Dissertation Ref. No. 001/06/014

GENETIC STUDIES ON REPLACEMENT RATE AND FIRST LACTATION TRAITS IN HOLSTEIN FRIESIAN CATTLE AT HOLETA BULL DAM STATION, ETHIOPIA

Ph.D. Dissertation

By

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Addis Ababa University
College of Veterinary Medicine and Agriculture
Department of Animal Production Studies
PhD Program in Animal Production

March 2014
Bishoftu

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A Dissertation Submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Animal Production

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As members of the Examining Board of the final PhD open defense, we certify that we have read and evaluated the Dissertation prepared by Gebeyehu Goshu titled '**Genetic Studies on Replacement Rate and First Lactation Traits in Holstein Friesian Cattle at Holeta Bull Dam Station, Ethiopia'** and recommend that it be accepted as fulfilling dissertation requirement for the degree of Philosophy in Animal Production.

Prof Berhan Tamir Chairman	________________ Signature	________________ Date
Prof Tsefu Kassa Internal Examiner	________________ Signature	________________ Date
Dr Azage Tegegne External Examiner	________________ Signature	________________ Date

Final approval and acceptance of the dissertation is contingent upon the submission of its corrected copy to the CGC through the concerned departmental graduate committee.

I hereby certify that I have read the revised version of this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Prof Harpal Singh Dissertation advisor	________________ Signature	________________ Date
Prof Berhan Tamir Department chair	________________ Signature	________________ Date

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Statement of the Author

First, I declare that this thesis/dissertation is my *bona fide* work and that all sources of material used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for a PhD degree at Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University/College library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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Gebeyehu Goshu	________________	________________
Name	Signature	Date

Dedication

To my mother Nigatua Setegne

Acknowledgments

I take privilege to extend heartfelt sincere with great pride and deep pleasure to my advisor Prof Harpal Singh for his altruistic support, patience, keen interest and constructive criticism and valuable suggestions throughout the study period. He also has availed reference materials which otherwise would have been difficult to get in domestic. I thank Dr Karl Johansson for making available the DMU software which was used for genetic analysis. My special appreciation goes to Prof Nils Lundeheim for introducing the software and assisting in genetic data analyses.

I am highly indebted and very much grateful to the management of the National Artificial Insemination Center and the Holeta Bull Dam Station for allowing me to use the data collected over a long period of time. My sincere thanks are due to Ato Hilegebrael Minale and Ato Sisay Misganaw for their unreserved collaboration during data collection. Hearty thanks to Ato Birhanu Yalew and Ato Besufekad Jufar for liaisoning the process at both Kaliti and Holeta center.

I acknowledge with gratitude the financial assistance provided by Sida/SAREC and Ethio-Italy projects. My grateful thanks go to the Addis Ababa University, College of Veterinary Medicine and Agriculture and Animal Production Studies Department for awarding the scholarship. The author expresses his immense gratitude to Dr Getachew Terefe, Associate Dean for Graduate Program, for his encouragement and support. I am highly indebted to Prof Berhan Tamir, chairperson of the Department of Animal Production Studies, for active facilitation and in time decision matters pertaining to the research.

There is no way to express my feeling to Ato Melaku Yayehyirad and Dr Gezahegne Mamo for their infallible love, support and everlasting inspiration. I am indebted to Prof Merga Bekana, Dr Fikre Lobago and Dr Kelay Belihu for their continuous follow up regarding the progress of the whole exercise. Many thanks are to Hirut Tesfaye and Birtukan Abate for printing the thesis. I thank Dr Fekadu Regassa, Dr Yacob Hailu, Ato Legesse Wolde, Ato Gossa Getachew, Ato Elias G/egziabiher, Ato Berihun G/eyesus, w/o Ehite Bireda, w/o

Birhane Waqjira, w/t Elbethel Tadesse, w/t Melkam Abate, Sister Samrawit Worku and the college community at large for their sustained and enthusiastic encouragement.

My special thanks are reserved to w/o Lucia Carleto, Dawit Gebeyehu, Dereje Gebeyehu and Sehin Gebeyehu for their patience and unfailing support.

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Abbreviations and Acronyms

AFC	Age at first calving
AI	Artificial insemination
ANOVA	Analysis of variance
ASCII	American Standard Code for Information Interchange
BS	Brown Swiss cattle
CGR	Coefficient of gene replication
CSA	Central Statistical Authority, Ethiopia
DDE	Dairy Development Enterprise, Ethiopia
df	Degrees of freedom
FC	Replacement rate from female calves born
FCI	First calving interval
FDP	First dry period
FLMY	First lactation milk yield
305 DMY	305 day milk yield
FLP	First lactation period
FSP	First service period
h^2	Heritability
HARC	Holeta Agricultural Research Center
HF	Holstein Friesian
IAR	Institute of Agricultural Research
J	Jersey cattle
MDF	Military Dairy Farm, India
MoA	Ministry of Agriculture, Ethiopia
MoARD	Ministry of Agriculture and Rural Development, Ethiopia
N	Number of records
NAIC	National Artificial Insemination Centre
NS	Not significant
PHL	Productive herd life
R	Red Dane cattle
r_e	Environmental correlations
REML	Restricted Maximum Likelihood
r_g	Genetic correlations
r_p	Phenotypic correlation
S	Sahiwal cattle
SAS	Statistical Analysis System
se	Standard error
TC	Replacement rate from total calves born
TCP	Total calves born
USA	United States of America

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GENETIC STUDIES ON REPLACEMENT RATE AND FIRST LACTATION TRAITS IN HOLSTEIN FRIESIAN CATTLE AT HOLETA BULL DAM STATION, ETHIOPIA

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Ph.D. Dissertation
Addis Ababa University (2014)

Abstract

The study was conducted on 901 Holstein Friesian cows maintained at Holeta Bull Dam Station from 1976 to 2003 with the objectives of estimating demographic parameters, genetic of replacement rates and first lactation traits. The lactation specific parameters viz. loss rate, survival rate, stayability, expected herd life, female calf births and reproductive value at first lactation were estimated at 0.2619, 0.7381, 0.7373, 2.4573, 0.4808 and 1.0488, respectively. Overall lifetime parameter values for mean lactations of cows present, mean lactations of cows lost, mean rate of loss per cow per lactation, average life expectancy at birth, net reproductive rate and generation interval were computed as 3.4949 lactations, 4.3548 lactations, 0.3204, 1.2825 lactations, 1.4984 female calves per cow and 3.5451 years, respectively. The overall averages for abnormal and normal births, male-female sex ratios, mortality and culling rate in females up to age at first calving and female replacement rates based on female births and total pregnancies were 12% and 88%, 52.5% and 47.5%, 23% and 7% and 70% and 29%, respectively. The effects of parity and year of calving on above traits were found to be significant, except parity effects on culling rate and replacement rate based on total pregnancies, which were non-significant. The season effects for all traits were non-significant. Sire affected significantly the type of birth, calf loss, replacement rate and coefficient of gene replication. About 1/3rd of cows calved only once and similar proportion of the cows experienced abnormal calving during first lactation. The overall means for longevity, productive herd life, total calves, female calves, selective values and coefficient of gene replication were 2864±63 days, 1638±58 days, 3.55±0.12, 1.68±0.07, 1.12±0.06 and 0.56±0.03. Cows calved at early age and low producers had short herd life, less number of total and female calves. Heritability for abnormal birth, sex ratio, mortality, culling, and replacement rate from total calves produced and total pregnancy were 0.16±0.009, 0.10±0.019, 0.18±0.029, 0.71±0.029, 0.00±00 and 0.66±0.029, respectively. The repeatability for the above traits were 0.964±0.012, 0.038±0.017, 0.060±0.028, 0.0895±0.029, 0.780±0.019 and -0.2403±0.022, respectively. The heritability estimates for longevity, productive herd life**,** total calves born, total normal calves born, total female calves born, coefficient of gene replication and selective value were 0.31±0.085, 0.32±0.088, 0.11±0.018, 0.12±0.018, 0.10±0.019, -0.08±0.029 and 0.66±0.029, respectively. The heritability for age at first calving (AFC), first service period (FSP), first dry period (FDP), fist lactation period (FLP), 305 day milk (305DMY), first lactation milk yield (FLMY) and first calving interval (FCI) were 0.53±0.116, 0.26±0.113, 0.24±0.1170, 0.23±0.102, 0.23±0.106, 0.28±0.124 and 0.28±0.141, respectively. The phenotypic correlations of AFC with FLMY, 305DMY, FLP, FSP and FCL were very small. High phenotypic, genetic and environmental correlations existed between FLMY and 305DMY. All correlations among FSP, FDP and FCL were high and positive. Sire affected the additive genetic variances for abnormal birth, mortality, culling and replacement rate and their frequency can be changed through selection of the sire. Moreover, information on the genotype of semen must be available along with production. Age at first calving had high heritability value and it can be included in the selection index. Further research is required on identification of genetic abnormalities at embryonic and progeny level and the effect of storage and deposition of semen on sex ratio.

Key words: *Demography, first lactation traits, Holstein Friesian, replacement rate, genetic parameters, Holeta.*

1. INTRODUCTION

The economy of Ethiopia is largely dependent on livestock. According to CSA (2010) report, the nation has 50.8, 25.9, 21.9, 7.2 and 0.8 million heads of cattle, sheep, goat, equines and camel, respectively. Moreover, the country owns about 17.6% cattle, 22.4% sheep, 13.4% goats and 8.7% camels of the ruminant population of sub-Saharan Africa (Azage *et al.,* 1993). Livestock contributes some 45% of the total GDP (IGAD LPI, 2010). However, productivity of cattle in terms of milk and meat is very low. Lactation yield of cows is within the range of 300 kg to 600 kg and average carcass weight of mature cattle is only 112 kg (Azage *et al.,* 1993).

In Ethiopia, modern dairying started in the early 1950s when the country received the first batch of dairy cattle from United Nations Relief and Rehabilitation Administration. A recent political development in the country coincides with three phases of dairy development policy. These include the imperial regime, characterized by almost a free market economic system and the of modern emergence commercial dairying (1960-1974), the socialist Dergue regime that emphasized central economic system and the state farms (1974-1991), and the current phase (1991 to present) under the structural adjustment program and market liberalization (EPTD, 2004)

Dairy development attempts in the area of animal breeding were made in the second phase to increase milk production in the country. The former Institute of Agricultural Research (IAR) started its livestock research in 1974 where the Boran, Horro, Barca and Fogera breeds were studied. Preliminary results of the Institute (IAR, 1976) indicated that the indigenous breeds have low capacity for milk production. This low level of milk production from indigenous cattle/breeds led to a long term crossbreeding program which was initiated in 1980s and the above breeds were introduced as a dam line to be crossed with Holstein Friesian and Jersey as a sire line. Other institutions that were involved in crossbreeding studies include Alemaya College of Agriculture and Chilalo/Arsi Agricultural Developmnet Unit (EPTD, 2004; Kefena *et al*., 2006). As a result, several dairy farms were established in line with the ever increased demand of the population for dairy products. Moreover, crossbreeding was considered as the main strategy for up grading the dairy potential of indigenous cattle. Since then, several works on the performance of those animals on government ranches, research institutions and dairy farms have been published (Mekonnen, 1987; Asheber, 1992; Gashaw, 1994; Teferi, 1994; Addisu, 1999; Gebeyehu, 1999; Giday, 2001; Fikre, 2007). The review of these documents revealed that the first generation of Holestien Friesian crosses had demonstrated better performance compared to the indigenous breeds. However, a decline in the estimates of age at first calving and calving interval were observed as the Holstein Friesian inheritance increased to 75%. Moreover, little difference in milk yield was observed among the genetic groups. Previous reports largely focused on reproductive and preoductive performances of pure and and crossbred cattle. Evaluation of dairy farms for demographic parameters, replacement rate, selective values and other production traits is essential for decision and future improvement.

Demographic analyses are used extensively in humans, wildlife, and fisheries to characterize populations. They involve estimation of parameters such as reproduction and mortality rates, growth in numbers and biomass age structure and other vital statistics of the population. In livestock results of such analyses have been used to formulate strategies for culling and replacement, organize breeding scheme and as a check on management practices (Andrus *et al.,* 1969; Basu and Ghai, 1980; Greer *et al.,* 1980; Schones *et al.,* 1985; Ahmed *et al.,* 1992; Arthur *et al.,* 1995 and Atrey *et al*., 2005).

Age distribution and herd life expectancy are primary interest to individuals associated with dairy production. Knowledge of life expectancy for cows of a given age is needed to plan mating for perspective bull calves, to determine culling policies. Age specific birth rate is very important statistics in beef and dairy cattle production. In beef cattle the increase growth rate and more efficient production of lean meat by male calves has financial advantages. In contrast dairy farmers seek dairy breeds to perpetuate their herd. Furthermore, the requirement for lower sex ratio in dairy cattle is increased when replacement rates are high (Berry and Cromie, 2006).

Replacement rate is the function of calf production, which is the prenatal calf loss by abortion and still birth, sex ratio, post natal mortality and culling of heifers from birth to reaching the age at first calving (Banik and Naskar, 2006). The number of replacements heifers is the most important vital aspect to the advantage of culling inferior females. The genetic gain to a great extent depends on the intensity of selection which in turn is function of the number of replacement heifers entering the herd (Rawal and Tomar, 1998). A higher replacement rate can be obtained through regular breeding of adult females, low rate of abnormal births, low male births and low mortality and culling of female calves from birth to their age at first calving. Furthermore, information on replacement rate is helpful to estimate the number of inseminations and pregnancies required from each bull to produce a heifer that reach in the milking herd and the number of lactations a cow should have in the herd to replace herself.

The genetic contribution of a cow to the next generation depends upon productive herd life, longevity, total calves born, total normal calves born, total female calves born (Atrey *et al.,* 2005) and this contribution in the form of living progeny is known as selective value. It is associated with the life time calf production and their survival up to milking age (Arun *et al.,* 2009).

Information on replacement rate and selective value is required for planning, operating and evaluating the breeding programs for genetic improvement through taking the advantage of culling the old and low producer cows in the herd. A herd of a specific breed may be good producer but its selective value may be poor or differ among the animals and in animals in different environments. Therefore, it is essential to know the variability in the selective value of animals (Kumar *et al.*, 2009).

Maximization of genetic improvement in traits of economic importance is the primary objective of breeder. The potential for genetic improvement of a trait largely depends upon genetic variation existing in a population of interest. The variability for a particular trait in a herd or population is measured by heritability estimate of a trait under given environmental conditions. Knowledge of genetic parameters viz., the heritability and genetic correlations among traits help in deciding the appropriate selection method and mating system. Until recently breeding programs worldwide within the Holstein-Friesian breed have been based almost entirely on increased milk production per cow. Little or no emphasis was placed on ancillary traits relating to health and reproduction efficiency. It has now been recognized that selection in dairy cattle solely for high milk production is generally accompanied by reduced fertility (Berry *et al.*, 2005). Selection of sires is of great importance for bringing the genetic improvement in dairy animals. The true genetic merit of an animal is never known, it can at best be informed from records on itself and its relative's relevant available records to predict a bull's breeding value. The main objectives of sire evaluation are to determine the transmitting ability as well as ranking of sires as required in progeny testing program.

In dairy cattle breeding, studying genetic parameters for early expressed traits (age at first calving, first service period, first calving interval first lactation yield and length) are highly important for further improvement. Moreover, determination of the inheritance level of threshold traits like abnormal births, mortality of calves and number of female calves reaching to first lactation is essential to control the introduction of undesirable genes in the population.

The Holeta Bull Dam Station was established for improving milk production in Ethiopia. The breeding policy, which has been executed since 1973, was maintenance of the pure breed by using bulls and deep frozen semen of Holstein Friesian from different countries. Since 1973, semen produced at the National Artificial Insemination Center (NAIC) has been used and distributed to the dairy farmers for breeding the dairy cows. The NAIC is the only place where semen is produced for use all over the country and is responsible for the coordination of artificial insemination operations in the country. Desalegne (2008) reported that semen production capacity of the center was grown from 2000 dose in 1983/4 to 140,000 doses in 2003/4 which indicates that it plays a vital role in dairy cattle improvement. The Holeta Bull Dam Station is the main source of sires to the NAIC. A total of 118 Holstein Friesian young sires were recruited for artificial insemination. This suggests that the cattle breeding activities undergoing throughout the country is largely affected by these centers. Previously works on the lactation traits (Mureja, 2004; Besufekad, 2008; Berhanu, 2009), reproductive (Melaku, 1194; Besufekad, 2008), breeding efficiency and annual milk yield (Berhanu, 2009) performance were reported for the station. However, replacement rate, selective values, genetic parameters for threshold and first lactation traits were not studied.

It was hypothesized that there would be no difference in mortality, survivability, sex ratio and reproductive value among parities; that genetic and non genetic factors did not affect replacement trait and selective value; and, genetic and environment have similar effect on the variances and covariance of first lactation traits. Therefore, the research questions were:

i. How are the lactation specific and overall demographic parameters estimated?
ii. What are the effects of random (sire and dam) and fixed factors on replacement trait?
iii. How do the genetic and environmental variances affect genetic parameters of first lactation traits?

2. LITERTURE REIVIEW

This chapter is intended to review available literatures on demographic parameters, replacement traits, life time and genetic parameters for first lactation traits. Whenever possible, genetic and non-genetic factors affecting the traits were discussed along with the estimates. Tough this work focused on Holstein Friesian cattle, findings for other cattle breeds and crosses are included due to un availability of reports on the breed per se.

2.1. Demographic Parameters

Demographic study involves estimation of parameters such survival rate, expected herd life, cows present/left the herd, reproductive value and birth rate, mean age of cows present/left the herd, net reproductive rate and generation interval. In livestock results of such analyses have been used to formulate strategies for culling and replacement, organize breeding scheme and as a check on management practices (Andrus *et al.,* 1969; Basu and Ghai, 1980; Greer *et al.,* 1980; Schones *et al.,* 1985; Ahmed *et al.,* 1992; Arthur *et al.,* 1995 and Atrey, 2003).

2.1.1. Lactation specific demographic parameters

Age distribution and herd life expectancy are primary interest to individuals associated with dairy production. Knowledge of life expectancy for cows of a given age is needed to plan mating for perspective bull calves, to determine culling policies (Andrus *et al.,* 1969). Age specific birth rate is very important statistics in beef and dairy cattle production. Lactation specific survival rate expected herd life, reproductive value and birth rate are reviewed in the following sections and summarized in Table 1.

2.1.1.1. Survival rate (P_x)

The survival rates as observed by various workers in different herds of dairy cattle are presented in Table 1. The survival rate of exotic cows was minimum 0.78 in second lactation after which it started declining (Nieuwhof *et al.* 1989). Tomar *et al.*(1994), Lathwal *et al.*(1995) and Tomar *et al.*(1996) reported the survival rate in Sahiwal, Red Sindhi and Tharparkar cows respectively and showed that it was around 0.70 after first parity and remained nearly constant up to 5-6 parities after which it decreased along with parity. Kumar (1999) in Hariana cattle found the lactation specific survival rate around 0.80 up to the seventh lactation and thereafter a decreasing trend along the increase in lactation. Singh (2001) in Karan Fries cattle reported that the probability of survival rate was maximum (0.72) in first lactation and further observed that there was no definite trend of survival rate from 2nd to 14th lactation

2.1.1.2. Survivorship or stayability (L_x)

Table 1 showed the stayability in different dairy cattle. Sharma and Singh (1974) have reported a survivorship of 0.94 lactation at first lactation which decreased slowly to 0.002 lactation at 13th lactation in zebu cattle. Tomar *et al.*(1994) for Sahiwal, Lathwal *et al.*(1995) for Red Sindhi and Tomar *et al.*(1996) for Tharparkar observed that the survivorship as unity in first lactation and it decreased along with increased parity the order being less than 0.10 after eighth parity. Singh (2001) in Karan Fries cattle reported that 0.72 survivorship at first lactation and it decreased along with increases in parity

Table 1. Lactation specific demographic parameters in different dairy cattle breeds

Lactation															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	Breed	Reference
						i. Survival rate (P_x)									
-	0.78	0.57	0.40	0.27	0.17	0.10	0.05							Exotic	Nieuwhof *et al.*(1989)
0.65	0.70	0.73	0.60	0.57	0.51	0.49	0.55	0.56	0.22	0.00				Frieswal	Atrey (2003)
0.79	0.76	0.84	0.87	0.85	0.84	0.80	0.69	0.65	0.64	0.46	0.32	0.28	0.00	Hariana	Kumar (1999)
0.72	0.68	0.59	0.70	0.69	0.70	0.71	0.66	0.63	0.67	0.63	0.53	0.12	0.00	Karan Fries	Singh (2001)
0.71	0.69	0.75	0.76	0.67	0.69	0.55	0.54	0.53	0.70	0.15	1.00	1.00		Red Sindhi	Lathwal *et al.*(1995)
0.78	0.73	0.74	0.78	0.74	0.70	0.66	0.60	0.60	0.27	0.63	0.00	0.00		Sahiwal	Tomar *et al.*(1994)
0.78	0.73	0.74	0.78	0.76	0.74	0.75	0.65	0.60	0.62	0.43	0.00	0.00		Tharparkar	Tomar *et al.*(1996)
						ii. Survivorship or stayability									
0.88	0.83	0.83	0.80	0.76	0.70	0.68	0.59	0.52	0.37	0.00				Exotic	Ochoa *et al.*(1991)
0.65	0.46	0.34	0.20	0.11	0.06	0.03	0.01	0.01	0.00					Frieswal	Atrey (2003)
0.79	0.60	0.50	0.44	0.37	0.31	0.25	0.17	0.11	0.07	0.03	0.01	0.03		Hariana	Kumar (1999)
0.72	0.49	0.29	0.21	0.14	0.09	0.07	0.05	0.03	0.02	0.01	0.006	0.008	0.00	Karan Fries	Singh (2001)
1.00	0.71	0.49	0.37	0.28	0.19	0.13	0.07	0.04	0.02	0.01	0.002	0.002	0.002	Red Sindhi	Lathwal *et al.*(1995)
1.00	0.78	0.54	0.41	0.32	0.24	0.17	0.11	0.07	0.04	0.01	0.006			Sahiwal	Tomar *et al.*(1994)
1.00	0.77	0.56	0.41	0.32	0.24	0.18	0.13	0.09	0.05	0.03	0.01	0.00		Tharparkar	Tomar *et al.*(1996)
0.94	0.72	0.53	0.39	0.29	0.21	0.15	0.10	0.07	0.04	0.02	0.01	0.02		Zebu	Sharma and Singh(1974)

Table 1 Lactation specific demographic parameter in different dairy cattle breeds (contd.)

Lactation															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	Breed/herd	Reference
iii. Expected herd life (E_x)															
2.72	2.50	2.45	2.32	1.99	1.70	1.43	1.12	0.86	0.43	0.63				Sahiwal	Tomar *et al.*(1994)
2.38	2.34	2.41	2.22	1.90	1.49	1.16	1.12	1.06	1.00	0.44	2.00	1.00		Red Sindhi	Lathwal *et al.*(1995)
2.82	2.65	2.63	2.57	2.31	2.04	1.78	1.39	1.14	0.87	0.42	0.00			Tharparkar	Tomar *et al.*(1996)
3.52	3.66	3.88	3.54	3.06	2.61	2.09	1.61	1.33	1.05	0.64	0.41	0.28	0.00	Hariana	Kumar (1999)
2.14	1.97	1.89	2.17	2.04	2.03	1.89	1.64	1.47	1.33	1.00	0.60	0.12	0.00	Karan Fries	Singh (2001)
1.91	1.90	1.69	1.31	1.16	1.01	0.95	0.93	0.69	0.22	0.00				Frieswal	Atrey (2003)
iv. Proportion of cows left the herd (q_x)															
0.31	0.23	0.17	0.12	0.08	0.05	0.03	0.01							Exotic	Nieuwhof *et al.*(1989)
0.15	0.09	0.17	0.23	-	-	0.35								Exotic	Gadzhiev *et al.*(1991)
0.34	0.19	0.12	0.13	0.08	0.05	0.03	0.01	0.00						Frieswal	Atrey (2003)
0.21	0.19	0.09	0.06	0.06	0.06	0.06	0.07	0.06	0.04	0.04	0.02	0.007	0.003	Hariana	Kumar (1999)
0.28	0.23	0.19	0.08	0.06	0.04	0.03	0.02	0.01	0.01	0.01	0.005	0.005	0.008	Karan Fries	Singh (2001)
0.28	0.22	0.12	0.08	0.09	0.06	0.03	0.02	0.006	0.012	0.00	0.00	0.002		Red Sindhi	Lathwal *et al.*(1995)
0.22	0.21	0.15	0.09	0.08	0.07	0.05	0.04	0.03	0.03	0.004	0.006			Sahiwal	Tomar *et al.*(1994)
0.22	0.22	0.15	0.09	0.08	0.07	0.05	0.05	0.03	0.02	0.01	0.01			Thraparkar	Tomar *et al.*(1996)

Table 1. Lactation specific demographic parameter in different dairy cattle breeds (contd.)

Lactation															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	Breed/herd	Reference
v. Proportion of cows present in the herd (q_x)															
0.31	0.23	0.17	0.11	0.08	0.05	0.03	0.02							Exotic	Nieuwhof *et al.*(1989)
0.34	0.24	0.17	0.10	0.06	0.03	0.01	0.008	0.004	0.001	0.00				Frieswal	Atrey (2003)
0.21	0.17	0.13	0.11	0.09	0.08	0.07	0.05	0.04	0.02	0.02	0.007	0.002		Hariana	Kumar (1999)
0.33	0.23	0.14	0.09	0.07	0.05	0.03	0.02	0.01	0.009	0.006	0.004	0.004	0.00	Karan Fries	Singh (2001)
0.30	0.21	0.14	0.11	0.08	0.06	0.04	0.02	0.01	0.006	0.004	0.001	0.001		Red Sindhi	Lathwal *et al.*(1995)
0.27	0.21	0.15	0.11	0.09	0.06	0.04	0.03	0.02	0.01	0.03	0.003			Sahiwal	Tomar *et al.*(1994)
0.26	0.20	0.15	0.11	0.09	0.06	0.05	0.04	0.02	0.01	0.008	0.003			Tharparkar	Tomar *et al.*(1996)
vi. Reproductive value (V_x)															
1.38	1.25	1.09	1.01	0.95	1.06	1.02	0.87	0.56	0.75	0.00				Frieswal	Atrey (2003)
2.27	2.22	2.29	2.17	1.88	1.65	1.40	1.18	1.03	0.95	0.71	0.61	0.89	0.50	Hariana	Kumar (1999)
-	1.57	1.31	1.23	1.40	1.45	1.43	1.60	1.43	1.40	1.14	1.01	0.82	0.65	Karan Fries	Mukherjee (1993)
1.46	1.40	1.51	1.45	1.43	1.40	1.28	1.21	1.12	0.87	0.76	0.52	0.44	0.00	Karan Fries	Singh (2001)
1.86	1.77	1.75	1.82	1.52	1.47	1.25	1.14	1.05	0.85	0.67	0.44			Tharparkar	Tomar *et al.*(1996)

2.1.1.3. Expected herd life

The reports of Tomar *et al.* (1994) for Sahiwal, Lathwal *et al.*(1995) for Red Sindhi, Tomar *et al.*(1996) for Tharparkar and Kumar (1999) for Hariana cows observed the expected herd life during first lactation to be 2.72, 2.38, 2.82 and 3.52 lactations respectively, with a decreasing trend along with increasing lactation number. Singh (2001) reported the expected herd life at first lactation to be 2.14 lactations and approximately the same expected herd life was observed up to 6 lactations and thereafter it decreased along with the increase in lactation number.

2.1.1.4. Proportion of cows left the herd (q_x)

The lactation specific proportion of cows left the herd indicated in different breeds of cattle by various workers is given in Table 1. The lactation specific distribution of Sahiwal, Red Sindhi, Tharparkar and Hariana cows which left the herd was studied by Tomar *et al.*(1994), Lathwal *et al.*(1995), Tomar *et al.*(1996) and Kumar (1999). They observed that about one fourth of the total cows left the herd after first lactation.

The proportion of cows left the herd after second lactation was nearly the same as that in first lactation thereafter it decreased appreciably. Singh (2001) in Karan Fries cattle reported that more than half of the total females of the first lactation left the herd till they completed third lactation. After third lactation the probability of a female was being lost from the herd was similar up to 9th lactation.

2.1.1.5. Proportion of cows present in the herd (p_x)

Tomar *et al.*(1994) on Sahiwal, Lathwal *et al.*(1995) on Red Sindhi and Tomar *et al.*(1996) on Tharparkar cows reported that the herd comprised the younger cows viz., about one fourth of total cows in the herd belonged to first parity and two third of the total cows belonged to first through third parity. Kumar (1999) reported in Hariana cattle that about one fifth (21.3) of the herd comprised of first calvers and 16.8 percent of second calvers. It was also observed that 71 percent of the total females present in the herd belonged to one to fifth lactation and about 5 percent in the herd belonged to 10 or more lactations. Singh (2001) on Karan Fries cattle observed that one third of the total (33.7%) herd comprised of the first calvers and 22.9 percent females were second calvers. It was reported that 70.3 percent of total females present in the herd belonged to 10^{th} lactations and about 1.94 percent females in the herd belonged to 10 and more than 10 lactations.

2.1.1.6. Reproductive value

Singh (2001) in Karan Fries cattle observed the reproductive value of 1.46 at 1^{st} lactation and almost same up to 6^{th} lactation and thereafter decreased along with increase in lactation. The information revealed that very old cows had low reproductive value than younger cow. This indicated that cow should be culled at lactation, when its reproductive value is less than one.

2.1.2. Overall life time statistics

The various overall life time statistics for different breeds as reported by different workers have been indicated in Table 2. The mean age of cows present in the herd varied from 2.94 lactations (Singh, 2001) to 4.49 lactations (Kumar, 1999). The mean age of cows lost from the herd ranged 2.96 lactations in Red Sindhi (Lathwal *et al.,* 1995) to 4.68 lactations in Hariana (Kumar, 1999). The mean rate of loss per cow per lactation ranged from 0.21 lactations (Kumar, 1999) to 0.46 lactations (Singh, 2001). The mean life expectancy at first lactation was minimum i.e., 1.64 in lactations in Karan Fries (Singh, 2001) and maximum i.e., 4.19 lactations in Hariana (Kumar, 1999).

Net reproductive rate can be defined as expected number of daughters produced by each cow entering in the herd. The net reproductive rate ranged from 1.06 lactations in Karan Fries (Singh, 2001) to 2.27 lactations in Hariana (Kumar, 1999). The generation interval

Table 2. Overall life time statistics for different breeds

Breeds	Mean age of cows (lactation)		Mean rate of loss /cow/ lactation (proportion)	Life expectancy at first lactation (lactation)	Net reproductive rate (female calves per cow)	Generation interval (years)	Reference
	Present in the herd	Lost from the herd					
Sahiwal	3.52	3.69	0.27	3.22	1.78	-	Tomar *et al.*(1994)
Red Sindhi	3.05	2.96	0.30	2.81	1.60	-	Lathwal *et al.*(1995)
Tharparkar	3.81	3.43	0.26	3.32	1.79	-	Tomar *et al.*(1996)
Hariana	4.49	4.68	0.21	4.19	2.27	3.99	Kumar (1999)
Karan Fries	2.94	3.13.	0.46	1.64	1.06	2.88	Singh (2001)
Frieswal	2.54	2.91	0.52	1.41	0.91	2.54	Atrey (2003)

ranged from 2.88 years in Karan Fries cattle (Singh, 2001) to 3.99 years in Hariana (Kumar, 1999).

2. 2. Replacement Rate and Its Components

The replacement rate is defined as the proportion of young females that becomes replacement to that of the total females born and of total pregnancies in any particular year (Atrey, 2003). The replacement rate affects the genetic gain and economy of the herd. It is determined by the number of births, sex ratio, prenatal calf losses and female calf loss due to their death and culling up to age at first calving

2.2.1. Estimates of replacement rate and its components

The average of replacement rate and its component traits in different dairy cattle breeds and crosses are indicated in Table 3.

2.2.1.1. Abnormal births and sex ratio

Abnormal births are taken as the proportion of unsuccessful births (abortion, stillbirth, premature birth and dystocia) from total pregnancies. The values for different breed groups are presented in Table 3. The estimates of abnormal births ranged from 1.10% for Sahiwal (Tomar and Singh, 1973) to 17.10% for Karan Fries (Sharma and Jain, 1984).

Sex ratio is the percentage of female births of the total normal births. The normal expectation is 1:1for both sexes. Table 3 showed that male births ranged from 47.5% (Tomar *et al.*, 1976) to 58.10 (Tomar and Verma (1988a) and in a good proportion the reports the estimate was above 50%.

2.2.1.2. Mortality and culling rate among female calves

Mortality rate is considered as the death rate of female calves from birth to age at first calving. In Table 3, the mortality rate ranged from 3.90% for Holstein×Tharparkar cross (Tomar and Verma, 1988a) to as high as 48.6% in exotic crosses (Singh and Jain, 1997).

Culling rate is the disposal of female calves for various reasons before reaching age at first calving. The reported culling rate of female calves ranged from 1.60% (Chaudhary *et al.*, 1984) to 31.6% (Thomar and Verma, 1988b) in Holstein crosses.

Table 3. Estimates of replacement rates and its components in different dairy cattle

Genetic group	Location	Number of calvings	Average loss/ replacement rate (%)	References
	i. Abnormal births from total pregnancies			
Brown Swiss×(Holstein× Tharparkar F_1)	Karnal	186	14.10	Sharma and Jain (1984)
Brown Swiss×Hariana	-	118	3.39	Tomar and Singh (1973)
Frieswal	MDF	2774	11.3	Atrey (2003)
Holstein×Hariana	Hissar	178	2.24	Tomar and Singh (1973)
Holstein ×(Jersye×Gir F_1)	Jabalpur	108	2.20	Shukla *et al.*(1980)
Holstein ×Gir	Jabalpur	408	2.20	Shukla *et al.*(1980)
Holstein ×Sahiwal	MDF	240	8.40	Tomar *et al.*(1975)
Holstein ×Sahiwal	MDF	1523	9.5	Negi and Luktuke (1982)
Holstein×(BS×Holstein)	Karnal	183	4.37	Tomar and Verma (1988b)
Holstein×(HF×ThatparkarF_1)	Karnal	482	4.56	Tomar and Verma (1988b)
Holstein×Hariana	Mukteshwar	732	6.00	Mehrotra and Dey (1998a)
Holstein×Sahiwal	Pantnagar	1220	12.45	Singh *et al.*(2002)
Holstein×Tharparkar	Karnal	299	5.40	Sharma and Jain (1984)
Holstein×Tharparkar	Karnal	318	3.10	Tomar and Verma (1988a)
Karan Fries	Karnal	505	17.10	Sharma and Jain (1984)
Karan Fries	Karnal	1098	6.36	Mukherjee *et al.*(1993)
Karan Fries	Karnal	3795	7.11	Singh (2001)
Red dane×Hariana	-	55	3.63	Tomar and Singh (1973)
Red Sindhi	Bangalore	605	4.30	Reddy and Sampath (1981)
Red Sindhi	Karnal	1604	4.70	Lathwal *et al.*(1993)
Sahiwal	Hissar	3245	3.50	Rawal and Tomar (1996a)
Sahiwal	Pantnagar	162	9.87	Singh *et al.*(2002)
Sahwal	Hissar	259	1.10	Tomar and Singh (1973)
Tharparkar	Karnal	-	10.30	Sharma and Jain (1983)
Tharparkar	Karnal	1576	4.40	Tomar and Verma (1988a)

Table 3. Estimates of replacement rates and its components in different dairy cattle (contd.)

Genetic group	Location	Number	Average loss/ replacement rate (%)	References
		ii. Sex ratio (males)		
3/4Holstein×1/2Holstein	Karnal	357	48.40	Tomar and Verma (1988b)
3/4Holstein×3/4Holstein	Karnal	332	47.90	Tomar and Verma (1988b)
Frieswal	MDF	2774	52.23	Atrey (2003)
Holstein ×(Jersey×Gir)	-	685	52.10	Singh and Parekh (1982)
Holstein Friesian	Mukteshwar	942	52.20	Mehrotra and Dey (1988a)
Holstein ×Hariana	Izatnagar	535	53.3	Kaushik and Singhal (1982)
Holstein×(BS×Hariana)	Izatnagar	161	53.40	Kaushik and Singhal (1982)
Holstein×(BS×Sahiwal)	Karnal	300	49.90	Sethi and Rao (1981)
Holstein×(HF×Tharparkar	Karnal	460	50.20	Tomar and Verma (1988b)
Holstein×Hariana	Hissar	175	54.80	Tomar and Singh (1973)
Holstein×Hariana	-	-	49.80	Singh and Balaine (1973)
Holstein×Hariana	Mukteshwar	-	52.20	Mehrotra and Dey (1988a)
Holstein×Sahiwal	MDF	221	47.50	Tomar *et al.*(1976)
Holstein×Tharparkar	Karnal	308	58.10	Tomar and Verma (1988a)
		iii. Mortality rates among female calves		
<50% exotic	Udaipur	130	48.60	Singh and Jain (1997)
> 50% exotic	Udaipur	293	43.40	Singh and Jain (1997)
Frieswal	MDF	1175	13.70	Atrey (2003)
Hariana	Hissar	3556	21.10	Kumar (1999)
Holstein×(HF×Tharprakar)	Karnal	229	15.70	Tomar and Verma (1988b)
Holstein crosses	Haringhata	1575	11.40	Chaudhary *et al.* (1984)
HF×Tharparkar¾	Karnal	141	12.10	Tomar and Verma (1988b)
HF×Tharparkar 5/8	Karnal	60	6.60	Tomar and Verma (1988b)
Holstein×Tharparkar	Karnal	129	3.90	Tomar and Verma (1988a)
Karan Fries	Karnal	1740	13.67	Singh (2001)
Local	Udaipur	227	32.10	Singh and Jain (1997)
Red Sindhi	Karnal	643	13.50	Lathwal *et al.*(1993)
Sahiwal	Karnal	1064	14.00	Reddy and Nagarcenkar (1989a)
Tharparkar	Karnal	388	23.0	Tomar and Verma (1988a)
Tharparkar	Karnal	2222	21.10	Rawal (1991)

Table 3. Estimates of replacement rates and its components in different dairy cattle (contd.)

Genetic group	Location	Number	Average loss/ replacement rate (%)	References
		iv. Culling rates among female calves		
<50% exotic	Udaipur	130	8.70	Singh and Jain (1997)
> 50% exotic	Udaipur	293	11.60	Singh and Jain (1997)
Exotic×Tharparkar F_1	Karnal	337	3.20	Singh *et al.*(1987)
Frieswal	MDF	1175	11.57	Atrey (2003)
Hariana	Haringhata	2578	22.80	Lemka *et al.*(1973)
Hariana	Hissar	1648	30.60	Kumar (1999)
Holstein crosses	Haringhata	1575	1.60	Chaudhary *et al.*(1984)
Holstein×Tharparkar ½	Karnal	129	3.90	Thomar and Verma (1988a)
Holstein×Tharparkar 5/8	Karnal	141	31.90	Thomar and Verma (1988b)
Holstein×(HF×Tharparkar) ¾	Karnal	229	17.90	Thomar and Verma (1988b)
Karan Fries	Karnal	1740	23.21	Singh (2001)
Local	Udaipur	227	11.20	Singh and Jain (1997)
Red Sindhi	Karnal	472	13.00	Singh *et al.*(1987)
Sahiwal	Karnal	848	12.30	Singh *et al.*(1987)
Sahiwal	Karnal	1064	13.25	Reddy and Nagarcenkar (1989a)
Sahiwal	Karnal	1180	15.10	Tomar and Rawal (1994)
Tharparkar	Karnal	2222	14.90	Rawal (1991)
Tharprakar	Karnal	1151	13.60	Singh *et al.*(1987)
Tharprakar	Karnal	388	8.50	Thomar and Verma (1988a)
		v. Replacement rate on the basis of total female calves born		
<50% exotic	Udaipur	130	42.5	Singh and Jain (1997)
> 50% exotic	Udaipur	293	45.0	Singh and Jain (1997)
Bostaurus	Haringhata	221	51.0	Lemka *et al.*(1973)
Frieswal	DMF	878	74.7	Atrey (2003)
Hariana	Haringhata	2578	53.6	Lemka *et al.*(1973)
Hariana	Hissar	1648	48.4	Kumar (1999)
HF×Tharparkar ½ bred	Karmal	129	92.2	Tomar and Verma (1988a)
HF×Tharparkar ¾	Karmal	141	56.0	Tomar and Verma (1988a)
HF×Tharprakar 5/8	Karmal	60	75.0	Tomar and Verma (1988a)
Holstein	-	1806	77.8	Loyd and Hargrove (1991)
Holstein crosses	Haringhata	1576	86.3	Chaudhary *et al.*(1984)
Karan Fries	Karnal	1740	63.1	Singh (2001)
Local	Udaipur	227	56.0	Singh and Jain (1997)
Red Sindhi	Karmal	643	57.6	Lathwal *et al.* (1993)
Sahiwal	Karmal	1180	69.5	Tomar and Rawal (1994)

BS=Brown Swiss; HF=Holstein Friesian; MDF= Military Dairy Farm, India

Table 3. Estimates of replacement rates and its components in different dairy cattle (contd.)

Genetic group	Location	Number	Average loss/ Replacement rate (%)	References
Tharparkar	Karmal	2222	64.0	Rawal (1991)
Tharprakar	Karmal	388	68.5	Tomar and Verma (1988a)
vi. Replacement rate on the basis of total pregnancies				
Frieswal		878	31.65	Atrey (2003)
Hariana		3556	22.50	Kumar (1999)
Holstein ×Tharprakar		482	33.90	Tomar and Verma (1988b)
Karan Fries		3795	31.14	Singh (2001)
Karan Swiss		4696	24.00	Mukherjee (1993)
Red Sindhi		1604	27.50	Lathwal (1993)
Sahiwal		3242	32.40	Tomar and Rawal (1994)
Tharparkar		1576	33.88	Tomar and Verma (1988a)
Tharparkar		4774	29.80	Rawal (1991)

2.2.1.3. Replacement rate on female calf basis and total preganancy

Replacement rate on female calve basis is the average number of calves survived up to age at first calving on female calf basis. Reports in Table 3 indicated that replacement rate on female calf basis ranged from 42.5% (Singh and Jain, 1997) to 92.2% (Tomar and Verma, 1988a) for different Holstein crosses.

Replacement rate on total pregnancy basis (total calf basis) is the percentage of female calves survived to age at first calving from total pregnancies. The replacement rate on total pregnancy basis ranged from 22.5% in Hariana cattle (Kumar, 1999) to 33.90% in Holstein×Tharparkar crosses (Tomar and Verma (1988b)

2.2.2. Non genetic factors affecting replacement rate and its components

Non genetic factors that affect replacement rate can be grouped in to year of calving, season of calving and parity of the cow. The effect of year could be attributed to change in climate, feed, disease incidence and management.

