of season of calving on first calving interval was noticed by Talape (2010) in Jersey crossbreds Mhasade (2010) in FG crossbreds and Ambhore *et al.* (2017) in Phule Triveni cows.

**c. Effect of age at first calving group**

The significant effect of age at first calving group on first calving interval was reported by Rathi (2015) in Frieswal cattle. While non significant effect of age at first calving group on first calving interval was noticed by Saha (2001) and Nehara (2011) in KF cattle and Ambhore *et al.* (2017) in Phule Triveni cattle.

**d. Effect of sire**

The non significant variation due to sire in first calving interval was reported by Akhtar *et al.* (2003) in 5/8 HF x 3/8 SW, Mukharjee (2005) in Frieswal and Nehra (2011) in KF cattle.

**Heritability estimates**

The heritability estimates of FCI varied from 0.01 to 0.35 inKaran Fries cattle. Except for few studies, in majority of the cases a very low heritability was observed. This indicates that direct selection for fertility traits is inefficient as it may lead to lower accuracy of estimated breeding values. These traits can be improved to a large extent by proper management.

**2.2 Estimates of Genetic and Phenotypic Correlations Among Milk Production and Reproduction Traits**

**2.2.1 Genetic correlations among first lactation production and reproduction traits**

Genetic correlation gives an idea about nature and magnitude of the relationship between two traits and determines the genetic improvement in other traits when selection is based on any of the two traits. The genetic correlations among milk production and various reproduction traits as reported by various research workers are presented in Table 2.9.

**Table 2.9 Genetic and phenotypic correlations among various first lactation traits**

Breed	Traits	AFC	FLPMY	FLL	CAFS	IFLS	FCI	Reference
Frieswal	AFC		0.24 ± 0.15	0.17 ± 0.16	0.26 ± 0.20	0.34 ± 0.21	0.35 ± 0.17	Mukharjee (2005)
	FLPMY	0.11 ± 0.16		0.35 ± 0.16	0.30 ± 0.23	0.18 ± 0.25	0.28 ± 0.24	
	FLL	0.05 ± 0.016	0.56 ± 0.007		0.79 ± 0.14	0.12 ± 0.33	0.73 ± 0.17	
	CAFS	0.001 ± 0.016	0.39 ± 0.01	0.74 ± 0.002		0.72 ± 0.19	NE	
	IFLS	0.006 ± 0.016	0.11 ± 0.02	0.20 ± 0.02	0.73 ± 0.002		0.82 ± 0.14	
	FCI	0.022 ± 0.019	0.38 ± 0.014	0.71 ± 0.01	0.93 ± 0.002	0.80 ± 0.001		
Sahiwal	AFC		0.96 ± 0.49	0.75 ± 0.25	0.60 ± 0.27	0.65 ± 0.30	0.93 ± 0.28	Chander <i>et al.</i> (2008)
	FLPMY	0.15 ± 0.00		0.93 ± 0.46	0.35 ± 0.28	-0.84 ± 0.54	0.29 ± 0.32	
	FLL	0.13 ± 0.04	0.66 ± 0.02		0.63 ± 0.23	-0.08 ± 0.36	0.64 ± 0.19	
	CAFS	0.12 ± 0.05	0.17 ± 0.40	0.38 ± 0.03		0.91 ± 0.07	0.98 ± 0.02	
	IFLS	0.06 ± 0.00	-0.11 ± 0.00	-0.01 ± 0.00	0.84 ± 0.01		0.84 ± 0.15	
	FCI	0.14 ± 0.04	0.17 ± 0.05	0.39 ± 0.03	0.86 ± 0.01	0.81 ± 0.02		
Frieswal	AFC		0.009 ± 0.256	-0.372 ± 0.594				Chander <i>et al.</i> (2008)
	FLPMY	0.127 ± 0.036*		0.590 ± 0.402*				
	FLL	-0.028 ± 0.036	0.570 ± 0.024*					

**Note :** Above the diagonals are phenotypic correlation estimates and below the diagonal are genetic correlation estimates

Gawari (1999) reported positive and significant ( $P < 0.01$ ) genetic correlation of FLTMY with FL 300 DMY ( $0.85 \pm 0.08$ ). Sing *et al.* (2008) noticed positive and significant genetic correlation ( $>1$ ) between FLPMY and FL 300 DMY in HF x Sahiwal cows.

Ambhore *et al.* (2017) found the genetic ( $r_g$ ) and phenotypic ( $r_p$ ) correlations between FLL and FL300DMY trait in the range of  $-0.01 \pm 0.43$  to  $-0.98 \pm 0.75$  and  $-0.07 \pm 0.04$  to  $0.35 \pm 0.04$ , respectively from four trait animal models in Phule Triveni cattle.

Pol *et al.* (2013) observed negative ( $-0.11$ ) genetic correlation of FLL with FL300 DMY in Phule Triveni cows. Nikam (2010) reported negative and significant ( $-0.786$ ) genetic correlation of FLL and FL 300 DMY in Phule Triveni cows. Komatwar *et al.* (2009) noticed positive and significant ( $P < 0.01$ ) genetic correlation of lactation length with FLPMY in HF x Sahiwal crossbred cows. Basu and Ghai (1980) studied on

inheritance of some reproductive traits and the relation with milk production in Friesian x Sahiwal crossbreds and reported that the service period was strongly correlated (0.984) with calving interval. Singh *et al.* (2016) reported genetic correlations of AFC with FSP, FLL and IFLS as positively significant in Sahiwal and its crosses with Jersey and Red Dane.

Banerjee and Banerjee (2002) studied the correlation between some reproduction and production traits in HF x Sahiwal crossbred cows and reported that there was a positive and significant ( $P < 0.01$ ) correlation between lactation yield and calving interval. Nikam (2010) observed genetic correlation between FLL and FLPMY to be negative (-0.632) and significant ( $P < 0.01$ ) in Phule Triveni synthetic cows. Lakshmi *et al.* (2009) noticed low genetic correlation of FL 300 DMY and FLL ( $0.26 \pm 0.28$ ) in HF x Sahiwal cows.

Singh *et al.* (2005) studied the genetic correlations of AFC with FLPMY and FL 300 DMY which were positive and significant in crossbred cattle. The genetic correlations of age at first calving with milk production in different breeds of cattle ranged from  $-0.57 \pm 0.23$  (Singh *et al.*, 1991) to  $0.59 \pm 0.17$  (Jadhav and Khan, 1996). In majority of the reports a positive and high correlation was noticed. The genetic correlation between service period and milk production ranged from -0.29 (Singh and Tomar, 1991) to 0.44 (Seykora and Mac-Daniel, 1983). A wide range of estimates were observed in different studies. The genetic correlation between first calving interval and milk production ranged from  $-0.57 \pm 0.23$  (Singh *et al.*, 2002) to  $0.67 \pm 1.05$  (Panja, 1997).

The positive and high genetic correlations were reported by Singh (1987) and Panja (1997) between lactation length and FLPMY (0.52 to 0.86) for 1<sup>st</sup> to 6<sup>th</sup> lactations in crossbreds of Haryana cattle with HF and Jersey. Rahumathulla *et al.* (1994) observed significant genetic correlation ( $0.61 \pm 0.26$ ) between lactation length and LMY in J x RS cows.

### 2.2.2 Phenotypic Correlations among first lactation milk production and reproduction Traits

D'souza *et al.* (1979) recorded phenotypic correlation of lactation length with first lactation peak milk yield as 0.57 and 0.67 in HF x Red Sindhi and Red Sindhi cows, respectively.

Kumar (1981) noticed positive and non-significant phenotypic correlation between the AFC and calving interval ( $0.14 \pm 0.33$ ) and  $0.05 \pm 0.03$ ) in Haryana cattle. Chaturvedi *et al.* (1999) studied the correlations between AFC with service period and calving interval which were positive and non-significant in Malvi cows. Barwe *et al.* (2003) reported that the phenotypically AFC was positively and significantly correlated with SP ( $0.16 \pm 0.04$ ) and calving interval ( $0.85 \pm 0.20$ ) in Gir cows. Rahumathulla *et al.* (1993) observed positive and significant ( $0.89 \pm 0.02$ ) phenotypic correlation between FLPMY and 305 days milk yield in J x Red Sindhi crossbreds. Tomar *et al.* (1999) observed positive and significant ( $P < 0.01$ ) phenotypic correlation of lactation length (0.72) and peak yield (0.56) with 305 days milk yield in crossbred dairy cows.

Cylek and Tekyn (2007) observed positive and significant correlation between 305DMY and calving interval (0.16) in Brown Swiss cows. The phenotypic correlation between AFC and milk production was  $0.13 \pm 0.12$  (Nehra, 2011), with CI it ranged from  $0.09 \pm 0.40$  (Nehra, 2011) to 0.20 (Sivakumar, 1998) and with service period it ranged from  $- 0.06 \pm 0.07$  (Panja, 1997) to 0.15 (Sivakumar, 1998) in Karan Fries cattle.

### 2.3 Single Trait versus Multiple-Trait Animal Model for Predicting the Breeding Values

The simple mixed model used in animal breeding is a single trait animal model. It is an animal model because in this one can fit a breeding value for each animal. Single trait refers to the fact that animals have only observations on one character (trait) and there are only fixed effects and additive genetic effects and no other random effects such as maternal over-dominance, the model is

$$y = Xb + Zu + e$$

Whereas in multi trait model, which is an extension of the single trait case, data on a number of traits are available in Y, and EBV's are calculated for each trait. The

results are generally different from what is expected from a number of separate single-trait BLUPs, because each trait is used to help to give information about all other traits.

For the genetic evaluation of animals, the information which is available on all traits is used. Originally the main reason for using information on all traits was to obtain more accurate evaluations. With using information on correlated traits the accuracy of the estimated breeding value increases. A second advantage arose later, namely a multiple trait analysis is the only way to obtain unbiased estimates for a trait, which is observed only on animals selected based on values of a correlated trait. A model including information of the correlated trait, on which selection was based, is able to correct for this type of selection (Bourdon, 1997). The importance of increase of accuracy by using extra information, i.e. importance of using a multiple trait (MT) model, depends on several aspects.

### **Information available on each animal**

If few or no observations are available for a particular trait, using observations on another trait when both traits are genetically correlated can increase the accuracy.

### **Parameter structure**

If genetic and environmental correlations are low the multiple trait models have few advantages. Furthermore, in a situation with a high  $h^2$ , only a few observations are needed for an accurate estimate of the breeding value. In other words, information of other traits is less important in such case. Besides, the difference between  $r_g$  and  $r_e$  is important; the larger the difference, the larger is the contribution of a correlated trait to the reduction of the Prediction Error Variance (Schaeffer 1984).

### **Correctness of parameters**

In multiple trait models, estimated values of the genetic parameters (heritability's, correlations) are used. This variance-covariance (VCV) matrix has to be checked on incorrectness (or consistency). Schaeffer (1984) discussed the effects of incorrect estimated parameters. This distinguished two kinds of mistakes. First, the VCV matrices may not be valid, i.e. within the parameter space. A valid VCV matrix, by definition, is a positive definite matrix. This can be checked by looking at all the given

values of the matrix. All given values of covariance matrices have to be positive, making the matrix “positive definite”.

The second and most common mistake, mentioned by Schaeffer, is that estimates used in the model, could be greatly different from the underlying true values. Assume that the true parameters give maximum response of selection. The realized response then depends on the difference with parameters used, namely  $(r_g - r^{\wedge}_g)$  and  $(r_e - r^{\wedge}_e)$ . In this respect, it is good to realize that single trait animal models with the assumption that  $r^{\wedge}_e = r^{\wedge}_g = 0$ . Therefore, inaccurate correlations are often still closer to the true values than zero correlations.

### **Correction for selection**

Multiple trait evaluation was able to avoid selection bias. This reflects a more general rule, also applicable in single trait genetic evaluation to avoid selection bias, all information that was used to base selection decisions should be included in the analysis (Henderson, 1975 and Mrode, 2005). This is not only the case with missing records in sequentially recorded traits; when two traits are recorded simultaneously and all animals have records for all traits, however selection is only for one of the traits. Single trait evaluation of one trait only would lead to biased EBV's and generally to an underestimate of the genetic trend for the correlated trait (although this depends on the genetic and environmental correlation between the traits). Since selection is usually on an index (a linear combination on all traits), single trait evaluation leads to incorrect estimates of the genetic trend in most of the cases.

The results of studies carried out by Jain (1996), Kadarmideen *et al.* (2003) Biffani *et al.* (2005) and Sun *et al.* (2010) indicated that genetic evaluation of fertility traits can be improved by using a multiple-trait model including milk production traits. Jain (1996) compared the heritability estimate of first lactation milk yield (F305MY and PY305) traits and age at first calving (AFC) with or without first service period (FSP) as co-variable under single and multiple trait models using restricted maximum likelihood (REML) method of estimation under BLUP animal model in Murrah buffaloes. It was found that the heritability estimates under multi trait models were higher than that of single trait models.

Kadarmideen *et al.* (2003) estimated the genetic parameters and breeding values for cow fertility traits like calving interval, interval from calving to first service, calving to first conception and first to last service, conception success to first service and number of services per conception by single trait as well as multi-trait analysis along with milk production. The estimates of heritability was similar for two types of analysis, however, there were differences between estimated breeding values and rankings for the same trait for single versus multi-trait analysis. The range of rank correlation was 0.69-0.83 for all animals.

Improvement in EBV of reproduction traits when estimated using multiple trait analysis along with milk production was shown by Biffani *et al.* (2005). They analysed fertility traits (CI, CTFS and NRR56) using 3-trait model (including only fertility traits) and 5-trait model (adding milk and angularity as correlated traits) and found that the 5-trait model increased accuracy of EBV (5.5, 9.9 and 10.8 % higher) and the Spearman Rank correlations between bulls EBV for fertility traits using 3-trait and 5-trait model were 0.98 and 0.95. All these results discussed under review of literature point to the importance of multi-trait evaluation especially in case of reproduction traits where the heritability is low. By including reproduction traits along with evaluation of milk production, even though the improvement in heritability is not significant the ranking of animals based on breeding value estimation in single and multi - trait evaluation showed significant variation. This revealed that if animals are selected on the basis of single trait evaluation only, the decision will be biased.

#### **2.4 Phenotypic, Genetic and Environmental Trends in Performance Traits**

Variation in the average observed performance of a herd over time does not give precise indication of the genetic change. Partitioning of phenotypic change into genetic and environmental components of change is very important to estimate the change in real breeding worth for assessing the change in performance per unit of the time. Harville and Henderson (1967) defined genetic trend as a change in performance per unit of time due to change in mean breeding value. The environmental trend has been defined as a change in performance per unit of time due to change in mean environment.

The estimates of phenotypic, genetic and environmental trends reported in literature in different breeds of cattle for various performance traits have been summarized as follows.

Singh and Nagarcenkar (2000) estimated phenotypic, genetic and environmental trends in some economic traits (FLTMY, FLL and FDP) in five Sahiwal herds (Karnal, Meerut, Durg, Hisar and Chak- Ganjaria) in Northern India to evaluate the effectiveness of selection. The rate of phenotypic change was negative in larger herds and positive change was observed in small and medium herds for FLTMY. The genetic trends showed increase in milk yield for Drug, Hisar and Chak - Ganjaria.

Hansen (2000) reported that the annual genetic trends for milk yield in HF cows was accelerated with time and had means of 37 kg in 1960's, 79 kg in 1970's, 102 kg in 1980's and 116 kg from 1990 to 1996.

Topanurak *et al.* (2001) obtained a negative genetic trend of 17.05 kg/yr from estimates made on data collected from members of a dairy cooperative. They reasoned that it was due to farmers reluctance to culling poor performing cows either because of psychological bond or poor judgment resulted from lacking solid information regarding the cow's actual genetic potential. The phenotypic trend for FL305DMY (Singh and Gurnani (2004)) was higher than genetic trend because of improvement in environmental conditions such as nutrition, management and health.

Mayer and Musani (2002) estimated the genetic and environmental progress in Jersey herd of Kenya for period of 14 years by incorporating polynomial functions of rainfall in the statistical model. The purpose was to separate the year-season effect into casual components, i.e. influence of rainfall pattern, temporary management effect and environmental trends. In first model, year-season of calving, parity and AFC proved to be significant ( $P < 0.01$ ). In second model, parity and AFC significantly ( $P < 0.01$ ) influenced milk production. It was indicated that the proposed models proved successful in separating year- season effect into its causal components and thus gave better estimates of genetic and environmental trends.

Singh and Gurnani (2004) estimated phenotypic, genetic and environmental trends for different production and reproduction parameters in Karan Fries and Karan Swiss cattle. The phenotypic and genetic trends for AFC were significantly negative; whereas, for traits like FL305DMY, FLTMY and FCI the phenotypic trends

were negative and non-significant while genetic trends for traits were negative and significant. For FLL, FDP and FSP, the phenotypic trend was non-significant while, genetic trends were positive and non-significant. In Karan Swiss, phenotypic and genetic trends for AFC were negative and significant and negative and non-significant, respectively. The phenotypic trends were positive for FL305DMY, FLTMY and FCI and negative for FLL, FSP and FCI in Karan Swiss cattle. The corresponding genetic trends were positive for FL305DMY, FLTMY, FDP and FCI and negative for FLL and FSP.

Gaur (2003) studied the genetic and phenotypic trends for various production and reproduction traits of Frieswal cattle at different military farms (Meerut, Jall andhar and Ambala). It was observed that the genetic trends for most of the production traits were positive and reproduction traits were negative revealing desirable improvement in performance traits over the time.

De Vries and Risco (2005) determined the trends and seasonality of reproductive performance in Georgia and Florida dairy herds and concluded that average calving interval increased from 399 days in 1976 to 429 days in 2000. In another study, trends for reproductive performance in 1772 Ohio dairy herds from year 1992 to 1998 revealed that herd average calving interval lengthened from 13.6 to 14.1 months (Mostert *et al.* 2010). In contrast Robertson and Rendel (1954) indicated that average calving interval was varied between 12.4 and 12.6 months in Norwegian cattle from year 1985 to 2005 without showing a specific trend.

Ansari *et al.* (2009) reported negative trend for age at first calving (decreased significantly from 30 months In year 2000 to 26 months in 2005) and calving interval (435 days in year 2000 and declined to 389 days in 2004) in the Iranian Holsteins in Fars province. This could be attributed to better management and nutrition practices during this period and also to the fact that large genetic trend for milk which has been observed in countries with decreasing reproductive performance has not occurred in these herds yet.

Sarakul *et al.* (2010) estimated genetic and phenotypic trends for 305-day milk yield of cows from year 1990 to 2007 and noticed that genetic trends for the complete population of Thail and were  $0.29 \pm 1.02$  kg/yr for cows,  $-1.47 \pm 1.89$  kg/year

for sires, and  $1.44 \pm 0.91$  kg/yr for dams. Phenotypic trend for milk yield during this period was  $14.57 \pm 10.63$  kg/yr.

Mostert *et al.* (2010) estimated the genetic trend of calving interval in order to know the effect of selection on production traits and fertility performances of Ayrshire, Guernsey, Holstein and Jersey breeds of dairy cattle in South Africa. They reported that calving interval increased genetically for all breeds. Golverdi *et al.* (2012) used DFREML animal model procedure for the estimation of genetic trend of first lactation 305 days milk yield, fat yield and fat per cent in Holstein. The genetic trends of all three studied traits were calculated by using regression of means of breeding values over the years. The genetic trends were positive for milk (6.791) and fat yield (0.139) and negative for fat per cent(-0.04). Robertson and Rendel (1954) reported a positive genetic trend (0.70 days) in days open (service period) in case of Holstein Friesian herd of dairy cattle. A low, positive and non-significant genetic trend of  $0.073 \pm 0.346$  days was observed in Holstein cows in Egypt by Hammond and Salem (2013).

Nehra (2011) estimated the phenotypic trend for AFC and FCI in Karan Fries cattle as  $2.37 \pm 1.14$  and  $1.17 \pm 0.83$  days and the genetic trends estimated for AFC and FCI in Karan Fries cattle were  $0.59 \pm 3.38$  and  $-3.64 \pm 5.10$  days by SM-II and  $0.58 \pm 0.24$  and  $-0.59 \pm 1.09$  days by BLUP method. Dash (2014) carried the phenotypic and genetic trend analysis in Karan Fries cattle and observed the phenotypic trend for first service period as  $1.14 \pm 0.51$  days while the corresponding genetic trend was  $0.02 \pm 0.03$  days which was positive and non-significant for FSP. A positive significant environmental trend ( $1.12 \pm 0.51$  days) was also observed for FSP.

Rathi (2015) reported the overall phenotypic trends of FLMY, FL305MY, FLL, FLMY/FLL and FLMY/FCI as  $-10.99 \pm 4.75$ ,  $-0.31 \pm 4.23$ ,  $-2.13 \pm 0.27$ ,  $0.02 \pm 0.00$  and  $-0.01 \pm 0.01$  kg, respectively. The overall genetic trends estimated by Smith I and II and BLUP method for FLMY were  $20.55 \pm 20.70$ ,  $-27.71 \pm 18.23$  and  $1.06 \pm 1.08$  kg, while for FL300MY the values were  $19.1 \pm 18.37$ ,  $-23.18 \pm 15.99$  and  $0.42 \pm 0.99$  kg, respectively. The overall environmental trends for FLMY estimated by Smith methods I and II and BLUP were  $-31.54 \pm 21.24$ ,  $16.72 \pm 18.84$  and  $12.05 \pm 4.87$ , respectively in Frieswal cattle.

Ambhore *et al.* (2016) estimated the phenotypic, genetic and environmental trend in Phule Triveni cattle using Smith II (SM-II) and best linear unbiased prediction (BLUP) methods in these traits. The estimated annual phenotypic, genetic and environmental trends were  $20.70 \pm 1.42$  kg,  $33.38 \pm 48.99$  kg (SM-II) and  $1.31 \pm 0.60$  kg (BLUP) and  $-54.08 \pm 49.01$  kg (SM-II) and  $-22.01 \pm 1.58$  kg (BLUP) for FL 300 DMY,  $-21.01 \pm 4.18$ ,  $21.35 \pm 60.09$  kg (SM-II) and  $2.15 \pm 0.73$  kg (BLUP) and  $-42.36 \pm 60.23$  kg (SM-II) and  $-23.16 \pm 4.24$  kg (BLUP) for FLTMY,  $-0.44 \pm 0.30$  days,  $4.27 \pm 4.94$  (SM-II) and  $0.09 \pm 0.13$  (BLUP) days for FLL,  $0.98 \pm 0.24$  days,  $-0.99 \pm 3.58$  (SM-II) and  $-0.11 \pm 0.08$  (BLUP) days,  $1.97 \pm 3.59$  (SM-II) and  $1.09 \pm 0.25$  (BLUP) days for FDP, respectively.

## **2.5 Methods of Sire Evaluation**

### **2.5.1 Least Squares Method**

Robertson and Rendel (1954) initially proposed the least squares procedure for determining the genetic worth of sires. The procedure was based on the principle to minimize the error variance after adjusting the data for various non-genetic or environmental factors. Cunningham (1965) described the method for obtaining weighted least squares estimates of sires based on non-orthogonal data.

Harvey (1979) gave the concept of least squares analysis for non-orthogonal data. The least squares analysis for estimation of breeding value of sires has widely been used in India by several workers. Singh (2006), Kokate (2009) and Rashia (2010) have used least squares method to evaluate Karan Fries sires using uni-trait (305-day milk yield) model. Parekh *et al.* (1994) estimated breeding value of HF and HF cross sires based on this method. Gaur and Raheja (1996) Pundir *et al.* (2004), Banik and Gandhi (2006), Bajetha (2006) and Kumar (2007) have used least squares method to evaluate Sahiwal sires.

Singh (1991) in Sahiwal, Jain (1996) in Murrah buffalo and Mukharjee (2005) in Frieswal used this method to evaluate sires. Singh (2013) and Dash (2014) applied this method for sire evaluation in Karan Fries cattle. Dongre and Gandhi (2014) in Sahiwal cattle, Ambore (2015) applied this method for Phule Triveni cattle and Singh and Singh (2016) in Sahiwal cattle.

### **2.5.2 Simple Regressed Least Squares Analysis (SRLS)**

Harvey (1979) described the computational procedure of simple regressed least squares (SRLS) analysis for sire evaluation under mixed model. Several workers in India utilized this model for estimating sire's breeding value. Kokate (2009) and Rashia (2010) have used SRLS method to evaluate Karan Fries sires. Tajane and Rai, (1989) and Parekh *et al.* (1994) estimated breeding value of HF and HF cross sires based on this method.

Gandhi and Gurnani (1991), Singh (1992), Parekh *et al.* (1994), Raheja (1992), Deulkar and Kothekar (1999), Pundir *et al.* (2004), Banik and Gandhi (2006), Bajetha (2006) and Kumar (2007) used this method to evaluate Sahiwal sires. Jain (1996) in Murrah and Mukharjee (2005) in Frieswal used this method to evaluate sires. Singh (2013) used this method for sire evaluation in Karan Fries cattle.

### **2.5.3 Best Linear Unbiased Prediction (BLUP) Method**

Henderson (1973) reported the basis and methodology of best linear unbiased prediction (BLUP). The method combines the features of selection index and least-square technique and was reported be the most powerful and flexible (Henderson, 1974). The BLUP evaluations are unbiased and have minimum predication error variance.

Henderson (1975) described the incorporation of numerator relationship matrix which has the benefit of increase in accuracy, earlier evaluation and accounting for genetic and environmental trends. Henderson (1976) extended the BLUP procedure to the multiple traits and Henderson and Quaas (1976) further extended it to multiple traits with utilization of numerator relationship matrix. Henderson (1974), Singh (2013) and Dash (2014) applied BLUP method of sire evaluation in Karan Fries cattle, Ambore (2015) in Phule Triveni cattle and Singh and Singh(2016) in Sahiwal cattle.

### **2.5.4 Restricted Maximum Likelihood Method (REML)**

Restricted maximum likelihood (REML) method is a maximum likelihood method that accounts for the loss of degrees of freedom due to fitting fixed effects. The aim in REML is to find the sets of parameters which maximize the likelihood of the data. The data are analyzed to get REML estimates by Derivative Free Restricted Maximum Likelihood (DFREML) approach, introduced by Graser *et al.* (1987).

The multivariate, multidimensional analysis of animal model for evaluating merit of sire was proposed by Meyer and Smith (1996). Later Smith (2002) described the procedure of restricted or residual maximum likelihood (REML) for linear models. Dahlin *et al.* (1998) and Khan *et al.* (1999) used the restricted maximum likelihood method (REML) in Sahiwal cattle of Pakistan to estimate the heritability values for different production and reproduction traits.

Espinosa *et al.* (2001) in Holstein dairy cattle, Hossain *et al.* (2002) in Bangladeshi local cattle, Mukharjee (2005) in Frieswal cattle, Banik and Gandhi (2006) and Kumar (2007) in Sahiwal cattle used multiple trait restricted maximum likelihood method for estimating variance components with a derivative free algorithm.

Singh (2013) evaluated Karan Fries sires under single trait (LSQ, SRLS, BLUP, ST-SM and ST-AM) and multi-trait animal models for FL305DMY and traits presented variation in estimates which resulted into variation in percentage of sires having breeding values above or below to the average breeding value of sires for a given trait and evaluation methods. The ST-AM was considered better among single trait models for FL305DMY. The multi-trait animal models took account of all inter correlations and information of traits involved in models of analysis besides the existing relationships among the animals pedigree. The three trait animal model with AFC and FSP as covariate and four trait animal models with SNF yield, AFC and FSP for FL 300 DMY combinations had the highest averages and range of breeding values and appeared better methods in their respective model groups.

Ambhore (2015) evaluated Phule Triveni sires under single trait (LSQ, SRLS, BLUP, ST-Sire model and ST-Animal model) and multi-trait animal models for FL305DMY. The results of genetic parameters demonstrated wide variability among themselves for a given trait depending upon method of estimation and type of trait included in the model. The heritability estimate for a trait ST-AM was considerably higher (26%) than the corresponding to ST-SM estimate. The per cent increase in the heritability by multi trait animal model over ST-AM was 17.20 per cent into traits (FL 300 DMY and AFC), 10.3 per cent in three traits (FL 300 DMY, AFC and FDP) and 45.0 per cent in four trait model (FL 300 DMY, FLL, AFC and FCI) combination.

## 2.6 Comparison of Sire Evaluation Methods

Gurnani and Nagarcenkar (1982) compared BLUP method with contemporary comparison (CC) method for estimating the breeding value of 28 sires having records on at least 10 daughters. They reported that BLUP method was costlier and gave higher errors of approximation in analysis where numbers of daughters were small. They opined that CC method may be appropriate under Indian conditions where computers were not readily available and progeny size was often limited.

Sahana and Gurnani (1999) estimated the EBVs of 72 Karan Fries bulls on contemporary comparison, least squares, simple regressed least squares analysis (SRLS) and best linear unbiased prediction (BLUP). They reported that rank correlation among the methods ranged from 0.98 to 0.99 indicating similar rankings of sires for these methods.

