ECONOMIC LOSSES DUE TO SELECTED DISEASES OF DAIRY ANIMALS IN PUNJAB

Dissertation

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in
VETERINARY AND ANIMAL HUSBANDRY EXTENSION EDUCATION
(Minor Subject: Veterinary Public Health and Epidemiology)

By

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2018

CERTIFICATE – I

This is to certify that the dissertation entitled, **"ECONOMIC LOSSES DUE TO SELECTED DISEASES OF DAIRY ANIMALS IN PUNJAB"** submitted for the degree of **Ph.D.** in the subject of **Veterinary and Animal Husbandry Extension Education** (Minor Subject: **Veterinary Public Health and Epidemiology**) of Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, is a bonafide research work carried out by **Mohd. Hussain Malik (L-2014-V-05-D)** under my supervision and that no part of this dissertation has been submitted for any other degree.

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

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ABSTRACT

The present study was carried out to analyze the epidemiological aspect and economic losses associated with the important disease of dairy animals as perceived by the farmers in different agro climatic zones (ACZ) of Punjab. The disease had been reported by dairy farmers and no testing or diagnostic procedures had been undertaken to confirm the disease. The important diseases of dairy animals selected for this study were FMD, HS, Mastitis, Repeat Breeding and Anestrus. The reference period for this study was one year from June 2016 to May 2017. The sampling design adopted for this study was multistage stratified random sampling of 720 dairy farmers. On the basis of herd size dairy farmers were divided into 3 groups viz., Small (5-10), Medium (11-50) and Large (>50) and the study included following variables, viz. socio-economic profile of dairy farmers associated with dairy business, epidemiological aspects of selected diseases, economic losses and its impact associated with the diseases and various constraints in controlling these diseases as perceived by the farmers. Majority of dairy farmers selected in the present study were young age, male, having higher secondary education, from the joint families, of medium family size, having agriculture as main occupation with majority of land holding upto 2 hectares with small herds rearing mainly buffaloes. The overall incidence risk of FMD, HS, Mastitis, Repeat Breeding and Anestrus were 7.37, 5.45, 27.10, 27.63 and 25.78 percent respectively. The overall CFR risk of FMD and HS were 21.32 and 45.15 percent respectively. The overall incidence risk of FMD, HS, Mastitis, Repeat Breeding and Anestrus in cross bred cattle were 10.30, 4.67, 38.75, 41.77, and 13.34 percent, indigenous cattle were 9.13, 3.91, 30.47, 32.05 and 13.10 percent and in buffaloes were 5.02, 6.27,18.50, 17.59 and 36.54 percent respectively. On herd basis, the incidence risk of FMD, HS, Mastitis, Repeat Breeding and Anestrus was highest in small herd size followed by medium and large herd size. The overall financial loss among the selected diseases was highest in Anestrus, followed by Repeat Breeding, FMD, Mastitis and HS per affected animal per year was Rs.24362.9±1273.04,Rs. 16997±2894.44, Rs.13,871.14±5707.80, Rs.12028.0±5030.7 and Rs. 5,111.64±1482.32, respectively. Annual losses per animal due to FMD was estimated highest in cross bred animals (Rs. 25148.68±3492.9), followed by indigenous cattle (Rs. 9765.36±1549.2) and lowest in buffaloes (Rs. 6699.38±1858.3). Annual losses per animal due to HS was estimated highest in buffaloes (Rs. 7265.08±735.27), followed by cross bred (Rs. 5799.55±447.48) and lowest in indigenous cattle (Rs. 2270.30±405.22). Annual losses per animal due to Mastitis highest in cross bred (Rs. 20606.24± 224.55), followed by indigenous (Rs. 12292.42± 544.19) and lowest in buffaloes (Rs. 3185.34± 219.728). Annual losses per animal due to RB was highest in cross bred (Rs. 22595.32± 965.43), followed by indigenous (Rs. 15473.77± 507.44) and lowest in buffaloes (Rs. 12922.04± 773.06). Similarly, annual losses per animal due to Anestrus was highest in cross bred (Rs. 27511.48±1227.60), followed by buffaloes (Rs. 27038.69±1128.05) and least in indigenous cattle (Rs. 18296.95±1317.53). Major impact of economic losses was due to loss of livestock asset of the farm families and its creation (93.47%), regular income loss affected their savings pattern (81.80%), affected agricultural productivity (80.97%) and increased psychological stress (73.88%). The highest ranking constraint with respect to each disease condition was an ineffective prophylactic vaccination for controlling FMD and HS, inability to bear the cost of treatment in control of mastitis and anestrus, and lack of effective and accurate estrus detection technique for control of Repeat Breeding. It may be concluded, that through this study, the projected annual losses associated with these important diseases in Punjab are FMD (Rs. 775.67 crores), HS (Rs. 211.37 crores), Mastitis (Rs. 1108.47 crores), RB (Rs. 1597.04 crores) and Anestrus (Rs. 2135.79 crores).

Keywords: Animals, Buffalo, Cattle, Crossbred, Diseases, Economics and Farmers

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Signature of Major Adviser **Signature of the student**

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LIST OF ABBREVIATIONS USED

$	:	US Dollar
%	:	Percentage
χ^2	:	Chi Square
€	:	Euro
<	:	Less Than
>	:	Greater Than
ACZ	:	Agro Climatic Zones
AI	:	Artificial Insemination
ANOVA	:	Analysis of Variance
BCA	:	Benefit Cost Analysis
BCS	:	Body Condition Score
CFR	:	Case Fatality Rate
CMT	:	California Mastitis Test
CSO	:	Central Statistical Organization
DADF	:	Department of Animal Husbandry Dairying and Fisheries
ESO	:	Economic and Statistical Organization
et al	:	And Others
FAO	:	Food and Agriculture Organization
FMD	:	Foot and Mouth Disease
GADVASU	:	Guru Angad Dev Veterinary and Animal Sciences University
HF	:	Holstein Friesian
Hr	:	Hour
HS	:	Hemorrhagic Septicaemia
Kg	:	Kilogram
KVK	:	Krishi Vigyan Kendra
NDDB	:	National Dairy Development Board
OIE	:	Office International des Epizootics
PDADMAS	:	Project Directorate on Animal Disease Monitoring & Surveillance
PDDB	:	Punjab Dairy Development Board
PDFA	:	Progressive Dairy Farmer's Association
RB	:	Repeat Breeding
Rs	:	Rupees
SCC	:	Somatic Cell Count
SE	:	Standard Error
USD	:	United States Dollar

CHAPTER I

INTRODUCTION

India has vast resource of livestock and poultry, which play a vital role in improving the socio-economic conditions of rural masses. The livestock sector alone contributes nearly 25.6 percent of value of output at current prices of total value of output in agriculture. The overall contribution of livestock sector in total gross domestic product is nearly 4.4 percent at current prices (CSO 2016). India continues to be the largest producer of milk in the world. Milk production during 2015-16 was 155.5 million tonnes with an annual growth rate of 6.27 percent and the per capita availability of milk was 337 grams per day. Agriculture and crop sector is the mainstay of Punjab economy contributing 25.81 percent to the gross state domestic product at constant prices of which agriculture and livestock sector contributes 16.6 and 7.75 percent respectively (ESO Punjab, 2016-17). Punjab accounted for just 1.27 percent of the total cattle and 4.75 percent of the total buffaloes in the country but still ranks 6th in milk production with 1032 grams per capita availability of milk (NDDB 2016).

Major challenges for animal husbandry sector include diseases, shortage of feed and fodder, breed improvement, along with the poor productivity of our native breeds. In order to improve the livestock population and their production, the state has to be free of livestock diseases through vaccination and other disease control measures. Animal diseases undermine the potential of livestock sector and compromise food security that encompasses food self-sufficiency, nutritional and health status of the population, food availability, accessibility and stability of food supply and stocks (Bonnet *et al* 2011). Animal diseases cause losses of up to 30 percent of the annual livestock output in developing countries (Tambi *et al* 2006), thus reducing household incomes. Quantifying the economic losses of important animal diseases is rarely addressed in developing countries to estimate the effects of livestock diseases on milk production, fertility and survival to assess the cost–benefits of diagnosis, treatment and prevention efforts.

Economic losses due to FMD comprises of losses due to high morbidity and mortality in young animals and production losses in older animals due to decreasing milk production and weight gain (Alexandersen and Garland 2003). FMD is endemic

in two thirds of the world (Grubman and Baxt 2004 and Kompas *et al* 2015) where it causes annual losses of US$6.5–21 billion (Knight and Rushton 2013). Increasing international movements and trade present an on-going threat to FMD-free countries leads to a number of outbreaks in previously free countries despite the application of stringent quarantine measures. These outbreaks resulted in estimated financial losses of more than US$1.5 billion (Knight and Rushton, 2013) and substantial disruption to the international livestock trade (Blayney *et al* 2006). In India, FMD losses due to mortality, milk loss, drought losses and treatment costs were US$ 2.7-3.6 billion (Ganesh 2012). The annual total economic loss due to FMD in India ranged from Rs. 12,000 crore to 14,000 crore, the total losses per infected animal due to FMD in cattle and buffaloes were Rs. 12,532 and 21,682 respectively (Prabu *et al* 2004).

Haemorrhagic Septicemia (HS) is another important bacterial disease caused by *Pasteurella multocida* that primarily affects cattle and buffaloes. It is an acute, septicemic fatal disease in bovines, especially in tropical countries of Asia and Africa (Bain *et al* 1982, De Alwis 1992 and Ahmed 1996b). HS is considered economically to be the most important disease in Southeast Asia (Verma and Jaiswal 1998). The organism remains in the upper respiratory tract as a commensal and causes the disease when the animal undergoes stress. It is clinically characterized by an initial phase of temperature elevation (often unnoticed), followed by a phase of respiratory involvement, and a terminal phase of septicemia and recumbence leading to death. HS is endemic in India with most of the states reporting the disease (Venkataramanan *et al* 2005). In India, HS ranked second during 1991–2010 in terms of number of outbreaks reported after FMD outbreaks (Gajendragad and Uma 2012). HS accounted for 58.8 percent of the aggregate bovine mortalities due to five major diseases and caused 50,000–55,000 deaths in animals leading to significant financial losses to farmers (Dutta *et al* 1990, Singh *et al* 1996 and Dua 2003). In India, a number of studied are available on economic impact of livestock diseases (Thirunavukkarasu and Kathiravan 2010, Govindaraj *et al* 2015 and Govindaraj *et al* 2016), however, studies on impact of HS in cattle and water buffaloes are limited. Few studies have used secondary information for various time periods and while some studies assumed few factors/components such as mortality and culling levels, and projected the losses for the entire country (Venkataramanan *et al* 2005and Singh *et al* 2014a).

Mastitis is a multifactorial disease, closely related to the production system and environment (Mekibib *et al* 2010) and is a challenge to veterinarians worldwide. Depending upon the climatic conditions, animal species and animal husbandry practices, its prevalence varies from place to place. Thus, control and prevention of Mastitis is a challenge and despite the continuous efforts, it is a cause behind the most severe economic losses to the dairy industry (FAO 2007). Sharma and Sindhu (2007) reported the high incidence of subclinical Mastitis ranging from 20 to 80 percent in cows and 45 percent in buffaloes and the overall prevalence of Mastitis in India ranges from 25 to 97 percent with an average prevalence of about 50 percent.

Mastitis is characterized by physical, chemical and usually bacteriological changes in milk and pathological changes in glandular tissue affecting its production and its quality (Samad 2008). Poor milking hygiene, milking machine faults, teat injuries and environmental factors predispose the cow to Mastitis (Majic *et al* 1993). In India, Mastitis is the most devastating disease in terms of economic losses in dairy animals (Kumar *et al* 2010) due to which the annual economic losses rose by 114 folds from 1962 to 2001 (Sharma *et al* 2012). The estimated annual economic losses due to this disease in India is around Rs. 16,702 million (PDC Meerut, 2012). However, another report has estimated the losses amounting to Rs. 6053.21 crore with Rs. 4365.32 crore (70-80%) due to sub-clinical Mastitis (Dua 2001). The economic losses due to Mastitis were reported to be same for cows (3649.56 crores) and buffaloes (3515.95 crores) by PDADMAS (2011). The estimated milk loss following clinical Mastitis is almost 700 kg for cows in first lactation and 1200 kg for cows in second lactation (Wilson *et al* 2004). In fact, Mastitis has not really been studied systematically in the developing world, resulting in only limited information being available on the prevalence of disease and associated economic losses.

Reproductive performance is a crucial factor for the dairying sector because of vast impact of reproductive performance on dairy production system (De Vries 2006, Giordano *et al* 2012). Reproductive performance has a long-term effect on the entire lactation including length of calving interval, milk production and breeding costs. Poor reproductive performance of dairy animals results in economic losses due to reduced production and additional cost of management, Anestrus, extended dry period, late maturity, decreased calving percentage, less lactation per animal, less number of calves born and lifetime productivity of the animal, increased cost of

management and intense culling of the animals (Meadows *et al* 2005, Agarwal 2005, Mulligan *et al* 2006, Inchaisri *et al* 2010). Reproductive performance is an essential risk factor in the culling decision (Beaudeau *et al* 1995) and will reduce the revenue from selling calves and the availability of replacement cows (Boichard 1990). About 18-40 percent of cattle and buffaloes were culled mainly due to infertility (Sharma *et al* 1993). Among reproductive disorders, RB and Anestrus cause most devastating losses to livestock owners in India.

RB is a cyclic non-breeder dairy animal that failed to conceive after 3 or more inseminations and exhibit normal signs of estrus every 18 to 24 days (Parkinson *et al* 2001). It is an important reproductive disorder and causes great economic loss in dairy industry in India. Its prevalence ranges from 10 to 60 percent between different states and varies with breed, farm, agro-climatic and management conditions. The incidence of RB in India has been reported from 5.5 to 33.33 percent in cattle and from 6 to 30 percent in buffaloes (Saxena 2004). In Punjab, the incidence of RB in cattle and buffalo was reported from various previous studies viz. Sharma and Karwani (2003) 19.61 and 15.63 percent, Singh *et al* (2003) reported 12.20 percent in buffaloes, Kaur *et al* (2011) reported incidence of RB 11.67 and 11.04 percent in cattle and buffaloes, respectively and Kumar *et al* (2011) in commercial dairy farms was 8.82 percent.

Anestrus, the absence of periodic manifestation of estrus, with the absence of palpable follicular or luteal structures (smooth ovaries) or absence of normal physiological signs of estrus associated with a corpus luteum. Incidence of Anestrus is more in buffalo than the cattle, and problem is severe during summer. Summer Anestrus is the major problem occurring in buffaloes caused by many factors like managemental, nutritional, animal comfort, breeding and hormonal changes (Windig *et al* 2005). The factors related to anestrous in buffalo involve silent estrus particularly in summer season, failure to detect estrus by the farmer, poor display of estrus signs by buffalo as well as limited resources of nutrition. As pregnancy rate decreases, average days in milk increases, leading to increased management, feed, and veterinary costs for animals in the least profitable portion of lactation (Joseph and Amin 2009). In Punjab, 17-67 percent cattle and 31-55 percent buffaloes experienced Anestrus (Dua 2003 and Singh *et al* 2006).

Reproduction, milk production, and disease are the top culling risk factors (Millan-Suazo *et al* 1989). Replacing the current cow with a new cow can be considered an investment in future farm profitability. Culling decisions should rely on economic principles instead of biological phenomena (Lehenbauer and Oltjen 1998, Groenendaal *et al* 2004). Within herd conditions and input and output prices determine the current and future values of a cow, so culling decisions are also tied to internal and external factors (Dhuyvetter *et al* 2007). Culling is preferred when the future value of the current cow is lower than the cost of replacing it with a young replacement cow. Death or pre-optimal culling removes the cow out of the production system, ends her productive life, and reduces the total profit (Groenendaal *et al* 2004). Impact of disease is an important estimation to guide where to apply resources to animal health, which needs to be strengthened through examining the marginal costs and benefits of applying disease control measures. A control campaign is, therefore, useful if the avoidable losses in production are greater than the costs of control. Government can strongly control various important diseases of dairy animals creating an institutional environment where population level control costs reflect sufficiently the benefits that a livestock owner can capture. It is done by the investments in veterinary education, research and general infrastructure to develop the animal health system (fixed costs) and the specific programmes that cover the costs of animal disease control and management (variable costs).

Constraints are the problems that hurdle the adoption of technology but, once these constraints are identified, it helps to bridge the gap between dairy technology and its adoption by livestock farmers (Rathod *et al* 2014). Animal diseases also cause economic losses when they deter farmers from investing in better inputs such as better breeds and compel them to adopt less profitable risk management strategies such as less productive indigenous breeds to minimize disease impacts (Swallow 2012). So the study of constraints pave the way to solving the current issues.

The state of Punjab is divided into six ACZ's (Mahi and Kingra 2013) and the farmers have different management practices. Therefore, it is imperative to study the various practices for managing production, reproduction and animal health economics in these zones.

Due to very limited literature available on the economic losses of animal diseases in Punjab, the present study entitled **"Economic losses due to selected diseases of dairy animals in Punjab"** has been planned with the following objectives

1. To study the prevalence of various selected diseases of dairy animals in Punjab.
2. To estimate the economic losses due to selected diseases.
3. To analyze the impact of economic losses on the dairy farmers.
4. To analyse the constraints due to selected diseases and also to suggest measures for controlling the economic losses.

Scope and Significance of Study

The data had been collected from the random population under study with the help of well-structured questionnaire by personally interviewing the farmers. The present study will provide the basic information on:

1. The current scenario of economic implications of animal diseases in bovines in different ACZ's of Punjab, as diseases represent avoidable waste of scarce resources. These problems seriously reduce the production potentials of animals, especially crossbreds, as they stand more susceptible to diseases, hardships and contingencies peculiar to the Indian climate. However, there is little evidence available on how much the farmers and the nation lose as a result of animal diseases. A deeper insight into the animal diseases will help provide a better view of the overall economic losses and the extent to which these losses could be avoided. Quantification of losses due to diseases in the livestock sector would adequately support the decision-making process in optimizing animal health management.
2. Information about the epidemiological aspect would help the planners and policy makers concerned with livestock development policies, how to tackle the ongoing most prevalent disease.
3. To prioritize the decision-making focused on the economic aspects of the disease and define the priorities in terms of the cost-benefit of the control procedures.
4. To uptake the technologies and practices to control the economic losses or financial impact of important disease on poor and marginal dairy farmers.
5. To discover which particular disease had the greatest economic impact on dairy farmers to issue a strong policy focus, or for earmarking a large expenditure from public budget or private investment to deal with it.

6. To guide the design of research studies on epidemiological aspect and economic aspect of disease control measures.
7. To help in determining which management practices and technologies will be most suitable for livestock owners in a particular herd group or species of animals.

Limitations of Study

Although every effort was made to make this study as comprehensive as possible, but it was subjected to some limitations. The study being a student's dissertation project, suffered with the limitations of time and resources. Some farmers had improper farm records, so some information were based on their memory basis. The perception level of the dairy farmers about their losses due to various diseases were based on expressed opinions of the respondents which varied among persons, places, environments, existing conditions and available facilities. However, every possible care was taken and efforts were made to get the objective responses and accurate data. The data was collected from random population under study. Thus the results would be applicable to that particular area, although the results might have relevant application to other similar areas also.

CHAPTER II

REVIEW OF LITERATURE

2. General introduction about important animal diseases

Animal diseases in developing countries cause losses up to 30% of the annual livestock output (Tambi *et al* 2006) from the household incomes. Animal diseases are main constraints of the livestock sector development and affect livelihoods via their impact on animal health, animal food production, availability and quality and in addition disease outbreaks significantly damage the livestock sector throughout the world due to their economic impacts and measures taken to mitigate the risk of disease transmission (Perry and Grace 2009 and Rich and Perry 2011), with implications on food security and poverty alleviation efforts (Heath 2008). Animal diseases cause loss of livelihoods to farmers having mainly poor background and increase disease control costs through increased vaccination and treatment costs (Rushton 2009 and Webber and Labaste 2010). In order to minimize the disease impacts as a risk management strategy, farmers choose less productive indigenous breeds as compared to better breeds (Swallow 2012). The losses during disease outbreaks have multiple effects associated with lost sales and wages besides the mitigation measures such as quarantine and movement control plus consumer responses such as animal feeds industry (Pritchett *et al* 2005, Rich and Wanyoike 2011).

The underlying economic theory on animal disease and their control has been well explained by McInerney 1988 and 1996, McInerney et al 1992 for small additions to control. An important extension on these theories is detailed by Tisdell (2009) who looked at the need for fixed cost investments in veterinary education, research and infrastructure. Impact of disease outbreak gives an insight that guides us where to apply resources to animal health, which needs to be strengthened through examining the marginal costs and benefits of applying disease control measures. For example if money is spent on disease control, which will increase the indirect losses of the disease, the intention is to reduce the direct losses due to losses in animal and herd productivity. A control campaign is, therefore, useful if the avoidable losses in production are greater than the costs of control.

2.1. Foot and Mouth Disease in dairy animals.

FMD is the most contagious, trans-boundary, animal disease (FAO 2007). It is characterized by vascular and ulcerative lesions of the mouth and feet of cloven footed animals and ranked first among the most noticeable infectious diseases of animals by Office International des Epizootics (OIE 2000). Due to the severity of its economic impacts, and the nature of the virus, affects the trade of animals and related products throughout the world (Arzt *et al* 2011a). FMD is one of the most infectious diseases of domestic livestock and is endemic in two thirds of the world (Grubman and Baxt 2004, Kompas *et al* 2015) causing annual losses of US$6.5–21 billion (Knight and Rushton 2013). FMD outbreaks resulted in estimated financial losses of more than US $1.5 billion (Knight and Rushton 2013) and substantial disruption to the international livestock trade (Blayney *et al* 2006). Economic losses due to FMD comprise of losses due to high morbidity and mortality in young animals and production losses in older animals due to decreasing milk production and weight loss (Alexandersen and Garland 2003).

2.1.1. Epidemiological aspect of FMD in dairy animals

Govindaraj *et al* (2017) estimated that the FMD incidence risk was high across the herd sizes, whereas the mortality risk was high in small herds.

Jemberu *et al* (2014) estimated the prevalence of FMD morbidity rates of 85.2% and 94.9% at herd level; and 74.3% and 60.8% at animal level in the affected herds were determined for crop–livestock mixed system and pastoral system, respectively. The overall and calf specific mortality rates were 2.4% and 9.7% for the crop–livestock mixed system, and 0.7% and 2.6% for the pastoral system, respectively. Herd level morbidity rate was statistically significantly higher in the pastoral system than in the crop–livestock mixed system ($p < 0.01$).

Baluka *et al* (2014) conducted a case study to determine the prevalence and financial losses associated with FMD outbreaks in cattle herds in Isingiro and Nakasongola districts. There was a very highly negative correlation of reported FMD prevalence with the cattle herd size. Average reported herd prevalence of FMD was 23.6%. There were no mortalities among large case study herds.