2.2.2.1. Effect of non genetic factors on abnormal births

Non-significant effects of year on abnormal calving have been observed by Tomar *et al*. (1975), Tomar and Verma (1981, 1988a) and Kumar (1999) in Sahiwal, Red Sindhi, Tharparkar and Hariana cows, respectively. Significant year effects on the incidence of abnormal births have been reported by Sharma and Jain (1984), Lathwal *et al.* (1993), Rawal and Tomar (1996a), Singh (2001) and Atrey (2003).

Seasonal effects could be related to amount of rainfall and temperature which directly influence vegetation growth and breeding of disease and parasite. Higher incidence of abnormal calving have been reported during summer and lower during winter season by Chatterjee *et al.* (1985) in exotic and Kumar *et al.* (1995) in Holstein×Sahiwal crosses. Similar incidence of abnormal births of cross bred cows during July to October was reported by Pandey and Desai (1973). Moreover, Lathwal *et al.* (1993) reported higher incidence of abnormal birth in summer than in other seasons in Red Sindhi cattle. Mukherjee *et al.* (1993) found that incidence of abnormal birth was comparatively lower in winter season than in other seasons in Karan Fries cattle.

2.2.2.2. Effect of non genetic factors on sex ratio

Tomar and Arora (1970) and Kumar (1999) for Hariana, Kale *et al.* (1982) for Red Sindhi, Tomar *et al.* (1976), Sethi and Rao (1981), Rawal and Tomar (1995) for Sahiwal and Atrey (2003) reprted non significant effect of year of calving for Frieswal cattle, while Kumar *et al.* (1992) in Holstein×Sahiwal crossbred cows, Lathwal *et al.* (1993) in native and crossbred cattle reported the significant effects of year of calving.

Effect of season of calving on sex ratio was also reported by different authors. Tomar *et al.* (1976) and Tomar (1995) in Sahiwal cows, Lathwal *et al.* (1993) in Red Sindhi and Shukla and Parekh (1988) in Gir and their crosses, Tomar and Verma (1988b) for Friesian×Sahiwal crosses and Atrey (2003) in Frieswal observed non significant effects of season of calving on sex ratio. Significant effect were reported by (Sethi and Rao, 1981) and Tomar and Verma (1988a). The male births were found to be significantly higher during winter born calves followed by those born during summer and rainy seasons in Sahiwal cows mated to Holstein (Sethi and Rao, 1981). Significantly higher sex ratio was found during summer and autumn seasons than during winter and rainy seasons among purebred Tharparkar and crossbred F_2 calves by Tomar and Verma (1988a).

Non significant effects of parity were reported by Singh *et al.* (1983) Kumar (1999), Mukherjee *et al.* (2000) and Atrey (2003). Significantly higher male sex ratio in first and fifth parity of calving was observed by Tomar and Verma (1988a) in Tharparkar cattle.

2.2.2.3. Effect of non genetic factors on female calf mortality

The mortality rates during the first three months of birth were higher than at later ages. Some authors (Rao and Nagarcenkar, 1982; and Mukherjee and Tomar, 1997) observed that about half of the total mortality occurred in first month of life and mortality rate decreased with the increase age. Significant effect of year of calving on mortality rate of female calves from birth to age at first calving have been reported by Chaudhary *et al.*(1984), Rawal and Tomar (1994b), Kumar (1999), Singh and Jain (1997) and Atrey (2003). Non significant year effects on mortality of female calves up to the age at first calving were reported by Lathwal *et al.* (1983).

Cahudhary (1984) reported that lower mortality rate among Holstein Friesian female calves born during rainy and summer seasons than those born during winter. Similarly, Tomar and Verma (1988a) in crossbred F_1 calves from birth to age at first calving have reported low mortality rates among calves born during rainy season than in other seasons. Lathwal *et al.* (1993), Singh and Jain (1997), Singh (2001) found non significant effect of season of birth on female calf mortality.

Mukherjee and Tomar (1997b), Singh and Jain (1997), Kumar (1999) and Singh (2001) have observed non significant effect of parity on post calving losses. However, dam's parity had significant effect on mortality rate as reported by Lathwal *et al.* (1993) and Singh *et al.*(2002).

2.2.2.4. Effect of non genetic factors on female calf culling

Significant differences over years for culling rate have been found by Mukherjee and Tomar (1997b), Reddy and Nagarcenkar (1989a), Rawal and Tomar (1996), Singh (2001) and Atrey (2003). Season had significant effect on culling rate as reported by Tomar and Verma (1988b) for crossbred calves. The culling rate was significantly higher in calves born during autumn season than in winter, summer and rainy season. The non significant effect of season on culling rate among female calves was reported by Lathwal *et al*. (1993), Singh and Jain (1997) and Atrey (2003). Lower culling rates among calves born to cows of later parities have been found by Rawal and Tomar (1994b), Mukherjee and Tomar (1997b) and Kumar (1999). Tomar and Verma (1988a, b), Lathwal *et al.* (1993), Singh (2001) and Atrey (2003) have observed that parity had no effect on the culling rate.

2.2.2.5. Effect of non genetic factors on replacement rate from female calves born

Significant effects of year were reported by Lathwal *et al*. (1993), Singh and Jain (1997), Singh (2001) and Atrey (2003), whereas Tomar and Verma (1988b) observed non-significant effects of year of birth on replacement rate computed on female calf basis. Highly significant differences due to season of birth in replacement rate were reported by Rawal (1991) and Kumar (1999).

Parity of dam had highly significant effect on replacement rate on female calf basis as reported by Lathwal *et al*. (1993) for Red Sindhi, Tomar and Rawal (1994) for Sahiwal, Kumar (1999) for Hariana and Atrey (2003) for Frieswal herd. Non significant effect of parity of dam on this trait was reported by Singh (2001) in Karan Fries cattle.

2.2.2.6. Effect of non genetic factors on replacement rate from total pregnancies

Year of birth had highly significant effect on replacement rate (Lathwal *et al.*, 1993; Kumar, 1999, Singh, 2001 and Atrey, 2003), whereas Tomar and Verma (1988b) did observe non significant effect of year of birth on replacement rate. Season of birth on total pregnancies had significant effect on replacement rate as reported by Tomar and Verma (1988a) and Kumar (1999).

Mukherjee (1993), Kumar (1999) and Atrey (2003) reported highly significant effect of parity on replacement rates of crossbred and Hariana cattle, respectively. non significant effect of dam's parity were observed in Karan Fries, Tharparkar and Red Sindhi cattle by Tomar and Verma (1988a,b), Rawal (1991) and Lathwal *et al*.(1993), respectively.

2.2.3. Effect of sire on replacement rate and its components

2.2.3.1. Effect of sire of calf on abnormal births

Sire had significant effect on abnormal birth as reported by Tomar *et al*. (1975) in Sahiwal cows bred to Sahiwal and Holstein Friesian sires. They observed that abnormal birth occurred among the progeny of 64 per cent Sahiwal and 50 per cent Holstein Friesian bulls. The sire effect was significant on abortions but not on still birth in zebu and crossbred cattle reported by Singh and Jain (1983). Tomar and Verma (1988a, b) and Lathwal and Kumar (1993) observed that breed of sire and genetic group had no effect on the rate of abnormal birth in Tharparkar, Karan Fries and Red Sidnhi cattle, respectively.

According to the reports of Kumar *et al.*(1991), Sahiwal sires had significant effect on abnormal parturitions as sire of the calf and grand sire of the calf while Holstein sires had no effect on this trait. Abnormal births occurred among the pregnancies settled from 70 per cent Sahiwal and 82 per cent Holstein. Rawal and Tomar (1996 a, c) reported that sire had significant effect on the rate of abnormal calving in Sahiwal and Tharparkar cattle. They also reported no incidence of abnormal births among the pregnancies settled from 48 per cent Sahiwal sires and 42 per cent Tharparkar sires indicating 50-60 percent of the total bulls used for breeding were responsible for the abnormal births ranging from 0.1 to 25.0 per cent abnormal birth among the progeny of different sires.

Sire had significant effect on abnormal births in Hariana cattle reported by Kumar (1999). The average incidence of abnormal birth was 4.4 per cent among 3390 pregnancies from 36 sires and out of 36 bulls used for breeding, there was no incidence of abnormal birth among the pregnancies from 8 sires (22.3 per cent of total bulls). About 78 per cent out of total bulls used for breeding were responsible for abnormal births with average incidence ranging from 2.2 to 24.0 per cent.

Significant effect of sire on abortion has been found by Mukherjee and Tomar (2000) in Karan Fries cattle and ranged from 2.9 to 20.0 percent among the progeny of different sires. Singh (2001) in Karan Fries cattle observed that the average incidence of abnormal births was estimated 6.6 percent among 3382 pregnancies from 71 sires. It was noted that about 89 percent of the total bulls used to breed were responsible for abnormal births and the rate of abnormal births varied from 2.1 to 25.0 percent and the effect of sire was non significant on the rate of abnormal birth.

Atrey (2003) in Frieswal cattle reported that the average incidence of abnormal births was 11.0 percent among 2629 pregnancies from 65 sires. Pregnancies from three bulls had no incidence of abnormal birth. However, pregnancies from 95 percent total bulls used for breeding ended in to varying rates of abnormal births, ranging from 1.8 to 52.9%.

2.2.3.2. Effect of sire on sex ratio

Tomar and Arora (1970) in Hariana, Tomar *et al.*(1976) and Sethi and Rao (1981) in Sahiwal, Singh *et al.*(1983) in Gir, Tomar and Verma (1988 a,b) in Tharparkar and crossbred, Lathwal and Kumar (1993) in Red Sindhi and Mukherjee *et al.*(2000) in Karan Swiss cattle observed that sire had non significant effect on sex ratio. However, Powell *et al.*(1975) reported significant effect of sire of calf on the sex ratio in exotic cattle. Moreover, Kumar *et al.*(1993) found significant effect of sire on sex ratio for Sahiwal breed varying from 16.7 to 100 percent, while among the progeny of Holstein sires the differences were not significant though the sex ratio among the progeny of different sires ranged from 22.2 to 68.0 percent. Similarly, Rawal and Tomar (1995) reported the sire of calf had highly significant effect on sex ratio in Sahiwal herd.

Rawal and Tomar (1996c) reported that sire had significant effect on sex ratio in Tharparkar cattle. They further observed that the sex ratio was zero percent among the pregnancies of 1 out of 79 sires and there were six sires whose pregnancies consisted of about 75 percent male calves whereas the sex ratio was below 40 percent among the pregnancies settled from 9 out of 79 bulls. Kumar (1999) in Hariana cattle also observed significant effect of sire on sex ratio. Moreover, Atrey (2003) reported that the overall sex ratio was significantly higher from normal expectation; the sire wise sex ratios were ranged from 30.0 to 84.0%. However, Singh (2001) in Karan Fries cattle has shown that the effect of sire was non significant on the sex ratio.

2.2.3.3. Effect of sire on mortality rate among female calves

Chaudhary *et al.* (1984) in crossbred cattle reported that the sire had significant effect on female calf mortality from birth to age at first calving. Highly significant effect of sire on female calf mortality of Sahiwal herd has been observed by Rawal and Tomar (1994 b) to the extent that there was no mortality of the female calves from birth to age at first calving among the progeny of 19.2 percent of the total sires and the maximum mortality was 50 percent among the progeny of one Sahiwal sire. Tomar and Rawal (1996) found that the effect of sire was highly significant on mortality of female calves from birth to age at first calving (AFC) in Tharparkar cattle. There was no mortality of female calves from birth to AFC among the progeny of 12.7 percent sires and maximum mortality was 63.1 percent among the female calves of 1 sire. Mukherjee and Tomar (1997b) in Karan Swiss female calves were found the highly significant effect of sire on mortality rate.

Non significant effect of sire on female calf mortality from birth to AFC for zebu as well as crossbred cattle was reported by Tomar and Verma (1988 a, b); and Lathwal and Kumar (1993). Similarly, Singh (2001) in Karan Fries cattle reported that there was no mortality from birth to AFC among the female progeny of 11 out of 71 sires. The average mortality was found to be 14.2 percent and it ranged from 6.8 to 45.0 percent among the female calves of 60 sires. However, he observed that the differences in mortality rate from birth to AFC the progeny of different sires were found non significant. Highly significant difference was observed on mortality of female calves among sires in Frieswal cattle. The average mortality among female calves up to AFC observed to be 13.82. There was no mortality from birth to AFC among the female progeny of 23.08 percent sires but female progenies of about 77 percent sires showed varying rates of mortality up to AFC. Singh *et al.* (2002) in crossbred and Sahiwal cattle also observed non-significant effect of sire on female calf mortality from birth to AFC.

2.2.3.4. Effect of sire on culling rate among female calves

Significant effect of sire was observed by Lathwal and Kumar (1993) on culling percentage of female calves in from birth to age at first calving in Red Sindhi cattle. It ranged from 2.5 to 69.2 percent among the progeny of different sires. Rawal and Tomar (1994 b) reported highly significant differences for the culling percentage from birth to AFC among the female calves from different sires in Sahiwal cattle. None of the female calf born to 25.0 percent sires was culled, whereas the culling percentage was as high as 42.8 percent among the female progeny of one sire. More than 30.0 percent of the female calves were culled for 6.4 percent of the total sires.

Tomar and Rawal (1996) in Tharparkar cattle reported that highly significant differences in culling rates of female calves from different sires. About one fourth of total Tharparkar sires had none of the females calf culled from the herd up to age at first mating. The culling rate observed were 10.0 percent among the female calves of 20.2 percent sires and about two third of female claves from one sire were culled before their AFC.

The effect of sire was significant on culling of Karan Swiss and Hariana female calves as reported by Mukherjee and Tomar (1997b) and Kumar (1999), respectively. Singh (2001) in Karan Fries cattle reported that there was no culling from birth to AFC among the progeny of 10 out of 71 sires, culling rate being varied from 16.0 to 53.0 percent among the progeny of rest 61 sires. Atrey (2003) reported that calf sire had significant effect on culling rate in female calves up to their AFC. There was no culling from birth to AFC among the progenies of 15 sires out of 65 sires and an overall average culling rate was found to be 11.13. However, Tomar and Verma (1988 a,b) reported that sire had no significant effect on culling rate of Tharparkar and its half bred and Karan Fries cattle.

2.2.3.5. Effect of sire of calf on replacement rate on female calf basis

Rawal (1991) and Rawal and Tomar (1992) observed significant differences on replacement rate among the progeny of different sires for Tharparkar and Shiwal breeds; replacement rate was varied from 28.5 to 95.6 percent Tharparkar breed and corresponding figures were 25.0 to 97.0 percent among the progeny of different sires for Sahiwal breed. The effect of sire was observed to be significant on replacement rate in Red Sindhi as reported by Lathwal and Kumar (1993) on female calves born. Moreover, significant effect of sire on replacement rate reported by Mukherjee and Tomar (1997b) in crossbred cattle. Kumar (1999) in Hariana cattle and Singh (2001) in Karan Fries cattle and Atrey (2003) in Frieswal cattle reported that the sire had significant effect on replacement rate on female calf basis.

However, Tomar and Verma (1988a) in Tharparkar reported that sire of calf had no significant effect on percentage of female calves reaching to milking herd from the total female calves born.

2.2.3.6. Effect of sire of calf on replacement rate on total pregnancy basis

The effect of sire on replacement rate on total pregnancies was reported significant by Rawal (1991) in Tharparkar, Rawal and Tomar (1992) in Sahiwal, Lathwal and Kumar (1993) in Red Sindhi, Mukherjee and Tomar (1997b) in crossbred, Kumar (1999) in Hariana, Singh (2001) in Karan Fries and Atrey (2003) in Frieswal cattle, whereas Tomar and Verma (1988a) in Tharparkar cattle did not found any effect of sire of calf on replacement rate on total pregnancies.

2.3. Life Time Traits

Lifetime traits refer to productive herd life, number of calf produced and total milk yield recorded by the cow before calling or mortality.

2.3.1. Selective value and its components

The genetic contribution of an individual cow to the future generation depends upon the total calving, total female calves born and survived up to the milking age. The number of replacement heifers from each adult cow decides its contribution to the next generation and this contribution is called the selective value. In dairy animals, the number of live female calves born and reached to the milking herd from each adult cow is important because it is the female which replaces the old and unproductive cows from the herd.

2.3.1.1. Estimates of selective value and its components

The reports available in the literature on lifetime calf production traits have been given in Table 4. Total calves produced ranged from 3.07 in Karan Fries cows (Singh, 2001) to 5.20 in Hariana cows (Kumar, 1999). The total normal (alive) calves produced varied from 2.91 in Karan Fries to 6.34 in Friesian×Sahiwal at Miltary Dairy farm Raheja (1997)

2.3.1.2. Effect of sire on calf production traits

The effect of sire on calves born was investigated by different workers. Rawal (1991), Mukherjee and Tomar (1996), Kumar (1999) and Singh (2001) observed highly significant effect of sire of cow on total calves born, whereas Rawal and Tomar (1994a) found non significant effect of sire of cow on total calves born from their daughter.

Rawal (1991) Mukherjee and Tomar (1996), Kumar (1999) and Singh (2001) found significant effect of sire on total normal calves born. However, Rawal and Tomar (1994a) found non significant effect of sire on the trait.

Significant effect of sires on total female calves born was reported for different cattle breeds (Rawal, 1991; Lathwal *et al.,* 1992; Kumar, 1999 and Singh, 2001). However, Rawal and Tomar (1994a) and Mukherjee and Tomar (1996) found non significant effect of sire on total female calves born for Sahiwal and crossbred, respectively.

Table 4. Average values of lifetime calf production traits and coefficient of gene replication (CGR) in different cattle herd

Breed	Location	Number	Number of calf produced per cow	Alive calf produced per cow	Female calf produced per cow	Replacement daughters per cow	CGR per cow	Reference
Angus	Wyoming	1586	3.78	-	-	1.10	0.48	Schons *et al.*(1985)
Crossbred	Bikaner	978	-	5.04	-	-	-	Singh *et al.*(1997)
Friesian×Hariana	MDF	690	-	5.72	-	-	-	Raheja (1997)
Friesian×Sahiwal	MDF	690	-	6.34	-	-	-	Raheja (1997)
Frieswal	MDF	953	2.91	2.57	1.23	0.92	0.46	Atrey (2003)
Hariana	Hissar	735	5.20	4.90	2.38	1.20	0.60	Kumar (1999)
Karan Fries	Karnal	1210	3.07	2.91	1.36	0.86	0.43	Singh(2001)
Karan Swiss	Karnal	1399	-	3.14	1.47	0.77	0.39	Mukherjee and Tomar (1996)
Red Sindhi	Karnal	483	-	3.10	1.59	0.92	-	Lathwal (1989)
Red Sindhi	Karnal	448	3.32	3.16	1.53	-	0.47	Tomar *et al.*(1995)
Sahiwal	Karnal	744	3.72	3.61	1.80	1.26	0.63	Rawal and Tomar (1994a)
Tharparkar	Karnal	1368	-	3.68	1.75	1.16	0.58	Rawal *et al.*(1993)

Table 5. Frequency distribution of cow (percent) according to total calves born, total female calves born and replacement daughters during the life time for different breeds

Breed	Total calves															Reference
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
i. Percent cows given birth to total calves																
Frieswal	-	34.2	19.3	12.4	13.4	8.6	5.77	3.1	1.4	0.7	0.7	0.2	-	-	-	Atrey (2003)
Hariana	-	21.2	18.7	9.6	6.5	6.7	5.9	6.2	7.8	6.0	4.1	4.0	2.2	0.7	0.3	Kumar (1999)
Karan Fries	-	32.1	29.2	12.7	8.0	3.6	2.6	2.1	2.1	1.7	1.8	1.5	1.5	0.4	0.3	Mukherjee and Tomar (1996)
Karan Fries	-	27.9	23.1	19.6	8.7	6.4	4.2	2.8	2.4	1.7	1.0	0.7	0.6	0.6	0.1	Singh (2001)
Red Sindhi	-	28.9	22.1	12.2	8.6	9.1	5.7	5.7	3.3	1.8	0.6	1.2	-	-	-	Lathwal (1989)
Sahiwal	-	22.2	21.4	14.9	9.3	8.3	7.1	5.7	4.4	2.7	3.0	0.4	0.1	0.4	0.1	Rawal and Tomar (1994a)
ii. Percent cows given birth to female calves																
Frieswal	32.4	34.6	18.2	10.2	2.8	0.7	0.6	0.2	0.1	-	-	-	-	-	-	Atrey (2003)
Hariana	19.3	25.3	17.4	14.3	11.9	6.8	3.4	0.9	0.7	0.1	-	-	-	-	-	Kumar (1999)
Karan Fries	25.8	37.3	19.6	8.6	5.0	1.7	0.8	0.6	0.2	0.2	0.1		-	-	-	Singh (2001)
Karan Swiss	30.5	36.5	16.4	7.1	3.8	2.1	1.8	1.1	0.6	0.07	-	-	-	-	-	Mukherjee and Tomar (1996)
Red Sindhi	24.4	36.0	18.6	10.7	5.4	3.3	1.0	0.2	0.2	-	-	-	-	-	-	Lathwal (1989)
Sahiwal	19.1	33.9	21.0	11.7	7.5	3.9	1.8	0.7	0.5	-	-	-	-	-	-	Rawal and Tomar (1994a)
Tharparkar	22.1	31.6	20.7	12.1	7.0	3.1	1.8	1.0	0.4	0.1	0.05	-	-	-	-	Rawal (1991)
iii. Percent cows given birth to replacement daughters																
Frieswal	44.5	31.3	15.1	6.6	1.4	0.5	0.4	-	-	-	-	-	-	-	-	Atrey (2003)
Hariana	49.3	21.4	12.9	8.7	5.5	1.9	0.15	0.15	-	-	-	-	-	-	-	Kumar (1999)
Karan Fries	43.3	36.0	12.4	5.0	1.8	0.8	0.2	0.2	0.1	-	-	-	-	-	-	Singh (2001)
Karan Swiss	54.8	29.9	8.0	4.2	1.8	0.8	0.2	0.1	-	-	-	-	-	-	-	Mukherjee and Tomar (1996)
Red Sindhi	42.4	36.0	13.4	5.3	1.6	0.6	0.4	-	-	-	-	-	-	-	-	Lathwal (1989)
Sahiwal	33.9	32.4	18.4	7.9	4.6	2.0	0.7	-	-	-	-	-	-	-	-	Rawal and Tomar (1994a)
Tharparkar	39.6	30.0	15.6	7.9	4.2	2.2	0.4	0.1	0.1	-	-	-	-	-	-	Rawal (1991)

Significant sire effects on female calves reaching to the milking herd (selective value) were observed by Rawal (1991), Lathwal (1992), and Singh (2001) whereas, Rawal and Tomar (1994a) and Mukherjee and Tomar (1996) failed to observe significant effect of sire on the trait

2.3.1.3. Frequency distribution of calf production performance

The frequency (percent) distribution of cows according to the life time calf production traits viz., total calves born, total female calves born and replacement daughters is given in Table 5. Cows that gave one normal birth ranged from 21.2% (Kumar, 1999) to 34.2% (Atrey, 2003). The table also showed that less than 10% of cows in genetic group gave five normal births and the proportion declined to 5% for cows delivered 10 births.

Percent of cows did not delivered female calves at all ranged from 19.1% (Rawal and Tomar, 1994a) to 32.4% (Atrey, 2003) and those cows delivered one female calf were in the range of 25.3 (Singh, 2001) to 36.5 (Mukherjee and Tomar, 1996) percent. Table 5 revealed that only 7.0 and 0.1 percent of cows gave five and ten female calves, respectively.

About 33.9% of Sahiwal cows (Rawal and Tomar, 1994a) and 54.8% of Karan Fries cows (Singh, 2001) did not replace themselves. Cows reached one replacement daughter ranged from 21.4% (Kumar, 1999) to 36.0% (Lathwal, 1999 and Singh, 2001).

2.3.2. Productive herd life

2.3.2.1. Estimates of productive herd life

Productive herd life (PHL) is the number of years a cow stayed in the herd after first calving. The minimum PHL of 2.90 years in Holstein×Tharparkar crossbred (Singh and Tomar, 1989) and in Guernsey (Nieuwhof *et al.,* 1989) and maximum of 7.70 years in Tharparkar (Basu *et al.,* 1983) were reported. The estimate for pure Holstein cows was from 2.92 in Ohio (Gill and Allaire, 1978) to 5.47 (Birhanu, 2009) in Ethiopia (Table 6).

2.3.2.2. Non genetic factors affecting productive herd life

Birth year of the cow affects productive herd life through the combined effect of feed avaialbity, disease and parasite dynamics during the growth period as reported by Basu *et al.*(1983) for Tharparkar cows, Hegade and Bhatnagar (1985) and Reddy and Basu (1985) for crossbreds, Tanida *et al.*(1988) for Hereford and Angus breeds, Singh and Tomar (1989) for Karan Fries, Mukherjee *et al.*(1999) for Karan Swiss, Kumar (1999) for Hariana and Singh (2001) for Karan Fries cattle, Atrey (2003) for Frieswal cattle and Gebeyehu *et al*.(2007) and Birhanu (2009) for Holstein cows.

Table 6. Estimates of productive herd life (PHL) for different cattle breeds

Breeds	Location	Number	PHL (years)	References
Angus	Wyoming	1586	4.49	Schons *et al.*(1985)
Ayrshire	-	20127	3.10	Nieuwhof *et al.*(1989)
Ayrshire crossbreds	Kenya	-	3.30	Thorpe *et al.* (1994)
Brown Swiss	-	19336	3.30	Nieuwhof *et al.*(1989)
Brown Swiss×zebu F_1	Karnal	210	4.40	Hegade and Bhatnagar (1985)
Brown Swiss×zebu F_2	Karnal	63	3.10	Hegade and Bhatnagar (1985)
Brown Swiss×zebu F_3	Karnal	14	4.70	Hegade and Bhatnagar (1985)
Frieswal	MDF	953	3.50	Atrey (2003)
Guernsey	-	84506	2.90	Nieuwhof *et al.*(1989)
Hariana	Hissar	735	5.38	Kumar (1999)
Holstein	Ohio	933	2.92	Gill and Allaire (1976)
Holstein	USA	55813	3.20	Nieuwhof *et al.*(1989)
Holstein	Ethiopia	105	4.80	Gebeyehu *et al*.(2007)
Holstein	Ethiopia	-	5.47	Birhanu (2009)
Holstein	Cuba	-	3.75	Leon and Gomez (1988)
Holstein×Boran crosses	Ethiopia	401	3.56	Gebeyehu (2005)
Holstein cross (<50%)	MDF	813	4.92	Reddy and Basu (1985)
Holstein cross (>50%)	MDF	842	5.24	Reddy and Basu (1985)
Holstein×Tharparkar	Karnal	634	2.90	Singh and Tomar (1989)
Holstein×Tharparkar	Palampur	796	3.47	Singh (1995)
Horro cross	Ethiopia	-	6.20	Gebregziabher and Mulugeta (2006)
Jersey	USA	83838	3.30	Nieuwhof *et al.*(1989)
Jersey×Sahiwal	Pantnagar	108	5.50	Singh *et al.*(1988)
Karan Fries	Karnal	1210	3.06	Singh (2001)
Karan Swiss	Palampur	553	3.32	Singh (1995)
Karan Swiss	Karnal	1399	3.20	Mukherjee *et al.*(1999)
Red Sindhi	Kerala	88	4.80	Nair (1976)
Sahiwal	MDF	189	5.30	Matharu and Gill (1981)
Sahiwal	Pantnagar	38	5.87	Singh *et al.*(1988)
Sahiwal × Friesian	India	-	6.24	Sahota and Gill (1990)
Tharparkar	Karnal	958	7.70	Basu *et al.*(1983)

USA= United States of America; MDF=Military Dairy Farm, India

Non significant effect of age at first calving on productive herd life were reported by Comacho *et al.* (1985) for Brahman cows and Sahota and Gill (1990) for crossbred cattle have reported. However, Dentine *et al.*(1987), Durocq *et al.*(1988), Rogers (1991) for exotic cattle and Mukherjee *et al.*(1999) for crossbred cows found that lower age at first calving was associated with longer productive herd life. Kumar (1999) in Hariana cattle and Singh (2001) and Atrey (2003) for Karan Fries cattle also reported that AFC had significant effect on productive herd life.

First lactation milk also had effect on on productive herd life. Durocq *et al.*(1988) and Rogers *et al.*(1991) for exotic cattle, Mukherjee *et al.*(1999) for crossbred cattle and Atrey (2003) for Frieswal cattle reported that first lactation milk production had significant effect on productive herd life in a way that high yielders were having longer productive herd life which may be due to the deliberately culling of low producers. Moreover, Kumar (1999) on Hariana cattle and Singh (2001) on Karan Fries cattle reported that first lactation milk yield had highly significant effect on PHL. However, Sahota and Gill (1990) in crossbred cattle reported that first lactation milk yield had non-significant effect on productive herd life.

2.4.2.3. Effect of sire on productive herd life

Significant sire effect on PHL have been reported by Singh and Tomar (1989) for Karan Fries, Mukherjee *et al.*(1999) for Karan Swiss, Kumar (1999) for Hariana and Singh (2000) for Karan Fries cattle. However, non significant effect of sire on productive herd life was found by Comacho *et al*. (1995) in Brahman herd.

2.3.3. Longevity

2.3.3.1. Estimates of longevity

Longevity is the number of years from date of birth to the date of disposal of cows from the herd either due to culling or death. Table 7 indicated that longevity estimates ranged from 6.0 years in Karan Fries cattle (Singh, 2001) to 10.1 years for different crosses at Bako (Gebreegziabher and Mulugeta, 2006).

2.3.3.1. Non-genetic factors affecting longevity

Significant effect of birth year on longevity were reported by Basu *et al*. (1983) in Tharparkar cows, Hedge and Bhatnagar (1985) and Reddy and Basu (1985) in crossbreds Singh and Tomar (1989) in Karan Fries, Mukherjee *et al.*(1999) in Karan Swiss, Kumar (1999) in Hariana cattle, Atrey (2003) in Frieswal cattle, Gebeuyehu *et al.* (2007) and Birhanu (2009) in Holstein Friesian cattle.

Similarily, significant effect of age at first calving on longevity were reported by Dentine *et al.* (1987), Duroc *et al.*(1988) and Rogers *et al.* (1988) in exotic cattle, Mukherjee *et al.* (1999) in Karan Fries and Kumar (1999) in Hariana and Atrey (2003) in Frieswal cattle. However, Singh (2001) in Karan Fries cattle noted non-significant effect of AFC on longevity.

Table 7. Some estimates on longevity of dairy cows

Breed groups	Country	Longevity (years)	Reference
Crossbred cattle	Ethiopia	6.02	Eneyew *et al.* (1999)
Fogera	Ethiopia	9.60	Gidey (2001)
Friesian×Boran crosses	Ethiopia	7.83	Gebeyehu (2005)
Hariana	India	9.12	Kumar (1999)
Holstein-Friesian	Ehtiopia	9.04	Birhanu (2009)
Holstein-Friesian	Cuba	6.25	Leon and Gomez (1988)
Holstein-Friesian	Ethiopia	8.35	Gebeyehu *et al*.(2007)
Horro cross	Ethiopia	10.1	Gebregziabher and Mulugeta (2006)
Karan Fries	India	6.00	Singh (2001)
Sahiwal	India	8.76	Singh,Umesh *et al.* (2011)

Likewise, significant effect of first lactation milk yield on longevity were observed by Dentine *et al.*(1987), Durocq *et al*.(1988) and Rogers *et al.*(1991) in exotic cattle, Mukherjee *et al.*(1999) in Karan Swiss, Kumar (1999) in Hariana and Singh (2001) and Atrey (2003) in Karan Fries cattle.

2.3.3.2. Effect of sire on longevity

Limited reports of sire on longevity have been available. It was noted that sire had significant effect on longevity for different breeds (Mukherjee *et al*., 1999), Kumar (1999) and Singh (2001).

2.4. Genetic Parameters

The potential for genetic improvement of a trait largely depends upon genetic variation existing in a population of interest. The variability for a particular trait in a herd or population is measured by heritability estimate of a trait under given environmental conditions. Knowledge of genetic parameters viz., the heritability and genetic correlations among traits help in deciding the appropriate selection method and mating system. The genetic parameters have been reviewed in terms of heritability, repeatability and correlation estimates of replacement rate and selective value and first lactation traits.

2.4.1. Genetic parameters for replacement traits

2.4.1.1. Heritability estimates for replacement traits

The heritability estimates of replacement rate and its components in dairy cattle herds of different breeds have been given in Table 8. Heritability for abnormal births ranged from 0.042 for Red Sindhi (Lathwal and Kumar, 1993) to 0.43 for exotic breed in Sweden (Lindhe, 1967). Sex ratio had very low heritability and ranged from 0.00 for crossbred (Parekh and Singh, 1981) to 0.095 for Sahiwal (Rawal and Tomar, 1995). The estimate for mortality was 0.003 (Parekh and Singh, 1981) to 0.38 (Lathwal and Kumar, 1993). Heritability of replacement rate from female birth was higher in all reports than heritability of replacement rate from total pregnancy. The estimates were 0.02 (Singh, 2001) to 0.57 (Kumar, 1999) for replacement rate from female births and 0.01 (Singh, 2001) to 0.1 (Lathwal and Kumar, 1993) for replacement rate from total pregnancy.

Table 8. Heritability estimates of replacement rate and its components in dairy herds of different breeds

Breed	Location	Abnormal calving	Sex ratio	Mortality	Culling	Replacement rate		References
						FC	TP	
Crossbred	-	-	0.00	0.003	-	-	-	Parekh and Singh (1981)
Crossbred	Ambala	0.07	-	-	-	-	-	Kumar *et al.*(1991)
Crossbred	Ambala	-	0.06	-	-	-	-	Kumar *et al.*(1993)
Crossbred	Pantnagar	0.066	0.021	0.052	-	-	-	Singh and Singh (1998)
Exotic	Sweden	0.43	-	-	-	-	-	Lindhe (1967)
Exotic	USA	-	0.017	-	-	-	-	Powell *et al.* (1975)
Exotic	German	-	-	-	0.065	-	-	Schwenger *et al.*(1989)
Frieswal	MDF	0.085	0.054	0.193	0.213	0.21	0.063	Atrey (2003)
Hariana	Hissar	0.285	0.052	0.187	0.101	0.571	0.066	Kumar (1999)
Karan Fries	Karmal	0.28	0.013	0.028	0.013	0.02	0.01	Singh (2001)
Karan Swiss	Karnal	0.056	0.002	-	-	-	-	Mukherjee *et al.* (1993)
Karan Swiss	Karnal	-	-	0.137	0.115	0.225	0.064	Mukherjee and Tomar (1997b)
Red Sindhi	Karnal	-	-	0.18	-	-	-	Singh (1979)
Red Sindhi	Karnal	0.042	0.016	0.001	0.347	0.23	0.10	Lathwal and Kumar (1993)
Sahiwal	Karnal	-	0.05	-	-	-	-	Sethi and Rao (1981)
Sahiwal	Ambala	-	-	-	-	0.28	0.06	Rawal and Tomar (1992)
Sahiwal	Karnal	-	-	0.38	-	-	-	Lathwal and Kumar (1993)
Sahiwal	Karnal	-	-	0.116	0.17	-	-	Rawal and Tomar (1994b)
Sahiwal	Karnal	-	0.095	-	-	-	-	Rawal and Tomar (1995)
Sahiwal	Karnal	0.10	-	-	-	-	-	Rawal and Tomar (1996b)
Tharparkar	Karnal	-	-	0.31	-	-	-	Singh (1979)
Tharparkar	Karnal	-	-	-	-	0.11	0.031	Rawal (1991
Tharparkt aar	Karnal	0.16	0.067	-	-	-	-	Rawal and Tomar (1996c)

2.4.1.2. Repeatability of abnormal births and sex ratio

Repeatability estimates of abnormal caving and sex ratio in different dairy cattle herds have been depicted in Table 9. The repeatability of abnormal calving ranged from 0.0015 in Karan Fries cattle (Singh, 2001) to 0.065 in crossbred (Kumar *et al.,* 1991).

The repeatability of sex ratio varied from -0.00053 in Karan Fries cattle (Singh, 2001) to 0.084 in Sahiwal (Rawal and Tomar, 1995). From the above information it is revealed that abnormal birth and sex of the calf in future gestation cannot be predicted based on the calf in the previous gestation. Stonekar and Knapp (1974) and Elbarbery (1983) observed the tendency of calves of the same sex to be born in successive calving viz. more females will be born following a female calf.

Table 9. Repeatability estimates of abnormal calving and sex ratio in different dairy cattle

Breed	Location	Abnormal calving	Sex ratio	References
Crossbred	Ambala	0.065	-	Kumar *et al.*(1991)
Crossbred	Ambala	-	-0035	Kumar *et al.*(1993)
Frieswal	MDF	0.102	-0.0217	Atrey (2003)
Hariana	Hissar	0.0043	0.0176	Kumar (1999)
Karan Fries	Karnal	0.0015	-0.00053	Singh (2001)
Karan Swiss	Karnal	0.026	-	Mukherjee and Tomar (2000)
Karan Swiss	Karnal		0.002	Mukherjee *et al.*(2000)
Sahiwal	Karnal	-	0.034	Sethi and Rao (1981)
Sahiwal	Karnal	-	0.084	Rawal and Tomar (1995)
Sahiwal	Karnal	0.025	-	Rawal and Tomar (1996a)
Tharparkar	Karnal	0.032	-	Rawal and Tomar (1996b)

2.4.2. Genetic parameters for selective values

2.4.2.1. Heritability estimates for selective values

The heritability estimates for productive herd life, longevity and life time calf production trait ar*e* give*n* in Table 10. The heritability for productive herd life ranged from 0.005 *(*Reddy and Nagarcenkar, 1989c) to 0.975 (Kumar, 1999). Few reports were available for longevity and the estimate was between 0.44 (Singh, 2001) to 0.94 (Kumar, 1999). Total

Table 10. Heritability estimates of productive herd life (PHL), longevity, and life time calf production traits for different cattle breed

Breed	PHL	Longevity	Total calves born	Total normal calves born	Number of female calves		References
					Born	Reaching milking herd	
<50 exotic	0.21	-	-	-	-	-	Reddy (1979)
≥50 exotic	0.27	-	0.15	-	-	-	Reddy (1979)
Frieswal	0.66	0.63	0.69	0.64	0.30	0.25	Atrey (2003)
Hariana	0.975	0.945	0.967	0.994	0.761	0.729	Kumar (1999)
Hariana	0.07	-	-	-	-	-	Dalal *et al.*(2002)
HF×Sahiwal							
Holstein	0.15	-	0.14	-	-	-	Hargrove *et al.* (1969)
Jersey	0.03	-	-	-	-	-	Roger *et al.* (1991)
Karan Fries	0.49	-	-	-	-	-	Singh and Tomar (1989)
Karan Fries	0.44	0.44	0.52	0.69	0.35	0.49	Singh (2001)
Karan Swiss	-	-	0.206	0.177	0.043	0.036	Mukherjee and Tomar (1996)
Karan Swiss	0.118	-	-	-	-	-	Mukherjee *et al.*(1999)
Sahiwal	0 .005	-	-	-	-	-	Reddy and Nagarcenkar (1989c)
Sahiwal	-	-	0.02	-0.20	0.02	-0.07	Rawal and Tomar (1994a)
Tharparkar	0.69	-	0.67	-	-	-	Basu *et al.*(1983)

HF= Holstein Friesian

calves born had heritability of 0.02 (Rawal and Tomar, 1994a) to 0.96 (Kumar, 1999). The value for total female calves born, and number of female calves reaching to the milking herd were from 0.02 (Rawal and Tomar, 1994a) to 0.76 (Kumar, 1999) and from -0.07 (Rawal and Tomar, 1994a) to 0.72 (Kumar, 1999), respectively.

2.4.2.2. Correlations for selective value and its components

Sire evaluation has been investigated by many workers on the basis of production traits. the authors has not come across any work on ranking of sires for selective value except Mukherjee (1993) for cross bred, Kumar (1999) for Hariana, Singh (2001) and Atrey (2003) for Karan Fries cattle.

The sires were evaluated by estimating the transmitting ability for abnormal birth, female calf loss up to AFC and for the proportion of daughters reached up to AFC by Mukherjee (1993). Negative and low rank correlation was found for ranking sires for abnormal birth with female calves culled up to AFC (-0.08), with female calf mortality up to AFC (-0.20) and with selective value (-0.20) which are all non significant and further observed a moderately and positive correlation of ranking sires between selective value and female culled (0.69) and between selective value and female mortality (0.58).

Kumar (1999) evaluated sires for different traits. It was found that the values of rank correlation were positive and medium for the transmitting ability of abnormal birth with sex ratio (0.44), female mortality up to AFC (0.49), female culled (0.54) and with female calves retained (0.37) which were all highly significant. It was further observed that there was high and positive correlation of ranking of sires between selective value and female calf mortality (0.67) and between selective value and female calf culling (0.68), which were also highly significant.

Singh (2001) observed that the value of rank correlation was positive and low for abnormal birth with female culled up to AFC (0.204). The value of rank correlation for female mortality and selective value with abnormal birth were negative and non significant. It was seen that there was low and positive correlation of ranking of sires between selective value and female culled (0.126) whereas, between selective value and mortality the correlation was negative (-0.003).

Mukherjee (1993) reported that the rank correlation between selective value and 305 day for first lactation milk yield (FLMY) was 0.30 which means the rank of sires of selective value also improve the milk yield, whereas, very low positive rank correlation between selective value and first lactation milk yield (0.04) indicted that there was no correlation between selective value and total first lactation milk yield. The rank correlation between selective value and AFC was low but positive (0.19).

Kumar (1999) observed that the correlation between selective value and FLMY was 0.34, which means that increase in selective value also improves milk yield whereas, the correlation between selective value and AFC was low but positive (0.29). Singh (2001) observed that the rank correlation between selective value and 305 days FLMY was found to be very low (0.094). However, in comparison of 305 day FLMY the rank correlation for FLMY with selective value was found as 0.166. The rank correlation between selective value and AFC was found to be positive and very low (0.031).

Atrey (2003) found that the selective value of rank correlation of abnormal birth with females culled to AFC was positive, very low (0.03) and non-significant indicating that selection of sire for reduced abnormal birth will not make any improvement in female to be culled up to AFC. Moreover, he noted that rank correlation of 0.37, 0.55, -0.24 and -0.49 between abnormal birth and female mortality up to AFC, selective value with AFC, abnormal birth with selective value and female mortality up to AFC with selective value.

2.4.3. Means and heritability estimates for first lactation traits

Mean and heritability for age at first calving, first lactation milk yield, first lactation period, first service period, first dry period and first calving interval were presented in Tables 11 to 16.

2.4.3.1. Age at first calving (AFC)

The age at first calving has a direct bearing on the life time performance of milking cows. Early AFC reduces the cost of rearing the heifers, generation interval and generates the records of first lactation milk yield early, thereby helping early selection and consequently increasing annual genetic gain. Table 11 summarized average age at first calving and heritability values as reported by different workers.