Dhaka and Raheja (2000) estimated the EBVs of 26 Sahiwal sires using first lactation milk yield records of 380 daughters to compare the effectiveness of three different sire evaluation methods namely least squares, regressed least squares and BLUP. They concluded that BLUP method could be used in a situation where correct ratio of residual to sire variance is known and ordinary least squares could be used in a situation where the ratio of residual variance to sire variance is unknown.

Jain and Sadana (2000) used first lactation records of 683 Murrah buffaloes maintained at National Dairy Research Institute, Karnal for comparing the sire evaluation method for age at first calving, first lactation 305-days or less milk yield and first service period. The sires were evaluated using Simple daughter's average, contemporary comparison, least-squares and BLUP methods. The BLUP evaluations were obtained under single, two and three-trait individual animal models. The results revealed that for taking a decision regarding the method of sire evaluation to be used for selecting sires with high breeding values, criteria of the rank correlation could be misleading and comparison of the selected sires is likely to give a variable picture. The BLUP method under multi-trait animal model incorporating first lactation milk yield with first service period and age at first calving as a covariable in the model was found to be more efficient and accurate for sire selection in Murrah buffaloes.

Gaur *et al.* (2001) estimated the breeding value of Frieswal sires using simple daughter's average, contemporary comparison, least squares and BLUP procedures and computed rank correlations among the values obtained in order to judge the efficiency of various methods. Rank correlations among breeding value of sires estimated from BLUP, LS, and CC procedures were near to unity (0.96 to 0.97). They suggested that either of the methods could be used for the evaluation of sires for breeding purpose.

Pundir *et al.* (2004) compared 33 Sahiwal sires using first lactation records of 514 daughters by different sire evaluation methods *viz.*, simple daughter average (SD), contemporary comparison (CC), least squares (LS) and BLUP and suggested that BLUP and contemporary comparison procedures were almost equally good and superior over simple daughter average and least squares method.

Banik (2004) evaluated the Sahiwal sires using various single trait and multiple trait methods namely contemporary daughter average index (CDAI), LSM (FL305MY), SRLS (FL305MY), BLUP (FL305MY), DFREML-I (FL305MY) and DFREML-IV (FL305MY, AFC, FSP and FCI). The relative efficiency of these methods were 81.78, 78.11, 78.11, 75.91, 99.72 and 100.00 per cent, respectively. The DFREML-IV method was found most efficient in comparison to others based on lower value of error variance of prediction and relative efficiency.

Mukharjee (2005) evaluated the Frieswal sires using various single trait and multiple trait methods namely SRLS, BLUP, DFREML-I (FL305MY), DFREML-II (FL305MY and FPY), DFREML-III (FL305MY, AFC and FLL), DFREML-IV (FL305MY, AFC, FLL and FPY). The relative efficiency of these methods were 85.00, 85.00, 96.00, 96.00, 96.11 and 100 per cent, respectively. The DFREML-IV method was found most efficient in comparison to others based on lower value of error variance of prediction and relative efficiency.

Singh (2006) reported that the rank correlations between EBVs for the first lactation 305-days or less milk yield by least squares and BLUP methods were the highest (0.939 and 0.001) followed by between simple daughter average (SDA) and BLUP (0.686 and 0.001). The rank correlations of CC and LSQ with SDA had relatively lower estimates (0.444 and 0.539). The rank correlations of LSQ and BLUP with CC were

found to be negative, though of lower magnitude. The results revealed a wide variation in the ranking of EBVs by CC in comparison to LSQ and BLUP. He reported that LSQ and BLUP methods could be used with greater reliability for evaluation of sires.

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

Kokate (2009) observed that the rank correlations estimated between EBVs by LS and SRLS were the highest (0.98). The rank correlations between LS and CC (0.32) and between SRLS and CC (0.30) were nearly equal for actual 305-days or less milk yield. The rank correlations of LS and BLUP and SRLS with BLUP were found to be 0.84 and 0.86. However, the rank correlations of CC with BLUP were found to be negative. The coefficient of determination of SRLS was relatively higher than the LS and BLUP methods. The coefficient of variation for LS, SRLS and BLUP ranged between 23–24.5 indicating nearly equal stability for these methods. Based on predicted 305-days milk yield, in general, the error variance of BLUP was lower than LSQ and SRLS. The relative efficiency of LSQ and SRLS in comparison with the BLUP was more than 95 per cent.

Rashia (2010) evaluated the Karan Fries sires using various methods namely CC, SRLS, LSQ and BLUP. They concluded that either of three methods *viz.*, SRLS, LSQ and BLUP could be used for genetic evaluation of Karan Fries sires for 305-day or less milk yield due to high rank correlations between them and comparable efficiency and accuracy of these sire evaluation methods.

Singh (2013) reported that the single trait animal model (ST-AM) for FL305DMY was found more stable among other mixed model of single trait evaluation (BLUP and ST-AM). The single trait animal model gave more stable prediction of breeding values than other single trait sire evaluation methods. Under two trait animal model of traits combination SNF yield with FL305DMY was observed better method of evaluation among other two trait animal models based on CV %. The three traits animal model of traits combination AFC and FSP as coverable with FL305DMY was found superior to other three traits animal models in their respective groups based on CV%. Among four traits animal models the model of traits combination SNF yield, AFC and FSP with FL305DMY appeared superior to other four trait animal models based on CV %. The difference among CV % of different multi-trait animal models was attributed to the difference in magnitude and direction of genetic and phenotypic correlation of trait included in multi-traits animal models with FL305DMY trait.

Dongre and Gandhi (2014) studied sire evaluation method in Sahiwal cattle by applying four sire evaluation methods *viz.*, least squares, simple regressed least squares, best linear unbiased prediction and derivative free restricted maximum likelihood. The derivative free restricted maximum likelihood method had lowest error variance for both actual and predicted first lactation 305 days milk yield and it was considered to be the most efficient method. The BLUP method was second efficient followed by LSM and SRLS method.

Al-Samari *et al.* (2015) evaluated the sire of Holstein for the TMY by three methods *viz.*, Best Linear Unbiased Prediction (BLUP) using Harvey programme, Transmitting Ability (TA) according to the Least Squares Means of sire progeny (TALSM) and according to means (TAM). The highest and lowest BLUP values of sires for the TMY were 542.44 kg and 402.14 kg, while the corresponding estimates for TALSM and TAM were -470.38 kg 380.88 kg and -370.12, 388.50 kg, respectively. The Spearman rank correlation coefficient among BLUP, TALSM and TAM ranged from 0.81 to 0.67.

Sikander *et al.* (2016) studied the effectiveness of different sire evaluation methods in Sahiwal cattle and reported that the breeding values of sire estimated by two methods *viz.*, least squares and best linear unbiased prediction methods. The BLUP and

least squares method had variation in the estimated value of coefficient of variation (CV%). It indicated that the BLUP method was the best over the least squares method (LSM) because estimated value of coefficient of variation (CV%) by BLUP method was smaller than that of least squares method. The BLUP using single trait *viz.*, FSP, FDP, FCI, FLMY, PL and HL was having lowest error variances as compared to the least squares method (LSM). Hence BLUP was the most efficient sire evaluation method.

## **2.7 Breeding Values of Sires by Using Single Trait vs. Multiple Trait Models**

Banik and Gandhi (2010) compared DFREML method for single (305 day milk yield) and multiple trait (305 days milk, AFC, FSP and FCP) in Sahiwal cattle. They compared the single trait model with multiple trait method and found that the breeding value and the ranks of sires do not differ significant from both the models. The breeding value of sires for 305 DMY ranged from 1912.64 to 846.89 kg from multi trait model. These estimates were 27.17 per cent higher and 43.69 per cent lower than the average breeding value. The difference between these two extremes was 1065.75 kg.

Singh *et al.* (2014) studied the relative effectiveness of BLUP-Animal Model using REML-algorithm by WOMBAT software (Meyer, 2007). *vis-à-vis* other sire evaluation methods *viz.*, least squares, simple regressed least squares (SRLS) and BLUP sire evaluation models on the basis of efficiency, accuracy and stability and reported average, maximum and minimum breeding values by LSQ as 1755.98, 2428.02 and 1247.62 kg, SRLS as 1794.82, 2328.40 and 1302.60, BLUP-SM as 1845.10, 1950.50 and 1733.90, BLUP-AM as 1805.70, 2087.38 and 1557.50 kg, respectively.

Mallick *et al.* (2016) studied the sire evaluation method by single and multi-trait animal model in Red Sindhi cattle. The average breeding values of sires of single trait from different method ranged from 1536.35 kg (LSM, DFREML and BLUPI-90 Dairy Pack) to 1588.50 kg (Simple daughter average) however in multi-trait method the breeding value does not vary with each other. The comparison of different methods of sire evaluation based on single trait for FLMY only showed that the DFREML model for single trait should be preferred over the BLUP, LSM and simple daughter average methods for evaluating the sire breeding value. However, if a sire breeding value is to be

computed from multi-traits then BLUPF 90 model may be preferred over DFREML model.

Ambhore *et al.* (2017) studied the performance of 102 sires maintained at RCDP on Cattle, M.P.K.V., Rahuri by unvariable and multivariable methods of sire evaluation by REML and reported large variation between estimated breeding values of sire. The estimated breeding value of sires for 300 DMY by REML i.e. using multi-trait methods showed small genetic variation in comparison to LSQ, SRLS and BLUP-SM methods.

### **3. MATERIAL AND METHODS**

The present investigation entitled, “Genetic evaluation of HF x GIR halfbred sires using fertility and milk production traits” was undertaken by utilizing the data maintained at Research Cum Development Project on Cattle (RCDP), Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.).

#### **3.1 General Information**

##### **3.1.1 Location and Climate**

The Research Cum Development Project on Cattle, Mahatma Phule Krishi Vidyapeeth, Rahuri is situated on Ahmednagar-Manmad state highway No.14, about 160 km North East of Pune and 30 km from Ahmednagar in semiarid scarcity zone of Maharashtra state. It is situated at an elevation of 559 meters above the mean sea level. It approximately lies between 19<sup>0</sup>57' North latitude and 74<sup>0</sup>19' East latitude in Maharashtra state. The day time temperature is going to reach 30<sup>0</sup>C . It will be dry with no precipitation and cloud covering 5 per cent of the sky, the humidity will be around 31 per cent.

##### **3.1.2 History of Herd**

The All India Co-ordinated Research Project on Cattle started functioning at M.P.K.V., Rahuri on 1<sup>st</sup> December, 1970 which was then converted into Research Cum Development Project on Cattle from 1<sup>st</sup> April, 1986. The foundation stock of 237 Gir cows and 160 heifers were purchased from Gujarat, Bombay Goshala and Panjarpoles during year 1971 to 1973.

The main objective of the project was to evolve a new breed, which could produce minimum 2000 kg of milk with a herd average of 3200 kg milk per lactation and fat test not less than 3.5 per cent.

The foundation stock of 300 Gir cows were inseminated with frozen semen of progeny tested sires of Holstein Friesian (HF) and Jersey (J) to generate FG and JG halfbreds. The FG halfbreds were interse mated to generate IFG group. The sire indices of Holstein Friesian and Jersey were 5500 and 4500 kg, respectively.

### 3.1.3 Breeding Programme

The Research Cum Development Project on Cattle, M.P.K.V., Rahuri was initiated under All India Co-ordinated Research Project of Indian Council of Agricultural Research (ICAR), New Delhi in fourth five year plan period. The foundation stock of Gir cows were inseminated with frozen semen of proven sires of HF and Jersey from the year 1971 to 1975 and 277 FG and 170 JG halfbreeds were generated. The second generation cross with 50 per cent inheritance of Holstein Friesian breed and remaining 50 per cent from local Gir were generated and maintained by *interse* mating. The comparative performance of *interse* generations was studied up to 9<sup>th</sup> generation.

### 3.1.4 General Feeding and Management

The animals were confined in loose housing system. The separate buyers were provided for different categories of animal's *viz.*, young calves, heifers, milch cows, dry cows, pregnant cows, breeding bulls etc.

Tattooing of calves were carried out within 10 days of birth. The animals were culled on the basis of poor milk production, reproductive efficiency and poor health as per the recommendations of ICAR workshops. Drying off of milking pregnant cows two months prior to due date of calving was also followed. Hand and machine milking was practiced and cows were milked twice a day.

Green fodder was fed to the animals throughout the year which included Lucerne, Berseem, Cowpea, Maize, Jowar and Oat. The major source of dry fodder used for feeding was *Jowar Kadabi*. The concentrate mixture used for feeding different categories of animals was as per their nutritional requirement. Salt licks were provided in byres.

### 3.1.5 Health Cover

The animals were vaccinated against Foot and Mouth Disease, Haemorrhagic-Septicaemia and Black Quarter diseases. All the animals were screened for Tuberculosis, Johne's disease, Brucellosis and Mastitis. Deworming of animals at a regular interval was also carried out. Animal sheds were sprayed regularly with insecticides and pesticides to control ticks, lice, mosquitoes and flies.

### **3.1.6 Source of Data**

The data pertaining to fertility and milk production traits of HF x Gir halfbred maintained at Research Cum Development Project on Cattle, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.) for a period of 44 years (1974 to 2017) were utilized for the present investigation.

### **3.1.7 Collection of Data**

The observations regarding the fertility and milk production traits of HF x Gir halfbred were collected from the history, pedigree sheets and daily milk recording sheets maintained over a period of 44 years (1974 to 2017) at RCDP on Cattle, MPKV, Rahuri.

#### **a. Observations**

The following information were recorded

1. Animal number
2. Date of birth
3. Sire number
4. Dam number
5. Date of calving
6. Date of first service after first calving
7. Date of successful service after first calving
8. First lactation peak milk yield
9. First lactation 300 day's milk yield
10. Date of disposal (Death/Sale)

### **3.2 Traits for Study**

#### **3.2.1 First Lactation Traits**

##### **a. First lactation fertility traits**

1. Age at first calving - AFC
2. First calving interval – FCI
3. Interval between calving and first service – CAFS
4. Interval between first and last service – IFLS
5. Interval between first calving and conception - CACO

### 3.2.2 First Lactation Production Traits

1. First lactation 300 days milk yield -FL300DMY
2. First lactation peak milk yield –FLPMY
3. First lactation length- FLL

### 3.3 Standardization of Records

Culling in middle of lactations, abortion, still-birth or any other pathological causes which affected the lactation yield was considered as abnormalities and thus such records were not taken for the study. The outliers beyond two standard deviation on both the tail ends of normal distribution were excluded from the data. The cows that had produced milk of at least 150 days in the first lactation were considered for the study.

### 3.4 Classification of Data

The data was classified according to the season of birth, period of birth and age at first calving for various first lactation milk production and fertility traits.

#### a. Period of Birth

The data of 46 years were divided into following seven periods

Sr. No.	Period of birth (year)	Code
1	1972-1978	B <sub>1</sub>
2	1979-1985	B <sub>2</sub>
3	1986-1992	B <sub>3</sub>
4	1993-1999	B <sub>4</sub>
5	2000-2006	B <sub>5</sub>
6	2007-2013	B <sub>6</sub>
7	2014 -2017	B <sub>7</sub>

#### b. Period of calving

The data of 44 years were divided into following six calving groups

Sr. No.	Period of calving (year)	Code
1	1974-1980	P <sub>1</sub>
2	1981-1987	P <sub>2</sub>
3	1988-1994	P <sub>3</sub>
4	1995-2001	P <sub>4</sub>
5	2002-2008	P <sub>5</sub>
6	2009 – 2017	P <sub>6</sub>

The appropriate periods were formed keeping in view of the spread of data for various first lactation milk production and fertility traits.

**c. Season of birth**

Each year was divided into three seasons on the basis of rainfall, temperature and humidity over the years:

Sr. No.	Name of season	Group of months	Code
1.	Rainy	June to September	S <sub>1</sub>
2.	Winter	October to January	S <sub>2</sub>
3.	Summer	February to May	S <sub>3</sub>

**d. Age at first calving group**

The data recorded were divided into following three AFC groups

Sr. No.	Age at first calving (day)	Code
1	<950	A <sub>1</sub>
2	951 to 1050	A <sub>2</sub>
3	1051 and above	A <sub>3</sub>

**3.5 Statistical Analysis**

Statistical analysis of data was carried out under the following headings.

**3.5.1 Least Squares Analysis**

Least squares means of AFC was estimated by considering the effects of genetic (sire) and non-genetic factors (period and season of birth) by using following model (Harvey, 1990).

**Model I**

$$Y_{ijkl} = \mu + P_i + S_j + M_k + e_{ijkl}$$

Where,

$Y_{ijkl}$  = Observations on AFC of  $l^{\text{th}}$  animal belonging to  $i^{\text{th}}$  period of birth  $j^{\text{th}}$  season of birth and  $k^{\text{th}}$  sire

$\mu$  = Overall mean

$P_i$  = Fixed effect of  $i^{\text{th}}$  period of birth ( $i = 1, 2, \dots, 7$ )

$S_j$  = Fixed effect of  $j^{\text{th}}$  season of birth ( $j = 1, 2$  and  $3$ )

$M_k$  = Random effect of  $k^{\text{th}}$  sire ( $k = 1, 2, \dots, n$ )

$e_{ijkl}$  = Random error associated with NID ( $0, \sigma_e^2$ )

## Model II

The least squares means of various first lactation milk production and fertility traits were estimated by considering the effects of genetic and non-genetic factors by using following mixed model, (Harvey, 1990) :

$$Y_{ijklm} = \mu + P_i + S_j + M_k + A_l + e_{ijklm}$$

Where,

$Y_{ijklm}$  = Observations on milk production and fertility traits of  $m^{\text{th}}$  animal belonging to  $i^{\text{th}}$  period of calving,  $j^{\text{th}}$  season of calving,  $k^{\text{th}}$  Sire and  $l^{\text{th}}$  age at first calving group

$\mu$  = Overall mean

$P_i$  = Fixed effect of  $i^{\text{th}}$  period of calving ( $i = 1, 2, \dots, 7$ )

$S_j$  = Fixed effect of  $j^{\text{th}}$  season of calving ( $j = 1, 2$  and  $3$ )

$M_k$  = Random effect of  $k^{\text{th}}$  sire ( $k = 1, 2, \dots, n$ )

$A_l$  = Fixed effect of  $l^{\text{th}}$  age at first calving group ( $l = 1, 2$  and  $3$ )

$e_{ijklm}$  = Random error associated with NID ( $0, \sigma_e^2$ )

### 3.5.2 Duncan's Multiple Range Test (DMRT)

Duncan's Multiple Range Test (DMRT) as modified by Kramer (1957) was used to make pair wise comparison between the least squares means with the use of inverse elements and roots mean square for error

If the values

$$\sqrt{(Y_i - Y_j) / (C_{ii} + C_{jj} - 2C_{ij})} > \sigma_e Z(P, ne)$$

Where,

$Y_i - Y_j$  = Difference between the two least squares means

$C_{ii}$  = Corresponding  $i^{\text{th}}$  diagonal elements of C matrix

$C_{jj}$  = Corresponding  $j^{\text{th}}$  diagonal elements of C matrix

$Z(P, ne)$  = Standardized range value in Duncan's table the chosen level of probability for  $ne$  the error degrees of freedom

$P$  = Number of means involved in the comparison

$\sigma_e^2$  = Root mean squares of error.

### 3.5.3 Genotypic and Phenotypic Correlations

The genotypic and phenotypic correlations of AFC, FCI, CAFS, SOFS, IFLS, CACO and FLL with FLPMY and FL300DMY were estimated from the analysis of variance and covariance among sire groups as given by Becker (1986).

#### Genotypic correlation

Genotypic correlations were estimated as

$$\gamma_G(XY) = \frac{Cov_s(XY)}{\sqrt{(\sigma_X^2)(\sigma_Y^2)}}$$

Where,

$Cov_s(XY)$  – sire component of covariance between traits X and Y

$\sigma_X^2$  and  $\sigma_Y^2$  = sire components of variance for traits X and Y

The standard error of genetic correlation was estimated by using the formula of Roberston (1954) as

$$S.E.(\gamma_G) = \frac{(1 - \gamma_G^2)}{\sqrt{2}} \sqrt{\frac{SE(h_X^2)SE(h_Y^2)}{(h_X^2)(h_Y^2)}}$$

Where,

$h_X^2$  and  $h_Y^2$  are the heritability estimates of the two traits x and Y

Statistical significance of genotypic correlations were tested by using ‘t-test’.

#### Phenotypic correlation

The phenotypic correlations was estimated by using the following formula

$$\gamma_P(XY) = \frac{Cov_s(XY) + Cov_e(XY)}{\sqrt{[\sigma_s^2(X) + \sigma_e^2(X)][\sigma_s^2(Y) + \sigma_e^2(Y)]}}$$

Where,

$Cov_s(XY)$  – sire component of covariance between traits x and Y

$\sigma_e^2(X)$  and  $\sigma_e^2(Y)$  – Error components of variance for traits x and Y

Standard error of phenotypic correlations were estimated as :-

$$SE(\gamma_P) = \sqrt{\frac{1 - \gamma_P^2(XY)}{N - 2}}$$

Where,

$\gamma_p(XY)$  = Phenotypic correlations between traits X and Y in the same individual

N-2 = Degree of freedom

Statistical significance of correlations were tested by using 't-test'.

### **3.6 Single and Multiple Trait Model Analysis**

For estimation of (co)variance components using REML, the data were analyzed by WOMBAT program (Meyer, 2007) for single and multiple trait models. The details of different single and combinations of multiple traits are given below.

#### **3.6.1 First Lactation Single Trait**

1. Age at first calving (AFC)
2. First lactation length (FLL)
3. First calving interval – (FCI)
4. First lactation peak milk yield – (FLPMY)
5. FL 300-days milk yield – (FL300DMY)
6. Interval between first calving and first service – (CAFS)
7. Interval between first and last service after calving – (IFLS)
8. Interval between first calving and conception – (CACO)

#### **3.6.2 First Lactation Two-Trait Combinations**

1. FL 300DMY and AFC
2. FL300DMY and CAFS
3. FL300DMY and FCI
4. FL300DMY and IFLS
5. FL300DMY and CACO

#### **3.6.3 First Lactation Three-Trait Combinations**

1. FL300DMY, AFC and FCI
2. FL300DMY, IFLS and CACO
3. FL300DMY, FCI and CAFS

**a. Animal model**

$$\mathbf{Y} = \mathbf{Xb} + \mathbf{Zu} + \mathbf{e}$$

For three traits the model was expressed as :

$$\begin{pmatrix} Y_1 \\ Y_2 \\ Y_3 \end{pmatrix} = \begin{pmatrix} X_1 & 0 & 0 \\ 0 & X_2 & 0 \\ 0 & 0 & X_3 \end{pmatrix} \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} + \begin{pmatrix} Z_1 & 0 & 0 \\ 0 & Z_2 & 0 \\ 0 & 0 & Z_3 \end{pmatrix} \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \end{pmatrix} + \begin{pmatrix} e_1 \\ e_2 \\ e_3 \end{pmatrix}$$

Where,

**Y** = Vector of observations of traits under study

**b** = Vector of observations of unknown fixed effects of period and season

**u** = Vector of observations of unknown random effects (animals)

**X and Z** = Incidence matrices pertaining for fixed and random animal effect

respectively.

The following are the assumptions of the model:

$$E(\mathbf{Y}) = \mathbf{Xb}, \text{Var}(\mathbf{s}) = \mathbf{G}, \text{Var}(\mathbf{h}) = \mathbf{R} \text{ and } \text{Cov}(\mathbf{s}, \mathbf{e}') = 0 \text{ so that ,}$$

$$\text{V}(\mathbf{y}) = \mathbf{ZGZ}' + \mathbf{R}$$

The multi-trait combinations of various milk production and fertility traits are as below :-

**Table 3.1 Multi-trait combinations of first lactation traits along with their respective codes for BLUP animal model analysis**

Sr. No.	Trait combination	Code
<b>Two trait model</b>		
1.	FL 300DMY and AFC	MT2_1
2.	FL300DMY and CAFS	MT2_2
3.	FL300DMY and FCI	MT2_3
4.	FL300DMY and IFLS	MT2_4
5.	FL300DMY and CACO	MT2_5
<b>Three trait model</b>		
1.	FL300DMY, AFC and FCI	MT3_6
2.	FL300DMY, IFLS and CACO	MT3_7
3.	FL300DMY, FCI and CAFS	MT3_8

## Univariate analysis

In case of univariate analysis  $R = \sigma_e^2 I$  and the error variance was estimated directly from the residual sum of squares as:

$$\sigma_e^2 I = y'Py / [N - r(X)]$$

Hence, the likelihood can be maximized with respect to the remaining parameters expressed as a function of the original variances and  $\sigma_e^2$  dimension of search was reduced by one (Graser *et al.*, 1987 and Meyer, 1989).

### Maximizing likelihood

As described by Graser *et al.* (1987), the quadratic approximation method was used for single trait model which required on dimensional search. In the case of multiple-trait analysis Simplex method suggested by Nelder and Mead (1965) was used for maximization of likelihood.

### Convergence criteria

The convergence criteria was taken as the variance among the functions value; convergence was assumed when his variance was less than  $10^{-8}$ . In WOMBAT software package the default convergence criterion requires the square root of the sum of squared deviations in solutions between iterated divided by the sum of squared solutions to be less than  $10^{-8}$ .

## 3.7 Sire Evaluation

### 3.7.1 Least Squares Technique

The following fixed effect least squares model of Harvey (1990) was employed to estimate the breeding value of sires:

$$Y_{ijklm} = \mu + P_i + S_j + M_k + A_l + e_{ijklm}$$

Where,

$Y_{ijklm}$  = observations on the  $m^{\text{th}}$  progeny in  $i^{\text{th}}$  period of calving,  $j^{\text{th}}$  sire,  $k^{\text{th}}$  season of calving and  $l^{\text{th}}$  age of first calving group

$\mu$  = overall mean

$P_i$  = fixed effect of  $i^{\text{th}}$  period of calving ( $i = 1, 2, \dots, 7$ )

$S_j$  = fixed effect of  $j^{\text{th}}$  sire ( $j = 1, 2, \dots, n$ )

$M_k$  = fixed effect of  $k^{\text{th}}$  season of calving ( $k = 1, 2$  and  $3$ )

$A_l$  = fixed effect of  $l^{\text{th}}$  age of first calving group ( $l = 1, 2$  and  $3$ )

$e_{ijklm}$  = random error associated with NID  $(0, \sigma_e^2)$

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

$$\mathbf{I} = \boldsymbol{\mu} + \mathbf{S}_i$$

Where,

$\mathbf{I}$  = index of  $i^{\text{th}}$  sire

$\boldsymbol{\mu}$  = Population mean

$\mathbf{S}_i$  = Least squares constant of  $i^{\text{th}}$  sire

### 3.7.2 Best Linear Unbiased Prediction (BLUP)

The breeding value of sire using BLUP method was estimated under single and multi-trait models. In multi trait model two, three and four traits were considered simultaneously, only first lactation milk production trait was considered in combination with other traits. The REML estimate of genetic and residual (co) variance from the corresponding model was used in the formula.

The following general model was used

$$\mathbf{Y} = \mathbf{X}\mathbf{b} + \mathbf{Z}\mathbf{u} + \mathbf{e}$$

Where,

$\mathbf{Y}$  = Vector of observations for traits under study

$\mathbf{b}$  = Vector of observations of unknown fixed effects (periods of birth, season of calving, age)

$\mathbf{u}$  = Vector of observations of unknown random effects (sire)

$\mathbf{X}$  and  $\mathbf{Z}$  = Incidence matrices pertaining for fixed and random animal effect

The mixed model equation is

$$\begin{pmatrix} X^{0'}R^{-1}X^0 & X^0 \\ Z'R^{-1}X^0 & Z'R^{-1}Z + G^{-1} \end{pmatrix} \begin{pmatrix} \mathbf{b} \\ \boldsymbol{\mu} \end{pmatrix} = \begin{pmatrix} X^{0'}R^{-1}\mathbf{Y} \\ Z'R^{-1}\mathbf{Y} \end{pmatrix}$$

By solving the mixed model equations the BLUP breeding value of the random effects were obtained.

### 3.7.3 Simple Regressed Least Squares Technique (SRLS)

The simple regressed least squares technique (SRLS) was applied as per Harvey (1979) by using least squares analysis, as follows :

$$\hat{S}_i = \frac{V_s}{V_s + A^{ii} + V_e} \hat{s}_i$$

Where,

- $\hat{S}_i$  = Simplified regressed least squares estimate of  $i^{\text{th}}$  sire
- $A^{ii}$  = Diagonal element of inverse of coefficient matrix of  $i^{\text{th}}$  sire
- $V_S$  = Least squares variance component for sire
- $V_e$  = Least squares variance component for error
- $\hat{S}_i$  = Least squares constant for the  $i^{\text{th}}$  sire

The index of  $i^{\text{th}}$  sire was estimated as follows:

$$\text{Breeding value of } i^{\text{th}} \text{ sire} = \mu + \hat{S}_i$$

### 3.7.4 Restricted Maximum Likelihood Method (REML)

Restricted maximum likelihood method (REML) is a maximum likelihood method that accounts for the loss of degrees of freedom due to fitting fixed effects. The aim in REML is to find the sets of parameters which maximize the likelihood of the data. The data were analyzed to get REML estimates by **WOMBAT** (Meyer, 2007).