Shamsudeen *et al* (2013) investigated FMD in cattle and buffaloes and observed that the disease caused 17.1 per cent mortality in cattle and 11.1 per cent

mortality in buffaloes. Among morbid animals, the mortality in adults (cow and buffalo) and young ones (calves and buffalo calves) were 13.7 per cent and 26.8 per cent, respectively.

Subramaniam *et al* (2012) reported incidence rate in different regions of India viz; 43% in Eastern region, 31.5% in Southern region, 11.6% in North-eastern region, 5% Central region, 4.4% Western region and 4% in Northern region. Highest numbers of outbreaks/cases were recorded in the month of September and lowest in June. Unrestricted animal movements in the country play a major role in the spread of FMD.

Shah *et al* (2011) reported the incidence rate of infection was highest (47.12%) in July (Summer) followed by September (39.32 %) (Early Autumn). The rate of infection was 17.13% and 4.16% during spring and winter seasons respectively. Crossbred cattle (Jersey x Local Hill and Holstein x Local Hill) exhibited severest clinical signs. Non-descript local Hill cattle were also affected, however pathological lesions were mild. The average age group of affected cattle with high morbidity and mortality was 0-2 years.

Gorsi *et al* (2011) estimated that the morbidity, mortality and case fatality rates were 53.20%, 15.25% and 28.65%, respectively. In young cattle, out of 834, morbidity, mortality and case fatality rates were 56.47%, 22.90% and 40.55% while in adult population of 1737, these were 51.64%, 11.57% and 22.40%, respectively. Out of total population of 5926 buffaloes, morbidity, mortality and case fatality rates were 61.69%, 20.80% and 33.72%, respectively. In young buffalo calves 283 morbidity, mortality and case fatality rates were 65.82%, 30.77% and 46.75%, respectively. In adult population of 3843 buffaloes, morbidity, mortality and case fatality rates were 59.46%, 15.40% and 25.9%, respectively. Young animals of both species were most susceptible than adults.

Mannan *et al* (2009) studied that FMD is still endemic in Bangladesh with a high prevalence of 24.5% which tends to be even higher in rural household farms than in the intensive dairy farms.

Saxena (1994) reported that the highest incidence of FMD in India was in indigenous cattle and draught animals (both 29%), followed by dairy cattle (25%), young animals (23%), buffaloes (20%), crossbred animals (17%) and sheep, pigs and goats (16% each). The highest incidence was in the eastern region of the country (35%) and lowest in the southern region (11%).

2.1.2. Economic losses and its impact due to FMD

Govindaraj *et al* (2017) studied that in indigenous cattle, the highest loss due to FMD was distress sale (208 USD) followed by other losses, whereas, in Crossbred cattle, the highest loss was mortality loss (515 USD) followed by distress sale (490 USD), milk yield loss (327 USD), treatment cost (38 USD) and extra labour engagement expenses for nursing of FMD affected bovines (30 USD). In local and upgraded buffaloes, the mean total loss per affected animal was 440 USD and 513 USD, respectively. A very high variability in the loss per animal was observed across the type of losses in the Crossbred cattle, and it may be due to differences in age of the FMD infected animal, value of the animal, milking stage, lactation levels, herd sizes and labour engagement levels, etc. In local and upgraded buffaloes, the mean total loss per animal was 639 USD and 1008 USD, respectively. Further, the social impact elicitation revealed that majority of the livestock owners perceived FMD had caused permanent asset loss, which in turn increased psychological stress of the family.

Sharma *et al* (2017) reported that systematic vaccination programme is ongoing in India to control the three prevailing of FMD virus and an inverse relationship between the herd immunity and FMD incidences was observed following vaccination practices.

Tozer *et al* (2014) concluded the negative consequences on milk production and farm incomes due to FMD. He estimated the economic consequences of FMD outbreak to a tone of $26.4 billion (present value terms over the 30 years) while taking a necessary and important first step in evaluating the consequences of a worst case (nationwide) outbreak scenario as compared to other workers who consider a more likely local and contained disease outbreak.

Jemberu *et al* (2014) estimated the economic losses of FMD outbreak due to milk loss, draft power loss and mortality were on average USD 76 per affected herd and USD 9.8 per head of cattle in the affected herds in crop–livestock mixed system; and USD 174 per affected herd and USD 5.3 per head of cattle in the affected herds in the pastoral system. The herd level economic losses were statistically significantly higher for the pastoral system than for the crop–livestock mixed system ($p < 0.01$). The major loss due to the disease occurred as a result of milk losses and draft power losses whereas mortality losses were relatively low.

Baluka *et al* (2014) estimated the FMD control cost and annual economic cost per head of cattle was highest in small herds. Farmers with small and medium herds incurred higher control costs whereas farmers with large herds experienced the highest milk losses during FMD outbreaks. It is more costly for smallholder farmers who are disproportionately affected by FMD to control these diseases. Overall, treatment costs were higher than vaccination costs. Farmers ought to invest more in vaccination against FMD rather than wait to incur higher costs in treatment.

Singh *et al* (2013) estimated the morbidity losses contributed about 97.64% and rest (2.36%) by mortality of animals. Among different components of losses the maximum loss of 49.83% was observed due to milk loss (direct and indirect), followed by opportunity cost (16.15%) and reduction in growth (12.20%). The total losses per infected animal due to FMD in cattle, buffalo, sheep, goat and pig were Rs 12,532, 21,682, 2,023, 3,046 and 2,830, respectively. From this study it is concluded that the annual total economic loss due to FMD in India ranges from Rs 12,000 crore to 14,000 crore.

Young *et al* (2012) estimated the average post-FMD infection of cattle farmers, varied from 216 to 370 USD per animal, including the average cost of treatment, the costs due to the animal death and draft replacement.

Bhavani *et al* (2012) reported the mean short-term burden of FMD on households is 7.6% of their income. Lower-income households face greater burdens in excess of 10% and those figures are to be considered significant shocks on affected households. From a disease control perspective, the study highlighted additional important aspects: (i) 84% of the interviewed farmers were willing to pay an amount of $1.3 for each animal to have them protected for a period of 6 months and (ii) the implementation of any diseases control programme should include an educational campaign component to improve awareness among livestock keepers and stimulate the adoption of basic biosecurity measures.

Di Nardo *et al* (2011) estimated that FMD reduces milk yields, increases the probability of Mastitis, abortion, perinatal mortality, lameness in milch and draft animals which reduces their ability to work. There is loss of body weight in growing animals due to productivity thus affecting farmers livelihoods, food security, rural income generation and the national economy by impairing livestock trade. Reduced feed intake resulting from FMD lesions and premature culling of animals from

intensive production systems that recover from FMD as a result of permanent foot, udder or thyroid damage.

Gorsi *et al* (2011) calculated the economic losses due to FMD were observed Rs. 2.74 crore during the study period (Six months) in the infected/ outbreak villages.

Vallat (2009) reported that the FMD infected countries are deprived of access to international markets, which are the most profitable for livestock producers and Otieno *et al* (2008) reported that FMD outbreak can cause nearly 31.8% drop in beef export as a result of animal health implications and production losses.

Hagerman *et al* (2009) reported that overall FMD costs included the disease management costs such as vaccination costs, slaughter, disposal, cleaning, disinfecting, administrative, labor, equipment, material costs and changes in market prices that contribute to the total losses incurred by farmers suffer.

Mannan *et al* (2009) estimated the total economic loss was calculated as Rs 313900/- out of which loss in milk production accounted for 80.68%. Cost of milk was calculated at the rate of Rs. 12/ litre, to assess the economic loss. Treatment cost includes vehicle charges and cost of medicine. An average loss of 8 hrs/ day/ animal was calculated. Vaccination cost of Rs. 5/ animal was also considered. Towards the nursing of animal and disinfection of shed, loss of manpower of 2-hrs/ animals for 5 days was calculated.

Mathew and Menon (2008) reported 2.42% incidence rate and 0.12% mortality rate in bovines in Chazhoor Panchayath of Thrissur district in Kerala.

Barasa *et al* (2008) studied to address the potential consequences of FMD, of which the benefit/cost ratio is higher than the one we have estimated if other costs are included in the analysis. In this regard, the benefit cost of FMD vaccination was 11.5 using a sample of livestock holders living in South Sudan.

Otte *et al* (2004) studied about the transboundary nature of FMD associated with widespread transmission and can reach epidemic levels thus increasing the scope of private and public costs of measures taken at individual, collective and international levels to prevent or control disease outbreaks.

Bandyopadhyay (2003) estimated the economic losses due to FMD US $ 800 million per annum at national level in India.

Yalcin and Senturk (1999) estimated the average financial losses per infected animal were estimated to be US $294 for milking cow, US $152 for dairy heifer, US $197 for beef cattle, US $69 for sheep and US $64 for goat. However, the amount of the financial losses was considerably varied amongst the animals depending on species, breeds, age and sex. The overall cost of FMD in 1999 was estimated to be US $51.3 million of which financial losses, disease control expenditures at the outbreaks and routine disease prevention expenditures accounted for 33.6%, 2.6% and 63.8% respectively.

Singh (1995) developed a model to estimate the economic losses caused by morbidity and mortality and introduction of vaccination programme as a main strategy to control the disease. The overall expected economic losses due to morbidity and mortality of FMD outbreak were Rs. 15.44 and Rs. 4.58 respectively which were 3.16% and 0.94% respectively of the average price value of animals. The overall total expected economic loss due to morbidity and mortality combined was Rs. 20.02 amounting to 4.10% of the average price value of the animals in the farm. Even in the absence of mortality which is not a common phenomenon in Zebu breeds, vaccination of the animals against FMD is still a profitable strategy in Indian context in the endemic areas.

Tufan (1993) reported on average 19% milk yield loss due to FMD in Turkey. Power and Harris (1973) stated 25% depression in the lactation yield of Holstein cows in the UK. Nazlioglu and Orun (1969) observed between 20% and 44% milk yield loss in cows.

2.2. Hemorrhagic Septicemia in dairy animals

HS is endemic in India with most of the states reporting the disease (Venkataramanan *et al* 2005). The disease is acute and often causes death primarily in water buffaloes and cattle, with occasional reports on other domesticated and wild mammals (Bain *et al* 1982, De Alwis 1992, Ahmed 1996a and De Alwis 1999). In India, HS ranks second during 1991–2010 in terms of the number of outbreaks reported after FMD outbreaks (Gajendragad and Uma 2012). HS accounts for 58.8% of the aggregate bovine mortalities due to five major diseases and causes 50,000–55,000 deaths in animals causing significant financial losses to farmers (Dutta *et al* 1990, Singh *et al* 1996 and Dua 2003). In India, there are few studies on impact on livestock diseases (Thirunavukkarasu and Kathiravan 2010 andGovindaraj *et al*

2015), but the loss due to HS in cattle and water buffaloes are limited. Few studies have used secondary information for various time periods and while some studies assumed few factors/components such as mortality and culling levels, and projected the losses for the entire country (Venkataramanan *et al* 2005 and Singh *et al* 2014a).

HS is a disease of utmost economic importance particularly in Asia and to a lesser extent in Africa. In India, during the twelve years period since 1974 to 1986. In an active surveillance study in Sri Lanka, it was shown that in the 1970‘s, around 15% buffaloes and 8% cattle in the HS endemic areas died of HS annually. During the same period, the passive reporting systems recorded only 1200 to 1500 deaths a year in a cattle and buffalo population of approximately 2.5 million (De Alwis and Vipulasiri 1981). Other countries in South Asia also ranked HS as the most economically important infectious disease or the most economically important bacterial disease. Pakistan reports that 34.4% of all deaths in susceptible stock are due to HS. With a cattle and buffalo population of 17.7 and 18.8 million respectively, the annual economic losses have been estimated at Rs. 1.89 billion (Sheikh *et al* 1994).

2.2.1. Epidemiological aspect of Hemorrhagic Septicemia in dairy animals

Govindaraj *et al* (2017) studied the epidemiological features of Haemorrhagic Septicemia (HS) in bovines in Karnataka state. The morbidity and mortality risks were lower in large farms than medium and small farms, and lower in indigenous cattle compared to high yielding crossbred cattle and water buffaloes. The disease occurrence was more in in-milk animals causing serious economic loss to the farmers. Most outbreaks were observed during monsoon season, though the disease was prevalent throughout the year.

Farooq *et al* (2011) reported that the morbidity rate, mortality and case fatality due to Hemorrhagic septicemia was greater in the young calves as compared to the adult in both buffaloes and cattle. The morbidity, mortality and case fatality rates were 57.58, 52.30 and 90.83% in young buffalo calves; and 3.17, 1.92 and 60.65% in adult buffaloes, respectively. In case of young cattle calves, morbidity, mortality and case fatality rates were 8.63, 5.27 and 61.11%, respectively, while in adult cattle, these values were 4.83, 2.18 and 45.23%, respectively.

Khan *et al* (2006) studied that in young buffalo calves, incidence rate, mortality rate and morbidity rate was observed as 22.25%, 21.19% and 95.25%, respectively. In adult buffaloes, morbidity, mortality and case fatality rates were

5.49%, 1.65% and 30%, respectively. In case of young cattle calves, morbidity, mortality and case fatality rates were recorded as 3.94%, 1.77% and 45%, respectively. While in case of adult cattle, morbidity, mortality and case fatality rates were recorded as 2.51%, 0.39% and 15.79%, respectively.

Verma *et al* (2004) studied epidemiology of bovine Hemorrhagic Septicemia (HS) in Haryana and reported that prevalence of HS in buffaloes and cattle was low (0.31 and 0.25%, respectively), but case fatality rate (CFR) was high (58.90 and 38.94%, respectively). The CFR was significantly ($p<0.01$) higher in young buffaloes than young cattle. The data revealed an increasing trend of HS outbreaks and found a positively correlation with high rainfall, humidity and low temperature. Foot and Mouth Disease (FMD) was a common preceding infection in many HS outbreaks.

De Alwis (1981) reported that the overall mortality for buffaloes was higher than for cattle (45.2 and 15.8% respectively, $p < 0.01$). For buffaloes in enzootic areas only the overall mortality was 29% whilst in non-enzootic areas it was 64.5% ($p < 0.05$).

2.2.2. Economic losses and its impact due to Hemorrhagic Septicemia

Govindaraj *et al* (2017) estimated financial losses of dairy animals, the mean milk loss per animal were $2, $11 and $50 in indigenous cattle, water buffaloes and crossbred cattle, respectively. In the case of draught animals, the average effective draught power was unavailable for 1.2 days/outbreak resulting in a loss of $5 per affected oxen. The treatment and extra labor expenses incurred per animal were $24 and $7, respectively. The average loss per animal due to mortality loss was $275, $284 and $415 in case of indigenous cattle, water buffaloes and crossbred cattle, respectively. The projected loss for the state of Karnataka was $23.89, $17.92 and $11.95 million under high, medium and low HS incidence scenarios, respectively. The Benefit Cost Analysis (BCA) of the vaccination against HS has been estimated at 5.97:1, 4.48:1 and 2.98:1 under high, medium and low incidence scenarios, respectively.

Singh *et al* (2014a) estimated the economic losses in cattle and buffalo. It was revealed that the morbidity losses account for 23 per cent of the total losses and the rest (77 %) are due to mortality of the animals. Of the total morbidity losses, about

half have been due to reduction in growth and one-fifth due to loss in milk. The total economic loss per infected animal due to Haemorrhagic Septicaemia has been estimated as Rs. 6816 in case of cattle and Rs. 10901 in buffalo. These losses when scaled-up at the national level have indicated a loss of Rs. 5255 crore. The direct losses contribute 80.3 per cent and indirect losses contributed 19.7 per cent to the total economic loss. The study has found that calves contribute 74.8 percent and adults contribute 25.2 per cent to the total economic loss due to Hemorrhagic Septicaemia.

Singh *et al* (2014b) evaluated economic losses due to HS in Purvanchal Region of Uttar Pradesh. Total economic losses due to HS in ND cattle were Rs. 37, 692.50, in which share of morbidity losses and mortality losses were 11.5% and 88.47%, respectively. Per animal total losses in case of ND cattle was Rs. 2, 355.78. Total economic losses due to HS in CB cattle were Rs. 61, 342, in which share of morbidity losses and mortality losses were 7.48% and 92.51%, respectively. Total economic loss per crossbred cattle was Rs. 3,228.52. In case of buffaloes, total economic losses due to HS were Rs. 2, 72, 805 in which share of morbidity losses and mortality losses were 4.30% and 95.69%, respectively. Per buffalo economic loss was Rs. 4, 262.57. Total economic losses due to HS in sampled animals in study area were Rs. 3, 71, 839.50, in which share of morbidity losses and mortality losses were 5.5% and 94.43% respectively.

Singh and Prasad (2008) have reported an average annual loss of 287.81 lakh due to HS in cattle in India based on the number of cases and deaths reported during 1991-2005 by the Department of Animal Husbandry, Dairying and Fisheries, Government of India.

Verma *et al* (2004) reported the annual economic loss due to HS in buffaloes in Haryana was around Rs. 58 millions.

One study in Bangladesh by Ahmed (1996a), attempted to compute the economic losses resulting from three important endemic diseases, anthrax, blackquarter and HS. It was found that the direct losses which took into account the market value of the animals that died and the cost of treatment was 2.3 million US dollars. Their computation of indirect losses took into account the value of the rice that would have been produced from the land left uncultivated as a result of loss of

draught power. These losses amounted to 148 million USD annually due to these three diseases.

De-Alwis (1981) estimated annual losses Rs. 90 million in Sri Lanka due to HS.

2.3. Epidemiological aspect of Mastitis in dairy animals

In India, the prevalence of Mastitis is increasing in parallel with the development of new, high-milk-producing breeds of cows and buffaloes. The various factors that have been identified to contribute to increased spread of the disease include lack of awareness, delay in disease detection in the absence of visible signs of abnormal milk, unhygienic milking practices, and delayed and incomplete treatment of clinical and chronic Mastitis (Sharma *et al* 2012). Several factors indicate an increased risk of developing Mastitis. Multiparous cows are generally at higher risk of developing clinical Mastitis (CM) (Rajala *et al* 1999) except in the very early stages of lactation where the relationship is the opposite (Steeneveld *et al* 2008). In multiparous cows, the risk of developing CM increases with increasing parity (Steeneveld *et al* 2008). The risk of developing CM is highest in early lactation (Persson *et al* 2009; Steeneveld *et al* 2008), whereas the risk of subclinical Mastitis (SCM) increases with increasing days in milk (Busato *et al* 2000). Mastitic cows tend to have higher milk yield than non-mastitic cows before they develop CM (Grohn *et al* 2004; Wilson *et al* 2004), indicating that high milk yield is a risk factor for CM. Previous occurrences of Mastitis, CM or high SCC, substantially increased the risk of a cow developing a new case of CM (Steeneveld *et al* 2008). Other disorders, such as dystocia; milk fever; retained placenta; metritis; ketosis; and lameness, are also known to increase the risk of CM (Svensson *et al* 2006). Season also affects the incidence of Mastitis, and the incidence of CM has been reported to be highest during the winter months (Steeneveld *et al* 2008). There is a definite impact of seasonal variation on incidence of bovine Mastitis and the microbes associated with it (Ranjan *et al* 2011). The pattern of Mastitis occurrence is significantly increasing in both cattle and buffaloes which is a major challenge for field veterinarians and researchers (Awale *et al* 2012). Cows of certain breeds are more prone to Mastitis. Among the Swedish breeds, national statistics (Swedish Dairy Association, 2008), as well as several studies (Nyman *et al* 2007 and Persson *et al* 2009), show that Swedish Red cows have a lower incidence of Mastitis than Swedish Holstein cows.

2.3.1. Epidemiological aspect of Mastitis in dairy animals

Mpatswenumugabo *et al* (2017) investigated a cross-sectional study in Western Rwanda, the overall SCM prevalence at cow level was 50.4%. About 67.1% of the farmers checked for Mastitis; of these, 58.9% relied on clinical signs and only 6.8% screened with CMT. Only 5.5% and 2.7% of the farmers tried to control Mastitis using dry cow therapy and teat dips, respectively.

Anusha *et al* (2017) conducted the study on epidemiological aspect of subclinical Mastitis in cows in Hyderabad. According to CMT, WST and SFMT, the quarter wise incidence was 35.02%, 32.96% and 30.52%, respectively, and animal wise incidence was 66.18%, 59.56% and 55.15%, respectively.

Swami *et al* (2017) study on prevalence of subclinical Mastitis in dairy animals in Latur district of Marathwada region of Maharashtra during the year 2015-16. The incidence was found more in cows as compared to buffaloes. Hind quarters were affected more as compared to forequarters. The incidence of Subclinical Mastitis was also observed due to the some risk factors, viz. are Age, lactation number, stage of lactation, method of milking and housing was important risk factors precipitating occurrence of subclinical Mastitis.

Suresh *et al* (2017) examines the incidence of clinical Mastitis among dairy cattle under small holder farming condition to facilitate derivation of economic weight of Mastitis in the planning process. The Mastitis incidence was more prevalent in fifth lactation during rainy season, in crossbred Holstein Friesian, in higher average daily milk yield of more than 15 litres, during early stage of lactation (53.65%), in cows having pendulous udder (60.00%) and previous occurrence of Mastitis, and in cows kept on muddy soil floor.

Sarba and Tola (2017) reported 41.7% cows had Mastitis, of which 9.9% were clinical and 32.8% were subclinical Mastitis cases. The quarter level prevalence was 44.4%, (comprising 9.3% clinical and 32.8% subclinical forms) of Mastitis. In addition, 5.5% of teats were found to be blind on the clinical examination of udder and teat. The Chi-square analysis of intrinsic risk factors revealed significantly ($p<0.05$) higher prevalence of Mastitis in crossbred cattle (47.2%) than indigenous (15.4%), in cattle above 7 years (75%) than less than 2-6 years of age (28%) and cows given more than 4 calves (81.3%) than those with

less than 4 calves (31.1%) irrespective to their lactation stage. There was also significantly ($p<0.05$) higher Mastitis prevalence in larger (46.6%) than smaller herds (24.2%) and among the farming systems in semi-intensive (47.1%) and intensive (42.3%) than extensive (8.1%) management system.

Zeryehun and Abera (2017) reported the prevalence of clinical and subclinical Mastitis and quarter level prevalence for clinical and subclinical Mastitis were 12.5% and 51.8% at cow level and 10.7% and 46.4% at quarter level, respectively. Clinically, 101 (6.6%) quarters which belong to 75 (19.5%) animals were found to be with blind teat. In the present study prevalence of Mastitis was significantly associated with parity and age ($p < 0.05$).

Abebe *et al* (2016) studied on CMT result and clinical examination, the prevalence of Mastitis at herd-level was 74.7%. The corresponding cow-level prevalence was 62.6% of which 59.2 and 3.4% were sub-clinical and clinical Mastitis cases, respectively. Staphylococcus aureus was isolated from 51.2% of the milk samples cultured and 73.2% of the herds affected with Mastitis in the herds examined revealed the huge potential economic loss the sector suffers

Bangar *et al* (2015) observed that the prevalence of subclinical Mastitis on cow basis varied from 20.73 to 78.55 %.