Table 11. Means and heritability of age at first calving among different breed groups

Genetic group	No of observation	Mean (days)	h^2±se	References
Friesian×Sahiwal	-	1182	0.36±0.13	Singh (1982)
	291	1157	-	Prasad (1983)
	338	1116	0.78±0.16	Rathi (1984)
	1787	-	0.42±0.09	Sachdeva and Gurnani (1989)
	-	-	0.36±0.19	Singh *et al.*(1989)
	1825	955	0.12±0.02	Tajane *et al.*(1990)
	793	1022	-	Kumar (1992)
	-	-	0.11±0.09	Rao and Nagercenkar (1992)
	250	1052	0.41±0.01	Banerjee (1996)
	328	-	0.46±0.06	Singh *et al.*(1996)
	791	-	0.24±0.11	Gaur (2001)
	226	1040	0.35±0.14	Singh (1979)
	-	1032	0.05±0.03	Singh (1982)
	-	1173	0.75±0.12	Suresh Chand and Sharma (1985)
	291	1095	0.18±0.00	Prasad (1986)
	338	1174	0.21±0.03	Rathi (1984)
	-	1109	0.21±0.12	Rai (1986)
	200	1098	0.20±0.05	Kumar (1987)
	-	-	0.45±0.03	Singh *et al.*(1989)
Red Dane ×Sahiwal	338	1197	0.09±0.08	Rathi (1984)
	-	1144	0.32±0.18	Singh (1982)
	-	1163	0.10±0.01	Suresh Chand and Sharma (1985)
	-	-	0.32±0.18	Singh *et al.*(1989)
Sahiwal×Jersey	142	-	0.21±0.12	Rai *et al.*(1996)
Frieswal	906	961	0.27±0.10	Bharti, 2004
Crossbred	1170	1350	0.20±0.05	Garima *et al.*(2010)

The average AFC ranged from 955 days (Tajan *et al.,* 1990) to 1500 days (Melaku, 1994). The heritability estimates of AFC in crossbred cows ranged from 0.05 in Jersey×Sahiwal (Singh, 1982) to 0.78 (Rathi, 1984).

The significant effect of season of calving on AFC in different herds of crossbred cows have been observed by Kaushik *et al.* (1978), Roy (1983), Kumar (1987), Butt and Deshpande (1987), Nayak and Raheja (1996) while Raheja and Balain (1976) Subodh Kumar (1992), Raheja (1997), Banerjee and Banerjee (2002) and Bharti (2004) reported non-significant effect of season of calving on same trait in crossbred cattle.

Significant effect of period of calving on AFC in different herds of crossbred cows were reported by Taneja and Bhat (1974), Jain and Dhillon (1975), Kaushik *et al.*(1978), Kumar (1987), Deshmukh and Kaikini (1991), Melaku (1994) Jadeva and Khan (1996), Raheja(1997), Narang *et al.* (2001) and Banerjee and Banerjee 92002), while non-significant differences in the AFC due to period of calving were observed by Nayak and Raheja (1996) and Bharti (2004) in various crossbred cattle.

2.4.3.2. First lactation milk yield (FLMY)

Milk production is the end product of long chain of events, caused by numerous and complex physiological processes. It is established that many genes are involved in it and these genes, each individually, have either large or small effects, the frequency of which determine animal milk yield. Genetic improvement of a population is a result of underlying changes in frequency of genes. Selection and gene migration are used by animal breeders to increase the frequency of desirable genes. Milk yield in a particular lactation varies from place to place depending on the management practices and the environmental conditions under which the genotypes are reared.

The averages of FLMY and heritability estimates in different crossbred cows are summarized in Table 12. The average FLMY ranged from 1702 (Zinjarde *et al.,* 1987) to 3182 (Jain *et al.,* 1995). Mureja (1994) and Million and Tadelle (2003) reported the overall average of 3157 and 3183kg for Holstein Friesian cows. The reported heritability values ranged from 0.01 (Jain *et al*., 1995) in Holstein×(Red Dane×Sahiwal) crosses to 0.89 (Suresh Chand and Sharma, 1985) in Friesian×Sahiwal crosses.

Table 12. Means and heritability of first lactation milk yield among different breed groups

Genetic group	No of observation	Mean (days)	h^2±se	References
Friesian×Sahiwal	-	2222	0.43±0.18	Singh (1976)
	-	2386	0.17±0.07	Bhat (1977)
	-	3118	0.56±0.21	Singh (1982)
	338	3112	0.10±0.10	Rathi (1984)
	-	3063	0.89±0.13	Suresh Chand and Sharma (1985)
	-	2601	0.16±0.05	Reddy and Basu (1986)
	1787	-	0.51±0.11	Sachdeva and Gurnani (1989)
	2069	2466	0.48±0.03	Tajane and Rai (1989)
	-	3140	0.32±0.04	Singh *et al.*(1990)
	-	3023	0.23±0.12	Singh *et al.*(1990)
	-	-	0.48±0.20	Rao and Nagercenkar (1992)
	328	3140	0.19±0.00	Singh *et al.*(1996)
	155	2585	0.77±0.37	Tomar *et al.*(1996)
	791	-	0.23±0.12	Gaur (2003)
Jersey×Sahiwal	-	2776	0.38±0.00	Singh (1982)
	338	2629	0.04±0.03	Rathi (1984)
	-	2620	0.08±0.00	Suresh Chand and Sharma (1985)
	291	2546	0.10±0.00	Prasad (1986)
	200	2594	0.37±0.06	Kumar (1987)
	200	2594	0.48±0.03	Mishra *et al.*(1989)
		2791	0.32±0.00	Singh *et al.*(1989)
	328	2638	0.19±0.00	Singh *et al.*(1996)
	142	-	0.23±0.05	Rai *et al.*(1996)
	116	2662	0.12±0.01	Kumar *et al.*(2003)
		2655	0.45±0.21	Singh (1982)
	338	2685	0.32±0.08	Rathi (1984)
		2863	0.17±0.00	Suresh Chand and Sharma (1985)
		2844	0.11±0.09	Kumar *et al.*(1989)
		2825	0.19±0.00	Singh *et al.*(1996)
Holstein× (Red dane×Sahiwal)	128	3182	0.01±0.24	Jain *et al.*(1995)
Karan Fries	517	2687	0.23±0.12	Singh and Tomar (1990)
Frieswal	906	2899	0.39±0.11	Bharti (2004)

Effect of season of calving on FLMY were found to be significant by Prakash and Sahu (1978), Deshpande and Bonde (1983), Frietas *et al.*(1991), Garcha and Dev (1994), Shettar and Govindaiah (1999), Sahana and Gurnani (2000) and Gaur (2001) while Raheja and Balain (1976), Prasad (1983), Roy (1983), Bhatnagar *et al.* (1986), Kumar (1987), Singh (1987), Taneja and Rai (1989), Subodh Kumar (1992), Nayak and Raheja (1996), Raheja (1997) and Singh *et al.*(2000) in different crossbred cattle. However, Bharti (2004) found non significant effect of season of birth on FLMY of Frieswal cows.

Khana and Bhat (1972), Taneja and Bhat (1974), Jain and Dhillon (1975), Prakash and Sahu (1978), Roy (1983), Kumar (1987), Garch and Dev (1994), Raheja (1997), Shettar and Govindaiah (1999), Gaur (2001), Narang *et al*.(2001) and Bharti (2004) reported significant effect of period of calving on first lactation milk yield in different crossbred cattle herds. However, non significant effects of period of calving on FLMY have been reported by Deshpande and Bonde (1983), Prasad (1983) and Nayak and Raheja (1996) in crossbred cattle.

2.4.3.3. First lactation period (FLP)

A standard lactation length with production record is necessary for valid comparison of sire and dam for selection. Average of first lactation period and its heritability estimates as reported by various workers are summarized in Table13. The lactation length for different genotype ranges from 277 days (Chaudhary, 1987) to 361 days (Garima *et al.,* 2010). The heritability value reported were from 0.01 (Tajan and Rai, 1989; Dalal *et al*. (1993) to 0.43 (Gaur, 2003).

Miliagres *et al*. (1988b), Singh *et al*.(1996), Gaur (2001) and Narang *et al.*(2001) reported the significant differences in FLP due to season of calving while non-significant differences in FLP due to season of calving have been observed by Nehra *et al.*(1987), Tajan and Rai (1989), Subodh Kumar (1992), Nayak and raheja (1996), Raheja (1997), Singh *et al.*(2000) and Bharti (2004) in different crossbred cattle.

Studies of Taneja and Bhat (1974), Reddy and Basu (1985), Miliagres *et al.* (1988b), Garecha and Dev (1994), Shettar and Govindaiah (1999) and Gaur (2001) found the significant effect of period of calving on FLP in various crossbred cattle. However, Nehar *et al.*(1987), Singh *et al.*(1996), Nayak and Raheja (1996) and Bharti (2004) reported the non-significant effect of period of calving on FLP in different crossbred cows.

Table 13. Means and heritability of first lactation length among different breed groups

Genetic group	No of observation	Mean (days)	h^2±se	References
Friesian × Sahiwal	2069	312	0.01±0.01	Tajan and Rai (1989)
	250	325	0.02±0.04	Banerjee (1996)
	155	249	0.36±0.29	Tomar *et al*.(1996)
	791	-	0.43±0.19	Gaur (2003)
Jersey × Sahiwal	552	293	0.41±0.05	Chaudhary (1983)
	338	307	0.17±0.05	Rathi (1984)
	292	294	0.11±0.06	Singh (1984)
	-	309	0.37±0.00	Suresh Chand and Sharma (1985)
	291	309	0.32±0.01	Prasad (1986)
	200	313	0.27±0.05	Kumar (1987)
	650	312	0.16±0.01	Kumar (1993)
	116	312	0.16±0.02	Kumar *et al*.(2003)
Friesian×Red Sindhi		345	0.05±0.08	Kumar (1992)
Jersey×Red Sindhi	208	288	0.60±0.00	Gogoi *et al*.(1992)
Jersey×Hariana	-	277	0.06±0.00	Chaudhary (1987)
Friesian×Hariana	410	331	0.01±0.01	Dalal *et al*.(1993)
Frieswal	906	314	0.06±0.07	Bharti (2004)

2.4.3.4. First service period (FSP)

The period lapsed between calving to conception is known as service period and is considered as an economically important trait in cattle. This period is not only a physiological function but also greatly depends on managerial practices like heat detection and artificial insemination. A long service period reduces the number of lactations which cow should complete in her life time and there by decreases the overall life tie production.

The means and heritability of first service period in crossbred cattle is as reported by different workers is showed in Table 14. Service period ranged from 116 days (Kumar *et al.*, 2003) to 1170 (Garima *et al.*, 2010). Heritability values were from 0.01 (Bharti, 2004) to 0.65 (Gaur *et al*., 1999)

The significant effect of season of calving on FSP were reported by Bhat *et al.(*1978), Due and Taneja (1984), Jadhav *et al*.(1991), Sahana and Gurnani (2000), Gaur (2000) and Dahiya *et al.(*2003) in different crossbred cows while non-significant differences in

FSP due to season of birth were observed by Singh *et al.*(2000) and Bharti (2004) in crossbred cattle.

Table 14. Means and heritability of first service period among different breed groups

Genetic group	No of observation	Mean (days)	h^2±se	References
Friesia×Sahiwal			0.65±0.22	Gaur *et al*.(1999)
	791	-	0.49±0.21	Gaur (2003)
Jersey×Sahiwal	116	151	0.23±0.01	Kumar *et al*.(2003)
Friesian×(Red dane×Sahiwal)	128	191	0.38±0.32	Jaine *et al*.(1995)
Frieswal	906	280	0.01±0.06	Bharti (2004)

Significant effect of period of calving on FSP were reported by Duc and Taneja (1984), Rao and Suderesan (1982), Sahana and Gurnani (2000), Singh *et al.*(2000), Gaur (2001) and Dahiya *et al.*(2003) while Kuralkar *et al.*(1995a) and Bharti (2004) found it to be non significant in Red Sindhi cattle.

2.4.3.5. First dry period (FDP)

Dry period, a period of rest before calving, is an unproductive period in milking cattle. This period in cows is considered important as she is getting ready for calving and production during the next lactation. However, standard dry period among cows is considered to be about 60 days, to keep the cost of milk production low. The average first dry period and its heritability estimates in different cross bred cattle herds are depicted in Table 15.

The average length of dry period was from 67 days (Singh *et al*., 1990) to 177 days (Garima *et al.*, 2010). The heritability values estimated were from 0.01 (Taneja *et al*., 1990; Bharti, 2004) in Friesian×Sahiwal and Frieswal synthetic breed, respectively to 1.0 (Tomer *et al*., 1996) in Friesian×Sahiwal crosses.

Studies of Raheja and Balain (1976), Subodh Kumar and Singh *et al*.(1993) and Sahana and Gurnani (2000), Gaur (2001) and Bharti (2004) observed the non significant

Table 15. Means and heritability of first dry period among different breed groups

Genetic group	No of observation	Mean (days)	h^2±se	References
Friesian×Sahiwal	1354	148	0.10±0.01	Taneja (1978)
	1136	138	0.09±0.05	Butte and Deshpande (1987)
	-	67	0.10±0.14	Singh *et al*.(1990)
	-	171	0.01±0.12	Taneja *et al*.(1990)
	250	108	0.17±0.07	Banerjee (1996)
	155	120	1.00±0.00	Tomer *et al*.(1996)
	367	-	0.67±0.22	Gaur *et al*.(1999)
	791	-	0.43±0.19	Gaur (2001)
Jersey×Sahiwal	226	118	0.41±0.21	Singh (1979)
	338	75	0.03±0.03	Rathi (1984)
	-	83	0.02±0.05	Suresh Chand and Sharma (1985)
Frieswal	906	124	0.01±0.06	Bharti (2004)

differences in FDP due to season of calving of crossbred cows. Effect of year of calving on FDP in various crossbred cattle was observed to be significant by Deshpande *et al.* (1992), Garcha and Dev (1994) and Nayak and Raheja (1996) while non significant effects were estimated by Singh *et al.* (1993), Sahana and Gurnani (2000) and Bharti (2004) in crossbred cattle.

2.4.3.6. First calving interval (FCI)

Calving interval is a period between two successive calving and is composed of service period and gestation period. Since gestation period is the least variable trait, the variation in calving interval is mostly attributable to the service period. Longer inter-caving period increases generation interval and results in decreased genetic gain.

The reviewed literature for average FCI and heritability estimates in different genetic groups is presented in Table 16. The estimates for FCI ranged from 338 days (Banerjee, 1996) to 538 days (Garima *et al.,* 2010). Average CI of 461 (Melaku, 1994) and 456 days (Gebeyehu *et al.,* 2007) were also reported for Friesian cows in Ethiopia. The heritability values were from 0.03 in Frieswal cattle (Bharti, 2004) to 0.52 in Friesian×Sahiwal cross (Gaur, (2003).

Reddy and Basu (1985), Jadhav *et al.*(1991), Raheja (1997), Sahana and Gurnani (2000), Gaur (2000), and Dahiya *et al.*(2003) have observed the significant season effect on FCI in different crossbred cattle herds while studies of Raheja and Balain (1996), Subodh Kumar (1992), Nayak and Raheja (1996), Singh *et al.*(2000) and Gebeyehu *et al.* (2007) in different crossbred cattle revealed the non-significant effects of season of calving on FCI.

Table 16. Means and heritability of first calving interval among different breed groups

Genetic group	No of observation	Mean (days)	h^2±se	References
Friesian×Sahiwal	552	425	0.36±0.02	Chaudhary (1983)
	338	441	0.04±0.14	Rathi (1984)
	-	405	0.07±0.05	Suresh Chand and Sharma (1985)
	1136	422	0.11±0.06	Butte and Deshpande (1986)
	250	338	0.13±0.02	Banerjee (1996)
	791	-	0.52±0.24	Gaur (2003)
Jersey×Sahiwal	552	400	0.15±0.00	Chaudhary (1983)
	338	383	0.07±0.03	Rathi (1984)
	-	392	0.13	Suresh Chand and Sharma (1985)
	291	406	0.07±0.03	Prasad (1986)
	200	404	0.22±0.05	Kumar (1987)
	-	409	0.21±0.06	Singh *et al.*(1990)
	116	440	0.11±0.01	Kumar (1993)
Friesian×(Red dane×Sahiwal)	128	465	0.43±0.32	Jain *et al.*(1995)
Frieswal	906	439	0.03±0.07	Bharti (2004)

Significant effect of period on FCI were reported by Prasad (1983), Nehra *et al.*(1987), Miliagres *et al.*(1988b), Jadhav *et al.*(1991), Garcha and Dev (1994), Nayak and Raheja (1996), Shana and Gurnani (2000), Singh *et al.*(2000), Gaur (2001), Dahiya *et al.*(2003) and Bharti (2004) in crossbred cattle. However, period effects on FCI were reported to be non-significant by Reddy and Basu (1985) and Raheja (1997) in crossbred cattle.

2.4.4. Correlations for first lactation traits

Table 17 depicts the phenotypic, genetic and environmental correlations among first lactation traits.

Table 17. Phenotypic, genetic and residual correlation among different dairy cattle

Trait	Genetic group	N	Correlation coefficients			Reference
			Phenotypic	Genetic	Residual	
			i. AFC with other first lactation traits			
FLMY	HF×S	552	0.04	0.18±0.08	-	Chaudhary (1983)
		338	0.50±0.11	0.89	-	Rathi (1984)
		-	-0.02±0.02	-0.64±0.09	-	Sachdeva and Gurnani (1989)
		1017	0.05±0.01	1.0	-	Jadheva *et al.*(1996)
		367	0.21±0.08	0.54±0.28	-	Gaur *et al.* (1999)
	J×S	552	-0.11	0.32±0.83	-	Chaudhary (1983)
		291	-0.10±0.07	-0.04	-	Prasad (1986)
		200	0.51±0.06	-0.43±0.29	-	Kumar (1987)
		-	0.01	-	-	Jain *et al.*(1995)
	R×S	338	-	-0.31	-	Rathi (1984)
		-	0.22±0.17	0.75	-	Suresh Chand and Sharma (1985)
	Crossbred	793	0.08±0.01	1.0±0.01	-	Kumar (1992)
		563	0.04±0.03	0.84	0.07	Akhter (1998)
	Frieswal	906	0.13±0.03	-0.16±0.23	0.27	Bharti (2004)
FLP	HF×S	1017	0.11±0.03	0.13±0.95	-	Jadheva *et al.* (1996)
		367	-0.14±0.07	-0.40±0.30	-	Gaur *et al.*(1999)
	Crossbred	563	0.28±0.04	0.50±	0.09	Akhter (1998)
	Frieswal	906	-0.04±0.03	-0.60±0.58	0.04	Bharti (2004)
FCI	HF×S	552	0.01 ±0.08	-0.35	-	Chaudhary (1986)
		338	0.33±0.13	0.94	-	Rathi (1984)
		-	0.15±0.15	1.0	-	Suresh Chand and Sharma (1985)
		1017	0.04±0.03	0.49±0.20	-	Jadheva *et al.*(1996)
		367	-0.06±0.01	-0.39±0.31	-	Gaur *et al.*(1999)
	J×S	552	0.15±0.09	-0.27	-	Chaudhary (1983)
		338	-	-0.85	-	Rathi (1984)
		-	-0.09±0.08	0.55	-	Suresh Chand and Sharma (1985)
		291	-0.07±0.07	-0.54	-	Prasad (1986)
	R×S	338	-	-0.45	-	Rathi (1984)

Table 17. Phenotypic, genetic and residual correlation among different dairy cattle (contd.)

Trait	Genetic group	n	Correlation coefficients			Reference
			Phenotypic	Genetic	Residual	
	F(R×S)	128	0.12	0.38±0.36	-	Jain *et al.*(1995)
	Crossbred	563	0.09±0.04	0.35±0.01	0.11	Akhter (1998)
	Frieswal	906	-0.01±0.03	-0.73±0.91	0.07	Bharti (2004)
FDP	HF×S	552	0.01±0.08	-0.83	-	Chaudhary (1983)
		-	-0.03±0.14	0.23±0.05	-	Suresh Chand and Sharma (1985)
		250	-0.13±0.03	-	-	Banerjee (1996)
		1017	0.02±0.03	0.43±0.68	-	Jadheva *et al.* (1996)
		367	-0.02	-0.24±0.32	-	Gaur *et al.*(1999)
	J×S	552	0.02±0.09	-0.07	-	Chaudhary (1983)
		338	-	-0.08±0.01	-	Rathi (1984)
	Crossbred	563	-0.17±0.04	-0.53±0.09	-0.05	Akhter (1998)
	Fireswal	906	0.04±0.03	-056±0.73	0.09	Bharti (2004)
FSP	F×S	367	-0.06±0.02	-0.34±0.32	-	Gaur *et al.*(1999)
	F(R×S)	128	0.12	0.37±0.38	-	Jain *et al.*(1995)
			ii. FLMY with other first lactation traits			
FLP	HF×S	-	0.52	0.44	-	Taneja *et al.*(1978)
		552	0.68±0.04	0.47±0.02	-	Chaudhary (1983)
		250	0.49	0.94±0.0	-	Banerjee (1996)
		367	0.25±0.05	0.13±0.28	-	Gaur *et al.*(1999)
	J×S	552	0.81±0.03	1.0	-	Chaudhary (1983)
		338	0.72±0.04	-	-	Rathi (1984)
		-	0.73±0.04	1.0	-	Suresh Chand and Sharma (1985)
		291	0.06±0.07	-0.03	-	Prasad (1986)
	R×S	-	0.73±0.52	0.17±0.02	-	Taneja *et al.*(1978)
		338	0.74±0.06	-	-	Rathi(1984)
		287	-0.09±0.06	0.076±0.09	-	Kumar (1994)
		-	0.59±0.03	0.62±0.31	-	Singh and Tomar (1996)
	Crossbred	563	0.63±0.03	0.79±0.01	0.55	Akhter (1998)
	Fireswal	906	0.57±0.03	0.58±0.32	0.64	Bharti (2004)
FCI	F×S	552	0.48±0.06	1.0±0.01	-	Chaudhary (1983)
		-	0.50±0.12	1.0±0.01	-	Suresh Chand and Sharma (1985)
		-	-0.09±0.04	-0.57±0.29	-	Kaul (1987)
		367	0.29±0.07	0.16±0.29	-	Gaur *et al.*(1999)

Table 17. Phenotypic, genetic and residual correlation among different dairy cattle (contd.)

Trait	Genetic group	n	Correlation coefficients			Reference
			Phenotypic	Genetic	Residual	
	Frieswal	906	0.52±0.02	0.81±0.61	0.56	
		563	0.07±0.04	0.67±0.04	0.27	Akhter (1988)
FDP	J×S	338	-0.46±0.06	-0.75±0.01	-	Rathi (1984)
		291	-0.11±0.07	0.21	-	Prasad (1986)
		287	-0.02±0.05	0.47±0.14	-	Kumar (1994)
		250	-0.01	0.10±0.27	-	Banerjee (1996)
		-	-0.23±0.06	-0.44±0.34	-	Singh and Tomer (1996)
	HF×S	367	0.18±0.04	0.08±0.30	-	Gaur *et al.*(1999)
	Crossbred	563	-0.40±0.04	-0.93±0.09	0.37	Akhter (1998)
	Frieswal		0.24±0.03	0.96±0.45	0.22	Bharti (2004)
FSP		367	0.30±0.06	0.09±0.30	-	Gaur *et al.*(1999)
	HF(R×S)	128	0.43	0.62	-	Jain *et al.*(1995)
	Frieswal	906	0.07±0.03	0.13±0.90	0.08	Bharti (2004)
			iii. FLP with other first lactation traits			
FDP	HF×S	552	0.70±0.04	0.59	-	Chaudhary (1983)
		338	0.65±0.08	-	-	Rathi (1984)
		-	0.39±0.13	-1.0	-	Suresh Chand and Sharma (1985)
		250	0.18	-1.0±0.33	0.18	Banerjee (1996)
		367	0.27±0.14	-0.02±0.27	-	Gaur *et al.*(1999)
	Crossbred	287	-0.09±0.05	0.46±0.15	-	Kumar (1994)
	Frieswal	906	0.42±0.03	0.01±0.98	0.44	Bharti (2004)
		563	-0.35±0.04	-0.95±0.05	-0.39	Akhter (1998)
	J×S	552	0.53±0.06	-0.33	-	Chaudhary (1983)
		338	0.57±0.05	-		Rathi (1984)
		-	0.61±0.05	-0.85±0.02	-	Suresh Chand and Sharma (1985)
		291	-0.45±0.06	1.00	-	Prasad (1986)
FCI	HF×S	1346	0.62±0.02	0.46±0.03	-	Deshpande and Bonde (1983)
		338	0.71±0.07	0.42±0.01	-	Rathi (1984)
		-	0.73±0.07	1.0±0.01	-	Suresh Chand and Sharma (1985)
		367	0.52±0.21	0.44±0.22	-	Gaur *et al.*(1999)
	J×S	552	0.51±0.06	-0.30	-	Chaudhary (1983)
		338	0.50±0.06	0.57	-	Rathi (1984)
		-	0.44±0.07	-0.47±0.01	-	Suresh Chand and Sharma (1985)

Table 17. Phenotypic, genetic and residual correlation among different dairy cattle (contd.)

Trait	Genetic group	n	Correlation coefficients Phenotypic	Genetic	Residual	Reference
	Crossbred	287	0.48±0.04	0.59±0.11	-	Kumar (1994)
		563	0.63±0.03	0.26±0.01	0.75	Akhter (1994)
	Frieswal		0.92±0.01	0.97±0.17	0.92	Bharti (2004)
FSP	HF×S	367	0.54±0.31	0.38±0.23	-	Gaur *et al.*(1999)
	Frieswal		0.08±0.03	0.84±0.53	0.06	Bharti (2004)
			iv. FSP with FDP and FCI			
FDP	HF×S	367	0.85±0.23	0.86±0.07	-	Gaur *et al.*(1999)
	Frieswal		-0.01±0.03	-035±0.60	0.03	Bharti (2004)
FCI		367	0.94±0.31	0.97±0.01	-	Gaur *et al.*(1999)
	HF(R×S)	128	0.93	1.00±0.04	-	Jain *et al.*(1995)
	Frieswal	906	0.06±0.03	-0.06±0.27	0.06	Bharti, 2004
			v. FDP with FCI			
FCI	HF×S	552	0.94±0.01	0.71	-	Chaudhary (1983)
		1346	0.85±0.01	0.95±0.09	-	Deshpande and Bonde (1983)
		338	0.46±0.08	0.66±0.05	-	Rathi (1984)
		250	0.21±0.03	-	-	Banerjee (1996)
		367	0.93±0.28	0.87±0.06	-	Gaur *et al.*(1999)
	J×S	-	0.38	0.68	-	Singh (1979)
		552	0.99	0.99	-	Chaudhary (1983)
		338	0.32±0.07	-	-	Rathi (1984)
		291	0.04±0.06	0.39	-	Prasad (1986)
	Crossbred	287	0.58±0.04	0.89±0.02	-	Kumar (1994)
		563	0.43±0.03	0.67±0.02	0.43	Akhter (1998)

HF= Holstein Friesian; J= Jersey; R= Red Dane; S=Sahiwal; n= number of observations

Most reports did not report the residual (environmental) correlations between first lactation traits. It is evident that phenotypic, genetic and environmental correlations vary from breed to breed and from location to location.

3. MATERIALS AND METHODS

3.1. Establishment of the Holeta Bull Dam Station

The Holeta Bull Dam Station was established by the Ministry of Agriculture (MoA) in 1955 with a foundation stock of 120 Holstein-Friesian pregnant heifers imported from the USA. Moreover, 109 and 120 Holstein Friesian heifers were imported from Kenya and Cuba in 1959 and 1980, respectively. The objective was to fulfill the demand for milk and milk products for the growing population of Addis Ababa.

The farm had been managed from 1972 to November 1999 under the former Ministry of State Farms Dairy Development Enterprise (DDE). The farm was again transferred to the Ministry of Agriculture and Rural Development (MoARD) in December 1999 to serve as a bull dam farm for the production of young Holstein Friesian bull for semen to the National Artificial Insemination Center (NAIC). The center has a total area of 266 hectare of which 220 hectare is used for grazing and production (Besufkad, 2008; Birhanu, 2009). Hay was made mainly from andropgon grass during the month of October.

3.2. Description of the Study Area

Holeta Bull Dam Station is located 33 km west of Addis Ababa, in West Shoa Zone of Oromia Regional State. The center lies at longitude 38º 30' E and latitude 9º 3' N; and an altitude of 2400 meter above sea level. The site is characterized by cool sub-tropical climate with mean maximum and minimum temperatures of 22.3ºC and 6.16ºC, respectively with average annual tempraure of 15.9ºC with mean relative humidity of 59%. The mean annual rainfall ranges from 818 to 1247 with an average of 1134 mm. The study area enjoys dry, short rainy and long rainy seasons which last from October to February, from March to May and from June to September, respectively (HARC, 2008).

3.3. Herd Management

Cows are allowed grazing on native pasture from 8:00 am to 3:00 pm. The herd is supplied with cultivated green vetches from December to January and also allowed to graze on irrigated pasture from February to May. Pasture improvement attempts had been practiced to some extent using perennial and annual improved grasses and legumes species such as cocks foot (*Dactilic glomerata*), oat (*Avena sativa*), rhodes (*Chloris gayana*), vetches (*Vicia dasycarpa*) and Phalaris species. Manure is sprayed on the pasture land to increase forage production of the farm. Animals are grouped and managed based on age groups as calves, young heifers, and mature stock. Dry cows and heifers are predominantly left to graze and supplemented with hay harvested from the farm pasture land and concentrates purchased from feed mill industries found around Addis Ababa**.** Milking cows are also grouped according to their milk production classes as high (>14 liters), medium (8 to 14 liters) and low (< 8 liters) yielding and each milking cow is provided with additional 0.5 kg concentrate per liter of milk above 8 litres, while pregnant dry cows are supplied with 3 kg of concentrates during the last two months of pregnancy.

Calves are separated from their dams after birth and allowed to receive colostrums for the first 5 days of their age. Bucket-feeding of whole milk continues until weaning at 120 days of age. Calves are given 5, 4, 3, and 2 liters of milk per day from 5 to 65; 66 to 85; 86 to 105; and 106 to 120 days of ages, respectively. Besides, some concentrate feed and hay starting from the age of 15 days are provided. However, calves born in calving years 1999 and 2000 from tuberculosis positive cows were deprived of receiving colostrums from their dams but were fed milk produced from tuberculosis negative cows. Female calves are retained for future replacement purposes, while bull calves from superior dams that produced 4000 liters over 305-days were recruited as future young bulls for semen production at NAIC. The remaining bull calves whose individual health and physical condition are normal and their respective dams` production was above the average of the herd are distributed for natural service to the surrounding farmers.

Hand-milking is practiced twice daily, from 4:00 to 6:00 am in the morning and from 4:00 to 6:00 pm in the afternoon. Every milkman is responsible to milk, feed and keep clean a specific number of cows every day and the milk produced by each cow is weighed and recorded daily and summarized in individual cards at the end of lactation. The data are seldom used for evaluating the milk yield performance of cows up on which decision was depended.

Regular vaccinations against contagious bovine pleura-pneumonia, lumpy skin disease, anthrax, and blackleg, foot and mouth disease and pasteurellosis is given and treatments are provided when incidences of cases observed. Culling is practiced as a result of fertility failures, chronic mastitis, tuberculosis, old age, and emaciation and in some cases due to low daily milk production. However, the routine activities are not done consistently and it is difficult to understand which cutting point is used for low milk production.

Most of the cows are served at first observed heat after calving, taking the body conditions of the cows into consideration. Heifers are inseminated after attaining 280 kg of body weight. Heat detection is routinely followed three times a day, i.e. early in the morning after milking; during the resting period in mid day; and in the afternoon before milking. Heat detection is carried out by herd attendants and artificial insemination (AI) technicians. Service is given after the AI technicians confirmed the heat status and then pregnancy diagnosis is conducted by manual rectal palpation after three months of last service.

3.4. Study Animals and Data Source

The study animals were 901 Holstein Friesian cows maintained during the period 1976 to 2003 Ethiopian Calendar. Moreover, records of 118 Friesian sires maintained in the same period were used for studying genetic parameters.

The following information was generated from the available records at the farm: cow, sire and calf identification number, service date, calving and drying off date, lactation number, first lactation milk yield, life time calf production traits, cow disposal date and reasons, type of calf birth (normal vs abnormal), sex of calf, female calf disposal date and reasons up to age at first calving.

3.5. Parameters Studied and Their Definitions

The following sections explain the meaning of different demographic parameters, replacement rate, life time and first lactation traits along with the respective mathematical expression.

3.5.1. Demographic parameters

Lactation specific parameters included in the study were loss rate, survival rate, survivorship, life expectancy, sex ratio, reproductive value and lactation specific herd structure.

Loss rate (Q_x): it is the probability of a cow, assuming survival to lactation x, of dying or culling before lactation x+1. Thus,

$$Q_x=d_x/n_x$$

Where,

d_x is the number of animals died and culled during lactation x;

n_x is the number of animals present in the herd at the beginning of lactation x.

Survival rate (P_x): is the complement of Q_x. It is the probability of a cow assuming survival to lactation x, of surviving to lactation x+1.

$$P_x = L_x + 1/L_x = 1- Q_x$$

Thus it is the probability of an animal being present to lactation x in the herd to the next lactation x+1.

Survivorship or Stayability (L_x): the probability of a cow at first lactation present in the herd to lactation x and estimated as number present at lactation x divided by the number alive at first lactation. The survivorship at first lactation was taken as unity and hence, L_0=1.0. The $L_x= n_x/n_0$, this can also be estimated as:

$$L_x = P_x . L_x - 1$$

where,

n_x is the number of survivors at lactation x

n_0 is the number of cows at first lactation

Expected herd life (E_x): this is the number of additional years that an animal of lactation x is expected to remain in the herd E_x more years and it was estimated as the sum of probability of an animal of a given lactation remaining in the herd (P_x) through each succeeding lactation up to the last lactation. Thus, average life expectancy is estimated as per Ahmed *et al.* (1992):

$$E_x = P_x + P_x.P_{x+1} + P_x.P_{x+1}.P_{x+2}.....+P_x.P_{x+1}.P_{x+n}$$

Average life expectancy at birth: this was estimated as the sum of survivorships at each lactation minus 0.5 (Caughley, 1966):

$$\sum_{t=1}^{n} L_{xi} - 0.5$$

Lactation (age) specific birth rate (M_x): this is defined as the probability of a cow of lactation x producing a live female calf. Thus

$$Mx = \frac{Number\ of\ calves\ produced\ by\ cows\ of\ lactation\ x}{Number\ of\ cows\ in\ lactation\ x}$$

Reproductive value (V_x): is age specific expectation of all present and future offspring and partitioned in to M_x and residual reproductive value devalued by chance of mortality before that age. Therefore, V_x is the relative contribution of a cow of lactation X to future generation and estimated as

$$V_x = \left[\sum_{x-1}^{n} L_x . M_x . X\right] / L_x$$

Mean rate of loss per female per lactation ($\overline{q}_x$): it is the average probability of a female animal being lost from the herd each lactation and was calculated as per Caughley (1966) formula:

$$\overline{q_x} = \frac{1}{\sum L_x} \quad \text{per female per year}$$

Mean lactation of cows being lost (death and culling): this parameter was calculated by multiplying each lactation (x) by proportion of cows lost from the herd (q_x) and adding the products i.e.,

$$\sum L_x.q_x$$ (Greer *et al.,* 1980)

Mean lactation of cows present in the herd: this parameter was estimated by multiplying each lactation (Lx) by proportion of total cows present in the herd (px) and adding the product i.e.,

$$\sum L_x.q_x$$ (Greer *et al.,* 1980)

Net reproductive rate (NRR): expected number of daughters produced by each animal entering the population or finite rate of population increase per generation is known as net reproductive rate. This was estimated as according to Schons *et al.* (1985)

$$\text{NRR}= \sum_{x=0}^{n}(L_x)(M_x)$$

Generation interval (T): this is the mean interval between birth of a parent and birth of its offspring and estimated according to Schons *et al.* (1985) as follows

$$\text{T} = \left[\sum_{x-1}^{n} L_x.M_x.X\right] / NRR$$

Rate of increase or decrease (r): The rate of increase or decrease of the population estimated according to Caughley (1971)

$$\text{r} = \frac{\log_e NRR}{T}$$

3.5.2. Replacement rate

The replacement rate was computed as the 'proportion of young females that become replacements to that of the total females born and of total pregnancies in particular year' (Tomar and Verma, 1988a). Replacement rate is the function of the death and culling of female calves from birth to age at first caving, in addition to the loss of female calves through abnormal births and male births.

3.5.3. Life time parameters

Longevity: is the time interval in years from the date of birth to the date of disposal of cows from herd either due to culling or death.

Productive herd life: the number of days from first calving to the date of disposal of cow from the herd was defined as productive herd life.

Selective value (lifetime calf production): the selective value of an animal is the proportionate contribution of the living female progeny to the next generation. This depends on total calving, total female calves produced and survived to the milking age. Therefore, the total number of calves, total live calves, total female calves born and total number of female calves reached to the milking herd from each cow counted.

Coefficient of gene replication (CGR): it is the additive genetic relationship between adult female and its female descendents reached to milking herd and has become a replacement heifer. These relationships were considered to be the proportion of a cow's genes that were replicated and given further opportunity to make genetic contribution to the future generation. These relationships were added over each cow's lifetime female descendants that reached to the milking herd to become the parents of the next generation. They have given the value to one female replacement as 0.5 and this measurement of additive genetic relationship is termed as CGR (Schons *et al.*; 1985)

3.5.4 First lactation traits

First service period (FSP): the time interval (days) between date of calving and there after date of successful conception.

First dry period (FDP): the time interval (days) between the date on which the animal was dried off and the date of next normal calving.

Age at first calving (AFC): the difference (days) between the date of birth and date of first calving.

First lactation milk yield (FLMY): milk yield (kg) from the day of first calving to the day on which cows dried off.

305 day milk yield (305DMY): adjusted first lactation milk yield to 305 day lactation length, using the factors given in Annex1.

First lactation period (FLP): the difference (days) between date of calving and date of drying off an animal.

First calving interval (FCI): the time interval (days) between dates of first two successive calving.

3.6. Classification of Data

Cows were grouped in to age at first calving (AFC) and first lactation milk yield (FLMY) to study their effect on longevity, productive herd life, and total calf production. Accordingly, they were grouped in to nine classes of each for AFC and FLMY based on 1/2σ unit for each trait respectively as indicated in Table 18.

Table 18. Classification of age at first calving and first lactation milk yield data

Class	Age at first calving (AFC)		First lactation milk yield (FLMY)	
	Interval (days)	N	Interval (kg)	N
1	≤886	35	≤1500	47
2	887-1042	73	1501-2065	29
3	1043-1198	74	2066-2630	56
4	1199-1354	75	2631-3195	67
5	1355-1510	58	3196-3760	70
6	1511-1666	21	3761-4325	49
7	1667-1822	12	4326-4890	25
8	1821-1978	7	4891-5455	14
9	≥1979	9	≥5456	7

3.7. Statistical Analyses

3.7.1. Demographic parameters

Lactation records of 901 cows were entered in the Excel spreadsheet. The edited data were tabulated and estimation of probability for all different demographic parameters was performed according to the formulae given in Section 3.6.1.

3.7.2. Replacement rate and its components

A total of 3092 birth records from 1979 to 2003 (25 years data) were considered to study replacement rate and its components. The replacement rate and its components viz. incidence of abnormal births, sex ratio, mortality, culling and survival rate up to age at first calving are the threshold characters and do not follow the normal distribution on phenotypic scale. Abnormal birth includes abortion and still birth. A calf born dead between 260 days and full term or calf died within 24 hours of birth is termed as still birth, while the loss of the fetus between 42 days and 259 days of pregnancy is designated as abortion. Sex ratio is defined as the probability of a cow at a given lactation producing a live female calf. Mortality is defined as the probability of a calf being died or culled before reaching the age of one year, while culling is the probability of a female calf culled before reaching age at first calving.

Proportion was estimated for each trait (abnormal and normal birth from total births, sex ratio from normal births, mortality and culling, and survival rate up to age at first calving from female calf births). Then, the respective proportion was transformed to Arcsine ($Angle = Arcsin\sqrt{proportion}$) after which the analyses of variance was made on the arcsine values using the following model:

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

Where,

Y_{ijkl} = l^{th} observation (replacement rate/its components) from a cow belonging to k^{th} parity, calved in j^{th} season of i^{th} year;

μ = overall mean;

P_i = effect of i^{th} year of calving (1, 2,…25);

S_j = effect of j^{th} season of calving (1, 2, 3);

L_k = effect of k^{th} parity of lactation (1, 2, … 9);

e_{ijkl} = random error specific to the particular observation and assumed to be normally and independently distributed with mean zero and variance σ^2 ie.σ^2~NID(0, σ^2_e).

The transformed data were analyzed using the SAS procedures of General Linear Model (SAS, 2002) but results are presented in the original scale.

Sex ratio is expected to be 1:1. The equality of observed overall sex ratio (percent female birth) with expected overall sex ratio was tested by Goodness of Fit of Chi Square (χ^2) test.

3.7.3. Selective value and its components

Data collected from 1976 to 1998 were used to estimate selective values. A total of 364 cows that had disposal records and given normal birth at AFC were classified based on 1/2σ unit of the trait in to nine categories of AFC and FLMY, respectively (Table 18). The least squares analyses of variance (Harvey, 1975) was conducted to study the fixed effects of season and year of birth of cows, age at first calving group and first lactation milk yield group on longevity, reproductive herd life, selective value and its components (total calves born, total female calves born and CGR) by using the following model:

$$Y_{ijkl\,m} = \mu + P_i + S_j + A_k + M_l + e_{ijklm}$$

Where,

Y_{ijklm} = m^{th} observation from a cow belonging to i^{th} year, j^{th} season, k^{th} AFC group and l^{th} milk yield group;

μ= overall mean;

P_i= effect of i^{th} year of birth (i=1, 2, ...25);

S_j= effect of j^{th} season of birth (j=1, 2, 3);

A_k= effect of k^{th} AFC group (j= 1, 2, ...9);

M_l= effect of l^{th} FLMY group (k=1, 2, …9);

$\mathbf{e_{ijkl}}$= random error specific to the particular observation and assumed to be normally and independently distributed with mean zero and variance σ^2_e i.e. σ^2~NID (0, σ^2_e). Data were analyzed using the General Linear Model of SAS (SAS, 2002).

3.7.4. Estimation of genetic parameters

3.7.4.1. Heritability, repeatability and correlations of threshold characters

Threshold traits are a special class of characters which are qualitative on phenotypic scale but they are, on the contrary, affected by polygenes and environment. Data on replacement trait and selective values (total calves born, total female calves born and total female calves reaching milking herd from each cow), sex ratio, mortality and culling are threshold characters or proportion data. Tomar *et al*. (1991) devised a method for genetic analysis of proportion data without transformation by conducting the analysis of variance using the following method.

$$\text{Total sum of squares} = pN - p^2N = pqN$$

$$\text{Sire sum of squares} = \sum p_i^2 n_i - p^2N = pqN - \sum p_i q_i n_i$$

$$\text{Error sum of squares} = pN - \sum p_i^2 n_i = \sum p_i q_i n_i$$

Where,

n_i = the number of total progenies for the i^{th} sire

a_i = number of affected progenies of i^{th} sire

$N = \sum n_i$

$p_i = a_i / n_i$ is the average incidence of the trait among the progenies of i^{th} sire

$q_i = 1 - p_i$

Sum of squares (SS), mean squares (MS) and the expected mean square (EMS) for the between sire component of variance (σ^2_s) and within sire component of variance (σ^2_w), were obtained as shown in Table 19.