For REML estimation the following model was considered:

$$\mathbf{Y}_{ijk} = \mathbf{X}\mathbf{b}_i + \mathbf{Z}\mathbf{u}_j + \mathbf{e}_{ijk}$$

Where,

- $Y_{ijk}$  = Observation on  $k^{\text{th}}$  animal in  $i^{\text{th}}$  period of birth and  $j^{\text{th}}$  sire
- $b_i$  = Fixed effect of  $i^{\text{th}}$  period of birth
- $u_j$  = Random effect of  $j^{\text{th}}$  sire
- $e_{ijk}$  = Residual error associated with NID ( $0 \sigma_e^2$ )

X and Z are incidence matrices pertaining to b and u.

### 3.8 Effectiveness of Various Sire Evaluation Methods

The effectiveness of different sire evaluation methods was judged by using the following criteria within sire variance or error variance:

The method giving the lowest error variance was higher efficiency and would be most appropriate.

The efficiency was measured by following formula :

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

Relative efficiency (RE) of method II with respect to method I (most efficient method) were calculated by the following equations :

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

**a. Coefficient of determination**

The coefficient of determination ( $R^2$ -value) of different models was estimated for judging the effectiveness of sire evaluation methods. The model with the higher  $R^2$  value was considered as most accurate.

**b. Rank correlations**

The correlations between the rankings of the sires based on their breeding values estimated by the above methods were tested by using Spearman's rank correlation method (Spearman, 1904), as follows :

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

Where,

R = Rank correlation coefficient

N = Number of sires under evaluation

$d_i$  = Difference of rank between paired items under two methods

The significance of rank correlation was tested by t-test with  $n-2$  degrees of freedom as given below :

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

**3.9 Estimation of Performance Trends**

**3.9.1 Phenotypic Trend**

The phenotypic trends for each trait was calculated by taking regression of performance of the population on the year as :

$$\Delta P = b_{P,T} = \frac{\sum Pt}{\sum t}$$

Where,

$b_{P,T}$  = Linear regression of population performance (P) on time (year) of calving (T)

$\sum Pt$  = Corrected sum of products for trait (P) and time (T)

$\sum t$  = Corrected sum of squares for time taken as deviation from its mean

### 3.9.2 Genotypic Trend

The following methods were used for estimation of genotypic trends:

1. Smith (1962) Method II
2. BLUP (Best linear unbiased prediction) method (1978)

#### a. Smith's method II

The procedure utilizes the fact that progeny of sires in several years provides some continuity of genotypes over years from which the genetic change may be estimated. Annual change in performance consists of two parts *viz.*

$\hat{g}$  = Genetic trends

$\hat{t}$  = Environmental trends

When sires were used over several years, their genetic contribution to the daughters was the same for all years. Therefore, the genetic change from sire side was zero. Other half of genotype was contributed by changing group of females to which the sire is mated in his first, second and subsequent years of service. Hence, comparison of performance of paternal sisters calving in continuous years should indicate  $t + \frac{1}{2}g$ . Thus smith's methods based on following expectation:

$$E(b_{P,T}) = g + t$$

$$E(b_{P,T/S}) = 0.5g + t$$

$$E(b_{(P-\bar{P}),T/S}) = -0.5g$$

Where,

$b_{P,T}$  = Regression of population performance on time

$b_{P,T/S}$  = Within sire regression of progeny performance on time

$b_{(P-\bar{P}),T/S}$  = Within sire regression of progeny performance on time record being deviated from population mean.

Estimation of genetic trends can be obtained by combining the above expectations to give two estimates of trends as:

$$g = -2(b_{(P-\bar{P}),T/S})$$

**b. BLUP**

The estimated transmitting ability (ETA) of sire is half of additive genetic value and therefore genetic trends was obtained as 2 times regression of weighted average of sire's transmitting abilities (WAETA) for each year on year as follows :

$$WAETA = \sum n_{ik} \hat{S}_i / n.k$$

Where,

$n_{ik}$  = Number of daughters of sire i (i= 1, 2, ..., m) in k<sup>th</sup> year

$\hat{S}_i$  = Estimated transmitting ability (ETA) of sire i<sup>th</sup>

$n.k$  = Number of daughters of m sires in the k<sup>th</sup> year

The transmitting ability is half of the breeding value and the breeding values was estimated by BLUP (best linear unbiased prediction) method by solving the mixed model equations.

**3.9.3 Environmental Trends**

Environmental trend ( $\Delta E$ ) was obtained by subtracting the genetic trend ( $\Delta G$ ) from the overall phenotype trend ( $\Delta P$ )

$$(\Delta E) = (\Delta P) - (\Delta G)$$

The standard error of environmental trend,  $SE(\Delta E)$  as:

$$SE(\Delta E) = \sqrt{SE(\Delta P)^2 + SE(\Delta G)^2}$$

Estimates of genetic trends obtained by the two methods were compared by their standard errors.

## 4. RESULTS AND DISCUSSION

The results obtained in the present investigation entitled, “Genetic evaluation of HF x Gir halfbred sires using fertility and milk production traits” are presented and discussed in this chapter.

The data on production (FLPMY, FL300DMY and FLL) and fertility traits (AFC, FCI, CAFS, IFLS and CACO) were utilized to estimate (co) variance components and genetic parameters and to evaluate sires using single trait (fitting ANOVA) and multiple trait animal models fitting REML by WOMBAT software (Meyer, 2007). The estimated genetic parameters and breeding values were compared among various models used. The results of the present study have been presented under the following headings in accordance with the objectives:

- 4.1 First Lactation Milk Production and Fertility Traits And Factors Affecting Them
- 4.2 Estimates of Genetic and Phenotypic Parameters Under Single Trait and Multiple Trait Animal Models of First Lactation
- 4.3 Least-Squares Means of Milk Production and Fertility Traits and Factors Affecting Them
- 4.4 Genetic and Environmental Trends of First Lactation Production and Fertility Traits
- 4.5 Sire Evaluation under Single Trait and Multiple Trait Animal Models
- 4.6 Comparison of Effectiveness of Different Sire Evaluation Methods
- 4.1 First Lactation Fertility and Production Traits and Factors Affecting Them**

The estimates of variance components and least squares means of different traits obtained from the LSML were used for further computations and presented in Table 4.1, Table 4.2 and Table 4.3, respectively.

**Table 4.1 ANOVA of age at first calving as affected by genetic and non-genetic factors in HF x Gir halfbred**

Source of variation	Mean sum of squares (AFC)
Period of birth	527377.82**
Season of birth	10639.42
Sire	10798.38*
Error	9892.39

\*P<0.05 and \*\*P<0.01

**Table 4.2 Least squares means of age at first calving as affected by various factors in HF x Gir halfbred**

Factors	N	Mean $\pm$ S.E
<b>Overall mean</b>	403	940.05 $\pm$ 5.85
<b>Periods of birth</b>		
P <sub>1</sub> (1974-1980)	163	806.69 $\pm$ 7.85 <sup>c</sup>
P <sub>2</sub> (1981-1987)	60	914.88 $\pm$ 12.85 <sup>b</sup>
P <sub>3</sub> (1988-1994)	51	957.64 $\pm$ 14.02 <sup>b</sup>
P <sub>4</sub> (1995-2000)	64	991.38 $\pm$ 12.44 <sup>a</sup>
P <sub>5</sub> (2001-2008)	41	1000.42 $\pm$ 15.60 <sup>a</sup>
P <sub>6</sub> (2009 and above)	24	969.43 $\pm$ 20.40 <sup>a</sup>
<b>Season of birth</b>		
S <sub>1</sub> Rainy	131	946.00 $\pm$ 9.49
S <sub>2</sub> Winter	146	929.92 $\pm$ 8.85
S <sub>3</sub> Summer	126	944.24 $\pm$ 9.25

Note : Means under each class in the same column with different superscripts differ significantly

#### 4.1.1 Age at first calving

The AFC is an important economic trait in dairy cows and genetic improvement for lowering AFC is desirable for reducing unproductive period, culling uneconomic animals at an early age and increasing their lifetime milk production. Such an improvement could only be brought about, firstly by knowing accurate magnitude of the AFC, its heritable fraction or variance and planning an appropriate selection system which can be adopted for achieving the desired goal.

The overall least squares means of age at first calving in HF x Gir halfbred cows was 940.05  $\pm$  5.85 days. Almost similar estimates of average AFC were observed by Jadhav and Khan (1996), Sahana (1996), Panja (1997), Mukharjee (2005) and Rathi (2015) in HF crossbred cattle. The present results were higher than Bhoite (1996) reported in JG halfbred. However, the age at first calving was lower than Thombare *et al.* (2002) observed in HF x D halfbreds and Dubey and Singh (2005) in Sahiwal crossbred.

##### a. Effect of period of birth

The period of birth was found to have significant ( $P < 0.01$ ) influence on AFC in HF x Gir halfbred (Table 4.1). The difference in age at first calving of cows born during period P<sub>4</sub>, P<sub>5</sub> and P<sub>6</sub> were at par with each other and significantly higher than cows

born in P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> periods (Table 4.2). Similar results were reported by Singh *et al.* (2014) and Rathi (2015) in Frieswal cattle. The differences in AFC during different periods may be due to reason that feeding and management practices of young stock varied from year to year and young stock raised during the year of better nutrition grew faster than others.

#### b. Effect of season of birth

The influence of season of birth on age at first calving of HF x Gir halfbred was non significant. The highest age at first calving (days) was observed in heifers born during rainy season ( $946.00 \pm 9.49$ ) followed by summer ( $944.24 \pm 9.25$ ) and winter ( $929.92 \pm 8.85$ ) season. These results were in agreement with Bhoite (1996), Shinde (2010), Mukharjee (2005) and Singh *et al.* (2014) reported in HF crossbred cattle. Whereas, contradictory results were noticed by Akhtar *et al.* (2003), PDC AR (2003-04) and Dubey and Singh (2005) in different crossbred cattle.

#### c. Effect of sire

The effect of sire on AFC was significant ( $P < 0.05$ ). The significant effect of sire on AFC was also reported by Jadhav (1990) in HF x SW cattle, Akhtar *et al.* (2003) in 5/8 HF x 3/8 SW cattle, Singh *et al.* (2014) in Frieswal and Ambhore *et al.* (2017) in Phule Triveni cattle.

**Table 4.3 ANOVA of various first lactation production traits as affected by genetic and non-genetic factors in HF x Gir halfbred**

Source of variation	Traits	Mean sum of squares		
		FL300DMY	FLPMY	FLL
Period of calving		5488652.63**	28.98**	278.30
Season of calving		185220.20	0.63	178.18
Age at first calving group		47868.43	1.85	22.99
Sire		437426.13*	6.69*	894.51
Error		378267.73	7.48	893.25

\* $P < 0.05$  and \*\*  $P < 0.01$

**Table 4.4 Least squares means ( $\pm$  SE) of first lactation milk production traits of HF x Girhalfbred**

Factors	N	FL300DMY (kg)	FLPMY (kg)	FLL (days)
		Mean $\pm$ S.E	Mean $\pm$ S.E	Mean $\pm$ S.E
Overall mean	403	2780.17 $\pm$ 37.31	15.28 $\pm$ 0.16	326.77 $\pm$ 1.81
<b>Periods of calving</b>				
P <sub>1</sub> (1974-1980)	163	3279.70 $\pm$ 70.83 <sup>a</sup>	16.23 $\pm$ 0.31 <sup>a</sup>	325.10 $\pm$ 3.44 <sup>bc</sup>
P <sub>2</sub> (1981-1987)	60	2907.82 $\pm$ 80.40 <sup>b</sup>	14.76 $\pm$ 0.35 <sup>bc</sup>	328.83 $\pm$ 3.90 <sup>b</sup>
P <sub>3</sub> (1988-1994)	51	2431.92 $\pm$ 87.58 <sup>c</sup>	14.44 $\pm$ 0.39 <sup>c</sup>	325.15 $\pm$ 4.25 <sup>bc</sup>
P <sub>4</sub> (1995-2000)	64	2587.11 $\pm$ 81.01 <sup>bc</sup>	15.05 $\pm$ 0.36 <sup>b</sup>	327.57 $\pm$ 3.93 <sup>c</sup>
P <sub>5</sub> (2001-2008)	41	2715.49 $\pm$ 100.4 <sup>bc</sup>	15.64 $\pm$ 0.44 <sup>b</sup>	330.63 $\pm$ 4.87 <sup>a</sup>
P <sub>6</sub> (2009 and above)	24	2758.97 $\pm$ 126.4 <sup>bc</sup>	15.56 $\pm$ 0.56 <sup>b</sup>	323.36 $\pm$ 6.14 <sup>bc</sup>
<b>Season of birth</b>				
S <sub>1</sub> Rainy	131	2773.79 $\pm$ 59.90	15.20 $\pm$ 0.26	325.46 $\pm$ 2.90
S <sub>2</sub> Winter	146	2745.85 $\pm$ 55.73	15.30 $\pm$ 0.24	327.05 $\pm$ 2.70
S <sub>3</sub> Summer	126	2820.86 $\pm$ 57.87	15.34 $\pm$ 0.25	327.81 $\pm$ 2.81
<b>Age group</b>				
A1 (< 950 days)	226	2790.38 $\pm$ 62.56	15.42 $\pm$ 0.27	326.84 $\pm$ 3.04
A2 (951-1050 days)	72	2751.96 $\pm$ 74.94	15.11 $\pm$ 0.33	327.28 $\pm$ 3.64
A3 (1051 days and above)	105	2798.16 $\pm$ 66.14	15.31 $\pm$ 0.29	326.20 $\pm$ 3.21

#### 4.1.2 First Lactation 300DMY

The milk yield is the basic and most important economic trait on which the whole economy of dairying is based. The FL300DMY provides most efficient measure to assess the inherent capacity of an individual and indicate the breeding value of a dairy animal accurately. Therefore, it has been internationally agreed that the milk yield during first 300 days after calving be considered for comparison of production performance of dairy cattle

The least squares mean of FL300DMY in HF x Gir halfbred was 2780.17  $\pm$  37.31 kg (Table 4.3). The present results were in consonance with the reports of Saha (2001) reported in Karan Fries and Shelke (2012) and Ambhore *et al.* (2017) in Phule Triveni cattle. Rathi (2015) found higher estimates (3292.61  $\pm$  53.6 kg) in Frieswal cattle. The differences in the estimates of average FL300DMY reported by many researchers

could have been due to sampling variations, as different studies were based on small and different number of observations or herd to herd differences or differences that might have occurred over time depending on the period to which the data pertained.

**a. Effect of period of calving**

The analysis of variance showed that the period of calving had significant ( $P < 0.01$ ) effect on FL300DMY (Table 4.3). The DMRT revealed that the 300 days milk yield of cows calved during  $P_1$  ( $3279.70 \pm 70.83$  kg) was significantly higher than those calved in  $P_2$  to  $P_6$  period. The 300 days milk yield recorded during period  $P_3$ ,  $P_4$ ,  $P_5$  and  $P_6$  were at par with each other. The present results were in accordance with the reports of Saha (2001), Annual Report, PDC(2003-04), Mukharjee (2005), Kokate (2009), Shelke (2012) and Ambhore (2017) reported in various crossbreds. However, Singh and Gurnani (2004), Nehra (2011) and Divya (2012) reported non significant effect of period of calving on FL305DMY.

**b. Effect of season of calving**

The influence of season of calving on 300 days milk yield was found to be non significant in HF x Gir halfbred cows. It may hence be deduced that the milch stock was maintained under optimum management conditions round the year. The non significant effect of season of calving on FL300DMY was also reported by many workers (Rashia, 2010, Nehra, 2011 and Divya, 2012) in KF cattle. Contrary to the present results, significant effect of season of calving on FL300DMY had been documented by Singh and Gurnani (2004), Mukharjee (2005), Kokate (2009) and Rathi (2015) in different crossbred cattle. The cows calved during summer season ( $2820.86 \pm 57.87$  kg) had higher 300 days milk yield than winter ( $2745.85 \pm 55.73$  kg) and rainy season ( $2773.79 \pm 59.90$  kg). However, the differences between different seasons were not statistically significant.

**c. Effect of age at first calving group**

The least squares analysis revealed that the AFC group had non-significant effect on FL300DMY (Table 4.4). Similar results were reported by Singh (1995), Panja (1997) and Divya (2012) in KF cattle. However, significant effect of AFC on the FL300DMY was noticed by Saha (2001) in KF cattle, Annual Report PDC (2003-04) and Mukharjee (2005) in Frieswal cattle.

#### **d. Effect of sire**

Significant variation ( $P < 0.05$ ) due to sire was observed in FL300DMY in HF x Gir halfbred (Table 4.3). These results corroborated with the results of Mukharjee (2005), Nehra (2011) and Divya (2012) in Frieswal and Karanfries cattle and Ambhore *et al.* (2017) in Phule Triveni cattle.

However, Pol *et al.* (2013) and Gaikwad (2010) observed non significant effect of sire on FL300DMY in Phule Triveni cow.

#### **4.1.3 First lactation peak milk yield**

As the first lactation yield becomes available at an early age and has high correlation with later lactation yield, it gives an indication on genetic potential of animals. However, as the milk producing ability is influenced by a number of genetic and non genetic factors as well, the use of information on first lactation production is essential for bringing about genetic improvement through selection.

The overall least squares mean of FLPMY was  $15.28 \pm 0.16$ kg (Table 4.4). Almost similar estimates of average FLPMY were observed by Saha (2001) in KS cattle, Akhtar *et al.* (2003) in HF x S crossbred, Kumar *et al.* (2008) in Frieswal, Rasia *et al.* (2009) in KF cattle and Ambhore *et al.* (2017) in Phule Triveni cattle. However, Singh *et al.* (2008) in HF x S crossbred, Nehra (2011) and Dash (2014) in KF cattle reported higher estimate of FLPMY. The difference in average FLPMY reported by many researchers may be attributed to difference in breeds used for crossing, herds, reproductive management strategies and time/ period considered.

#### **a. Effect of period of calving**

The effect of period of calving on FLPMY was significant ( $P < 0.01$ ). Similar result was reported by Mukharjee (2005), Kumar *et al.* (2008) and Rathi (2015) in Frieswal cattle. However, Nehra (2011) in Karan Fries and Radhika *et al.* (2012) in HF crossbred reported non-significant effect. The highest FLPMY ( $16.23 \pm 0.31$  kg) was recorded during P<sub>1</sub> (1974-1980) and the lowest ( $14.44 \pm 0.39$  kg) during P<sub>3</sub> (1988-1994). The DMRT revealed that the FLPMY recorded during period P<sub>4</sub>, P<sub>5</sub> and P<sub>6</sub> was at par with each other. The results indicated that FLPMY gradually declined from cows calved during P<sub>1</sub> to P<sub>3</sub>.

#### **b. Effect of season of calving**

The influence of season of calving on FLPMY was non significant (Table 4.3). The first lactation peak milk yield (Table 4.4) was highest ( $15.34 \pm 0.25$  kg) in summer calvers followed by winter ( $15.30 \pm 0.24$  kg) and rainy season ( $15.20 \pm 0.26$  kg) calvers. The non-significant effect of season of calving on first lactation peak milk yield was reported by Singh *et al.* (2008) in HF x SW crossbred, Chavan (2010) in HF x Gir halfbred and their interbreeds and Radhika *et al.* (2012) in HF crossbred. However, significant effect of season of calving on FLPMY was observed by Bhoite (1996), Kale *et al.* (2001), Mukharjee (2005) in Frieswal and Nikam (2010) in Phule Triveni cows.

#### **c. Effect of age at first calving group**

The least squares analysis revealed that the age at first calving had non significant effect on the FLPMY (Table 4.3). Similar to the present findings, Saha (2001) and Nehra (2011) reported non significant effect of AFC on FLPMY in KS and KF cattle, respectively. However, Sahana and Gurnani (2000) and Saha (2001) in KF cattle; Akhtar *et al.* (2003) in HF x S and Mukharjee (2005) in Frieswal cattle observed significant variation in FLPMY due to the age at first calving.

#### **d. Effect of sire**

Least-squares ANOVA revealed significant ( $P < 0.05$ ) variation due to sire in FLPMY (Table 4.3). Hadge *et al.* (2009) reported significant ( $P < 0.01$ ) effect of sire on FLPMY in Sahiwal x Jersey crossbred cattle at Bull Mother Farm, Wadsa, District Gadchiroli (M.S.). While, Ambohre *et al.* (2017) observed non significant effect of sire in Phule Triveni.

#### **4.1.4 First lactation length**

The value of a milch breed to the practical dairyman is dependent not only upon the quantity of milk the cow gives, but also upon the number of days she remains in milk. Milk production in lactation generally increases with an increase in lactation length. A lactation length of more than 305 days is not optimum as it amounts to enhanced calving interval. A shorter duration also cannot be beneficial as it would not be possible to reduce inter calving period to less than one year.

The overall least-squares mean of FLL in HF x Gir halfbred was  $326.77 \pm 1.81$  days (Table 4.4). The estimate obtained in the present study was in close agreement

with those reported by Saha (2001) in KF cattle and Mukharjee (2005) and Kumar *et al.* (2008) in Frieswal. However, various other workers (Deokar, 2003; PDCAR, 2003-04; Nehra *et al.*, 2011 and Ambhore *et al.*, 2017) reported higher estimates of FLL than obtained in the present study.

**a. Effect of period of calving**

The difference due to period of calving in FLL was non-significant. The highest ( $330.63 \pm 4.87$  days) FLL was recorded in cows calved during P5(2001-2008) and lowest ( $323.36 \pm 6.14$  days) calved during P6 (2009-2017). Similar results were noticed by Saha (2001) and Akhtar *et al.* (2003) in different HF crossbred cattle. While, Mukharjee (2005), Kumar *et al.* (2008), Nehra (2011) and Dash (2014) reported significant effect of period of calving on FLL in different HF crossbred cattle.

**b. Effect of season of calving**

The effect of season of calving on FLL was non significant (Table 4.3). The highest FLL was recorded in calves calved during summer ( $327.81 \pm 2.81$ ) and lowest ( $325.46 \pm 2.91$  days) calved during rainy season. The non-significant effect of season of calving on FLL observed in the present study was in agreement with Saha (2001) in KF, Akhtar *et al.* (2003) in 5/8 HF x 3/8 SW and Saha *et al.* (2010) in KF. However, Bhoite *et al.* (1999), Singh (1995), Sahana (1996), Sahana and Gurnani (2000), PDC AR (2003-04) and Mukharjee (2005) reported significant effect of season of calving on FLL in different HF crossbred cattle.

**c. Effect of age at first calving group**

The influence of AFC group on the FLL was found to be statistically non significant (Table 4.3). It was apparent from the results that there was no much variation in FLL among the cows of different AFC groups. The non significant effect of AFC on FLL in different HF crossbred cattle was also noted by Saha (2001), PDC AR (2003-04) and Nehra *et al.* (2011) in KF cattle. However, Mukharjee (2005), Rathi (2015) in Frieswal and Ambhore *et al.* (2017) reported significant ( $P < 0.05$ ) effect of AFC group on FLL in Phule Triveni cattle.

**d. Effect of sire**

Least-squares ANOVA showed non significant variation due to sire in FLL (Table 4.3). The results were inconsonance with Akhtar *et al.* (2003) and Ambhore

*et al.* (2017) noticed in 5/8 HF x 3/8 SW and Phule Triveni cattle, respectively. The results of present study were not in agreement with Mukharjee (2005) observed in Frieswal and Hadge *et al.* (2009) in Jersey x Sahiwal crossbred cows.

**Table 4.5 ANOVA of various first lactation fertility traits as affected by genetic and non-genetic factors of HF x Gir halfbred**

Source of variation	Traits	Mean sum of squares			
		FCI	CAFS	IFLS	CACO
Period of calving		2395.12	7.24	1344.49**	218.65
Season of calving		1264.69	56.53	109.67	41.97
Age at first calving group		4686.01	24.45	99.94	833.70
Sire		2829.64	216.64*	195.19	761.26
Error		3164.64	198.54	227.32	980.46

\*P < 0.05 and \*\* P < 0.01

**Table 4.6 Least squares means of first lactation fertility traits of HF x Girhalfbred**

Factors	n	FCI (days)	CAFS (days)	IFLS (days)	CACO (days)
		Mean $\pm$ S.E	Mean $\pm$ S.E	Mean $\pm$ S.E	Mean $\pm$ S.E
Overall mean	403	408.38 $\pm$ 3.41	72.71 $\pm$ 0.85	64.22 $\pm$ 2.10	85.19 $\pm$ 1.90
<b>Periods of calving</b>					
P <sub>1</sub> (1974-1980)	163	405.94 $\pm$ 6.47	72.28 $\pm$ 1.62	60.68 $\pm$ 3.35 <sup>bc</sup>	86.41 $\pm$ 3.60
P <sub>2</sub> (1981-1987)	60	398.43 $\pm$ 7.35	73.10 $\pm$ 1.87	68.68 $\pm$ 5.45 <sup>b</sup>	82.74 $\pm$ 4.09
P <sub>3</sub> (1988-1994)	51	405.06 $\pm$ 8.01	72.19 $\pm$ 2.00	71.17 $\pm$ 5.82 <sup>b</sup>	82.65 $\pm$ 4.45
P <sub>4</sub> (1995-2000)	64	415.69 $\pm$ 7.41	72.74 $\pm$ 1.85	74.81 $\pm$ 5.06 <sup>a</sup>	84.90 $\pm$ 4.12
P <sub>5</sub> (2001-2008)	41	418.54 $\pm$ 9.18	72.99 $\pm$ 2.30	69.74 $\pm$ 5.42 <sup>b</sup>	86.25 $\pm$ 5.11
P <sub>6</sub> (2009 -2017)	24	406.61 $\pm$ 11.5	72.99 $\pm$ 2.89	40.22 $\pm$ 3.34 <sup>c</sup>	88.20 $\pm$ 6.43
<b>Season of birth</b>					
S <sub>1</sub> Rainy	131	405.40 $\pm$ 5.47	73.23 $\pm$ 1.37	61.90 $\pm$ 3.86	84.91 $\pm$ 3.05
S <sub>2</sub> Winter	146	411.53 $\pm$ 5.09	72.97 $\pm$ 1.27	66.41 $\pm$ 2.96	86.33 $\pm$ 2.83
S <sub>3</sub> Summer	126	408.21 $\pm$ 5.29	71.95 $\pm$ 1.32	64.34 $\pm$ 3.36	84.33 $\pm$ 2.94
<b>Age group</b>					
A1 (< 950 days)	226	400.94 $\pm$ 5.72	72.07 $\pm$ 1.43	63.80 $\pm$ 3.26	81.94 $\pm$ 3.18
A2 (951-1050 days)	72	416.41 $\pm$ 6.85	73.00 $\pm$ 1.71	67.06 $\pm$ 4.13	88.48 $\pm$ 3.81
A3 (1051 days and above)	105	407.78 $\pm$ 6.05	73.07 $\pm$ 1.51	65.33 $\pm$ 3.84	85.15 $\pm$ 3.36

Means under each class in the same column with different super scripts differ significantly

#### 4.1.5 First calving interval

Calving interval is an important reproductive trait which directly influences the economy of the dairy farm. Too short calving interval reduces the milk production in both the current and succeeding lactations. Whereas, too long calving interval reduces the lifetime milk production. The service period significantly influences the calving interval and a calf every year will help in rapid multiplication of superior genetic material as well as increase in the efficiency of a dairy farm.

The overall mean calving interval of Gir halfbred recorded at the farm was  $408.38 \pm 3.41$  days. The longer calving interval than the present results was reported by Thombre *et al.* (2002) in HF x Deoni crossbreds ( $457.12 \pm 4.97$ ) and Rathi (2015) in Frieswal ( $432.92 \pm 3.92$ ). However, shorter calving interval was observed by Deokar *et al.* (2005) in HF x Gir and Jersey x Gir halfbreds ( $401.03 \pm 15.20$  days).

##### a. Effect of period of calving

The analysis of variance showed non significant influence of period of calving on calving interval in Gir halfbred (Table 4.5). Non significant effect of period of calving on FCI was supported by Saha (2001) in KF and Akhtar *et al.* (2003) in 5/8 HF x 3/8 SW crossbred cattle.

On the contrary the significant effect of period of calving on calving interval was noted by Mukharjee (2005) in Frieswal, Nehra (2011) in KF, Rathi (2015) in Frieswal and Ambhore *et al.* (2017) in Phule Triveni.

The first calving interval of cows calved in period P<sub>5</sub> ( $418.54 \pm 9.18$  days) was highest and the lowest calving interval was noticed in P<sub>2</sub> ( $398.43 \pm 7.35$  days) period.