Kvapilík (2015) the clinical Mastitis attacks 17 – 48% of dairy cows per year, annual average can be estimated approximately at 30 – 35%.

Srinivasan *et al* (2013) reported that 26.20 % of animals were positive for SCM in SCC and bacteriological examination. Prevalence in graded Murrah buffaloes were found to be higher compared to graded Surti and Non-descript breeds. The prevalence of SCM was highest in above 6th stage of lactation. Single quarter infection (51.85%) was more common compared to multiple quarter infection. Hind (83.34%) and left side (57.41%) quarters were more prone to SCM.

Pankaj *et al* (2012) reported that the overall Milk samples from 364 quarters of 95 lactating cows at an organized farm were screened. The overall quarter wise and animal wise prevalence on the basis of cultural examination was 64.21 and 39.83%, respectively. The prevalence of latent Mastitis (SCC < 5 x 105/ml and culturally positive) and non-specific Mastitis (SCC > 5 x 105 /ml of milk and culturally negative) was observed as 24.45 and 4.67 %, respectively.

Arnold (2011) reported that new infections are controlled by adopting measures like proper milking procedures, improved milking hygiene and housing management. Bacteria transmit to the uninfected from the contaminated hands of the milker. Thus, the milker's hands should be washed thoroughly with disinfected soaps before milking, clinically infected cows should be milked last and teats should be cleaned and dried before milking.

Rahman *et al* (2009) reported that the overall prevalence of Mastitis in dairy farms of Bangladesh was 19.9% and 44.8% in dry and wet seasons, respectively. The prevalence of mild Mastitis was 17.3% and 40.7%, whereas that of moderate Mastitis was 2.6% and 4.1% in dry and wet seasons, respectively. The prevalence of Mastitis was higher ($p<0.01$) in wet than in dry season. On average, 18.7% quarters had Mastitis during the wet season and 6.9% in the dry season. In the dry and wet seasons, respectively, 63.9% and 11.2% had completely dry floors, and the prevalence of Mastitis was 22.6% and 30.0%. On the other hand, 88.8% and 36.1% of 83 farms had partly or completely wet and soiled floor and the prevalence of Mastitis was 40.0% and 59.5% in the dry and wet seasons, respectively. Udder cleanliness, milk yield and peri-parturient diseases significantly ($p<0.01$) increased the risk of Mastitis.

Awandkar *et al* (2009) have suggested the necessity of microbiological and antibiogram studies for treatment and control of bacterial Mastitis.

Mdegela *et al* (2009) reported that subclinical Mastitis has a higher prevalence than clinical Mastitis. And was found to be more important (10–50% in cows and 5–20% in buffaloes).

Joshi and Gokhale (2006) reported the high incidences of subclinical Mastitis have been reported from various parts of the country with figures ranging from 18.40%7 to 72.60% in cross bred cows and 15.78% to 81.60%, in local cows.

Biffa *et al* (2005) A high rate of development of Mastitis in Holstein-Friesian (56.5%) as compared to local zebu (30.9%) and Jersey cows (28.9%) has been placed on record.

Shukla *et al* (2005) recorded the prevalence of clinical and sub-clinical Mastitis in crossbred and Sahiwal cows and Murrah buffaloes as 8.97% and 67.94%, 8.33% and 47.22% and 7.50% and 42.50%, respectively.

Rakesh *et al* (2004) studied the prevalence of sub-clinical and clinical Mastitis in hand-milked cows which was higher than machine-milked cows. This observation can be attributed to irregular and incomplete milking and maintenance of unhygienic conditions in hand-milked animals.

Mustafa (2003) confirms his opinion that only 6 – 8% herds of cows show chronic Mastitis from 40 to 50% of all clinical Mastitis.

Miltenburg *et al* (1996) reported the prevalence of Mastitis in dairy herds is about 50% of cows and a quarter infection rate is about 25%. The average annual incidence rate of clinical Mastitis in individual herds ranges from 10-12 % in most herds, but higher values, ranging from 16-65% also occur in some herds. In beef herds, 32-37 % of cows and 18% of quarters may have intramammary infection which has a significant negative effect on new born calf weaning weights (Simpson *et al* 1995). Case fatality rates vary widely depending upon the causative agent.

2.3.2. Economic losses, its impact and control measures due to Mastitis in dairy animals

Mastitis results in economic loss for producers by increasing the costs of production and by decreasing productivity. The premature culling of potentially profitable cows because of chronic Mastitis is also a significant loss. The component economic losses can be due to loss of milk production, discarded milk from cows with clinical Mastitis and treated cows, replacement cost of culled cows, extra labor required for treatment and monitoring, veterinary service for treatment and control, cost of first trimester abortions due to clinical Mastitis (Risco *et al* 1999) and cost of control measures. However production losses contributed major part to the economic losses (Huijps *et al* 2008 and Nielsen 2009). There are additional costs such as antimicrobial residues in milk from treated cows, milk quality control, dairy food manufacturing, and nutritional quality of milk, degrading of milk supplies due to high bacteria or SCC, and interference with the genetic potential of some cows from early involuntary culling because of chronic Mastitis. The total annual cost of Mastitis in the dairy cattle population is estimated to be 10% of the total value of farm milk sales, and about two-thirds of this loss is due to reduced milk production in sub-clinically affected cows. Losses due to Mastitis may even be higher in developing countries because standard Mastitis control and prevention practices recommended by national

Mastitis council of USA are not being carried out promptly (Sharif and Muhammad 2008).

Studies indicate that the economic loss due to both forms of Mastitis has increased almost five-fold from Rs. 16,072 millions (Singh and Singh 1994) to Rs. 71,655 millions (Bansal and Gupta 2009) in a span of just 15 years. Globally, the losses due to Mastitis amount to about $53 3billion (Ratafia 1987), Rs. 6053.21 crores per annum in India (Dua 2001) and much higher, ascribed to lack of Mastitis prevention practices in Pakistan (Shakoor 2004). Economic losses owing to Mastitis in Bangladesh are Takka 122.6 (US $ 2.11) million per year (Rabbani and Samad 2010). Two billion dollar losses occur annually in United States, due to Mastitis (Cullor 1993). Mastitis, costs about estimated 301 US dollars per cow per year, above the desired baseline in European dairy herds. The estimated loss of milk per cow per one lactation cycle is 70% of the total losses and the cost of cows lost due to premature culling is 14%, while the cost of milk downgraded/discarded due to Mastitis is 7% and the cost incurred on medical treatment and other veterinary expenses amount to 8%, of the total losses, reported worldwide (Abdel-Rady and Mohammed 2009). Mastitis low prevalence herds can save up to 25% cost on losses than the high prevalence herds

Jingar *et al* (2017) reported that average days under treatment were maximum in 1st parity (14.28) and minimum in 3rd parity (8.63). The total treatment cost was more ($p<0.05$) in 4th parity (Rs. 470.52) and less in 2^{nd} parity (Rs. 250.00). The fibrosis rate of quarter was maximum in 5^{th} parity resulting in higher loss of animal value. The parity wise result indicated highest loss in milk yield/day and the production loss in third parity (5.40 kg and Rs. 1020.24) than in first parity (4.45 kg and Rs. 754.80). The overall actual loss of milk yield/day (kg) of Mastitis infected cows was higher ($p<0.01$) in Karan Fries followed by Sahiwal, Tharparkar, Karan Swiss cows and Murrah buffaloes.

Getaneh *et al* (2017) reported the annual incidence of clinical Mastitis varied from 0 to 50% with a mean annual incidence of 21.6%, whereas the mean annual incidence of subclinical Mastitis was 36.2% which varied between 0 and 75%. The total costs due to Mastitis for a default farm size of 8 lactating cows were 6,709 ETB (Ethopian Birr) per year (838 ETB per cow per year). The costs varied considerably, with 5^{th} and 95^{th} percentiles of 109 ETB and 22,009 ETB, respectively. The factor

most contributing to the total annual cost of Mastitis was culling. On average a clinical case costs 3,631 ETB, varying from 0 to 12,401, whereas a sub clinical case costs 147 ETB, varying from 0 to 412.

Juliana *et al* (2017) calculated the economic impact of US$19,132.35. The three main components of the economic impact were culling cows (39.4%) and the reduction in milk production due to subclinical and clinical Mastitis (32.3% and 18.2%, respectively). The reduction in milk production due to Mastitis was the main component of the economic impact (54.9%). The culling of cows with chronic infection was associated with an increase in the economic impact of Mastitis and a reduction in the average productivity per cow.

El-Tarabany and Ali (2017) reported that the total veterinary management as percent from total costs showed more increase in mastitic cows compared to healthy contemporaries (4.22 vs. 2.68%). The Mastitis cows recorded decreased total returns / total cost % versus healthy cows (108.7 vs. 121.4%).

Rushton and Bruce (2017) studied about the economic impact of diseases on livestock animals taking account both economic assess and social and environmental assess related to production and increase costs in disease control.

Kaur *et al* (2014) studied the incidence of sub-clinical Mastitis of water buffalo in Doaba region of Punjab as 20.4%, out of this 7.8%, 9.8% and 2.8% were found effected with latent Mastitis, specific Mastitis and nonspecific Mastitis, respectively. Left hind quarters were affected more with subclinical Mastitis (33.9%), followed by RH (24%), RF (22.4%) and the least in LF (14.5%). Farm management determinants like type of floor, education of the owner, feeding after milking, type of labor were associated with sub-clinical.

Kvapilík *et al* (2015) reported the loss of 9000 CzC per cow with Mastitis and 3140 CzC per dairy cow in herd is equal to revenue from sales for 950 and 330 litres of milk at the current farmer milk price 9.5 CzC per litre. Increasing the proportion of cows with Mastitis by 1% in the CR would increase the economic loss by other 38 500 000 CzC.

Rollin *et al* (2015) estimated the average case of clinical Mastitis resulted in a total economic cost of $444, including $128 in direct costs and $316 in indirect costs.

Direct costs included diagnostics ($10), therapeutics ($36), non-saleable milk ($25), veterinary service ($4), labor ($21), and death loss ($32). Indirect costs included future milk production loss ($125), premature culling and replacement loss ($182), and future reproductive loss ($9). Future milk production loss represents 28% of total cost, and future culling and replacement loss represents 41% of the total cost of a case of clinical Mastitis. In contrast to older estimates, these values represent the current dairy economic climate, including milk price ($0.461/kg), feed price ($0.279/kg DM (dry matter), and replacement costs ($2,094/head), along with the latest published estimates on the production and culling effects of clinical Mastitis.

Sinha *et al* (2014) reported that the losses due to Mastitis in monetary terms were estimated to be Rs.1390 per lactation, among which around 49% was owing to loss of value from milk and 37% on account of veterinary expenses. Higher losses were observed in crossbred cows due to their high production potential that was affected during Mastitis period. The cost of treating an animal was estimated to be Rs. 509 which includes cost of medicine (31.10%) and services (5.47%).

Wolter and Bonsels (2013) estimated annual losses due to Mastitis in Germany at € 1.4 billion which corresponds to the theoretical loss (increased costs and reduced profits) of 4.7 cents per kg of milk. Each subclinical Mastitis costs at least 250 €, severe clinical Mastitis costs up to about 500 € per cow and lactation.

Schroeder (2012) adverts to the high efficiency of the preventive anti-Mastitis program. He reported about reduced losses from the sale of milk by 136 US$ (2.850 CzC) at the costs of preventive measures US$ 24. These correspond to 500 CzC of which 210 on teat disinfection, 85 for medication of dry cows and 210 CzC for paper towels. This amount is equal to the benefit of prevention of US$ 112 (2.355 CzC).

Hand *et al* (2012) found that milk loss due to high somatic cell count (SCC) in the multiparous cow was greater than the primiparous cow. Milk loss was correlated with milk production level and SCC in milk; high-producing cows lost more milk than low producing cows. Moreover, the lactation milk loss varied from 165 kg to 919 kg, with SCC increasing from 200,000 to 2,000,000 cells/mL.

Hogeveen *et al* (2011) reported about published estimates of average losses caused by Mastitis which are most often ranging between 61 and 97 € for each

(healthy and Mastitis cow). The losses due to clinical and subclinical Mastitis reach usually from 17 to 198 € per cow and year in the Netherlands.

Kumar *et al* (2010) calculated the average per day cost of treating clinical Mastitis worked out to be Rs. 73.00. On an average 1.3 quarters were affected in Mastitis infected animals and 7% of the Mastitis affected quarters ended up in complete fibrosis. Culling of Mastitis animals is rarely practiced, but animal with fibrosis udder is a definite loss to the farmers. As per market opinion, a complete fibrosis of one quarter causes on an average decrease in animals market value by Rs. 4000, Rs. 2000, and Rs. 2500 for cross bred, indigenous cows and buffaloes respectively.

Schukken *et al* (2009) estimated the milk loss in multipara (primipara) due to gram-negative CM was approximately 304 kg (228 kg) in the 50 d following CM. This loss was approximately 128 kg (133 kg) for gram-positive cases and 92 kg (112 kg) for other cases.

Jones and Bailey (2009) estimated annual losses due to Mastitis in the USA at 1.7 to 2.0 billions US$ which corresponds to 11% of annual milk production. The main losses are caused by a reduction in milk yield (loss of about US$ 102), by milk excluding from the sale (US$ 24) and by more intense cow herd recovery (US$ 33) per cow and year.

Huijps *et al* (2008) estimated weight (percent) of each component on the total economic impact of Mastitis at the herd level combined with clinical and subclinical Mastitis indicators can assist in decision-making focused on the economic aspects of the disease and define the priorities in terms of the cost-benefit of the control procedures. In an ideal situation, the culling of approximately 15% of the animals with chronic Mastitis is recommended to eliminate the animals considered reservoirs of pathogenic agents and sources of infection for the healthy animals in the herd.

Bar *et al* (2008) Relevant estimations about disease costs can be used in evaluating the benefits of applying preventive measurements to decrease disease incidence, disease losses, or both, and in the process allow the evaluation of individual cow disease treatment options.

Nyman *et al* (2007) reported that the incidence of Mastitis is influenced by managerial and environmental factors, such as housing of cows, milking equipment, feeding regime, hygienic quality of feed and water, cleanliness of cows,

implementation of preventive measures, and general practices related to, for instance, drying-off.

A recent study by Wilson *et al* (2004) at Cornell University showed that clinical Mastitis tends to strike high producing animals in second-plus lactation. In other words Mastitis often hits the cows with the highest production potential, which expands the loss due to Mastitis. According to this study, the estimated loss following clinical Mastitis was almost 700 kg for cows in first lactation and 1,200 kg for cows in second or higher lactation.

Varshney and Naresh (2004) reported that the annual losses in the dairy industry due to Mastitis have been approximately 2 billion dollars in USA and 526 million dollars in India due to subclinical Mastitis. Whereas, clinical Mastitis is responsible for approximately 70% and 30% respectively of dollar losses

Seegers *et al* (2003) calculated the different effects on milk production due to clinical and subclinical Mastitis. The average milk production decrease of clinical Mastitis was 375 kg (5% of the lactation level).

According to Kron (2002) calculation, there is apparent benefit of preventive treatment of cow group against mammary gland inflammation in the amount 136 € (3.400 CzC) per cow during the first 100 days of lactation.

Oliver *et al* (2001) reported that pre-partum antibiotic treatment of heifers yielded net revenue of around $200/heifer/year.

Rüsch (2000) estimated the loss of 1545 million (€) for enterprises with the milk production in Switzerland.

Karimuribo *et al* (2000) studied that the first step in Mastitis control programmes is to quantify udder health by determining the prevalence and incidence of both clinical and sub-clinical Mastitis, and assess bacteriological aspects of the disease .

Bhikane and Kawitkar (2000) estimated economic losses associated with Mastitis due to reduced milk yield (up to 70%), milk discard after treatment (9%), cost of veterinary services (7%) and premature culling (14%).

Hortet and Seegers (1998) summarized a 0.5 kg daily milk production decrease with two-fold increase in crude somatic cell score (SCS, 0.4 in primiparous and 0.6 multiparous cows).

Kossaibati and Esslemont (1997) concluded that total cost of Mastitis be much higher than the direct cost. The cost associated with each component is likely to vary between herds; partly because of differences in performance parameters (yield level, fertility, etc.) and partly because of different preferences of farmers influencing, for instance, their inclination to contact a veterinarian when Mastitis is detected.

Singh and Singh (1994) reported that the average decrease in milk yield due to clinical and subclinical Mastitis was 50 and 17.5 %, respectively.

DeGraves and Fetrow (1993) estimated benefit of $57 per cow if the herd is vaccinated, assuming that 1 % of the cows would normally contract coliform Mastitis during the season.

Bartlett *et al* (1991) studied that cows experiencing clinical Mastitis produced approximately 341 kg less salable milk during the 60 days after clinical onset compared with projected production. Pluriparous cows lost 2.06 times as much milk as first lactation cows, and cows with Mastitis occurring before 150 d in lactation lost 1.40 times as much milk when compared with other cows. Cows with Mastitis occurring in the winter showed a milk loss 1.37 times greater than cows with Mastitis in summer.

Gill *et al* (1990) studied about the importance of education by regular visit a veterinarian or udder health specialist, more years of ownership or managing a farm, more education, and frequent attendance at dairy extension seminars were associated with lower SCC, while the increase in the total number of people working on the dairy farm was associated with an increased SCC.

2.4. Reproductive Disorders

Milk production of individual cows depends on their ability to become pregnant because the lactation cycle is initiated and renewed by pregnancy. Although, the relative contribution of individual factors leading to infertility can be debated, the cumulative effect (infertile animals) impairs the normal reproductive function resulting into infertility and sterility leading to economic losses due to widening of dry period, reduced calvings and lactations during the life span of the animal (Agarwal and Tomer 2003). Failure to establish a successful pregnancy could arise from failure to show or detect estrus, failure to ovulate, inappropriate patterns of

ovarian cyclicity, embryonic or fetal loss (Royal *et al* 2000). It is presumed that majority of cattle and buffaloes (18-40%) are culled and reach to slaughterhouse primarily due to infertility (Agarwal *et al* 2005). However, it has been reported that 37.5% buffaloes end up in slaughter houses due to various reproductive problems (Sharma *et al* 1993).

2. 4.1. Epidemiological aspect of Repeat Breeding in dairy animals

Repeat breeder animal is usually defined as sub-fertile animal which mated three or more times during the proper period and does not become pregnant and continually return to service in the absence of any obvious pathological disorder in the genital tract and normal estrus cycles (Parkinson 2001). The condition contributes to longer calving interval, increasing culling rates and replacement costs, wasting semen and insemination costs and losing genetic gain through increased generation interval (Bartlett *et al* 1986) and reducing fertility (Garcia-Ispierto *et al* 2007). The cause of this type of subfertility can be divided into two major categories, fertilisation failure and early embryonic deaths (Agarwal *et al* 2005).

Table 1. Region wise incidence of Repeat Breeding in India

Reference	Place	Species	Incidence (%)
Asthana *et al* 2008	Bihar	Cattle	18.44
Patel *et al* 2007	Gujarat	Cattle Buffalo	18.79 8.68
Das *et al* 2004	Orissa	Cattle	38.18
Bhattacharyya and Buchoo 2008	J&K	Cattle	27.52
Selvaraju *et al* 2005	Tamil Nadu	Cattle	37.2
Karwani and Sharma 2003	Punjab	Cattle Buffalo	37.2 15.63
Pandit 2004	Madhya Pradesh	Cattle Buffalo	1.51 0.61
Ambore *et al* 2009	Maharashtra	Cattle	21.48
Kumar and Singh 2009	Haryana	Cattle	10.8
Kutty and Ramachandran 2003	Kerala	Cattle	35.0
Naidu and Rao 2004	Andhra Pradesh	Buffalo	29.80

Incidence of typical RB ranges from as low as 1.51 % (Pandit *et al* 2004) to as high as 35% (Kutty and Ramachandran 2003) among Indian cattle and in buffaloes ranges from 0.61% (Pandit 2004) to 29.80% (Naidu and Rao 2004).

Khan *et al* (2016) reported the overall incidence of RB in 82 villages of Pakistan was 8.29% which were 8.9% (1799/21189) in buffaloes and 7.27% (883/12149) in cattle. The incidence was higher in buffaloes that are mostly because of their silent heat and docile nature which makes it difficult to detect it at the right time. Incidence of RB had found higher in older and higher milk producing dairy animals.

2.4.2. Epidemiological aspect of Anestrus in dairy animals

Anestrus is the most common single cause of infertility in the tropics and subtropics, where inadequate nutrition, high ambient temperature, high parasite burdens and disease exacerbate the condition. It is defined as absence of periodic manifestation of estrus, with absence of palapable follicular or luteal structure (true Anestrus), or absence of normal physiological signs of estrus associated with a corpus luteum (subestrus, physiological Anestrus) (Agarwal *et al* 2005). Anestrum due to persistent CL is mostly associated with uterine pathology (Pyometra, fetal resorption, mummification), early embryonic motility, pregnancy, subestrum and unobserved estrum. Broadly speaking, Anestrus may either follow parturition (postpartum Anestrus) or following service (Postservice Anestrus).

Factors that suppress LH pulse frequency are negative energy balance, malnutrition, environmental stress, lameness, endogenous opioid peptide, lactational stress, suckling and lower insulin concentration. High Proportion of postpartum anoestrum and suboestrum cases are indicative of overall deficiency of nutrients (Agarwal *et al* 2001), while postpartum and post service Anestrus are reflections of energy deficiency and/or poor service and obstetrical management (Rao and Naidu 2000). Post service Anestrus is very high in buffaloes. Among different forms of Anestrus, postpartum Anestrus is considered as major hindrance limiting the overall productive of a dairy setup. The disorder results in increase of days open, long intercalving interval, decreases lifetime productivity of a cow and increased culling rate.

Incidence of Anestrus has been reported higher in buffaloes and indigenous cattle than exotic or cross bred cattle (25-67% vs 2-20%) (Singh *et al* 2003 and Pandit 2004). Incidence is higher in adult cattle and buffaloes than their heifers (Bharkad and Markandeya 2003).

Table 2. Region wise incidence of Anestrus in India

State/region	Incidence in cattle	Reference(s)	Incidence in buffalo	Reference(s)
Andhra Pradesh			30.67	Naidu and Rao 2004
Gujarat	24.73	Patel *et al* 2007	20.84 – 45.97	Kulkarni et al 2002, Modi *et al* 2011
Madhya Pradesh	53.15	Pandit 2004	29.12 – 60. 83	Pandit 2004, Kumar *et al* 2013
Maharashtra	30.5	Bharkad and Markandeya 2003	29.5	Bharkad and Markandeya 2003
Tamilnadu	16.6	Selvaraju *et al* 2005	9.09	Selvaraju *et al* 2005
Punjab	43.0	Dua 2003	55.5	Dua 2003
Bihar	39.01	Singh 1981		
Kerala	65.0	Kutty and Ramachandran 2003		
Kashmir	31.0	Bhattacharyya and Buchoo 2008		
Orissa	15.97	Das *et al* 2004		

The postpartum Anestrus / PPI in cattle and buffalo have been identified as one of the major hindrance in the achievement of the goal of production systems throughout the world. Although initiation of ovarian follicular growth in the postpartum period is generally not affected, subsequent development (deviation) and the fate of the dominant follicle are the primary factors that affect reestablishment of ovarian cyclicity (Peter *et al* 2009). The condition is characterized by the absence of estrous behavior over a prolonged period of time postpartum, which may be an

indication of suboptimal conditions (e.g. inadequate peripartum nutrition) or pathologic conditions (e.g. chronic debilitating diseases or uterine and ovarian diseases). PPI is affected by several factors like suckling, nutrition, season, breed, age or parity, dystocia, presence of bull, carryover effects from previous pregnancy.