Table 19. Variance analysis for the effect of sire

Sources of variation	Df	SS	MS	EMS
Between sires	S-1	SS_s	MS_s	$\sigma^2_w + K\sigma^2_s$
Within sires (error)	N-S	SS_w	MS_w	σ^2_w
Total	N-1			

$$\sigma_s^2 = \frac{MS_s - MS_w}{K}$$

Where,

K= average number of progenies per sire

$= 1/S-1 \; (\sum ni - \sum n_i^2 / \sum n_i)$

Where,

S = number of sires;

N = total number of observations;

n_i = number of observations for i^{th} sire.

Heritability (h^2) was estimated using paternal half-sib correlation method using least squares analysis of variance for different traits.

The intraclass correlation, $t = \frac{(\sigma^2 s)}{(\sigma^2 s + \sigma^2 w)}$

And, heritability, $h^2 = 4t = \frac{4(\sigma^2 s)}{(\sigma^2 s + \sigma^2 w)}$

Where,

$\sigma^2 s$ = sire component of variance;

$\sigma^2 w = \sigma^2 e$ = error variance.

Repeatability (t) was calculated for cows that had more than one successful pregnancy and a total of 630 cows were available for this particular study used for sire analysis was applied expect number of sire was replaced by cows (Table 20).

Table 20. Variance analysis for the effect of dam

Sources of variation	Df	SS	MS	EMS
Between cows	C-1	SS_c	MS_s	$\sigma^2_w + K\sigma^2_c$
Within sires (error)	N-C	SS_w	MS_w	σ^2_w
Total	N-1			

$$\sigma_c^2 = \frac{MSc - MS_w}{K}$$

Where,

K = average number of records per cow

Repeatability, t = $(\sigma^2_c / \sigma^2_{c} + \sigma^2_w)$

3.7.4.2. Genetic parameters for first lactation traits, longevity and PHL

Records of 433 cows from 48 sires that had at least three daughters were employed for the study of genetic parameters. The heritability for first lactation traits (AFC, 305DMY, FLMY, FLP, FSP, FDP and FCL), longevity and productive herd life were estimated using Restricted Maximum Likelihood Method (REML) of Meyer (1998). In univariate analysis for first lactation traits the following general formulation of mixed model was fitted on the observations.

$$Y_{ijkl} = \mu + A_i + P_j + Q_k + e_{ijkl}$$

Where,

Y_{ijkl} = is the l^{th} trait observation of i^{th} animal in j^{th} season in k^{th} year;

μ = the overall mean;

A_i = the random effect of i^{th} animal (i=1,…, 433);

P_j = the fixed effect of j^{th} season of birth (j=1, 2, 3);

Q_k = the fixed effect of the k^{th} year of birth (k=1, 2…, 20);

e_{ijkl} = the random error which is normally and independently distributed with zero mean and variance σ^2_e i.e σ^2~NID(0, σ^2_e).

The formulation of animal model in matrix notation was

$$\mathbf{y = X\beta + Zu + e}$$

Where,

y = a vector of n×1 records;

ß = a vector of fixed effect season and year (no covariable was taken);

u = a vector of breeding values for additive genetic effects fitted which is random;

X = a n×p design matrix for fixed effects with column rank = r ≤ (n, p);

Z = a n×q design matrix for random animal effects where Z=I;

e = a vector of n×1 random residual errors.

Assumptions of the model were:

$$\mathbf{E[u] = E[e] = 0}$$

With variances

$$\mathbf{Var\ (u) = A\sigma^2_u = G}$$

$$\mathbf{Var\ (e) = I\sigma^2_e = R}$$

$$\mathbf{Cov\ (u, e) = 0}$$

$$\mathbf{Var(y) = ZAZ'\sigma^2_u + I\sigma^2_e = ZGZ' + R = V}$$

$$\mathbf{E[y] = X\beta}$$

Where,

A= numerator relationship matrix;

$\boldsymbol{\sigma^2_u}$ = direct additive genetic variance;

$\boldsymbol{\sigma^2_e}$ = residual variance;

I = represents identity matrix.

The genetic correlation among first lactation traits and their standard errors were calculated by using the following formula (Robertson, 1959)

$$r_g(x, y) = \frac{Covs(x, y)}{\sqrt{[\sigma^2 s(x)\sigma^2 s(y)]}}$$

Where,

(x, y)= two different characters under study;

Cov s(x, y) = sire components of covariance between characters x and y;

$\sigma^2(x)$= sire components of variance of trait x;

$\sigma^2(y)$= sire components of variance of trait y.

$$\text{S.E. } r_g\,(x, y) = \frac{1-r_A^2}{\sqrt{2}} * \sqrt{\frac{\delta(h_x^2)(h_y^2)}{h_x^2 h_y^2}}$$

The phenotypic correlation between character x and y and their standard errors were estimated by the following formula from Tomar (1998):

$$r_p(x,y) = \frac{Covs(x,y) + Cove(x,y)}{\sqrt{2[\sigma^2 s(x)\sigma^2 e(x)] * [\sigma^2 s(y)\sigma^2 e(y)]}}$$

Where,

Cov e(x, y) = the error component of covariance between traits x and y;

Cov s(x, y) = the sire component of covariance between traits x and y;

$\sigma^2 s(x)$ = the sire components of variance for trait x;

$\sigma^2 s(y)$ = the sire components of variance for trait y;

$\sigma^2 e(x)$ = the error component of variance for trait x;

$\sigma^2 e(y)$ = the error component of variance for trait y.

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

Variances, covariances, heritability and genetic correlations were estimated using DMU (Derivative free Multivariate analysis by restricted maximum likelihood) version 6, release 6.4 packages (Madsen and Jensen, 2008). The DMUAI module in the package was used for estimation of (co)variance components using Average Information Restricted Maximum Likelihood (AI-REML) (Jensen *et al.,* 1997). The algorithm is based on the use of Average Information (AI) as second differentials of the likelihood function. Expectation Maximization (EM) was used to maximize the restricted likelihood functions.

The data and pedigree were read from individual files; therefore, separate data file, pedigree file and driver (command) file were prepared in ASCII (American Standard Code for Information Exchange) format. Bivariate analyses were used for first lactation traits, whereas for longevity and productive herd life univariate analyses were employed. The module iterates up to 200 rounds before convergence was reached. The convergence criterion was taken as the variance among the function values; the default convergence was assumed when this variance was less than 10^{-9}. In other words, iterations were assumed to have converged when the difference in the variance of successive log likelihood was less than 10^{-9}.

4. RESULTS

4.1. Lactation Specific Demographic Parameters

The Probability based on averages of lactation specific traits viz. loss rate (Q_x), survival rate (P_x), survivorship or stayability (L_x), expected herd life (E_x), female birth rate (M_x) and reproductive value (V_x) of Holstein Friesian herd are given in Table 21.

Table 21. Lactation specific demographic parameters of Holstein Friesian herd at Holeta Bull Dam Station

Lact. No	Total cows	Loss Rate (Q_x)	Survival Rate (P_x)	Stayability (L_x)	Expected herd life (E_x)	Female birth rate (M_x)	Reproductive value (V_x)
1	901	0.2619	0.7381	0.7373	2.4573	0.4808	1.0488
2	665	0.2541	0.7459	0.5499	1.7192	0.4452	0.8306
3	496	0.2520	0.7480	0.4113	1.1687	0.4533	0.6993
4	371	0.2938	0.7062	0.2905	0.7569	0.5000	0.6434
5	262	0.3359	0.6641	0.1929	0.4661	0.5022	0.5812
6	174	0.3276	0.6724	0.1297	0.2730	0.4839	0.5207
7	117	0.4017	0.5983	0.0776	0.1432	0.5196	0.5323
8	70	0.5143	0.4857	0.0377	0.0655	0.3770	0.3828
9	34	0.5588	0.4412	0.0166	0.0277	0.4333	0.4359
10	15	0.6000	0.4000	0.0067	0.0111	0.5385	0.5396
11	6	0.5000	0.5000	0.0033	0.0044	0.6000	0.6002
12	3	0.6667	0.3333	0.0011	0.0011	0.5000	0.5000

The probability of a cow being lost from herd was found as 0.2619 during the first lactation which means about one-fourth of the cows will leave the herd either due to death or culling during their first lactation (Table 21). This probability of depletion was almost same during 2^{nd}, and 3^{rd}, lactations but increased continuously from 4^{th} lactation (about $1/3^{rd}$) to 12^{th} lactation when almost $2/3^{rd}$ of the cows will be lost from the herd. Further, it was also observed that about 71% of the total cows in first lactation left the herd by the end of fourth lactation and only about 29 % of the superior most cows remained after 4^{th} lactation to produce their progeny in the herd.

The probability of survival rate (Table 21) in the herd during first lactation was estimated as 0.7381. The probability of survival rate increased during first three lactations and there after survival rate declined at an inconsistent rate till it reached to it's lowest of 0.3333 in the 12^{th} lactation. These lactation specific survival rates indicated that cows had low survival after the 7^{th} lactation.

Stayability (L_x) in the farm was maximum (0.7373) for cows in first lactation, indicating that 73.73% of the total cows in first lactation were likely to stay in the herd after completion of their first lactation. The probability of staying in the herd continuously decreased in order of increased lactation number. The probability of a cow surviving in the herd up to the completion of 12^{th} lactations was 0.0011, which means only 0.11% cows survived or retained in the herd at the end of 12^{th} lactation.

The lactation specific expected herd life of cows present in the herd at the first lactation was observed as 2.5 lactations. Thereafter, expected herd life of cows decreased to 1.7192 lactations for cows in second lactation and continued to decline with the increase in the lactation order till 12^{th} lactation at which it was 0.0011 lactations only indicating that cows at the end of the 12^{th} lactation had almost zero expected herd life.

The probability of producing a live female calf (M_x) by a cow at her first lactation was as 0.4808 and approached the expected sex ratio of 50:50 at the 4^{th}, 5^{th} and 12^{th} calving/lactations. However, female sex ratios varied between 0.3770 in 8^{th} lactation to 0.6000 in 11^{th} lactation and cows after the 9^{th} lactation had relatively higher sex ratio.

The lactation specific reproductive value (V_x) of cows at the 1^{st} lactation was 1.0448 and all other lactations had less than one. The lowest value was observed for the 8^{th} (0.3828) and 9^{th} (0.5349) lactations indicating that older cows had lower reproductive value than that of replacement heifers and younger cows.

4.2. Life Time Demographic Parameters

Table 11 depicts the overall life time mean lactation of cows present in the herd, mean lactation of cows lost from the herd, mean rate of loss per cow per lactation, average life expectancy at birth, net reproductive rate and generation interval.

Table 22. Overall life time statistics of Holstein Friesian herd at Holeta Bull Dam Station

Parameters	Unit	Average value
Mean lactation of cows present in the herd	Lactation	3.4949
Mean lactation of cows lost from the herd	Lactation	4.3548
Mean rate of loss per cow per lactation	Proportion	0.3204
Average life expectancy at birth	Lactation	1.2825
Net reproductive rate	Female calves per cow	1.4984
Generation interval	Years	3.5451

The cows present in the herd and lost from the herd had on the average 3.4949 and 4.3548 lactations, respectively. The average probability of a cow being lost from the herd was estimated as 0.3204 per lactation. These results indicated that 32.04 % of the cows were lost either due to death or culling from the herd per lactation.

The average life expectancy of cows at birth was observed as 1.2825 lactations i.e., any female calf born will complete more than one lactations. The average net reproductive rate and generation interval observed was 1.4948 female calves per cow and 3.5451 years respectively.

4.3. Replacement Rate and Its Components in Relation to Non Genetic Factors

Average replacement rate, its components and effects of non genetic factors viz. season and parity, are given in Table 23 and for year of calving are given in Table 24. The analysis of variance (mean square values) for the effect of non-genetic factors on different type of births traits are given in Table 25.

4.3.1. Abnormal births

The overall average incidence of abnormal birth rates based on total pregnancy was observed as 12%, while 88% of births were normal in Holstein Friesian herd at Holeta farm. The incidences of prenatal calf losses due to abnormal births during different parities were highest (16%) in first parity. From 2nd to 9th parity abnormal births varied from 9% to 13%. However, there was no abnormal birth in 10th and thereafter calvings. Though there was no definite trend in prenatal calf losses due to abnormal births, analysis of variance revealed the differences between parities were significant ($P \leq 0.05$).

The prenatal calf loses due abnormal birth during different years ranged from 0% to 21.1% (Table 23). The year effects on prenatal calf lose were found to be significant ($P \leq 0.05$). The average prenatal calf losses due to abnormal births revealed that incidence of abnormal births were higher in dry season than both rainy seasons but the differences were non-significant (Table 25).

4.3.2. Sex ratio

The overall male and female calves birth ratios among total normal calves born in Holstein Friesian cattle were 52.5% and 47.5%, respectively (Table 23) and the difference was significant ($\chi^2_{c\ (1,\ 0.01)} = 7.31$). The observed over all male sex ratio was significantly higher than the female sex ratio and both male female sex ratios significantly deviated from the expected sex ratio of 50%. The percentage of male births varied from 61% (parity 8) to 40% (parity 10) among different parity groups (Table 23). Higher than the average male calf ratios were observed in the young (1st, 2nd and 3rd parity) and older (8th and 9th parity) cows. These differences in sex ratios among parities were significant ($P \leq 0.01$) as showed in Table 25.

Table 23. Analyses of variance for the effect of non genetic factors on components of replacement rate at Holeta Bull Dam Station

Source	Total pregnancy	Proportion of birth from total pregnancy		Proportion from normal births (sex ratio)		Proportion from female calves birth		Female replacement rate from	
		Abnormal	Normal	Male births	Female births	Died	Culled	Female births	Total Pregnancy
Overall	3092	360(0.12)	2732(0.88)	1435(0.525)	1297(0.475)	303(0.23)	90(0.07)	904(0.70)	0.29
Season of calving									
Dry	1368	172(0.13)	1198(0.88)	615(0.51)	583(0.49)	142(0.24)	36(0.06)	405(0.70)	0.30
Short rainy	739	83(0.11)	656(0.89)	355(0.54)	301(0.46)	66(0.22)	20(0.07)	215(0.71)	0.29
Long rainy	983	105(0.11)	878(0.89)	465(0.53)	413(0.47)	95(0.23)	34(0.08)	284(0.69)	0.29
Parity									
1	898	141(0.16)	757(0.84)	391(0.52)	366(0.48)	97(0.27)	22(0.06)	247(0.67)	0.28
2	660	70(0.11)	590(0.89)	329(0.56)	261(0.44)	61(0.23)	16(0.06)	184(0.70)	0.28
3	493	43(0.09)	450(0.91)	245(0.54)	205(0.46)	46(0.22)	14(0.07)	145(0.71)	0.29
4	373	34(0.09)	339(0.91)	169(0.50)	170(0.50)	35(0.21)	18(0.11)	117(0.69)	0.31
5	258	32(0.12)	226(0.88)	111(0.49)	115(0.51)	30(0.26)	9(0.08)	76(0.66)	0.29
6	169	17(0.10)	152(0.90)	75(0.49)	77(0.51)	10(0.13)	6(0.08)	61(0.79)	0.36
7	113	13(0.12)	100(0.88)	49(0.49)	51(0.51)	14(0.27)	3(0.06)	34(0.67)	0.30
8	66	7(0.11)	59(0.89)	36(0.61)	23(0.39)	2(0.09)	2(0.09)	19(0.83)	0.29
9	42	5(0.12)	37(0.88)	22(0.56)	17(0.44)	5(0.29)	0(0.00)	12(0.71)	0.29
10+	20	0(0.00)	20(1.00)	8(0.40)	12(0.60)	3(0.25)	0(0.00)	9(0.75)	0.45

*= (P ≤0.05); ***= (P ≤0.01); NS=not significant
Figures in parentheses are proportions.

Table 24. Average replacement rate and its components during different years at Holeta Bull Dam Station

Calving Year	Total Pregnancy	Abnormal births	Normal births	Male Calves	Total female calves	Female calves Died	Female calves culled	Proportion of female calves retained from	
								Female births	Total pregnancy
1979	11	0 (0.0)	11 (100)	4 (36.4)	7(63.6)	0 (0.0)	0(0.0)	1.00	0.64
1980	20	2 (10)	18 (90)	12 (66.7)	6(33.3)	0 (0.0)	0(0.0)	1.00	0.30
1981	39	2 (5.1)	37 (94.9)	22 (59.5)	15(40.5)	0 (0.0)	0(0.0)	1.00	0.38
1982	71	6 (8.5)	65 (91.5)	39 (60.0)	26 (40.0)	0(0.0)	0(0.0)	1.00	0.37
1983	89	11(12.4)	78 (87.6)	42 (53.9)	36 (46.1)	0(0.0)	0(0.0)	1.00	0.40
1984	52	8 (16.4)	44 (83.6)	21 (47.7)	23 (52.3)	0(0.0)	0(0.0)	1.00	0.44
1985	39	7 (18.9)	32 (81.1)	12 (37.5)	20 (62.5)	0(0.0)	0(0.0)	1.00	0.51
1986	117	10 (8.6)	107(91.4)	48 (44.9)	59 (55.1)	7 (11.9)	0(0.0)	0.88	0.44
1987	193	28 (14.5)	165 (85.5)	84 (50.9)	81 (49.1)	12(14.8)	3 (3.7)	0.81	0.34
1988	123	8 (6.5)	115 (93.5)	62 (53.9)	53 (46.1)	13(24.5)	2 (3.7)	0.72	0.31
1989	143	19 (13.3)	124 (86.7)	69 (55.6)	55 (44.4)	4 (7.3)	1 (1.8)	0.91	0.35
1990	159	14 (8.8)	145 (91.2)	81 (55.9)	64 (44.1)	22(34.4)	2 (3.1)	0.63	0.25
1991	177	19 (10.7)	158 (89.3)	78 (49.4)	80 (50.6)	17(21.3)	18(22.5)	0.56	0.25
1992	157	9 (5.7)	148 (94.3)	75 (50.7)	73 (49.3)	21(28.8)	14(19.2)	0.52	0.24
1993	200	19 (9.5)	181 (90.5)	100(55.3)	81 (44.7)	15(18.5)	10(12.3)	0.69	0.28
1994	190	40 (21.1)	151 (78.9)	76 (50.3)	75 (49.7)	17(22.7)	8(10.7)	0.67	0.26
1995	214	25 (11.7)	189 (88.3)	113(59.8)	76 (40.2)	15(19.7)	10(13.2)	0.67	0.24
1996	193	31 (16.1)	162 (83.9)	83 (51.2)	79 (48.8)	26(32.9)	5 (6.3)	0.61	0.25
1997	175	20 (11.4)	155 (88.6)	80 (51.6)	75 (48.4)	20(26.7)	8 (10.7)	0.63	0.27
1998	147	17 (11.6)	130 (88.4)	65 (50.0)	65 (50.0)	29(44.6)	6 (9.2)	0.46	0.20
1999	162	20 (12.4)	142 (87.6)	74 (52.1)	68 (47.9)	33(48.5)	1(1.5)	0.50	0.21
2000	175	25(14.3)	150 (85.7)	76 (50.6)	74 (49.4)	36(47.4)	2 (2.70	0.49	0.21
2001	86	4 (4.7)	82 (95.3)	38 (46.3)	44 (53.7)	14(31.8)	0 (0.0)	0.68	0.35
2002	77	9 (11.7)	68 (88.30	41 (60.3)	27 (39.7)	2 (7.4)	0(0.0)	0.93	0.32
2003	84	9 (10.7)	75 (89.3)	40 (53.3)	35 (46.7)	0 (0.0)	0 (0.0	1.00	0.42

Table 25. Analyses of variance for the effect of non-genetic factors on replacement rate and its components at Holeta Bull Dam Station

		Mean squares						
							Proportion of female calves retained from	
Source	df	Abnormal births	Normal births	Female claves births (sex ratio)	Female calves died	Female calves culled	Female births	Total Pregnancy
Parity	9	0.2017*	0.2186*	0.8745***	0.4043*	0.0322^{NS}	0.2782***	0.1800^{NS}
Calving season	2	0.1489^{NS}	0.1446^{NS}	0.0582^{NS}	0.0264^{NS}	0.0327^{NS}	0.0304^{NS}	0.1567^{NS}
Calving year	24	0.1076*	0.1027*	0.2542***	0.8216	0.2116***	1.1698***	0.3398*
Error	364	0.0583	0.05812	0.1006	0.1728	0.0677	0.2006	0.2006

*=P ≤0.05; **=P ≤0.01; ***=P ≤0.0001; NS= not significant

The highest difference in sex ratios of male and female calves among the normal calves born was found in caving during short rainy season (54% males: 46% females) followed by long rainy season (53% males: 47% females) and dry season (51% male: 49% females) but analysis of variance showed the season differences within a males or female groups to be non significant. The sex ratio (male birth) was found highest (66.7%) among the normal calves born during the year 1980 and lowest (36.45) in the year 1979. The analysis of variance (Table 25) showed that effect of year on sex ratios were significant ($P \leq 0.01$).

4.3.3. Mortality in female calves from birth to age at first calving

The average mortality rate from birth to age at first calving among the Holstein Friesian female calves born was found to be 23% percent at Holeta farm (Table 23). The mortality of female calves in dam's parity order ranged from 9% in 8th parity to 29% in 9th parity though mortality in dam's first 5 parities ranged between 21 % in 4th parity to 27% in 1st parity. The analysis of variance (Table 25) indicated that parity effects on female calf mortality from birth to age at first calving were significant ($P \leq 0.05$).

The highest average mortality in female calves from birth to age at first calving was observed in during the dry season (24%) followed by long (23%) and rainy (22%) seasons, respectively (Table 23) but these season effects on mortality rates in female calves during different seasons were non significant (Table 25). The average mortality rate in female calves during first 7 years (from 1979 to 1985) and last year (2003) was zero (Table 23). However, during years from 1986 to year 2002 mortality ranged from lowest (7.3%) in the year 1989 to highest (48.5%) in the year 1999. The year effects (Table 25) on mortality of female calves were found to be significant ($P \leq 0.05$).

4.3.4. Culling of female calves from birth to age at first calving

The heifer's culling rates according to dam's parity order ranged from 0% in parity 9th and 10th to 11% in parity 4th (Table 23). However, these differences in culling rates due to dam's parity were non significant ($P \leq 0.05$) and there was no definite trend in culling rates among parity order (Table 23).

The culling rate in female calves during dry, short rainy and long rainy seasons were estimated as 6%, 7% and 8%, respectively (Table 23; P>0.05). There was no culling among heifers up to AFC during first 8 years (from 1979 to 1986) and last three years (from 2001 to 2003) of study period. The culling rate of heifers during rest of the years varied from lowest (1.5%) in the year 1999 to highest (22.5%) in the year 1991. The analysis of variance (Table 25) indicated that the effect of year of calving on culling of heifers was highly significant ($P \leq 0.001$).

4.3.5. Replacement rate on female calf's birth basis

The overall replacement rate on the basis of total female calves born was estimated to be 70% (Table 23) indicating that this proportion of the total female calves born reached to AFC and became the replacement to the older cows in the herd and the rest 30% were lost either due to death or culling from the herd.

The replacement rates on female calf born basis according to dams' parity order ranged from 66% in 5^{th} parity to 83% in 8^{th} parity (Table 23). Though there was no definite relationship between dam's parity and replacement rate but the observed differences in replacement rates between dam's parity were found to be highly significant ($P \leq 0.01$). The average replacement rates computed from female calves born during different seasons were estimated as 70%, 71% and 69% in dry, short and long rainy seasons of calving, respectively and these differences were non significant.

The average year effects on replacement rate on female calf's birth basis (Table 24) revealed that during first 7 year, (1979 to 1985) and during last year (2003), all female calves born (100%) survived to their AFC and became the replacement heifer in the herd. However, during other calving years from 1986 to 2002, the replacement rate on the basis of female calf's birth basis ranged from highest (0.93) in the year 2002 to lowest (0.49) in the year 2000. The analysis of variance (Table 25) revealed that the effect of year of calving on replacement rate on female calf's birth basis was highly significant ($P \leq 0.001$).

4.3.6. Replacement rate on total pregnancies basis

The overall replacement rate (Table 23) computed on the basis of total pregnancies in Holstein Friesian herd at Holeta farm was estimated as 29%. These observations indicated that about 3 to 4 pregnancies were required to produce one heifer replacement. The average replacement rate computed on total pregnancy basis among dam's parity order mostly ranged from lowest of 28 % in 1^{st} and 2^{nd} parity to 36% in 6^{th} parity, though it was highest (45%) in 10^{th} parity of lactation. However, these differences in replacement rates computed on the basis of total pregnancies were non-significant (Table 25).

The replacement rates computed on total pregnancies basis (Table 23) during different seasons did not vary much and season effects were be non significant (Table 25). The replacement rates during different years of study varied from highest (0.64) in the year 1979 to lowest (0.20) in the year 1998 (Table 24). The analysis of variance indicated that effect of year of calving on replacement rate computed on total pregnancy basis was significant ($P \leq 0.05$).

Table 26. Sire wise distribution of different types of birth, mortality, culling and female calves reached to AFC at Holeta Bull Dam Station

			Type of birth				Sex ratio				Female calves				Female calves reached to AFC		CGR (n)	
SN	Sire ID	Total (N)	Abn (n)	%	Normal (n)	%	Male (n)	%	Female (n)	%	Died (n)	%	Culled (n)	%		%		%
		2983	364	12.2	2623	87.8	1400	53.4	1223	46.6	284	23.2	111	9.1	828	67.7	414	13.9
1	711225	1	0	0.0	1	100.0	0	0.0	1	100.0	0	0.0	0	0.0	1	100.0	0.5	50.0
2	734534	1	0	0.0	1	100.0	0	0.0	1	100.0	0	0.0	0	0.0	1	100.0	0.5	50.0
3	734537	5	0	0.0	5	100.0	5	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
4	741765	8	1	12.5	7	87.5	0	0.0	7	100.0	0	0.0	0	0.0	7	100.0	3.5	43.8
5	751247	43	3	7.0	40	93.0	24	60.0	16	40.0	0	0.0	0	0.0	16	100.0	8	18.6
6	752081	26	2	7.7	24	92.3	12	50.0	12	50.0	0	0.0	0	0.0	12	100.0	6	23.1
7	752795	4	0	0.0	4	100.0	2	50.0	2	50.0	0	0.0	0	0.0	2	100.0	1	25.0
9	758923	1	0	0.0	1	100.0	1	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
10	761351	9	3	33.3	6	66.7	0	0.0	6	100.0	0	0.0	3	50.0	3	50.0	1.5	16.7
11	761513	11	0	0.0	11	100.0	7	63.6	4	36.4	0	0.0	0	0.0	4	100.0	2	18.2
12	762872	10	2	20.0	8	80.0	4	50.0	4	50.0	0	0.0	0	0.0	4	100.0	2	20.0
13	764591	17	1	5.9	16	94.1	12	75.0	4	25.0	0	0.0	0	0.0	4	100.0	2	11.8
14	773841	3	0	0.0	3	100.0	2	66.7	1	33.3	0	0.0	0	0.0	1	100.0	0.5	16.7
15	774921	2	0	0.0	2	100.0	2	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
16	781628	3	1	33.3	2	66.7	1	50.0	1	50.0	0	0.0	0	0.0	1	100.0	0.5	16.7
17	791191	20	3	15.0	17	85.0	10	58.8	7	41.2	0	0.0	0	0.0	7	100.0	3.5	17.5
18	792176	4	0	0.0	4	100.0	0	0.0	4	100.0	0	0.0	0	0.0	4	100.0	2	50.0
19	792179	4	0	0.0	4	100.0	2	50.0	2	50.0	0	0.0	0	0.0	2	100.0	1	25.0
20	792181	2	0	0.0	2	100.0	2	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
21	792186	2	1	50.0	1	50.0	1	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
22	792189	3	0	0.0	3	100.0	2	66.7	1	33.3	0	0.0	0	0.0	1	100.0	0.5	16.7

Table 26.Sire wise distribution of different types of birth, mortality, culling and female calves reached to AFC at Holeta Bull Dam Station (contd.)

SN	Sire ID	Total (N)	Type of birth: Abn (n)	%	Normal (n)	%	Sex ratio: Male (n)	%	Female (n)	%	Female calves: Died (n)	%	Culled (n)	%	Female calves reached to AFC	%	CGR (n)	%
23	801363	5	2	40.0	3	60.0	3	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
24	801367	2	1	50.0	1	50.0	1	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
25	801851	5	1	20.0	4	80.0	2	50.0	2	50.0	0	0.0	0	0.0	2	100.0	1	20.0
26	801866	2	0	0.0	2	100.0	2	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
27	810493	6	0	0.0	6	100.0	0	0.0	6	100.0	0	0.0	0	0.0	6	100.0	3	50.0
28	810882	5	0	0.0	5	100.0	2	40.0	3	60.0	0	0.0	0	0.0	3	100.0	1.5	30.0
29	811741	17	3	17.6	14	82.4	8	57.1	6	42.9	0	0.0	0	0.0	6	100.0	3	17.6
30	812532	4	0	0.0	4	100.0	1	25.0	3	75.0	0	0.0	0	0.0	3	100.0	1.5	37.5
31	813425	2	0	0.0	2	100.0	1	50.0	1	50.0	0	0.0	0	0.0	1	100.0	0.5	25.0
32	813428	3	1	33.3	2	66.7	1	50.0	1	50.0	0	0.0	0	0.0	1	100.0	0.5	16.7
33	813433	3	1	33.3	2	66.7	1	50.0	1	50.0	0	0.0	0	0.0	1	100.0	0.5	16.7
34	813436	11	3	27.3	8	72.7	4	50.0	4	50.0	0	0.0	0	0.0	4	100.0	2	18.2
35	813439	5	1	20.0	4	80.0	4	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
36	813446	2	0	0.0	2	100.0	1	50.0	1	50.0	0	0.0	0	0.0	1	100.0	0.5	25.0
37	813449	2	0	0.0	2	100.0	1	50.0	1	50.0	0	0.0	0	0.0	1	100.0	0.5	25.0
38	813451	2	0	0.0	2	100.0	1	50.0	1	50.0	0	0.0	0	0.0	1	100.0	0.5	25.0
39	813457	2	0	0.0	2	100.0	0	0.0	2	100.0	0	0.0	0	0.0	2	100.0	1	50.0
40	820521	3	0	0.0	3	100.0	1	33.3	2	66.7	0	0.0	0	0.0	2	100.0	1	33.3
41	821563	9	1	11.1	8	88.9	6	75.0	2	25.0	0	0.0	0	0.0	2	100.0	1	11.1
42	825083	16	4	25.0	12	75.0	5	41.7	7	58.3	0	0.0	0	0.0	7	100.0	3.5	21.9
43	826712	107	21	19.6	86	80.4	48	55.8	38	44.2	12	31.6	14	36.8	12	31.6	6	5.6
44	826715	3	1	33.3	2	66.7	1	50.0	1	50.0	0	0.0	0	0.0	1	100.0	0.5	16.7

Table 26. Sire wise distribution of different types of birth, mortality, culling and female calves reached to AFC at Hleta Bull Dam Station (contd.)

			Type of birth				Sex ratio				Female calves				Female calves reached to AFC		CGR (n)	
SN	Sire ID	Total (N)	Abn (n)	%	Normal (n)	%	Male (n)	%	Female (n)	%	Died (n)	%	Culled (n)	%				%
45	826717	2	0	0.0	2	100.0	2	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
46	830123	2	0	0.0	2	100.0	0	0.0	2	100.0	0	0.0	0	0.0	2	100.0	1	50.0
47	831451	26	4	15.4	22	84.6	8	36.4	14	63.6	0	0.0	0	0.0	14	100.0	7	26.9
48	831453	3	0	0.0	3	100.0	1	33.3	2	66.7	0	0.0	0	0.0	2	100.0	1	33.3
49	832199	8	1	12.5	7	87.5	3	42.9	4	57.1	2	50.0	1	25.0	1	25.0	0.5	6.3
50	832201	5	1	20.0	4	80.0	2	50.0	2	50.0	0	0.0	0	0.0	2	100.0	1	20.0
51	832203	1	0	0.0	1	100.0	0	0.0	1	100.0	0	0.0	0	0.0	1	100.0	0.5	50.0
52	832207	3	0	0.0	3	100.0	1	33.3	2	66.7	0	0.0	0	0.0	2	100.0	1	33.3
53	832231	2	0	0.0	2	100.0	0	0.0	2	100.0	0	0.0	0	0.0	2	100.0	1	50.0
54	841843	135	13	9.6	122	90.4	68	55.7	54	44.3	12	22.2	5	9.3	37	68.5	18.5	13.7
55	842671	3	1	33.3	2	66.7	1	50.0	1	50.0	0	0.0	0	0.0	1	100.0	0.5	16.7
56	842682	12	1	8.3	11	91.7	3	27.3	8	72.7	1	12.5	0	0.0	7	87.5	3.5	29.2
57	847391	109	12	11.0	97	89.0	51	52.6	46	47.4	5	10.9	0	0.0	41	89.1	20.5	18.8
58	849131	9	1	11.1	8	88.9	5	62.5	3	37.5	1	33.3	0	0.0	2	66.7	1	11.1
59	849531	35	3	8.6	32	91.4	14	43.8	18	56.3	1	5.6	0	0.0	17	94.4	8.5	24.3
60	850991	109	20	18.3	89	81.7	41	46.1	48	53.9	12	25.0	17	35.4	19	39.6	9.5	8.7
61	851241	88	21	23.9	67	76.1	52	77.6	15	22.4	1	6.7	0	0.0	14	93.3	7	8.0
62	851531	8	0	0.0	8	100.0	4	50.0	4	50.0	3	75.0	0	0.0	1	25.0	0.5	6.3
63	852391	123	20	16.3	103	83.7	50	48.5	53	51.5	10	18.9	2	3.8	41	77.4	20.5	16.7
64	852448	18	1	5.6	17	94.4	7	41.2	10	58.8	2	20.0	0	0.0	8	80.0	4	22.2
65	852463	17	1	5.9	16	94.1	11	68.8	5	31.3	3	60.0	0	0.0	2	40.0	1	5.9
66	852731	12	2	16.7	10	83.3	4	40.0	6	60.0	1	16.7	0	0.0	5	83.3	2.5	20.8

Table 26. Sire wise distribution of different types of birth, mortality, culling and female calves reached to AFC at Holeta Bull Dam Station (contd.)

			Type of birth				Sex ratio				Female calves				Female calves reached to AFC		CGR (n)	
SN	Sire ID	Total (N)	Abn (n)	%	Normal (n)	%	Male (n)	%	Female (n)	%	Died (n)	%	Culled (n)	%		%		%
67	853281	19	1	5.3	18	94.7	17	94.4	1	5.6	1	100.0	0	0.0	0	0.0	0	0.0
68	853284	6	2	33.3	4	66.7	2	50.0	2	50.0	1	50.0	0	0.0	1	50.0	0.5	8.3
69	856173	9	1	11.1	8	88.9	4	50.0	4	50.0	0	0.0	0	0.0	4	100.0	2	22.2
70	856177	2	1	50.0	1	50.0	0	0.0	1	100.0	0	0.0	0	0.0	1	100.0	0.5	25.0
71	862191	1	0	0.0	1	100.0	0	0.0	1	100.0	0	0.0	0	0.0	1	100.0	0.5	50.0
72	867371	29	7	24.1	22	75.9	10	45.5	12	54.5	10	83.3	0	0.0	2	16.7	1	3.4
73	867591	64	13	20.3	51	79.7	26	51.0	25	49.0	5	20.0	2	8.0	18	72.0	9	14.1
74	869021	134	11	8.2	123	91.8	60	48.8	63	51.2	16	25.4	6	9.5	41	65.1	20.5	15.3
75	869042	16	4	25.0	12	75.0	8	66.7	4	33.3	1	25.0	0	0.0	3	75.0	1.5	9.4
76	873093	9	4	44.4	5	55.6	0	0.0	5	100.0	1	20.0	0	0.0	4	80.0	2	22.2
77	874127	9	4	44.4	5	55.6	4	80.0	1	20.0	0	0.0	0	0.0	1	100.0	0.5	5.6
78	874138	3	0	0.0	3	100.0	2	66.7	1	33.3	0	0.0	0	0.0	1	100.0	0.5	16.7
79	882431	78	12	15.4	66	84.6	39	59.1	27	40.9	6	22.2	1	3.7	20	74.1	10	12.8
80	882436	1	0	0.0	1	100.0	0	0.0	1	100.0	1	100.0	0	0.0	0	0.0	0	0.0
81	882438	2	0	0.0	2	100.0	1	50.0	1	50.0	1	100.0	0	0.0	0	0.0	0	0.0
82	882439	5	0	0.0	5	100.0	2	40.0	3	60.0	0	0.0	0	0.0	3	100.0	1.5	30.0
83	882442	2	0	0.0	2	100.0	1	50.0	1	50.0	0	0.0	0	0.0	1	100.0	0.5	25.0
84	890131	84	6	7.1	78	92.9	39	50.0	39	50.0	10	25.6	22	56.4	7	17.9	3.5	4.2
85	890137	3	0	0.0	3	100.0	2	66.7	1	33.3	0	0.0	0	0.0	1	100.0	0.5	16.7
86	903972	14	3	21.4	11	78.6	5	45.5	6	54.5	2	33.3	0	0.0	4	66.7	2	14.3
87	910205	17	1	5.9	16	94.1	7	43.8	9	56.3	1	11.1	6	66.7	2	22.2	1	5.9
88	923157	12	0	0.0	12	100.0	8	66.7	4	33.3	1	25.0	2	50.0	1	25.0	0.5	4.2

Table 26. Sire wise distribution of different types of birth, mortality, culling and female calves reached to AFC at Holeta Bull Dam Station (contd.)

			Type of birth				Sex ratio				Female calves				Female calves reached to AFC		CGR (n)	
SN	Sire ID	Total (N)	Abn (n)	%	Normal (n)	%	Male (n)	%	Female (n)	%	Died (n)	%	Culled (n)	%		%		%
89	923159	4	0	0.0	4	100.0	4	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
90	923167	3	0	0.0	3	100.0	2	66.7	1	33.3	0	0.0	0	0.0	1	100.0	0.5	16.7
91	923171	3	1	33.3	2	66.7	2	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
92	930061	14	2	14.3	12	85.7	8	66.7	4	33.3	0	0.0	0	0.0	4	100.0	2	14.3
93	930148	15	4	26.7	11	73.3	7	63.6	4	36.4	2	50.0	0	0.0	2	50.0	1	6.7
94	931013	209	15	7.2	194	92.8	102	52.6	92	47.4	19	20.7	11	12.0	62	67.4	31	14.8
95	931472	99	10	10.1	89	89.9	55	61.8	34	38.2	13	38.2	2	5.9	19	55.9	9.5	9.6
96	932051	251	26	10.4	225	89.6	131	58.2	94	41.8	24	25.5	9	9.6	61	64.9	30.5	12.2
97	932514	124	7	5.6	117	94.4	51	43.6	66	56.4	19	28.8	3	4.5	44	66.7	22	17.7
98	940181	26	5	19.2	21	80.8	11	52.4	10	47.6	3	30.0	1	10.0	6	60.0	3	11.5
99	952193	30	3	10.0	27	90.0	16	59.3	11	40.7	3	27.3	0	0.0	8	72.7	4	13.3
100	961113	14	3	21.4	11	78.6	7	63.6	4	36.4	3	75.0	0	0.0	1	25.0	0.5	3.6
101	962191	1	0	0.0	1	100.0	1	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
102	976543	30	3	10.0	27	90.0	17	63.0	10	37.0	0	0.0	0	0.0	10	100.0	5	16.7
103	976548	3	0	0.0	3	100.0	2	66.7	1	33.3	0	0.0	0	0.0	1	100.0	0.5	16.7
104	983875	9	0	0.0	9	100.0	6	66.7	3	33.3	1	33.3	0	0.0	2	66.7	1	11.1
105	986911	204	20	9.8	184	90.2	94	51.1	90	48.9	45	50.0	3	3.3	42	46.7	21	10.3
106	987948	16	0	0.0	16	100.0	9	56.3	7	43.8	1	14.3	0	0.0	6	85.7	3	18.8
107	987951	50	3	6.0	47	94.0	26	55.3	21	44.7	7	33.3	0	0.0	14	66.7	7	14.0
108	987955	22	2	9.1	20	90.9	11	55.0	9	45.0	0	0.0	0	0.0	9	100.0	4.5	20.5
109	987959	22	0	0.0	22	100.0	11	50.0	11	50.0	0	0.0	0	0.0	11	100.0	5.5	25.0
110	987961	3	1	33.3	2	66.7	1	50.0	1	50.0	0	0.0	0	0.0	1	100.0	0.5	16.7

Table 26. Sire wise distribution of different types of birth, mortality, culling and female calves reached to AFC at Holeta Bull Dam Station (contd.)

			Type of birth				Sex ratio				Female calves							
SN	Sire ID	Total (N)	Abn (n)	%	Normal (n)	%	Male (n)	%	Female (n)	%	Died (n)	%	Culled (n)	%	Female calves reached to AFC	%	CGR (n)	%
111	987967	4	1	25.0	3	75.0	2	66.7	1	33.3	0	0.0	0	0.0	1	100.0	0.5	12.5
112	990141	11	4	36.4	7	63.6	2	28.6	5	71.4	4	80.0	0	0.0	1	20.0	0.5	4.5
113	990546	8	0	0.0	8	100.0	2	25.0	6	75.0	0	0.0	1	16.7	5	83.3	2.5	31.3
114	990564	63	9	14.3	54	85.7	25	46.3	29	53.7	7	24.1	0	0.0	22	75.9	11	17.5
115	990571	39	5	12.8	34	87.2	17	50.0	17	50.0	3	17.6	0	0.0	14	82.4	7	17.9
116	990761	54	6	11.1	48	88.9	25	52.1	23	47.9	7	30.4	0	0.0	16	69.6	8	14.8
117	990766	2	0	0.0	2	100.0	2	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
118	990768	10	5	50.0	5	50.0	3	60.0	2	40.0	0	0.0	0	0.0	2	100.0	1	10.0

Table 27. Analysis of variance (mean squares) for the effect of sire of calf on different type of births mortality, culling and female calves reached to AFC at Holeta Bull Dam Station

Source	Abnormal	Normal	Sex ratio	Mortality	Culling	Reached to AFC	CGR
Sire	0.015367*	0.55688***	0.39211**	0.32040**	0.23733***	0.59647***	0.14906NS
	(117)	(117)	(117)	(117)	(117)	(117)	(117)
Error	0.10349	0.08861	0.24295	0.16547	0.06840	0.18418	0.23097
	(2888)	(2887)	(2526)	(1113)	(1113)	(1113)	(1113)

*P≤0.05; **P≤0.01; ***P≤0.001; NS=not significant
Numbers in parentheses are *df*

4.4. Sire Effect on Replacement Rate, Its Components and Selective Value

The overall and sire wise distribution of different type of births (abnormal vs. normal), sex ratio, mortality, culling and female calves reached to AFC (replacement rate) and CGR are given in Table 26 and their analysis of variance for sire effects are given in Table 27. Moreover, the source, birth date and disposal reasons of bulls are depicted in Appendix II.