##### b. Effect of season of calving

The results indicated non significant variation due to season of calving in calving interval. The first calving interval of cows calved in season S<sub>2</sub> winter ( $411.53 \pm 5.09$  days) was highest and the lowest calving interval was noticed in S<sub>1</sub> rainy ( $405.40 \pm 5.47$  days) season. These results were in accordance with Nehra (2011) in KF, Rathi (2015) in Frieswal and Ambhore *et al.* (2017) in Phule Triveni. However, significant effect was reported by Saha (2001), Akhtar *et al.* (2003), Mukharjee (2005) and Dash (2014) in various crossbreds.

**c. Effect of age at first calving group**

The effect of age at first calving group was found to be non-significant on FCI (Table 4.5). The first calving interval of cows calved in AFC group A<sub>2</sub> (961-1050 days) was highest ( $416.81 \pm 6.85$  days) and the lowest calving interval ( $400.94 \pm 5.72$ ) was noticed in A<sub>1</sub> (< 950 days)  $400.94 \pm 5.72$  days. Similar, non-significant effect of age at first calving group on FCI was reported by Singh (1995), Saha (2001), Nehra (2011) in Karan Fries cattle and Ambhore *et al.* (2017) in Phule Triveni cattle. However, significant effect of age at first calving group on FCI was observed by Rathi (2015) in Frieswal cattle.

**d. Effect of sire**

The difference due to sire in FCI was found to be statistically non-significant in HF x Gir halfbred. The non significant effect of sire on FCI was reported by Saha (2001), Nehra (2011) in Karan Fries cattle, Akhtar *et al.* (2003) in 5/8 HF + 3/8 SW and Ambhore *et al.* (2017) in Phule Triveni cattle

**4.1.6 Interval between calving and first service (CAFS)**

As the first lactation yield becomes available at an early age and has high correlation with later lactation yield, it gives an indication on genetic potential of animals. However, as the milk producing ability is influenced by a number of genetic and non- genetic factors as well, the use of information on interval between first calving and first service is essential for bringing about genetic improvement through selection.

The overall least squares mean for CAFS was  $72.71 \pm 0.85$  days (Table 4.6) which was well within the range of earlier studies reported in crossbred cattle. Almost similar estimates of average CAFS were observed by Saha (2001) in KS cattle, Akhtar *et al.* (2003) in HF x S crossbred, Kumar *et al.* (2008) in Frieswal, Rashia *et al.* (2009) in KF cattle and Ambhore *et al.* (2017) in Phule Triveni cattle. However, Singh *et al.* (2008) in HF x S crossbred, Nehra (2011) and Dash (2014) in KF cattle reported higher estimate of CAFS in crossbred cattle.

**a. Effect of period of calving**

The effect of period of calving on CAFS was non-significant. Similar result was reported by Mukharjee (2005), Kumar *et al.* (2008) and Rathi (2015) in Frieswal cattle. However, Nehra (2011) in Karan Fries and Radhika *et al.* (2012) in HF

crossbred reported non significant effect. The highest CAFS ( $73.10 \pm 1.87$  days) was recorded during P2 (1814-1987) and the lowest ( $72.28 \pm 1.62$  days) during P1 (1974-1980). The DMRT revealed that the CAFS recorded during period P<sub>4</sub>, P<sub>5</sub> and P<sub>6</sub> was at par with each other.

**b. Effect of season of calving**

The influence of season of calving on CAFS was non significant (Table 4.5). The interval between calving and first service (Table 4.6) was highest ( $73.23 \pm 1.37$  days) in rainy season calvers. followed by winter ( $72.97 \pm 1.27$  days) and ( $71.95 \pm 1.32$ ) summer calvers . The non significant effect of season of calving on interval between calving and first service was reported by Singh *et al.* (2008) in HF x SW crossbred, Chavan (2010) in HF x Gir halfbred and their interbreeds and Radhika *et al.* (2012) in HF crossbred. However, significant effect of season of calving on CAFS was observed by Kale *et al.* (2001), Mukharjee (2005) in Frieswal and Nikam (2010) in Phule Triveni cows.

**c. Effect of age at first calving group**

The least squares analysis revealed that the age at first calving had non significant effect on CAFS (Table 4.5). Similar to the present results, Saha (2001) and Nehra (2011) reported non significant effect of AFC on CAFS in KS and KF cattle, respectively. However, Sahana and Gurnani (2000) and Saha (2001) in KF cattle, Akhtar *et al.* (2003) in HF x S and Mukharjee (2005) in Frieswal cattle showed significant variation in CAFS due to the age at first calving. The highest CAFS was found in A2 group i.e. 951-1050 days ( $73.07 \pm 1.51$ 951-1050 days) and lowest in A 1 < 950 i.e. days ( $72.07 \pm 1.43$ days).

**d. Effect of sire**

Least-squares ANOVA indicated significant ( $P < 0.05$ ) variation due to sire in CAFS (Table 4.4). Hadge *et al.* (2009) reported significant ( $P < 0.01$ ) effect of sire on CAFS in Sahiwal x Jersey crossbred cattle, While, Ambohre *et al.* (2017) observed non significant effect of sire in Phule Triveni.

**4.1.7 Interval between first and last service (IFLS)**

The value of a milch breed to the practical dairyman is dependent not only upon the quantity of milk the cow gives, but also upon the number of days she remains in

milk. Milk production in lactation generally increases with decreases in IFLS. Interval between first and last service is more than 60 days is not optimum as it amounts to enhanced calving interval. A shorter duration also cannot be beneficial as it would not be possible to reduce inter calving period to less than one year.

The overall least-squares mean of IFLS in HF x Gir halfbred was  $64.22 \pm 2.10$  days (Table 4.6). The estimate obtained in the present study was in close agreement with those reported by Saha (2001) in KF cattle and Mukharjee (2005) and Kumar *et al.* (2008) in Frieswal. However, various other workers (Deokar, 2003; PDCAR, 2003-04; Nehra *et al.*, 2011 and Ambhore *et al.*, 2017) noticed higher estimates of IFLS than obtained in the present study.

**a. Effect of period of calving**

The difference due to period of calving in IFLS was significant ( $P < 0.01$ ). The highest ( $74.81 \pm 5.06$  days) IFLS was recorded during P4 (1995-2000) and lowest ( $40.22 \pm 3.34$  days) during P6 (2009 and above). The similar results were noticed by Saha (2001) and Akhtar *et al.* (2003) in different HF crossbred cattle. While, Mukharjee (2005), Kumar *et al.* (2008), Nehra (2011) and Dash (2014) reported non-significant effect of period of calving on IFLS in different HF crossbred cattle.

**b. Effect of season of calving**

The effect of season of calving on IFLS was non significant (Table 4.4). The highest IFLS was recorded in calves calved during winter ( $66.41 \pm 2.96$  days) and lowest ( $61.90 \pm 3.86$  days) during rainy. The non-significant effect of season of calving on IFLS was also observed by Saha (2001) in KF, Akhtar *et al.* (2003) in 5/8 HF x 3/8 SW and Saha *et al.* (2010) in KF. However, Bhoite *et al.* (1999), Singh (1995), Sahana (1996), Sahana and Gurnani (2000), PDC AR (2003-04) and Mukharjee (2005) reported significant effect of season of calving on IFLS in different HF crossbred cattle.

**c. Effect of age at first calving group**

The influence of AFC group on the IFLS was found to be statistically non-significant (Table 4.5). It was apparent from the results that there was no much variation in IFLS among the cows of different AFC groups. The non significant effect of AFC on IFLS in different HF crossbred cattle was also noted by Saha (2001), PDC AR (2003-04) and Nehra *et al.* (2011) in KF cattle. However, Mukharjee (2005), Rathi (2015) in

Frieswal and Ambhore *et al.* (2017) reported significant ( $P < 0.05$ ) effect of AFC group on IFLS in Phule Triveni cattle.

**d. Effect of sire**

Least-squares ANOVA showed non significant effect of sire on FLL (Table 4.5). These results were in consonance with Akhtar *et al.* (2003) and Ambhore *et al.* (2017) noted in 5/8 HF x 3/8 SW and Phule Triveni cattle, respectively. The results of present study were not in agreement with Mukharjee (2005) observed in Frieswal and Hadge *et al.* (2009) in Jersey x Sahiwal crossbred cows.

**4.1.8 Interval between first calving and conception (CACO)**

The milk yield is the basic and most important economic trait on which the whole economy of dairying is based. The interval between first calving and conception provides most efficient measure to assess the inherent capacity of an individual and indicate the breeding value of a dairy animal accurately.

The least squares mean of CACO in HF x Gir halfbred was  $85.19 \pm 1.90$  days (Table 4.4). The present results were in accordance with the reports of Saha (2001) in Karan Fries and Shelke (2012) and Ambhore *et al.* (2017) in Phule Triveni cattle. Rathi (2015) found higher estimates ( $96.19 \pm 1.57$  days) in Frieswal cattle. The differences in the estimates of average CACO reported by many researchers could have been due to sampling variations, as different studies were based on small and different number of observations or herd to herd differences or differences that might have occurred over time depending on the period to which the data pertained.

**a. Effect of period of calving**

The analysis of variance showed that the period of calving had non-significant effect on CACO days (Table 4.5). The results revealed that the highest CACO was found in calves calved during P<sub>6</sub> ( $88.20 \pm 6.43$  days) and lowest in P<sub>3</sub> ( $82.65 \pm 4.45$  days). The present result was in accordance with the reports of Saha (2001), Annual Report, PDC(2003-04), Mukharjee (2005), Kokate (2009), Shelke (2012) and Ambhore (2017) noticed in various crossbreds. However, Singh and Gurnani (2004), Nehra (2011) and Divya (2012) reported significant effect of period of calving on CACO.

### **b. Effect of season of calving**

The influence of season of calving on CACO was found to be non-significant in HF x Gir halfbred cows. The non-significant effect of season of calving on CACO was also reported by many workers (Rashia, 2010, Nehra, 2011 and Divya, 2012) in KF cattle. Contrary to the present study, significant effect of season of calving on CACO had been documented by Singh and Gurnani (2004), Mukharjee (2005), Kokate (2009) and Rathi (2015) in different crossbred cattle. The cows calved during winter season ( $86.33 \pm 2.83$  days) had highest CACO followed by rainy ( $84.91 \pm 3.05$  days) and summer season ( $84.33 \pm 2.94$  days).

### **c. Effect of age at first calving group**

The least squares analysis revealed that the AFC group had non-significant effect on interval between first calving and conception (Table 4.4). Similar results were reported by Singh (1995), Panja (1997) and Divya (2012) in KF cattle. The CACO was highest in A-2 (951-1050 days) i.e.  $88.48 \pm 3.81$  and lowest in A-1 (< 950 days) i.e.  $81.94 \pm 3.18$  (Table 4.6). However, significant effect of AFC on the interval between first calving and conception was obtained by Saha (2001) in KF cattle, Annual Report PDC (2003-04) and Mukharjee (2005) in Frieswal cattle.

### **d. Effect of sire**

Non- Significant variation due to sire was observed in CACO of HF x Gir halfbred (Table 4.4). These observations collaborated with the results of Mukharjee (2005), Nehra (2011) and Divya (2012) in Frieswal and Karanfries cattle and Ambhore *et al.* (2017) in Phule Triveni cattle.

## **4.2 Estimates of Genetic and Phenotypic Parameters under Single and Multiple Trait Models using Harvey and Wombat Software**

### **4.2.1 Heritability Estimates of Reproduction and Production Traits using LSML**

The heritability of various economic traits *viz.*, first lactation 300 days milk yield, first lactation peak milk yield, first lactation length, age at first calving, first calving interval, interval between calving and first service and interval between first, last service and interval between first calving and conception of HF x Gir halfbred were estimated by least-squares maximum likelihood method of Harvey (1990).

### 1. Heritability of AFC

The heritability of AFC from mixed model using LSML was  $0.22 \pm 0.11$  (Table 4.7). The estimate was in close agreement with Mukharjee (2005) who reported heritability estimate of  $0.23 \pm 0.10$  in Frieswal cattle. On the contrary, Nehra (2011), Dash (2014) and Ambhore *et al.* (2017) noticed higher heritability as  $0.28 \pm 0.16$ ,  $0.26 \pm 0.13$  and  $0.32 \pm 0.18$ , respectively in Karan Fries and Phule Triveni cattle.

### 2. Heritability of FL300DMY

The heritability of FL300DMY of HF x Gir halfbred from mixed model using LSML was  $0.20 \pm 0.12$  (Table 4.4). The estimate was in close agreement with Mukharjee (2005) who reported heritability estimate of 0.23 in Frieswal cattle. On the contrary, Nehra (2011), Dash (2014) and Ambhore *et al.* (2017) reported higher heritability as  $0.43 \pm 0.13$ ,  $0.36 \pm 0.08$  and  $0.48 \pm 0.19$ , respectively in Karan Fries and Phule Triveni cattle.

### 3. Heritability of FLPMY

The heritability of FLPMY from mixed model using LSML was  $0.18 \pm 0.12$  (Table 4.7). The estimate of heritability of FLPMY was close to the estimate,  $0.16 \pm 0.059$  (Rathi, 2015) in Frieswal cattle and  $0.17 \pm 0.03$  (Mukharjee, 2005) in Frieswal cattle. However, the higher estimate of heritability ( $0.25 \pm 0.16$ ) was reported in JG crossbred Nehra *et al.* (2012) and Dash (2014) in various HF crossbred cattle.

### 4. Heritability of FLL

The heritability of FLL from mixed model using LSML was  $0.14 \pm 0.10$  (Table 4.7). The estimate was in close agreement with Mukharjee (2005) who reported heritability estimate of FLL  $0.12 \pm 0.43$  in Frieswal cattle. On the contrary, Nehra (2011), Dash (2014) and Ambhore *et al.* (2017) reported higher heritability as  $0.43 \pm 0.13$ ,  $0.36 \pm 0.08$  and  $0.48 \pm 0.19$ , respectively in Karan Fries and Phule Triveni cattle.

### 5. Heritability of FCI

The heritability of FCI was  $0.15 \pm 0.12$  from mixed model using LSML (Table 4.7). Which was in close agreement with Panja (1997) in Karan Fries and Mukharjee (2005) and Rathi (2015) in Frieswal cattle. However, higher estimates of heritability were observed by Saha (2001) in Karan Fries and Ambhore *et al.* (2017) in

**Table 4.7** Estimates of heritability, phenotypic and genetic correlations among first lactation production and fertility traits

Traits	FL300DMY (kg)	FLPMY (kg)	FLL (days)	AFC (days)	FCI (days)	CAFS (days)	IFLS (days)	CACO (days)
FL300 DMY	<b>0.20 ± 0.12</b>	0.99 ± 0.49	0.38 ± 0.51	0.17 ± 0.41	0.19 ± 0.06*	-0.19 ± 0.44	-0.02 ± 0.06*	-0.40 ± 0.07*
FLPMY	0.19 ± 0.04*	<b>0.18 ± 0.12</b>	-0.72 ± 0.06*	0.20 ± 0.46	0.99 ± 0.63	-0.24 ± 0.44	-0.31 ± 0.93	0.37 ± 0.67
FLL	0.25 ± 0.04*	-0.02 ± 0.05*	<b>0.14 ± 0.10</b>	0.47 ± 0.37	0.92 ± 0.10	-0.33 ± 0.41	0.11 ± 0.80	0.27 ± 0.63
AFC	0.05 ± 0.04*	0.40 ± 0.52	0.80 ± 0.05*	<b>0.22 ± 0.11</b>	0.08 ± 0.12	-0.51 ± 0.38	0.38 ± 0.05*	0.60 ± 0.59
FCI	0.20 ± 0.04*	-0.26 ± 0.05*	0.39 ± 0.45	-0.03 ± 0.05*	<b>0.15 ± 0.12</b>	0.05 ± 0.08	0.99 ± 0.52	0.10 ± 0.45
CAFS	0.07 ± 0.05*	-0.03 ± 0.05*	-0.10 ± 0.05*	-0.09 ± 0.05*	-0.01 ± 0.05*	<b>0.04 ± 0.10</b>	0.94 ± 0.75	0.82 ± 0.38
IFLS	-0.06 ± 0.05*	0.05 ± 0.05*	-0.08 ± 0.05*	0.06 ± 0.49	-0.25 ± 0.05*	0.16 ± 0.05*	<b>0.21 ± 0.09</b>	0.66 ± 0.54
CACO	0.04 ± 0.05*	0.02 ± 0.05*	0.04 ± 0.51	-0.53 ± 0.08*	-0.02 ± 0.05*	0.58 ± 0.03*	0.89 ± 0.01*	<b>0.16 ± 0.08</b>

The estimates above the diagonal are genetic correlations and below diagonal are the phenotypic correlations, the diagonal values are estimates of heritability

\*P < 0.05 and \*\* P < 0.01

Phule Triveni cattle. The results of the present study revealed that the heritability estimates for various reproduction traits were very low indicating little influence of genetic factors over these traits. Hence, these traits can be improved only through improving the feeding, housing, health, and reproductive management practices.

#### **6. Heritability of CAFS**

The heritability of CAFS HF x Gir halfbred was very low ( $0.04 \pm 0.10$ ) and not different from zero. The heritability of CAFS reported by different scientists varied from 0.04 (Singh and Tomar, 1991) to 0.16 (Saha, 2001) in Karan Fries cattle. Many workers (Singh and Tomar, 1991; Sahana, 1996; Panja, 1997; Mukharjee, 2005) also reported low heritability estimates for CAFS in HF crossbred cattle. The low estimate of heritability for CAFS obtained in the present study indicates that most of the variation in this trait was of non-genetic nature and as such this trait could be improved through better feeding and management practices.

#### **7. Heritability of IFLS**

The heritability of IFLS from mixed model using LSML was  $0.21 \pm 0.09$  (Table 4.7). Singh and Tomar, 1991; Sahana, 1996; Panja, 1997 and Mukharjee, 2015 reported heritability estimates higher than the value obtained in the present study. However, lower heritability of IFLS  $0.13 \pm 0.065$  was reported as by Rathi (2015) in Frieswal cattle.

The heritability estimate of IFLS observed was moderate in magnitude which indicated that the trait can be improved by selection.

#### **8. Heritability of CACO**

The heritability of CACO in HF x Gir halfbred was  $0.16 \pm 0.08$  (Table 4.7). The estimate obtained in the present study was near to Rathi (2015) in HF x S cattle and Nehra (2011), in Frieswal cattle. The lower estimates of heritability were reported by Sahana, (1996) in Frieswal cattle ( $0.14 \pm 0.066$ ). However, higher heritability was noticed by Nehra *et al.* (2012) in KF and Ambhore *et al.* (2017) in Phule Triveni cattle as  $0.29 \pm 0.17$  and  $0.31 \pm 0.15$ , respectively.

#### 4.2.2 Genetic and Phenotypic Correlations of Reproduction and Production Traits using LSML

##### 1. Genetic and phenotypic correlations of reproduction and production traits with FL300DMY

The genetic constitution of a population is measured in terms of heritability of various economic traits and their phenotypic and genetic correlations. These estimates express the genetic variability and co-variability of different traits measured on individuals constituting the population. The heritability of a trait gives an idea on the proportion of genetic variance to the total phenotypic variance in a given population for a particular trait during a specified period of time. It also measures the regression of additive genetic value of an animal on its phenotype. The knowledge of these parameters is required in formulation of appropriate evaluation and selection criteria for bringing about genetic improvement.

The genetic and phenotypic correlations of reproduction traits (AFC, FCI, CAFS, IFLS and CACO) using LSML with milk production traits (FL300DMY, FLPMY and FLL) are presented in Table 4.7.

The genetic and phenotypic correlations between FLPMY and FL300DMY was  $0.99 \pm 0.49$  and  $0.19 \pm 0.04$ , between FLL and FL300DMY was  $0.38 \pm 0.51$  and  $0.25 \pm 0.04$ , between FL300DMY and AFC was  $0.17 \pm 0.41$  and  $0.05 \pm 0.04$ , between FCI and FL300DMY was  $0.19 \pm 0.06$  and  $0.20 \pm 0.04$ , between CAFS and FL300DMY was  $0.19 \pm 0.44$  and  $0.07 \pm 0.05$ , between IFLS and FL300DMY was  $-0.02 \pm 0.06$  and  $-0.06 \pm 0.05$  and between CACO and FL300DMY was  $-0.40 \pm 0.07$  and  $0.04 \pm 0.05$ . The standard errors of genetic correlations were quite high between different traits except between FLPMY and FL300DMY. Similar to the present results, Mukharjee (2005) reported higher genetic correlations of FLTMY with FL305DMY and FLL in Frieswal cattle. Based on the higher estimate of genetic correlation between FLPMY and FL300DMY it may be concluded that these two traits are influenced by the same genes which can be utilized for improving the milk production through indirect selection. The phenotypic correlation of FL300DMY with other first lactation traits *viz.*, FCI and FL300DMY was high, positive and significant ( $P < 0.01$ ). The study showed positive and significant ( $P < 0.01$ ) correlation between CAFS and FL300DMY. The genetic

correlation between first calving interval and milk production reported from  $-0.567 \pm 0.231$  (Singh *et al.*, 1988) to  $0.67 \pm 1.05$  (Panja, 1997). The genetic correlation of age at first calving with milk production in different crossbred cattle ranged from  $-0.57 \pm 0.23$  (Singh *et al.*, 1988) to  $0.59 \pm 0.17$  (Jadhav and Khan, 1996).

## **2. First lactation peak milk yield (FLPMY) with other first lactation production and reproduction traits**

The genetic and phenotypic correlations between FLPMY and FL300DMY was  $0.99 \pm 0.49$  and  $0.19 \pm 0.04$ , between FLPMY and FLL was  $0.72 \pm 0.06$  and  $-0.02 \pm 0.05$ , between FLPMY and AFC was  $0.20 \pm 0.46$  and  $0.40 \pm 0.52$ , between FLPMY and FCI was  $0.99 \pm 0.63$  and  $-0.26 \pm 0.05$ , between FLPMY and CAFS was  $-0.24 \pm 0.44$  and  $-0.03 \pm 0.05$ , between FLPMY and IFLS was  $-0.31 \pm 0.93$  and  $-0.06 \pm 0.05$  and between FLPMY and CACO was  $0.37 \pm 0.67$  and  $0.02 \pm 0.05$ .

The phenotypic correlations reported by Rahumathulla *et al.* (1993) between TLMY and 305 days milk yield was  $0.89 \pm 0.02$  in J x Red Sindhi crossbreds, Pol *et al.* (2013) between FLL and FL300DMY in Phule Triveni synthetic cows as  $-0.02$ , D'souza *et al.* (1979) between lactation length with lactation milk yield as  $0.572$  and  $0.668$  in HF x Red Sindhi and Kumar (1981) between milk production and AFC and FCI as  $0.14 \pm 0.033$  and  $0.053 \pm 0.033$  in Haryana crossbred cattle.

Mukharjee (2005) observed genetic correlation of FL305DMY with FLL, FSP, FDP and FCI as  $0.13 \pm 0.17$ ,  $0.18 \pm 0.23$ ,  $0.26 \pm 0.24$  and  $0.17 \pm 0.24$ , respectively in Frieswal cattle. Dash (2014) also estimated the genetic correlation of FLL and FL305 DMY as  $0.38 \pm 0.25$  while, between with FSP and FCI as  $0.09 \pm 0.33$  and  $0.17 \pm 0.36$ , respectively in KF cattle.

## **3. First lactation length (FLL) with other first lactation reproduction and production traits**

The genetic and phenotypic correlations between FLL and FL300DMY was  $0.38 \pm 0.51$  and  $0.25 \pm 0.04$ , between FLL and FLPMY was  $-0.72 \pm 0.06$  and  $-0.02 \pm 0.05$ , between FLL and AFC was  $0.47 \pm 0.37$  and  $0.80 \pm 0.05$ , between FLL and FCI was  $0.92 \pm 0.10$  and  $0.39 \pm 0.45$ , between FLL and CAFS was  $-0.33 \pm 0.41$  and  $-0.10 \pm 0.05$ , between FLL and IFLS was  $0.11 \pm 0.80$  and  $0.05 \pm 0.05$  and between FLL and CACO was  $0.27 \pm 0.63$  and  $0.04 \pm 0.51$ .

The phenotypic correlations reported by Rahumathulla *et al.* (1993) between LMY and 305 days milk yield was  $0.89 \pm 0.02$  in J x Red Sindhi crossbreds, Pol *et al.* (2013) between FLL and FL300DMY in Phule Triveni synthetic cows as  $-0.02$ , D'souza *et al.* (1979) between lactation length with lactation milk yield as  $0.572$  and  $0.668$  in HF x Red Sindhi and Kumar (1981) between milk production and AFC and FCI as  $0.14 \pm 0.033$  and  $0.053 \pm 0.033$  in Haryana crossbred cattle.

The phenotypic correlations of milk production with FLL was  $0.13 \pm 0.12$  (Nehra, 2011), with CI it ranged from  $0.09 \pm 0.40$  (Nehra, 2011) to  $0.195$  (Sivakumar, 1998) and with service period it ranged from  $-0.057 \pm 0.065$  (Panja, 1997) to  $0.152$  (Sivakumar, 1998) in Karan Fries cattle.

#### **4.2.3 Heritability Estimates of Different Milk Production and Reproduction Traits from Single Trait-Sire Model (ST-SM), Single Trait-Animal Model (ST-AM) using WOMBAT**

The data for present study had complete information on all traits with equal design matrices for both single-trait and multi-trait analysis. The same data set was used for genetic parameters estimation of different traits and genetic evaluation of sires from single-trait sire model (ST-SM), single-trait animal model (ST-AM) and multiple-trait animal models of two, three and four traits combinations using WOMBAT (Meyer, 2007). Best Linear Unbiased Prediction of breeding values from animal model had become method of choice for genetic evaluation of sires and cows because of their higher reliabilities and accuracy. The genetic evaluation of sires and cows by animal model makes use of all existing relationships among animals (sires and cows) with or without their performance records in the pedigree. The essential difference between single-trait animal model and multiple-trait animal models analysis is that multi-trait model takes into account all inter-correlations (positive or negative) and information of traits involved in the models for the estimation of genetic and phenotypic parameters. Single-trait animal model and different multi-trait animal models of two, three and four traits combinations were used to obtain the estimates of variance and covariance components fitting mixed linear model by REML method using WOMBAT.

Both the sire and animal models included period of calving, season of calving and age at first calving as fixed effects for all traits except AFC and animal as

well as residual error as random effect. The models for AFC included season of birth and period of birth as fixed effect and animal as well as residual error as random effect. The results of the genetic and phenotypic parameters estimated from the above methods have been described in the ensuing paragraphs.

The heritability estimates of various traits along with variance and covariance components from single-trait sire model (ST-SM) and single-trait animal model (ST-AM) are presented in Table 4.8. The estimates of variance and covariance components of traits obtained by REML method using WOMBAT from two and three traits combinations of multiple-trait animal models along with estimates of phenotypic and genetic correlations and heritability are presented in Tables 4.9 and 4.10, respectively.

**a. Comparison among heritability estimates of various milk production and reproduction traits from single trait-sire model (ST-SM) and single trait-animal model (ST-AM) using WOMBAT**

The HF x Gir halfbred dairy animals were evaluated for milk yield traits (FL300DMY, FLPMY and FLL) together with other positively or negatively correlated reproduction traits (AFC, FCI, CAFS, IFLS and CACO) of high economic importance.

**Table 4.8 Heritability and REML estimates of (co) variance components under single traits sire model and single trait animal model**

Parameters	Sire model			Animal model		
	Additive genetic variance	Residual variance	Heritability	Additive genetic variance	Residual variance	Heritability
FL300DMY	22260.9	358815	0.05 ± 1.00	75631.5	301617	0.20 ± 0.98
FLPMY	0.1203	7.4130	0.01 ± 0.029	0.8015	6.7698	0.10 ± 0.080
FLL	16.1134	881.726	0.01 ± 0.032	97.64	802.44	0.10 ± 0.076
AFC	2218.30	7812.66	0.22 ± 0.099	2218.30	7812.66	0.22 ± 0.099
FCI	0.0122	3145.08	0.04 ± 0.030	0.091	3145.06	0.00 ± 0.074
CAFS	2.9301	194.26	0.01 ± 0.030	34.17	164.19	0.17 ± 0.087
IFLS	0.0010	659.34	0.03 ± 0.025	6.057	653.81	0.06 ± 0.57
CACO	0.0010	979.41	0.05 ± 0.027	48.88	934.36	0.05 ± 0.065

**First lactation 300 days milk yield**

The (co)variance components were estimated by fitting AIREML with single trait-sire model (ST-SM) and single trait-animal model (ST-AM) and multi-trait animal models using WOMBAT (Meyer, 2007) in order to obtain genetic and phenotypic

parameters. The heritability estimates of FL300DMY along with variance and covariance components from single-trait sire model (ST-SM) and single-trait animal model (ST-AM) are presented in Table 4.8.

The extent of additive genetic variance and residual variance by animal model (ST-AM) versus sire model (ST-SM) showed that magnitude of additive genetic variance was higher and magnitude of residual variance was lower under ST-AM compared to ST-SM. Consequently, the heritability estimates of production and reproduction traits were higher (with lower SE estimates) under ST-AM compared to ST-SM. Divya (2012), Singh (2014) and Ambhore *et al.* (2017) also reported that heritability estimates by ST-AM were higher compared to ST-SM in Karan Fries cattle.