Post-partum anestrous has been recognized as a major reproductive limitation in buffalo. The calving interval in 48-66% of buffaloes has been >14 months as dictated by exposure to the environment and unpredictable management (Perera 1999). 34–49% of buffaloes showed estrus during the first 90 days after calving and 31–42% remained Anestrus for more than 150 days. Anestrous periods due to cessation of cyclic activity (true Anestrus) for 3 or more weeks and prolonged luteal activity for 28 days or more were described to occur in about 25 and 8–11% of the buffaloes, respectively, after the first or second ovulation (El-Wishy 2007).

Table 3. Region wise incidence of postpartum Anestrus

Reference	**Species**	**Place**	**Incidence**
Rajkumar *et al* 2008	Cows	IVRI cattle and buffalo farm	37.66
Kumar and Kumar 1999	Cows	Uttrakhand	50
Ambore *et al* 2009	cows	Maharashtra	25.88
Kutty and Ramachandran 2003	Cows	Kerela	48.4

Khan *et al* (2016) reported the overall incidence of RB in 82 villages of Pakistan was 8.29% which were 8.9% (1799/21189) in buffaloes and 7.27% (883/12149) in cattle. The incidence was higher in buffaloes that are mostly because of their silent heat and docile nature which makes it difficult to detect it at the right time. Incidence of RB had found higher in older and higher milk producing dairy animals.

Khair *et al* (2013) reported that the cumulative incidence of Anestrus was highest in rainy season (0.34%), followed by summer season (0.27%) and lowest in winter (0.21%). The proportionate incidence was highest for repeat breeder (32.76%) followed by Anestrus (20.69%) in cross bred dairy cattle.

Maji and Samanta (2013) reported that the overall infertility problem incidence of anestrous and RB were 67.68 % and 32.32 % respectively. Incidence of anestrous was higher in non-descript cattle (53.86 %) than that crossbred Jersey cattle (46.14 %) and incidence of RB was also significantly ($p < 0.001$) higher in non-descript cattle (68.05%) than that of crossbred (31.95%) animal.

Islam *et al* (2012) reported anestrous syndrome as the most important causes of infertility of cows in Bangladesh. The prevalence of reproductive diseases to be abortion (1.0%), stillbirth (1.1%), retained placenta (7.1%), metritis (1.5%), pyometra (1.7%), vaginal prolapse (1.1%), uterine prolapse (1.3%), dystocia (1.6%), RB (12.8%) and Anestrus (14.7%) in relation to genotype, age and parity of cows.

Rabbani *et al* (2010) reported incidence of RB and anestrous 15.69 percent and 9.74 percent, respectively among buffaloes in Pakistan

Ghuman and Singh (2010) reported that RB, retention of placenta and Anestrus were the commonly encountered problems in cattle and buffaloes, whereas silent estrus was an additional reproductive issue in buffaloes. Estrus detection procedures were faulty. The frequency of estrous detection was twice a day and the duration was <5 min. Moreover, 73 percent persons engaged in estrous detection were 'multitasking' during the period of estrous detection. For taking a decision regarding breeding of animal, 'Doka' was ranked as the most prominent estrus sign in buffaloes, whereas 'standing to be mounted' was ranked as the least important estrus sign in cattle.

Meena and Malik (2009) identified constraints viz. lack of facility of doctors during night, high incidence of RB, and lack of good quality bulls at village level. Mostly respondents faced medium level of constraints (61.67 percent) in medication of these reproductive problems. They concluded that there is need of an efficient extension set up, and with solid infrastructural back up which can cater the needs of dairy farmers. Imparting quality practical training and periodical assessment of performance of lay inseminators will improve their skill and knowledge level.

Siddiquee *et al* (2007) studies that majority of animals were suffering from Anestrus and RB. Out of total cows treated, 110 (45.45 percent) were suffering from reproductive disorders and the incidence of Anestrus (34.71 percent) was highest followed by, RB (5.37 percent). In buffaloes, the incidence of reproductive disorders

was much higher (61.70 percent) and the incidence of Anestrus and RB was 41.49, 10.64 percent, respectively.

Singh *et al* (2006) reported an overall incidence of 19.11 percent reproductive disorders in buffaloes which included Anestrus having incidence of 31.98 percent followed by RB (14.67 percent). However, the overall incidence of reproductive disorders in cows was 15.05 percent, which included RB having incidence of 35.06 and anestrous (17.28 percent).

2.1.4.2. Economic losses, Impact and control measures of Anestrus and Repeat Breeding

High milk production and excellent fertility are desirable traits for a profitable dairy enterprise. Infertility due to cyclicity failure or Anestrus has great economic impact. Anestrus and RB leads to economic losses through increased intercalving interval, poor net calf crops, production loss, treatment expenses and cost of replacing mature animal with first calving heifer. There are only few reports from India pertaining to economic impact analysis.

Tamador-Elkhansaa *et al* (2014) reported the annual economic loss including the cost of milk loss, cost of calf loss, cost of culling and the cost of veterinary intervention. The total annual loss accounted to $US 418,779.1, loss per farm was $US 34,898.261 and loss per cow was $US 4,927. Milk loss accounted to 89% of the total cost. Raising the awareness of the farmers towards better management of infertility problems will act to increase their income as well as milk supply.

Kumar *et al* (2013) reported Rs. 372.90 per day in buffalo. While Pawshe *et al* (2011) reported an estimated loss from Anestrus of around Rs. 193.00 per day in cow.

Yusuf *et al* (2010) studied the effect of RB in dairy cows, including risk factors and reproductive performance. In case of normal fertility, cows required 114 days to conceive and 1.7 inseminations per pregnancy. While repeat breeders required more days to conceive (211) and more numbers of inseminations per pregnancy (4.7). Analysis showed that 94 days were required to become pregnant after calving for 50% of normal fertility cows, compared to 155 days for repeat breeders. In case of repeated cows, 31.4, 50.0, and 58.1% of the cows became pregnant within 210, 300, and 435 days after calving, respectively.

Inchaisri *et al* (2010) estimated that the economic losses due to non-optimal fertility in an average reproductive performance cow were €34 per cow per year as compared to the losses of €231 per cow per year in a good reproductive situation cow. These losses were due to the decreased production of milk and increased non pregnant cows due to poor reproductive performance.

Khan *et al* (2008) stated that as the calving interval increased due to delayed conception, a steady trend was shown, in the low, moderate and high yielding buffaloes. There was a steady decline in milk yield per day of calving interval with delayed conception, associated with lengthened calving interval. An animal that conceive at a later stage of lactation showed a decline in financial returns by 24% to 27% than those that conceived earlier.

DeVries and Conlin (2003) estimated that the net returns per cow per year at 65% estrous detection efficiency were $1305.27 which at 35% of estrous detection efficiency decreased to $1253.34. The overall average losses in net return per cow per year per point decrease from 65% to 55%, from 55% to 45%, and from 45% to 35% of the estrous detection efficiency were $0.78, $1.71, and $2.71, respectively. Similarly, the average costs associated with extra day open were $0.73, $1.13, and $1.24, respectively.

Mayne *et al* (2003) studied that poor reproductive performance is a major problem on dairy farms throughout the United Kingdom (UK). Direct financial cost was approximately £50 million per annum in Northern Ireland (or £9000 per farm).

Arbel *et al* (2001) reported that during the first experimental lactation there were advantages of $0.19 per extra day of calving interval in first calf heifers and $0.12 per extra day of calving interval in older animals. When the first 150 days of the subsequent lactation was also included, the net return per day of CI was $0.21 and $0.16 higher with extended calving interval in primiparous and multiparous animals, respectively.

Esslemont *et al* (2000) estimated that per day loss due to per day of delay was £1.73 when the calving interval was extended from 85 days to 100 days post-calving. This loss had risen to £2.86 per day when calving interval was extended from 116 to 145 days post-calving and £3.55 per day when it further extended up to the day when

no extra milk came from the current lactation. The net final value of a lost day was calculated at £2.30. The costs cumulated over time reached at £253 when the calving interval extends by 3 months.

Esslemont (1992) used the calving index as a measure of herd fertility and neglects the proportion of the herd that is culled and failing to conceive. On an average, calving interval of the herd was 380.3 days, with 23.1% of culling rate. As a result 92.1% of the cows were served and 85.3% of those which calved, conceived again, with an average of 1.9 services per conception. In order to assess the herd fertility on financial basis, with costs associated to calving interval, pregnancy rate and culling rate to give a fertility index, the average herd was suffering a loss of 62 pounds/cow/year, compared with target levels.

Shah (1992) found the nutritional impact of modern dairy development processes on the rural economy in India. It was a significant issue given that 70-80% of small and marginal farmers and agricultural laborers were involved in dairying. The extra income generated by the sale of milk allows the purchase of other foods not produced by the farmers. On the other hand, it was also feared by some experts that by providing better marketing for the sale of surplus milk through cooperatives will further reduce the nutritional status of poor.

Shah *et al* (1991) estimated the economic losses in Nili-Ravi buffaloes due to reproductive failure. Losses caused by sub-optimal calving intervals were Pakistani Rs. 9–14 per extra day per calving interval. Losses for forced replacement as a result of reproductive failure average Rs. 133 per buffalo present on the farm.

Erling *et al* (1989) studied the result on net return per year by varying the conception time from 60 days to 220 days after calving of the cows for different combinations. Early conception was the very cost-effective for all combinations of characteristics. The consequences of one day of delayed conception on net return per year ranged from 0.3 Sw. kr to 11.6 Sw. kr. The cyclic deviation in price of milk had a strong impact on the association between net return per year and conception time.

Jansen *et al* (1987) studied the interactions between herd fertility and financial losses due to reproductive failure in dairy herds. The herd fertility parameters were moderate to highly related to loss due to suboptimal calving interval ($r=0.20-0.79$ in absolute values), but only slightly related to losses due to forced replacement ($r<0.17$

in absolute values). Repeatabilities, calculated over a 3-year period, were high for the interval to first service, non-return rate and the estrus index (0.52−0.67) and moderate for percentage correct re-inseminations, fertility status, calving interval and loss due to suboptimal calving interval (0.38−0.48).

Bartlett *et al* (1986) studied that the loss of milk with repeat breeder symptoms was about $385. A calculated extra cost of $140 was linked with a second insemination, $279 with third insemination, $429 with fourth insemination and $612 with fifth insemination.

Dijkhuizen (1984) estimated the loss of per cow per year was Dfl. 63. Out of which Dfl. 35.50 were resulted from sub-optimal interval and Dfl. 27.50 were estimated due to reproductive failure by the forced replacement. On an average, the total loss due to the reproductive failure was estimated to about Dfl. 80 per cow per year. The difference between 20% of the farms with the highest estimated loss and 20% of the farms with the lowest estimated loss was greater than the average loss.

James and Esslemont (1979) reported that cows calved at 320-day to 360-day intervals to maximize the annual margins over feed, but the month of initial calving affects the complete level of margins over feed markedly (Maximum: £382·10 for 365-day interval for calving in November, Minimum: £318·10 for calving in April). The change in margin over feed for each day's delay in conception varies broadly, with a loss as high as £1·80 per day's delay.

Olds *et al* (1979) calculated that within herds each day open between 40 and 140 days during lactation resulted in an average of 4.5 kg less annual milk production during current lactations of first calf heifers and 8.6 kg less for cows in later lactations.

CHAPTER III

MATERIALS AND METHODS

The various methods, procedures, tools, economic models, mathematical techniques and statistical tests followed in the present study have been explained under the following subheads:

3.1 Location of the study

3.2 Selection of Districts

3.3 Selection of Tehsils

3.4 Selection of Villages

3.5 Selection of Respondents

3.6 Operationalization of variables and their measurements

3.6.1 Independent variables

3.6.2 Dependent variables

3.6.2.1. Incidence of various selected diseases

3.6.2.2. Estimation of economic losses

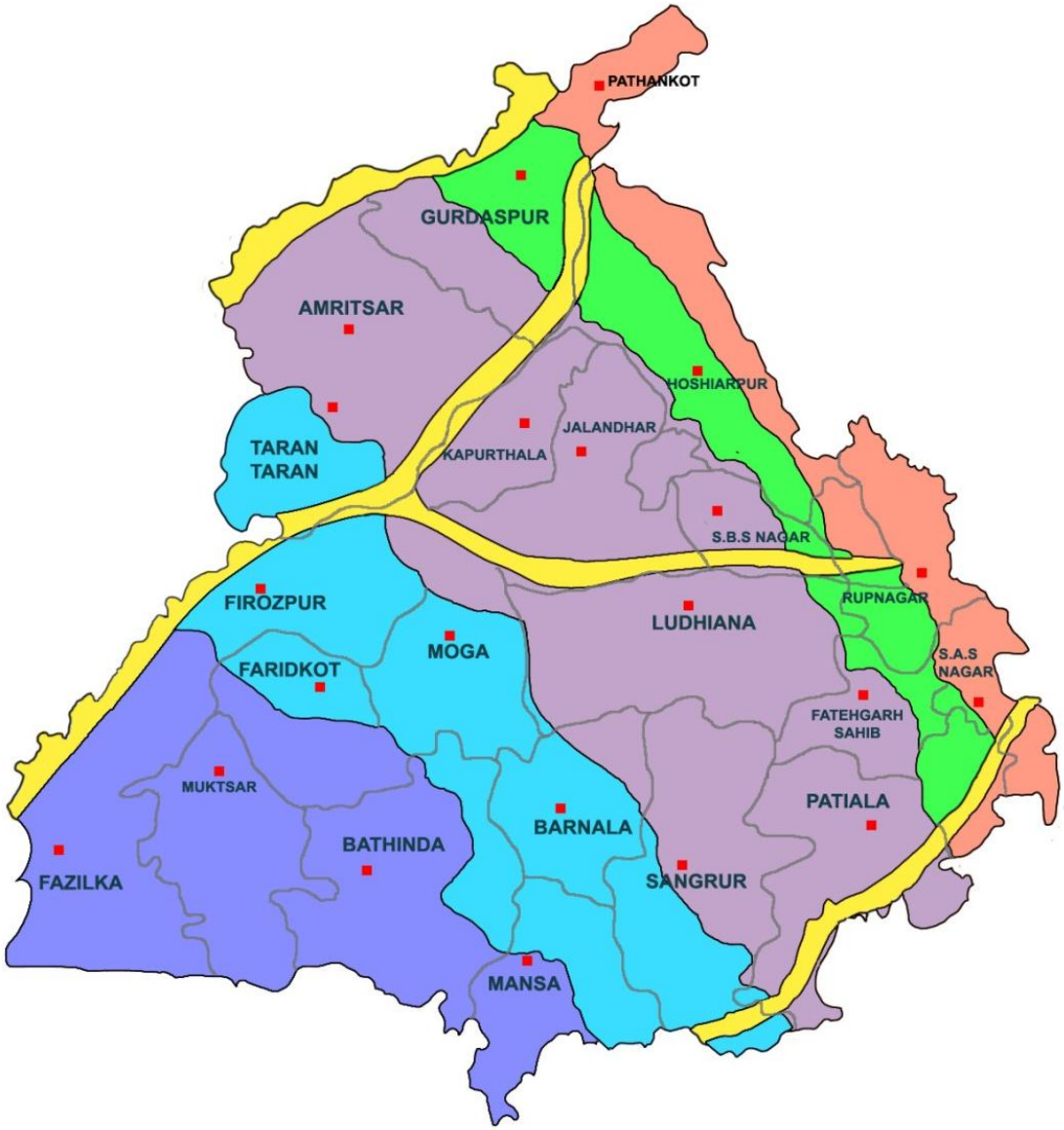
3.6.2.3. Various constraints for controlling selected diseases

3.6.2.4. Statistical analysis of data

3.1 Location of the study

On the basis of agro-climatic conditions, Punjab state was divided into six different zones (Mahi and Kingra, 2013). All these zones were included in the present study:

1. Sub-mountainous undulating region
2. Undulating plain region
3. Central plain region
4. Western plain region
5. Western region
6. Flood plain region



AGROCLIMATIC ZONES OF PUNJAB

Zone I	(Submountain undulating region)
Zone II	(Undulating plain region)
Zone III	(Central plain region)
Zone IV	(Western plain region)
Zone V	(Western region)
Zone VI	(Flood plain region)

3.2 Selection of districts and Tehsils

From each zone, two districts were selected randomly. Two Tehsil from each district and from each Tehsil three villages were selected randomly as given below:

Table 4: Selection of districts and Tehsils

Zones	District	Tehsil
Sub Mountainous Undulating region	Rupnagar	Rupnagar
		Chamkaur Sahib
	S.A.S. Nagar	Nawanshahr
		Balachaur
Undulating Plain region	Gurdaspur	Gurdaspur
		Batala
	Hoshiarpur	Hoshiarpur
		Mukerian
Central Plain region	Patiala	Rajpura
		Nabha
	Sangrur	Sangrur
		Malerkotla
Western Plain region	Barnala	Barnala
		Tapa
	Bathinda	Bathinda
		Rampuraphul
Western region	Sri Muktsar Sahib	Gidderbaha
		Malout
	Faridkot	Faridkot
		Kot Kapura
Flood Plain region	Ludhiana	Jagraon
		Samrala
	Pathankot	Pathankot
		Dhar Kalan

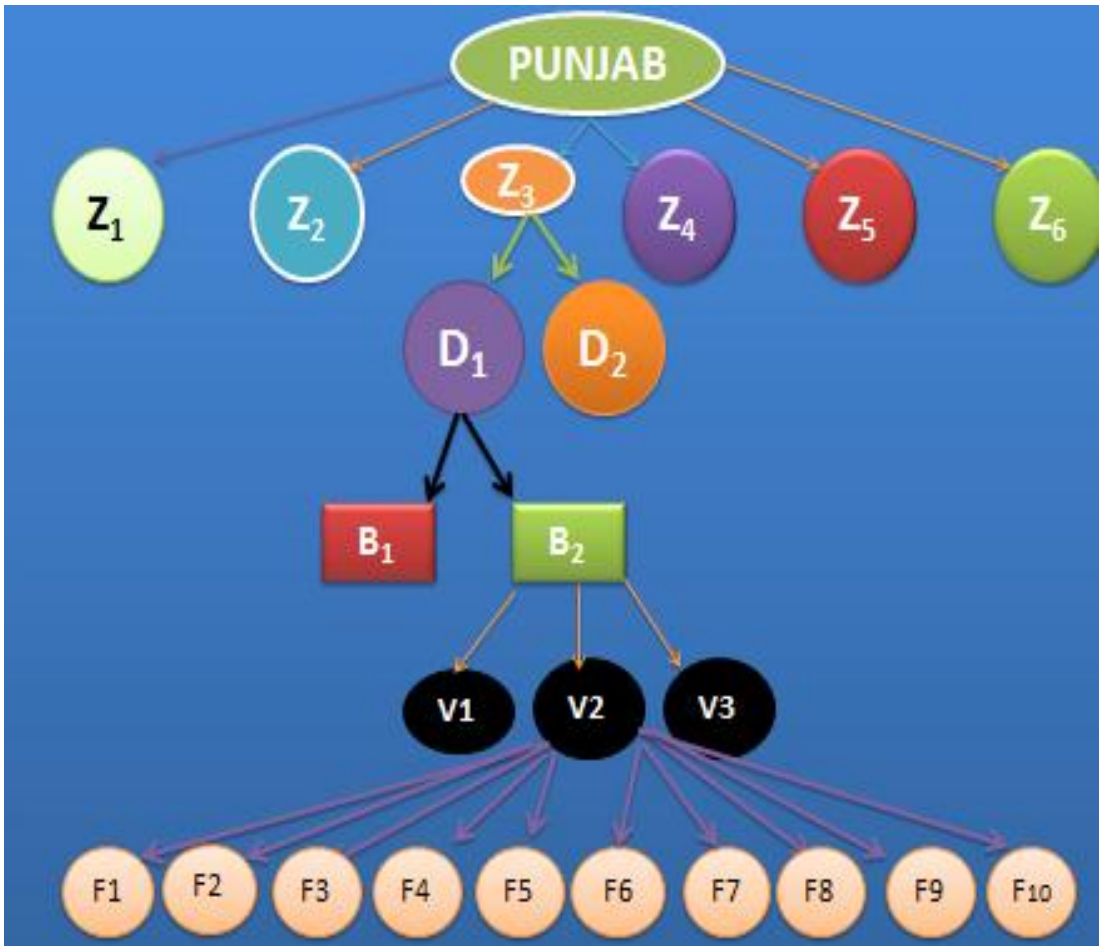
3.4 Selection of Villages

Various quantitative parameters related to assess the prevalence of important diseases and their economic impact on dairy farmers was studied in the six agro-climatic zones of Punjab. The following villages were randomly selected in each selected Tehsil.

Table 5: Selection of Villages

Zones	District	Tehsil	Village-1	Village-2	Village-3
Sub Mountainous Undulating region	Rupnagar	Rupnagar	Chack Kalan	Marholi Kalan	Sihon Majra
		Chamkaur Sahib	Chamkaur Sahib	Saloh Majra	Mane Majra
	Nawanshahr	Nawanshahr	Hiala	Jafarpur	Begumpur
		Balachaur	Lohgarh	Bakapur	Mehindipur
Undulating Plain region	Gurdaspur	Gurdaspur	Baniwal	Daburi	Tibar
		Batala	Abdal	Jaintipur	Said Mubarak
	Hoshiarpur	Hoshiarpur	Bulhowal	Bajwara	Nasrala
		Mukerian	Singowa	Rakhri Mohala	Karari
Central plain region	Patiala	Rajpura	Sultanpur	Basant Pura	Sarai Banjara
		Nabha	Rakhra	Kalla Majra	Lakhkani
	Sangrur	Sangrur	Langowal	Balian	Bindran
		Malerkotla	Kanganwal	Kup Kalan	Ahmedgarh
Western plain region	Barnala	Barnala	Mahal Kalan	Sehjra	Moom
		Tapa	Patti Khatar	Draka	Dhillwan
	Bathinda	Bathinda	Gulabgarh	Gulab Ki Patti	Tungwali
Western region	Sri Muktsar Sahib	Gidderbaha	Madhir	Husnar	Kotbhai
		Malout	Danewala	Kattian Wali	Dhaula
	Faridkot	Faridkot	Pakhi Kalan	Mehmuana	Rajowala
		Kot Kapura	Dhilwan Kalan	Sandhwan	Wara Daraka
		Rampura Phul	Lehra Dhurkor	Phul	Gill Kalan
Flood plain region	Ludhiana	Jagraon	Dholan	Chachrari	Roomi
		Samrala	Neelon Kalan	Dhande	Roula
	Pathankot	Pathankot	Kailashpur	Sujanpur	Azizpur
		Dhar Kalan	Dhar Kalan	Bhatwan	Nalloh

SAMPLING PLAN



3.5 Selection of Respondents

Sampling was done by multistage stratified random sampling across six agro-climatic zones of Punjab. From each zone two districts were selected randomly, and then from each selected district, two tehsils were selected randomly. From each selected tehsil, 3 villages were selected and then 10 dairy farmers from each selected village having at least 5 dairy animals were selected randomly. This makes the sample size up to 720.