4.4.1. Abnormal vs. normal birth

The overall average incidence of prenatal mortality due to abnormal births was estimated as 12.2% among 2983 pregnancies from 118 sires (Table 26). It was observed that out of 118 bulls used, there was no incidence of abnormal birth among the pregnancies from 47sires. However, pregnancies from 71 sires used for breeding resulted in to varying rates of abnormal births ranging from 5.3% (Sire no 67) to 50% (Sires no. 21, 24, 70 and 118), though the number of total births from these sires were small. The reverse was true for normal birth. Means under 47 sires there 100% normal birth while under 71 sires normal birth ranged from 94.7% (Sire 67) to 50% (Sires no. 21, 24, 70 and 118). The analysis of variance revealed that sire differences in prenatal mortality due abnormal birth vs. normal birth in Holstein Friesian cattle were statistically significant ($P \leq 0.001$).

4.4.2. Sex ratio

The overall average sex ratio was observed to be 52.5%. Chi-square test ($\chi^2_{c\ (1,\ 0.01)}$ =7.31), indicated that overall sex ratio was significantly higher (Table 23) from normal expectation. The sire wise sex ratios were observed to be ranging from 0% to 100%. Out of 118 Holstein Friesian sires used in the Holeta herd, 14 sires did not have any male progeny, while another 14 sires had 100% male progeny (Table 25). Analysis of variance (Table 27) showed that frequency of male birth among the progeny of different sires differed significantly ($P \leq 0.01$).

4.4.3. Mortality rate among female calves

The average mortality among female calves up to AFC was 23.2% (Table 26). The mortality rates among the female progenies of different sires ranged from 0% to 100%. There was no mortality from birth to AFC among the female progeny of 73 (61.8%) sires while there was 100 percent mortality in female progenies of sire no 67, 80, and 81. From the analysis of variance (Table 27), it was found that sire of calf had highly significant ($P \leq 0.01$) effect on mortality of female calves from birth to their AFC.

4.4.4. Culling of female calves

Table 26 indicated that there was no culling from birth to AFC among the progenies of 98 (83.1%) sires out of a total of 118 sires used. The overall culling rate was observed as 9.1%. The highest culling rate from birth to AFC was (66.7%) for sire no 87. From the analysis of variance (Table 27) it was found that sire of calf had highly significant effect on culling of female calf from birth up to their AFC.

4.4.5. Female reached to AFC

The overall replacement rate on female calf basis (proportion of females born reached to AFC) was observed to be 67.7% (Table 26). This indicated that to produce 12 daughters for progeny testing of bulls at least 18 daughters from each sire would be required. Sire wise replacement rate ranged from 0.0% to 100%. Out of 118 sires used to produce progeny, 17 sires did not have any replacement heifer while pregnancy from 57 sires 100 % daughters reached to AFC. Analysis of variance (Table 27) showed that sire differences for replacement rate on female calf basis were highly significant ($P \leq 0.01$).

4.4.6. Coefficient of gene replication

The overall value of coefficient of gene replication (CGR) was found to be 0.50 (50%) in Holstein Friesian herd (Table 26). This indicated that it was equal to one gene replication that could materially contribute again to the future generation. The

CGR value under different sires ranged from 0% to 50%. The CGR value of zero for a sire indicated that no daughter of such sire reached to AFC to become replacement heifer in the herd while CGR value of 50 percent indicated that a female calf born to a sire reached to AFC and became replacement heifer in the herd. The analysis of variance indicated that sire differences in CGR were non-significant (Table 27).

4.5. Distribution of Cows According to Daughters Reached to Milking Herd

The percent distribution of 902 cows for total abnormal births, normal birth, female calf birth, female calf loss and total female calves reached to milking herd under different life time calving (0 to 12 calving) were computed. The percent distribution of cows for life time calving (calf production) revealed that 30.8% of total cows calved only once and proportion of cows reduced under each calving as the number of calving increased and it was only 0.3% of the cows that calved 11 and 12 times in the Holstein Friesian herd at Holeta farm. About 65.3% of cows did not show any abnormality in calving or calved normal throughout their life time calf production, while 27.7% cows calved abnormally during their first calving, 5.3% of cows calved abnormal by their 2rd calving and it was only 11.3, 0.2, 0.1 and 0.1 percent in cows calved 3, 4, 5 and 6 times, respectively. There was no abnormal calving in cows calved more than 6 times.

Table 28 shows that 5.2% of total cows left the herd without any normal calving while 31.6 % cows calved normal once, 18.5% calved normal twice and 11.8, 9.9, 9.4, 5.4, 3.2, 2.8, 1.2, 0.9, 0.1 and 0.0% cows calved normal during 3, 4, 5, 6, 7, 8, 9, 10,11 and 12 times calving. Also, 27.3% of the cows left the herd without producing any female calf in the herd and 33.1% cow produced one female calf, The percentage of cows that produced 2, 3, 4, 5, 6 and 7 female calves in their herd life time were 20.1, 11.0, 5.8, 1.9, 0.5 and 0.4, respectively.

The distribution of cows according female calf loss under different calvings revealed that 69.2% of the cows in the herd did not loss any calf either due to mortality or culling from the herd while 25.1, 4.9, 0.9, 0.2% of the cows lost their 1, 2, 3, and 4 female calves from the herd during their herd life time calf production in Holeta farm.

Table 28. Percentage distribution of cows for life time calf production traits (n=902) at Holeta Bull Dam Station

Life time calf	Value of traits												
Production	0	1	2	3	4	5	6	7	8	9	10	11	12
Total births	-	30.8	18.0	13.0	11.2	8.6	6.7	4.5	4.0	1.6	1.0	0.3	0.3
		(278)	(162)	(117)	(101)	(78)	(60)	(41)	(36)	(14)	(9)	(3)	(3)
Abnormal	65.2	27.7	5.3	1.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
births	(588)	(250)	(48)	(12)	(2)	(1)	(1)	(0)	(0)	(0)	(0)	(0)	(0)
Normal births	5.2	31.6	18.5	11.8	9.9	9.4	5.4	3.2	2.8	1.2	0.9	0.1	0.0
	(47)	(285)	(167)	(106)	(89)	(85)	(49)	(29)	(25)	(11)	(8)	(1)	(0)
Female calf	27.3	33.1	20.1	11.0	5.8	1.9	0.5	0.4	0.0	0.0	0.0	0.0	0.0
birth	(246)	(299)	(181)	(99)	(52)	(17)	(4)	(3)	(1)	(0)	(0)	(0)	(0)
Female calf	69.2	25.1	4.9	0.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
loss	(624)	(226)	(44)	(8)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Female calf	45.7	28.4	16.1	6.5	2.4	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0
reached to milking herd	(412)	(256)	(145)	(59)	(22)	(5)	(2)	(1)	(0)	(0)	(0)	(0)	(0)

Figures in parenthesis are number of a given type of birth

Moreover, 45.7% of the cows left the herd without producing any replacement daughter and 28.4 percent cows left only one female replacement, while 16.1, 6.5, 2.4, 0.6, 0.2 and 0.1% of cows left 2, 3, 4, 5, 6, and 7 female replacements in the herd before they left the herd.

4.6. Selective Value and Its Components

The genetic contribution of an adult cow to the next generation in terms of the number of replacement heifers reaching the herd is termed as selective value. This depends upon the longevity in terms of the number of years from birth to the date of disposal of cow from the herd either due to death or culling, productive herd life (PHL) in terms of the number of years a cow stayed in the herd after its first calving, total number of calving, total normal calves born, total female calves born and survived up to the milking age. The average PHL, longevity, selective value, various components of selective value and coefficient of gene replication were computed and presented in Table 29 and their analysis of variance to study the significance of the effects of age groups, FLMY group, season of birth and year of birth on selective value and its components are given Table 30.

4.6.1. Longevity

The average longevity of Holstein Friesian cows at Holeta farm was measured as the time interval in years from date of birth to the date of disposal from the herd either due to culling or death was estimated to be 2864±63 days (7.85 years). The averages of longevity for various AFC groups of Holstein Friesian cows (Table 28) showed that cows with lowest AFC (≤886 days) had minimum longevity (1748±365days), while it was highest (4102±586days) in cows with AFC of 1821-1978 days. These differences in longevity were mainly due to the differences in AFC of cows. However, the longevity had no relation with AFC as analysis of variance showed non-significant effects of AFC on longevity.

Cows with ≤1500 kg FLMY had minimum longevity (2170±329days) while cows with ≥5456 kg FLMY had maximum longevity. Though, longevity had no definite relation with FLMY but analysis of variance showed that FLMY had highly significant effects on longevity in Holstein Friesian cows at Holeta farm. The average longevity in cows born during the dry, short rainy and long rainy seasons were 2847±97 days, 3008±115 days and 2795±110 days, respectively. Analysis of variance showed that effect of season effects on longevity of cows were statistically non-significant. The average longevity in different years (1976-98) ranged from a maximum 4508 days in cows born in 1976 to a minimum of 1156 days in cows born in the year 1998. Statistical analysis of variance showed that year effects on longevity of cows were highly significant ($P<0.001$).

4.6.2. Productive herd life (PHL)

Productive herd life was computed as the number of days from first calving to the date of disposal of cow from the herd. The average productive herd life of Holstein Friesian cows at Holeta farm was observed to be 1638±58 days. Average PHL for different age groups (Table 29) showed that Holstein Friesian cows with lowest AFC had lowest PHL (919±366 days). Statistical analysis of variance (Table 29) showed that AFC had significant (P=0.001) effect on PHL of cows.

The average PHL for different FLMY groups (Table 28) showed that shortest PHL (869±330 days) was estimated for the group of cows which had ≤1500 kg FLMY while cows which produced ≤5456 kg milk in their first lactation had longest PHL of 2484±325 days. Analysis of variance revealed that effect of FLMY on PHL were highly significant (P≤0.001). The average PHL for cows born in the dry, short rainy and long rainy seasons were estimated as 1624±98 days, 1758±12 days and 1571±11 days, respectively and was not statistically significant. Table 29 also revealed that cows born during early years had longer PHL than those born in later years. The average PHL was longest (3101 days) during the year 1976 which showed almost a continuous declining trend as the year of birth advanced and it was lowest (254 days) in the year 1997, though it was 300 days in the year 1998. The decreasing trend in PHL during later years could be perhaps due to changed policy for culling of older cows through early replacement by newly calved heifers. Statistically, year differences in PHL of Holstein Friesian cows at Holeta farm were highly significant (P≤0.001).

Table 29. Least squares means ±se of longevity (days), productive herd life (days), selective values and coefficient of gene replication at Holeta Bull Dam Station

Source	N	Longevity (days)	PHL (days)	Total calves born (TCP)	Female calves born	Selective Value	CGR
Overall	364	2864±63	1638±58	3.55±0.12	1.68±0.07	1.12±0.06	0.56±0.03
AFC group							
≤886	35	1748±365	919±366	2.40±0.87	1.27±0.59	0.68±0.52	0.34±0.026
887-1042	73	2246±514	1274±516	2.97±0.26	1.36±0.16	0.87±0.12	0.43±0.78
1043-1198	74	2851±514	1279±516	3.59±0.27	1.60±0.17	1.13±0.16	0.56±0.71
1199-1354	75	3239±518	1970±520	4.36±0.30	2.05±0.18	1.30±0.15	0.65±0.75
1355-1510	58	3400±522	1972±524	4.20±0.28	2.08±0.17	1.51±0.17	0.78±0.76
1511-1666	21	3092±534	1499±536	2.97±0.38	1.28±0.23	0.76±0.18	0.38±0.44
1667-1822	12	3523±557	1781±559	3.33±0.46	1.75±0.41	1.16±0.38	0.58±0.50
1821-1978	7	4102±586	2248±588	4.87±0.48	2.57±0.52	1.85±0.50	0.92±0.75
≥1979	9	3533±497	1385±498	2.33±1.18	1.22±0.80	1.00±0.70	0.50±0.35
FLMY group							
≤1500	47	2170±329	869±330	2.06±0.26	0.87±0.15	0.59±0.13	0.29±0.12
1501-2065	29	2530±335	1261±336	2.75±0.38	1.55±0.25	0.93±0.20	0.46±0.14
2066-2630	56	3019±319	1760 ±321	4.08±0.30	2.17±0.21	1.57±0.19	0.78±0.38
2631-3195	67	3115±319	1891±320	4.28±031	2.01±0.18	1.34±0.16	0.67±0.32
3196-3760	70	2941±320	1795±321	3.82±0.28	1.84±0.18	1.22±0.16	0.61±0.31
3761-4325	49	3049±324	1829±325	3.61±0.31	1.61±0.14	1.02±0.17	0.51±0.25
4326-4890	25	2844±b339	1602±340	3.24±0.33	1.44±0.21	0.84±0.17	0.42±0.09
4891-5455	14	2686±361	1498±362	3.21±0.45	1.14±0.37	0.78±0.30	0.39±0.07
≥5456	7	3833±396	2484±325	4.42±0.57	1.71±0.47	1.28±0.36	0.64±0.01
Birth season							
Dry	154	2847±97	1624±98	3.50±0.17	1.66±0.10	1.12±0.10	0.56±0.06
Short	87	3008±115	1758±115	3.90±0.25	1.78±0.15	1.19±0.15	0.59±0.08
Long	123	2795±110	1571±101	3.36±0.21	1.65±0.12	1.08±0.10	0.54±0.05

Table 29. Least squares means ±se of longevity (days), productive herd life (days), selective values and coefficient of gene replication at Holeta Bull Dam Station (contd.)

Source	N	Longevity (days)	PHL (days)	Normal calves born	Female calves born	Selective value	CGR
Birth year							
76	8	4508±207	3101±194	6.50±0.63	3.13±0.79	3.00±0.78	1.50±0.39
77	10	3990±213	2703±228	4.80±0.49	1.90±0.48	1.80±0.47	0.90±0.23
78	17	4070±218	2719±218	5.24±0.62	3.06±0.47	2.82±0.41	1.41±0.20
79	8	3708±269	2495±249	5.00±0.73	2.00±0.33	1.38±0.32	0.69±0.16
80	8	3520±345	1894±511	3.50±1.00	2.25±0.56	2.00±0.57	1.00±0.28
81	7	4003±442	2426±385	4.43±0.65	2.00±0.44	1.57±0.37	0.79±0.18
82	16	3373±232	1694±239	3.44±0.52	1.81±0.37	1.13±0.26	0.56±0.13
83	26	3491±185	2097±181	4.08±0.41	1.81±0.26	1.19±0.23	0.60±0.11
84	14	3919±347	2653±361	5.00±0.53	2.50±0.31	1.79±0.26	0.89±0.13
85	12	3468±339	2294±361	5.33±0.92	1.75±0.46	1.67±0.39	0.58±0.19
86	23	3355±197	1987±211	4.30±0.48	1.65±0.26	0.78±0.22	0.39±0.11
87	21	3655±213	2292±218	4.86±0.71	2.57±0.41	1.43±0.24	0.71±0.12
88	14	3606±235	2378±229	5.36±0.71	2.79±0.41	1.79±0.23	0.89±0.12
89	12	3429±221	2073±248	4.92±0.66	2.08±0.36	1.58±0.31	0.79±0.16
90	16	2742±168	1500±178	3.31±0.46	1.50±0.32	1.06±0.32	0.53±0.16
91	13	2315±248	1130±288	2.62±0.51	1.23±0.28	0.69±0.21	0.35±0.10
92	18	2412±149	1318±152	2.67±0.37	1.72±0.30	1.67±0.26	0.52±0.13
93	30	2257±110	1256±113	3.13±0.32	1.40±0.22	0.80±0.18	0.40±0.09
94	9	2247±134	1238±123	2.67±0.33	1.00±0.24	0.44±0.18	0.22±0.09
95	24	1813±70	736±72	2.04±0.21	1.13±0.20	0.42±0.15	0.21±0.07
96	19	1593±69	442±65	1.47±0.18	0.74±0.17	0.32±0.13	0.16±0.07
97	21	1252±29	254±27	1.14±0.09	0.48±0.13	0.14±0.09	0.07±0.04
98	18	1156±45	300±44	1.28±0.011	0.56±0.15	0.44±0.15	0.22±0.07

*=P≤0.05; **=P≤0.01; ***=P≤0.001 NS = not significant

Table 30. Variance analyses for the effect of non-genetic factors longevity, PHL, normal and female calves born, and selective values and CGR at Holeta Bull Dam Station

Source	df	Longevity	PHL	Normal calves born	Female calves born	Selective value	CGR
		Mean squares					
AFC group	8	390232^{NS}	1873603**	8.5507**	2.4870^{NS}	1.5697^{NS}	0.3924^{NS}
FLMY group	8	2690057***	2802634***	13.4647***	4.3929*	1.8868^{NS}	0.4717^{NS}
Season of birth	2	33438^{NS}	46601^{NS}	1.1477^{NS}	0.5632^{NS}	0.1810^{NS}	0.0453^{NS}
Year birth	22	875243***	8591290***	26.5091***	6.7032***	6.5488***	1.6372***
Error	321	554373	558095	3.1735	1.4761	1.1296	0.2823

df=degree of freedom; *=P<0.05; **=P<0.01; ***=P<0.0001; ^{NS}= not significant

4.6.3. Total normal calves born (TCP)

The average number of total calves born by each Holstein Friesian cow during its herd life at Holeta farm was estimated as 3.55±0.12 normal calves. Results in Table 29 showed that less number of total calves were produced by cows with very short AFC than those cows which had longer AFC. The average number of normal calves born in cows with lowest AFC (≤886days) was 2.40±0.87 which continuously increased up to 4.36±0.30 as AFC of cows increased to 1199-1354 days, which may be considered as optimum AFC in Holstein Friesian cows. After this average number of normal calves born decreased as per the increase in AFC of cows and reached to its lowest of 2.33±1 in cows with AFC of ≥1979 days. The highest number of normal calves born was 4.87±0.48 in cows in AFC group of 1821-1978 days. Average number of total calves born from each cow was 2.06±0.26 in the lowest FLMY group (≤1500 kg) which increased to 4.28±031 in medium producers group (2631-3195 kg) but again decreased to 3.21±0.45 in high producing group (4326-4890 kg). The effects of FLMY on total calves born in Holstein Friesian cows were found to be highly significant (P≤0.001).

The average number of total calves born by each Holstein Friesian cow during the dry, short rainy and long rainy seasons was estimated as 3.50±0.17, 3.90±0.25 and 3.36±0.21, the difference being non significant. The average number of total normal calves born from each cow born during different years, from 1976 to 1998, ranged from a maximum of 6.5 normal calves born in the year 1976 to a minimum of 1.28 normal calves born from cows that calved in the year 1998. Statistically the year differences in total normal calves born from each cow according to their year of birth were found to be highly significant (P≤0.001).

4.6.4. Total normal female calves born

The average number of normal female calves born from each Holstein Friesian cow during its herd life farm was estimated to be 1.68±0.07. Cows with the lowest AFC (≤886 days) produced the lowest number of 1.27±0.59 normal female calves during their herd life. The average normal female calves born per cow increased as the as AFC increased and reached to a maximum of 2.08±0.17 in AFC group of 1355-1510 days, as cows in these AFC groups also had higher PHL and hence produced more normal female calves. Average number of normal female calves born per cow in higher AFC groups was generally lower than in medium AFC groups except in cows of 1821-1978 days AFC. Analysis of variance revealed that effects of AFC on total normal female calves born from each Holstein Friesian cows were non significant.

Cows with FLMY of ≤1500 kg produced the lowest number of total normal female calves (0.87±0.15) while cows with FLMY of 2066-2630 kg produced highest number of total female calves (2.17±0.21). However, cows in higher FLMY groups produced lower number of total normal female calves and it was only 1.14±0.37 in cows with 4891-5455 kg FLMY. Statistically, the effect of FLMY on total normal female calves born were found to be significant (P≤0.001). The average number of total normal female calves born during dry, short rainy and long rainy season were 1.66±0.10, 1.78±0.15 and 1.65±0.12, respectively and the season differences for normal female calves born were non significant. The average total normal female calves born from each Holstein Friesian cow was highest (3.13) in year 1976 (1^{st} year) and thereafter it showed a decreasing trend in later years with a minimum (0.48) in the year 1997. However, this was completely in accordance of the observed PHL of cows in the herd. Analysis of variance showed that the effect of year on total normal female calves born was highly significant (P≤0.001).

4.6.5. Selective value

The average number of female calves reached to the milking herd from each cow was estimated to be 1.12±0.06. Cow in AFC groups of ≤886 and 887-1042 days did not replace herself in the herd. The selective values in cows in all other higher AFC groups were generally more than 1.0, except in cows in 1511-1666 days AFC group where selective value 0.76. Averages of selective value of different cow groups based on FLMY revealed that lowest producers in the herd (≤1500) left minimum replacement heifers (0.59±0.13) in the herd. The low selective value in cows in FLMY groups of 4326-4890 kg (0.84±0.17) and 4891-5455kg (0.78±0.30) could be due to their longer first lactation period and low PHL in the herd. However, effects of FLMY on selective value of Holstein Friesian cows were found to be non significant. The average selective value (number of female calves reached to the milking herd) from each Holstein Friesian cow at Holeta farm during dry, short rainy and long rainy seasons was estimated to be 1.12±0.10, 1.19±0.15 and 1.08±0.10, respectively, the difference being non significant.

It was observed that the cows in first year (1976) left highest number of replacement heifers (3.0) in the milking herd and there was a decreasing trend in selective value of cows in later years with lowest value (0.14) being in the year 1997. The effect of year on selective value was found to be highly significant (P≤0.001).

4.6.6. Coefficient of gene replication (CGR)

The average value of CGR was estimated as 0.56 ±0.03, in Holstein Friesian herd at Holeta farm. This indicated that there was more than one time gene replication from each cow to the future generations in the herd. The average CGR according to AFC groups revealed that CGR values in AFC group's ≤886, 887-1042 and 1511-1666 days were 0.34±0.026, 0.43±0.78 and 0.38±0.44, respectively. The highest CGR value

(0.92±0.75) was estimated for cows in 1821-1978 days AFC group. Statistically, effects of AFC on CGR were found to be non significant.

The average CGR values under different FLMY groups ranged from 0.29±0.12 in ≤1500 kg to 0.78±0.38 in 2066-2630 kg FLMY group. Statistically, the effect of FLMY on CGR was non significant. The average CGR of cows born during dry, short rainy and long rainy seasons were estimated as 0.56±0.06, 0.59±0.08 and 0.54±0.05, respectively. Analysis of variance showed that season effects on CGR were non-significant. Average CGR values estimated for Holstein Friesian cows grouped according to year of birth revealed that it was highest in the year 1976 (1.5) and thereafter there was a decreasing trend. Statistically, year effects on CGR values of were highly significant (P≤0.001).

4.7. Genetic Parameters

4.7.1. Heritability of threshold traits

The heritability estimates of replacement rate and its component traits are given in Table 31**.** The heritability estimates of abnormal birth, sex ratio and mortality were 0.16±0.009, 0.10 ±0.019 and 0.18 ±0.029, respectively. The highest heritability observed for threshold characters were 0.71±0.029 for culling and 0.66±0.029 for replacement rate from female calves born.

Table 31. Heritability of threshold traits in Holstein Friesian herd at Holeta Bull Dam Station

Trait	Heritability ± se
Abnormal births	0.16 ±0.009
Sex ratio	0.10 ±0.019
Mortality	0.18 ±0.029
Culling	0.71±0.029
Replacement rate from total pregnancy	0.0±0.0
Replacement rate from female calves born	0.66±0.029

4.7.2. Repeatability of threshold traits

Table 32 depicted the repeatability estimates of replacement rate and its component traits. The repeatability estimate of mortality and sex ratio observed were very low and ranged from 0.060±0.028 to 0.038±0.017, respectively. The repeatability of culling in female calves was 0.895±0.029 and showed that the frequency of culling was 89.5% in second female calves of the cows whose first female progenies (calves) were culled.

Table 32. Repeatability of threshold traits in Holstein Friesian herd at Holeta Bull Dam Station

Trait	Repeatability ±se
Abnormal births	0.964±0.012
Sex ratio	0.038±0.017
Mortality	0.060±0.028
Culling	0.0895±0.029
Replacement rate from total pregnancy	0.780±0.019
Replacement rate from female calves born	-0.240±0.022

4.7.3. Heritability estimates of lifetime traits

Table 33 shows the heritability estimates of longevity, PHL**,** total calves born, total normal calves born, total female calves born, CGR and selective value.

Table 33. Heritability of selective value and it's components in Holstein Friesian herd at Holeta Bull Dam Station

Trait	Heritability ± se
Longevity	0.31±0.085
Productive herd life (PHL)	0.32±0.088
Total calves born	0.11±0.018
Total normal calves born	0.12±0.018
Total female calves born	0.10±0.019
Coefficient of gene replication (CGR)	-0.08±0.029
Selective value	0.66±0.029

The heritability estimate of longevity and productive herd life were medium and estimated as 0.31±0.085 and 0.32±0.088, respectively. Low h^2 were observed for total calves born, total normal calves born and female calves born which were 0.11±0.018, 0.12±0.018 and 0.10±0.019, respectively. The heritability of CGR was small and negative (-0.08±0.029) presumably due to insufficient number of observation per sire to estimate presence of additive genetic variance for this trait. Whereas selective value had high estimate of 0.66±0.029

4.8. First Lactation Traits

4.8.1. General means for first lactation traits

The general means of various traits along with their standard deviation and coefficient of variation of Holstein Friesian cows at Holeta farm are presented in Table 34. The least squares means of AFC, FSP, FDP, FLP, 305 DMY, FLMY and FCI estimated from records of 433 Holstein Friesian cows were 1225±14.6 days, 256±7.3 days, 203±8.0 days, 327±4.6 days, 3084±47.6 kg, 3260±53.6 kg, and 523±7.0 days, respectively.

Table 34. General means, standard deviation (S.D.) and coefficient of variation (C.V.) of first lactation traits in Holstein Friesian at Holeta Bull Dam Station

Trait	N	Mean	S.D.	C.V. (%)
Age at first calving (days)	748	1211	312.6	25.8
Service period (days)	671	250	159.5	63.8
Dry period (days)	634	207	169.1	81.9
First lactation length (days)	809	299	108.8	36.4
305Day milk yield (kg)	743	3072	966.2	31.5
First lactation milk yield (kg)	794	3019	1255.7	41.6
First calving interval (days)	653	521	149.5	28.7

4.8.2. Non genetic factors affecting first lactation traits

The least squares means for age at first calving, first service period, first dry period, first lactation period, 305 day milk yield, first lactation milk yield and first calving interval along with least squares estimates of effects of year of calving and season of birth on these traits are given in Table 35 and their analysis of variance is given in Table 36.

The year wise least squares means of AFC ranged from the lowest (803±19.1 days) in the year 1999 to the highest (1688±89.2 days) in the year 1976. Generally the average AFC were higher during early years and showed reducing trend during later years. The analysis of variance showed that year differences in AFC were highly significant ($P \leq 0.001$). Season birth did not affect AFC.

First service period ranged from 155 days in the year 2000 to 389 days in the year 1984 and these year differences were found statistically significant ($P \leq 0.001$). The average FSP during the dry, short rainy and long rainy season were estimated as 253±10.0, 254±17.5 and 251±12.8 days, respectively. The season effects on FSP were non significant.

The average FDP in Holstein Friesian cattle at Holeta farm were ranged from shortest of 83±10.1 days in the year 1976 to the longest 288±45.8 days in the year 1995. These year differences in FDP were found statistically significant ($P \leq 0.001$). The average FDP during the dry, short rainy and long rainy season were estimated as 212±12.1, 175±16.8 and 198±14.0 days and the differences were statistically non significant.

The effect of year of birth on FDP was found statistically significant ($P \leq 0.05$) and the estimate during different years varied from shortest of 274±58.0 days in the year 1984 to longest of 408±41.7 days in the year 1976. The average FLP for the dry, short rainy and long rainy seasons of birth were estimated as 314±5.4 days, 346±11.5 days and 334±8.6 days, respectively and these estimates of FLP were significantly different from each other at ($P \leq 0.05$).

The averages of first lactation 305DMY ranged from the lowest of 2340±208.2kg in the year 1984 to the highest of 4710±245.3kg in the year 2000 (Table 35) and analysis of variance (Table 36) showed that observed year differences were statistically highly significant (P≤0.001). Analysis of variance revealed that season of birth differences were statistically non significant

The least squares means of FLMY during different years at Holeta farm ranged from a lowest of 2220±339.7kg in the year 1984 to a highest of 4794±249.3kg in the year 2000 (Table 35) and the observed year differences were highly significant (P≤0.001). The least squares means for dry, short rainy and long rainy seasons were estimated as 3214±77.0kg, 3491±110.5kg, and 3288±98.9kg, respectively. The effect of season on FLMY was non significant.

Table 35. Least squares mean ± se for the effect of birth of year and season on first lactation traits at Holeta Bull Dam Station

Source	N	AFC (days)	FSP (days)	FDP (days)	FLP (days)	305DMY (kg)	FLMY (kg)	FCI n	FCI (days)
Overall	433	1225±14.6	256±7.3	203±8.0	327±4.6	3084±47.6	3260±53.6	397	523±7.0
Year of birth									
1976	4	1688±89.2	210±51.1	83±10.1	408±41.7	3320±403.1	3873±504.6	4	492±51.1
1977	13	1402±77.8	232±18.0	240±63.8	351±22.6	2633±213.9	2812±257.2	13	531±20.7
1978	25	1295±50.0	258±31.0	137±23.3	387±24.5	2885±158.2	3306±173.5	23	527±29.2
1979	8	1180±68.0	323±85.3	250±84.1	352±36.2	2757±150.9	2902±276.1	8	548±41.9
1980	11	1281±133.6	286±82.9	164±72.5	398±48.6	2944±258.4	3377±322.1	11	518±55.4
1981	12	1585±182.6	181±32.1	115±28.9	331±27.2	2520±135.1	2925±274.7	10	483±34.8
1982	26	1677±49.7	322±37.3	235±39.9	364±19.9	2428±149.0	2941±211.6	24	581±37.8
1983	17	1403±42.1	283±41.7	136±29.4	345±24.3	2813±225.1	3489±298.5	10	460±37.5
1984	9	1257±83.9	389±65.6	393±89.2	274±58.0	2340±208.2	2220±339.7	9	665±65.5
1985	12	1202±50.9	300±43.0	221±57.1	356±32.0	2927±245.2	3339±343.4	12	576±41.9
1986	32	1357±38.5	320±22.9	253±32.8	335±22.6	2568±131.5	2811±217.5	31	596±23.6
1987	29	1342±34.7	247±21.9	176±29.4	351±19.9	2779±11.7	3126±184.9	24	523±27.2
1988	23	1317±55.7	265±29.9	238±28.3	318±26.4	3049±252.6	3137±270.4	21	542±33.3
1989	16	1328±39.1	226±24.7	189±27.8	306±7.8	3424±295.6	3426±312.8	13	510±26.0
1990	23	1223±25.5	226±22.8	190±22.1	308±4.2	3662±150.0	3623±156.7	20	486±22.2
1991	9	1161±70.3	205±61.0	150±39.3	296±25.	3661±327.1	3648±399.4	8	453±32.7
1992	18	1081±23.9	176±25.2	143±23.0	305±5.1	3783±259.0	3766±237.6	18	452±25.0
1993	33	1005±28.1	235±18.0	191±19.1	318±4.0	3916±123.0	3938±134.1	32	512±19.1
1994	19	1008±35.3	194±21.5	163±31.3	317±23.4	3083±205.0	3231±283.2	18	487±29.4
1995	27	1093±31.4	340±36.2	288±45.8	312±18.0	2498±159.3	2617±204.5	24	590±34.5
1996	23	1154±37.3	219±31.2	177±29.5	313±4.1	3176±167.4	3221±157.5	21	487±32.3
1997	10	1012±35.3	222±37.9	187±36.7	315±16.9	3508±165.4	3569±214.1	9	503±40.7
1998	10	878±24.1	309±53.9	263±84.8	317±39.2	2921±360.5	2995±476.7	9	524±30.0
1999	15	803±19.1	203±30.1	179±29.0	301±2.8	4229±258.3	4184±267.5	14	466±25.9
2000	9	806±12.3	155±21.8	117±17.8cd	312±11.0	4710±245.3	4794±249.3	9	430±23.3

Table 35. Least squares mean ± se for the effect of birth of year and season on first lactation traits at Holeta Bull Dam Station (contd.)

Source	N	AFC (days)	FSP (days)	FDP (days)	FLP (days)	305DMY (kg)	FLMY (kg)	n	FCI (days)
Season of birth									
Dry	189	1212±21.5	253±10.0	212±12.1	314±5.4	3096±66.5	3214±77.0	170	513±9.2
Short	94	1232±29.2	254±17.5	175±16.8	346±11.5	3235±91.4	3491±110.5	86	522±16.9
Long	150	1221±26.6	251±12.8	198±14.0	334±8.6	3093±92.8	3288±98.9	141	519±12.4

Table 36. Least squares analysis of variance for first lactation traits at Holeta Bull Dam Station

		Mean squares							
Source	df	AFC	FSP	FDP	FLP	305DMY	FLMY	Df	FCI
Yearof birth	26	811846***	50267***	54251**	13980*	5612532***	4048041***	26	39793***
Season of birth	2	11688NS	284NS	38246NS	33940*	673116NS	2237303NS	2	2662NS
Error	406	49829	21307	26394	8612	709554	1080254	370	17851

df= degree of freedom; *=P<0.05; **=P<0.01; ***=P<0.001; NS = not significant

Year of calving affected FCI (P≤0.001) and the means varied from a shortest of 430±23.3 days in the year 2000 to longest of 665±65.5days. The least squares means of FCI of Holstein Friesian cows calved during the dry, short rainy and long rainy seasons were estimated as 513±9.2 days, 522±16.9 days and 519±12.4days, respectively. The differences being non- significant (Table 36).

4.8.3. Genetic parameters for first lactation trait

4.8.3.1. Heritability

Heritability estimates of age at first calving, first lactation milk yield, 305 day milk yield, first lactation period, first service period, first dry period, first calving interval are presented in Table 37. The heritability estimate for AFC was found to be 0.53±0.116. This heritability value was high and indicated sufficient additive genetic variance to alter the AFC through selection.

Table 37. Heritability of first lactation traits in Holstein Friesian cows at Holeta Bull Dam Station

Trait	Heritability ±se
Age at first calving	0.53±0.116
FLMY	0.23±0.102
305 DMY	0.23±0.106
First lactation period	0.28±0.124
First service period	0.26±0.113
First dry period	0.24±0.117
First calving interval	0.28±0.141

The heritability estimates for FLMY, 305DMY, FLP, FSP, FDP and FCI were medium in magnitude.

4.8.3.2. Correlations

The phenotypic, genetic and environmental correlation coefficients among first lactation traits in Holstein Friesian cattle were computed in all possible combinations using sire components of variance and covariance. The sire components of variance and covariance are presented in Table 38 and the phenotypic, genetic and environmental correlations are depicted in Table 39.

AFC with other traits

The phenotypic, genetic and environmental correlations of AFC with FLMY were 0.060±0.05, 0.234 ±0.26 and -0.036; and with 305DMY were 0.043±0.05, 0.191±0.26 and -0.039, respectively. These correlations indicated that higher AFC were related with higher FLMY and 305DMY.

Table 38. Genetic (above diagonal) and phenotypic (below diagonal) covariance of first lactation traits at Holeta Bull Dam Station

Trait	AFC	FLMY	305DMY	FLP	FSP	FDP	FCI
AFC	27684 (52662)	19603	13052	-68	- 1945	-2719	-1714
FLMY	14421	249812 (1106836)	165556	7900	-26013	-34769	-27353
305DMY	8441	829224	166730 (721193)	-4412	-25870	-21397	-22986
FLP	592	54804	17907	2503 (8980)	1691	-598	1030
FSP	241	-17564	-28556	2285	5755 (21969)	4438	5320
FDP	- 432	-71969	-44491	-6622	17644	6450 (27350)	5663
FCI	391	-7986	-20044	2580	18241	16380	5242 (18628)

Values on diagonal are genetic variances and with in parenthesis are phenotypic variances

Positive but very small in magnitude and non-significant phenotypic, genetic and environmental correlations of 0.027±0.05, 0.008 ±0.25and 0.058, respectivly were observed between AFC and FLP which indicate that though higher AFC were associated with longer FLP on phenotypic scale due to both genetic and environmental reasons.

The phenotypic, genetic and environmental correlations of AFC with FSP, were estimated as 0.007±0.05, -0.154±0.26, and 0.109, respectively (Table 39). The phenotypic, genetic and environmental correlations of AFC with FDP were -0.011±0.05, -0.203±0.27 and 0.100, respectively. These correlations revealed that higher AFC were related to shorter FDP essentially due to genetic reasons while on environmental scale higher AFC were associated with longer FDP in Holstein Friesian cows. The phenotypic, genetic and environmental correlations of AFC with FCI were 0.013±0.05, -0.142±0.27 and 0.115, respectively.

FLMY with other traits

The phenotypic, genetic and environmental correlations of FLMY with 305DMY were 0.900±0.02, 0.793±0.12 and 0.893, respectively which were all positive and highly significant indicating that higher FLMY were associated with higher 305DMY on phenotypic scale essentially due to both genetic and environmental reasons (Table 39). The correlations of FLMY with FLP were found to be all positive and highly significant indicating that higher FLMY were associated with longer lactation period and selection for higher FLMY will increase length of lactation period.

The correlations of FLMY with FSP and FDP were negative indicating that low FLMY was associated with high FSP and FDP. The phenotypic, genetic and environmental correlations between FLMY and FCI were -0.056±0.05, -0.724±0.33 and 0.018, respectively. The negative and significant phenotypic and genetic correlations indicated that higher FLMY were associated with shorter FCI, on phenotypic scale due to genetic reasons.

3005DMY with other traits

The phenotypic, genetic and environmental correlations of 305DMY with FLP were estimated as 0.229±0.05, -0.221±0.40 and 0.371 respectively. Phenotypic correlation was positive and significant and this relationship was due to environmental reasons as indicated by positive environmental and negative genetic correlations.

Table 39. Phenotypic (r_p), genetic (r_g) and environmental (r_e) correlations among first lactation traits at Holeta Bull Dam Station

Trait	Correlations	AFC	FLMY	305DMY	FLP	FSP	FDP
FLMY							
	$\mathbf{r_p}$	0.060±0.05					
	$\mathbf{r_g}$	0.234±0.26					
	$\mathbf{r_e}$	-0.036					
305DMY							
	$\mathbf{r_p}$	0.043±0.05	0.900±0.02				
	$\mathbf{r_g}$	0.191±0.26	0.793±0.12				
	$\mathbf{r_e}$	-0.039	0.893				
FLP							
	$\mathbf{r_p}$	0.027±0.05	0.545±0.04	0.229±0.05			
	$\mathbf{r_g}$	0.008±0.25	0.317±0.07	-0.221±0.40			
	$\mathbf{r_e}$	0.058	0.630	0.371			
FSP							
	$\mathbf{r_p}$	0.007±0.05	-0.113±0.05	-0.228±0.05	0.163±0.05		
	$\mathbf{r_g}$	-0.154±0.26	-0.692±0.31	-0.867±0.27	0.435±0.23		
	$\mathbf{r_e}$	0.109	-0.072	-0.028	0.059		
FDP							
	$\mathbf{r_p}$	-0.011±0.05	-0.414±0.04	-0.317±0.05	-0.423±0.04	0.719±0.03	
	$\mathbf{r_g}$	-0.203±0.27	-0.844±0.22	-0.656±0.28	-0.150±0.34	0.707±0.16	
	$\mathbf{r_e}$	0.100	-0.280	-0.213	-0.516	0.723	
FCI							
	$\mathbf{r_p}$	0.013±0.05	-0.056±0.05	-0.173±0.05	0.200±0.05	0.899±0.02	0.727±0.03
	$\mathbf{r_g}$	-0.142±0.27	-0.724±0.33	-0.781±0.31	0.285±0.34	0.986±0.04	0.936±0.12
	$\mathbf{r_e}$	0.115	0.018	0.034	0.166	0.868	0.653

The correlations of 305DMY with FSP and FDP were all negative and significant, indicating that higher 305DMY on phenotypic scale were associated with shorter FSP and FDP due to mainly genetic reasons. The phenotypic, genetic and environmental correlations between 305DMY and FDP were found as -0.317±0.05, -0.656±0.28 and -0.213, respectively, and all were negative and significant. These correlations indicated that higher 300DMY were associated with shorter FDP and any efforts made to reduce the FDP either on genetic or environmental scales will improve the 305DMY in the Holstein Friesian herd under study. The correlations of 305DMY with FCI were -0.173±0.05, -0.781±0.31 and 0.034 respectively which showed that on phenotypic and genetic scales higher 305DMY were associated with shorter FCI though reverse was true on environmental scale.

FLP with other traits

The phenotypic, genetic and environmental correlations of FLP with FSP were 0.163±0.05, 0.435±0.23 and 0.059 respectively indicating that Holstein Friesian cows with longer FSP have longer FLP due to both genetic and environmental reasons. The correlations of FLP with FDP were all negative and significant (Table 39). The genetic correlation was very small and non significant while the phenotypic, genetic and environmental correlations between FLP and FCI were 0.200±0.05, 0.285±0.34 and 0.166 respectively, which were all positive and highly significant, indicating that longer FCI were associated with longer FLP in Holstein Friesian cattle.

FSP with other traits

High and positive phenotypic, genetic and environmental correlations were observed between FSP and FDP, and FSP and FCI. These correlations indicated that longer FSP were associated with longer FDP and FCI and Holstein Friesian cows with longer FSP had longer FDP and FCI in the herd.

FDP with FCI

The phenotypic, genetic and environmental correlations between FDP and FCI were all positive and highly significant. These correlations indicated that longer FSP on phenotypic scale were associated with longer FCI due to both genetic and environmental reasons.

5. DISCUSSION

5.1. Lactation Specific Demographic Parameters

The probability of females being lost from herd was found as 0.2619 during the first lactation (Table 21) and this probability of depletion was almost same during 2^{nd}, and 3^{rd}, lactations but increased continuously from 4^{th} lactation (about $1/3^{rd}$) to 12^{th} lactation when almost $2/3^{rd}$ of the cows lost from the herd. Further, it was also observed that about 71% of the total cows in first lactation left the herd by the end of fourth lactation and only about 29% of the superior most cows remained in the herd after 4^{th} lactation to produce their progeny in the herd. These findings were in conformity with the reports of Nieuwhof *et al.* (1989), Gadzhiev *et al.* (1991), Tomar *et al.* (1994), Lathwal *et al.*(1995), Tomar *et al.*(1996), Kumar (1999) and Singh (2001) for various Zebu and crossbred cows.