#### **i. Single trait models**

The heritability estimates of FL300DMY were  $0.05 \pm 1.00$  and  $0.20 \pm 0.98$  (Table 4.8) from single-trait sire model and single-trait animal model (ST-AM), respectively. The genetic variance and heritability of FL300DMY trait from sire model was lower than the corresponding estimates of traits from animal model (Table 4.8). The improvement in  $h^2$  of FL300DMY by ST-AM was 100 % compared to the estimate of ST-SM analysis. The single-trait animal model appeared to be better method than sire model for heritability estimation. The lower heritability estimate of sire model in comparison to corresponding animal model of same trait was in agreement with Divya (2012), Singh (2013), Dash (2014) and Ambhore *et al.* (2017) reported in different crossbreds.

#### **ii. Two trait animal models**

The heritability estimates by two traits animal models were  $0.17 \pm 0.41$  (FL300DMY and AFC),  $0.40 \pm 0.39$  (FL300DMY and FCI),  $0.19 \pm 0.44$  (FL300DMY and CAFS),  $0.21 \pm 0.15$  (FL300DMY and IFLS) and  $0.38 \pm 0.44$  (FL300DMY and CACO).

The highest heritability of FL300DMY among two-trait animal model was observed in FL300DMY and FCI combination ( $0.40 \pm 0.39$ ). This may be ascribed to fairly sufficient additive genetic variation present in both these traits. Which was in close agreement with the findings of the heritability estimate for FL300DMY as  $0.231 \pm 0.109$

by Divya (2012),  $0.238 \pm 0.087$  by Singh (2013) and  $0.31 \pm NE$  by Dash (2014) in Karan Fries cattle. However, Ambhore *et al.* (2016) reported higher heritability estimates ( $0.34 \pm 0.14$ ) under two trait model in Phule Triveni. The heritability estimates of FL300DMY from two traits animal models was moderate in magnitude and produced changed (lower or higher) heritability estimates compared to heritability estimate obtained from single-trait animal model. All combinations of traits under two trait animal models could be taken for genetic evaluation of animals, depending upon breeding objective and selection criteria of genetic improvement programme.

#### **4.2.4 Genetic and Phenotypic Correlations of Reproduction Traits (AFC, FCI, CAFS, IFLS and CACO) with Milk Production Traits (FL300DMY, FLPMY and FLL) using WOMBAT**

The genetic and phenotypic correlations of reproduction traits (AFC, FCI, CAFS, IFLS and CACO) with milk production traits (FL300DMY, FLPMY and FLL) were estimated using two trait models by WOMBAT and results are presented Table 4.9. The genetic and phenotypic correlations of FL300DMY with other traits from two-trait models have been discussed in the ensuing paragraphs.

##### **Genetic and phenotypic correlations between AFC and FL300DMY**

The estimates of genetic and phenotypic correlations between AFC and FL300DMY from two-trait animal model were observed as  $0.11 \pm 0.04$  and  $0.04 \pm 0.05$ . The genetic correlation was low with high SE. These results were in agreement with the report of Singh (2012), Divya (2013) and Ambhore *et al.* (2016) in different crossbreds.

It was observed that the estimates of genetic and phenotypic correlations between AFC and FL300DMY from two trait combinations were in general, changed in magnitude and in certain trait combinations even change in sign was noticed.

##### **Genetic and phenotypic correlations between FL300DMY and FCI**

The estimates of genetic ( $r_g$ ) and phenotypic ( $r_p$ ) correlations between FL300DMY and FCI in HF x Gir halfbred for two-trait animal model were  $0.15 \pm 0.05$  and  $0.20 \pm 0.49$ . Similar results were reported by Lin and Lee (1986), Singh (2013) and

Ambhore *et al.* (2016) in different crossbreds. However, Lakshmi *et al.* (2009) reported low genetic correlation between FL300DMY and FCI ( $0.18 \pm 0.28$ ) in HF x Sahiwal cows.

**Table 4.9 Heritability and REML estimates of (co) variance components under two trait animal model**

Traits	Additive genetic (co) variance matrix		Residual genetic (co) variance matrix		Parameter estimates	
<b>FL 300DMY and AFC</b>						
FL300 DMY	43849		334943		<b>0.17 ± 0.41</b>	0.04 ± 0.05
AFC	1489.20	1608.13	857.70	6372.8	0.11 ± 0.04	<b>0.20 ± 0.09</b>
<b>FL 300 DMY and FCI</b>						
FL300 DMY	58728.2		323443		<b>0.40 ± 0.39</b>	0.20 ± 0.49
FCI	915.90	14.29	1618.54	3139.83	0.15 ± 0.05	<b>0.22 ± 0.07</b>
<b>FL300DMY and CAFS</b>						
FL300 DMY	39578.5		338738		<b>0.19 ± 0.44</b>	0.07 ± 0.05
CAFS	-224.14	33.63	868.93	167.02	0.10 ± 0.03	<b>0.16 ± 0.08</b>
<b>FL300DMY and IFLS</b>						
FL300DMY	60028.2		321957		<b>0.21 ± 0.15</b>	0.06 ± 0.05
IFLS	-63191	6.66	-327.61	648.35	0.15 ± 0.12	<b>0.01 ± 0.57</b>
<b>FL300DMY and CACO</b>						
FL300DMY	38566.4		365697		<b>0.38 ± 0.44</b>	0.04 ± 0.05
CACO	2971.19	1558.56	-190.45	6407.63	0.09 ± 0.10	<b>0.19 ± 0.09</b>

The diagonals are heritability estimates, above the diagonal are phenotypic correlation estimates and below the diagonal are genetic correlation estimates

### Genetic and phenotypic correlations between FL300DMY and CAFS

The estimates of genetic and phenotypic correlations between FL300DMY and CAFS from two-trait animal model were observed as  $0.10 \pm 0.03$  and  $0.07 \pm 0.05$ , respectively. It was observed that the estimates of genetic and phenotypic correlations between FL300DMY and CAFS from two trait combinations were in general, changed in magnitude.

### Genetic and phenotypic correlations between FL300DMY and IFLS

The estimates of genetic and phenotypic correlations between FL300DMY and IFLS from two-trait animal model were observed as  $0.15 \pm 0.12$  and  $0.06 \pm 0.05$ . However, Mukharjee (2005) reported genetic and phenotypic correlation between FL300DMY and IFLS as  $0.18 \pm 0.25$  and  $0.11 \pm 0.02$ , respectively in Frieswal cattle.

### **Genetic and phenotypic correlations between FL300DMY and CACO**

The estimates of genetic and phenotypic correlations between FL300DMY and CACO from two-trait animal model were observed as  $0.09 \pm 0.10$  and  $0.04 \pm 0.05$ . Whereas, Nehra (2011) observed genetic and phenotypic correlation between FL300DMY and CACO as  $-0.09 \pm 0.40$  and  $0.20$ , respectively in Karan Fries cattle.

Difference in genetic and phenotypic correlations estimates of 2 trait animal model reflects joint contribution of other inter correlated trait included in the multi trait models. Multi trait model analysis remove biasness from selection of any correlated traits included in model of analysis (Rothschild and Henderson, 1979) which add further in reliability and accuracy of estimates obtained. The difference in sign between genetic and phenotypic correlation estimates from various animal model analysis exerts the need of traits to be included in multi trait analysis.

#### **iii. Three-trait animal models**

The heritability estimates of FL300DMY under three-trait animal models were  $0.22 \pm 0.09$  (FL300DMY, AFC and FCI),  $0.25 \pm 0.06$  (FL300DMY, IFLS and CACO),  $0.27 \pm 0.11$  (FL300DMY, FCI and CAFS), under three-trait animal models (Table 4.10). The heritability estimates of FL300DMY under three-trait animal models had relatively higher magnitude of heritability compared to ST-AM while at par with two traits animal model.

The estimate of heritability of FL300DMY was close to Zulkadir *et al.* (2009), Jafarabadi (2011), Golverdi *et al.* (2012) and Toghiani (2012) which ranged from 0.22 to 0.36 by three-trait animal analysis along with other production and reproduction traits in Holstein and other breeds of cattle. In Karan Fries cattle, the heritability estimates for FL300DMY in three-trait model was reported to be lower ( $0.19 \pm 0.10$  for FL305DMY, FCI and AFC combination;  $0.23 \pm 0.02$  for FL305MY, AFC and FSP combination) by Divya (2012) and Singh (2013), respectively. The combinations of traits under three-trait animal models could be taken for genetic evaluation of animals, depending upon breeding objective and selection criteria of genetic improvement programme.

#### 4.2.5 Genetic and Phenotypic Correlations of Reproduction Traits (AFC, FCI, CAFS, IFLS and CACO) with Milk Production Traits (FL300DMY, FLPMY and FLL) using WOMBAT

The genetic and phenotypic correlations of reproduction traits (AFC, FCI, CAFS, IFLS and CACO) with milk production traits (FL300DMY, FLPMY and FLL) were estimated using three trait models by WOMBAT and results are presented Table 4.10. The genetic and phenotypic correlations of FL300DMY with other traits from three-trait models have been discussed in the ensuing paragraphs.

**Table 4.10 Heritability and REML estimates of (co) variance components under three trait animal model**

Traits	Additive genetic (co) variance matrix			Residual genetic (co) variance matrix			Parameter estimates		
<b>FL300DMY, AFC and FCI</b>							<b>FL300 DMY</b>	<b>AFC</b>	<b>FCI</b>
FL300 DMY	2747.9			37745			<b>0.22 ± 0.09</b>	0.07 ± 0.05	0.20 ± 0.04
AFC	509.87	2242.8		3110.4	5221.4		0.20 ± 0.05	<b>0.30 ± 0.17</b>	-0.03 ± 0.05
FCI	-199.9	168.6	34.26	7381	-352	3139	0.65 ± 0.06	0.60 ± 0.05	<b>0.21 ± 0.09</b>
<b>FL300DMY, IFLS and CACO</b>							<b>FL300 DMY</b>	<b>IFLS</b>	<b>CACO</b>
FL300 DMY	4068.9			375690			<b>0.25 ± 0.06</b>	-0.05 ± 0.05	-0.02 ± 0.05
IFLS	-5198.9	126.3		-390.0	535.5		-0.72 ± 0.085	<b>0.19 ± 0.13</b>	0.89 ± 0.01
CACO	-810.5	169.9	235	412.3	552.6	755	-0.82 ± 0.06	0.98 ± 0.05	<b>0.23 ± 0.14</b>
<b>FL300DMY, FCI and CAFS</b>							<b>FL300 DMY</b>	<b>FCI</b>	<b>CAFS</b>
FL300DMY	10818			368837			<b>0.27 ± 0.11</b>	0.20 ± 0.14	0.07 ± 0.10
FCI	-573.3	30.4		7757.8	3146.98		0.99 ± 0.11	<b>0.60 ± 0.11</b>	-0.01 ± 0.12
CAFS	-507.4	26.8	23.8	1132.7	-35.7	176.1	a ± 0.20	a ± 0.12	<b>0.40 ± 0.12</b>

The diagonals are heritability estimates, above the diagonal are phenotypic correlation estimates and below the diagonal are genetic correlation estimates. "a" figures are not presige

#### Genetic and phenotypic correlations between FL300DMY, AFC and FCI

The estimate of genetic and phenotypic correlations between AFC with FL300DMY was observed as  $0.20 \pm 0.05$  and  $0.07 \pm 0.05$ . Between FL300DMY with FCI was observed as  $0.65 \pm 0.06$  and  $0.20 \pm 0.04$ . Genetic correlation was high with low SE. These results were in agreement with the report of Singh (2012), Divya (2013) and Ambhore *et al.* (2016) observed in different crossbreds.

### **Genetic and phenotypic correlations between FL300DMY, IFLS and CACO**

The estimate of genetic and phenotypic correlations between FL300DMY and IFLS was as  $-0.72 \pm 0.08$  and  $-0.05 \pm 0.05$ . Between FL300DMY with CACO was observed  $-0.82 \pm 0.06$  and  $-0.02 \pm 0.05$ . The genetic correlation was high with low SE. These results were in agreement with the report of Singh (2012), Divya (2013) and Ambhore *et al.* (2016) in different crossbreds. These results were in accordance with the report of Lin and Lee (1986) and Ambhore *et al.* (2016) reported in crossbreds. Similar to the present findings Ambhore *et al.* (2016) reported negative genetic correlation ( $-0.25 \pm 0.38$  to  $0.41 \pm 0.27$ ) and positive phenotypic correlation ( $0.01 \pm 0.04$  to  $0.13 \pm 0.04$ ) between production and reproduction traits.

### **Genetic and phenotypic correlations between FL300DMY, FCI and CAFS**

The estimates of genetic and phenotypic correlations between FL300DMY with FCI was observed  $0.99 \pm 0.11$  and  $0.20 \pm 0.14$ . Between FL300DMY with CAFS was observed as  $a \pm 0.20$  and  $0.07 \pm 0.10$ . The genetic correlation was low with low SE. These results corroborated with the report of Lin and Lee (1986) and Singh (2013) in crossbred cows.

Difference in genetic and phenotypic correlations estimates of three traits animal model reflects joint contribution of other inter correlated trait included in the multi trait models. Multi trait model analysis remove bias from selection of any correlated traits included in model of analysis (Rothschild and Henderson, 1979) which add further reliability and accuracy of estimates obtained. The difference in sign between genetic and phenotypic correlation estimates from various animal model analysis exerts the need of traits to be included in multi trait analysis.

### **4.3 Genetic and Environmental Trends of First Lactation Production and Fertility Traits**

The estimation of genetic trend helps to monitor the efficiency of breed improvement programme implemented as it corresponds to observed changes in the average breeding values of animals studied for the traits concerned during the selection process. Hudson and Kennedy (1995) suggested that the follow up and interpretation of genetic trend estimates allows monitoring the efficiency of improvement strategies and assure that the selection pressure is directed towards traits of economic importance. In the present study two

different methods *viz.*, Smith II and BLUP were used to estimate the genetic, phenotypic and environmental trends for various first lactation production and reproduction traits.

The breeding values estimated by sire model were used for estimation of genetic trends as per the method described by Hintz *et al.* (1978). Phenotypic and environmental trends were also estimated for these traits and the results are discussed here under.

**Table 4.11 Phenotypic, genetic and environmental trends for first lactation production and fertility traits of HF x Girhalfbred by different methods**

Method Trend Trait	Phenotypic trend	Smith-II		BLUP	
		Genetic	Environmental	Genetic	Environmental
FL300DMY	-23.03 ± 2.83**	-45.64 ± 16.74**	22.603 ± 20.60	-91.71 ± 20.92**	68.68 ± 18.89**
FLPMY	-0.03 ± 0.01*	0.54 ± 0.06*	-0.57 ± 0.08**	0.47 ± 0.05*	-0.50 ± 0.03**
FLL	-0.05 ± 0.13*	0.18 ± 11.40	-0.13 ± 09.15**	0.29 ± 12.60*	-0.23 ± 08.25**
AFC	6.40 ± 0.47*	-2.12 ± 14.62**	8.53 ± 20.90**	-0.13 ± 11.80	4.27 ± 16.20**
FCI	0.603 ± 0.24*	2.73 ± 25.48**	3.33 ± 21.36**	1.52 ± 22.60**	2.12 ± 27.58
CAFS	0.06 ± 0.06*	-1.87 ± 2.08**	1.94 ± 1.60*	-1.74 ± 1.35**	1.80 ± 1.20
IFLS	0.03 ± 0.11*	-2.68 ± 3.26**	2.71 ± 2.86*	-2.62 ± 3.07**	2.65 ± 2.98
CACO	0.10 ± 0.13*	4.49 ± 5.69**	4.59 ± 3.11**	-4.28 ± 5.12**	4.38 ± 4.18

\*P < 0.05 and \*\*P < 0.01

#### 4.3.1 Trend Estimates for FL300DMY

A overall average phenotypic trend for FL300DMY was negative (-23.03 ± 2.83) in HF x Gir cattle, indicating 1.08 per cent decrease in FL300DMY over the herd average. On the contrary, Mukharjee (2005) and Nehra (2012) reported positive phenotypic trend for in different crossbred cattle.

The genetic trend for FL300DMY was -45.64 ± 16.74kg (SM-II) and -91.71 ± 20.92 kg (BLUP) per year. The genetic trend was negative and significant (P<0.01) by both SM-II and BLUP methods. On the contrary, Mukharjee (2005) found positive genetic trend for FL300DMY in Meerut farm while, positive and low trend for Ambala farm by Smith method II indicating the genetic improvement occurred in this trait over the later years. Nehra (2012) reported negative genetic trend of -6.00 ± 35 kg for FL305DMY by Smith method II while, positive genetic trend of 19 ± 36 kg by BLUP method in KF cattle.

The environmental trends were  $22.60 \pm 20.60$  kg per year by SM-II and  $68.68 \pm 18.89$  kg per year by BLUP method, respectively. Environmental trend was in positive direction by both the methods. This showed that decline in milk production over years was due to deterioration in environmental conditions coupled with management. However, the positive environmental trends for FL300DMY were reported by Nehra *et al.* (2012) as  $42.24 \pm 51.80$  and  $38.47 \pm 12.90$  by SM-II and BLUP methods in Karan Fries cattle.

#### **4.3.2 Trend Estimates for FLPMY**

The overall average phenotypic trend for the FLPMY of HF x Gir halfbred was  $-0.03 \pm 0.01$  kg which was negative and nonsignificant. The phenotypic trend accounted for -1.67 per cent of the herd average. Similar to the present study Gaur (2003) also reported a negative phenotypic trend of -0.42 kg estimated by LRM in Frieswal cattle. On the contrary, Mukharjee (2005) and Nehra (2012) reported positive phenotypic trends for this trait in Frieswal and KF cattle, respectively. The overall genetic trends estimated by Smith II and BLUP methods were  $0.54 \pm 0.06$  and  $0.47 \pm 0.05$ . In general, the estimates were statistically non significant and the trend estimated by BLUP methods were lower than the trend estimated by Smith method II. Mukharjee (2005) reported a negative and non significant genetic trend by Smith method II while positive and non significant genetic trend by Smith method I for FLPMY in Frieswal cattle. The overall calculated environmental trends estimated by Smith methods II and BLUP were  $-0.57 \pm 0.08$ , and  $-0.50 \pm 0.03$  kg, respectively. The study revealed an overall decline in the FLPMY over the years. The large negative environmental trends obtained by different methods indicated necessity of improving the managerial conditions for increasing the FLPMY. The environmental trends reported by Nehra *et al.* (2012) were  $0.29 \pm 0.03$  and  $0.18 \pm 0.05$  kg by SM-II and BLUP methods in Karan Fries cattle which were in positive direction.

#### **4.3.3 Trend Estimates for FLL**

The phenotypic trends estimated for FLL in the HF x Gir cattle was  $-0.05 \pm 0.13$  (0.18 % of HA) days. The phenotypic trend was negative and nonsignificant. Mukharjee (2005) and Ambhore *et al.* (2017) also reported negative and highly significant phenotypic trends for FLL in Frieswal and Phule Trveni cattle, respectively.

However, Nehra *et al.* (2012) reported positive phenotypic trend as  $1.02 \pm 0.65$  days per year (0.28 % of HA) in Karan Fries cattle.

The overall genetic trends of FLL by Smith II and BLUP methods were  $0.18 \pm 11.40$  and  $0.29 \pm 12.60$  days, respectively which were statistically significant. The positive genetic trends for FLL were also reported by Gaur (2003) as 4.37 by BLUP, method in Frieswal cattle at military dairy farm and Nehra (2011) as  $0.59 \pm 3.89$  (17 % of HA) and  $0.58 \pm 0.24$  (0.16 % of HA) by SM-II and BLUP methods in Karan Fries cattle at NDRI farm. However, Mukharjee (2005) reported negative and non significant genetic trends for both Ambala and Meerut farms by Smith method II and positive estimates by BLUP method.

The environmental trends for FLL were  $-0.13 \pm 09.15$  and  $-0.23 \pm 08.25$  days per year by SM-II and BLUP respectively. Environmental trends were statistically significant and in negative direction. However, Nehra (2011) reported positive environmental trends in Karan Fries cattle as  $0.43 \pm 3.95$  and  $1.59 \pm 0.69$  by SM-II and BLUP methods, respectively.

#### **4.3.4 Trend Estimates for AFC**

The estimation of phenotypic trends for AFC in HF x Gir halfbred was  $6.40 \pm 0.47$ . The positive and significant trend obtained in the present study showed the increase in the AFC over the years. Similar to the present results Mukharjee (2005), Nehra (2012) and Ambhore *et al.* (2017) noted positive phenotypic trend for AFC in Frieswal, KF and Phule Triveni cattle, respectively. The overall genetic trends for Smith II and BLUP methods were  $-2.12 \pm 14.62$  and  $-0.13 \pm 11.80$  days, respectively. The estimates obtained in Smith II methods was negative and statistically highly significant. Mukharjee (2005) and Nehra (2012) also reported negative and significant genetic trend of AFC in Frieswal and KF cattle, respectively. The overall environmental trends for, Smith II and BLUP methods were found to be positive and significant ( $8.53 \pm 20.90$  and  $4.27 \pm 16.20$  days), respectively. However, Nehra (2012) noticed environmental trends for AFC as  $37.68 \pm 6.61$  days by SM-II and  $3.45 \pm 1.16$  days by BLUP method in Karan Fries cattle.

#### 4.3.5 Trend Estimates for FCI

A positive and significant ( $P < 0.05$ ) phenotypic trend estimate of  $0.603 \pm 0.24$  days was observed for FCI in HF x Gir cattle. Similar to the present results Herbert (1987) and Mukharjee (2005) reported positive phenotypic trends for FCI in Karan Swiss and Frieswal cattle, respectively. While, Kurien (2011) observed negative phenotypic trend of FCI in crossbred cattle.

The genetic trend by Smith method II ( $2.73 \pm 25.48$  days) and BLUP method ( $1.52 \pm 22.60$  days) was positive and significant. Herbert (1987) also reported positive genetic trend for FCI in Karan Swiss cattle for Smith method I. While, Mukharjee (2005) used Smith I and II methods to estimate the genetic trend of FCI in Frieswal cattle and found negative and positive genetic trends for FCI in Meerut and Ambala farms, respectively.

The environmental trends for the trait were  $3.33 \pm 21.36$  and  $2.12 \pm 27.58$  days estimated by Smith-II and BLUP methods, respectively. The environmental trend obtained by BLUP method for FCI was low, positive and non significant. The undesirable environmental trend was also reported by Nehra *et al.* (2012) in Karan Fries cattle as  $2.34 \pm 3.13$  and  $1.76 \pm 1.37$  days per annum by Smith-II and BLUP methods.

#### 4.3.6 Trend Estimates for CAFS

A positive and significant phenotypic trend estimate of  $0.06 \pm 0.06$  days was noticed for CAFS in HF x Gir cattle. Mukharjee (2005) also reported positive phenotypic trend for the trait in Meerut and Ambala farms. On the contrary, Kurien (2011) noticed negative and significant phenotypic trend of CAFS in crossbred cattle.

The annual genetic trends were estimated to be  $-1.87 \pm 2.08$  and  $-1.74 \pm 1.35$  days by SM-II and BLUP methods, respectively. The genetic trend for CAFS was significant and had high standard errors. The negative genetic trend for CAFS was desirable for the herd. Dash (2014) reported low and non significant annual genetic trend of FSP as  $0.02 \pm 0.03$  days (0.015% of herd average) in Karan Fries cattle. In general, the genetic trends estimated by both methods were very low indicating the absence of selection of cows for this trait. Mukharjee (2005) found negative genetic trend for CAFS in Meerut and Ambala farm.

The environmental trends for CAFS were estimated as  $1.94 \pm 1.60$  and  $1.80 \pm 1.20$  days by SM-II and BLUP methods. Similar to the present results very low

environmental trend was reported by Dash (2014) as  $1.12 \pm 0.51$  days per annum in Karan Fries cattle.

The results of the present study showed that the genetic, phenotypic and environmental trend for CAFS were very low indicating the consistency over the years as neither the breed improvement programme nor the managerial conditions improved this trait.

#### **4.3.7 Trend Estimates for IFLS**

A positive and significant ( $P < 0.05$ ) phenotypic trend estimate of  $0.03 \pm 0.11$  days was obtained for IFLS in HF x Gir cattle. Similar to the present results Herbert (1987) and Mukharjee (2005) observed positive phenotypic trends for IFLS in Karan Swiss and Frieswal cattle, respectively. While, Kurien (2011) observed negative phenotypic trend of IFLS in crossbred cattle.

The genetic trend by Smith method II ( $-2.68 \pm 3.26$  days) and BLUP method ( $-2.62 \pm 3.07$  days) was negative and significant. Herbert (1987) also reported positive genetic trend for IFLS in Karan Swiss cattle by Smith method I. While, Mukharjee (2005) used Smith I and II methods to estimate the genetic trend of IFLS in Frieswal cattle and found negative and positive genetic trends for FCI in Meerut and Ambala farms, respectively.

The environmental trends for the trait were  $2.71 \pm 2.86$  and  $2.65 \pm 2.98$  days by Smith-II and BLUP methods, respectively. The environmental trend obtained by BLUP method for IFLS was low, positive and significant. The undesirable environmental trend was also reported by Nehra *et al.* (2012) in Karan Fries cattle as  $2.34 \pm 3.13$  and  $1.76 \pm 1.37$  days per annum by Smith-II and BLUP methods.

#### **4.3.8 Trend Estimates for CACO**

A positive and significant ( $P < 0.05$ ) phenotypic trend estimate of  $0.10 \pm 0.13$  days was obtained for CACO in HF x Gir cattle. Similar to the present results Herbert (1987) and Mukharjee (2005) reported positive phenotypic trends for CACO in Karan Swiss and Frieswal cattle, respectively. While, Kurien (2011) observed negative phenotypic trend of CACO in crossbred cattle.

The genetic trend by Smith method II ( $4.49 \pm 5.69$  days) and BLUP method ( $-4.28 \pm 5.12$  days) was negative. Mukharjee (2005) used Smith I and II methods to estimate the genetic trend of CACO in Frieswal cattle and found negative and positive

genetic trends for CACO in Meerut and Ambala farms, respectively. While Herbert (1987) also reported positive genetic trend for FCI in Karan Swiss cattle for Smith method I.

The environmental trends for the trait were  $4.59 \pm 3.11$  and  $4.38 \pm 4.18$  days by Smith-II and BLUP methods, respectively. The environmental trend obtained by BLUP method for CACO was positive and nonsignificant. The undesirable environmental trend was also reported by Nehra *et al.* (2012) in Karan Fries cattle as  $2.34 \pm 3.13$  and  $1.76 \pm 1.37$  days per annum by Smith-II and BLUP methods.

#### **4.4 Sire Evaluation under Single-Trait and Multi-Trait Animal Models**

The objective of the present study was to evaluate the HF x Gir sires on the basis of first lactation 300 days milk yield by different methods. A total of 44 HF x Gir halfbred sires with three or more daughters were evaluated and ranked on the basis of first lactation 300 days milk yield by least squares (LSQ), Simple regressed least squares (SRLS) and Single trait-sire model (ST-SM), Single trait-animal model (ST-AM) and Multiple trait models separately as well as along with other traits in various models of two and three trait combinations.

##### **4.4.1 Sire Evaluation under Single-Trait Models**

###### **a. Least Squares Method**

The average breeding value of 44HF x Gir halfbred sires evaluated on the basis of first lactation 300 day or less milk yield by least squares method was 2920 kg (Table 4.12). The results revealed that the estimated breeding values (54.54%) of 24 HF x Gir halfbred sires were above the average breeding value. The top ranking sire (sire no H-65) with highest breeding value of 3038 kg had 4.04 per cent genetic superiority over the overall average, whereas, sire NumberH-245 ranked at bottom with lowest breeding value of 2698 kg which was 7.60 per cent below the overall average breeding value of sires. The difference between highest and lowest breeding values was 340 kg.

###### **b. Simple Regressed Least Squares (SRLS) Method**

The estimated average breeding value of 44HF x Gir halfbred sires by SRLS method for first lactation 300 day or less milk yield was 2953 kg.