On the basis of herd size, the dairy farmers were categorized into Small (5-10), Medium (11-50) and Large (>50). The data was collected from above mentioned dairy farmers. The respondents were interviewed for data collection using interview schedule specially prepared for the purpose.

3.6 Operationalization of variables and their measurements

3.6.1 Socio-economic profile of dairy farmers.

3.6.2 Parameters for estimation of economic losses of selected diseases.

3.6.1 Socio-economic profile of dairy farmers

a) Age

It refers to the chronological age of the respondents in years to the nearest whole numbers, at the time of interview and determined by direct questioning. According to the procedure followed by Singh (2004), age of the farmers had been categorized into following categories:

<40 years : Young

40-60 years : Middle

>60 years : Old

b) Educational status of dairy farmers

It refers to the academic qualification of respondents acquired through formal schooling and college education. Education status was measured in terms of number of schooling years and category was given one score. The procedure followed by Maheswaran (1993) was adopted in this study.

Category	**Year of schooling**	**Score**
Illiterate	No formal education	0
Primary	1-5	1
Middle	6-8	2
High school	9-10	3
Higher secondary	11-12	4
Graduate and PG	Above 12	5

c) **Occupation**

It was the main and subsidiary / secondary source of livelihood. It was categorized into following categories:

a. Agriculture

b. Dairying

c. Service

d. Business

d) Family Size

It was measured as the total number of members residing together in one household at the time of investigation. Family size was categorized as per the procedure followed by Singh (2004).

a. Small (members up to 4)

b. Medium (members 5 – 8)

c. Large (members more than 8)

e) Family type

It refers to whether there was single or joint family system in the respondent's family. A family was considered as single when it consisted of husband, wife, and unmarried children while a joint family corresponds to members of collateral relations under the same roof. The scoring system developed by Pareek and Trivedi (1964) in their socio-economic status scale was followed to quantify the family type of the respondents. The scores were:

- Nuclear family : 1
- Joint family : 2

f) Land holding

It refers to the total area of land in acres under cultivation and owned by the respondents at the time of investigation. It was measured by direct questioning. The respondents were then classified into four categories as done by National Informatics Centre (NIC) Ministry of Electronics and Information Technology (NIC, DIT, and GOI).

Landless farmer (no land)

Small or marginal (< 2 hectares)

Medium (2- 5 hectares)

Large farmer (> 5 hectares)

g) Herd Size

It is the total number of cows (heifer, dry and milch), buffaloes (heifer, dry and milch), calves and bulls/bullocks. The herd size had a direct impact on the disease occurence and health management parameters. The farmers with larger herd were having more capital, more work experience, better knowledge and more liquid money that helps them to adopt the costly animal health management practices also. The farmers with larger herd also had an impact on the meeting with extension agency and timely contact the expert for any query.

These were further categorized as follows:

a. Small herd size (1-10 animals)

b. Medium herd size (11-50 animals)

c. Large herd size (more than 50 animals)

h) **Training received in dairy farming:**

This means that the dairy farmers had received formal training regarding dairy farming from dairy related institutional training like Veterinary extension department of GADVASU or regional KVK; Animal Husbandry department; Punjab Dairy Development Board, Dairy Co-operative Society or associations like Verka etc. The respondents were asked whether they had attended any training on dairy farming or not.

Attended	:	1
Not attended	:	0

i) Institutional Participation

It was conceptualized as the respondent's participation and involvement in informal and formal organization such as Gram panchayat, co-operative society, educational committee, Kisan club, and progressive dairy farmer's association as a member or office bearer. The respondents were asked whether they had attended any training on dairy farming or not.

Attended	:	1
Not attended	:	0

j) Extension agency contacts:

This indicate whether the respondents had come in contact with the change agents such as Veterinary Officer/ Veterinary Assistant Surgeon, Extension Officer, KVK scientists/officers, Veterinary Field Assistants (VFA's), progressive farmers, NGO's and neighbor's in connection with seeking information.

Extension contacts were divided into two parts:

i. It was frequency of visits by the dairy farmers with the various sources of information like veterinary doctor, veterinary pharmacist, dairy development assistant, agriculture and veterinary extension officer, fodder development officer, member / officials of co-operative society / Verka / Mother Dairy / PDFA / NGO. Frequency of visits were measured on four point continuum scale i.e. Frequent, often, seldom, never, and scores of 3, 2, 1and 0 respectively. So, total expected score could be 18.

ii. The extension contacts also included the participation of dairy farmers in the various activities like farmer's meetings, field trips, animal exhibitions / shows, training camps, campaigns, seminar / workshops and kisan melas. For participation score 1 was given and for no participation score 0 was given. So, total expected score could be 7.

So, total maximum score an individual can have regarding extension contacts was 25. Dairy farmers were divided into three categories based on their scores regarding extension contacts:

a.	Low level of extension contacts	:	Score ≤ 9
b.	Medium level of extension contacts	:	Score 10 - 18
c.	High level of extension contacts	:	Score > 18

k) Fodder availability

Fodder availability plays an important role in dairy farming; It was classified as cultivated at home, purchased from market (excluding the branded feed) or both.

l) Access to financial facility

To finance a dairy farmer to make an appropriate decision, where he can invest his money or take a loan from financial institutions plays an important role in dairy farming. It was categorized into cooperatives, banks, insurance agencies and landlords. Farmers were asked whether they had taken financial help or not from these financial institutions.

3.6.2.1. Parameters for Estimation of Economic Losses

The epidemiological parameters pertinent to various important diseases most prevalent in Punjab region like morbidity, mortality, case fatality and culling of animals etc. were studied. The information was obtained with the help of a structured interview schedule about economic losses of FMD, HS, Mastitis, RB and Anestrus. On the basis of the information collected the data were tabulated and processed so as to develop certain conclusions.

3.6.2.1.1. Estimation of prevalence, Economic losses and its impact.

3.6.2.1.1.1. Epidemiological analysis of various diseases

In the interview, farmers were asked to describe the main epidemiological and clinical features of important diseases viz. Mastitis, FMD, HS, RB and Anestrus that they observed in their animals. Then for each category of dairy animals, the number of animals affected, culled and died during its occurrence was recorded (2016-17) to

determine morbidity, culling rate and mortality rates respectively at species level and herd levels. The animal level morbidity risk was determined as the number of animals infected divided by the total number of animals at risk, and the herd level morbidity rate was determined as the number of positive herds (herds with one or more infected animals) divided by the total number of herds. Mortality rate was determined as the number of animals died during the outbreak divided by the total number of animals at risk. Calves that apparently died due to a FMD, HS or due to shortage of milk as a consequence of an infection in the nursing cow were taken into account in the determination of the calf mortality. Different formulae used for incidence risk, prevalence rate, case fatality rates and culling rate were as below:

$$\textbf{Incidence Risk} = \frac{\text{No. of new cases of animals affected at risk during a period}}{\text{No. of animals exposed to the risk during that period}} \times 100$$

$$\textbf{Prevalence rate} = \frac{\text{Total Number of affected animals during a period}}{\text{Number of animals exposed to the risk during that period}} \times 100$$

$$\textbf{Case fatality rate} = \frac{\text{Number of deaths due to a disease}}{\text{Total population affected due to that disease}} \times 100$$

$$\textbf{Culling rate} = \frac{\text{Total number of animals culled due to affected disease condition}}{\text{Total population affected due to that disease}} \times 100$$

3.6.2.1.1.2 Statistical analysis

The chi-square test was carried out to assess the significant levels of incidence risk, prevalence rate, CFR and culling rate across herd size and different species. The one way ANOVA was employed to assess the significant levels of economic losses in different species between the study zones. All the tests were carried out using Microsoft Windows Excel and SPSS Version 22.0.

3.6.2.1.2.1 Estimation of financial losses associated with FMD

The visible loss due to FMD during the whole lactation includes the milk loss, cost of treatment, mortality cost, miscellaneous cost (transportation of affected animal, affected bedding, rope, utensils etc.) and extra labor engagement cost incurred to nurse the FMD infected animals) in different species were calculated using primary data and the formulae for calculating the different losses are presented below;

3.6.2.1.2.1 (a). Average milk yield reduction loss per animal

It includes the short term losses and long term reduction for the whole lactation. Short term loss includes reduction in milk during the disease condition while the long term loss includes the losses associated during the whole lactation period. Adibes *et al* (1998) reported FMD induced milk yield depression in HF, crossbred and indigenous animals as 37%, 17% and 5%, respectively.

$$\mathbf{L_{MY} = \sum_{n=1}^{n}((Ei - Ai) * D * P) + Long\ term\ milk\ losses}$$

Where, L_{MY} = Milk yield reduction loss due to FMD per animal (Rs.); E_i = Expected milk yield in i^{th} animal/day (litres); A_i = Actual observed milk yield in i^{th} animal/day (litres); D = the average duration of illness in days of affected lactating cows in herd; P = prevailed average price of milk (Rs./litre); n = In-milk/lactating cows recovered from FMD (number). Similarly, for indigenous cattle and buffaloes, reduction in milk yield loss was calculated.

3.6.2.1.2.1 (b). Extra labor engagement cost per animal

$$\mathbf{E_L = \sum_{j=1}^{f}([(Dj - Pj)/8] * T * W/n)}$$

Where, E_L = Extra labor engagement cost for nursing the animal (Rs.); D_j = Manpower engaged during FMD infected period in j^{th} farm (hrs/day); P_j = Manpower engaged during pre – FMD period j^{th} (hrs/day); T = Average duration of illness (days); W = Wage rate/day (Rs.); f = Number of farms; n = Number of FMD affected animals.

Since all the species of animals were reared by farmers under one roof for the purpose of calculation of the extra labor cost it was assumed that the extra labor engaged for nursing the animal was equal across the species (indigenous cattle, crossbred cattle and water buffaloes). To convert the extra labor hours engaged in the farm into man days, the total labor hours was divided by 8, as since eight hours of work is equivalent to one man-day. But for young ones we consider the wage rate for them half to the adult rate per day during the disease condition.

3.6.2.1.2.1. (c). Average mortality loss per animal

$$M_L = \frac{\left(\sum_{K=1}^{n} A_k * P_k\right)}{n}$$

Where, M_L = Mortality loss in crossbred cattle (Rs); k = Animal categories, *viz.* lactating cow, bull, heifer, male calf and female calf; A = Number of animals died due to FMD; P = Average Animal value (Rs); n = Total number FMD death cases. Similarly, for indigenous cattle and buffaloes mortality loss was calculated.

3.6.2.1.2.1 (d). Average treatment cost per animal

$$T_C = \frac{\left(\sum_{J=1}^{f}(V+M)*Z\right)}{n}$$

Where, Tc = Cost of treatment (Rs.); V = Veterinarian fees/visit (Rs.); M = Medicine cost/visit (Rs.); Z = Visits by veterinarian (number); j= animal category; f = Number of farms; n = Number of FMD affected animals.

3.6.2.1.2.1 (e). Other miscellaneous charges

This sought of cost includes transportation charges of affected animal carried to veterinary clinics, charges of disposing affected bedding, rope, utensils etc. Since all the species of animals were reared by farmers under one roof for the purpose of calculating the miscellaneous charges which were assumed to be the same across the different species.

3.6.2.1.2.2 Estimation of financial losses associated with HS

The visible loss due to HS includes the milk loss, cost of treatment, mortality cost, Miscellaneous cost (transportation of affected animal, affected bedding, rope, utensils etc.) and extra labor engagement cost incurred to nurse the HS infected animals in different species were calculated using primary data and the formulae for calculating the different losses are presented below;

3.6.2.1.2.2 (a). Average milk yield reduction loss per animal

It includes reduction in milk during the disease condition

$$\mathbf{L_{MY} = = \sum_{n=1}^{n}\left((Ei - Ai) * D * P\right)}$$

Where, L_{MY} = Milk yield reduction loss due to HS per animal (Rs.); E_i = Expected milk yield in i^{th} animal/day (litres); A_i = Actual observed milk yield in i^{th} animal/day (litres); D = the average duration of illness in days of affected lactating cows in herd; P = prevailed average price of milk (Rs./litre); n = In-milk/lactating cows recovered from HS (number). Similarly, for cattle and buffaloes, reduction in milk yield loss was calculated.

3.6.2.1.2.2 (b). Extra labor engagement cost per animal

$$\mathbf{E_L = \sum_{j=1}^{f}([(Dj - Pj)/8] * T * W/n)}$$

Where, E_L = Extra labor engagement cost for nursing the animal (Rs.); D_j = Manpower engaged during HS infected period in j^{th} farm (hrs/day); P_j = Manpower engaged during pre – HS period j^{th} (hrs/day); T = Average duration of illness (days); W = Wage rate/day (Rs.); f = Number of farms; n = Number of HS affected animals.

Since all the species of animals were reared by farmers under one roof for the purpose of calculation of the extra labor cost it was assumed that the extra labor engaged for nursing the animal was equal across the species (indigenous cattle, crossbred cattle and water buffaloes). To convert the extra labor hours engaged in the farm into man days, the total labor hours was divided by 8, since eight hours of work is equivalent to one man day. But for young ones we consider the wage rate for them half to the adult rate per day during the disease condition.

3.6.2.1.2.2 (c). Average mortality loss per animal

$$M_L = \frac{\left(\sum_{K=1}^{f} A_k * P_k\right)}{n}$$

Where, M_L = Mortality loss in crossbred cattle (Rs.); k = Animal categories, viz. lactating cow, bull, heifer and calf; A = Number of animals died due to HS; P = Average Animal value (Rs.); n = Total number HS death cases. Similarly, for indigenous cattle and buffaloes mortality loss was calculated.

3.6.2.1.2.2 (d). Average treatment cost per animal

$$T_C = \frac{\left(\sum_{J=1}^{f} (V+M)*Z\right)}{n}$$

Where, Tc = Cost of treatment (Rs.); V = Veterinarian fees/visit (Rs.); M = Medicine cost/visit (Rs.); Z = Visits by veterinarian (number); j= animal category; f = Number of farms; n = Number of HS affected animals.

3.6.2.1.2.2 (e). Other miscellaneous charges

This sought of cost includes transportation charges of affected animal carried to veterinary clinics, loading and unloading charges, charges of disposing affected bedding, rope, utensils etc. Since all the species of animals were reared by farmers

under one roof for the purpose of calculating the miscellaneous charges which were assumed to be the same across the different species.

3.6.2.1.2.3. Estimation of financial losses associated with Mastitis

The visible loss due to Mastitis includes the milk loss, cost of treatment, replacement cost, miscellaneous cost and extra labor engagement cost incurred to nurse the infected animals in different species were calculated using primary data and the formulae for calculating the different losses are presented below;

3.6.2.1.2.3. (a). Average milk yield reduction loss per animal

It includes the short term and long term reduction of milk for the whole lactation. Short term loss includes reduction in milk during the disease condition while the long term loss includes the losses associated during the whole lactation period. As per Schepers and Dijkhuizen (1991), there is reduction of 18.5% milk per affected quarter per lactation.

$$L_{MY} = \sum_{n=1}^{n}((Ei - Ai) * D * Q * P) + 18.5\%$$ **reduction of milk affected quarter per lactation**

Where, L_{MY} = Milk yield reduction loss due to Mastitis per animal (Rs.); E_i = Expected milk yield in i^{th} animal/day (litres); A_i = Actual observed milk yield in i^{th} animal/day (litres); D = the average duration of illness in days of affected lactating cows; Q= Average affected quarter; P = prevailed average price of milk (Rs./litre); n = In-milk/lactating cows recovered from Mastitis (number). Similarly, for indigenous cattle and buffaloes, reduction in milk yield loss was calculated.

3.6.2.1.2.3.(b). Extra labor engagement cost per animal

$$E_L = \sum_{j=1}^{f}([(Dj - Pj)/8] * T * W/n)$$

Where, E_L = Extra labor engagement cost for nursing the animal (Rs.); D_j = Manpower engaged during Mastitis infection period in j^{th} farm (hrs/day); P_j = Manpower engaged during pre – Mastitis period j^{th} (hrs/day); T = Average duration of illness (days); W = Wage rate/day (Rs.); f = Number of farms; n = Number of Mastitis affected animals.

Since all the species of animals were reared by farmers under one roof for the purpose of calculation of the extra labor cost it was assumed that the extra labor engaged for nursing the animal was equal across the species (indigenous cattle,

crossbred cattle and water buffaloes). To convert the extra labor hours engaged in the farm into man-days, the total labor hours was divided by 8, as since eight hours of work is equivalent to one man-day.

3.6.2.1.2.3. (c). Average replacement cost per animal

Replacement cost includes the number of animals culled due to development of fibrosis in the affected quarter and the depreciation value of animals affected due to Mastitis.

$$C_R = \frac{\left(\sum_{K=1}^{n} A_L * Q_a P_k\right)}{n}$$

Where, C_R = replacement cost of animal (Rs.); L = lactation stage, viz. lactating cow (<2), (2-5) and (>5); A = Number of animals culled due to Mastitis; Qa= Fibrosis rate or average quarters affected; P = Average Animal value (Rs.); n = Total number Mastitis replaced cases. Similarly, for indigenous cattle and buffaloes replacement cost was calculated.

Fibrosis rate (Qa) = Number of quarters resulted in fibrosis due to Mastitis/4.

The loss of book value of an animal due to incidence of disease or defect was evaluated as per the practice followed at Livestock Research Centre at National Dairy Research Institute, Karnal. The prices of adult animals were kept same up to third lactation. Depreciation @10% was accounted for 4th and 5th lactations. The rate of depreciation was doubled beyond 6th lactation to the maximum of 80 per cent.

The depreciation was calculated in non-pregnant animals suffering from Mastitis as; One teat blind (15%), Two teat blind (40%),Three teat blind (60%) and Four teat blind (90%), if not pregnant.

3.6.2.1.2.3. (d). Average treatment cost per animal

$$T_C = \frac{\left(\sum_{J=1}^{f} (V+M)*Z\right)}{n}$$

Where, Tc = Cost of treatment (Rs.); V = Veterinarian fees/cost of inseminations (Rs.); M = Medicine cost/visit (Rs.); Z = Visits by veterinarian (number); f = Number of farms; n = Number of Mastitis affected animals.

3.6.2.1.2.3.(e). Other miscellaneous charges

This sought of cost includes transportation charges of affected animal carried to veterinary clinics, loading and unloading charges and other maintenance charges. Since all the species of animals were reared by farmers under one roof for the purpose of calculating the miscellaneous charges which were assumed to be the same across the species.

3.6.2.1.2.3. Estimation of financial losses associated with RB and Anestrus

The invisible avoidable loss due to Anestrus and RB includes the expected milk yield reduction and future calf reduction value. While, the visible loss includes cost of veterinary intervention, replacement cost, extra labor engagement cost incurred and the miscellaneous cost (transportation of affected animal and other maintenance cost) of different species were calculated using primary data and the formulae for calculating the different losses are presented below;

3.6.2.1.2.4.(a). Average milk yield reduction loss per animal due to involuntary extended lactation

The reduction of milk yield was based on the study conducted by Ribeiro *et al* (2012), where he calculated that high-producing animals reducing 1.51 kg/cow/day of calving interval or 498 kg of milk/cow/year. While for moderate-producing herd averaging 305 days of lactation and reducing 1.11 kg of milk/cow/day of calving interval or approximately 366 kg/cow/year. The difference in milk yield between the period of extended lactation being considered and the average of the whole lactation (optimum lactation length) times the price of milk. For RB the average extended days consists of the average number of insemination to its estrous cycle (i.e. 21 days) while for Anestrus the extended days ranges from 290 to 310 days.

$$\mathbf{M_L = (\mu_m - \mu_p) \times P}$$

Where, M_L = Average milk yield reduction per animal per lactation; $\mu_{m=}$ Mean milk yield of the whole lactation (liters/cow/day), with lactation length defined by the user; μ_p = Period milk yield is the average milk yield of the period of involuntary extended lactation being considered (liters/cow/day); and P= Prevailed average price of milkin the market (Rs./litre). Similarly, it was assumed for indigenous cattle and buffaloes as low producers, reduction in milk yield loss was calculated.

3.6.2.1.2.4.(b). Extra labor engagement cost per animal

$$\mathbf{E_L = \sum_{j=1}^{f}([(Dj - Pj)/8] * T * W/n)}$$

Where, E_L = Extra labor engagement cost for nursing the animal (Rs.); D_j = Manpower engaged during affected period in j^{th} farm (hrs/day); T = Average duration of handling (days); W = Wage rate/day (Rs.); f = Number of farms; n = Number of affected animals.

Since all the species of animals were reared by farmers under one roof for the purpose of calculation of the extra labor cost it was assumed that the extra labor engaged for nursing the animal during the veterinary intervention only was equal across the species (indigenous cattle, crossbred cattle and water buffaloes). To convert the extra labor hours engaged in the farm into man-days, the total labor hours was divided by 8, as since eight hours of work is equivalent to one man-day.

3.6.2.1.2.4. (c). Average replacement cost per animal

Replacement cost includes the number of animals culled not recovering properly from the affected condition of Anestrus and RB.

$$C_R = \frac{\left(\sum_{K=1}^{n} R_C * (V_a - V_r)\right)}{N}$$

Where, $\mathbf{C_R}$ = Replacement cost of animal (Rs.); $\mathbf{R_c}$ = Culling rate of animals in a herd; $\mathbf{V_a}$ = Average value of animal in the market (Rs.); $\mathbf{V_r}$ = Average market value of replaced animal; and N = Average number of days extended due to Anestrus and RB. Similarly, for indigenous cattle and buffaloes replacement cost was calculated. Replaced animals were assumed to have half its premium value maintaining the same lactation yield to maintain the herd size.

Culling rate (R_c)= Number of animals not recovered from the treatment to the total number of affected animals.

3.6.2.1.2.4. (d). Average treatment cost per animal

$$T_C = \frac{\left(\sum_{J=1}^{f} (AI + V_C + M_C) * D\right)}{n}$$

Where, Tc = Total average Cost of treatment (Rs.); AI= cost of extra AI inseminations (Rs.); V_c = Veterinarian examination cost (Rs.); M_c = Treatment cost/visit (Rs.); D =

No. of veterinary intervention (number); f = Number of farms; n = Number of affected animals.