The observed probability of lactation specific survival rate in Holstein Friesian was 0.7381 in first lactation which increased to a maximum of 0.7480 in third lactation and there after survival rate declined at an inconsistent rate till it reached to its lowest of 0.3333 in the 12^{th} lactation. These lactation specific survival rates indicated that cows had low survival likelihood after the 7^{th} lactation. These lactation specific survival rates were generally low, which could be due to stringent culling and high mortality rates. These results are supported by the observations of Berhanu *et al.* *(*2011), who has reported a culling of 603 cows due to various diseases in the same herd during the period of 1987 to 2008 (21 years). The survival rate (0.7381) for 1^{st} lactation is closer to the values reported by Lathwal *et al.* (1995) and Singh (2001) for Red Sindhi and Karan Fries cattle breeds, respectively. Tomar *et al.* (1994, 1996) and Kumar (1999) estimated 0.78, 0.78 and 0.79 survival rate at first lactation for Sahiwal, Tharparkar and Hariana, respectively. Similarly, Nieuwhof *et al.* (1989) studied survival rate of exotic cows for eight consecutive lactations and reported 0.78 for 2^{nd} lactation and the rate declined to 0.27,0.17 and 0.10 units for 5^{th}, 6^{th} and 7^{th} lactations, respectively concluding that pure breeds exhibit lower survival rate. Arthur *et al.* (1995) studied age specific parameters of purebred Hereford and beef synthetic (composite of Charolais, Angus, and Gallowey). They reported that the survival rate was similar for the pure breed and synthetic composite at ages 1 and 2 and P_x for pure breed Hereford declined at a higher rate. The differences in the observations of various workers could be due to the differences in death and culling rates at different farms because of difference in management practices.

Stayability (L_x) of Holstein Friesian cows in the Holeta herd was maximum (0.7373) in first lactation, indicating that 73.73% of the total cows were likely to stay in the herd after completion of their first lactation. The probability of staying in the herd continuously decreased in order of increased lactation number. The probability of a cow surviving in the herd up to the completion of 12^{th} lactations was 0.0011, which means only 0.11% cows survived or were retained in the herd at the end of 12^{th} lactation. Stayability of cows at Holeta farm (Table 21) in the present study was lower than that reported by Kumar (1999) for Hariana cattle (0.79). A stayability of 1.0 was reported by Tomar *et al.*(1994), Lathwal *et al.*(1995) and Tomar *et al.*(1996) for Sahiwal, Red Sindhi and Tharparkar breeds in first lactation, respectively. Moreover, Sharma and Singh (1974) in zebu cattle and Ochoa *et al*. (1991) in exotic cows estimated stayability of 0.94 and 0.88 at first lactation, respectively. Lower stayability of the Holeta herd could be attributed to high culling and death rate of cows. The loss rate (Q_x) was increased with the increased of lactation number.

The probability of lactation specific expected herd life of cows present in the herd at the first lactation was 2.46 lactations (Table 21). Thereafter, expected herd life of cows decreased to 1.7192 lactations for cows in second lactation and continued to decline with the increase in the lactation order till 12^{th} lactation at which it was 0.0011 lactations only indicating that cows at the end of the 12^{th} lactation had almost zero expected herd life. Expected herd life (E_x) is a function of survival rate at each lactation which in turn may be influenced by disease and feeding management condition of the farm. Expected herd life of 2.46 lactations at birth is comparable to the findings of Lathwal *et al.* (1995) and higher than the value for Karan Fries (Singh, 2001). Higher estimates of 2.72, 2.82 and 3.52 lactations of E_x than the present study were reported for Sahiwal (Tomar *et al.,* 1994), Tharparkar (Tomar *et al.,* 1996) and Hariana (Kumar, 1999) cattle, respectively. The pattern of declining of E_x with age is in agreement with the reports of Tomar *et al.* (1994, 1996) and Kumar (1999).

The estimates of lactation specific female birth rates (Table 21) revealed that the probability of producing a live female calf (M_x) by a cow at her first lactation was 0.4808 and ranged from 0.38 in 8th lactation to 0.60 in 11th lactation. The expected sex ratio of 50:50 was observed at the 4th, 5th and 12th calving (lactations). However, cows after the 9th lactation had relatively higher sex ratio. Studies indicated that sex ratio is affected by the type of services, place of deposition of semen, and time of insemination. Berry and Cromie (2006) studied the effect of AI (artificial insemination) and natural mating on sex ratio of Holstein Friesian, Simmental, Angus, Hereford, Charolais, Limousine, Belgian Blue and their composite. They reported that the odds of a male calf being born were high when the service sire was a beef than Holstein Friesian and AI increased the likelihood of male calf by 1.04 to 1.08 times.

Furthermore, Xu *et al.* (2000) reported that frozen semen resulted in 1.24-1.66% units more male. At Holeta farm, the AI service was based on frozen semen collected from imported Holstein Friesian bulls and young male calves selected from those bull calves born at the farm. This might affect the capacitating ability of X-chromosome bearing sperm cells. Moreover, the usual practice of deposition of semen was in the body of uterus and might favor male calf births. Zobel *et al.* (2011) investigated effects of different semen deposition sites on the sex ratio of Simmental cattle and concluded that intra cornual semen deposition resulted in a higher ratio of female calves whereas uterine body deposition site resulted in higher male calf ratio. The effect of AI timing was investigated by Orkun *et al.* (2007) considering standing to be mounted as the beginning of estrus. The authors found that insemination at interval of 6h, 9h, 12h and 15h after the onset of estrus in cows did not alter sex ratio. High female calve births at the older ages in the current study was different from the finding of Berry and Cromie (2006) who noted that the probability of a male calf being born was higher in older cows compared to younger cows. However, Yilmaz *et* *al.* (2010) reported that management, calving year/season, parity and sire had no effect on the sex ratio of the calves. Furthermore, Arhur *et al.*(1995) found that the mean M_x across all ages for pure and synthetic breed was 0.46 and 0.48, respectively and older crossbred cows had higher (0.56) sex ratio, confirming the present observation.

The lactation specific reproductive value (V_x) of cows at the 1st lactation was estimated as 1.0448 and all other lactations had less than one. The lowest V_x value (0.3828) was observed for 8th lactation indicating that older cows had lower reproductive value than that of replacement heifers and younger cows. Reproductive value is the function of current (female birth rate) and future female calve births. The reproductive value at first lactation for the current study is lower than earlier findings 1.86 (Tomar *et al.,* 1996), 2.27 (Kumar, 1999) and 1.46 (Singh, 2001), for Tharparkar, Hariana and Karan Fries cattle, respectively. Studies showed that older cows had a reproductive value of less than1.0 after 9th (Tomar *et al.,* 1996; Kumar, 1999; Singh, 2001) lactations. Arthur *et al*.(1995) reported that V_x at age of one year for pure bred and composite was 1.05 and 1.10 and after age three the value was less than 0.74 and 0.91, respectively indicating crossbred cows had higher reproductive value. The net reproductive rate was 1.78 for Sahiwal (Tomar *et al.,* 1994), 1.60 for Red Sindhi (Lathwal *et al.,* 1995), 1.79 for Tharparkar (Tomar *et al.,* 1996), 2.27 for Hariana (Kumar, 1999), 1.06 for Karan Fries (Singh, 2001). These indicate that Holstein Friesian at Holeta station produced less female calves per cow than Sahiwal, Red Sindhi, Tharparkar and Hariana cattle breeds.

5.2. Life Time Demographic Parameters

The cows present in the herd on average had 3.50 lactations. The mean was comparable with that reported by Tomar *et al.* (1994) for Sahiwal. However, the present average was higher than those reported by Lathwal *et al*. (1995) in Red Sindhi, and Singh (2001) in Karan Fries but lower than the reports of Tomar *et al.* (1996) in Tharparkar and Kumar (1999) Hariana and Kumar (2003) in Frieswal breeds.

The cows lost from the herd on average completed on an average 4.3548 lactations in the herd, indicating that most of the cows were replaced at a higher age after completion of four lactations in the Holeta herd. This average was very close to that reported by Kumar (1999) in Hariana cattle while it was higher than those reported by Tomar *et al.* (1994) in Sahiwal, Lathwal *et al*. (1995) in Red Sindhi, Tomar *et al.* (1996), Atrey, (2003) in Frieswal and Singh (2001) in Karan Fries breeds. The present higher average lactations of cows lost from the herd showed that cows in Holeta herd were comparatively older at the time of their replacement than other herds. The variations in observations of different workers could be due to the difference in availability of replacement heifers in different herds.

The average probability of a cow being lost from the herd was estimated as 0.3204 per lactation (Table 22). These results indicate that 32.04 % of the cows were being lost either due to death or culling from the herd per lactation. This mean rate of cow loss per lactation for Holeta herd was higher reflecting that cows were culled or died at a higher rate at each lactation. The present observed rate of cow loss per lactation was higher than that reported by Kumar (1999) for Haryana cattle herd (0.21 per lactation) but lower than that reported by Singh (2001) for Karan Fries cattle (0.46 per lactations) and Atrey (2003) for Frieswal cattle (0.52 per lactation).

The average life expectancy of cows at birth was found to be 1.2825 lactations. These results indicated that any female calf born will be expected to complete more than one lactations in the Holeta herd. Higher values of life expectancy at birth than the present study were reported by Tomar *et al.* (1994), Lathwal *et al.* (1995), Tomar *et al*. (1996), Kumar (1999), Singh (2001) and Atrey (2003) for various Zebu and crossbred cows.

The average net reproductive rate in the Holeta herd was observed as 1.4948, indicating that each cow produced on an average 1.4948 female calves and the herd size was increasing (Table 22). Higher net reproductive rate were reported by Tomar *et al.* (1994) for Sahiwal (1.78), Lathwal *et al.* (1995) for Red Sindhi (1.60), Tomar *et* *al*. (1996) for Tharparkar (1.79), Kumar (1999) for Hayana (2.27) and Singh (2001) for Karan Fries (1.64) while Atrey (2003) observed lower net reproductive rate (0.96) for Frieswal crossbred cows. However, the rate of replacement and increment were small as a result of high Q_x.

The average generation interval in Holstein Friesian herd was found to be 3.5451 years at Holeta farm (Table 22). This average GI was lower than those reported by Kumar (1999) for Hariana (3.99 years) and Danchin-Burge *et al.* (2012) for Holstein Friesian (5.6 years) but higher than the reports of Singh (2001) for Karan Fries (2.88 years) and Atrey (2003) for Frieswal (2.54 years) herds.

5.3. Replacement Rate and Its Components in Relation to Non Genetic Factors

5.3.1. Abnormal births

The overall average incidence of abnormal birth rates based on total pregnancy was observed as 12%, while 88% of births were normal in Holstein Friesian herd at Holeta farm (Table 23). This observed average rate of abnormal birth rate was higher and this could be associated to fertility problems and sire of the calf. Mekonnen *et al.* (1999) studied major health problems of 33 dairy herds in urban and peri-urban areas in Ethiopia. They reported that the prevalence rate of reproductive diseases (metritis, pyometra, vulvo-vaginitis, retained placenta, dystocia, vaginal prolapsed, abortion) was 11.0%. Moreover, Birhanu (2009) indicated that about 11.4% calf births were abnormal. Similar prenatal death rate was reported by Shukla *et al.*(1980) in Brown Swiss×Holstein crosses, Sharma and Jain (1983) in Red Sindhi, Singh *et al*. (2002) in Holstein×Sahiwal crosses, and Atrey *et al.* (2005) in Frieswal cattle. Lower incidence of abnormal birth rate of 5.4%, 3.1% and 6.0% were reported for Holstein crosses by Sharma and Jain (1984), Tomar and Verma (1988a) and Mehrotra and Dey (1998a), respectively.

The average prenatal calf losses due to abnormal births in Holstein Friesian cattle at Holeta farm were higher in the dry season than short and long rainy seasons but the differences were non-significant (Table 23). Non significant effect of season of calving on abnormal birth might be because of very low seasonal climatic variations in the area, Holeta farm is located. Similar findings were also reported for different crosses of Holstein with Sahiwal (Tomar *et al*., 1975), Gir (Shukla *et al*., 1980), Tharparkar (Tomar and Verma, 1988a, b) and HF cows (Birhanu, 2009). However, significant seasonal effect on abnormal births of exotic and crossbred cows were observed by Pandey and Desai (1973), Chatterjee *et al.* (1985) Kumar *et al.*(1995), Atrey (2003) and Banik and Nashkab (2006). The observed differences in the observations of different workers could be due to wide differences in seasonal climatic conditions of the locations where the different herds were located.

The analysis of variance (Table 23) revealed that parity of calving had significant effect ($P \leq 0.05$) on prenatal calf losses due to abnormal birth. These results were in conformity with those observed by Tomar *et al*. (1975) in Sahiwal, Chatterjee *et al*. (19985) in HF×Sahiwal, Kumar *et al*. (1995) in HF×Sahiwal, Singh and Jain (1997) in native and crossbreds, Maherotra and Dey (1998a) in exotic and crossbred cattle, Mukherjee and Tomar (2000) in Karan Swiss cattle and Singh *et al.* (2002) for Sahiwal and crossbreds, whereas, non-significant differences in abnormal births due to parity order have been observed by Shukla *et al.*(1980), Reddy and Sampath (1981), Tomar and Verma (1981), Sharma and Jain (1983, 1984), Tomar and Verma (1988), Ramalingham *et al.* (1990), Kumar (1999) and Singh (2001) in various Zebu and crossbred cattle. The highest incidences of prenatal calf losses (16%) due to abnormal births was in the first parity. This could be related to the immature and under developed reproductive system of younger cows by the time of their first calving, resulting in dystocia and prenatal death of calves considered as abnormal births. This observation agreed with Birhanu (2009), who reported higher abnormal births for 1st parity. Higher rate of abnormal birth rates from 2nd to 9th parity (9% to 13%) observed in the current study were also reported by Chatterjee *et al.* (1985) for Holstein × Sahiwal crosses, Singh and Jain (1997) for native and cross bred cattle and Singh *et al.* (2002) for Sahiwal and crossbred cattle. However, higher incidences of abnormal calvings in later lactations were reported by Mehrotra and Dey (1998a), Kumar *et al.* (1995) and Atrey *et al.* (2005). The prenatal calf loses due abnormal birth in Holstein Friesian cattle during the different years varied significantly ($P<0.05$) and ranged from 0% to 21.1% (Table 24). Similar results were observed by Kumar *et al.* (1995), Rawal and Tomar (1996 a, c), Mukherjee and Tomar (2000) and Singh (2001). Significant yearly variation in the Holeta herd could be associated to change in management and health care of lactating cows over the different years.

5.3.2. Sex ratio

The overall male sex ratio (52.53%) was significantly higher($\chi^2_{c\ (1,\ 0.01)}=7.31$) than the female sex ratio (47.47%) and male: female sex ratios among the normal born in Holstein Friesian cattle significantly deviated from the expected sex ratio of 50%. Similar findings were reported by Tomar and Singh (1973) in Brown Swiss×Hariana and Red Dane, Tomar *et al.* (1976) in Sahiwal, Mehrotra and Dey (1998a, b) in Holstein Friesian and Hosltein Friesian×Hariana, Atrey *et al.* (2005) in Frieswal and Banik and Nashkab (2006). However, Shahi and Kumar (2006) reported no significant difference of sex ratio from the expected frequency. Higher deviations of male calf births than the present study were reported for crosses of Indian cattle. Kaushik and Singhal (1982) and Tomar and Verma (1988a) observed 62.2% and 58.1% male calf births for Holstein Friesian× (Jersey×Hariana) and Holstein Friesian×Tharparkar, respectively and lower value of sex ratio than the present study were also reported by Singh and Balaine (1973) in Holstein Friesian ×Hariana, Tomar *et al* (1976) in Friesian×Sahiwal, Shukla and Parekh (1988) in Gir breed of Indian cattle. These differences in the observations of various workers could be due to sampling variations. However, though sex determination of a calf is purely based on chance factor, some environmental factors (like storage, body condition of the cow) could influence the capacity of being fertilized by X or Y chromosome carrying semen.

The analysis of variance (Table 25) revealed that season effects on male: female sex ratio was non-significant. Non significant seasonal effects were also reported by Shukla and Parekh (1988) in Gir, Patel *et al.* (1988) in F_1 and F_2 Jersey×Kankrej crossbred, and Tomar and Verma (1988b) in Friesian×Sahiwal crosses Mukherjee *et* *al.*(2000) in Hariana cattle and Singh (2001) and Atrey (2003). However, significant season effects were reported by Tomar and Arora (1970), Sethi and Rao (1981) and Tomar and Verma (1988a) for sex ratio in zebu and crossbred herds. The non significant effect of season on sex ratio indicated that the trait is not influenced by the seasonal environmental variations. Moreover, the sex ratio is mostly determined by chance factor.

The percentage of male births varied ($P \leq 0.01$) from 61% (Parity 8) to 40% (Parity 10) among different parity of lactations (Table 23 and 24). This finding was contrary to the reports of Sethi and Rao (1981) and Rawal and Tomar (1995) in Sahiwal cattle, Singh *et al.* (1983) and Shukla and Parekh (1988) for Gir cattle, Kale *et al.* (1982) and Lathwal *et al.* (1993) for Red Sindhi, Tomar and Arora (1970) and Kumar (1999) in Hariana cattle, Mukherjee *et al*. (2000), Singh (2001) and Atrey (2003) in Frieswal Cattle. The observed higher male calf ratios than the overall average sex ratio in the young (1^{st}, 2^{nd} and 3^{rd} parity) and older (8^{th} and 9^{th} parity) cows were in agreement with Tomar and Verma (1988a), as they also observed significantly higher male sex ratio in first and fifth parity of calving in Tharparkar cattle while Tomar and Verma (1988b) reported that male sex ratio was significantly lower in second and third parity in crossbred cows. Such differences in observations for a chance determined traits may be difficult to explain with valid and logical reasons unless active data such as body condition of the cow and insemination technique are collected.

The sex ratio (male birth) was found highest (66.7%) among the normal calves born during the year 1980 and lowest (36.4%) in the year 1979 (Table 6). The analysis of variance (Table 25) showed that year effects on sex ratios were statistically significant ($P \leq 0.01$). Similar significant year effects on sex ratio have been reported by Kumar *et al.* (1992) in HF×Sahiwal and Lathwal *et al*. (1993) in native and crossbred cattle. However, Singh *et al.* (1991), Mukherjee *et al.* (2000) in crossbred cows, while Singh (2001) in Karan fries observed non-significant year effects for sex ratio.

5.3.3. Average mortality in female calves from birth to age at first calving

The average mortality rate from birth to age at first calving among the Holstein Friesian female calves born was found to be 23% (Table 23). This rate of mortality was high and could be related to health problems and inadequate feeding management of heifer calves. Berhanu (2009) attributed mortality of calves at Holeta to poor housing hygiene, nutritional stress and deprivation of colostrums feeding of calves born from tuberculosis positive cows. Absence of mechanism for controlling sexually transmitted diseases could contribute to the incidence rate of mortality. Desalegne *et al.* (2009) reported that bulls were recruited in the absence of tests for bovine brucellosis, bovine tuberculosis, bovine viral diarrhea, infectious bovine rhinotracheitis, campylobacter and bovine trichomoniasis. Chaudhary *et al.* (1984), Tomar and Verma (1988b), Atrey *et al.* (2005) and Shahi and Kumar (2006) reported lower mortality rate of 11.4% and 12.1%, 12.1% and 17.5%, respectively. Higher mortality of 35.4% to 63% among female calves was reported by Banik and Nashkab (2006). The difference in observations made by various workers may be related to the variations in herd management practices followed at different farms.

The highest average mortality in female calves from birth to age at first calving was observed in the dry season (24%) followed by the long (23%) and short rainy (22%) seasons, respectively (Table 23), the differences being non significant (Table 25). Non significant effect of season on calf mortality might indicate that the disease and parasite dynamics at the Holeta centre could be similar during all seasons. Similar non-significant season effects were observed by Lemka *et al.* (1973), Tomar and Verma (1988b), Reddy and Nagarcenkar (1989a), Rawal and Tomar (1994b), Lathwal *et al.* (1993), Tomar and Rawal (1996), Singh and Jain (1997), Mukherjee and Tomar (1997b), Kumar (1999) and Singh (2001) for various Zebu and crossbred cattle herds. However, significant season effects on mortality in female calves have been reported by Chaudhary *et al.* (1984) in Friesian and Jersey crossbreds, Tomar and Verma (1988a) in Tharparkar and crossbred F_1 and Singh *et al.* (2002) in Sahiwal and crossbred calves. The mortality of female calves in dam's parity order ranged from 9% in 8th parity to 29% in 9th parity though mortality in dam's first 5 parities ranged between 21 % in 4th parity to 27% in 1st parity (Table 23). The analysis of variance (Table 25) indicated that parity effects on female calf mortality from birth to age at first calving were found to be significant ($P \leq 0.05$). The highest mortality above average was observed in the 1st parity cows. Fries and Ruvinsky (1999) reviewed the genetic and biology of reproduction of cattle and showed that incidence of dystocia is three to four times as frequent in females calving for the first time compared to females in the second parity and the same was attributed to lighter body weight of first calvers because of the lesser skeletal development relative to mature female cow, and sex of the calf. Berhanu (2009) reported that from the total of 97 calf deaths recorded in 1st parity cows, 7.2%, 3.1% and 5.2% were associated with pneumonia, calf scour and sudden death, respectively and 71.2% calf deaths were not known suggesting that the veterinary unit was not strong enough to handle such cases. Higher mortality of calf from older cows could be attributed to the small sample size. Significant parity effects on calf mortality were reported by Chaudhary *et al.* (1984), Tomar and Verma (1988a), Singh and Jain (1997), Signh *et al.* (2002) and Atrey *et al*. (2005). On the contrary, parity had non-significant effects on female calf mortality as reported by Tomar and Verma (1998a, b), Rawal and Tomar (1994b), Rawal and Tomar (1996), Mukherjee and Tomar (1997b), Kumar (1999) in Zebu and crossbred cattle and Singh (2001) in Karan Fries cattle.

The average mortality rate in female calves during first seven years (from 1979 to 1985) and last year (2003) was zero (Table 24). However, during years from 1986 to year 2002 mortality ranged from the lowest (7.3%) in the year 1989 to the highest (48.5%) in the year 1999. The year effects (Table 25) on mortality of female calves were found to be significant ($P \leq 0.05$). These significant year differences in mortality rates of the Holstein Friesian female calves could be attributed to the management and environmental reasons. Significant period differences in mortality rates have also been reported by Rawal and Tomar (1994b) for Sahiwal, Mukherjee and Tomar (1997b) for Karan Swiss, Singh and Jain (1997) for native and crossbred calves and Singh (2001) in Karan Fries cattle. On the contrary, Lathwal *et al.* (1993) in Red Sindhi reported non-significant year effects on female calf mortality. The difference in observations of different workers could be due to difference in management practices observed at different farms over different years.

5.3.4. Culling of female calves from birth to age at first calving

The overall female culling rate up to age at first calving, computed from total female calves born was (Table 23). The main reasons associated to involuntary culling at the Holeta farm were fertility and diseases problems (Berhanu, 2009). Lower culling rate of female calves were reported by different authors for crosses of Friesian with indigenous breeds. Chaudhary *et al.* (1984) and Singh *et al.* (1987) noted 1.6%, 0.10% for three breed crosses (Friesian×(Jersey×Tharparkar) and Friesian×Tharparkar half bred, respectively. However, Tomar and Verma (1988b) and Shahi and Kumar (2006) reported a higher culling rate of 31.0% and 17.8% for Friesian crosses. The variations in the reports may be because of the differences in the management practices, standards of culling and replacement need at different livestock farms.

The culling rate in female calves during the dry, short and long rainy seasons were estimated as 6%, 7% and 8%, respectively (Table 23, 25). These results agreed with the reports of Tomar and Verma (1988a) in Tharparkar and half bred calves, Lathwal *et al*.(1993) for Red Sindhi cattle, Mukherjee and Tomar (1997b) in Karan Swiss, Singh and Jain (1997) in Native and crossbred calves and Singh (2001) for Karan Fries calves. Whereas, season of birth had significant effects on culling rate, as reported by Tomar and Verma (1988b) in crossbred calves, Reddy and Nagarcenkar (1989a) in Sahiwal, Tomar and Rawal (1996) in Tharparkar and Kumar (1999) in Hariana calves.

The rate according to dam's parity order ranged from 0% in parity 9th and 10th to 11% in parity 4th (Table 23, $P<0.05$) with no definite trend in culling rates among parity order. Moreover, examination of farm records showed that out of the 22 heifer calves culled from 1st parity cows 22.7%, 18.2% and 36.4% were due to reproduction failure, sale for slaughtering and unknown cases. Significantly lower culling rates among calves born to later parity cows have been found in native and crossbred calves (Singh and Jain, 1997). Similar non-significant effects on heifers culling up to AFC have also been observed by Tomar and Verma (1988a, b) in Tharparkar and Karan Fries, Lathwal *et al*. (1993) for Red Sindhi and Singh (2001) for Karan Fries cattle and Atrey (2003) for Frieswal cattle. The present results were not supported by Rawal and Tomar (1994b) in Sahiwal, Mukherjee and Tomar (1997b) in crossbred and Kumar (1999) in Hariana heifers, as they have reported significant differences in heifers culling rates among dam's parity orders.

There was no culling among heifers up to AFC during first 8 years (from 1979 to 1986) and last three years (from 2001 to 2003). However, during rest of the years culling rate of heifers varied from lowest (1.5%) in the year 1999 to highest (22.5%) in the year 1991 (Table 24) and the analysis of variance (Table 25) showed that differences in culling rates of heifers over different years were highly significant ($P \leq 0.001$). The significant effect of period/year of calving on mortality of female calves may be because of variations in disease, climatic fluctuation, and change of management practices. Moreover, culling among heifers is generally depends on the replacement need of the herd and type of stock available for replacement. Therefore, culling is not practiced uniformly over different years which may result in significant variation in the culling of heifers. Significant differences over years for culling rate have also been reported by Kulkarni and Sethi (1990), Mukherjee and Tomar (1997b), Tomar and Rawal (1996), Kumar (1999), Singh (2001) and Atrey (2003)**.** However, non-significant year effects on culling rate in Karan Swiss were reported by Kulkarni and Sethi (1990).

In summary, the results of this study showed that cows had lower survival accompanied by higher loss rate at first lactation. Stayability and reproductive value showed a declined trend after the first lactation. There was a higher male calves birth than female calves particularly at higher lactations. Although net reproductive rate was above one, there was high rate of cow loss per lactation as a result of forced culling and mortality. Better nutrition and health management will improve on survivorship and reproductive value by reducing culling and mortality rates of female calves at early ages.

5.3.5. Replacement rate on female calf birth's basis

The overall replacement rate on the basis of total female calves born was estimated to be 70% (Table 23) indicating that this proportion of the total female calves born reached to AFC and became the replacement to the older cows in the herd and the rest 30% were lost either due to their death or culling from the herd. These observations were in agreement with the 68.5% (Tomar and Verma (1998 a) in Tharparkar and 69.5% (Tomar and Rawal (1994) in Sahiwal cattle breed. Female calves retained for replacement at Holeta was lower than the 89.3% (Taneja and Bhatnagar, 1983) in BS×Sahiwal, 81.3% (Chaudhary *et al.,* 1984), in Jersey and Friesian crosses, and 92.2% (Tomar and Verma, 1998b) reported for ¾ (Friesian×Jersey×Tharparker) and 5/8 (Friesian×Tharparker) crosses, 77.8% (Loyd and Hargrove, 1991) for Holstein herd and 74.7% (Atrey *et al.,* 2005) for Frieswal cattle. However, it was higher than the replacement rate of 66.4% (Tomar and Verma, 1998 b) in Friesian×(Friesian×Tharparker)3/4, Friesian×(Brown Swiss×Tharparker)3/4 crossses, 56% (Singh and Jain, 1997) for exotic crosses, 64% (Shahi and Kumar (2006) and Banik and Nashkab (2006). These variations in the observations of different workers could be attributed to the difference in the early losses through mortality and culling of female calves at different livestock farms.

The average replacement rates computed from female calves born during different seasons were estimated as 70%, 71% and 69% in the dry, short and long rainy seasons, respectively (Table 23). The analysis of variance (Table 25) revealed that these differences were non significant. These findings were in agreement to the non-significant season effects reported by Tomar and Verma (1988a) in Tharparkar, Rawal (1991) in Zebu cattle, Lathwal *et al.* (1993), in Red Sindhi, Tomar and Rawal (1994) in Sahiwal, Singh and Jain (1997) and Kumar (1997) for Zebu and crossbred cattle. On the contrary, significant effects of season of calving on replacement rate on female calf basis were reported by Tomar and Verma (1988a), Tomar and Rawal (1994), Atrey *et al*. (2005).

The replacement rates on female calf born basis according to dams' parity order ranged from 66% in 5th parity to 83% in 8th parity (Table 23). Though there was no definite relationship between dam's parity of calving and replacement rate on female calf's birth basis but the observed differences in replacement rates between dam's parity of lactation were found to be highly significant ($P \leq 0.01$) as indicated by analysis of variance (Table 25). Similar findings were also reported by Lathwal *et al*. (1993), Tomar and Rawal (1994) and Kumar (1999) where as Mukherjee (1993), Singh (2001) and Atrey *et al.*(2005) in Frieswal cattle did not observe significant effect of dam parity on this trait. Lower replacement rate in some parity could be related to the combined effect of high mortality or culling and high male births.

The average year effect on replacement rate on female calf's birth basis (Table 24) revealed that during first 7 year (1979 to 1985) and during last year (2003), all female calves born (100%) survived to their AFC and became the replacement heifer in the herd. However, during other calving years from 1986 to 2002, the replacement rate on the basis of female calf's birth basis ranged from highest (0.93) in the year 2002 to lowest (0.49) in the year 2000. These variations in observed replacement rates during different years were due to difference in culling and mortality of female calves over different years. The analysis of variance (Table 25) revealed that effects of year of calving on replacement rate on female calf's birth basis were highly significant ($P \leq 0.001$). Similar observations have been reported by Tomar and Verma (1988 a), Rawal (1991), Lathwal *et al*. (1993), Singh and Jain (1997), Kumar (1999), Singh (2001) and Atrey (2005). However, Tomar and Verma (1988 b) reported non-significant effect of year of birth on replacement rate computed on female calf birth basis in Karan Fries cattle.

5.3.6. Replacement rate on total pregnancy basis

The overall replacement rate (Table 23) computed on the basis of total pregnancy in Holstein Friesian herd at Holeta farm was estimated as 29%. These observations indicated that about 3 to 4 pregnancies are required to produce one heifer replacement. This finding was in agreement with those of 29.8% (Rawal, 1991) in Tharparkar and 27.5% (Lathwal, 1993) in Red Sindhi cattle breeds. The present overall replacement rate on total pregnancy basis was lower than the 32.4% (Tomar and Rawal, 1994) in Sahiwal, 33.88 % (Tomar and Verma, 1998 a) in Tharparkar, 33.9% (Tomar and Verma, 1988 b) in Friesian×Tharparkar cross and 31.14% (Singh, 2001) in Karan Fries cattle whereas it was higher than the 24% (Mukherjee, 1993) in Karan Swiss and 22.5% (Kumar, 1999) in Hariana breed of cattle. The difference in observations of various workers could be due to the variations in managemental practices observed at different livestock farms. The managemental practice at Holeta farm could be considered below average and there is a considerable scope for improving the same for better performance of the herd.

The replacement rates computed on total pregnancy basis (Table 23) during different seasons did not vary much and analysis of variance indicated that season effects were found to be non significant (Table 25). Similar non significant effect of season on replacement rate from total pregnancy was observed by Rawal (1991), Lathwal *et al.* (1993), Tomar and Rawal (1994) and Singh and Jain (1997) and Singh (2001).Whereas, Tomar and Varma (1998 a) in Tharparkar, Kumar (1999) in Hariana and Atrey (2005) in Frieswal cattle have reported significant season effects on replacement rate on total pregnancy basis.

The average replacement rate computed on total pregnancies basis among dam's parity order were non-significant and ranged from lowest of 28 % in 1st and 2nd parity to 36% in 6th parity, though it was highest (45%) in 10th parity of lactation with no definite relationship observed for replacement rate among dam's parities. Non significant effects of dam's parity were also reported by Karan Fries, Rawal (1991) in

Tharparkar, Lathwal *et al.* (1993) in Red Sindhi, Tomar and Verma (1988 a, b) in Tharparkar and Singh (2001) in Kara Fries cattle.

The replacement rates during different years of study varied from highest (64%) in the year 1979 to lowest (20%) in the year 1998 (Table 24, $P \leq 0.05$). Significantly lower replacement rates during years (1998, 1999 and 2001) because of very high abnormal birth, mortality and culling rates during these years. Similar significant year/period effects on replacement rate on total pregnancy basis were observed by Lathwal *et al.* (1993), Tomar and Rawal (1994), Tomar and Verma (1998 a), Sahiwal, Kumar (1999), Singh (2001) and Atrey (2005) in Frieswal cattle. However, Tomar and Verma (1998 b) in Karan Fries could not observe any significant effect of year of birth on replacement rate based on the total number of pregnancies.

From the foregoing discussion on replacement rates computed on total female calves born and total pregnancies, it could be concluded that on an average 3.45 pregnancies are required to produce one heifer that become replacement of the old and low productive cow. Furthermore, in a progeny testing programme, with present observed rates of sex ratio, mortality and culling in female calves up to AFC, it can be recommended that about 38 successful inseminations (pregnancies) are required to produce 16 females so that about 12 daughters per sire may be available for performance recording. Besides, this also necessitates improvement in feeding and health care of the herd so that cows could produce at least two calves before removal from the herd.

5.4. Sire Effect on Replacement Rate, Its Components and Selective Value

5.4.1. Abnormal vs. normal birth

The overall average incidence of abnormal births was estimated as 12.2% among 2983 pregnancies from 118 sires (Table 26). It was observed that out of 118 bulls used for breeding in Holstein Friesian cattle at Holeta farm, there was no incidence of abnormal birth among the pregnancies from 47 sires. However, pregnancies from 71 sires used for breeding resulted in to varying rates of abnormal births ranging from

5.3% (Sire at no 67) to 50 % (Sires no. 21,24,70 and 118) and just reverse was true for normal birth. Means under 47 sires there were 100% normal birth while under 71 sires normal birth ranged from 97.5% (Sire 67) to 50% (Sires no. 21, 24, 70 and 118). The analysis of variance revealed that sire differences in prenatal mortality due abnormal birth in Holstein Friesian cattle were statistically significant (P≤0.001). Similar significant sire effects for incidence of abnormal births in different pure breed Zebu and crossbreed cattle have also been reported by Tomar *et al*. (1975), Kumar *et al* (1991) Rawal and Tomar (1996a, c), Kumar (1999) Mukherjee and Tomar (2000), Singh *et al*. (2002) and Atrey (2005). On the contrary, non-significant sire effects on abnormal births of calf were reported by Tomar and Verma (1988 a, b) in Tharparkar and Karan Fries, Lathwal and Kumar (1993) in Red Sindhi and Singh (2001) in Karan Fries cattle. However, quite a high and varying proportions of sires used in breeding have been observed affecting the abnormal birth of calf by Tomar e*t al*. (1975) in Sahiwal (64%) and HF (50%), Kumar *et al.* (1991) in Sahiwal (70%) and HF (82%), Rawal and Tomar (1996a, b) in Sahiwal (50%) and Tharparkar (60%), Kumar (1999) in Hariana (78%), Singh (2001) in Karan Fries bulls (89%) and Atrey *et al.* (2005) in Frieswal bull (95%).

5.4.2. Sex ratio

The overall average sex ratio was observed to be as male 52.5% and female 47.5% births. Chi-square test ($\chi^2_{c(1,\ 0.01)}$=7.31), indicated that overall sex ratio was significantly apart from normal expectation. The sire wise male births were observed to be ranging from 0 to 100%. Out of 118 Holstein Friesian sires used in the Holeta herd, 14 sires did not have any male progeny while another 14 sires had 100 percent male progeny (Table 26). Analysis of variance (Table 27) showed that frequency of male birth among the progeny of different sires differed significantly (P≤0.01). This finding agreed with Powell *et al.* (1975) in exotic cattle, Kumar *et al.* (1993) in Sahiwal, Rawal and Tomar (1995) in Sahiwal, Rawal and Tomar (1996c) in Tharparkar, Kumar (1999) in Hariana and Atrey *et al.* (2005) in Frieswal cattle whereas, non-significant sire differences for sex ratio were reported by Tomar and Arora (1970), Tomar *et al.* (1976) Sethi and Rao (1981), Singh *et al.* (1983), Tomar and Verma (1988 a,b), Lathwal and Kumar *et al.*(1993), Mukherjree *et al*. (2000) and Singh (2001) in various zebu and crossbred cattle.

5.4.3. Mortality rate among female calves

The average mortality of 22.4% among Friesian female calves up to AFC at Holeta farm as observed in the present study ranged from 0 to 100 percent under different sires (Table 26). There was no mortality from birth to AFC among the female progeny of 73 (61.8%) sires while there was 100 percent mortality in female progenies of sire no 67, 80, 81 and these sire differences in female calf mortality up to AFC were highly significant ($P \leq 0.01$) as revealed by analysis of variance (Table 27). Significant sire effects on female calf mortality up to AFC have also been reported by Rawal and Tomar (1994b) in Sahiwal, Tomar and Rawal (1996) in Tharparkar, Mukherjee and Tomar (1997b) in Karan Swiss, Kumar (1999) Hariana and Atrey *et al.* (2005) in Frieswal cattle. While Tomar and Verma (1988a, b) in Tharparkar and Karan Fries, Lathwal and Kumar (1993) in Red Sindhi, Singh (2001) in Karan Fries and Singh *et al.*(2002) in Sahiwal and crossbred cattle reported non-significant sire effects on female calves mortality from birth to age at first calving.

5.4.4. Culling of female calves

The overall average culling rate from birth to AFC among the female progenies at Holeta farm was observed as 9.1% (Table 26) for daughter with known sires. Furthermore, there was no culling from birth to AFC among the progenies of 98 (83.1%) sires out of a total of 118 sires used. The highest culling rate from birth to AFC was (66.7%) under sire no 87. Analysis of variance (Table 27) indicated that sire of calf had highly significant effect on culling of female calf from birth up to their AFC. This finding was in conformity with those reported by Lathwal and Kumar (1993) in Red Sindhi, Rwawal and Tomar (1994 b) in Sahiwal, Tomar and rawal (1996) in Tharparkar, Mukherjee and Tomar (1997 b) in Karan Swiss, Kumar (1999) in Hariana and Atrey *et al*.(2005) in Frieswal cattle while non-significant sire effects on culling of female calves from birth to AFC were reported by Tomar and Verma (1988 a,b) in Tharparkar and Karan Fries and Singh (2001) in Karan Fries cattle.

5.4.5. Replacement rate on female calf basis

The overall replacement rate on female calf basis (proportion of females born reached to AFC) was observed to be 67.7 percent (Table 26). This indicated that about two-third of the Holstein Friesian female calves born at Holeta farm survived up to AFC and became replacement in the herd. Furthermore, it also indicated that to produce 12 daughters for progeny testing of bulls at least birth of 18 daughters from each sire would be required. Sire wise replacement rate ranged from 0.0 to 100%. Out of 118 sires used to produce progeny, 17 sires did not have any replacement heifer while from 57 sires 100 percent daughters reached to AFC. These results indicated that the replacement rate was very high among the progeny of certain sires than other sires. This might be because of preference to daughters of genetically good sires to use as replacement heifer. Analysis of variance (Table 27) showed that sire differences for replacement rate on female calf basis were highly significant ($P \leq 0.01$). These results were in agreement of Rawal (1991), Rawal and Tomar (1992), Lathwal and Kumar (1993), Mukherjee and Tomar (1997b), Kumar (1999), Singh (2001) and Atrey *et al.* (2005) for various Zebu and Crossbred cattle but did not agree with the reports of Tomar and Verma (1988a) in Tharparkar, as they had observed non-significant sire effect on percentage of female calves reaching to milking herd based on total female calves born.

5.4.6. Coefficient of gene replication (CGR)

The overall value of coefficient of gene replication (CGR) was found to be 0.50 (50 percent) in Holstein Friesian herd (Table 26). This indicated that it was equal to one gene replication that could materially contribute again to the future generation. The CGR value under different sires ranged from 0% to 50%. The CGR value of zero for a sire indicated that no daughter of such sire reached to AFC to become replacement heifer in the herd while CGR value of 50% indicated that all female calves born to a sire reached to AFC and became replacement heifer in the herd. The analysis of variance indicated that sire differences in CGR were non-significant (Table 27).

5.5. Distribution of Cows According to Daughters Reached to Milking Herd

The percent distribution of 901 cows for total abnormal births, normal birth, female calf birth, female calf loss and total female calves reached to milking herd under different life time calf production (0 to 12 calving) were computed and presented in Table 28. The percent distribution of cows for life time calving (calf production) revealed that 30.8% of total cows calved only once and proportion of cows reduced under each calving as the number of calving increased and it was only 0.3% cows calved 11 and 12 times in the Holstein Friesian herd at Holeta farm (Table 28). These results indicated that the highest culling of cows was done on the basis of FLMY in the herd. The observed 30.8% of the cows which left the herd after only first calving in the present investigation was higher than Rawal (1991) in Tharparkar, Rawal and Tomar (1996a) in Sahiwal, Kumar (1999) in Hariana cows but lower than those reported by Lathwal and Kumar (1993) in Red Sindhi, Mukherjee and Tomar (1996) in Karan Swiss, Singh (2001) in Karan Fries and Atrey *et al.* (2005) in Frieswal cattle. The difference in observations could be due variations in culling rate and availability of replacement heifers and management practices at different dairy cattle farms.

The percent distribution of total Holstein Friesian cows (Table 28) showed that 65.3% of cows did not show any abnormality in calving or calved normal through out their life time calf production while 27.7 percent cows calved abnormally during their first calving, 5.3% of cows calved abnormal during their 3rd calving and it was only 1.3%, 0.2%, 0.1% and 0.1% in cows calved 3, 4, 5 and 6 times, respectively. There was no abnormal calving in cows calved more than 6 times. These results did not agree with the observations of Singh (2001) and Atrey *et al.* (2005) as they have observed higher normal calvings in Karan Fries and Frieswal cattle.

The percent distribution of cows according to the number of calving in their life time indicated that 5.2% of total cows left the herd with out any normal calving (Table 28). While 31.6% cows calved normal once, 18.5% calved normal twice and 11.8%, 9.9%, 9.4%, 5.4%, 3.2%, 2.8%, 1.2%, 0.9%, 0.1% and 0.0% cows calved normal during 3, 4, 5, 6, 7, 8, 9, 10,11 and 12 times calving. The observed 5.2% cows always calved abnormal and left the herd without producing any live calf was in agreement with the report of Atrey *et al.*(2005) but were higher than those reported by Rawal (1991), Rawal and Tomar (1994a), Mukherjee and Tomar (1996), Kumar (1999) and Singh (2001). The difference in observation of various workers could be attributed to the genetic (breed) and environmental (feeding) reasons.