**Table 4.12 Estimated breeding values of HF x Gir sires along with their ranks for FL300 DMY by different single trait sire evaluation methods**

Sr. No.	Sire	N	LSQ		SRLS		ST-AM		ST-SM	
			BV	Rank	BV	Rank	BV	Rank	BV	Rank
<b>Overall mean</b>		<b>403</b>	<b>2920</b>		<b>2953</b>		<b>2920</b>		<b>2928</b>	
1	H114	7	2899	26	2970	14	2880	29	2907	26
2	H73	6	3025	3	3016	4	3115	1	3033	3
3	H100	17	2839	39	2960	18	2743	42	2847	39
4	H204	5	2895	27	2964	17	2873	30	2903	27
5	H187	6	2829	40	2943	28	2703	43	2837	40
6	H183	3	2994	6	3023	2	3046	6	3002	6
7	H186	3	2973	15	3006	6	2996	14	2981	15
8	H65	5	3038	1	3026	1	3109	3	3046	1
9	H141	4	2986	10	3011	5	2975	18	2994	10
10	H245	10	2698	44	2920	32	2480	44	2706	44
11	H387	12	2998	5	2996	8	3075	5	3006	5
12	H271	4	3007	4	3021	3	3040	7	3015	4
13	H330	10	2934	21	2980	12	2932	22	2942	21
14	H144	5	2959	17	2993	9	2977	17	2967	17
15	H281	11	2977	12	2991	11	3021	10	2985	12
16	H325	12	2987	9	2992	10	3080	4	2995	8
17	H268	5	2975	14	3001	7	3013	12	2983	14
18	H242	6	2840	38	2948	23	2815	36	2848	38
19	H214	14	2771	43	2943	28	2744	41	2778	43
20	H233	17	2792	42	2953	22	2786	39	2799	42
21	H413	3	2870	33	2944	26	2865	31	2878	33
22	HG1	15	2988	7	2972	13	3035	8	2995	9
23	HG599	37	2930	22	2957	21	2920	23	2938	22
24	HG15	5	2894	29	2947	25	2885	26	2901	29
25	HG45	3	2967	16	2959	20	2994	16	2975	16
26	HG59	11	2887	31	2918	35	2844	32	2895	31
27	HG43	5	2984	11	2948	23	3027	9	2991	11
28	HG129	5	2988	7	2960	18	3012	13	2996	7
29	2HG191	3	2977	12	2966	16	3018	11	2985	13
30	3HG217	34	2869	34	2909	39	2843	33	2877	34
31	3HG183	16	2912	25	2912	38	2936	21	2919	25
32	3HG272	14	2956	18	2917	37	2968	19	2963	19
33	3HG45	4	2855	36	2902	40	2806	38	2863	36
34	3HG129	4	2924	24	2920	32	2910	25	2931	24
35	4HG297	9	2855	36	2891	42	2810	37	2862	37
36	4HG321	6	2885	32	2895	41	2882	27	2892	32
37	4HG322	17	2947	20	2918	35	2961	20	2954	20
38	4HG369	3	2956	18	2938	30	2995	15	2964	18
39	4HG370	4	3034	2	2970	14	3115	1	3041	2
40	4HG377	7	2823	41	2889	43	2746	40	2830	41
41	5HG451	14	2927	23	2944	26	2915	24	2935	23
42	7HG369	14	2891	30	2922	31	2832	35	2898	30
43	4HG329	3	2868	35	2879	44	2834	34	2876	35
44	5HG435	4	2895	27	2919	34	2881	28	2903	28

It was also observed that estimated breeding values of 21 (47.72%) out of 44 sires were above the average breeding value, while, remaining 23 (52.27%) sires were having breeding value below the overall average. The highest and lowest breeding values were estimated as 3026 and 2879 kg for sires H65 and 4HG-329, respectively. The sire with highest breeding value had superiority of 2.47 per cent above the average breeding value. On the other hand, the inferior sire had 2.50 per cent lower breeding value than the average. The difference between the highest and lowest average breeding values was 147 kg.

**c. Single trait - BLUP Animal model (ST-AM) Method**

The overall estimated average breeding value for the first lactation 300 days or less milk yield by ST-AM (BLUP) method was 2920 kg (Table 4.12). The highest estimate of breeding value of sire from this method was 3115 kg (Sire No H-73) and the lowest of sire was 2480 kg (Sire No. H-245). It was also observed that estimated breeding values of 22 (50.00 %) out of 44 sires were above the average breeding value, while, remaining 22 (50.00 %) sires had below the overall average breeding value.

The sire with highest breeding value had superiority of 6.67 per cent above the average breeding value. On the other hand, the inferior sire had 15.06 per cent lower breeding value than the average. The difference between the highest and lowest average breeding values was 635 kg.

**d. Single trait-BLUP Sire model (ST-SM) Method**

The overall estimated average breeding value for the first lactation 300days or less milk yield by ST-SM (BLUP) method was 2928kg (Table 4.12). The highest estimate of breeding value by this method was 3046 kg (sire No.H-65) and the lowest as 2706 kg (sire No. H-245).

It was noticed that estimated breeding values of 25 (56.81 %) out of 44 sires were above the average breeding value, whereas remaining 19 (43.19 %) sires were having breeding value below the overall average.

The sire with highest breeding value had superiority of 4.03 per cent above the average breeding value. On the other hand, the inferior sire had 7.58 per cent

lower breeding value than the average. The difference between the highest and lowest average breeding values was 340 kg.

#### 4.4.2 Sire Evaluation under Multi-Trait Animal Models

The breeding value of HF x Gir halfbred sires were estimated by multiple traits methods for first lactation 300days or less milk yield along with reproduction (AFC, FCI,CAFS,IFLS and CACO) traits in various models of two and three traits combinations using WOMBAT software (Meyer, 2007).

**Table 4.13 Codes of different multi-trait combination of animal models for FL300DMY along with production and fertility traits**

First Lactation traits	
TWO-TRAITS MODELS	CODE
FL300DMY and AFC	AMT2_1
FL300DMY and CAFS	AMT2_2
FL300DMY and FCI	AMT2_3
FL300DMY and IFLS	AMT2_4
FL300DMY and CACO	AMT2_5
THREE-TRAITS MODELS	
FL300DMY, AFC and FCI	AMT3_6
FL300DMY, IFLS and CACO	AMT3_7
FL300DMY, FCI and CAFS	AMT3_8

#### Two traits animal models

##### i. FL300DMY and AFC

The overall average breeding value for first lactation 300days or less milk yield along with AFC by two traits animal model (AMT2-1) method was 2915 kg (Table 4.14). The highest estimate of breeding value by this method was 3050 kg (Sire No. H-73) and the lowest was 2629 kg (Sire NoH-245). In this method, as many as 21 sires (47.72 %) out of 44 sires had higher than the average breeding value and remaining 23 sires (52.27 %) had lower breeding value than the average breeding value. The sire with highest breeding value had superiority of 4.63 per cent above the average breeding value. On the other hand, the inferior sire had 9.81 per cent lower breeding value than the average. The difference between the highest and lowest average breeding values was 421 kg.

**Table 4.14 Estimated breeding values (EBVs) along with their ranks of HF x Gir sires for FL300DMY by two trait animal models**

Sr. No.	SIRE	N	FL300DMY									
			EBV's and ranks by 2-trait models									
			AMT2-1	Rank	AMT2-2	Rank	AMT2-3	Rank	AMT2-4	Rank	AMT2-5	Rank
<b>Overall mean</b>		<b>403</b>	<b>2915</b>		<b>2915</b>		<b>2915</b>		<b>2915</b>		<b>2915</b>	
1	H114	7	2898	28	2894	30	2888	28	2915	24	2919	23
2	H73	6	3050	1	3045	1	3071	1	3059	3	3070	1
3	H100	17	2802	41	2800	42	2770	40	2750	42	2851	37
4	H204	5	2898	27	2918	23	2877	30	2873	31	2942	18
5	H187	6	2771	43	2828	39	2745	43	2742	43	2774	43
6	H183	3	2995	8	2974	11	3013	8	3024	8	2998	5
7	H186	3	2954	18	2932	21	2966	17	2960	18	2943	17
8	H65	5	3021	4	3020	2	3062	2	3028	6	2997	6
9	H141	4	2975	14	2946	17	2971	16	2976	14	2986	10
10	H245	10	2629	44	2653	44	2566	44	2537	44	2637	44
11	H387	12	3022	3	2994	8	3045	5	3070	1	2986	9
12	H271	4	3000	7	2983	10	3015	7	3028	7	2988	8
13	H330	10	2915	21	2948	15	2925	21	2931	22	2882	31
14	H144	5	2957	16	2946	16	2957	18	2958	19	2949	16
15	H281	11	2991	9	3009	4	2999	12	3005	11	2988	7
16	H325	12	3016	5	3020	3	3051	3	3065	2	3035	3
17	H268	5	2979	13	2950	14	2996	13	2973	15	2970	14
18	H242	6	2841	36	2827	40	2832	36	2854	33	2824	39
19	H214	14	2788	42	2782	43	2758	42	2752	41	2790	42
20	H233	17	2815	39	2846	36	2799	39	2800	39	2807	40
21	H413	3	2875	33	2876	33	2869	32	2878	29	2865	33
22	HG1	15	2988	10	2969	12	3011	9	3018	9	2959	15
23	HG599	37	2908	24	2911	27	2902	24	2876	30	2918	24
24	HG15	5	2899	26	2908	28	2885	29	2900	25	2909	28
25	HG45	3	2971	15	2935	20	2981	15	2966	16	2973	11
26	HG59	11	2878	32	2894	31	2860	33	2815	37	2893	30
27	HG43	5	2957	17	2986	9	2986	14	2999	12	2925	20
28	HG129	5	2984	11	2999	7	3003	10	2991	13	2971	13
29	2HG191	3	2983	12	2953	13	2999	11	3008	10	2971	12
30	3HG217	34	2839	37	2875	34	2852	34	2872	32	2801	41
31	3HG183	16	2912	23	2924	22	2914	22	2938	21	2914	25
32	3HG272	14	2945	19	2939	19	2956	19	2948	20	2923	22
33	3HG45	4	2849	35	2829	37	2829	37	2841	36	2860	34
34	3HG129	4	2906	25	2914	24	2895	27	2897	26	2911	26
35	4HG297	9	2834	38	2829	38	2807	38	2801	38	2853	36
36	4HG321	6	2894	29	2876	32	2870	31	2849	34	2935	19
37	4HG322	17	2881	31	2895	29	2897	26	2883	28	2856	35
38	4HG369	3	2926	20	2945	18	2951	20	2965	17	2900	29
39	4HG370	4	3015	6	3005	5	3047	4	3030	5	3007	4
40	4HG377	7	2809	40	2810	41	2765	41	2787	40	2841	38
41	5HG451	14	3029	2	3000	6	3025	6	3034	4	3039	2
42	7HG369	14	2914	22	2913	25	2912	23	2928	23	2909	27
43	4HG329	3	2874	34	2852	35	2835	35	2848	35	2923	21
44	5HG435	4	2887	30	2911	26	2901	25	2890	27	2868	32

**ii. FL300DMY and CAFS**

The overall average breeding value for first lactation 300 days or less milk yield along with CAFS by two traits animal model (AMT2-2) method was 2915 kg (Table 4.14). The highest breeding value from this method was 3045 kg (Sire No. H-73) and the lowest was 2653 kg (Sire No. H- 245). In this method, as many as 23 sires (52.27 %) out of 44 sires had breeding values higher than the average breeding value and the remaining 21 sires (47.72 %) had breeding value lower than the average breeding value. The sire with highest breeding value had superiority of 4.45 per cent above the average breeding value. On the other hand, the inferior sire had 8.98 per cent lower breeding value than the average breeding value. The difference between the highest and lowest average breeding values was 392 kg.

**iii. FL300DMY and FCI**

The overall average breeding value for the first lactation 300 days or less milk yield along with FCI by two traits animal model (AMT2-3) method was 2915 kg (Table 4.14). The highest breeding value for this method was 3071 kg (Sire No. H-73) and the lowest was 2566 kg (Sire No. H-245).

In this method, as many as 21 sires (47.72 %) out of 44 sires had breeding values more than the average breeding value and the remaining 23 sires (52.27 %) had lower breeding value than the average. The sire with highest breeding value had superiority of 5.35 per cent above the average breeding value. On the other hand, the inferior sire had 11.97 per cent lower breeding value than the average. The difference between highest and lowest average breeding values was 505 kg.

**iv. FL300DMY and IFLS**

The overall mean breeding value for the first lactation 300 days or less milk yield along with IFLS by two traits animal model (AMT2-4) method was 2915 kg (Table 4.14). The highest breeding value by this method was 3070 kg (Sire No. H-387) and the lowest as 2537 kg (Sire No. H 245).

In this method, as many as 23 sires (52.27 %) out of 44 sires had breeding values more than the average breeding value and the remaining 21 sires (47.72 %) had lower breeding value than the average breeding value. The sire with highest breeding value had superiority of 5.31 per cent above the average breeding value. On the other hand,

and, the inferior sire had 12.96 per cent lower breeding value than the average. The difference between the highest and lowest average breeding value was 537 kg.

**v. FL300DMY and CACO**

The overall average breeding value for the first lactation 300 days or less milk yield along with CACO by two traits animal model (AMT2-5) method was 2915 kg (Table 4.14). The highest breeding value from this method was 3070 kg (Sire No. H-73) and the lowest was 2637 kg (Sire No H-245).

In this method, as many as 23 sires (52.27 %) out of 44 sires had higher breeding values than the average breeding value and the remaining 21 sires (47.72 %) had lower breeding value than the average. The sire with highest breeding value had superiority of 5.31 per cent above the average breeding value. On the other hand, the inferior sire had 9.53 per cent lower breeding value than the average. The difference between the highest and lowest average breeding values was 433 kg.

**Three-traits animal models**

**i. FL300DMY, AFC and FCI**

The overall estimated average breeding value of first lactation 300 days or less milk yield along with AFC and FCI by three traits animal model (AMT3-6) was 2917 kg (Table 4.15). The highest breeding value from this method was 2933 kg (Sire No. H-114) and the lowest was 2892 kg (Sire No. 3HG-272).

In this method, as many as 23 sires (52.27 %) out of 44 sires had breeding values more than the average breeding value and the remaining 21 sires (47.72 %) had lower breeding values than the average. The sire with highest breeding value had superiority of 0.54 per cent above the average breeding value. On the other hand, the inferior sire had 0.85 per cent lower than the average breeding value. The difference between the highest and lowest average breeding values was 41 kg.

**ii. FL300DMY, IFLS and CACO**

The overall estimated average breeding value for the first lactation 300 days or less milk yield along with IFLS and CACO by three traits animal model (AMT3-7) method was 2917 kg (Table 4.15). The highest estimate of breeding value from this method was 2959 kg (Sire No. HG-129) and the lowest was 2769 kg (Sire No. H-325).

**Table 4.15** Estimated breeding values (EBVs) along with their ranks of HF x Gir sires for FL300DMY by different three animal model

Sr. No.	SIRE	N	FL300DMY					
			Models EBV's and ranks by 3-trait models					
			AMT3-6	Rank	AMT3-7	Rank	AMT3-8	Rank
<b>Overall mean</b>		<b>403</b>	<b>2917</b>		<b>2917</b>		<b>2917</b>	
1	H114	7	2933	1	2931	12	2977	6
2	H73	6	2922	16	2942	7	2966	9
3	H100	17	2925	9	2941	8	2989	2
4	H204	5	2926	8	2952	3	3005	1
5	H187	6	2914	29	2953	2	2983	3
6	H183	3	2924	13	2930	13	2926	17
7	H186	3	2917	25	2927	18	2917	20
8	H65	5	2929	3	2934	10	2942	14
9	H141	4	2911	33	2892	38	2849	41
10	H245	10	2925	10	2950	5	2981	4
11	H387	12	2912	31	2892	38	2879	35
12	H271	4	2933	2	2924	20	2961	10
13	H330	10	2926	7	2946	6	2972	8
14	H144	5	2913	30	2888	40	2860	40
15	H281	11	2914	27	2909	29	2873	38
16	H325	12	2896	42	2769	44	2724	44
17	H268	5	2904	39	2894	37	2830	43
18	H242	6	2912	32	2898	36	2900	29
19	H214	14	2905	38	2899	35	2899	31
20	H233	17	2895	43	2936	9	2886	34
21	H413	3	2919	20	2920	24	2912	23
22	HG1	15	2910	34	2921	23	2920	19
23	HG599	37	2914	28	2902	34	2912	23
24	HG15	5	2919	21	2930	13	2937	15
25	HG45	3	2924	12	2917	26	2905	27
26	HG59	11	2921	18	2904	33	2912	23
27	HG43	5	2927	6	2884	41	2943	13
28	HG129	5	2922	15	2959	1	2980	5
29	2HG191	3	2909	35	2932	11	2946	12
30	3HG217	34	2925	11	2908	30	2902	28
31	3HG183	16	2907	37	2951	4	2951	11
32	3HG272	14	2892	44	2930	13	2899	31
33	3HG45	4	2918	23	2928	16	2888	33
34	3HG129	4	2898	41	2911	27	2876	37
35	4HG297	9	2918	22	2919	25	2929	16
36	4HG321	6	2914	26	2875	43	2873	38
37	4HG322	17	2923	14	2911	27	2900	29
38	4HG369	3	2917	24	2923	21	2911	26
39	4HG370	4	2928	4	2908	30	2977	7
40	4HG377	7	2900	40	2880	42	2832	42
41	5HG451	14	2921	17	2928	16	2923	18
42	7HG369	14	2928	5	2905	32	2879	35
43	4HG329	3	2921	19	2925	19	2917	20
44	5HG435	4	2908	36	2923	21	2915	22

In this method, as many as 25 sires (56.81 %) out of 44 sires had breeding values higher than the average breeding value and the remaining 19 sires (43.19 %) had breeding value lower than the average breeding value. The sire with highest breeding value had superiority of 1.41 per cent above the average breeding value. However, the inferior sire had 5.07 per cent lower breeding value than the average breeding value. The difference between the highest and lowest average breeding values was 190 kg.

### **iii. FL300DMY, FCI and CAFS**

The overall average breeding value for the first lactation 300 days or less milk yields along with FCI and CAFS by three traits animal model (AMT3\_8) was 2917 kg (Table 4.15). The highest estimate of breeding value by this method was 3005 kg (Sire No.H-204) and the lowest was 2724 kg (Sire No.H-325).

In this method, as many as 19 sires (43.19 %) out of 44 sires had higher breeding values than the average breeding value and the remaining 25 sires (56.81 %) had breeding value lower than the average. The sire with highest breeding value had superiority of 3.01 per cent above the average breeding value. On the other hand, the inferior sire had 6.61 per cent lower than the average breeding value. The difference between the highest and lowest average breeding values was 281 kg.

## **4.5 Comparison of Effectiveness of Different Sire Evaluation Methods**

The effectiveness of different single and multi-trait sire evaluation methods for FL300DMY was compared on the basis of their efficiency (error variance) and accuracy (Table 4.16). The rank correlations among the EBVs of FL300DMY obtained from different single and multi-trait sire evaluation models are presented in Table 4.24.

### **4.5.1 Within Sire Variance or Error Variance (Efficiency)**

The within sire variance or error variance is one of the judging criteria of the effectiveness of different sire evaluation methods. An efficient method of sire evaluation must have minimum error variance (Table 4.16).

#### **i. Single-trait models**

The error variances among various single-trait methods of sire evaluation for FL300DMY showed that the ST-AM (BLUP) had lowest error variance (301617 kg) followed ascending order (358815, 385711, 439222) by ST-SM (BLUP), SRLS and LSQ

methods respectively. The relative efficiencies of ST-SM (BLUP), SRLS and LSQ methods in comparison to ST-AM method were 84.50, 78.19 and 68.67, respectively. The highest efficiency of ST-AM may be ascribed to all kinds of relationships among animals over all recorded generations accounted into animal model analysis which produced lowest error variance compared to other single-trait sire evaluation methods.

**Table 4.16 Effectiveness of different sire evaluation methods for FL300DMY**

Methods	Error variance (kg <sup>2</sup> )	RE (%)	R <sup>2</sup> (%)
<b>Single trait models</b>			
LSQ	439222	68.67	29.06
SRLS	385711	78.19	90.63
ST-SM	358815	84.50	28.36
ST-AM	301617	100	29.28
<b>Two trait models</b>			
FL300DMY and AFC	378793	99.87	26.56
FL300DMY and CAFS	378317	100	25.34
FL300DMY and FCI	382171	98.88	27.47
FL300DMY and IFLS	381985	99.03	25.47
FL300DMY and CACO	404264	93.58	23.39
<b>Three trait models</b>			
FL300DMY, AFC and FCI	380196	98.89	2.52
FL300DMY, IFLS and CACO	379761	99.00	0.30
FL300DMY, FCI and CAFS	379625	100	0.005

## ii. Multi-trait animal models

The error variances among two-trait animal models of sire evaluation for FL300DMY indicated that the two-trait animal models of traits FL300DMY and CAFS had lowest error variance (378317) than other two-trait animal models. The relative efficiencies of various two-trait models in comparison to best two-trait animal model (FL300DMY and CACO) ranged between 93.58, (FL300DMY and FCI) 98.88, (FL300DMY and IFLS) 99.03 per cent and (FL300DMY and AFC) 99.87 per cent, respectively. The difference among error variances of different two-trait animal models is attributed to the difference in magnitude and direction of genetic and phenotypic correlations of trait included in two-trait animal models with FL300DMY trait.

The error variance of three-trait animal model of FL300DMY, FCI and CAFS traits combination had relatively lower (379625) error variances compared to other three trait models. The highest (380196) error variance was observed for FL300DMY,

AFC and FCI three-traits combination. Accordingly, three-trait animal model of trait combinations FL300DMY, FCI and CAFS had relatively higher efficiency compared to other three-trait models. In practical situation, however, the three trait model combining FL300DMY, FCI and CAFS should be applied rather than FL300DMY, AFC and FCI to avoid delay in evaluation. The difference among error variance of three-trait animal models was attributed to the difference in magnitude and direction of genetic and phenotypic correlations of traits involved in three-trait animal models.

**Table 4.17. Rank correlations between estimated breeding values by different single and multi-trait sire evaluation methods for FL300DMY**

Methods	LSQ	SRLS	ST-AM	ST-SM	AMT-2-1	AMT-2-2	AMT-2-3	AMT-2-4	AMT-2-5	AMT-3-6	AMT-3-7	AMT-3-8
LSQ	1.000											
SRLS	0.72**	1.000										
ST-AM	0.97**	0.68**	1.000									
ST-SM	1.00**	0.72**	0.97**	1.000								
AMT-2-1	0.93**	0.69**	0.93**	0.94**	1.000							
AMT-2-2	0.93**	0.67**	0.93**	0.94**	0.97**	1.000						
AMT-2-3	0.96**	0.69**	0.95**	0.96**	0.98**	0.97**	1.000					
AMT-2-4	0.93**	0.68**	0.93**	0.93**	0.98**	0.96**	0.98**	1.000				
AMT-2-5	0.87**	0.66**	0.86**	0.87**	0.94**	0.89**	0.91**	0.89**	1.000			
AMT-3-6	0.16	0.18	0.08	0.16	0.10	0.12	0.12	0.10	0.13	1.000		
AMT-3-7	-0.06	0.06	-0.11	-0.06	-0.06	-0.01	-0.06	-0.08	-0.08	0.28	1.000	
AMT-3-8	0.04	0.13	-0.12	0.04	-0.02	0.03	0.18	-0.01	-0.20	0.60**	0.75**	1.000

\*\* P < 0.01

#### 4.5.2 Spearman's Rank Correlations

The Spearman's rank correlations between breeding values estimated by different single and multi-trait sire evaluation methods for FL300DMY are presented in Table 4.17.

The rank correlations among EBVs by single-trait (LSQ, SRLS, ST-SM and ST-AM) methods indicated that the rank correlation between ST-AM and ST-SM (0.97) was higher than between ST-AM and SRLS (0.68). The ranking of sires obtained from single-trait animal model for FL300DMY trait was least similar to the ranking of sires obtained from other single-trait based sire evaluation methods (LSQ, SRLS and ST-SM) and close to the ranking of sires obtained from various multi-trait animal evaluation methods. Similar results of rank correlations amongst EBVs by single-trait (LSQ, SRLS,

ST-SM and ST-AM) methods were also reported by Singh (2013) in Karan Fries cattle and Ambhore *et al.* (2018) in Phule Triveni cattle.

The rank correlations between breeding values of single-trait animal model (ST-AM) and various multi-trait animal models for FL300DMY varied from 0.98 (highest for FL300DMY and AFC) to 0.60 (lowest for FL300DMY, AFC and FCI). The difference among rank correlations between breeding values of single-trait animal model (ST-AM) method and various multi-trait animal models was attributed to the difference in magnitude and direction of genetic and phenotypic correlations of traits included in multi-trait animal models. It was observed that the rankings of sires based on breeding values for FL300DMY trait from multi-trait animal models were significantly changed than that of single-trait animal model. In the present study all the estimates of rank correlations were highly significant. These results agreed with the reports of Dalal *et al.* (2016), Dubey *et al.* (2006) and Mukharjee *et al.* (2007) obtained in different crossbreds.

**Table 4.18** Ranking of top 10 HF x Gir sires based on EBVs of FL300DMY trait by different single trait models

Rank	LSQ	SRLS	STSM	STAM
1	8 (3038)	8 (3026)	2 (3115)	8 (3046)
2	57 (3034)	6 (3023)	57 (3115)	57 (3041)
3	2 (3025)	12 (3021)	8 (3109)	2 (3033)
4	12 (3007)	2 (3016)	17 (3080)	12 (3015)
5	11 (2998)	9 (3011)	11 (3075)	11 (3006)
6	6 (2994)	7 (3006)	6 (3046)	6 (3002)
7	27 (2988)	18 (3001)	12 (3040)	36 (2996)
8	36 (2988)	11 (2996)	27 (3035)	17 (2995)
9	17 (2987)	14 (2993)	35 (3027)	27 (2995)
10	9 (2986)	17 (2992)	15 (3021)	9 (2994)

1:H114, 2: H73, 3:H100, 6:H183, 8:H65, 12: H271, 17:H325, 24:H233, 27:HG1, 35:HG43, 38:3HG217, 40:3HG272, 43:3HG45, 50: 3HG321, 51:4HG322, 52: 4HG369, 57: 4HG370, 63: 7HG369, 28: HG599 \*(Figures in parenthesis indicates EBV's of sires)

**Table 4.19 Ranking of top 10 HF x Gir sires based on EBVs of FL300DMY trait by different two trait models**

Rank	AMT2-1	AMT2-2	AMT2-3	AMT2-4	AMT2-5
1	2 (3050)	2 (3045)	2 (3071)	11 (3070)	2 (3070)
2	62 (3029)	8 (3020)	8 (3062)	17 (3036)	62 (3039)
3	11 (3022)	17 (3020)	17 (3051)	2 (3059)	17 (3035)
4	8 (3021)	15 (3009)	57 (3047)	62 (3034)	57 (3007)
5	17 (3016)	57 (3005)	11 (3045)	57 (3030)	6 (2998)
6	57 (3015)	62 (3000)	62 (3025)	8 (3028)	8 (2997)
7	12 (3000)	36 (2999)	12 (3015)	12 (3028)	15 (2988)
8	6 (2995)	11 (2994)	6 (3013)	6 (3024)	12 (2988)
9	15 (2991)	35 (2986)	27 (3011)	27 (3018)	11 (2986)
10	27 (2988)	12 (2983)	36 (3003)	37 (3008)	9 (2986)

1:H114, 2: H73, 3:H100, 6:H183, 8:H65, 12: H271, 17:H325, 24:H233, 27:HG1, 35:HG43, 38:3HG217, 40:3HG272, 43:3HG45, 50: 3HG321, 51:4HG322, 52: 4HG369, 57: 4HG370, 63: 7HG369, 28: HG599 \*(Figures in parenthesis indicates EBV's of sires)

**Table 4.20 Ranking of top 10 HF x Gir sires based on EBVs of FL300DMY trait by different three trait models**

Rank	AMT3-6	AMT3-7	AMT3-8
1	1 (2933)	45 (2959)	4 (3005)
2	12 (2933)	5 (2953)	3 (2989)
3	8 (2929)	4 (2952)	5 (2983)
4	57 (2928)	39 (2951)	10 (2981)
5	52 (2928)	10 (2950)	36 (2980)
6	35 (2927)	13 (2946)	1 (2977)
7	13 (2926)	2 (2942)	57 (2977)
8	4 (2926)	3 (2941)	24 (2972)
9	3 (2925)	24 (2936)	2 (2966)
10	10 (2925)	8 (2934)	12 (2961)

1:H114, 2: H73, 3:H100, 6:H183, 8:H65, 12: H271, 17:H325, 24:H233, 27:HG1, 35:HG43, 38:3HG217, 40:3HG272, 43:3HG45, 50: 3HG321, 51:4HG322, 52: 4HG369, 57: 4HG370, 63: 7HG369, 28: HG599 \*(Figures in parenthesis indicates EBV's of sires)

#### 4.6 Ranking of Top 10 HF x Gir Sires by Different Single and Multi Traits Models

The total number of HF x Gir halfbred sires were 44 in the first lactation production and reproduction data. The top 10 elite sires (~20 % of total sires) ranked by single-trait animal model (ST-AM) were compared with the ranking by different multiple-trait animal models by AMT2-1, AMT2-2, AMT2-3, AMT2-4, AMT2-5, AMT3-6, AMT3-7, AMT3-8 (Table 4.18, 4.19 and 4.20). It was observed that out of top 10 elite sires, the common sires found in multi-trait models in comparison to single-trait animal model (ST-AM) varied between 50 per cent (FL300DMY, IFLS and CACO : AMT3-7) to 80 per cent (FL300DMY and AFC:AMT2-1) in different sire evaluation methods used in the present study on HF x Gir halfbred sires (Table 4.21). The top 10 sires ranked on the basis of first lactation 300DMY revealed that all sires would not rank same for all the method. However, the rank of sire for different sire evaluation methods revealed that 4-5 top sires almost had similar rank for all the methods. Similar results were also reported by Dubey *et al.* (2006), Dalal *et al.* (2016) and Singh and Singh (2016).