3.6.2.1.2.4. (e). Average extra feeding cost

Extra feeding cost includes the extra feeding regime during the prolonged open days of animals after post partem period (60-90 days), after the failure of conception of AI of three or more times for repeat breeder animals. Average cost of feeding regime per day per animal was calculated as per the market rate from the farmers of different category on animals. The average days for RB were taken after the first heat i.e. after 60 to 90 days. Extra feeding cost of open days in Anestrus was not directly calculated, as it was assumed to put this in maintainance cost of miscellaneous charges.

3.6.2.1.2.4. (f). Other miscellaneous charges

This sought of cost includes transportation charges of affected animal carried to veterinary clinics and other maintenance charges. Since all the species of animals were reared by farmers under one roof for the purpose of calculating the miscellaneous charges which were assumed to be the same across the species (cattle and buffaloes). Feeding charges of animals for the maintainance during their Anestrus period.

3.6.2.1.3.1. Constraints for disease control measures practiced in the study area

Garett's ranking technique was used to analyse the constraints of controlling the selected diseases as perceived by the dairy farmers. The farmers were asked to rank the various disease control constraints enlisted which they percieve. These orders of merit were transformed into units of scores by using the following formula:

$$\textbf{Percent position} = \frac{100\,(R_{ij} - 0.50)}{N_j}$$

Where, R_{ij} - Rank given for the ith factor by the jth individual.

N_j - Number of factor ranked by the jth individual.

The percent position is converted into scores by referring to the table given by Garett and Woodworth (1969). Then for each factor the scores of the individual respondents are added together and divided by the total number of respondents for whom scores were added. These mean scores for all the factors were arranged in

descending order and the most influencing factors were identified through the ranks assigned.

3.6.2.4. Statistical analysis

Results were calculated using various standard mathematical and statistical analytical tools for estimation of various economic losses and the prevalence of various diseases.

CHAPTER IV

RESULTS AND DISCUSSION

4.1.1. Socio economic profile of dairy farmers

Distribution of socio economic profile of respondents according to their age, gender, education, family type and family size is presented in Table 6.

4.1.1.1 Age

Majority of dairy farmers selected in the present study were young age groups (G-I) upto 40 years (48.27%), followed by middle age groups (G-II) of 40-60 years (35.83 %) and above 60 years (G -III) of (15.69%). Among the young age group (G-I), maximum farmers were from Zone V (59.16 %) and minimum in Zone I and Zone IV (35.0% and 36.66%, respectively). In G-II, maximum (43.33%) farmers were from Zone I, while 28.83% were from Zone V. While, in G-III, maximum (21.66%) were from Zone I and minimum (9.16%) in Zone VI.

Kashish and Dhawan (2015) reported that 35.00% dairy farmers were up to 35 years, 27.50% under age between 35-45 years and remaining 37.50% were above 45 years. Contrary to the present study, the majority of the dairy farmers belonged to middle age group years (Chauhan *et al* 2004, Mohi 2004 and Singh 2004). In present study, young age groups across all the Zones constituted the maximum proportion of dairy farmers involved in dairying.

4.2.1.2. Gender

Majority of the respondents were males (82.63%) and females (17.36%), the largest percentage of male famers were 92.5% (Zone III) and female farmers were 28.33% (Zone VI). Similar observations were also reported by Sathyanarayan *et al* (2010) that more than three fourth (81.54%) of the dairy farmers were men who were the decision makers of the family in dairy business, followed by women (15.39%) and together (3.08%).

4.2.1.3. Education

Majority of the respondents had higher secondary education (27.77%), followed by graduate and post graduate (27.36%), middle school (12.91%), high school education (12.47%), primary education (10.69 %) and illiterate (7.77%).

Chauhan (2011) reported that maximum of dairy farmers had education level up to higher secondary (27.00%) followed by high school (22.00%), 20.80 % farmers

were illiterate. 15.20% farmers had education level up to middle and 10.00 % farmers were educated up to primary. Only 4.80% farmers had their education up to graduation. Kashish and Dhawan (2015) reported that 18.75% respondents were illiterate, 47.50% respondents were up to matric, 18.75% respondents were senior secondary and only 15.00% respondents were graduates and above.

4.2.1.3. Family Type

Majority of the dairy farmers in the present study were from the joint family (62.63%), the maximum proportion (77.5%) from Zone III, followed by Zone I (72.5%) and Zone IV (65%) and least in Zone V (46.66%). However, the overall proportion of nuclear family (37.36%), the largest proportion in Zone V (53.33%) and least in Zone II (22.5%).

Chauhan (2011) reported that maximum (54.40%) farmers were living in joint family while 45.60% farmers were living in nuclear family. Laldinpuii (2013) reported that 78.80% dairy farmers were living in joint family and 21.20% were living in nuclear family, respectively. However, Sathyanarayan *et al* (2010) reported that more than half (63.08%) of the livestock farmers lived in nuclear type family followed by joint family (36.92%) type.

4.2.1.4. Family Size

Majority of the families involved in dairy farming were medium sized (47.73%), followed by large family (28.05%) and small family (24.42%). Chauhan (2011) reported in her study that majority of dairy farmers were medium sized family (45.60%), large family size (36.80%) and small family size (17.60%).

Laldinpuii (2013) reported that 49.60% dairy farmers were having medium family size, followed by 32.00% having large family size and 18.40% were having small family size respectively.

4.2.1.5. Main Occupation

Distribution of main occupation of dairy farmers is presented in Table 7. Majority of dairy farmers (56.80%) were having agriculture as their main occupation due to larger land holding, followed by 29.02% having dairying as their supportive enterprise, and 7.16% in private business and 6.80% were in government service.

Singh (2004) reported in his study that majority (95%) farmers were having agriculture as their main occupation, followed by 2.78% having government service, 1.67% having dairying and 0.56% having business as their main occupation.

Table 6: Distribution of dairy farmers according to their age, gender, education, family type and family size in different ACZ's of Punjab.

Socio-Personal Information	Category	Agro climatic Zones						Overall
		I	II	III	IV	V	VI	
Age	<40 Years	42 (35.0)	65 (54.16)	59 (49.16)	44 (36.66)	71 (59.16)	68 (56.66)	349 (48.47)
	40-60 Years	52 (43.33)	37 30.83)	46 (38.33)	51 (42.5)	31 (25.83)	41 (34.16)	258 (35.83)
	> 60 Years	26 (21.66)	18 (15)	15 (12.50)	25 (20.83)	18 (15)	11 (9.16)	113 (15.69)
	Total	120	120	120	120	120	120	720
Gender	Male	105 (87.5)	98 (81.66)	111 (92.50)	102 (85.0)	93 (77.50)	86 (71.66)	595 (82.63)
	Female	15 (12.50)	22 (18.33)	9 (7.50)	18 (15.0)	27 (22.50)	34 (28.33)	125 (17.36)
	Total	120	120	120	120	120	120	720
Education	Illiterate	12 (10)	7 (5.83)	9 (7.5)	12 (10.0)	11 (9.16)	5 (4.16)	56 (7.77)
	Primary	16 (13.33)	14 (11.66)	17 (14.16)	9 (7.5)	13 (10.83)	8 (6.67)	77 (10.69)
	Middle	11 (9.16)	19 (15.83)	13 (10.83)	19 (15.83)	15 (12.5)	16 (13.33)	93 (12.91)
	High School	8 (6.66)	13 (10.83)	21 (17.5)	18 (15.0)	16 (13.33)	21 (17.5)	97 (12.47)
	Higher Secondary	28 (23.33)	36 (30.0)	43 (35.83)	24 (20.0)	40 (33.33)	29 (24.16)	200 (27.77)
	Graduate and P.G	45 (37.5)	31 (25.83)	17 (14.16)	38 (31.66)	25 (20.83)	41 (34.16)	197 (27.36)
	Total	120	120	120	120	120	120	720
Family type	Joint	87 (72.5)	73 (60.83)	93 (77.5)	64 (53.33)	78 (65.0)	56 (46.66)	451 (62.63)
	Nuclear	33 (27.50)	47 (39.16)	27 (22.5)	56 (46.66)	42 (35.0)	64 (53.33)	269 (37.36)
	Total	120 (100)	120 (100)	120 (100)	120 (100)	120 (100)	120 (100)	720 (100)
Family Size	Small (<4)	17 (14.16)	35 (29.16)	21 (17.5)	32 (26.66)	29 (24.16)	41 (34.16)	175 (24.30)
	Medium (4-8)	68 (56.66)	54 (45.0)	56 (46.66)	49 (40.83)	65 (54.16)	51 (42.5)	343 (47.63)
	Large (> 8)	35 (29.16)	31 (25.83)	43 (35.83)	39 (32.5)	26 (21.66)	28 (23.33)	202 (28.05)
	Total	120	120	120	120	120	120	720

Figures in parenthesis indicate percentage.

4.2.1.7. Landholding

Land holding distribution of farmers associated with dairy enterprises is presented in Table 7. Majority of the dairy farmers (38.88%) were having small landholding (<2 hectares), followed by medium landholding (29.02 %), large landholding (16.80%) and landless or marginal farmers (15.27%). Landholding in the present study was associated with the dairy business due to comparative cost advantage and regular flow of income to the farmers.

Table 7: Distribution of dairy farmers according to main occupation and landholding in different agro climatic Zones of Punjab.

	Category	Agro climatic Zones						Overall
		I	II	III	IV	V	VI	
Main occupation	Agriculture	65 (54.16)	77 (64.16)	82 (68.33)	71 (59.16)	68 (56.67)	86 (71.66)	409 (56.80)
	Dairying	41 (34.16)	28 (23.33)	29 (24.16)	26 (21.66)	32 (26.66)	53 (44.16)	209 (29.02)
	Service	6 (5.0)	5 (4.16)	3 (2.50)	9 (7.50)	16 (13.33)	10 (8.33)	49 (6.80)
	Business	8 (6.66)	10 (8.33)	6 (5.0)	14 (11.67)	4 (3.33)	11 (9.16)	53 (7.36)
	Total	120	120	120	120	120	120	720
Land holding of dairy farmer (Hectare)	Landless	23 (19.16)	14 (11.66)	18 (15.0)	24 (20.0)	9 (7.50)	22 (18.33)	110 (15.27)
	Small / Marginal Farmer (≤2)	42 (35.0)	37 (30.83)	54 (45.0)	46 (38.33)	55 (45.83)	46 (38.33)	280 (38.88)
	Medium (2-5)	36 (30)	51 (42.5)	27 (22.50)	35 (29.16)	29 (24.16)	31 (25.83)	209 (29.02)
	Large (> 5)	19 (15.83)	18 (15.0)	21 (17.50)	15 (12.50)	27 22.50)	21 (17.50)	121 (16.80)
	Total	120	120	120	120	120	120	720

Figures in parenthesis indicate percentage.

Singh (2004) reported that 45% farmers had small (up to 5 acres) landholding, 25.56% had medium (5-10 acres) landholding and 29.44 % had large (> 10 acres) landholding respectively.

Sathyanarayan *et al* (2010) reported that (92.30%) were having the small landholding, followed by medium (6.17%) and large (1.53%) in Karnataka state.

4.2.1.8. Herd Size

Herd sizes of different groups were categorized on the basis number of animals reared at their farms as presented in Table 8. Majority of the dairy farmers (66.67%) had small herd (rearing upto 10 dairy animals), followed by medium herd size (25.69%) rearing 11-50 dairy animals and large herd size (7.63%) rearing more than 50 dairy animals at their farms.

Table 8: Distribution of dairy farmers according to their herd size in different ACZ's of Punjab.

Herd Size	Agro climatic Zones						Overall
	I	II	III	IV	V	VI	
Small (≤ 10)	76 (63.33)	78 (65.0)	83 (69.16)	84 (70.0)	93 (77.50)	66 (55.0)	450 (62.50)
Medium (11-50)	42 (35.50)	33 (27.50)	29 (24.16)	30 (25.0)	26 (21.67)	25 (20.83)	238 (33.05)
Large (>50)	2 (1.66)	9 (7.50)	8 (6.66)	6 (5.0)	1 (0.83)	29 (24.16)	55 (7.63)
Total	120 (100)	120 (100)	120 (100)	120 (100)	120 (100)	120 (100)	720 (100)

Figures in parenthesis indicate percentage.

4.2.1.9 Composition of Herd

Animals were categorized on the basis of species, age and sex, and distributed in different Zones as presented in Table 9. Overall adult buffaloes constituted maximum proportion of dairy animals (38.83%), followed by adult cows (30.20%), heifers of cattle and buffaloes (6.04% and 7.88%, respectively), cattle and buffalo calves (9.31% and 6.27%, respectively) and adult cattle and buffalo males (0.64% and 0.79%, respectively). Among the different ACZ's of Punjab, Zone VI contributes largest proportion of animals (39.09%) due to commercial dairy business in this region and least in Zone V due to larger small group farmers rearing lesser number of animals.

Table 9: Composition of animals reared by dairy farmers in different ACZ's of Punjab.

Herd Composition	Agro climatic Zones						Overall
	I	II	III	IV	V	VI	
Lactating/Dry Cow	393 (10.81)	506 (13.92)	659 (18.13)	454 (12.49)	248 (6.80)	1374 (37.80)	3634 (30.20)
Cow heifer	68 (9.35)	126 (17.33)	143 (19.66)	63 (8.66)	86 (11.82)	241 (33.14)	727 (6.04)
Cow calves	156 (13.91)	129 (11.50)	194 (17.30)	111 (9.90)	95 (8.47)	436 (38.89)	1121 (9.31)
Bull	11 (14.28)	21 (27.27)	14 (18.18)	10 (12.98)	6 (7.79)	15 (19.48)	77 (0.64)
Buffalo	726 (15.53)	612 (13.09)	391 (8.36)	578 (12.37)	309 (6.61)	2056 (44.01)	4672 (38.83)
Buffalo heifer	137 (14.95)	104 (11.35)	116 (12.66)	118 (12.88)	125 (13.64)	316 (34.49)	916 (7.61)
Buffalo calves	67 (8.87)	125 (16.55)	94 (12.45)	102 (13.50)	119 (15.76)	248 (32.84)	755 (6.27)
Bull/ Bullocks	6 (6.25)	21 (21.87)	24 (25.0)	17 (17.70)	10 (10.41)	18 (18.75)	96 (0.79)
Total	1564 (12.99)	1677 (13.93)	1635 (13.58)	1453 (12.07)	998 (8.29)	4704 (39.09)	12031 (100)

Figures in parenthesis indicate percentage.

4.2.1.10. Training received in dairy farming

Distribution of respondents according to training received / attended in dairy farming is presented in Table 10. Overall, 56.38% of farmers from different Zones were receiving training from dairy related Institutional Training Centers/Institutions like GADVASU, KVK's, etc. Cooperative societies like Verka etc. provide training programmes and dairy farming inputs like feed and medicine to 50.27% of dairy farmers to uplift their business. Farmer club and other dairy farm associations and cooperative societies also play a role in imparting training services to dairy farmers.

Training received by farmers between different Zones varied significantly between the different ACZ's (χ^2 = 441.03, p<0.01), while for Farmers association at village level (p<0.05). The overall impact of training received by the farmers for dairy farming was significantly associated (p<0.01).

Table 10: Training received by farmers for dairy farming in different ACZ's of Punjab.

Category	Agro climatic Zones						Overall	χ^2 value
	I	II	III	IV	V	VI		
Cooperative societies (Verka etc)	65 (54.16)	43 (35.83)	56 (46.66)	47 (39.16)	67 (55.83)	84 (70.0)	362 (50.27)	37.4*
Dairy farmers Associations and PDDB	32 (26.66)	51 (42.5)	24 (20.0)	43 (35.83)	62 (51.66)	40 (33.33)	252 (35.0)	33.3*
Animal husbandry dpt.	36 (30.0)	47 (39.16)	27 (22.5)	33 (27.5)	42 (35.0)	73 (60.83)	258 (35.83)	47.9*
Farmers Association	15 (12.5)	8 (6.66)	3 (2.5)	6 (5.0)	9 (7.5)	13 (10.83)	54 (7.5)	11.8**
Dairy related Institutional Training Center/Institution	87 (72.5)	65 (54.16)	78 (65.0)	46 (38.33)	56 (46.66)	74 (61.66)	406 (56.38)	38.4*

*Figures in parenthesis indicate percentage; *(p<0.01) and **(p<0.05) indicate significant difference.*

Singh (2004) reported that only 2.78% farmers had received dairy training whereas 97.22% farmers had not received any training in dairy farming. Laldinpuii (2013) also reported that 32.40% farmers had attended/received training, while 67.60% farmers had not attended/received any training on dairy farming.

4.2.1.11. Social Participation

Social participation is mandatory for any development for upliftment of the small and marginal farmers through promotion of dairy enterprise for making it a profitable. It can be enhanced by proper extension which brings awareness and increases knowledge level of the farmers.

The mean score value of social participation (Table 11) was highest (23.19%) from the dairy cooperative society like Verka etc. followed by institutional centers (21.45%) like GADVASU, KVK's and other ICAR institutions. Among the dairy farm associations like Sahiwal breed association, etc. the farmer's participation (18.95) was followed by gram punchayat (4.37%) and Kisan club (3.61). The active social participation among the different categories varied significantly ($p<0.01$) between the different ACZ's of Punjab except in Kisan clubs varied non-significantly ($p>0.01$). Overall, the role of social participation by dairy farmers varied significantly between the different categories and between the different Zones of this region (χ^2 = 514.09, $p<0.01$). Singh (2004) reported that the 91.67% farmers had low level, 6.67% had medium level and 1.66% had high level of social participation.

Table 11: Social participation status of dairy farmers in different ACZ's of Punjab.

Social Participation	Agro climatic Zones						Overall	χ^2 value
	I	II	III	IV	V	VI		
Gram Panchayat	21 (17.5)	13 (10.83)	9 (7.5)	3 (2.5)	7 (5.83)	10 (8.33)	63 (4.37)	19.6*
Dairy Co-operative Society	41 (34.16)	54 (45.0)	48 (40.0)	63 (52.5)	55 (45.83)	73 (60.83)	334 (23.19)	21.2*
Institutional centres	40 (33.33)	59 (49.16)	35 (29.16)	46 (38.33)	53 (44.16)	76 (63.33)	309 (21.45)	37.2*
Kisan Club	12 (10.0)	8 (6.66)	5 (4.16)	5 (4.16)	8 (6.67)	14 (11.67)	52 (3.61)	8.37^{ns}
Dairy Farmer's Association	34 (28.33)	56 (46.67)	29 (24.17)	41 (34.17)	60 (50.0)	53 (44.16)	273 (18.95)	28.4*

Figures in parenthesis indicate percentage;(p<0.01) indicate significant difference.*

4.2.1.12. Extension Contacts

Distribution of dairy farmers according to their extension contacts is presented in Table 12. Majority of the dairy farmers (65.69%) had low level of extension contacts, 26.38% had medium level of extension contacts, while 7.91% had high level of extension contacts.

For the benefit in the changing scenario of dairying industry, extension contacts must be enhanced as they are the basis for adoption of any new innovation or technology.

Table 12: Distribution of dairy farmers according to their level of extension contacts in different ACZ's of Punjab.

Extension Contacts (Total Score 25)	Agro climatic Zones						Overall
	I	II	III	IV	V	VI	
Low (≤ 9)	79 (65.88)	85 (70.83)	89 (74.16)	76 (63.33)	88 (73.33)	56 (46.66)	473 (65.69)
Medium (10-18)	32 (26.66)	31 (25.83)	26 (21.66)	29 (24.16)	28 (23.33)	44 (36.67)	190 (26.38)
High (>18)	9 (7.5)	4 (3.33)	5 (4.16)	15 (12.5)	4 (3.33)	20 (16.67)	57 (7.91)

Figures in parenthesis indicate percentage

Laldinpuii (2013) reported that 57.20% of the farmers were occasionally in contact with extension agencies for seeking information about dairy farming, 28.00% were frequent in contact while 14.80% never had any contact with extension agencies.

4.2.1.13. Availability of feed and fodder

It plays an important role in dairy farming for optimizing the dairy business and was classified as per the cultivable fodder available for animals, market feed or both across the different ACZ's of Punjab (Table 13). Majority of the farmers were using both cultivable fodder and branded feed to animals (60.69%), followed by branded feed from the market (24.30%) and cultivable fodder (15%). The availability of feed and fodder varied significantly among the different categories and between the different Zones at ($p<0.05$).

Sathyanarayan *et al* (2010) reported that low level of green fodder (92.30%), followed by low level of dry fodder (92.30%) and low level of concentrates (90.76%) was the common feeding trend observed among the farmers of the study area.

Table 13: Distribution of dairy farmers according to availability of feed and fodder in different ACZ's of Punjab.

Feed Availability	Agro climatic Zones						Overall	Mean±SE
	I	II	III	IV	V	VI		
Cultivable fodder/ Homemade feed	16 (13.33)	13 (10.80)	23 (19.16)	21 (17.5)	24 (20.0)	11 (9.16)	108 (15.0)	18.0±5.44[a]
Market Feed	32 (26.66)	25 (20.83)	28 (23.33)	33 (27.5)	18 (15.0)	39 (32.5)	175 (24.30)	29.16±7.25[b]
Both	72 (60.0)	82 (68.33)	69 (57.5)	66 (55.0)	78 (65.0)	70 (58.33)	437 (60.69)	72.83±6.01[c]

Figures in parenthesis indicate percentage.
Different lower case superscripts (a,b,c) indicate siginificant difference ($F=127.72$; $p<0.05$).

4.2.1.14. Access to financial facility

Financial assistance to dairy farmers provides supportive role to set up the dairy business at commercial level, for landless or marginal farmers to have a small dairy set up at their homes. On the basis of financial assistance from various financial institutions like banks, insurance agencies, cooperatives and landlords etc. has been presented in Table 8.

Majority of the farmers take financial assistance from various cooperative banks (25.67±10.13), followed by commercial banks (10.83±5.49), insurance agencies (8.33±4.17) and least from the landlords (2.50±1.64) during emergency period. Requirement of financial assistance by the dairy farmers varied significantly ($F=15.27$; $p<0.05$).

Modern dairy farming is highly capital intensive and access to institutional credit at affordable rate of interest is central for adequate input use and productivity growth on small farms. Though, overall institutional credit supply has increased, yet availability of credit to small and marginal farmers is proportionately low. Major source of agriculture credit are the cooperatives banks. The institutional lending being inadequate and cumbersome the farmers resort to borrowing from private non-institutional source of finance at very high rate of interest leading to farmers suicide if not repaid back.

Table 14: Distribution of dairy farmers according to financial assistance in different ACZ's of Punjab.

Financial Assistance	Agro climatic Zones						Overall	Mean±SE
	I	II	III	IV	V	VI		
Commercial Banks	5	12	8	9	10	21	65	10.83 ± 5.49^{ab}
Cooperatives Banks	32	18	23	16	22	43	154	25.67 ± 10.13^{b}
Insurance agencies	6	5	9	4	11	15	50	8.33 ± 4.17^{ab}
Landlords	2	1	5	2	1	4	15	2.50 ± 1.64^{a}
Total	45	36	45	31	44	83	284	

Different lower case superscripts (a, b) indicate siginificant difference ($F=127.72$; $p<0.05$).