The percent distribution of cows (Table 28) according to the number of female calves produced in their herd life time showed that 27.3% of the cows left the herd with out producing any female calf in the herd and 33.1% cow produced one female calf, The percentage of cows that produced 2, 3, 4, 5, 6 and 7 female calves in their herd life time were 21.0%, 11.0%, 5.8%, 1.9%, 0.5% and 0.4%, respectively. The varying percentage of cows which were failed to produce any female calf have been observed by Lathwal (1989) for Red Sindhi, Rawal (1991) for Tharparkar, Rawal and Tomar (1994a) for Sahiwal, Mukherjee and Tomar (1996) in Karan Swiss, Kumar (1999) for Hariana and Singh (2001) for Karan Fries and Atrey *et al.* (2005) for Frieswal cows.

The percent distribution of cows according female calf loss under different calving revealed that 69.2% of the cows in the herd did not loss any calf either due to mortality or culling from the herd while 25.1%, 4.9%, 0.9%, 0.2% of the cows lost their 1, 2, 3, and 4 female calves from the herd during their herd life time calf production in Holeta farm.

The percent distribution of cows under different calving revealed that 45.7% of the cows left the herd without producing any replacement daughter and 28.4 percent cows left only one female replacement, while 16.1%, 6.5%, 2.4%, 0.6%, 0.2% and 0.1% of cows left 2, 3, 4, 5, 6, and 7 female replacement in the herd before they left the herd. The observed percentage of cows which could not left any replacement daughter under this investigation were well with in the range of percentage of such cows reported by Lathwal (1989), Rawal (1991), Rawal and Tomar (1994a), Mukherjee and Tomar (1996), Kumar (1999) and Atrey *et al.* (2005).

The above discussions showed that sire affects significantly the type of birth, calf loss, replacement rate and coefficient of gene replication. About 2/3rd of the heifers survived up to AFC and at least 18 daughters from each sire would be required to produce 12 replacement heifer. Therefore, these triats are affected by genetics and attention needs to be given in recruiting sires. 1/3rd of cows calved only once and similar proportion of the cows experienced abnormal calving during first laction culminating in 45.7% of cows leaving the herd without producing replacement daughter. This demands improvement in feeding and reproduction management particularly for young females.

5.6. Selective Value and Its Components

The average PHL, longevity, selective value, and various components of selective value and coefficient of gene replication were computed and presented in Table 29 and their analysis of variance to study the significance of the effects of age groups, FLMY group, season of birth and year of birth on selective value and its components are also given in Table 30.

5.6.1. Longevity

The longevity of Holstein Friesian cows, measured as the time interval in years from date of birth to the date of disposal of cow from the herd either due to culling or death, was 2864 days (7.85 years). This estimate was in agreement with the 7.83 years reported for Friesian crosses (Gebeyehu, 2005) and higher than 5.3 years for grade Boran in Tanzania (Trail *et al.*, 1985), 6.0 years for crossbred cows in Ethiopia (Enyew *et al.,* 2000) and 6.2 years for Frieswal cattle in India (Atrey *et al.,* 2005). The difference in observations could be mainly attributed to the difference in AFC along with mortality and culling age of cows at different dairy cattle farm.

The average longevity for various AFC groups of Holstein Friesian cows (Table 29) ranged from minimum of 1748±365days in cows with lowest AFC (≤886 days) to highest of 4102±586 days in cows with highest AFC of 1821-1978 days. Although not significant, there seems a direct relationship of AFC group with longevity. Higher longevity for higher AFC group was because of extended period before calving. These findings agreed with the reports of Singh (2001) in Karan Fries and Atrey *et al.*(2005) in Frieswal cattle, as they have also observed non significant effects of AFC on longevity but did not agree with the reports of Dentine *et al*. (1987), Duroec *et al.*(1988) and Rogers *et al.*(1991) in exotic cattle, Mukherjee *et al.* (1999) in Karan Swiss and Kumar (1999) in Hariana cattle as they have observed highly significant effect of AFC on longevity.

The cows with ≤1500 kg FLMY had minimum longevity (2170±329days) while cows with ≥5456 kg FLMY had maximum longevity. Though, longevity had no definite relation with FLMY (Table 29) but when cows were compared for their milk yield, intermediate groups had remained longer in the centre. However, analysis of variance (Table 12) showed that FLMY had highly significant effects on longevity in Holstein Friesian cows at Holeta farm. These results agreed with the reports of Dentine *et al*. (1987), Duroec *et al* (1988) and Rogers *et al.* (1991) in exotic cattle, Mukherjee *et al.* (1999) in Karan Swiss and Kumar (1999) in Hariana, Singh (2001) in Karan Fries and Atrey *et al.* (2005) in Frieswal cattle.

The average longevity in cows born during dry, short rainy and long rainy seasons were observed as 2847±97 days, 3008±115 days and 2795±110 days, respectively. Analysis of variance showed that season effects on longevity of cows were statistically non-significant which indicated the consistent environmental conditions throughout over all seasons of the year in the area Holeta farm is located.

The average longevity (Table 29) in Holstein Friesian cows born at Holeta farm in different years (1976-98) ranged from a maximum 4508 days in cows born in 1978 to a minimum of 1156 days in cows born in the year 1998 and revealed some extent a decreasing trend in longevity from 1978 to 1998. The decreasing trend in longevity over years could be due to the fact that best available cows might have been brought and maintained as long as they were reproducing at the farm. While during later years when good replacements heifers were available at the farm the low producers and cows with any other problem might have been culled out from the herd thus lowering the longevity of the cows at Holeta farm. Statistical analysis of variance (Table 30) showed that year effects on longevity of cows were highly significant ($P \leq 0.001$). These findings could be supported by Basu *et al.*(1983), Hedge and Bhatnagar (1985), Ready and Basu (1985), Tanida *et al.* (1988), Singh and Tomar (1989), Mukherjee *et al*.(1999), Kumar (1999), Singh (2001) and Atrey *et al.*(2005) for various zebu, crossbred and exotic cows.

5.6.2. Productive herd life (PHL)

Productive herd life is the time span between first calving and disposal. The average productive herd life of Holstein Friesian cows at Holeta farm was observed to be 1638±58 days (4.59 years). This was in conformity with the reports of Schons *et al.* (1985) in Angus, Hedage and Bhatnagar (1985) BS×Zebu F_1 crossbred. The higher PHL than the present estimate was observed by Nair (1976) in Red Sindhi, Basu *et al.* (1983) in Tharparkar, Ready and Basu (1985) in Holstein Friesian crosses, Singh *et al.* (1988), Thakur *et al.* (1992), in Jersey×RS, and Kumar (1999) in Hariana cattle while lower PHL than the present were reported Gill and Allaire (1976) in HF, Hedge and Bhatnagar (1985) BS×Zebu F_2, F_3 crossbred, Nieuwhof *et al.* (1989) in Jersey, HF, BS, Guernsey and Ayershire, Singh and Tomar (1989) in HF×TP, Rogers *et al.* (1991) in Jersey, Singh (1995) in Karan Swiss, Mukherjee *et al.* (1999) in Karan Swiss, Singh (2001) in Karan Fries, Atrey *et al.*(2005) in Frieswal cattle and Gebeyehu (2005) in crosses of HF with indigenous breeds. Difference in observations of different workers may be due to different management policies and practices adopted by different dairy cattle farm.

Average PHL for different age groups (Table 30) showed that Holstein Friesian cows with lowest AFC (≤886 days) had lowest PHL (919±366 days) while cows calved with medium AFC (1199 to 1510 days) had longest PHL at Holeta farm. The cows with high AFC (>1511 days) also observed to have generally lower PHL at Holeta farm. Perhaps the cows calved at a very low age could not have attained full mature size and therefore, might have been culled out just after taking two lactations, because calving at an immature age weakens the vitality of cows and such animals are likely to suffer with more problems like poor body condition, low milk yield, repeat breeding, infertility and disease susceptibility than cows calved at the mature age of 1199 to 1510 days. The declining trend of PHL for AFC group above 1511 days could be related to culling, as cows with very high AFC are not preferred in the herd and are culled out earlier than the cows with optimum AFC. Statistically, AFC had significant effect (P≤0.001) on PHL of cows (Table 30) at Holeta farm. Similar results were reported by Dentine *et al*. (1987), Duroec *et al.*(1988), Rogers *et al.*(1991), Mukherjee *et al.*(1999), Kumar (1999) and Singh (2001) and Atrey *et al.*(2005) as they have observed highly significant effect of AFC on longevity. Whereas, non significant of AFC on PHL has been reported by Camacho *et al.* (1985) for Brahman cows and Sahota and Gill (1990) for crossbred cattle.

The average PHL for different FLMY groups (Table 29) showed that shortest PHL of 869±330 days was estimated for the group of cows which had ≤1500 kg FLMY indicating that low producers had short PHL, presumably culling of those cows because of poor production. However, PHL increased to 1895±320 days in a group of cows producing 2631-3195 kg milk and thereafter in cows producing more than 3196 kg of milk PHL showed almost a decreasing trend except the group of cows produced ≤5456 kg milk in their first lactation had longest PHL of 2484±325 days. Higher milk producing cows (>4325 kg) did not have longer PHL, because of failure to meet out the production and maintenance requirement of those cows resulting in to ultimate loss of such cows either by mortality or culling. These results also indicated that HF cows with medium milk yield can be managed more effectively to have longer PHL at Holeta farm. However, in order to maximize the genetic contribution from high producing cows, differential treatment based on production level is important. Moreover, improvement of the overall management and health practices will reduce involuntary culling of productive animals. In the absence of improvement at the center, the preferred age at first calving and milk production level need to be checked between 1199 to 1510 days and 2000 to 3200 kg, respectively. These observations were in conformity with the reports of Duroec *et al.* (1988) and Rogers *et al.* (1988) in exotic cattle, Mukherjee *et al.* (1999) in Karan Swiss and Kumar (1999) in Hariana and Singh (2001) in Karan Fries and Atrey *et al.* (2005) in Frieswal cattle as they have also observed highly significant effect of FLMY on PHL and indicated that higher FLMY were associated with longer PHL. Whereas, non significant of FLMY on PHL has been reported by Sahota and Gill (1990) for crossbred cattle.

The average PHL for cows born in dry, short rainy and long rainy seasons were estimated as 1624±98 days, 1758±12 days and 1571±11 days, respectively. Statistically, the season effects on PHL were found to be non significant. These results indicated that there is not much environmental variation between seasons of a year which could be measured on phenotypic scale. Non signifcnat effect of season of birth on productive herd life was also reported previously for Holstein Friesian cows (Gebeyehu, 2005).

Average PHL for different years (Table 29) revealed that cows born during early years had the longer PHL than those born in later years. The average PHL was longest (3101days) during the year 1976 which showed almost a continuous declining trend as the year of birth advanced and it was lowest (254 days) in the year 1997, though it was 300 days in the year 1998. The decreasing trend in PHL during later years could be perhaps due to changed policy for culling of older cows through early replacement by newly calved heifers. Statistically, year differences in PHL of Holstein Friesian cows at Holeta farm were found to be highly significant ($P \leq 0.001$). These observations agreed with Basu *et al.* (1983), Hedage and Bhatnagar (1985), Reddy and Basu (1985), Tanida *et al.* (1988), Singh and Tomar (1989), Mukherjee *et al.* (1999), Kumar (1999), Singh (2001) and Atrey *et al.(*2005), as they have also reported significant period/year effects on PHL in various zebu, crossbred and exotic cows.

5.6.3. Total normal calves born (TCP)

The average number of total normal calves born (3.55±0.12) by each Holstein Friesian cows during its herd life at Holeta farm (Table 29) was closer to the findings of Schones *et al.*(1985) for Angus (3.78 calves), Rawal *et al.*(1993) in Tharparkar (3.68 calves), Rawal and Tomar (1994a) in Sahiwal (3.61 calves) and Gebeyehu (2005) for various Friesian×Boran crosses (3.58 calves). Higher normal births of 4.22 calves was observed by Thakur *et al.*(1992) in Jersey×Red Sindhi crosses, 6.34±0.06 calves by Raheja (1997) for Friesian×Sahiwal crossbreds, 5.04±0.026 calves by Singh *et al.* (1997) for crossbreds, and 4.90±0.15 calves by Kumar (1999) for Hariana cattle and 5.4 by Kumar *et al*. (2009) for Hariana cows. However, less number of alive calves born were reported by Tomar *et al*. (1995) for Red Sindhi (3.16±0.11 calves), Mukherjee and Tomar (1996) for Karan Swiss (3.14±0.10 calves), Singh (2001) for Karan Fries (2.91±0.07 calves) and Atrey *et al.*(2005) for Frieswal cows (2.91±0.07 calves). The difference in observations of various workers could be due to the differences in the productive herd life of cows.

Total number of normal calves produced was highest for intermediate AFC groups of cows while cows with very low or very high AFC had produced less number of normal calves, as indicated from Table 29. This could be related to the PHL of different groups of cows and as observed in earlier discussion for effects of AFC on PHL in HF at Holeta farm, cow with optimum AFC had longer PHL while cows with shorter and higher AFC had comparatively shorter PHL at Holeta farm. Therefore, HF cows with optimum AFC and longer PHL had produced more number of normal calves at Holeta farm. The present finding was different from Atrey *et al.* (2005) who reported that cows in the AFC group of 726-800 days produced more calves and attributed to the lower AFC and longer PHL of those cows in the herd. Moreover, Kumar *et al.* (2009) on Hariana cattle observed that cows calved early had produced more alive calves. Analysis of variance (Table 30) indicated highly significant effects ($P \leq 0.001$) of AFC on normal total calves born in Holstein Friesian cows at Holeta farm. This finding was in agreement with Mukherjee and Tomar (1996), Kumar

(1999), Singh (2001) and Atrey *et al.*(2005) as they all have observed significant effects of AFC on normal calves born in different zebu, crossbred and exotic cattle.

The effect of FLMY group on live calves born was significant (Table 30). The cows in the intermediate milk production group produced more normal calves than cows in low and high FLMY groups. This could be associated to the lower PHL of cows. This can be supported by earlier observations made for FLMY effects on PHL, where in cow with very low and high milk production, were found to have shorter PHL at Holeta farm. The present findings were in agreement with the Mukherjee and Tomar (1996), Kumar (1999), Atrey *et al*. (2005) and Kumar *et al*. (2009) as they have also reported significant effect of FLMY on total normal calves born from each cow for various breeds of cattle.

Analysis of variance (Table 30) showed that season effects on total calves born by each Holstein Friesian cows during dry, short rainy and long rainy were non-significant. This indicated that there might be no significant climatic environmental variation over different seasons of a year in the region, the Holeta farm is located. The average number of normal calves born to each cow (Table 29) was higher during initial years (1976-1989) than those produced by cows in subsequent years (1990 to 1998) when a declining trend was found. Statistically, the year differences in total normal calves born from each cow according to their year of birth were found to be highly significant ($P \leq 0.001$). The observed significant decrease in the total normal calves born during later years could be due to changed policy for culling of older cows through early replacement by newly calved heifers. These findings agreed with the reports of Mukherjee and Tomar (1996), for crossbred, Kumar (1999) for Hariana, Singh (2001) for Karan Fries and Atrey *et al.* (2005) for Frieswal cattle.

5.6.4. Total normal female calves born

The average number of normal female calves born from each Holstein Friesian cow during its herd life at Holeta farm was estimated to be 1.68±0.07. This observation was well in agreement with those reported by Lathwal (1989), Rawal *et al.*(1993), Rawal and Tomar (1994a). However, the present average was lower than those reported by Thakur *et al.* (1992), Kumar (1999) and Kumar *et al.*(2009) but higher than those of Tomar *et al*. (1995), Singh (2001) and Atrey *et al.* (2005). The difference in observations of different workers could be attributed to the difference in PHL of cows at different farms.

Table 29 revealed that average total normal female calves born from each Holstein Friesian cow at Holeta farm under different AFC groups were lowest in both lowest and highest AFC groups i.e., cows AFC ≤886 and ≥1979 days had 1.27±0.59 and 1.22±0.80 female calves, respectivlyin during their herd life. Though no definite trend was observed in total female calves born to each cows as per AFC groups but generally cows with medium AFC group produced higher number of female calves during their PHL at Holeta farm. This could be due to increased number of abnormal births in early maturing cows and probabale occurrence of reproductive disorders in very high AFC group of cows, resulting in to shorter PHL of cows in both groups. The higher average number of normal female calves born per cow in groups with medium AFC (1355-1510 days) could be due to longer PHL of cows. Analysis of variance (Table 30) revealed that AFC effects on total normal female calves born from each Holstein Friesian cow at Holeta farm were non significant. Similar findings of non significant effect of AFC on the trait have been reported by Kumar (1999) in Hariana, and Atrey *et al.*(2005) in Frieswal, and Kumar *et al.*(2009) in Hariana cattle. On the contrary, Mukherjee and Tomar (1996) and Singh (2001) for crossbred cow reported significant effect of AFC on total female calves produced.

The total number of female calves born were higher in cows producing milk in the range of 2066-2630 kg (2.17±0.21 calves) and 2631- 3195 kg (2.01±0.18 calves), this could be due the longer PHL of such cows with normal calving inter resulting in to more calving giving higher number of normal female progenies. The cows in low producing group (≤1500 kg) and high producing groups (4891-5455 kg) had produced less number of 0.87±0.15 and 1.14±0.37 female calves, respectively, indicating that low and high producing cows might have been culled from the herd either because of low production and/or reproductive problems. The high producing cows in higher FLMY groups (4891-5455kg) also produced lower number of total normal female calves (1.14±0.37). Since total milk produced by a cow in a lactation is the function of lactation length and average daily milk yield, it is quite likely that cows in higher FLMY groups might have longer first lactation period resulting in to a longer calving interval affecting net life time reproductive rate of the cow in terms of less number of total normal female calves produced. Atrey *et al.* (2005) noted that FLMY affected female calf production and higher milk producers calved more female calves. Non significant effect of milk yield group on female calf production was reported by Kumar *et al.* (2009). Higher normal and female calves reported for the highest (>5456 kg) milk group in this study could be related to the small sampling effect.

The average number of total normal HF female calves born during dry, short rainy and long rainy season at Holeta farm did not vary significantly (Table 30). This could be confounding effect of season on this trait since there exists little variations across seasons. Gebeyehu (2005) reported that season of birth had no significant effect on total calves produced.

The average total normal female calves born from each Holstein Friesian cow according to year of birth at Holeta farm ranged from highest (3.13) in year 1976 (1st year) to a minimum (0.48) in the year 1997 (Table 29). Though there was no specific trend in female calves born during diffent years but it completely was in accordance of the observed PHL of the cows the herd. The analysis of variance (Table 30) showed that year effects for female calve born to each cow were highly significant (P≤0.001). This finding was in conformity with the reports of Mukherjee and Tomar (1996), Kumar (1999), Singh (2001) and Atrey (2005).

5.6.5. Selective value

Selective value of an animal is the proportionate contribution of the living female progeny to the next generation. A selective value of 1.0 indicates that cow had replaced herself in the milking herd. The average number of female calves reached to the milking herd from each Holstein Friesian cow at Holeta farm was estimated to be 1.12±0.06. This indicated that on an average more than one replacement heifer from each HF cow reached to the milking herd resulting in increased herd size. Furthermore, it could be possible to practice culling of low producer cows while keeping the herd strength constant. The present observation was in conformity with those of Schone *et al.* (1985) for Angus and Rawal *et al.* (1993) for Tharparkar cows. However, present estimate was higher than those reported by Lathwal (1989) for Red Sindhi, Mukherjee and Tomar (1996) for Karan Swiss, Singh (2001) for Karan Fries, and Atrey *et al.* (2005) for Frieswal cows but it was lower than the reports of Thakur *et al*. (1992) for Jersey×Red Sindhi, Rawal and Tomar (1994a) for Sahiwal and Kumar (1999) for Hariana and Singh (2001) for Karan Fries cows. These differences in the observations of various workers could be attributed to the differences in PHL of cows in different herds.

Cows belonged in the AFC group of less than 1042 days had a selective value of less than 1.0 which may be related to low PHL and fewer calves produced. Intermediate producers had selective value greater than 1.0 may be related to optimum lactation length and calving interval allowed those cows calving regularly and hence producing more replacement heifer calves. Low selective value may be associated to culling at early age and reduced PHL especially in later periods or years (Table 29). All this indicated that medium to late maturing Holstein Friesian cows had better reproduction rate and produced more replacement heifers at Holeta farm. This finding agreed with the reports of Mukherjee and Tomar (1966), Kumar (1999) and Atrey *et al*. (2005) but contrary to the reports of Singh (2001).

Averages of selective value of different cow groups based on FLMY revealed that lowest producers (≤1500) left minimum replacement heifers (0.59±0.13) in the herd.

This could be because the cows with low milk production might have been culled out just after completion of their first lactation, while cows with higher milk yield were allowed to stay in the herd for longer time to produce more replacement heifers in the herd to replace herself by her own daughter. The low selective value in cows in FLMY groups of 4326-4890 kg (0.84±0.17) and 4891-5455kg (0.78±0.30) could be due to their longer first lactation period and low PHL in the herd. The similar findings were also reported by Mukherjee and Tomar (1996) for crossbred, Kumar (1999) for Hariana, Singh (2001) for Karan Fries and Atrey *et al.* (2005) for Frieswal cattle.

The average selective value (number of female calves reached to the milking herd) from each Holstein Friesian cow at Holeta farm during dry, short rainy and long rainy seasons was estimated to be 1.12±0.10, 1.19±0.15 and 1.08±0.10, respectively. Statistically season effects on selective value were found to be non significant indicating that there were no significant variations in feeding, management and other environmental conditions over all the seasons of a year at Holeta farm. It was observed that the cows in first year (1976) left highest number of replacement heifers (3.0) in the milking herd and there was a decreasing trend in selective value of cows in later years with lowest value (0.14) in the year 1997. The analysis of variance (Table 30) showed that year effects on selective value of Holstein Friesian cows at Holeta farm were highly significant ($P \leq 0.001$). Similar findings were also reported by Mukherjee and Tomar (1996), Kumar (1999), Singh (2001) and Atrey *et al.* (2005).

5.6.6. Coefficient of gene replication (CGR)

Coefficient of gene replication is the additive genetic relationship between the adult female to next generation through contribution of female progenies. A cow having 0.5 CGR is said to have replicated once or produced one female progeny reaching to the milking herd. The average value of CGR (0.56±0.03), estimated for Holstein Friesian herd at Holeta farm, indicated that there was more than one time gene replication from each cow to the future generations in the herd. These observations were in close agreement with the reported CGR value 0.58±0.02 by Rawal *et al.* (1993) for Tharparkar and 0.60±0.11 by Kumar (1999) for Hariana cattle. However, the present

CGR value was higher than those reported CGR value 0.48±0.08 by Schons *et al*. (1985) for Angus, 0.47±0.02 by Tomar *et al.* (1995) for Red Sindhi, 0.39±0.07 by Mukherjee and Tomar (1996), 0.43±0.22 by Singh (2001) Karan Fries and 0.46±0.02 by Atrey *et al*. (2005) for Freiswal cattle but lower than reported CGR value 0.63± 0.02 by Rawal and Tomar (1994a) for Sahiwal cows. The difference in observations of various workers could be attributed to the difference in PHL of cows at different dairy cattle breeding farms.

The CGR according to AFC groups in Holestein Friesian cows herd at Holeta herd indicated that cows in AFC group's ≤886, 887-1042 and 1511-1666 days were not replacing themselves. The estimates of highest CGR value (0.92±0.75) for cows in 1821-1978 days AFC group indicated that most of the cows of this AFC group left two daughters in the herd. This finding agreed with Kumar (1999) in Hariana, Atrey *et al.* (2005) in Frieswal and Kumar *et al.* (2009) for Hariana cattle while Mukherjee and Tomar (1996) for crosbred and Singh (2001) for Karan Fries cattle, reported significant effects of AFC on CGR.

The average CGR values of Holstein Friesian cows under different FLMY groups (Table 29) ranged from 0.29±0.12 in ≤1500 kg to 0.78±0.38 in 2066-2630 kg FLMY group. Further, it could be seen from table 12 that cows in FLMY groups 2066-2630, 2631-3195, 3196-3760, 3761-4325 and ≥5456 kg, have the CGR value more than one (0.50) gene replication and hence they had their full genetic contribution to further generation. The CGR value of less than 0.50 indicated that all the cows could not replace themselves. These results did not agree with those reported be Mukherjee and Tomar (1996) for crossbred, Kumar (1999) for Hariana and Singh (2001) for Karan Fries and Atrey *et al.* (2005) for Frieswal cattle as they observed significant effects of FLMY on CGR.

The CGR for cows' cows grouped according to dry, short rainy and long rainy seasons of birth ranged 0.54±0.05 to 0.59±0.08 (Table 29). Analysis of variance (Table 30) indicated that there was no significant variation among CGR values, reflecting to the uniform management and other environmental conditions prevailing at Holeta farm throughout all the three seasons of the year.

Average CGR values estimated for Holstein Friesian cows grouped according to year of birth revealed that it was highest in the year 1976 (1.5) indicating that cows born in this year contributed on an average 3.0 replacement daughters to the Holeta herd. Thereafter, a decreasing trend was observed. The lowest CGR value (0.07) was observed in the year 1997, indicating that very low proportion of cows born in this year could replace themselves by their own daughters. This finding was contrary to the non significant effects of FLMY on CGR, observed by Mukherjee and Tomar (1996), Kumar (1999), Singh (2001) and Atrey *et al*. (2005). The difference in observations of various workers could be due to difference in PHL of cows maintained in different herds during different.

Generally, longevity, PHL and total calves born were highest for intermediate AFC and FLMY groups indicating the necessity of improving the environment for early calvers and high producers. The continuous decline of lifetime traits through years is a refelection of deterioration of management.

5.7. Genetic Parameters

5.7.1. Heritability of threshold traits

The heritability (Table 31) estimate of 0.16±0.009 for abnormal birth in Holstein Friesian cattle indicated that though the trait is largely influenced by environmental factors (84%) but quite a good amount of additive genetic variance (16%) was available to affect the trait through selection to reduce the chances of abnormal birth in the herd. This finding was in complete confirmity of Rawal and Tomar (1996c). However, the present heritability estimate was higher than those reported by Kumar *et al.* (1991), Lathwal and Kumar (1993), Mukerjee (1993), Rawal and Tomar (1996a) and Atrey *et al.* (2005) as they all have reported heritability values ranging from 0.042 to 0.10 for abnormal birth in different cattle herds. But this estimate was lower than the reports of Lindhe (1967), Kumar (1999), and Singh (2001) as they found h^2

estimate of 0.43, 0.285 and 0.28, respectively in exotic and zebu cattle suggesting that in some conditions the trait could be medium to highly affect by genetics of sire.

The heritability estimate (0.10±0.02) of sex ratio in this study indicated that the variation in sex ratio was mainly due to non genetic reasons and the observed small additive genetic variance (10.0%) could be due to chance factor. This h^2 was in agreement to that of 0.095, reported by Rawal and Tomar (1995) in Sahiwal. Studies conducted in India on indigenous breeds and their crosses showed that the h^2 of sex ratio were lower than present h^2 estimated. Sethi and Rao (1981) in Sahiwal, Lathwal and Kumar (1993) in Red Sindhi, Kumar *et al*. (1993) in crossbreeds, Mukerjee (1993) in Karan Swiss, Rawal and Tomar (1996c) in Tharparkar cattle reported a value of 0.05, 0.016, 0.06, 0.002 and 0.067, respectively. Moreover, Powell *et al.* (1975) in USA found 0.017 estimates in exotic cattle. These reports showed that the variation in sex ratio was mainly due to non genetic factor and random combination of gametes played important role in the determination of sex of the calf.

The heritability estimate (Table 31) of mortality in Holstein Friesian female calves was 0.18±0.03. This heritability value indicated that sufficient additive genetic variance was available to affect the selection for altering the mortality in female calves genetically. Very close findings were reported by Singh (1979) for Red Sindhi, Kulkarni *et al*. (1997) for Tharparkar, Kumar (1999) for Hariana and Atrey (2003) for Frieswal cattle. Medium heritability estimate (0.38) was found in Sahiwal cattle (Lathwal and Kumar (1993). Some authors observed very low heritability for the trait. Parekh and Singh (1981), Lathwal and Kumar (1993), Rawal and Tomar (1996b) and Singh (2001) reported 0.003, 0.001, 0.088 and 0.028 heritability of calf mortality. Moreover, mortality of the calf could be related to the prevalence of diseases and parasites, level of feeding and overall management of cows at the farm. Improvement in these non-genetic factors might be highly helpful in reducing the calf mortality at the farm.

The heritability estimate of culling in Holstein Friesian female calves from birth to AFC was high, 0.71±0.03. This heritability value indicated that additive genetic variance existed among the female progenies of different sires which were culled out and culling rate in female calves of different sires could be altered through selection among the female progenies of the different sires. Moreover, culling in female calves at Holeta farm was the result of poor growth, reproductive problems and susceptibility to diseases and parasites. Some of these factors mentioned might have been influenced by many inherited genes related to the genetic makeup of the calf, hence contributing to the high heritability estimates of the trait. However, lower h^2 values of culling rate than the present estimate were reported by Schwenger *et al*. (1989), Rawal and Tomar (1994b), Mukherjee and Tomar (1997b), Kumar (1999), Singh (2001) and Atrey *et al*. (2005) for different breeds of cattle.

The heritability estimate of replacement rate on the basis of total pregnancies was found to be 0.0±0. This value indicated that no additive genetic variance for the trait existed and the variations in the trait were due to environmental reasons. Moreover, the negative estimate of the sire variance could be due to insufficient sample size for estimating the genetic variance and very large influence of non-genetic factors on the trait. However, small h^2 values of this trait were observed by Rawal (1991), Rawal and Tomar (1992), Lathwal and Kumar (1993), Mukherjee and Tomar (1997b), Kumar (1999), Singh (2001) and Atrey *et al*. (2005) for various cattle herds suggesting that the trait is largely influenced by environmental factors.

Replacement rate from female calf births had high heritability of 0.66±0.029, indicating that high additive genetic variance existed in the herd for replacement rate on female calf basis and sires of the daughter greatly affected the status of female calves reaching to the milking herd (Table 31). Therefore, in breeding programs it is necessary to identify those bulls to breed more cows to maintain or increase the size herd. The present finding was closer to the estimate of 0.57 (Kumar, 1999) in Hariana cattle. However, lower h^2 estimates of 0.11 (Rawal, 1991), 0.28 (Rawal and Tomar, 1992), 0.23 (Lathwal and Kumar, 1993), 0.23 (Mukherjee and Tomar, 1997b) have been reported for different tropical breeds of cattle.

5.7.2. Repeatability of threshold traits

The repeatability estimate of abnormal birth rate was observed as 0.964±0.192. This repeatability value was high, indicating that the variation in the trait was mostly due to permamnent environmental factors affecting the trait in Holstein Friesian cows and culling of cows based on this repeatability value may reduce the abnormal births in the herd. Further, this finding also indicated that the type of calf (normal vs. abnormal) to be born in future gestation can be predicted based on type of calf born in the previous calving. Different findings have been reported by Kumar *et al.* (1991), Rawal and Tomar (1996a), Mukherjee and Tomar (2000), Singh (2001) and Atrey *et al.* (2005) for various Zebu and Crossbred cattle.

The repeatability of sex ratio was found to be very low (0.038±0.0171) indicating that previous sex of the calf did not influence sex of subsequent pregnancy and the prediction of the sex of calf in subsequent calving was not possible based on the sex of calf in previous calving. Similar findings of very low repeatability have been also observed by Seth and Rao (1981), Kumar *et al.* (1993), Rawal and Tomar (1995), Rawal and Tomar (1996c), Kumar (1999), Mukherjee *et al*. (2000), Singh (2001) and Atrey *et al.* (2005) for various Zebu and crossbred cattle.

The repeatability of mortality in female calves observed to be 0.060±0.028. It indicated that frequency of mortality was 6.0% in second female calves of the cows whose first female progenies (calves) were died. This repeatability value was low and showed that the death of previous calf had weak correlation to the survival of next calf. This repeatability estimate can not be considered sufficient to predict the mortality among female calves based on single observation.

The repeatability of replacement rate from total pregnancy was 0.780±0.019. This heritability was high and indicates strong correlation between successive records. The repeatability of replacement rate based on female calves born from a cow was observed as -0.2403±0.022 in Holstein Friesian. This repeatability value was low and negative indicating a weak correlation between successive records of the cow on the trait. This repeatability value could not be used effectively to predict the replacement rate based on female calf born from a cow in subsequent calving.

In summary, sufficient additive genetic variance existed in the herd for abnormal birth, culling and replacement rate from both total pregnancy and female calves born and their frequency can be changed through selection. The inheritance of other threshold characters was low and improvement of the environment could decrease their frequency. Repeatbiltiy of threshold characters was very small and there is weak correlation between successive records.

5.7.3. Heritability estimates of lifetime traits

The heritability estimates of longevity, productive herd life**,** total calves born, total normal calves born, total female calves born, CGR and selective value are given in Table 33. The heritability estimate of longevity in Holstein Friesian herd at Holeta farm was medium (0.31±0.085) in magnitude and indicated that the trait had sufficient additive genetic variance for selection to act upon to alter the longevity of cows in the herd. This h^2 estimate was lower than those reported by Kumar (1999) in Hariana, Singh (2001) in Karan Fries and Atrey *et al.* (2005) in Frieswal cattle.

The medium heritability estimate (0.32±0.088) for PHL indicated sufficient additive genetic variance available to affect the selection to improve the PHL of Holstein Friesian cows at Holeta farm. Similar results were reported by Reddy (1979) for Friesian crosses. This h^2 estimate was higher than those obtained by Hargrove *et al*. (1969) for Holstein Friesian, Reddy and Nagarcenkar (1989c) for Sahiwal, Roger *et al*.(1991) for Jersey, Mukherjee *et al.* (1999) for Karan Swiss and Dalal *et al.* (2002) for Sahiwal and Hariana cattle but lower than the findings of Basu *et al.* (1983) for Tharparkar, Singh and Tomar (1989) for Karan Fries, Kumar (1999) for Hariana, Singh (2001) for Karan Fries and Atrey *et al.* (2005) for Frieswal cattle.

The heritability of total calves born to the daughters of the sires under study was 0.11±0.018. This value of heritability was low suggesting that the trait could not be improved much through selection. Similar low h^2 estimates for the trait were observed by Hargrove *et al*. (1979) for Holstein Friesian and Reddy (1979) for Friesian crosses. However, the present h^2 estimate was lower than those observed by Basu *et al.* (1983) and Rawal (1991) for Tharparkar, Mukherjee and Tomar (1996) for Karan Swiss, Kumar (1999) for Hariana, Singh (2001) for Karan Fries and Atrey *et al*. (2005) for Frieswal cattle. Rawal and Tomar (1994a) obtained a very low h^2 value of (0.02) for Sahiwal herd. Rawal and Tomar (1994a) obtained a negative h^2 value of (-0.20) for this trait in a Sahiwal herd.

The heritability estimate (Table 33) of total normal calves born was found to be 0.12±0.018, which was low and indicated that selection could not be used effectively to improve this trait. The higher h^2 estimates than the present results were observed by Rawal (1991) for Tharparkar, Mukherjee and Tomar (1996) for Karan Swiss, Kumar (1999) for Hariana, Singh (2001) for Karan Fries and Atrey *et al*. (2005) for Frieswal cattle

The heritability estimate of total female calves born in Holstein Friesian herd was low (0.10±0.019) indicating insufficient additive genetic variance to affect the selection to improve the trait through selection. However, Rawal (1991), Kumar (1999), Singh (2001) and Atrey *et al*. (2005) observed medium to high h^2 estimates for the trait. However, Rawal and Tomar (1994a) and Mukherjee and Tomar (1996) reported lower h^2 estimates than the present study.

The heritability of CGR in Holstein Friesian herd was negative (-0.08) indicating insufficient number of observation per sire to estimate presence of additive genetic variance for this trait. The negative sire components of variance are observed due to insufficient sample size and/or presence of large non genetic (environmental) variance affecting the trait. Rawal and Tomar (1994a) and Mukherjee and Tomar (1996) reported h^2 value of 0.02 and 0.04, respectively. However, Singh (2001) and Atrey (2003) found positive and medium value for the triat.

Heritability of female calves reaching to milking herd (selective value) for Holeta herd was high (0.66) strongly suggesting the existence of additive variances among daughter of different Holstein Friesian sires. Female calves obtained from high breeding value sires had high probability of joining milking cows. This is supported by the findings of Kumar (1999) and Singh (2001) who reported heritability of 0.72 and 0.49, respectively. However, Rawal (1991) for Tharparkar, Mukherjee and Tomar (1996) for Karan Swiss and Atrey *et al*. (2005) for Frieswal cattle observed lower h^2 estimate than the present study.

Therefore, longevity, productive herd life and selective values have sufficient additive genetic variance among the daughters of different sires and the same can be improved through selction. Other components of selective values can be improved by upgrading the environment.

5.8. First Lactation Traits

5.8.1. General means for first lactation traits

The general means±SD for AFC along with standard deviation and coefficient of variation (Table 34) revealed that average AFC, FSP, FDP, and FCI in Holeta herd were unusually very long with large standard deviation and coefficients of variation indicating poor feeding, breeding, and health management of the herd. The average FLP was observed to be almost optimum. The first lactation total milk yield as well as on 305 day milk yield were comparable to the reports in the literature. All the averages for first lactation traits and non genetic factors affecting them will be discussed under the next head of least square means and non genetic factors affecting first lactation traits.

5.8.2. Non genetic factors affecting first lactation traits

The least squares mean of AFC in Holstein Friesian cows at Holeta farm was estimated as 1225±14.6 days (Table 35). This finding was in close agreement to those of Prasad (1983) for Red Sindhi×(Jersey×Sahiwal) and Jersey×(Red Sindhi×Sahiwal) and Nayak and Raheja (1996) for Jersey×(Friesian×Hariana) crossbreds. However, this average AFC was higher than the AFC reported by Rathi (1984), Suresh Chandra and Sharma (1985), Viz and Basu (1986), Prasad (1986), Rai (1986), Kumar (1987), Singh and Bhat (1987), Tajani *et al*. (1990), Prasad *et al.* (1990), Kumar (1992), Jain *et al.*(1995), Banerjee (1996), Tomar *et al.*(1996), Jadahav *et al.*(1996), Poharkar *et al*. (1996), Nayak and Raheja (1996), Raheja (1997), Gaur (2001) and Bharti (2004) for various crossbred cattle but it was lower than the AFC reported by Nayak *et al.* (1996) for Brown Swiss×(Friesian×Hariana) crossbred cows. The difference in mean AFC reported as by different workers could be attributed to genetic and managemental reasons. However, the early puberty can be achieved by providing better nutrition, health and management and therefore, comparatively higher AFC in Holstein Friesian at Holeta farm indicate the overall poor quality feeding and management of heifers at Holeta farm.

The year wise least squares means (Table 35) of AFC in Holstein Friesian cows ranged from lowest (803±19.1 days) in the year 1999 to highest (1688±89.2 days) in the year 1976 and generally the average AFC were higher during early years and showed reducing trend during later years. The analysis of variance (Table 36) showed that year differences in AFC of Holstein Friesian cows at Holeta farm were highly significant ($P \leq 0.001$). These results were in conformity of the reports of Taneja and Bhat (1974), Jain and Dhillon (1975), Kaushik *et al.* (1978), Kumar (1987), Jadhav and Khan (1996), Raheja (1997), Narang *et al*. (2001), Banerjee (2002) and Dahiya *et al.*(2003) as they all have found significant period/year of calving effects on AFC in crossbred cattle but contrary to the report of Nayak and Raheja (1996) and Bharti (2004) as they have observed non significant effects of period of calving on AFC in crossbred cattle.

Analysis of variance for the differences in least squares means of AFC for HF cows born in dry, short rainy and long rainy seasons at Holeta farm indicated that season effects were non-significant. It is clear that there was management difference throughout the study period though difficult to quantify its effect on the traits. Therefore the result doesn't garnatee uniformity. Moreover, there could be confounding of factors which makes difficult to separate individual effects. These findings were in agreement with the reports of Raheja and Balain (1976), Subodh Kumar (1992), Nayak and Raheja (1996) Raheja (1997), Narang *et al*. (2001), Banerjee (2002), Dahiya *et al.* (2003) and Bharti (2004), but did not agree with the reports of Kaushik *et al*. (1978), Roy (1983), Kumar (1987), Butte and Deshpande (1987), Upadhyaya (1989), Tajane *et al.* (1990), Subodh Kumar (1992), Jadhav and Khan (1996), and Nayak and Raheja (1996), as they have observed significant effects of season on AFC in the crossbred cattle.

The least squares mean (±se) of FSP in Holstein Friesian cows at Holeta farm was estimated as 256±7.3 days (Table 35). This average FSP was unusually long and reflects to the poor feeding, breeding and post partum health management of the herd. Lower FSP have been reported by Singh (1982), Prasad (1985), Kumar (1987), Sreemannarayana *et al*.(1995), Jain *et al*. (1995) and Singh *et al*. (2000), Gaur (2001) and Kumar *et al*. (2003) for different crossbred cattle herds. However, Bharti (2004) observed longer FSP for Frieswal cattle. The difference in observations of different workers may be partially due to genetic causes and to a great extent due to variations in managemental practices.

The year wise least square means of FSP in Holstein Friesian cows at Holeta farm ranged from 155 days in the year 2000 to 389 days in the year 1984. The analysis of variance (Table 36) showed that year differences in FSP were highly significant ($P \leq 0.001$). This finding agreed with Rao and Sudresan (1982), Duc and Taneja (1984), Sahana and Gurnani (2000), Singh *et al.*(2000), Gaur (2001) and Dahiya *et al.* (2003) as they all have reported significant variations in FSP due period/year of calving in crossbred cattle. However, non-significant differences in FSP due to period of calving were found by Kuralkar *et al*. (1995b) and Bharti (2004) in crossbred cattle.

The season of calving was found to have no significant effect on FSP in Friesian cows under the present study. This was in agreement with the reports of Singh *et al.* (2000) and Bharti (2004). Statistically, significant differences in FSP over season of calving were reported by Bhat *et al.* (1978), Duc and Taneja (1984), Jadhav *et al.* (1991), Sahana and Gurnani (2000), Gaur (2001) and Dahiya *et al.*(2003) in crossbred cows.

The least square mean of FDP in Holstein Friesian art Holeta farm was found to be 203±8.0 days, which was abnormally long indicating that cows were out of production for a very long time. This could be mainly due to poor feeding and breeding management of the lactating Friesian cows at Holeta farm. This finding agreed with those of Kumar (1994) for Friesian (Jersey×Sahiwal) and over FDP for various crossbred cows. However, lower FDP have been reported by Chaudhary (1983), Roy *et al.*(1983), Rathi (1984), Suresh Chandra and Sharma (1985), Prasad (1986), Bhatnagar *et al.* (1986), Butte and Deshpande (1987), Roy *et al.*(1987), Singh *et al.*(1989), Singh *et al.*(1990), Taneja *et al.*(1990), Kumar (1993), Dalal *et al.*(1993), Kumar (1994), Kumar (1994), Banerjee (1996), Tomar *et al.*(1996), Singh *et al.* (1997), Sreemannarayana *et al.* (1995) and Nayak *et al.* (1996) Gaur (2001) and Bharti (2004) for various crossbred cow herds. The observed differences in the average FDP of crossbred cows at different cattle farms as reported by various workers could be due to difference in managemental practices followed at different farms.