**Table 4.21 Common sires selected in comparison to ST-AM based in various crossbreds on EBV's of FL300DMY by multi-trait models (Out of 10 sires)**

Methods	Error variance (kg <sup>2</sup> ) RE (%)	% of common sires
<b>Single trait models</b>		
1	LSQ	70
2	SRLS	80
3	STSM	70
4	STAM	100
<b>Two trait models</b>		
1	FL300DMY and AFC	80
2	FL300DMY and CAFS	70
3	FL300DMY and FCI	70
4	FL300DMY and IFLS	60
5	FL300DMY and CACO	60
<b>Three trait models</b>		
1	FL300DMY, AFC and FCI	60
2	FL300DMY, IFLS and CACO	50
3	FL300DMY, FCI and CAFS	60

**Table 4.22 Estimated maximum and minimum breeding values (EBVs) along with their mean and SD for FL300DMY by single and multi-trait animal models**

Method	ST-AM	Two trait model	Three trait model
Traits	FL300DMY	FL300DMY and AFC	FL300DMY, AFC and FLL
Mean ( $\mu$ )	2920	2917	2917
Standard deviation (SD)	123.81	81.80	9.93
Max. EBV	3115	3049	2933
Min (EBV)	2480	2629	2892

The average breeding value of sires for FL300DMY using single trait animal model was 2920 kg whereas, the average EBVs of best multi-trait models by two traits combinations was 2917kg and by three and four traits model were 2917 kg respectively. In general, standard deviations of EBVs for FL300DMY trait was higher for single-trait than multi-trait analysis. Both high variance and wide range of EBVs from multi-trait analysis indicated that joint analysis combining milk production and reproduction traits could provide more information on differentiating genetically best or worst animals and hence useful for breeding for good fertility. The findings of present study were in agreement with Kadarmideen *et al.* (2003), Biffani *et al.* (2005), Sun *et al.* (2009), Divya (2012) and Ambhore *et al.* (2017) reported in different crossbreds. They also observed higher variation in EBVs of fertility traits when estimated using multi-trait models combining reproduction traits with milk production.

## 5. SUMMARY AND CONCLUSIONS

### 5.1 Summary

The present investigation was aimed to compare the effectiveness of multiple trait animal models over single trait models for estimation of genetic parameters and sire evaluation using different methods. A total of 403 first lactation records of HF x Gir halfbred cows sired by 44 bulls were collected for reproduction and production traits spread over a period of 44 years (1974 to 2017) from Research-Cum Development Project on Cattle, Mahatma Phule Krishi Vidyapeeth, Rahuri, District Ahmednagar (Maharashtra). The data were classified into different subclasses based on period of calving, season of calving and age at first calving groups for all the traits under study except age at first calving (AFC). Further, the data of AFC were classified into different subclasses based on period and season of birth.

The effects of sire, period and season of birth/calving, age at first calving groups on FL300DMY, FLPMY, FLL, AFC, FCI, CAFS, IFLS and CACO traits and the variability in these first lactation traits were analyzed by using mixed model i.e. Least Squares Maximum Likelihood (LSML) software (Harvey, 1990) and genetic parameters of various traits for single trait models were estimated. The various genetic (sire) and non-genetic factors (period of birth/calving, season of birth/calving and age at first calving groups) affecting various production and reproduction traits were analyzed using LSML and REML (WOMBAT software).

Single trait sire model and single trait animal model and genetic parameters of various traits fitting multi-trait animal models were compared for various two-trait and, three-trait combinations using WOMBAT software (Meyer, 2007). The breeding values of HF x Gir halfbred sires were predicted by single-trait and multi-traits models for FL300DMY. The single-trait methods of sire evaluation used were least-squares method (LSQ), simple regressed least squares (SRLS), single-trait BLUP sire model (ST-SM) and single-trait BLUP animal model (ST-AM). Multi-trait animal models of sire evaluation were used for milk production and reproduction traits in various models of two and three traits combinations. The effectiveness of different single and multi-trait

methods of sire evaluation was compared on the basis of their relative efficiency (error variance), accuracy ( $R^2$ ) and rank correlations.

The phenotypic, genetic and environmental trends of various first lactation traits *viz.*, FL300DMY, FLPMY, FLL, AFC, FCI, CAFS, IFLS and CACO were also estimated to determine the effectiveness of selection programme over the years. Two methods *viz.*, Smith-II and BLUP were used for estimation of genetic and environmental trends over years.

The HF x Gir sires were also evaluated based on eight different models used for estimation of EBVs of sires for FL300DMY under single-trait animal model and multiple-trait animal models and all the sires were ranked based on these EBVs. However, only the best multi-trait models which were found for sire selection were considered for selection of sires on the basis of EBVs.

### **5.1.1 Least squares means**

#### **First lactation**

The average least squares mean of first lactation were FL300DMY  $2780.17 \pm 37.31$  kg, FLPMY  $15.28 \pm 0.16$  kg, FLL  $326.77 \pm 1.81$  days, FCI  $408.38 \pm 3.41$  days, CAFS  $72.71 \pm 0.85$  days, IFLS  $64.22 \pm 2.10$  days and CACO  $85.19 \pm 1.90$  days.

Among the different genetic and non-genetic factors studied, period of calving had significant effect on FL300DMY, FLPMY, FLL and IFLS and non significant effect on FCI, CAFS and CACO. Season of calving and age at first calving group had non significant effect on all first lactation production and reproduction traits. The sire had significant effect on FL300DMY, FLPMY, FLL and CAFS and non significant effect on FCI, IFLS, and CACO.

### **5.1.2 Correlation studies**

The phenotypic and genetic correlations between FL300DMY and FLPMY was  $0.19 \pm 0.04$  and  $0.99 \pm 0.49$ , between FL300DMY and FLL was  $0.25 \pm 0.04$  and  $-0.38 \pm 0.51$ , between FL300DMY and AFC was  $0.05 \pm 0.04$  and  $0.17 \pm 0.41$ , between FL300DMY and FCI was  $0.20 \pm 0.04$  and  $0.19 \pm 0.06$ , between FL300DMY and CAFS was  $0.07 \pm 0.05$  and  $-0.19 \pm 0.44$ , between FL300DMY and IFLS was  $-0.06 \pm 0.05$  and  $-0.02 \pm 0.06$  and FL300DMY and CACO  $0.04 \pm 0.05$  and  $-0.40 \pm 0.07$ . The standard

errors of genetic correlations were quite high between different traits except between FL300DMY and FLPMY.

The phenotypic and genetic correlations between FLPMY and FL300DMY was  $0.19 \pm 0.04$  and  $0.99 \pm 0.49$ , between FLPMY and FLL was  $-0.02 \pm 0.05$  and  $-0.72 \pm 0.06$ , between FLPMY and AFC was  $0.40 \pm 0.52$  and  $0.20 \pm 0.46$ , between FLPMY Y and FCI was  $-0.26 \pm 0.05$  and  $0.99 \pm 0.63$ , between FLPMY and CAFS was  $-0.03 \pm 0.05$  and  $-0.24 \pm 0.44$ , between FLPMY and IFLS was  $0.05 \pm 0.05$  and  $-0.31 \pm 0.93$  and FLPMY and CACO  $0.02 \pm 0.05$  and  $0.37 \pm 0.67$ . The standard errors of genetic correlations were quite high between different traits except between FLPMY and AFC.

### 5.1.3 Heritability estimates

The heritability estimates of FL300DMY, FLPMY, FLL, AFC, FCI, CAFS, IFLS and CACO were  $0.20 \pm 0.12$ ,  $0.18 \pm 0.12$ ,  $0.14 \pm 0.10$ ,  $0.22 \pm 0.11$ ,  $0.15 \pm 0.12$ ,  $0.04 \pm 0.10$ ,  $0.21 \pm 0.09$  and  $0.16 \pm 0.08$ , respectively using LSML. The heritability of all traits except FLPMY and FLL from mixed model using LSML was moderate in magnitude which indicated these traits are more influenced by additive genetic variability and hence there is more scope for improvement by selection. The low heritability estimate of FLPMY and FLL trait indicates that it is influenced more by managerial and environmental factors than by genetic factors.

The heritability of FL300DMY, FLPMY, FLL, AFC, FCI, CAFS, IFLS and CACO traits were  $0.05 \pm 1.00$ ,  $0.01 \pm 0.029$ ,  $0.01 \pm 0.03$ ,  $0.22 \pm 0.09$ ,  $0.04 \pm 0.030$ ,  $0.01 \pm 0.030$ ,  $0.03 \pm 0.025$  and  $0.05 \pm 0.027$ , respectively from single-trait BLUP sire model (ST-SM) using WOMBAT software. The corresponding heritability estimates of these traits from single-trait BLUP animal models were  $0.20 \pm 0.98$ ,  $0.10 \pm 0.080$ ,  $0.10 \pm 0.076$ ,  $0.22 \pm 0.099$ ,  $0.00 \pm 0.074$ ,  $0.17 \pm 0.087$ ,  $0.06 \pm 0.57$  and  $0.05 \pm 0.065$ , respectively using WOMBAT software. The residual error variance was higher for single-trait sire model (ST-SM) compared to single-trait animal model (ST-AM). The heritability estimate of traits from single-trait sire model (ST-SM) was considerably lower than corresponding single-trait animal model (ST-AM). The single-trait animal model (ST-AM) appeared to be better method than sire model for heritability estimation.

The heritability estimates by two-trait animal models were  $0.17 \pm 0.41$  (FL300DMY and AFC),  $0.40 \pm 0.39$  (FL300DMY and FCI),  $0.19 \pm 0.44$  (FL300DMY and CAFS),  $0.21 \pm 0.15$  (FL300DMY and IFLS) and  $0.38 \pm 0.44$  (FL300DMY and CACO). The highest heritability estimate of FL300 DMY among two-trait animal model was observed for FL300DMY and FCI combination ( $0.40 \pm 0.39$ ) and was 46.21 per cent higher than ST-AM. This may be ascribed to fairly sufficient additive genetic variation present in both these traits. The heritability estimates of FL300DMY from two traits animal models were moderate in magnitude and produced changed (lower or higher) heritability estimates compared to heritability estimate obtained from single-trait animal model.

The heritability estimates of FL300DMY under three-trait animal models were  $0.22 \pm 0.09$  (FL300DMY, AFC and FCI),  $0.25 \pm 0.06$  (FL300DMY, IFLS and CACO) and  $0.27 \pm 0.11$  (FL300DMY, FCI and CACO). The highest heritability estimate of FL300DMY among three-trait animal model was observed for FL300DMY, FCI and CACO combination ( $0.27 \pm 0.11$ ) and was 23.18 per cent higher than ST-AM.

The genetic ( $r_g$ ) and phenotypic ( $r_p$ ) correlations of milk production traits (FL300DMY, FLPMY and FLL) with reproduction (AFC, FCI, CAFS, IFLS and CACO) traits were estimated using two and three models by WOMBAT. It was observed that the estimates of genetic and phenotypic correlations between FL300DMY and FLPMY, FLL, AFC, FCI, CAFS, IFLS and CACO from different multi-trait models of two and three trait combinations were in general, changed in magnitude and in certain combinations signs were also changed.

#### **5.1.4 Performance trends**

Overall average phenotypic trend for FL300DMY was negative ( $-23.03 \pm 2.83$ ) in HF x Gir cattle, indicating 1.08 per cent decrease in FL300DMY over the herd average. The annual genetic trends for FL300DMY were  $-45.64 \pm 16.74$ kg (SM-II) and  $-91.71 \pm 20.92$  kg (BLUP) per year. The genetic trend was negative and significant ( $P < 0.01$ ) by both SM-II and BLUP method. The genetic trends were negative by Smith-II method but the genetic trend estimated by BLUP method was positive but relatively higher standard error compared to Smith-II method. The estimated environmental trends were  $-22.603 \pm 20.60$  kg by SM-II and  $-68.68 \pm 18.89$  kg per year by BLUP method,

respectively. Environmental trend was in positive direction by both the methods. This showed that decline in milk production over years was due to deterioration in environmental conditions coupled with management

The overall average phenotypic trend for the FLPMY of HF x Gir halfbred was  $-0.03 \pm 0.01$  kg which was negative and significant. The phenotypic trend accounted for -1.67 per cent of the herd average. The overall genetic trends estimated by Smith II and BLUP methods were  $0.54 \pm 0.06$  and  $0.47 \pm 0.05$ . In general, the estimates were statistically non significant and the trend estimated by BLUP methods were lower than the trend estimated by Smith method II. The overall calculated environmental trends estimated by Smith methods II and BLUP were  $-0.57 \pm 0.08$ , and  $-0.50 \pm 0.03$  kg, respectively. The study revealed an overall decline in the FLPMY over the years.

The phenotypic trends estimated for FLL in the HF x Gir cattle was  $-0.05 \pm 0.13$  (0.18 % of HA) days. The phenotypic estimate was negative and non significant ( $P < 0.05$ ). overall genetic trends of FLL by Smith II and BLUP methods were estimated as  $0.18 \pm 11.40$  and  $0.29 \pm 12.60$  days, respectively which were statistically non significant. The environmental trends for FLL were  $-0.13 \pm 09.15$  and  $-0.23 \pm 08.25$  days per year by SM-II and BLUP respectively. Environmental trends were statistically non significant and in negative direction.

The estimation of phenotypic trends for AFC in HF x Gir halfbred was  $6.40 \pm 0.47$ . The positive trend obtained in the present study showed the increase in the AFC over the years. The overall genetic trends for Smith II and BLUP methods were found to be  $-2.12 \pm 14.62$  and  $-0.13 \pm 11.80$  days, respectively. The estimates obtained in Smith II methods were high, negative and statistically highly significant. Overall environmental trends for, Smith II and BLUP methods were found to be  $8.53 \pm 20.90$ , and  $4.27 \pm 16.20$  days, respectively.

The positive and significant ( $P < 0.05$ ) phenotypic trend estimate of  $0.60 \pm 0.24$  days was obtained for FCI in HF x Gir cattle. The genetic trend by Smith method II ( $2.73 \pm 25.48$  days) and BLUP method ( $1.52 \pm 22.60$  days) was positive. The environmental trends for the trait were  $3.33 \pm 21.36$  and  $2.12 \pm 27.58$  days by Smith-II and BLUP methods, respectively. The environmental trend obtained by BLUP method for FCI was low, positive and non significant.

The average yearly changes in means of CAFS were quantified. A positive and significant phenotypic trend estimate of  $0.06 \pm 0.06$  days was obtained for CAFS in HF x Gir cattle. The annual genetic trends were estimated to be  $-1.87 \pm 2.08$  and  $-1.74 \pm 1.35$  days by SM-II and BLUP methods, respectively. The genetic trend for CAFS was non significant and had high standard error by BLUP methods. The environmental trends for CAFS were estimated as  $1.94 \pm 1.60$  and  $1.80 \pm 1.20$  days by SM-II and BLUP methods.

A positive and significant ( $P < 0.05$ ) phenotypic trend estimate of  $0.03 \pm 0.11$  days was obtained for IFLS in HF x Gir cattle. Genetic trend by Smith method II ( $-2.68 \pm 3.26$  days) and BLUP method ( $-2.62 \pm 3.07$  days) was negative. The genetic trend for IFLS was non significant ( $P < 0.05$ ) and had high standard error by both the methods. The environmental trends for the trait were  $2.71 \pm 2.86$  and  $2.65 \pm 2.98$  days by Smith-II and BLUP methods, respectively. The environmental trend obtained by BLUP method for IFLS was low, positive and significant.

A positive and significant ( $P < 0.05$ ) phenotypic trend estimate of  $0.10 \pm 0.13$  days was obtained for CACO in HF x Gir cattle. The genetic trend by Smith method II ( $-4.49 \pm 5.69$  days) and BLUP method ( $-4.28 \pm 5.12$  days) was negative. The environmental trends for the trait were  $4.59 \pm 3.11$  and  $4.38 \pm 4.18$  days by Smith-II and BLUP methods, respectively. The environmental trend obtained by BLUP method for CACO was low, positive and significant.

### **5.1.5 Sire evaluation**

The average breeding values of HF x Gir halfbreed sires estimated by different single and multi-trait animal models for FL300DMY exhibited variation in estimates which also resulted into variation in percentage of sires having breeding values above or below to the average breeding values of sires for a given trait and evaluation methods. The ranges of their breeding values also differed considerably among themselves. The ST-AM was found better among single trait models for FL300DMY because it took account of all existing relationships among the animals. The averages and ranges of their breeding values from different multi-trait animal models for FL300DMY also differed considerably from corresponding estimates of ST-AM. Thus, the different

multi-trait animal models should be considered depending upon the traits of the breeding goal and selection criteria.

The single-trait animal model (ST-AM) of sire evaluation for FL300DMY was found to be superior method than other single trait sire evaluation (LSQ, SRLS and ST-SM) methods based on error variance, relative efficiency and accuracy ( $R^2$ -value). It was observed that single trait animal model (ST-AM) method gave more accurate and precise prediction of breeding values and ranking of animals than other single trait sire evaluation (LSQ, SRLS and ST-SM) methods. The difference among error variance, coefficient of determination ( $R^2$ -value) values of different multi-trait animal models was attributed to the difference in magnitude and direction of genetic and phenotypic correlation of traits included in multi-trait animal models with FL300DMY trait.

However, based on error variance, relative efficiency and coefficient of determination ( $R^2$ -value) the two-trait animal model of trait combination FL300DMY with CAFS was observed better method of evaluation than other two-trait animal models. The three-trait animal model of trait combinations FL300DMY, FCI and CAFS had relatively higher efficiency compared to other three-trait models based on error variance.

The top 10 elite sires (~20% of total sires) ranked by single-trait animal model (ST-AM) were compared with the sire rankings by eight different multiple-trait animal models. It was observed that out of top 10 elite sires, the common sires observed in multi-trait models in comparison to single-trait animal model (ST-AM) varied between 50 per cent (AMT 3-7) to 80 per cent (AMT2-1) in different sire evaluation methods. It clearly brought out that multi-trait models instead of single-trait animal model (ST-AM) should be used for estimation of breeding values of HF x Gir halfbred sires for simultaneous improvement of production and reproduction traits.

## **5.2 Conclusions**

The following conclusions emerged from the present investigation:

1. Among the different genetic and non-genetic factors studied, period of calving had significant effect on FL300DMY, FLPMY, FLL and IFLS and non significant effect on FCI, CAFS and CACO. Season of calving and age at first calving group had non significant effect on all first lactation production and reproduction traits.

The sire had significant effect on FL300DMY, FLPMY, FLL and CAFS and non significant effect on FCI, IFLS, and CACO.

2. The  $h^2$  estimates of first lactation traits and life time traits by 3 trait models were quite high and significant compared to  $h^2$  estimates by single and two trait models. Hence, it was inferred that three trait combinations could be used for genetic evaluation and selection of cows.
3. The estimation of  $r_g$  and  $r_p$  among first lactation production and reproduction traits from different multi trait models were in general and changed in magnitude too. The estimates of genetic and phenotypic correlations of FL300DMY and FLPMY, FL300DMY and AFC and FL300DMY and FCI were positive and significant while other combinations were low and negative.
4. Phenotypic, trends for FL300DMY, FLPMY and FLL were Negative and significant while for AFC, FCI, CAFS, IFLS and CACO were Positive and significant.
5. Genetic and environmental trends for FLPMY, FLL, FCI and CACO were Positive and significant while, for FL300DMY, AFC, CAFS and IFLS were Negative and significant.
6. The rankings of sires based on breeding values for FL300DMY trait from multiple-trait animal models were significantly changed than that of single-trait animal model. Hence, multiple-trait animal models should be used for sire evaluation rather than taking 305-day milk yield exclusively.

## 6. LITERATURE CITED

- Akhtar, J., Singh, M., Kumar, D and Sharma, K. 2003. Factors affecting economic traits in crossbred cattle. *Indian J. Anim. Sci.* 73(4): 464-465.
- Al-Samarai, F.R., Abdulrahman, Y.K., Mohammed, F.,A., Al-Saidi, F.H. and Al-Anbari, N.N. 2015. Comparison of several methods of sires evaluation for total milk yield in a herd of Holstein cows in Yemen. *Open Veterinary Journal.* 5(1) : 11-17.
- Ambhore, G.S. 2015.Genetics evaluation of sires and cows of Phule Triveni cattle using single and multi-trait models. Ph.D. Thesis submitted to National Dairy Research Institute, Deemed University, Karnal (Haryana), India.
- Ambhore, G.S., Singh, A., Deokar, D.K., Gupta, A.K., Singh, M. and Ved Prakash. 2017. First lactation production and reproduction performance of Phule Triveni cattle in hot arid region of Maharashtra. *Indian J. Anim. Sci.*, 87(1) : 105-108.
- Ambhore, G.S., Singh, A., Deokar, D.K., Sahoo, S.K., Singh, M. and Divya, P. 2016. Heritability estimates of first lactation 300 days milk yield under single versus multi-trait animal models in Phule Triveni cattle. *Indian J. Anim. Sci.* 86(6) : 682-685.
- Ambhore, G.S., Singh, A., Deokar, D.K., Singh, M. and Sahoo, S.K. 2017.Life time performance of Phule Triveni synthetic cows at an organized farm. *Indian J. Anim. Sci.* 87(11) : 1406-1409.
- Ambhore, G.S., Singh, A., Deokar, D.K., Singh, M. and Sahoo, S.K. 2017.Phenotypic genetic and environmental trends of production traits in Phule Triveni synthetic cow. *Indian J. Anim. Sci.* 87(6) : 736-741.
- Ambhore, G.S., Singh, A., Deokar, D.K., Singh, M., Ved Prakash and Sahoo, S.K. 2018. Sire evaluation using REML and conventional methods for first lactation 300 days milk yield in Phule Triveni cattle. *Indian J. Anim. Sci.* 88(3) : 352-355.

- Ansari-Lari M., Maryam Rezaghali and Mahdie Reiszadeh. 2009. Trends in calving ages and calving intervals for Iranian Holsteins in Fars province, southern Iran. *Trop Anim Health Prod.* 41 : 1283-1288.
- Arora, D.N. and Sharma, J.S. 1983. Factors affecting some of the economic traits in Jersey cattle. *Indian Vet. J.*, 60(5) : 992-995.
- Banerjee, S.A. and Banerjee, S. 2002. Correlation between some reproduction and production traits in Holstein Friesian x Sahiwal crossbred cows. *Indian Vet. J.* 79(2) : 927-930.
- Banik, S. 2004. Sire evaluation in Sahiwal cattle. Ph.D. Thesis, NDRI, (Deemed University), Karnal, India.
- Banik, S. and Gandhi, R.S. 2006. Animal model versus conventional methods of sire evaluation in Sahiwal cattle. *Asian-Aust. J. Anim. Sci.* 19(9) : 1225-1228.
- Banik, S. and Gandhi, R.S. 2010. Sire evaluation using single and multiple trait animal models in Sahiwal cattle. *Indian J. Anim. Sci.*, 80(3) : 269-270.
- Barwe, V.K., Tomar, S.S. and Qureshi, M.L. 2003. Factors affecting calving interval and its genetic and phenotypic relationship with other reproductive traits in Gir cows. *Indian Vet. J.* 80(2) : 128-131.
- Basu, S.B. and Ghai, A.S. 1980. Studies on inheritance of some reproductive traits and relationship with milk production in crossbred cattle. *Indian J. Anim. Sci.*, 50(2) : 119-122.
- Becker, W.A. 1986. Manual of procedures in quantitative genetics. Publication of Washington, State Univ. Pullman, USA.
- Bhadauria, S.S. and Katpatal, B.G. 2003. Factors affecting age of first calving in Friesian x Shiwal crosses. *Indian Vet. J.* 80 (11):1138-1141.
- Bhoite, U.Y. 1996. Comparative performance of economic traits of halfbreds, triple crosses of Gir, and their interbred cows. Ph.D Thesis submitted to M.P.K.V., Rahuri.
- Bhoite, U.Y. and Kale, K.M. 1996. Production performance of three breed Gir crosses. *Indian Vet. J.* 73 (4): 473-474.
- Bhoite, U.Y., Bhoite, S.U. and Lawar, V.S. 1999. Genetic studies on reproductive traits in three breed crosses with Gir. *Indian Vet. J.*, 76 (9): 856-857.

- Biffani, S., Marusi, M., Biscarini, F. and Canavesi, F. 2005. Developing a genetic evaluation for fertility using angularity and milk yield as correlated traits. *Interbull Bull.*, 33 : 63-66.
- Bourdon, R.M. 1997. Understanding Animal Breeding. Prentice Hall, New Jersey.
- Chander, R., Singh, D., Dalal, S., Malik, Z.S. and Dixit, S.P. 2008. Genetic studies on components of first lactation and lifetime traits in Sahiwal cattle. *Indian J. Anim. Res.*, 42(1) 44-48.
- Chaturvedi, P.C., Dhingra, M.M., Tomar, S.S. and Bhadoria, H.B.S. 1999. Factors affecting age at first conception and age at first calving and phenotypic and genetic relationships of age at first calving with other reproductive traits in Malvi cows. *Indian J. Anim. Sci.*, 15(2) : 55-58.
- Chavan, D.B. 2010. Reproductive and productive performance of Friesian x Gir halfbreds and their interbreds. M.Sc. (Agri.) thesis submitted to MPKV, Rahuri.
- Chavan, S.M. 1995. To study the effect of growth on some economic reproductive and productive traits of FG halfbreds and their interbreds. Unpublished M.Sc. (Agri.) thesis submitted to MPKV, Rahuri.
- Cunningham, E.P. 1965. The evaluation of sires from progeny test data. *Animal Production*. 7(2) :221-231.
- Cylek, S. and Tekyn, M.E. 2007. Environmental factors affecting milk yield traits of Brown Swiss cows raised at Ulas state farm and phenotypic correlation between milk yield and fertility traits. *Indian J. Anim. Res.*, 37(1): 61-64.
- D'souza Casein, Bhat, P.N. and Mukundan, G. 1979. Genetic studies on some important economic traits in Red Sindhi and its crosses. *Indian J. Anim. Sci.*, 49(4) : 247-250.
- Dahiya, D.S., Singh, R.P. and Khanna, A.S. 2003. Genetic group differences and the effect of non-genetic factors in crossbred cattle for reproduction traits. *Indian J. Anim. Res.*, 37(1) : 61-64.
- Dahlin, A., Khan, U.N., Zafar, A.H., Saleem, M., Chaudry, M.A. and Philipsson, J. 1998. Genetic and environmental causes of variation in milk production traits of Sahiwal cattle in Pakistan. *Anim. Sci.*, 66(2): 307-318.

- Dalal, D.S., Rathi, S.S. and Raheja, K.L. 2002. Estimates of genetic and phenotypic parameters for first lactation and lifetime performance traits in Haryana cattle. *Indian J. Anim. Sci.*, 72(5) : 398-401.
- Dash, S.K. 2014. Genetic evaluation of Karan Fries cattle for fertility and production traits. Ph.D. thesis, NDRI Deemed University, Karnal. India.
- De Vries, A. and Risco, C.A. 2005. Trends and seasonality of reproductive performance in Florida and Georgia dairy herds from 1976 to 2002. *J. of Dairy Sci.*, 88(6) : 3155–3165.
- Deokar, D.K. 2003. System analysis for optimization of production in crossbred cattle. Ph.D. Thesis submitted to MPKV., Rahuri.
- Deokar, D.K. and Ulmek, B.R. 1997. Comparative study on productive and reproductive performance of triple crossbred cattle. *Indian J. Anim. Prod. Mgmt.*, 13(4): 206-208.
- Deokar, D.K., Desale, R.J., Kale, S.V., Kalhapure, S.P. and Fulpagare, Y.G. 2008. Source of variation in production traits of Phule Triveni crossbred cattle. *Indian J. Anim. Prod. Mgmt.*, 24(1/2) : 15-17.
- Deshmukh, D.S., Sakhare, P.G., Baig, M.I. and Dhaware, S.A. 2003. Studies on reproductive traits in Holsteian Friesian and Gir crossbred cows. *J. Bombay Veterinary College*, 11(1/2): 64-66.
- Deshmukh, P.V. 2008. Longevity and lifetime performance of Phule Triveni crossbred cattle. Unpublished M.Sc. (Agri.) Thesis submitted to M.P.K.V., Rahuri.
- Deshpande, K.S., Ingole, G.K., Sakhare, P.S. and Kamble, V.J. 1988. Factors affecting milk yield per day of age at 2<sup>nd</sup> calving in Friesian x Sahiwal crossbreds. *Indian J. Dairy Sci.*, 41(2) : 230-231.
- Deulkar, P.B. and Kothekar, M.D. 1999. Sire evaluation considering first lactation yield for improvement of lifetime production in Sahiwal. *Indian J. Anim. Sci.* 69(4): 240-242.
- Dhaka, S.S. and Raheja, K.L. 2000. A comparison of sire evaluation methods. *Indian J. Anim. Sci.*, 70(6) : 643-644.