Thus, the socio-economic profile of dairy farmers may be concluded that most of the dairy farmers were the males (82.63%) of young age groups upto 40 years (48.27%) and having higher secondary education (27.77%). Families of dairy farmers in the study region were mainly the medium sized of 4-8 family members (47.63%) and majority of families structure in the region were the joint family (62.63%). Agriculture was the main occupation (56.80%) among the dairy farmers in the study area and majority of the dairy farmers (38.88%) were having small landholding (< 2 hectares) to carry the agriculture and other allied activities. Majority of the dairy farmers (66.67%) were small herd groups rearing upto 10 dairy animals especially buffaloes and adult buffaloes constituted maximum proportion of dairy animals (38.83%), followed by adult cows (30.20%).

Training received by the dairy farmers for their dairy business in the study area from the different sources were perceived mostly from dairy related Institutional Training Centers/Institutions (56.38%) like GADVASU, KVK's, etc. While as, the the social participation among the dairy farmers was highest from the dairy cooperative society like Verka etc. followed by institutional centers like GADVASU, KVK's. However, the level of extension contact was low among the dairy farmers (65.69%). As per the availability of feed and fodder is concerned, majority of the

dairy farmers were feeding their animals both cultivable fodder and branded feed (60.69%). Financial assistance from the different financial sources for the promotion of dairy business or its establishment was highest various cooperative banks (21.38%).

4.2. Cattle herd size and structure

A total of 720 dairy farmers were surveyed in the six different ACZ's of Punjab during the year 2016- 2017. Farmers were categorized on the basis of their herd size viz. Small - keeping up to 10 dairy animals, Medium- keeping 11-50 dairy animals and Large-rearing more than 50 dairy animals (Table 8) to measure prevalence rate, case fatality rate and culling rate of their animals due to various disease conditions. From the different ACZ's of Punjab, herd size groups were varying and skewed towards small dairy farmers. Animals were also categorized on the basis of species they reared like cross bred (HF, Jersey), local cattle breeds (like Sahiwal, Hariana etc.) and buffaloes (like Murrah, Nilli Ravi, Upgraded buffaloes etc.). Small group farmers mainly rear the buffaloes and other local cattle breeds. Medium and large group farmers were business oriented and were mainly concerned with milk production hence they rear cross bred HF and buffaloes. The study was based on the primary data collected through survey, and hence, the results were to be visualized with certain limitations, for example the clinical signs observed by the farmer rather than the laboratory diagnosis were considered to assess the disease. Farmers in the study area keep poor farm records, and majority of information were collected based on memory recall, and hence, there may be certain recall bias on various facts of disease related parameters.

For estimation of various losses associated with the occurence of animal diseases, different economic values were incorporated for its estimation is presented in Annexure I.

4. 2.1. Epidemiological aspect of FMD in different ACZ's of Punjab

Several FMD outbreaks were reported by farmers in different Zones of this state and the farmers were severely affected by outbreaks in terms of their financial losses (Table 15-20). The overall incidence risk and case fatality rate (CFR) among

dairy animals was 7.37 and 21.32 percent respectively (Table 28-29). Prevalence of FMD on the species basis varied significantly (χ^2=114.91; p<0.01) and was observed highest in cross bred animals (10.30%), followed by indigenous cattle (9.13%) and buffaloes (5.02%). Similarly, the incidence risk of FMD (Fig 1) among the different ACZ's of Punjab in cross bred and indigenous cattle was not significant (p>0.05) and ranged from 8.41% (Zone III) to 12.69% (Zone II) and 5.84% (Zone VI) to 12.63% (Zone III) respectively. However, in buffaloes, it varies significantly (p<0.01) and ranges between from 2.75% (Zone V) to 9.38% (Zone II). Case fatality rate didn't varied significantly between the different categories of animals (p>0.05), however it varied significantly between the different ACZ's of Punjab for each category of species. In cross bred cattle, the CFR due to FMD (21.12%) varied significantly (p<0.05) and ranged from 10.63% (Zone VI) to 29.31% (Zone I). In indigenous cattle, CFR due to FMD (19.04%) varied significantly (p<0.05) and ranged from 12.5% (Zone I) to 33.33% (Zone V). Similarly, in buffaloes, the CFR value was highest (22.22%) and varied significantly (p<0.01) with no case found in Zone V and highest CFR value in Zone II (44.04%).

Among the herd sizes (Table 8), the incidence risk of FMD varied significantly (p<0.05) and was highest in medium herd (8.1%) size followed by small (7.64%) and large herd size (6.76%). Incidence risk between the different ACZ's of Punjab varied significantly (p<0.01) in small herd size ranged from 4.62% (Zone VI) to 12.90% (Zone II) and for medium herd size, ranges between 3.26% (Zone V) to 15.67% (Zone II). But in large herd size there were no cases found in Zone I and Zone V due to their fewer number and reared mostly buffaloes, whereas the highest Incidence risk (15.01%) was found in Zone II due to vaccination failure. Similarly, the CFR due to FMD (Fig 2) in dairy animals across the different herd size and different ACZ's didn't vary significantly (p>0.05) and was highest in medium herd size (24.91%) followed by small (22.27%) and large herd groups (17.41%). In small herd size, its incidence risk ranges from 17.14% (Zone I) to 33.33% (Zone IV). For medium herd size, it ranges from11.62% (Zone IV) to 34.11% (Zone III) and there were no mortality cases found in Zone I & V against the Zone II (42.10%). However, the overall CFR (Fig 4) due to FMD between the different ACZ's of Punjab varied

significantly (χ^2=10.69; p>0.05) and ranged from 17.46% (Zone IV) to 29.31% (Zone I).

The overall occurrence of FMD (Fig 1) among the different species of animals was highest in cross bred cattle followed by indigenous cattle and buffaloes, as the cows were inherently susceptible to this disease and various out breaks especially in medium sized herd groups in different farms caused death of animals especially among the young animals. However, the occurrences of FMD in buffaloes in some cases were associated with HS. Similar findings were reported by Murthy and Ramaswami (1999). Chandranaik *et al* (2007), Sunder *et al* (2008), Gorsi *et al* (2011), Mekonen *et al* (2011), Shah *et al* (2011), Shamsudeen *et al* (2013), Ashfaq *et al* (2015) and Govindaraj *et al* (2017).

Few previous studies didn't agree to our results due to very less incidence risk of FMD in this region. Saxena (1994) reported that the highest incidence of FMD in India was in indigenous cattle (29%), followed by dairy cattle (25%), young animals (23%), buffaloes (20%), crossbred animals (17%) and sheep, pigs and goats (16% each). Mannan *et al* (2009) and Baluka *et al* (2014), reported prevalence of FMD 24.5% and 23.6%, respectively. Because, Punjab is one of the leading state in dairy sector and farmers were well aware about this disease through Government agencies or Institutions and dairy cooperative societies providing extension activities in controlling this disease. Also the Government initiative through animal husbandry department in controlling FMD in the state was encouraging due to better vaccination coverage and effective extension programmes. Hence, the prevalence of this disease was much limited compared to other states of this country. However, Mathew and Menon (2008) reported lower incidence rate of 2.42% and 0.12% mortality rate in bovines in Chazhoor Panchayath of Thrissur district in Kerala. Because, there can be some negligence in cold chain storage which leads to failure in vaccination prophylaxis of animals and due to poor biosafety and sanitary measures in commercial dairy farms.

Table 15: Incidence and CFR risk due to FMD across herd sizes, species and categories of dairy animals in Zone I of Punjab.

	Category	Total Animals	Affected Animals	Prevalence Rate (%)	No. of Animals died	Mortality Rate (%)
Herd size	**Small**	406	24	5.91	7	29.16
	Medium	736	65	8.83	18	27.69
	Large	122	0	0	0	0
	Overall	1264	89	7.04	25	28.08
			$\chi^2 = 3.10^{ns}$		$\chi^2 = 0.18^{ns}$	
Cross Bred	**Lactating cow**	360	44	12.22	11	25.00
	Heifer	59	6	10.16	2	33.33
	Calf	135	8	5.92	4	50.00
	Overall	554	58	10.46	17	29.31
			$\chi^2 = 4.18^{ns}$		$\chi^2 = 2.09^{ns}$	
Local	**Lactating cow**	33	4	12.12	0	0
	Heifer	9	1	11.11	0	0
	Calf	21	2	9.52	1	50.00
	Adult Bull	11	1	9.09	0	0
	Overall	74	8	10.8	1	12.5
			$\chi^2 = 0.12^{ns}$		$\chi^2 = 0.0^{ns}$	
Buffalo	**Lactating buffalo**	426	12	2.81	3	25.00
	Heifer	67	3	4.47	1	33.33
	Calf	137	8	5.83	3	37.50
	Buffalo bull	6	0	0	0	0
	Overall	636	23	3.61	7	30.43
			$\chi^2 = 2.82^{ns}$		$\chi^2 = 0.36^{ns}$	

$^{*}(p<0.01)$ and ** $(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 16: Incidence and CFR risk due to FMD across herd sizes, species and categories of dairy animals in Zone II of Punjab.

	Category	Total Animals	Affected Animals	Prevalence rate (%)	No. of animals died	Mortality Rate (%)
Herd size	**Small**	488	63	12.90	16	25.39
	Medium	606	95	15.67	17	17.89
	Large	583	19	3.25	4	21.05
	Overall	1677	177	10.55	37	20.90
			$\chi^2 = 52.57^{**}$		$\chi^2 = 1.28^{ns}$	
Cross Bred	**Lactating cow**	348	41	11.78	7	17.07
	Heifer	83	11	13.25	5	45.45
	Calf	78	12	15.38	7	58.33
	Bull	3	1	33.33	0	0
	Overall	512	65	12.69	19	29.23
			$\chi^2 = 1.94^{ns}$		$\chi^2 = 9.15^{**}$	
Local	**Lactating cow**	158	13	8.22	0	0
	Heifer	43	5	11.62	1	20
	Calf	51	9	17.64	4	44.44
	Adult Bull	18	1	5.55	0	0
	Overall	270	28	10.37	5	17.85
			$\chi^2 = 4.20^{ns}$		$\chi^2 = 4.53^{ns}$	
Buffalo	**Lactating buffalo**	612	54	8.82	6	11.11
	Heifer	125	12	9.6	2	16.66
	Calf	137	16	11.67	5	31.25
	Buffalo bull	21	2	9.52	0	0
	Overall	895	84	9.38	37	44.04
			$\chi^2 = 1.08^{ns}$		$\chi^2 = 3.75^{ns}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 17: Incidence and CFR risk due to FMD across herd sizes, species and categories of dairy animals in Zone III of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of animals died	Mortality rate (%)
Herd size	**Small**	497	51	10.26	13	25.49
	Medium	568	41	7.21	7	17.07
	Large	570	35	6.14	4	11.42
	Overall	1635	127	7.76	24	18.89
			$\chi^2 = 6.66^{**}$		$\chi^2 = 2.80^{ns}$	
Cross Bred	**Lactating cow**	587	42	7.15	6	14.28
	Heifer	134	12	8.95	3	25
	Calf	186	22	11.82	8	36.36
	Bull	8	1	12.5	0	0
	Overall	915	77	8.41	17	22.07
			$\chi^2 = 4.24^{ns}$		$\chi^2 = 4.85^{ns}$	
Local	**Lactating cow**	72	6	8.33	0	0
	Heifer	9	2	22.22	1	50
	Calf	8	3	37.5	2	66.66
	Adult Bull	6	1	16.66	0	0
	Overall	95	12	12.63	2	16.66
			$\chi^2 = 6.52^{ns}$		$\chi^2 = 0.13^{ns}$	
Buffalo	**Lactating buffalo**	391	16	4.09	1	6.25
	Heifer	94	7	7.44	1	14.28
	Calf	116	13	11.20	3	23.07
	Buffalo bull	24	2	8.33	0	0
	Overall	625	38	6.08	5	13.15
			$\chi^2 = 8.56^{**}$		$\chi^2 = 2.36^{ns}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 18: Incidence and CFR risk due to FMD across herd sizes, species and categories of dairy animals in Zone IV of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of animals died	Mortality rate (%)
Herd size	**Small**	470	27	5.74	11	40.74
	Medium	610	43	7.04	4	9.30
	Large	373	56	15.01	2	3.57
	Overall	1453	126	8.67	17	13.49
			χ^2 =26.05**		χ^2 =22.54**	
Cross Bred	**Lactating cow**	287	29	10.10	2	6.896
	Heifer	31	5	16.12	1	20.0
	Calf	63	12	19.04	2	16.66
	Bull	5	1	20.0	0	0
	Overall	386	47	12.17	5	10.63
			χ^2 =4.67^{ns}		χ^2 = 10.01**	
Local	**Lactating cow**	167	11	6.58	1	9.09
	Heifer	32	3	9.37	0	0
	Calf	48	6	12.5	2	33.33
	Adult Bull	5	0	0	0	0
	Overall	252	20	7.93	3	15.0
			χ^2 = 2.35^{ns}		χ^2 = 1.59^{ns}	
Buffalo	**Lactating buffalo**	578	34	5.88	3	8.82
	Heifer	102	9	8.82	2	22.22
	Calf	118	15	12.71	4	26.66
	Buffalo bull	17	1	5.88	0	0
	Overall	815	59	7.23	9	15.25
			χ^2 =7.27^{ns}		χ^2 = 4.38^{ns}	

**(p<0.01) and **(p<0.05) indicate significant difference; ns(p>0.05) indicate no significant difference.*

Table 19: Incidence and CFR risk due to FMD across herd sizes, species and categories of dairy animals in Zone V of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of animals died	Mortality rate (%)
Herd size	**Small**	662	35	5.28	4	11.42
	Medium	552	18	3.26	4	22.22
	Large	84	0	0	0	0
	Overall	998	53	5.31	8	15.09
			$\chi^2 = 3.37^{ns}$		$\chi^2 = 1.08^{ns}$	
Cross Bred	**Lactating cow**	219	29	13.24	3	10.34
	Heifer	71	7	9.85	1	14.28
	Calf	87	4	4.59	2	50.0
	Overall	377	40	10.61	6	15.0
	Overall	915	77	8.41	17	22.07
			$\chi^2 = 4.95^{ns}$		$\chi^2 = 4.33^{ns}$	
Local	**Lactating cow**	29	3	10.34	1	33.33
	Heifer	15	1	6.66	0	0
	Calf	8	1	12.5	1	100
	Adult Bull	6	1	16.66	0	0
	Overall	58	6	10.34	2	33.33
			$\chi^2 = 0.51^{ns}$		$\chi^2 = 0.33^{ns}$	
Buffalo	**Lactating buffalo**	309	5	1.61	0	0
	Heifer	119	1	0.84	0	0
	Calf	125	1	0.8	0	0
	Buffalo bull	10	0	0	0	0
	Overall	254	7	2.75	0	0
			$\chi^2 = 5.97^{ns}$		$\chi^2 = 0.0^{ns}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 20: Incidence and CFR risk due to FMD across herd sizes, species and categories of dairy animals in Zone VI of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of animals died	Mortality rate (%)
Herd size	**Small**	238	11	4.62	2	18.18
	Medium	594	35	5.89	8	22.85
	Large	3872	269	6.94	42	15.61
	Overall	4704	305	6.48	52	17.04
			χ^2 =2.60 ^{ns}		χ^2 = 1.20 ^{ns}	
Cross Bred	**Lactating cow**	1262	112	8.87	15	13.39
	Heifer	215	23	10.69	4	17.39
	Calf	418	56	13.39	18	32.14
	Overall	1895	191	10.07	37	19.37
	Overall	1262	112	8.87	15	13.39
			χ^2 = 7.18**		χ^2 =8.46**	
Local	**Lactating cow**	112	5	4.46	1	6.42
	Heifer	26	2	7.69	0	
	Calf	18	3	16.66	2	66.66
	Adult Bull	15	0	0	0	0
	Overall	171	10	5.84	3	30.00
			χ^2 = 3.93 ^{ns}		χ^2 = 1.78 ^{ns}	
Buffalo	**Lactating buffalo**	2056	74	3.59	4	5.40
	Heifer	248	12	4.83	2	16.66
	Calf	316	17	5.37	6	35.29
	Buffalo bull	18	1	5.55	0	0
	Overall	2638	104	3.94	12	11.53
			χ^2 = 2.89^{ns}		χ^2 = 12.32**	

*(p<0.01) and **(p<0.05) indicate significant difference; ^{ns}(p>0.05) indicate no significant difference.

Table 27: Incidence and CFR risk due to FMD on species basis of dairy animals in different ACZ's of Punjab.

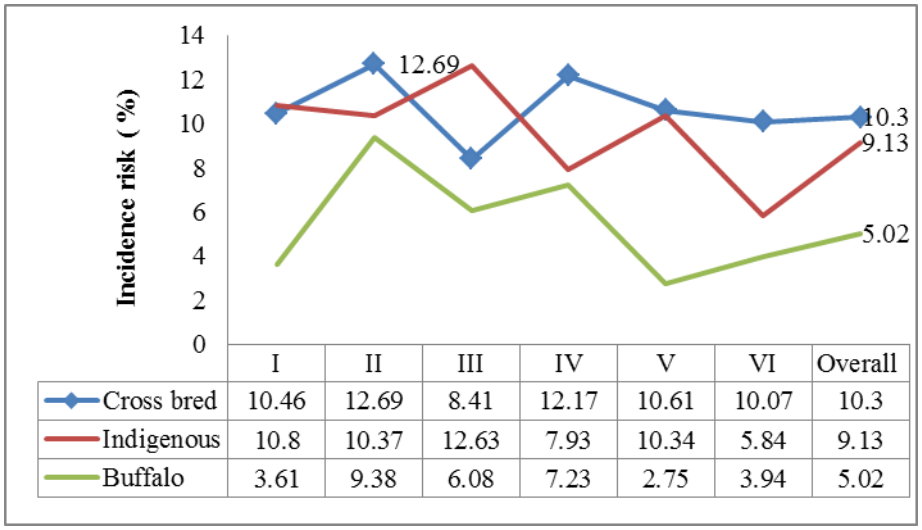
Species Basis	Category	Agro-climatic Zones of Punjab									
		I	II	III	IV	V	VI	χ^2 Value	Total animals	Affected animals	Prevalence (%)
Incidence rate (%)	Cross- bred Cattle	10.46	12.69	8.41	12.17	10.61	10.07	8.32^{ns}	4639	478	10.30
	Indigenous cattle	10.8	10.37	12.63	7.93	10.34	5.84	4.91^{ns}	920	84	9.13
	Buffalo	3.61	9.38	6.08	7.23	2.75	3.94	52.44^{*}	6472	325	5.02
									Overall χ^2 Value = 114.9^{*}		
CFR (%)	Cross- bred Cattle	29.31	29.23	22.07	10.63	15.0	19.37	9.21^{**}	478	101	21.12
	Indigenous cattle	12.5	17.85	16.66	15.0	33.33	30.0	22.07^{**}	84	16	19.04
	Buffalo	30.43	44.04	13.15	15.25	-	11.53	36.38^{*}	315	70	22.22
									Overall χ^2 Value = 0.42^{ns}		

*(p<0.01) and **(p<0.05) indicate significant difference; ^{ns}(p>0.05) indicate no significant difference.

Table 28: Incidence and CFR risk due to FMD on herd basis of dairy animals in different ACZ's of Punjab.

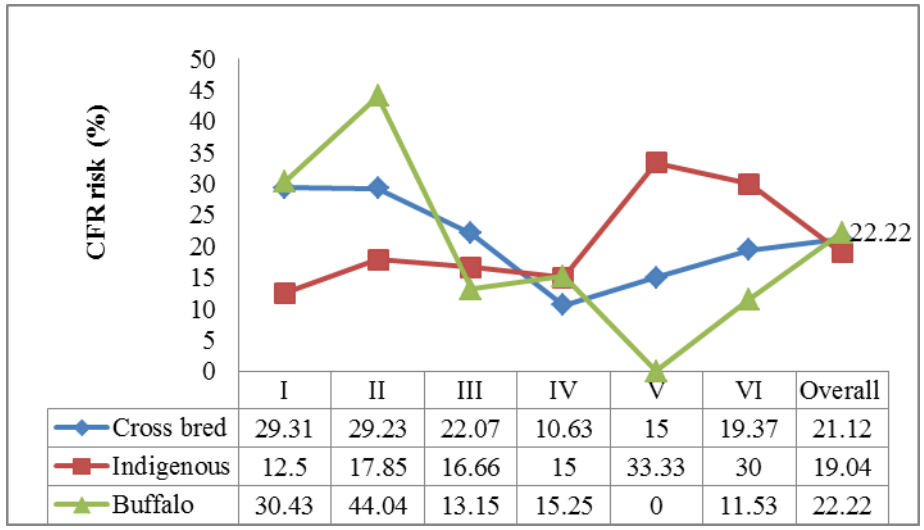
Herd basis	Category	Agro-climatic Zones of Punjab									
		I	II	III	IV	V	VI	χ^2 Value	Total Animals	Affected Animals	Prevalence (%)
Incidence rate (%)	Small	5.91	12.90	10.26	5.74	5.28	4.62	36.41^{*}	2761	211	7.64
	Medium	8.83	15.67	7.21	7.04	3.26	5.89	70.0^{*}	3666	297	8.10
	Large	-	3.25	6.14	15.01	-	6.94	67.11^{*}	5604	379	6.76
									Overall χ^2 Value = 6.19^{**}		
CFR (%)	Small	29.16	22.22	17.64	33.33	17.14	18.18	3.83^{ns}	211	47	22.27
	Medium	29.23	22.10	34.14	11.62	33.33	25.71	7.66^{ns}	297	74	24.91
	Large	-	42.10	17.14	14.28	-	16.35	8.64^{ns}	379	66	17.41
	Overall	7.04	10.55	7.76	8.67	5.31	6.48	55.49^{*}	12031	887	7.37
									Overall χ^2 Value = 5.86^{ns}		

*(p<0.01) and **(p<0.05) indicate significant difference; ^{ns}(p>0.05) indicate no significant difference.