The least squares means for FDP in Holstein Friesian cattle at Holeta farm ranged from shortest of 83±10.1 days in the year 1976 to the longest 288±45.8 days in the year 1995 (Table 35). This finding was in agreement with those of Deshpande *et al.* (1992), Garcha and dev (1994) and Nayak and Raheja (1996) as they have observed significant variations in FDP due to period/year of calving in crossbred cattle. But non-significant year effects on FDP have been reported by Singh *et al.*(1993), Sahana and Gurnani (2000) and Bharti (2004) in crossbred cattle.

The FDP in Friesian cows at Holeta farm was found to be non-significantly influenced by season of calving (Table 36). Non significant effects of season of calving on FDP agreed with the reports of Subodh Kumar (1992), Singh *et al.*(1993) Sahana and Gurnani (2000), Gaur (2001) and Bharti (2004) in different crossbred cattle.

The least square mean of FLP in Friesian cows at Holeta farm was found to be 327±4.6 days, which was higher than the standard lactation period of 305 days, considered for most efficient production and reproduction in dairy cattle. This average FLP agreed with the reports of Teotia (1984), Kumar (1994) and Banerjee (1996) for different crossbred cattle; Besufekad (2008) and Berihanu (2009) for Friesian cattle. The mean FLP were found to be higher than those reported by Srivastava (1986), Sharma *et al*. (1989), Tajane and Rai (1989), Tomar *et al.*(1996), Narang *et al.*(2001), Suresh chand (1982), Chaudhary (1983), Rathi (1984), Singh (1984), Suresh Chand and Sharma (1985), Prasad (1986), Chaudhary (1987), Kumar (1987 and 1993), Gogoi *et al.*(1992), Kumar *et al.*(2003) and Bharti (2004), for various dairy cattle. However, the present average FLP in Holestein Friesain cows at Holeta farm was found to be lower than those reported by Herbert *et al.* (1980), Parmar *et al*. (1986), Kumar (1992), Dalal *et al.*(1993), Kumar (1994), Nayak *et al.*(1996), Shettar *et al*.(1999), Singh *et al.* (2000) and Gaur (2001), for different crossbred cattle. The difference in observation of various workers could be attributed to genetic and environmental reasons.

The least squares means for FLP during different years varied from shortest of 274±58.0 days in the year 1984 to longest of 408±41.7 days in the year 1976 in Holstein Friesian and the observed differences were found to be statistically significant ($P \leq 0.05$). This indicated the variations in feeding and management practices of milking herd over years of study at Holeta farm. The finding was in agreement with those of significant effects of year on FLP reported by Reddy and Basu (1985), Milagres *et al*. (1988 b), Garcha and Dev (1994), Settar and Govindaiah (1999) and Gaur (2001) in crossbred cows. But did not agree with those of non-significant effects of period of calving on FLP observed by Nehra *et al.* (1987), Singh *et al.* (1996), Nayak and Raheja (1996) and Bharti (2004) for different crossbred cattle.

The average FLP in Holstein Friesian cows calved during dry, short rainy and long rainy seasons were estimated as 314±5.4 days, 346±11.5 days and 334±8.6 days, respectively. Significant effects of season of calving on FLP have been reported by Milagres *et al*. (1988 b), Singh *et al.* (1996), Gaur (2001) and Narang *et al*. (2001) in crossbred cattle while non significant season effects on FLP were observed by Nehra *et al.*(1987), Tajane and Rai (1989), Subodh Kumar (1992), Nayak and Raheja (1996), Raheja (1997) and Bharti (2004) for different crossbred cattle.

The least squares mean of first lactation 305 DMY at Holeta farm was estimated as 3084±47.6kg and closer to the 2926kg estimated by Besufekad (2008) for the same farm.

The averages of first lactation 305DMY ranged from lowest of 2340±208.2kg in the year 1984 to highest 4710±245.3kg in the year 2000 (Table 35) and analysis of variance (Table 36) showed that observed year differences were statistically highly significant ($P \leq 0.001$). Singnifcant year effect on first 305DMY was also reported by Bsufekad (2008) for Friesian cattle.

The average first lactation 305DMY during dry, short rainy and long rainy seasons were observed as 3096±66.5kg, 3235±91.4kg and 3093±92.8kg and analysis of variance (Table 36) revealed that season differences were statistically non significant. Similarly, Besufekad (2008) reported that season of calving had no significant effect on first lactation of 305 DMY.

The least squares means of first lactation milk yield (Table 35) were found to be 3260±53.6kg. The average obtained was closer to the 3157kg and 3241kg reported for Friesian cattle by Mureja (1994) and Birhanu (2009), respectively. The FLMY in the present study was lower than that reported by Singh *et al.*(1981), but was higher than those reported by Viz and Basu (1986), Parmar *et al.* (1986) Singh *et al.* (1987), Mishra *et al*. (1989), Singh (1989), Sachdeva and Gurnani (1989), Tajane and Rai (1989), Singh and Tomar (1990), Jain *et al.* (1995), Singh *et al.*(1996), Tomar *et al.* (1996), Singh *et al.* (2000), Narang *et al.* (2001), Gaur (2003), Kumar *et al*. (2003), Bharti (2004) and Atrey *et al.* (2005) for various crossbred cattle herds maintained at different locations. The difference in observations could be attributed to genetic and environmental reasons. However, the observed FLMY in the Holeta herd was higher than most of the observations reviewed, which generally were for different crossbred herds, reflects the superiority of Friesian cows over their crossbreds for milk production and the additive type gene inheritance mainly controlling the milk production.

The least squares means of FLMY for cows calved during different years ranged from a lowest of 2220±339.7kg in the year 1984 to a highest of 4794±249.3kg in the year 2000 (Table 35) and the observed year differences in FLMY were found to be highly significant (P≤0.001). This could be due to the use of sires with different genetic potentials for milk yield and variations in feeding and management practices over years. These significant year effects on FLMY were agreed with the reports of Khanna and Bhat (1972), Taneja and Bhat (1974), Jain and Dhillon (1975), Prakash and Sahu (1978), Roy (1983), Kumar (1987), Garcha and Dev (1994), Raheja (1997), Shettar and Goindaiah (1999), Gaur (2001), Narang *et al.*(2001), and Bharti (2004) in different crossbred cattle. However, non-signifcant effects of year of calving were reported by Deshpande and Bonde (1983), Prasad (1983) and Nayak and Raheja (1996) in crossbred cattle.

The least square means of FLMY for cows calved during dry, short rainy and long rainy seasons were estimated as 3214±77.0kg, 3491±110.5kg, and 3288±98.9kg, respectively. The season effects on FLMY of Holstein-Friesian cows were found to be non significant (Table 36). This indicated uniform feeding, management and climatic conditions over different seasons of the year at Holeta farm. These findings were in agreement with the reports of Raheja and Balain (1976), Prasad (1983), Roy (1983), Bhatnagar *et al.*(1986), Kumar (1987), Singh (1987), Taneja and Rai (1989), Subodh Kumar (1992), Nayak and Raheja (1996), Raheja (1997), Singh *et al*. (2001) and Bharti (2004) in different crossbred cattle, while significant effects of season of calving on FLMY were reported by Prakash and Sahu (1978), Deshpande and Bonde (1983), Frietas *et al.*(1991), Garcha and Dev (1994), Shettar and Govindaiah (1999), Sahana and Gurnani (2000) ans Gaur (2001) in crossbred cows. The significant season effect indicates differences in feeding, management and wide climatic variations over different seasons of the year.

The least squares means for FCI estimated was 523±7.0 days which was unusually very long. The reason for such a long FCI was the observed very long service period in the herd as gestation period is the least variable trait, and the length of calving interval is mainly determined by length of service period. The average FCI observed in this study was higher than those reported by various workers and reviewed for different crossbred cattle (Roy, 1983; Viz and Basu, 1986; Mishra *et al.,* 1989; Singh *et al.*, 1990; Jain *et al.*, 1995; Sreemannarayana *et al.,* 1995; Bharti *et al.,* 1996; Nayak *et al.,* 1996; Poharkar *et al.*, 1996; Raheja, 1997; Gaur, 2001; Kumar *et al.*, 2003 and Bharti, 2004). The difference in observations could be due to difference in feeding and managemental practices followed at different dairy cattle farms.

The least squares means of FCI according to their year of calving varied from a lowest of 430±23.3 days in the year 2000 to longest of 665±65.5 days and analysis of variance (Table 36) showed that year differences in FLMY were statistically highly significant ($P \leq 0.001$). Significant effect of birth year was also observed by Shana and Gurnani (2000), Singh *et al.* (2000), Gaur (2001), Dahiya *et al.* (2003) and Bharti (2004) in crossbred cattle. However, Reddy and Basu (1985) and Raheja (1997) were found non-significant effect of in crossbred cattle.

The least squares means of FCI of Holstein Friesian cows calved during dry, short rainy and long rainy seasons were estimated as 513±9.2, 522±16.9 and 519±12.4 days, respectively. Similarly, Subodh Kumar (1992), Raheja and Balain (1996), Nayak and Raheja (1996) and Singh *et al.* (2000) reported non-significant effects of season of calving on FCL.

5.8.3. Genetic parameters of first lactation trait

5.8.3.1. Heritability

The heritability (Table 37) for AFC was high in magnitude (0.53±0.116) and this estimate indicates sufficient additive genetic variance for affecting the selection to reduce the AFC in the Holeta herd. This h^2 estimate agreed with Gill and Allaire (1976) who has observed almost similar h^2 estimate (0.51) for AFC in Holstein cows. However, the present h^2 estimate was lower than the reports of Harville and Henderson (1966), Rathi (1984), Souresh Chand and Sharma (1985) who have found very high h^2 values, 0.74, 0.78±0.16 and 0.75±0.12, respectively for AFC, but this h^2 value was higher than the results of Sachdeva and Gurnani (1989), Banerjee (1996), Singh *et al.* (1996) who have reported h^2 values of 0.42, 0.41 and 0.46, respectively. These reports indicated that there was wide genetic variation for AFC in different cattle breeds. Early study (Allaire and Lin, 1977) on 3245 institutional herds in Ohio herds in California, however, showed lower h^2 of AFC (0.22 and 0.23, respectively) than the current study. Similarly, Montaldo *et al.* (2010) studied heritability and correlation of lactation traits of Holstein cows in Mexico and found moderate h^2 (0.28) for AFC.

The h^2 estimates (Table 37) for FLMY and 305DMY were 0.23±0.102 and 0.23±0.106. This shows that the inheritance pattern for both traits is similar and indirect selection can be used for improvement. The present h^2 estimate was in complete agreement to the value of 0.23 reported by Singh *et al.*(1990) and Gaur (2003) in Friesian×Sahiwal genetic group and Rai *et al.* (1996) in Jersey×Sahiwal genetic group. A slightly different h^2 value of 0.33 for first lactation yield was reported for Holstein Friesian cows (Schneider and Van Vleck, 1985). Higher h^2

estimates for FLMY were reported by Singh (1976), Singh (1982), Suresh Chand and Sharma (1985), Sachdeva and Gurnani (1989), Tajane and Rai (1989), Rao and Nagercekar (1992) and Tomar *et al.* (1996). They found 0.43, 0.56, 0.89, 0.51, 0.48, 0.48 and 0.77 for Holstein Friesian crosses, respectively. Lower h^2 of 0.17 was reported for Holstein cows in Mexico (Montaldo *et al.*, 2010). Earlier study showed that h^2 value depends on herd average. Lofgren *et al*. (1985) showed that the heritability for Holstein cows producing low, medium and high yield were 0.222, 0.163 and 0.206, respectively.

The h^2 estimate (Table 37) for FLP was 0.28±0.124 indicating presence of additive genetic variance to affect the individual selection for improving the trait though trait is largely affected by environmental factors. Medium estimates of 0.36 and 0.43 for h^2 of FLP were reported by Tomar *et al.* (1996) and Gaur (2003) for Friesian crosses. Very low values of 0.01, 0.02 and 0.01 were reported by Tajan and Rai (1989), Dalal *et al.* (1993) and Banerjee (1996) indicted environmentally controlled nature of the trait.

The service period is the period between calving to conception and is economically very important in dairy cattle, as it determines the length of calving interval. The h^2 for FSP was 0.26±0.113. This h^2 indicated that additive genetic variance was available to affect the selection to improve the trait genetically in HF herd at Holeta farm and appears to be against the non-genetic environmentally controlled nature of the trait. However, as per the nature of the trait it is largely controlled by feeding, management and post partum health care of the cow. This finding was in agreement with Kumar *et al.* (2003) for Jersey with Sahiwal cross. Guar *et al.* (1999) and Guar (2003) reported 0.65 and 0.49, respectively for Friesian×Sahiwal crosses. Much lower h^2 value of 0.02 was found for Frieswal cattle (Bharti, 2004).

Heritability (Table 37) for first dry period was 0.24±0.117 indicating that some additive genetic variance was available to affect selection for optimizing the dry period in Holstein Friesian herd at Holeta farm. Tomar *et al.* (1996), Guar *et al.*

(1999) and Guar (2003) found h^2 estmates of 1.0, 0.67 and 0.43, respectively for Friesian crosses with Sahiwal. Very low h^2 estimates of 0.09, 0.10 and 0.01 were reported for the same genetic group by Butte and Desphande (1987), Singh *et al.* (1990) and Taneja *et al.* (1990), respectively.

The h^2 for FCI in the Holeta herd was 0.28±0.141. This h^2 value also indicated that additive genetic variance exist to affect the selection for the improvement of first caving interval in Holstein Friesian herd at Holeta farm. Higher h^2 estimates of 0.36 and 0.52 than the present study were reported by Chaudhary (1983) and Gaur (2003), respectively. Very low h^2 estimates were found elsewhere. Rathi (1984) and Suresh Chand and Sharma (1985), and Montaldo *et al.* (2010) noted 0.04 and 0.07, 0.01, respectively. Moreover, Butte and Deshpande (1986), Banerjee (1996) reported 0.11 and 0.13, respectively.

5.8.3.2. Correlations

AFC with other traits

The phenotypic and genetic correlations of AFC with FLMY (0.060±0.05 and 0.234 ±0.26) and 300DMY (0.043±0.05 and 0.191±0.26) were positive but non significant while environmental correlations were negative but small (-0.036 and -0.039). These correlations indicated that higher AFC were related with higher FLMY and 300DMY due to genetic reasons in the Holstein Friesian cow herd at Holeta farm though at environmental level high AFC were found related with lower first laction milk yield on total as well as 305 day lactation basis. This could be due to that cows sexually maturing and calving at older age because of genetic reasons will attain bigger body size and hence is likely to produce more milk than cows maturing and calving at a younger age. However, cows attaining maturity and calving at a older age due to environmental reasons, especially due to poor feeding and management, possibly will have poor body condition and will produce lower milk yield. Similar positive phenotypic and genetic relationships were between AFC and FLMY have been reported by Chaudhary (1983), Rathi (1984) for F×S, Jadhav *et al*. (1996), Suresh Chand and Sharma (1985), Kumar (1992), Jain *et al.*(1995), Akhter (1998), Gaur *et* *al.*(1999) and Bharti (2004) in various crossbred cattle herds. However, negative genetic and phenotypic relationships of AFC with FLMY have been reported by Suchdeva and Gurnani (1989), Prasad (1986) for Jersey×Sahiwal, while only negative genetic correlations were reported by Rathi (1984) for Red Sindhi×Sahiwal cattle and kumar (1987) in Jersey×Sahiwal crossbred cattle.

The phenotypic, genetic and environmental correlations (Table 39) between AFC and FLP were all positive but very small and non-significant (0.027±0.05, 0.008±0.25and 0.058) and agreed with Jadhav *et al.*(1996) who has reported almost similar positive and non-significant correlations between these traits. However, Akhter (1998) found positive and significant relationship at all levels while Gaur *et al.*(1999) and Bharti (2004) observed negative phenotypic and genetic correlations between these traits in Friesian×Sahiwal crossbred cattle.

The phenotypic, genetic and environmental correlations of AFC with FSP were estimated as 0.007±0.05, -0.154±0.26, and 0.109, respectively (Table 38), indicating that phenotypically higher AFC were associated with longer FSP due to environmental reasons while on genetic scale reverse was true and higher AFC were associated with shorter FSP in Holeta herd. The negative genetic correlation was in agreement with Gaur *et al.* (1999) and Bharti (2004) in Friesian×Sahiwal but did not agree with Jain *et al.* (1995), who has observed positive genetic relationship between these trats.

The correlations of AFC with FDP were -0.011±0.05, -0.203±0.27 and 0.100 for phenotypic, genetic and environmental, respectively. These negative phenotypic and genetic correlations revealed that higher AFC were related to shorter FDP essentially due to genetic reason while on environmental level higher AFC were associated with longer FDP in Holstein Friesian cows. These correlations indicate that cows with higher AFC due to genetic causes might have attained optimum body weight by first calving age which in turn has reflected in terms of better lactation performance including low service period, longer lactation period and shorter dry period. However, higher AFC due to environmentl reasons might have resulted from poor growth rate and suboptimum body weight in turn lowering the performance for all first lactation traits including longer FDP in such cows. These negative genetic and phenotypic correlations can be supported with the findings of Rathi (1984), Singh and Tomar (1996), Akhter (1998) and Bharti (2004) in crossbred cattle. Contrary to the reports of Gaur *et al.*(1999) who has observed positive genetic and phenotypic correlation between these traits. Negative phenotypic but positive genetic relationships between these traits were also reported by Prasad (1986), Kumar (1994), and Banerjee (1996) in crossbred cattle.

The phenotypic, genetic and environmental correlations of AFC with FCI were 0.013±0.05, -0.142±0.27 and 0.115, respectively. The negative genetic correlation between AFC and FCI in Holstein Friesian cows indicated that lower AFC due to genetic reasons were associated with longer FCI, but on environmental level lower AFC were related to longer AFC. The possible reasons may be that cows maturing and first calving at a younger age due to genetic reasons may not attaine optimum body size and weight and hence is likely to suffer with reproductive problems at the time of parturition and also during first lactation performance, including prolonged FSP and FCI in such cows. While cows maturing and calving at older age genetically will have optimum body weight/condition and well developed reproductive system. Such cows are likely to perform better for first lactation traits, including shorter FSP resulting in shorter FCI. The small and positive phenotypic correlation indicates that cows with higher AFC had longer FCI and it was because of environmental reasons, as indicated by positive environmental correlation. This could be due to that cows maturing and calving late at higher age due to poor environmental conditions viz. inadequate feeding, management and disease control etc. may not have good body condition resulting in to poor performance for first lactation traits incuding longer FCI. Similar positive phenotypic and negative genetic correlations between AFC and FCI have been observed by Chaudhary (1983) in Friesian×Sahiwal and Jersey×Sahiwal and Rathi (1984) in Jersey×Sahiwal in crossbreds and Bharti (2004) in Frieswal cattle. However, Rathi (1984) for Friesian×Sahiwal, Suresh Chand and

Sharma (1985) in Friesian×Sahiwal and Red Sindhi×Sahiwal, Jadhav *et al*.(1996) in Friesian×Sahiwal, Jain *et al.* (1995), Akhter (1998) in crossbred have reported positive genetic and phenotypic correlations while Prasad (1986) observed negative relation ships between these traits.

FLMY and 305 DMY with other traits

The phenotypic, genetic and environmental correlations of FLMY with 305DMY were 0.900±0.02, 0.793±0.12 and 0.893, respectively which were all positive and highly significant indicating that higher FLMY were associated with higher 300DMY on phenotypic scale essentially due to both genetic and environmental reasons (Table 39). Very high correlations of FLMY with 305DMY showed that sires can be evaluated for milk yield on either of the trait and improvement on one trait could bring a concomitant increase on the other.

The phenotypic, genetic and environmental correlations of FLMY and 305DMY with FLP were 0.545±0.04, 0.317±0.07 and 0.630; and, 0.229±0.05, -0.221±0.40 and 0.371, respectively. The positive and significant correlations indicated that higher first lactation milk yields on total lactatation length as well as on 305 day lactation basis were associated with longer lactation period in Holstein Friesian cows and selection for higher FLMY will increase length of lactation period. These results can be supported with the similar finding of Taneja *et al.*(1978), Chudhary (1983), Banerjee (1996) and Gaur *et al.*(1999), Rathi (1984), Suresh Chand and Sharma (1985), Singh and Tomar (1996), Akhter (1998) and Bharti (2004) reported in various crossbred cattle. However, negative genetic correlation of 305DMY with FLP can be explained with the reasons that when milk yield of lactations of more than 305 days is adjusted to 305 day lactation period using per day average yield than on genetic basis it take reverse trend and milk yield is reduced as the length of lactation period increases. So it can be concluded that on genetic scale higher 305DMY was related to optimum lactation length. Negative genetic correlation of FLMY with FLP was reported by Prasad (1986) in J×S crossbred cattle.

The phenotypic and genetic correlations of FLMY and 305 DMY with FSP were -0.113±0.05, -0.692±0.31 and -0.072, respectively and -0.228±0.05, -0.867±0.27 and-0.028 respectively, which were negative and indicated that higher FLMY on total as well as on 305 lactation basis were associated with lower FSP on phenotypic scale essentially due both genetic and environmenatal reasons and cows with higher FLMY or 305 DMY conceived early and have shorter FSP. These observations were contrary to the findings of Gaur *et al*. (1999), Jain *et al.*(1995) and Bharti (2004), as they all have reported positive relation ships between these traits in crossbred cattle at all levels.

The phenotypic, genetic and environmental correlations of FLMY and 305DMY with FDP were -0.414±0.04, -0.844±0.22 and -0.280; and -317±0.05, -0.656±0.28 and -0.213, respectively. These correlations were all negative indicating that higher FLMY were related with shorter FDP and selection for higher FLMY or 305 DMY will reduce the FDP or selection of sires for short dry period could improve the milk yield in Holstein Friesian cattle at Holeta farm. These correlations were in agreement with the reports of Rathi (1984), Singh and Tomar (1996), Akhter (1998) but did not agree with Jain *et al.*(1995), Gaur *et al.*(1999), and Bharti (2004) as they have found positive genetic and phenotypic relationships between these traits in various brossbred cattle. However, Prasad (1986), Kumar (1994) and Banerjee (1996) have reported negative phenotypic but positive genetic correlation between FLMY and FDP in crossbred cattle.

The phenotypic, genetic and environmental correlations between FLMY and 305DMY with FCI were -0.056±0.05, -0.724±0.33 and 0.018, respectively -0.173±0.05, -0.781±0.31 and 0.034, respectively. The negative and significant phenotypic and genetic correlations indicated that higher FLMY and 305DMY were associated with shorter FCI, on phenotypic scale due to genetic reasons. These correlations as expected were in complete accordance of the above observed correlations of FLMY and 3005DMY with FSP in Holstein Friesian cattle because length of FCI is determined by the length of FSP and so relationships with both traits also behave in similar way. The observed negative genetic and phenotypic correlations between these traits were observed by Kaul (1987) in Friesian×Sahiwal cattle, Chaudhary (1983), Suresh chand and Sharma (1985), Gaur *et al.*(1999), Jain *et al.* (1995), Akhter (1998) and Bharti (2004) have reported both as positive relationships in different crossbred cattle herd. The environmental correlations were found positive but very small.

FLP with other traits

The phenotypic, genetic and environmental correlations of FLP with FSP were found as 0.163±0.05, 0.435±0.23 and 0.059, respectively. These correlations were all positive and former being significant (Table 39), indicating that Holstein Friesian cows with longer FLP were associarted with longer FSP on phenotypic scale due to both genetic and environmental reasons.These positive correlations completely agreed with the reports of Akhter (1998), and Bharti (2004).

The phenotypic, genetic and environmental correlations of FLP with FDP were estimated as -0.423±0.04, -0.150±0.34 and -0.516, respectively. These correlations were all negative and significant (Table 39). These correlations revealed that observed negative phenotypic relationship between FLP and FDP was due to both genetic and environmental reasons and any efforts in the direction of reducing FDP through improvement in management (environmental) conditions will improve the FLP in the herd. This finding was in agreement with the observation of Akhter (1998) in Jersey×Sahiwal crossbred cattle but did not agree with those of Chaudhary (1983), Rathi (1984), and Bharti (2004) in Frieswal cattle. However, Suresh Chand and Sharrma (1985), Banerjee (1996), and Gaur *et al*. (1999) have observed negative genetic but positive phenotypic correlations between these traits in different cross bred cattle herds. Kumar (1994) and Prasad (1986) estimated negative phenotypic and positive genetic correlations between these traits in crossbred cattle.

The phenotypic, genetic and environmental correlations between FLP and FCI were 0.200±0.05, 0.285±0.34 and 0.166, respectively which were all positive and highly significant (Table 39). These correlations indicated that longer FLP were associated with longer FCI on phenotypic scale and this was due to both genetic and environmental reasons and any increase in FLP of cows either due to genetic or environmental reasons will increase FCI in Holstein Friesian cows at Holeta farm. The obseverved relationship of these traits agreed with the reports of Desphande and Bonde (1983), Rathi (1984), Suresh Chand and Sharma (1985), Prasad (1986), Gaur *et al.* (1999) and Bharti (2004).

FSP with other traits

The phenotypic, genetic and environmental correlations of FSP with FDP were 0.719±0.03, 0.707±0.16 and 0.723 and with FCI were 0.899±0.02, 0.986±0.04 and 0.868 respectively. These correlations were all positive and significant (Table 39) and indicated that longer FSP were associated with longer FDP and FCI in Holstein Friesian cows at Holeta farm. The high positive correlations of FSP with FDP and FCL showed that reducing the FSP either due to genetic or environmental reasons will shorten the duration of both traits. These results were in agreement with the reports of Jain *et al.* (1995), Gaur *et al.*(1999) and Bharti (2004) for different crossbred cattle herds.

FDP with FCI

The correlations between FDP and FCI were found to be positively correlated on phenotypic, genetic and environmental scales and their coefficients were 0.727±0.03, 0.936±0.12 and 0.653 respectively. The phenotypic correlation between the traits was positive and highly significant (Table 39). These correlations indicated that longer FDP on phenotypic scale were associated with longer FCI due to both genetic and environmental reasons in Holstein Friesian cows at Holeta farm. This suggested that both the traits are controlled by similar genetic and environmental conditions and improvement in one trait will automatically improve the other trait. These results agreed with the reports of Singh (1979), Chaudhary (1983), Desphande and Bonde (1983), Rathi (1984), Prasad (1986), Kumar (1994), Banerjee (1996) and Gaur *et al.*

(1999), and Bharti (2004) as they all have observed positive correlations between these traits in different crossbred cattle herds.

From the above discussion it is clear that year significnaly affected all the traits and only FLP was affected by season of birth. The h^2 values were medium for all frist lactation traits, except AFC, indicting the possibility of improving the traits by selection. The high h^2 of AFC showed the importance of incuding the trait in the selection index chriteria when genetic improvement is sought. Further, FLMY and 300DMY have similar inheritance and had high correlations indicating the possibility of using the traits interchangeably. It was also noted that increament in the length of FSP, FDP, and FCI will reduce FLMY and 305DMY since there exists high and negative correlations among the traits. High and positive correlations among FSP, FDP and FCI indicate that reduction of the length of one triat can have subsequent result on the others.

6. CONCLUSIONS AND RECOMMENDATIONS

The study was conducted on Holstein Friesian cows maintained at Holeta Bull Dam Station with the objectives of estimating demographic parameters, genetic and non genetic factors affecting replacement rates, selective values and first lactation traits. Demographic parameters were studied from lactation records of 901 cows. About 3092 birth records spread from 1979 to 2003 were used to quantify replacement rate and its components. Selective value and its components were studied from records of 364 cows that had disposal records and normal first calving. Effects of year (25), season (3) and parity (9) for replacement rate were considered as fixed factors in the general linear model. Moreover, AFC and FLMY each grouped in to 9 classes based on $1/2\sigma$ of the traits were included in the model as fixed effect for analysis of selective value. Genetic parameters for threshold characters were analyzed for 2983 births obtained from 118 sires. Forty eight sires that had more than 3 daughters (a total of 433 cows) were used to estimate genetic parameters for first lactation traits. General linear model procedures were employed for replacement rate and selective values and their components. Heritability and repeatability for threshold characters were estimated from one-way variance analysis. Restricted maximum likelihood method was used to estimate phenotypic, genetic and environmental correlations between first lactation traits. Simple and multiple regressions were fitted for prediction of life time milk production.

The probabilities of a cow being lost from the herd and survival rate during the first lactation were 0.2619 and 0.7381, respectively. The lactation specific expected herd life of cows present in the herd at the first lactation was observed as 2.46 lactations and there was a decreasing trend and the value reached to 0.0011 at the 12^{th} lactation. The probability of producing a live female calf by a cow at her first lactation was 0.4808. The lactation specific reproductive value of cows at the 1st lactation was 1.0448 and all other lactations had less than one. The overall life time mean lactation of cows present in the herd, mean lactation of cows lost from the herd, mean rate of loss per cow per lactation, average life expectancy at birth, net reproductive rate and generation interval were 3.4949, 4.3548, 0.3204, 1.2825, 1.4948 and 3.5451, respectively.

The average incidences of abnormal and normal birth rates based on total pregnancy were 12.0% and 88.0%, respectively. Parity, season and year of calving significantly affected abnormal births and the highest incidence was noted in first calvers and during the dry season. There were high male births (52.5%). The average mortality rate of female calves before reaching age at first calving was 23.0% and the trait was significantly affected by parity and year of calving. Mortality of calf in different years ranged from 7.3% in 1989 to 48.5% in 1999. The average culling rate of female calves up to age at first calving was 7.0% and was affected only by birth year. The overall rate on the basis of female calf births and total pregnancy were 70.0% and 29.0%, respectively. There was no definite relationship between dam's parity and replacement rate although the observed differences in replacement rates between dam's parity of lactation were found to be highly significant. Year of calving affected replacement rate on female calf basis and ranged from the highest (1.00) in the first seven years (1979 to 1975) and last year (2003) to the lowest (0.49) in the year 2000. Also, effect of year of birth on replacement rate on the basis of total pregnancy was significant and varied from 0.64 in the year 1979 to 0.20 in the year 1998. Parity and season of birth did not affect replacement rate on the basis of total pregnancy.

Sire had significant effect on abnormal and normal births, mortality, culling and female calves reaching to the milking herd, but did not affect CGR (coefficient of gene replication). The overall estimates for abnormal and normal births from 2983 births were 12.2 and 87.8%, respectively. From the total of 118 bulls used for breeding there was no incidence of abnormal birth among progenies from the 47 sires. Rate of abnormal births among the rest 71 sires ranged from 5.3% (Sire at no 67) to 50 % (Sires no. 21, 24, 70 and 118). The average sex ratio among the progeny of 18 sires used was 53.6% male: 46.6% female and 14 sires did not have any male progeny while another 14 sires had 100% male progeny. Sire wise average of mortality and culling rates were 23.2 and 9.1%, respectively. There was no mortality from birth to

AFC among the female progeny of 73 (61.8%) sires while there was 100% mortality in female progenies of sire no 67, 80 and 81. There was no culling from birth to AFC among the progenies of 98 (83.1%) sires while the rest 28 sires (9.9%) had varied culling rate from birth to AFC the highest being 66.7% under sire no 87. The overall sire estimates for calf reached to the milking herd and CGR were 67.7 and 13.9%, respectively. Out of 118 sires used to produce progeny, 17 sires did not have any replacement heifer while from 57 sires 100.0% daughters reached to AFC.

The percent distribution of 901 cows for calf production showed that 30.8% of total cows calved only once and proportion of cows reduced under each calving as the number of calving increased and it was only 0.3% cows calved 11 and 12 times. About 27.7, 5.3, 1.3, 0.2, 0.1 and 0.1% of cows calved abnormal birth once, 2, 3, 4, 5 and 6 times. Only 5.2% of total cows left the herd without any normal calving whereas 31.6 % cows calved normal once, 18.5% calved normal twice and 11.8, 9.9, 9.4, 5.4, 3.2, 2.8, 1.2, 0.9, 0.1 and 0.0% cows calved normal during 3, 4, 5, 6, 7, 8, 9, 10,11 and 12 times calving. About 27.3% of the cows left the herd without producing any female calf in the herd and among cows produced female calves 25.1, 4.9, 0.9, 0.2% lost their 1, 2, 3, and 4 female calves from the herd during their herd life time calf production. Further, 45.7% of the cows left the herd without producing any replacement daughter and 28.4% cows left only one female replacement, while 16.1, 6.5, 2.4, 0.6, 0.2 and 0.1% of cows left 2, 3, 4, 5, 6, and 7 female replacements in the herd before they left the herd.

The average longevity was estimated to be 2864±63 days (7.85 years). The trait was not affected by AFC and birth season. First lactation milk yield and year of birth did affect longevity significantly and cows with ≤1500kg FLMY had minimum longevity (2170±329 days) while cows with ≥5456kg FLMY had maximum longevity. The average longevity in different years (1976-98) ranged from a maximum 4508 days in cows born in 1976 to a minimum of 1156 days in cows born in the year 1998. The overall mean for productive herd life was 1638±58 days and was affected by AFC and FLMY groups, and year of birth. Cows with early AFC (≤886 days) and lowest

FLMY (≤1500 kg) had shortest PHL of 919±366 and 869±330 days, respectively. PHL was also influence by birth year and minimum and maximum estimates were recorded in 1976 and 1997, respectively. Season of birth did not affect PHL.

AFC, FLMY groups and birth year affected significantly the number of normal calves produced. The average normal calf production for the herd was 3.55±0.12 and was affected significantly by AFC and FLMY groups. The estimated normal calf production for lowest AFC (≤886 days) was 2.40±0.87 and increased up to 4.36±0.30 for cows in the AFC group of 1199-1354 days. The highest (4.28±031) normal calf produced was observed for medium (2631-3195 kg) milk production group. Average number of total normal calves born ranged from 6.5 in to 1.28 in 1998. Seasonal effect was not significant. The average number of normal female calves born was estimated to be 1.68±0.07. Cow in the FLMY group of ≤1500 kg produced minimum number of total normal female calves (0.87±0.15) while those with FLMY of 2066-2630 kg produced maximum number of total female calves (2.17±0.21). The average total normal female calves born from each cow according to year of birth was highest (3.13) in year 1976 (1st year) and thereafter it showed a decreasing trend in later years with a minimum (0.48) in the year 1997. Grouping of cows in to AFC classes and season of birth had no significant effect on female calf produced. The average number of female calves reached to the milking herd and coefficient of gene replication were 1.12±0.06 and 0.56±0.03, respectively and both traits were not affected by AFC, FLMY groups and season of birth. Birth year had significant effect, the estimates being 3.00±0.78 and 1.50±0.39 for selective value and CGR, respectively.

The heritability for abnormal birth, sex ratio, mortality, culling, and replacement rate from total calves produced and total pregnancy were 0.16±0.009, 0.10±0.019, 0.18±0.029, 0.71±0.029, 0.00±00 and 0.66±0.029, respectively. The repeatability of abnormal birth, sex ratio, mortality, and replacement rate from total calves produced were 0.04±0.199, 0.004±0.020, 0.163±0.029 and 0.163±0.029, respectively. The heritability estimates for longevity, productive herd life**,** total calves born, total normal calves born, total female calves born, CGR and selective value were

0.31±0.085, 0.32±0.088, 0.11±0.018, 0.12±0.018, 0.10±0.019, -0.08±0.029 and 0.66±0.029, respectively.

The overall means for AFC, FSP, FDP, FLP, 305DMY, FLMY and FCI were 1225±14.6 days, 256±7.3 days, 203±8.0 days, 327±4.6 days, 3084±47.6 kg, 3260±53.6 kg, and 523±7.0 days, respectively. Season of birth affected only FLP but year of birth had significantly influenced all first lactation traits. The heritability for AFC, FSP, FDP, FLP, 305DMY, FLMY and FCI were 0.53±0.116, 0.26±0.113, 0.24±0.1170, 0.23±0.102, 0.23±0.106, 0.28±0.124 and 0.28±0.141, respectively.

The phenotypic correlations of AFC with FLMY, 305DMY, FLP, FSP and FCI were very small and with FDP being small and negative. Small genetic correlations were observed among AFC with FLMY and 305DMY. Further, the genetic correlation with FSP and FCI were small and negative (-0.14 to -0.20) indicating that there is negative relationship of AFC with service period and calving interval. High (>0.79) phenotypic, genetic and environmental correlations existed between FLMY and 305DMY; therefore, the traits can be substituted for each other. The phenotypic correlations between FLMY and FLP was moderate (>0.54), while with FSP, FDP and FCI it was small and negative (except with FLP). Moreover, small and negative correlations were observed between 305DMY with FSP, FDP and FCI. Similar trend of FLMY was observed regarding the genetic correlations of 305DMY with FSP, FDP and FCI. The phenotypic, genetic and environmental correlations of FLP with FSP, FDP and FCI were small, but negative for FDP. All correlations among FSP, FDP and FCI were high and positive hence can be exchanged for each other.

With in the limit of the results obtained, the following can be concluded for the Holeta Bull Dam Station

1. Cows had lower survival accompanied by higher loss rate at first lactation. Stayability and reproductive value declined after the first lactation.

2. There was a higher male calf births. About 38 successful inseminations are required to produce 16 females so that about 12 daughters per sire may be available for performance recording and 3.45 pregnancies are required to produce one heifer that becomes replacement of the old and low productive cow.
3. Sire affects significantly the type of birth, calf loss, replacement rate and coefficient of gene replication.
4. About $1/3^{rd}$ of cows calved only once and similar proportion of the cows experienced abnormal calving during first lactation culminating in 45.7% of cows leaving the herd without producing replacement daughter.
5. Longevity, PHL and total calves born were highest for intermediate AFC and FLMY groups. They also had sufficient additive genetic variance among the daughters of different sires and the same can be improved through selection.
6. The additive genetic variances for abnormal birth, mortality, culling and replacement rate from female calves born were sufficient enough and their frequency can be changed through selection of the sire.
7. Year of birth and parity affected most traits whereas season had no effect, therefore, close follow up is essential to check the declining pattern. Moreover, season and year of birth need to be considerd in estimation of genetic parameters.
8. Repeatability of abnormal birth and replacement rate from total pregnancy were high between successive records hence they can be used for prediction
9. The h^2 values were medium for all first lactation traits, except for AFC, indicating the possibility of improving the traits by selection. Age at first calving had high h^2 and the trait can be included in the selection index.
10. FLMY and 305DMY, and FSP, FDP and FCI have similar inheritance and had high correlations, therefore, can be used interchangeably. Increments in the length of FSP, FDP, and FCI will reduce FLMY and 305DMY.

Therefore, the following are recommended from the findings of the present research:

1. It has been observed that the causes of culling and mortality were not clearly known for a good proportion of animals. Also, the pedigree record was not complete for some imported sires. Moreover, it is essential to improve the survivorship, reproductive value and mortality of female calves. These require revisiting the routine activity and strengthening the capacity of the production and veterinary units.
2. Some sires were responsible for inheritng undesirable characters to the offsprings that information on the genotype of semen must be available along with other performance traits. Moreover, research need to be initiated on identification genetic abnormalities at embryonic and progeny level.
3. The effect of storage and deposition of semen in uterus during A.I. on sex ratio need to be studied.
4. Negative variance estimates were obtained for some threshold traits due to the analysis of variance (ANOVA) method; therefore, re-examination of genetic parameters for such traits is essential.

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8. APPENDICES

Appendix I. Standardization of total lactation length in to 305 days milk yield at Holeta at Holeta Bull Dam Station

Days in lactation (X)	Correction factor
21-50	3.56
51-80	2.78
81-110	2.37
111-140	1.98
141-170	1.74
171-200	1.54
201-230	1.38
231-260	1.24
261-290	1.11
291-320	1.00

Appendix II. Source, birth date and disposal reasons for some sires at Holeta Bull Dam Station

New ID	Farm ID	Bull name	Source	Birth date	Purchased	Culled	Reason	Remark
773841	348-84	Pino	Italy	29/11/77	23-Jun-90			
826712	2176	Ginosar	Israel	4/7/1982	5-Jun-94			Semen imported
810882	088-85	Marx-et	Italy	20/5/83	23-Jun-90			
841843	025-84	Sumolian	Finland	13/5/84	1-Jun-94			Semen imported
850991	3099	Goliat	Israel	5/3/85	5-Jun-94			Semen imported
851214	240-85	Hoikan	Finland	31/3/85	1-Jun-94			Semen imported
867371	90737	Kapitein	Finland		16-Aug-91			Semen imported
867591	90926	Menekki	Finland		16-Aug-91			Semen imported
869021	91099	Koivulan	Finland		16-Aug-91			Semen imported
882431	234-88	Lappalan	Finland	31/5/88	1-Jun-94			Semen imported
931013	10-010	Ethiopia-3	Israel	2/6/93	5-Jul-94	22/4/95	Aged	
931472	10-011	Ethiopia-4	Israel	13/8/93	5-Jul-94	28/4/91	Poor semen prod	
932051	10-013	Ethiopia-1	Israel	17/9/93	5-Jul-94	5/13/94	Poor semen prod	
932514	10-014	Ethiopia-2	Israel	21/9/93	5-Jul-94	27/4/96	Hoof problem	
983875	10-087		Addis Ababa	10/3/98				
986911	10-091		Holeta	15/11/98		18/5/99	Slaughter	
987951	3868	Lichy	Israel	14/9/98	12-Apr-07			Semen imported

Appendix II. Source, birth date and disposal reasons for some sires at Holeta Bull Dam Station (contd.)

New ID	Farm ID	Bull name	Source	Birth date	Purchased	Culled	Reason	Remark
990564	7003	Bavel	Israel	22/9/2000	12-Apr-07			Semen imported
990571	7005	Balon	Israel	26/9/2000	12-Apr-07			Semen imported
990761	7033	Lotem	Israel	21/12/2000	12-Apr-07			Semen imported
987961	04274	Boydesty	America	8/6/2002	10-Jun-10			Semen imported
987948	07800	Gun	Israel		15-Apr-09			Semen imported
987955	07145	Casmir	Israel		15-Apr-09			Semen imported
987959	07982	Regis	Israel		15-Apr-09			Semen imported
976543	07769	Alton	Israel		15-Apr-09			Semen imported
990766	04478	Delta Dexter	America	4/4/2003	10-Jun-10			Semen imported
990768	08784	Ready Packer	America	23/9/2004	10-Jun-10			Semen imported

Appendix III. List of Publications

Gebeyehu Goshu and Harpal Singh. 2013. Genetic and non-genetic parameters of replacement rate component traits in Holstein Friesian cattle. *Springer Plus* ***2****, 581* http://www.springerplus.com/content/2/1/581

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Gebeyehu Goshu, Harpal Singh, Karl-Johan Petersson. 2014. Effects of non genetic factors on herd life, selective value and its components in Holstein Friesian cows. *Indian J. Anim. Sci.,* **81(4)**: 48-51

Gebeyehu Goshu, Harpal Singh, Karl-Johan Petersson, Nils Lundeheim. 2014. Heritability and correlation among first lactation traits in Holstein Friesian cows at Holeta Bull Dam Station, Ethiopia. *Intl. J. Anim. Prod.,* **5(3)**: 47-53