- Divya, P. 2012. Single versus multi-trait models for genetic evaluation of fertility traits in Karan Fries cattle. M.V.Sc. Thesis, submitted to National Dairy Research Institute, Karnal, India.
- Djemali, M. and Berger, P.G. 1992. Yield and reproduction characteristics of Friesian cattle under North African conditions. *J. Dairy Sci.* 75(4) : 3568-3573.
- Dongare, V.B. and Gandhi, R.S. 2014. Study on sire evaluation methods in Sahiwal cattle. *Ind. J. Vet. and Animal Sci. Res.* 43(3) : 174-179.
- Dubey, P.P. and Singh, C.V. 2005. Estimates of genetic and phenotypic parameters considering first lactation and lifetime performance traits in Sahiwal and crossbreed cattle. *Indian J. Anim. Sci.*, 75(2) : 1289-1294.
- Dubey, P.P., Singh, C.V. and Prasad, R.B. 2006. Relationship between sire 's estimated breeding values for first lactation and lifetime traits and ranking of sires in Sahiwal and its crosses. *Indian J. Anim. Sci.*, 76(10): 824- 828.
- Dubey, P.P., Singh, C.V. and Prasad, R.B. 2006. Relationship between sires estimated breeding values for first lactation and lifetime traits and ranking of sires in Sahiwal and its cross. *Indian J. Anim. Sci.*, 76(10) : 824-828.
- Espinosa, A.P., Rodriguez, A.F., Jimenez, C.J., Espinoza, V.J.L and Nunez, D.R. 2001. Genetic evaluation of a Holstein dairy herd in Baja California Sur utilizing an animal model with repeated measurements. *Agrociencia*, 35(3): 347-353. (Cited: Anim. Breed. Abstr., 70:6873).
- Gaikwad, P.N. 2010. Genetic and environmental factors influencing cumulative part lactation and 300 day milk production in Phule Triveni cattle. M.Sc. (Agri.) Thesis submitted to MPKV, Rahuri.
- Garudkar, S.R. 2011. Peak yield and its relationship with persistency and lactation milk production in Phule Triveni synthetic cows. M.Sc. (Agri.) Thesis submitted to MPKV., Rahuri.
- Gatchearle, P.L., Mitkari, K.R., Mule, R.S., Baswade, S.V. and Adangale, S. B. 2009. Effect of age at first calving on lactation milk yield and lactation length. *Indian J. Anim. Res.*, 43(3): 228-229.
- Gaur, G.K. 2003. Estimating breeding values of Frieswal bulls for the performance traits. *Indian J. Anim. Sci.*, 73 (1):79-82.

- Gaur, G.K., Tripathi, V.N., Mukharjee, S. and Choudhary, V.K. 2001. Efficiency of sire evaluation procedures in Frieswal cattle. *Indian J. Vet. Res.* 10(2) : 1-6.
- Gawari, R.G. 1999. Genetic studies on persistency of milk yield in triple crossbred cattle. M.Sc. (Agri.) Thesis submitted to MPKV., Rahuri.
- Golverdi, Y.A., Hafezian, H., Chashnidel, Y. and Farhadi, A. 2012. Genetic parameters and trends of production traits in Iranian Holstein population. *African J. Biotech.*, 11(10) : 2429 -2435.
- Goshu, G., Singh, H., Petersson, K.J. and Lundeheim, N. 2014. Heritability and correlation among first lactation traits in Holstein Friesian cows at Holetan Bull Dam Station, Ethiopia. *Int. J. Livest. Prod.* 5 : 47-53.
- Graser, H.U., Smith, S.P. and Tier, B. 1987. A derivative - free approach for estimating variance components in animal models by Restricted Maximum Likelihood. *J. Anim. Sci.*, 64(4) : 1362-1370.
- Gurnani, M. 1977. Estimates of genetic and environmental trends in milk production of Dairy Cattle. Ph.D. Thesis submitted to Punjab University, Chandigarh, India.
- Gurnani, M., Joshi, B.K. and Nagacenkari, R. 1982. Comparison of breeding value of sires by Henderson's BLUP and Robertson's method. In: II World Cong. Genetics Applied to Livestock Prod., Madrid Spain, Oct. 4-8, 1982.
- Hadge, M.R., Kuralkar, S.V., Ali, S.Z. and Kharkar, K.P. 2009. Performance of Sahiwal and its Jersey crosses for reproductive traits in different lactations. *Indian J. Anim. Res.*, 43(1) : 75-76.
- Hammound, M.H. and Salem, M.M. 2013. The genetic evaluation of some first lactation traits of Holstein cows in Egypt. *Alexandria J. Agril. Res.* 58(1) : 1-8.
- Hansen, I.B. 2000. Consequences of selection for milk from a geneticist's viewpoint. *J. Dairy Sci.*, 83 (5): 1145-1150.
- Harvey, W.R. 1979. *Least squares Analysis of Data with Unequal Subclass Numbers*. ARSH-4 USDA, Washington, DC.
- Harvey, W.R. 1990. Guide for LSMLMW, PC-1 Version, mixed model least squares and maximum likelihood computer programme, January 1990. Mimeograph Ohio State Univ., USA.

- Hassan, F. and Khan, M. S. 2013. Performance of crossbred cattle at military dairy farms in Pakistan. *J. Anim. and Plant Sci.* 23(3): 705-714.
- Henderson, C.R. 1973. Sire evaluation and genetic trend. In: Animal Breeding and Genetics Symposium in Honor of Dr. Jay L. Lush, American Society of Animal Science and American Dairy Science Association, Champaign, IL, USA, 10-41.
- Henderson, C.R. 1974. General flexibility of linear model techniques for sire evaluation. *J. Dairy Sci.* 57(4) : 963-972.
- Henderson, C.R. 1975. Best linear unbiased estimation and prediction under a selection model. *Biometrics.* 31 : 423-447.
- Henderson, C.R. 1976. Multitrait sire evaluation using the relationship matrix. *J. Dairy Sci.* 59(4) : 769-774.
- Henderson, C.R., Kempthorne, O., Scorle, S.R. and Vankronsink, C.M. 1959. The estimation of environmental and genetic trend from records subjected to culling. *Biometrics*, 15 : 192.
- Henderson, C.R. and Quass, R.L. 1976. Multiple trait evaluation using relatives records. *J. Anim. Sci.*, 43(2) : 1188-1197.
- Herbert, S. 1987. Genetic and phenotypic trends of lactation production traits in Karan Swiss Cattle. M.Sc. Thesis, Kurukshetra University, Kurukshetra, India.
- Herbert, S. and Bhatnagar, D.S. 1988. Genetic trends of economic traits in dairy cattle : A review, *Agril. Rev.*, 9 (4) : 200-216.
- Herbert, S. and Bhatnagar, D.S. 1989. A note on production performance of Karan Swiss herd. *Indian J. Dairy Sci.*, 4(1) : 118-119.
- Hintz, R.L., Evertt, R.W. and Vanvleck, L.D. 1978. Estimation of genetic trends from cow and sire evaluation. *J. Dairy Sci.*, 61(2) : 607-613.
- Hudson, G.F.S. and B. W. Kennedy. 1985. Genetic evaluation for growth rate and back fat thickness. *J. Anim. Sci.* 61 : 83.
- Hussain, A., Gupta, A.K., Dash, S.K., Manoj, M. and Sahid Ahmad. 2015. Effect of non genetic factors on first lactation production and reproduction traits in Tharparkar Cattle. *Indian J. Anim. Res.*, 49(4) : 438-441.

- Jadhav, A. and Khan, F.A. 1996. Studies on age at first calving in Friesian Sahiwal crosses. *Indian Vet. J.*, 73(2) : 164-168.
- Jadhav, K.L. 1990. Evaluation of various Holstein grades for economic efficiency and health costs. Ph.D. Thesis, National Dairy Research Institute (Deemed University), Karnal, India.
- Jadhav, K.L., Tripathi, V.N. and Kale, M.M. 1991. Performance of crossbred cows for production and reproduction traits in different production level groups. *Indian J. Dairy Sci.*, 45(11): 620-622.
- Jain, A. 1996. Sire evaluation under multiple trait models in Murrah buffaloes. Ph.D. Thesis. NDRI (Deemed University) Karnal, India.
- Jain, A. and Sadana, D.K. 2000. Sire evaluation using animal model and conventional methods in Murrah buffaloes. *Asian-Aust. J. Anim. Sci.* 13(9): 1196.
- Jamrozik, J., Fatehi, J., Kistemaker, G.J. Schaeffer, L.R. 2005. Estimates of genetic parameters for Canadian Holstein female reproduction traits. *J. Dairy Sci.*, 88(3):2199-2208.
- Jaswant, S. and Singh, C.V. 2016. Evaluation of sires using different sire evaluation methods on the basis of first lactation traits in Sahiwal cattle. *J. Vet. Sci. Technol.*, 7(2) : 296.
- Kadarmideen, H.N., Thompson, R., Coffey, M.P. and Kossaibati, M.A. 2003. Genetic parameters and evaluations from single and multiple - trait analysis of dairy cow fertility and milk production. *Liv. Prod. Sci.*, 81 : 183-195.
- Kale, K.M. 1984. Growth, reproduction and production performance of Gir cow and its exotic crosses. Ph.D. Thesis submitted to MPKV., Rahuri.
- Kamble, S.S. 2003. Effect of different types of calving on reproductive and productive performance of crossbred cattle M.Sc. (Agri.) Thesis submitted to MPKV, Rahuri.
- Katore, S.B. 2004. Studies on lifetime milk production performance of Holstein Friesian x Girhalfbreds. Unpublished thesis of M.Sc. (Agri.) submitted to MPKV, Rahuri.
- Khan, H.M. and Kachwaha, R.N. 2008. Lifetime performance of Rathi cattle at an organized farm. *Indian J. Anim. Res.* 42(3): 186-190.

- Khan, V.N., Dahlin, A., Zafar, A.H., Saleem, M., Chaudhry, M.A. and Philipsson, J. 1999. Sahiwal cattle in Pakistan: Genetic and environmental causes of variation in body weight and reproduction and their relationship to milk production. *Animal. Sci.* 68(1):97-108.
- Kharat, A.S., Kuralkar, S.V. and Ali, S.Z. 2008. Genetic studies on first lactation and lifetime traits in Holstein Friesian crossbred cows. *Indian J. Anim. Res.*, 42 (4):261-263.
- Kheirabadi, K., Alijani, S., Zavadilova, L., Rafat, S.A. and Moghaddam, G. 2013. Estimation of genetic parameters for daily milk yields of primiparous Iranian Holstein cows. *Archiv. Tierzucht.* 56(44) : 455-466.
- Kokate, L.S. 2009. Genetic evaluation of Karan Fries sires based on test day milk yield records. M.V.Sc Thesis, National Dairy Research Institute (Deemed University) Karnal, India.
- Komatwar, S.J., Deshpande, A.D., Kulkarni, M.D., Kulkarni, A.P., Yadav, G.B., Shisode, M.G and Khanvilkar, A.V. 2009. Study of genotypic and phenotypic correlations on production traits in Holstein Friesian x Sahiwal crossbreds. *J. Bombay. Vet. College*, 17(1): 70-71.
- Kramer, C.V. 1957. Extension of multiple range test to group correlated adjusted mean. *Biometric.*, 13: 13-20.
- Krishna, G.V.R., Reddy, C.E. and Rao, M.R. 1991. Production and reproduction performance of Deoni x Holstein Friesian cows *Indian J. Dairy Sci.*, 44(3) : 247-248.
- Kulkarni, S.R. 1985. Studies on reproduction and productive performance of FJG, BFG and JFG triple crosses. M.Sc. (Agri.) Thesis submitted to M.P.K.V., Rahuri.
- Kumar, A. 2007. Genetic analysis of stayability in Sahiwal cattle. Ph.D. Thesis, NDRI, (Deemed University), Karnal, India.
- Kumar, D. 1981. Breeding efficiency and producing ability of Sahiwal cows. *Indian J. Dairy Sci.* 34(2) :191-194.
- Kumar, D. and Kumar, P. 2003. Genetic studies on breeding efficiency in crossbred cows. *Indian J. Anim. Sci.* 73(10):1180-1181.

- Kurian, M.T., Anilkumar, K., Pramod, S. and Anil, K.S. 2011. Phenotypic trends of certain reproductive traits in crossbred cattle. Proceeding of Kerala Veterinary Science Congress, Palakkad
- Lateef, M., Gondal, K.Z., Younas, M., Mustafa, M. and Bashir, M.K. 2008. Reproductive performance of Holstein Friesian and Jersey cattle in Punjab, Pakistan. *Pak. J. Agri. Sci.*, 45(2): 245-249.
- Lin, C.Y., Mcallister, A.J. and Lee, A.J. 1985. Multitrait Estimation of Relationships of First-Lactation Yields to Body Weight Changes in Holstein Heifers. *J. Dairy Sci.* 68 : 2954-2963.
- Mandakmale, S.D., Bhoite, U.Y., Lawar, V.S. and Deokar, D.K. 2002. Studies on effect of age and weight at first calving on production performance of Phule Triveni a triple crossbred cow. *J. Maharashtra. Agric. Univ.*, 27 (1): 94-95.
- Mathur, R.S. and Gill, G.S. 1981. Evaluation of different grades of HF x Sahiwal crosses on the basis of lifetime production and reproduction efficiency. *Indian J. Dairy Sci.* 34 (1):16-20.
- Mayer, M. and Musani, S.K. 2002. A surface regression approach for estimation of genetic and environmental trends under widely varying meteorological conditions between years. *J. Anim. Breed. Genet.* 119 (2) : 116-124.
- Meyer, K. 1989. Estimation of genetic parameters. In *evolution and animal breeding* (ed. W. G. Hill & T. F. C. Mackay), Oxford University Press 161–167.
- Meyer, K. 2007. WOMBAT—A tool for mixed model analysis in quantitative genetics by REML, *J. Zhejiang Uni. Sci.* B 8: 815–821.
- Meyer, K. and Smith, S.P. 1996. Restricted maximum likelihood estimation for animal models using derivatives of the likelihood. *Genet. Select. Evol.* 28: 23-49.
- Mhasade, B.S. 2010. Effect of age and weight at first calving on production performance of HF x Gir crossbreds. M.Sc. (Agri.) Thesis submitted to MPKV, Rahuri.
- Mishra, S. and Joshi, B.K. 2004. Genetic and non-genetic factors affecting lactation milk constituents and yield traits in Karan Fries cattle. *Indian J. Dairy Sci.*, 57(1):69-72.

- Mostert, B.E., Van Der Westhuizen, R.R. and Theron, H.E. 2010. Calving interval genetic parameters and trends for dairy breeds in South Africa. *South African J. Anim. Sci.* 40(2): 156-162.
- Mrode, R.A. 2005. Linear models for the prediction of animal breeding values. CAB Int. Wallingford, UK.
- Mukharjee, S., Joshi, B.K., Gaur, G.K. 2007. Sure evaluation methods in Frieswal cattle. *Indian J. Anim. Sci.* 77(8): 123-126.
- Mukharjee, S. 2005. Genetic evaluation of Frieswal cattle. Ph.D. Thesis, National Dairy Research Institute (Deemed University) Karnal, (India).
- Narula, H.K., Kanaujia, A.S. and Malik, C.P. 2005. Genetic investigation on reproduction efficiency traits in Friesian x Hariana halfbreds. ISAGB 111/31.
- Nehra, M. 2011. Genetic analysis of performance trends in Karan Fries cattle. M.V.Sc. Thesis. NDRI (Deemed University) Karnal, India.
- Nehra, M., Singh Avtar, Gandhi, R.S., Chakaravarty, A.K., Gupta, A.K., Sachdeva, G.K. and Singh R.K. 2012. Phenotypic, genetic and environmental trends of milk production traits in Karan Fries cattle. *Indian J. Dairy Sci.* 65(3): 242-245
- Neldar, J.A. and Mead, R. 1965. A simplex method for function minimization. *Computer J.* 7:308-313.
- Nikam, R. A. 2010. Effect of age and weight at first calving on reproduction and production performance of Phule Triveni synthetic cow. M.Sc. (Agri.) Thesis submitted to MPKV, Rahuri.
- Panja, P. 1997. Optimization of economic traits in Karan Fries cattle. M.Sc. Thesis, National Dairy Research Institute (Deemed University), Karnal, India.
- Parekh, H.K.B., Singh, V.K. and Rao, K.C. 1994. Comparative study of different sire evaluation procedures under two models using crossbred progeny. *Indian J. Anim. Sci.* 64(10) : 1070-1074.
- Patond, M.N. 2009. Persistency of milk yield in Jersey cattle. M.Sc. (Agri.) Thesis submitted to MPKV., Rahuri.
- PDC-AR 2003-04. Project Directorate on Cattle, Annual Report (2003-04), Meerut.

- Pol, K.E. 2011. Generation wise production efficiency of Phule Triveni synthetic cow. M.Sc. (Agri.) Thesis submitted to MPKV, Rahuri
- Pol, K.E., Dhage, S.A., Pachpute, S.T. and Khutal, B.B. 2013. Generation wise production efficiency of Phule Triveni synthetic cow. *J. Agric. Res. Technol.*, 38(1): 117- 129.
- Pollak, E.J., Vander Werf, J. and Quaas, R.L. 1984. Selection bias and multiple trait evaluation. *J. Dairy Sci.*, 67(1):1590–1595.
- Pundir, R.K., Malik, R.P.S. and Prakash, B. 2004. Comparison of different sire evaluation methods in Sahiwal cattle. *Indian J. Anim. Sci.* 74(2): 229-231.
- Radhika, G., Ajithkumar, S., Rani, A., Sathian, C.T., Anilkumar, K., Usha, A.P. and Dinesh, C.N. 2012. Milk yield and composition of crossbred cows in the hilly Wayanad district of Kerala, India. *Indian J. Anim. Sci.* 82(10): 1251–1254.
- Raheja, K.L. 1994. Genetic parameters for first lactation and lifetime production traits in Friesian-Haryana and Friesian- Sahiwal halfbreds estimated by multiple trait maximum likelihood procedure. *Indian J. Anim. Sci.*, 64(6): 616-621.
- Rahumathulla, P.S., Natarajan, N., Johan Edwin, M. Sivaselvam, S.N. Subramanian, A. and Mohmad Khan, M.M. 1994. Studies on first lactation traits in Jersey x Tharparkar cows. *Cherion.*, 23 (1): 1-7.
- Rana, P.S 1991. A note on the performance of crossbred cows at military dairy farms. *Cherion*, 20:1-5.
- Rao, M.K., Reddy, A. and Bhaskar, B.V. 2000. Performance of crossbred dairy cattle in Farmers herd. *Indian J. Anim. Sci.*, 70(6) : 608-612.
- Rashia Banu, N. 2010. Genetic evaluation of the lactation curve in Karan Fries cattle. Ph.D. Thesis. NDRI (Deemed University), Karnal, India.
- Rashia, B., Singh, Avtar and Joshi, B.K. 2009. Genetic and environment factors influencing first and overall lactation milk yield in Karan Fries cattle. *Indian J. Anim. Sci.* 79(7) : 726-728.
- Rathi, S. 2015. Genetic evaluation of Frieswal cattle for life time traits. Ph.D. Thesis submitted to National Dairy Research Institute, Deemed University, Karnal (Haryana), India.

- Reddy, C.O. and Basu, S.B. 1985. Factors affecting profit function and production traits in crossbred cattle. *Indian J. Anim. Sci.*, 55 (1): 35-41.
- Robertson, A. and Rendel, J.M. 1954. The performance of heifers got by artificial insemination. *J. Agri. Sci.*, 44(2): 184 -192.
- Saha. 2001. Generation-wise genetic evaluation of Karan Swiss and Karan Fries cattle. M.Sc. Thesis. NDRI Deemed University, Karnal, India.
- Saha, S., Joshi, B.K. and Singh, A. 2010. Generation-wise genetic evaluation of various first lactation traits and herd life in Karan Fries cattle. *Indian J. Anim. Sci.* 80(5) : 451–456.
- Sahana, G. 1996. Effectiveness of sire evaluation methods for milk production along with auxiliary traits vis- a- vis other methods in crossbred cattle. Ph.D. Thesis, National Dairy Research Institute (Deemed University), Karnal, India.
- Sahana, G. and Gurnani, M. 2000. Performance of crossbred cattle and comparison of sire evaluation methods under organized farm condition. *Indian J. Anim. Sci.*, 70(4):409-414.
- Sarakul, M., Koonawootrittriron, S., Elzo, M.A. and Suwanasopee, T. 2010. Factors Associated with Dairy Cattle Genetic Improvement for milk production at farm level in central thail and. Department of Animal Science, Kasetsart University, Bangkok 10900, Thail and
- Schaeffer, L.R. 1984. Sire and cow evaluation under multiple trait models. *J. Dairy Sci.* 67(3):1567–1580.
- Seykora, A.J. and McDaniel, B.T. 1983. Heritabilities and correlations of lactation yields and fertility for Holsteins. *J. Dairy Sci.* 66(2):1486-1493
- Shelke, M.G. 2012. Generation-wise persistency of milk production in Phule Triveni Synthetic cows. M. Sc (Agri.) Thesis submitted to MPKV, Rahuri.
- Shinde, A.S. 2010. Studies on breeding efficiency of HF crossbreds. M.Sc.(Agri.) thesis submitted to MPKV, Rahuri.
- Shubha Lakshmi, B., Ramesh Gupta, B., Sudhakar, K., GnanaPrakash. and Lt. Col. Susheel Sharma 2009. Genetic analysis of production performance of Holstein Friesian x Sahiwal cows. *Tamilnadu J. Vet.Sci.*, 5(4):143-148.

- Sik andar Abbas, Singh, C.V. and Barwal, R.S. 2016. Study of relative effectiveness of different sire evaluation methods in Sahiwal cattle. *J. Dairy Vet. Anim. Res.*, 3(6) : 00104.
- Singh, M.K. 1995. Factors affecting trend in performance of Karan Swiss and Karan Fries cattle. Ph.D. Thesis, NDRI, (Deemed University), Karnal, India.
- Singh, R.K. 2013. Genetic evaluation of Karan Fries sires using multiple trait models. Ph.D. Thesis submitted to NDRI, Karnal (Haryana).
- Singh, Simran., Das, A.K., Chakraborty, D., Taggar, R.K., Kumar, N., Gupta P. and Mahajan, V. 2014. Studies on genetic and non-genetic factors affecting performance traits of Frieswal cows. *Indian J. Anim. Res.*, 48(6) : 537-540.
- Singh, M.K. and Gurnani, M. 2004. Performance evaluation of Karan Fries and Karan Swiss cattle under closed breeding system. *Asian Asian- Australasian J. Anim. Sci.*, 17(1): 1 - 6.
- Singh, A., Kumar, A. and Gandhi, R.S. 2008. Persistency of milk production in dairy cattle. *Indian J. Dairy Sci.*, 61 (1): 1-11.
- Singh, S.K. and Nagarcenkar, R. 2000. Genetic, phenotypic and environmental trends in some economic traits in Sahiwal herds. *Indian J. Anim. Sci.*, 70 (1):75-76.
- Singh, K., Sangwan, M.L. and Dalal, D.S. 2002. Estimation of genetic, phenotypic and environmental trends in Haryana cattle. *Asian. J. Anim. Sci.* 15(1) : 7-10.
- Singh Jaswant and Singh, C.V. 2016. Evaluation of sires using different sire evaluation methods on the Basis on First lactation traits in Sahiwal cattle. *J. Veterinar Sci. Technol.*, 7(2) : 1000296.
- Singh, M., Singh, A., Gupta, A.K. and Chakravarty, A.K. 2014. Relative effectiveness of best linear unbiased prediction-animal model vis-à-vis other sire evaluation methods for genetic evaluation of Murrah sires. *Indian J. Dairy Sci.*, 67(6) : 510-514.
- Singh, V.K., Singh, C.V., Kumar, D. and Kumar, A. 2005. Genetic evaluation of some economic traits in Sahiwal and its crossbreds. *Indian J. Dairy Sci.*, 58 (3): 206.

- Singh, R. and Tomar, S. S. 1990. Inheritance of first lactation production traits and their inter-relationship in crossbred cattle. *Indian J. Dairy Sci.*, 43 : 147-151.
- Singh, M.R. and Tomar, S.S. 1991. Factors affecting the service period and its association with other traits in Karan Fries cattle. *Indian J. Dairy Sci.*, 44 (1): 6-8.
- Sinha, S. 1999. Studies on level of heterozygosity of Karan Fries animals. M.Sc. Thesis, National Dairy Research Institute (Deemed University) Karnal, India.
- Sivakumar, R. 1998. Reproductive performance at different levels of production in Karan Fries Cattle. M.Sc. Thesis, National Dairy Research Institute (Deemed University) Karnal, India.
- Smith, C. 1962. Estimation of genetic changes in farm livestock using field records. *Anim. Prod.*, 4: 239-251.
- Smith, S.P. and Quaas, R.L. 1984. Productive lifespan of bull progeny groups: Failure time analysis. *J. Dairy Sci.*, 67(3): 2999-3007.
- Sooraj, T. 2013. Estimation of genotypic and phenotypic trends in milk yield of crossbred cattle. M.V.Sc. Thesis, Kerala Veterinary and Animal Science University, Kerala.
- Sorenson, D.A. and Kennedy, B.W. 1984. Estimation of genetic variances from unselected and selected populations. *J. Anim. Sci.*, 58(2) : 1097-1106.
- Spearman, C. 1904. The proof and measurement of association between two rings. *Amer. J. Psychol.* 15: 72.
- Sturges, 1926. The choice of a class interval. *Journal American Statistical Association.* 21(153): 65-66.
- Sumit Kumar., Singh, Y.P. and Dharendra Kumar. 2008. Genetic studies on performance traits in Frieswal cattle. *Indian J. Anim. Sci.*, 78(1): 107-110.
- Sun, C., Madsen, P., Lund, M., Zhang, S.Y., Nielsen, U.S. and Su, G. 2010. Improvement in genetic evaluation of female fertility in dairy cattle using multiple-trait models including milk production traits. *J Anim Sci.*, 88 (4): 871-878.

- Talape, S.K. 2010. Studies on production performance and breeding efficiency of Jersey crossbreds maintained at Panjarpole, Ahmednagar. M.Sc. (Agri.) Thesis submitted to MPKV, Rahuri.
- Thombre, B.M., Mitkari, K.R., Padghan, P.V., Shaikh, F.G. and Chavan, K.R. 2002. Studies on age at first calving and first lactation performance in Holstein Friesian x Deoni straight breeds. *Indian J. Anim. Res.*, 36(2): 144-146.
- Thombre, V.S. 2007. Studies on morphological characterization of Phule Triveni crossbred cows and correlation among some phenotypic and milk production traits at organized farm. M.Sc. (Agri.) Thesis submitted to MPKV, Rahuri.
- Togashi, K., and Lin, R.L. 2004. Efficiency of different selection criteria for persistency and lactation milk yield. *J. Dairy. Sci.*, 87(2):1528-1535.
- Tomar, A.K.S., Sidhu, N.S., Joshi, J.D., Pandey, H.S., Narain, A.D., Singh, B.S. and Bisht, G.S. 1999. Genetic, phenotypic and environmental correlation among production, reproduction and milk production efficiency traits in Dairy cattle. *Indian J. Anim. Prod. Mgmt.*, 15(4): 168-171.
- Tomar, N.S. and Singh, B.P. 1981. Genetic trends of some economic traits in Haryana cows. *Indian Vet. J.*, 58(9): 701-709.
- Topanurak, S., Himarat, V., Jaidet, P., Chanpongsang, S. and Faarungsang, S. 2001. Developments of genetic evaluation of dairy cattle in Thail and. *Thail and Research Fund*, Thail and.
- Wall, E., Brotherstone, S., Wooliams, J.A. and Banos, G. 2003. Genetic evaluation of fertility using direct and correlated traits. *J. Dairy Sci.*, 86(2) : 4093-4102.
- Wondifraw, Z., Thombre, B.M. and Bainwad, D.V. 2013. Effect of non genetic factors on milk production of Holstein Friesian x Deoni crossbred cows. *African J. Dairy Farming and Milk Production*. 1(4) : 79-84.
- Zol, S.R., Bhoite, U.Y., Pachpute, S.T. and Deokar, D.K. 2009. Reproduction and production performance and breeding efficiency of Phule Triveni crossbred cows. *J. Maha. Agric. Univ.*, 2009, Vol. 34 No.2. 208-210.

Zulkadir, U., Aytakin, I. and Pala, A. 2009. Estimation of genetic trends for productive and reproductive traits of Holstein cattle in Turkey. *Journal. Animal Vet. Advances. Bio. Sci.* 8(5):857-862.

## 7. VITAE

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**Mr. Onkar Vishnu Shinde**  
**DOCTOR OF PHILOSOPHY (AGRICULTURE)**  
**in**  
**ANIMAL HUSBANDRY**  
**2021**

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