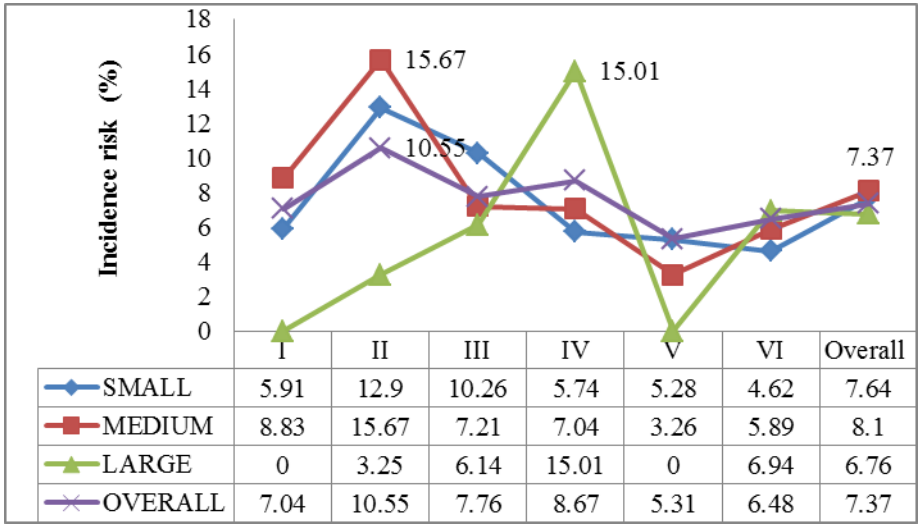
	I	II	III	IV	V	VI	Overall
Cross bred	10.46	12.69	8.41	12.17	10.61	10.07	10.3
Indigenous	10.8	10.37	12.63	7.93	10.34	5.84	9.13
Buffalo	3.61	9.38	6.08	7.23	2.75	3.94	5.02

Fig. 1: Incidence risk of FMD on Species basis



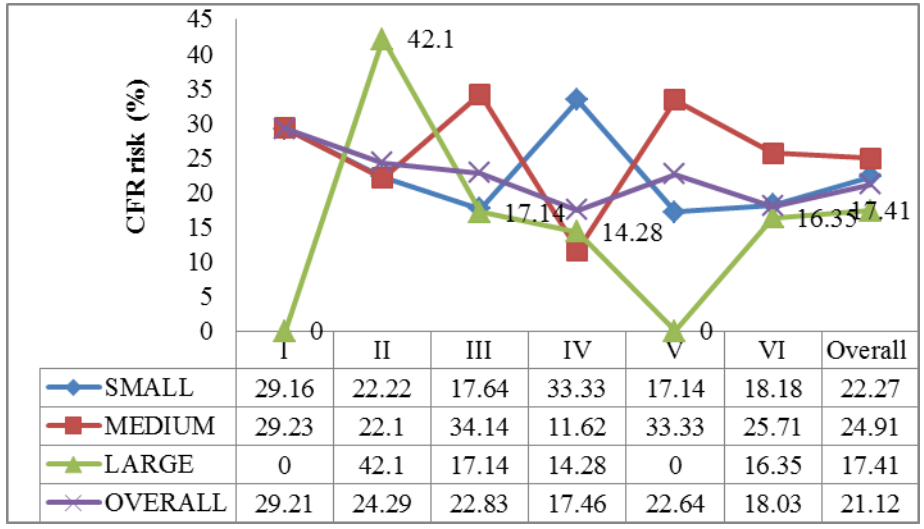
	I	II	III	IV	V	VI	Overall
Cross bred	29.31	29.23	22.07	10.63	15	19.37	21.12
Indigenous	12.5	17.85	16.66	15	33.33	30	19.04
Buffalo	30.43	44.04	13.15	15.25	0	11.53	22.22

Fig. 2: CFR risk of FMD on Species basis



	I	II	III	IV	V	VI	Overall
SMALL	5.91	12.9	10.26	5.74	5.28	4.62	7.64
MEDIUM	8.83	15.67	7.21	7.04	3.26	5.89	8.1
LARGE	0	3.25	6.14	15.01	0	6.94	6.76
OVERALL	7.04	10.55	7.76	8.67	5.31	6.48	7.37

Fig. 3: Incidence risk of FMD on Herd basis



	I	II	III	IV	V	VI	Overall
SMALL	29.16	22.22	17.64	33.33	17.14	18.18	22.27
MEDIUM	29.23	22.1	34.14	11.62	33.33	25.71	24.91
LARGE	0	42.1	17.14	14.28	0	16.35	17.41
OVERALL	29.21	24.29	22.83	17.46	22.64	18.03	21.12

Fig. 2: CFR risk of FMD on Herd basis

Between the different ACZ's, Zone II (undulating plain region) had largest cases of FMD observed, which can be due to unawareness, engagement of dairy farmers in their agricultural lands, failure of vaccination prophylaxis and improper vaccination coverage. Further spread of the disease might be possibly due to the movement of affected animals to the livestock market and other parts of this region. However, the lower occurrences of FMD were observed in Zone V (Western Region) and VI (Flood plain region) which could be due to better vaccination coverage and awareness of people about FMD control. CFR was observed exceptionally high in buffaloes followed by cross bred and indigenous cattle because FMD occurrence among the buffaloes was found mainly to young animals causing heavy mortality as young animals were more susceptibility to FMD. Furthermore, CFR among the different Zones, Zone I suffer the largest mortality followed by Zone II & III and least observed in Zone IV because of poor management and treatment of affected animals during the disease occurrence.

It may be concluded that, occurrence of FMD in the study area was more skewed towards the cross bred animals followed by indigenous cattle and buffaloes. However, CFR was almost same among the different categories of animals. On herd basis, medium herd groups of animals were more affected followed by small and large herd size. Among the different ACZ's of Punjab, undulating plain region suffered with highest occurrence of FMD followed by Central Plain region, where as the least affected region of the study area was the Western region.

4. 2.2. Economic losses due to FMD

Only the direct loss due to FMD which were visible to the dairy farmer were estimated viz. milk yield reduction, treatment cost, extra labour charges to nurse animal, loss due to mortality of affected animal and miscellaneous costs. Since the estimation of various financial losses due to FMD is based on simulation models to calculate their losses to frame certain assumptions. Few parameters like average lactation yield, average daily milk yield and average market value of animals were used to calculated the losses due to FMD. Average value of different categories of animals based on their market value according to their age, species and lactation yield and their value was depreciated by 10% after third lactation and 20% after 5^{th} lactation.

Assumtions incorporated for estimation of losses due to FMD in dairy animals has been presented in Annexure I. Labour charges on monthly basis were estimated from the average wage rate in the study area which was latter calculated on hour basis (@Rs 40 per hour per case) to simplify the estimate. Veterinary charges were estimated from the overall expenses incurred during the illness period. Average days of illness due to FMD was measured upto 12 days with 80% reduction in milk in cattle and 70% reduction of milk in buffaloes during the illness period. Average illness period due to FMD was assumed to 12 days. Vaccination coverage of animals was 93.4% (Directorate of Animal Husbandry, Punjab, 2016) but the occurrence of FMD in animals were assumed to be in non-vaccinated animals. Hence, for estimation of economic impact we assume that the affected animals were non-vaccinated.

4. 2.2.1. Loss in milk yield

The results regarding the loss in milk yield has been presented in Table 29. The milk loss calculated from the lactating animals affected due to FMD implies the reduction of milk per lactation period in different categories of animals from the different ACZ's of Punjab. A perceptible milk yield loss due to FMD was observed in short term and long term period. For short term loss, the average duration of illness among the different Zones was observed due to FMD (almost 12 days) where animals drastically reduce the milk production (up to 80% in cattle and 70% in buffaloes), the average cost of milk sold by the dairy farmers at their door step was Rs 37.5 per litre for cow milk and Rs 47.5 per litre for buffalo milk. However, the long term reduction in milk yield for the whole lactation was estimated as per the study conducted by Adibes *et al* (1998) and reported FMD-induced milk yield depression in Holstein, cross- and local breed cows as 37%, 17% and 5%, respectively.

From the Table 29, the mean total of milk yield loss per animal per year from the different species was highest in cross bred animals (29.38%) of Rs. 7389.87±643.5 and ranged from Rs.4962.10 (Zone III) to Rs 9188.56 (Zone V), followed by indigenous cattle (14.83%) of Rs 1448.94±191.4 ranging from Rs. 774.7 (Zone VI) to Rs 2105.24 (Zone I) and buffaloes (4.33%) of Rs 290.33±67.9) ranged between Rs. 104.65 (Zone V) to Rs 573.3 (Zone II). However, in case of buffaloes,

there was less impact on milk production compared to cattle due to lower incidence risk and lower milk yield from them as compared to cattle.

The average milk loss from all the six ACZ's was highest in cross bred cattle, followed by indigenous cow and buffaloes. Similar findings were reported by Govindaraj *et al* (2017) on farm community impacts of FMD in Karnataka and estimated the loss Rs. 21,255 due to reduction in milk yield in cross bred animals, Rs. 5395 in indigenous cattle, Rs. 5785 in local buffaloes and Rs. 12090 upgraded buffaloes. Power and Harris (1973) stated 25% depression in the lactation yield of Holstein cows in the UK.

Few earlier studies contradicts and show much higher losses, Singh *et al* (2013) estimates much higher (49.83%) milk loss (direct and indirect). Mathew and Menon (2008) estimated the loss in milk production around 80.68% because the authors had considered only treatment cost, loss in milk production and loss due to abortion without considering the replacement cost of animals affected due to FMD. Similarly, Jemberu *et al* (2014) reported that the major loss due to the FMD occurred as a result of milk losses and draft power losses whereas mortality losses were relatively low.

4.2.2.2. Treatment cost

The treatment cost incurred by the farmers was varying among the different categories of animals during the illness period (Table 22-27). From the Table 29, largest treatment cost per animal per year was perceived in cross bred cattle (5.14%) of Rs. 1293.12±214.7, ranging from Rs. 894.09 (Zone VI) to Rs. 2122.8 (Zone II) followed by indigenous cattle (10.55%) of Rs. 1030.51±184.7 ranging from (Rs. 548.27 (Zone VI) to Rs. 1178.2 (Zone V) and buffaloes (7.72%) of Rs. 517.51±130.57 ranging from Rs. 78.9 (Zones V) to Rs. 930.24 (Zone II). The differences in treatment cost from the different ACZ's of Punjab was due to variation in number of days of illness, incidence risk, treatment charges and recovery level. Govindaraj *et al* (2017) estimated treatment cost of affected animals of cross bred cattle, indigenous cattle, local buffalo and upgraded buffalo as Rs. 2470, Rs. 2145, Rs. 2210 and Rs. 1430, respectively.

4.2.2.3. Extra labor engagement cost

The cost incurred on additional labour to nurse the infected animal during the disease condition varied across the different Zones of this region and among the various categories of animals (Table 29). Extra labourswere used to nurse the affected animals during the illness period for treatment (twice a day) and to take care of them. were The estimated loss per animal per year in cross bred animals (1.23%) was Rs.311.04±57.31, ranging from Rs. 203.08 (Zone V) to Rs. 528.4 (Zone II), followed by indigenous cattle (3%) of Rs. 293.51 ± 53.58, ranging from Rs.163.84 (Zone VI) to Rs. 527.68 (Zone III) and buffalo (2.32%) of Rs.155.63± 39.21, ranging from Rs. 22.8 (Zone VI) to Rs. 270.2 (Zone II). The differences in additional labor cost incurred in the surveyed Zones was due to differences in duration of illness, recovery period, variation in wage rates and proportion of different category of animals owned by the farmer. Govindaraj *et al* (2017) estimated that extra labour engagement expenses for nursing of FMD affected bovines of Rs. 1950, although the value is higher compared to our result due to differences in wage rate and number of hours undertaken for nursing affected animals.

4.2.2.4. Loss due to mortality of animals

From Table 29 the loss due to mortality was the important factor and contributing the highest percentage from the total losses in the present study among the various categories of animals viz. crossbred (67.08%), indigenous (71.59%) and buffaloes (74.67%) from the different ACZ's of Punjab. In the study area, there was no salvage value to dead animals, hence it was the total loss of asset once animals were died due to FMD. The mean total loss per animal per year due to mortality in cross bred animal was Rs.16872.17, ranging from Rs. 10972.51 (Zone IV) to Rs. 27500.01 (Zone II), followed by indigenous cattle of Rs. 6991.43, ranging from Rs. 4267.81 (Zone IV) to Rs. 8567.6 (Zone I) and in buffalo of Rs.5003.1, ranging from Rs. 1158 (Zone V) to Rs. 9408 (Zone VI). Mortality among the animals was higher in young ones than adult animals. The variation in mortality loss among the different categories of animals was due to variation in their age and value of animals affected.

Table 21: Economic losses due to FMD and BCA of different species and categories of dairy animals in Zone I of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Vaccine coverage (%)	Vaccine Effectiveness (%)	Total benefits of vaccination per year (Rs)	Total cost of control (Rs)	BCA (B/C)
Cross Bred	**Lactating cow**	8848.06	513.24	97.76	9776	61.1	18928.78	94	87.78	15618.74	1000	17.8
	Heifer		304.8	81.28	3048	40.64	3474.72	94	89.84	2934.38		
	Calf		88.8	23.68	296	11.84	420.32	94	94.08	371.71		
	Overall	8848.06	906.84	202.72	13120	113.58	22823.82	94	83.0	17807.14		
Local	**Lactating cow**	2105.24	424.2	96.96	6060	60.6	8747.04	94	87.88	7225.68	1000	10.25
	Heifer		277.75	88.88	2222	44.44	2633.07	94	88.89	2200.10		
	Calf		114.24	38.08	285.6	19.04	456.96	94	90.48	388.65		
	Adult Bull		272.7	72.72	0	45.45	390.87	94	90.91	334.01		
	Overall	2105.24	1088.89	296.64	8567.6	169.53	12227.94	94	89.2	10252.88		
Buffalo	**Lactating buffalo**	182.65	84.3	22.48	1686	14.05	1989.48	94	97.19	1817.56	1000	3.01
	Heifer		111.75	35.76	894	17.88	1059.39	94	95.53	951.31		
	Calf		69.96	23.32	174.9	11.66	279.84	94	94.17	247.71		
	Buffalo bull	-	-	-	-	-	-	-	-			
	Overall	182.65	266.01	81.56	2754.9	43.59	3328.71	94	96.39	3016.03		

Table 22: Economic losses due to FMD and BCA of different species and categories of dairy animals in Zone II of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Vaccine Coverage (%)	Vaccine Effectiveness (%)	Total benefits of cination per year (Rs)	Total cost of control (Rs.)	BCA (B/C)
Cross Bred	**Lactating cow**	8175.32	494.76	94.24	9424	58.9	18247.22	94	88.22	15131.84	1000	31.70
	Heifer		397.5	106	3975	53	4531.5	94	86.75	3695.21		
	Calf		230.7	61.52	769	30.76	1091.98	94	84.62	868.59		
	Bull		999.9	266.64	13332	166.65	14765.17	94	66.67	9253.30		
	Overall	8175.32	2122.86	528.4	27500	309.31	38635.87	94	87.31	31709		
Local	**Lactating cow**	1427.81	287.7	65.76	4110	41.1	5932.37	94	91.78	5118.04	1000	10.1
	Heifer		290.5	92.96	2324	46.48	2753.94	94	88.38	2287.89		
	Calf		211.68	70.56	529.2	35.28	846.72	94	82.36	655.51		
	Adult Bull		166.5	44.4	-	27.75	2458.65	94	94.45	2182.86		
	Overall	1427.81	956.38	273.68	6963.2	150.61	11991.68	94	89.63	10103.25		
Buffalo	**Lactating buffalo**	573.3	264.6	70.56	5292	44.1	6244.56	94	91.18	5352.16	1000	11.32
	Heifer		240	76.8	1920	38.4	2275.21	94	90.4	1933.37		
	Calf		140.04	46.68	350.1	23.34	560.16	94	88.33	465.10		
	Buffalo bull		285.6	76.16	-	47.6	4217.36	94	90.48	3586.95		
	Overall	573.3	930.24	270.2	7562.1	153.44	13297.28	94	90.62	11327		

Table 23: Economic losses due to FMD and BCA of different species and categories of dairy animals in Zone III of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Vaccine Coverage (%)	Vaccine Effectiveness (%)	Total benefits of vaccination per year (Rs.)	Total cost of control (Rs.)	BCA (B/C)
Cross Bred	**Lactating cow**	4962.1	300.3	57.2	5720	35.75	11075.35	94	92.85	9666.45	1000	13.35
	Heifer		268.5	71.6	2685	35.8	3060.91	94	91.05	2619.73		
	Calf		177.3	47.28	591	23.64	839.22	94	88.18	695.62		
	Bull		375	100	5000	62.5	537.51	94	87.5	442.09		
	Overall	4962.1	1121.1	276.08	13996	157.69	15512.97	94	91.59	13355.83		
Local	**Lactating cow**	1446.92	291.55	66.64	4165	41.65	6011.76	94	91.67	5180.32	1000	11.32
	Heifer		555.5	177.76	4444	88.88	5266.14	94	77.78	3850.24		
	Calf		450	150	1125	75	1800.01	94	62.5	1057.5		
	Adult Bull		499.8	133.28	0	83.3	716.38	94	83.34	561.20		
	Overall	1446.92	1796.85	527.68	9734	288.83	13794.28	94	87.37	11328.94		
Buffalo	**Lactating buffalo**	265.85	122.7	32.72	2454	20.45	2895.72	94	95.91	2610.64	1000	4.90
	Heifer		186	59.52	1488	29.76	1763.28	94	92.56	1534.16		
	Calf		134.4	44.8	336	22.4	537.6	94	88.8	448.74		
	Buffalo bull		249.9	66.64	-	41.65	358.19	94	91.67	308.65		
	Overall	265.85	693	203.68	4278	114.26	5554.79	94	93.92	4904.03		

Table 24: Economic losses due to FMD and BCA of different species and categories of dairy animals in Zone IV of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Vaccine Coverage (%)	Vaccine Effectiveness (%)	Total benefits of vaccination per year (Rs)	Total cost of control (Rs.)	BCA (B/C)
Cross Bred	**Lactating cow**	6155.78	372.54	70.96	7096	44.35	13739.63	94	91.13	11769.67	1000	11.76
	Heifer		320.7	85.52	3207	42.76	3655.98	94	89.31	3069.24		
	Calf		200.85	53.56	669.5	26.78	950.69	94	86.61	773.98		
	Bull	6155.78	894.09	210.04	10972.5	113.89	18346.3	94	89.93	15508.9		
	Overall	774.7	156.1	35.68	2230	22.3	3218.78	94	91.13	11769.67		
Local	**Lactating cow**		192.25	61.52	1538	30.76	1822.53	94	95.54	2890.70	1000	2.89
	Heifer		199.92	66.64	499.8	33.32	799.68	94	92.31	1581.43		
	Calf	774.7	548.27	163.84	4267.8	86.38	5840.99	94	83.34	626.46		
	Adult Bull	774.7	156.1	35.68	2230	22.3	3218.78	94	94.16	5169.88		
	Overall		192.25	61.52	1538	30.76	1822.53	94	95.54	2890.70		
Buffalo	**Lactating buffalo**	233.35	107.7	28.72	2154	17.95	2541.72	94	96.41	2303.44	1000	5.13
	Heifer		120.75	38.64	966	19.32	1144.71	94	95.17	1024.05		
	Calf		64.44	21.48	161.1	10.74	257.76	94	94.63	229.28		
	Buffalo bull		118.2	31.52	1576	19.7	1745.42	94	94.45	1549.63		
	Overall	233.35	411.09	120.36	4857.1	67.71	5689.61	94	96.06	5137.51		

Table 25: Economic losses due to FMD and BCA of different species and categories of dairy animals in Zone V of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Vaccine Coverage (%)	Vaccine Effectiveness (%)	Total benefits of vaccination per year (Rs.)	Total cost of control (Rs.)	BCA (B/C)
Cross Bred	**Lactating cow**	9188.56	556.08	105.92	10592	66.2	20508.76	94	86.76	16725.8	1000	20.33
	Heifer		295.5	78.8	2955	39.4	3368.7	94	90.15	2854.67		
	Calf		68.85	18.36	229.5	9.18	325.89	94	95.41	292.27		
	Overall	9188.56	920.43	203.08	13776.5	114.78	24203.35	94	89.39	20337.25		
Local	**Lactating cow**	1796.05	361.9	82.72	5170	51.7	7462.37	94	89.66	6289.32	1000	8.72
	Heifer		166.5	53.28	1332	26.64	1578.42	94	93.34	1384.89		
	Calf		150	50	375	25	600	94	87.5	493.5		
	Adult Bull		499.8	133.28	-	83.3	716.36	94	83.34	561.19		
	Overall	1796.05	1178.2	319.28	6877	186.64	10357.16	94	89.66	8729.05		
Buffalo	**Lactating buffalo**	104.65	48.3	12.88	966	8.05	1139.88	94	98.39	1054.23	1000	1.25
	Heifer		21	6.72	168	3.36	199.08	94	99.16	185.56		
	Calf		9.6	3.2	24	1.6	38.4	94	99.2	35.80		
	Buffalo bull		-	-	-	-	-	-				
	Overall	104.65	78.9	22.8	1158	13.01	1377.36	94	97.25	1259.11		

Table 26: Economic losses due to FMD and BCA of different species and categories of dairy animals in Zone VI of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Vaccine Coverage (%)	Vaccine Effectiveness (%)	Total benefits of vaccination per year (Rs.)	Total cost of control (Rs.)	BCA (B/C)
Cross Bred	**Lactating cow**	7009.4	424.2	80.8	8080	50.5	15644.9	94	89.9	13220.88	1000	6.67
	Heifer		483.6	128.96	4836	64.48	5513.04	94	83.88	4346.87		
	calf		285.6	76.16	952	38.08	1351.84	94	80.96	1028.78		
	Overall		600	160	8000	100	8860	94	80	6662.72		
Local	**Lactating cow**	1142.94	230.3	52.64	3290	32.9	1559.46	94	93.42	1369.43	1000	3.79
	Heifer		234.25	74.96	1874	37.48	2220.69	94	90.63	1891.85		
	Calf		150	50	375	25	600	94	87.5	493.5		
	Adult Bull		-	-	-	-	-	-	-	-		
	Overall	1142.94	614.55	177.6	5539	95.38	4380.15	94	92.07	3790.83		
Buffalo	**Lactating buffalo**	382.2	176.4	47.04	3528	29.4	4163.04	94	94.12	3683.15	1000	9.54
	Heifer		220.5	70.56	1764	35.28	2090.34	94	91.18	1791.61		
	calf		152.52	70.56	1764	35.28	2090.34	94	87.29	1715.17		
	Buffalo bull		176.4	47.04	2352	29.4	2604.84	94	94.12	2304.57		
	Overall	382.2	725.82	235.2	9408	129.36	10948.56	94	92.77	9547.56		

Studies agree with the present work were, Alexandersen and Garland (2003) reported economic losses due to FMD were due to high mortality in young animals. Shamsudeen *et al* (2013) investigated FMD in cattle and buffaloes and reported that leads FMD leads to 17.1% mortality in young cattle and 11.1% mortality in buffaloes and among morbid animals, the mortality in adults (cow and buffalo) and young ones (calves and buffalo calves) were 13.7% and 26.8%, respectively. The findings of Govindaraj *et al* (2017) was similar to our study and estimated that the mortality loss due to FMD in cross bred cattle was Rs. 33475, local buffalo of Rs. 13585, upgraded buffalo of Rs 17875 and no deaths among the indigenous cattle, contrary to present result because the mortality rate of animals in present study was lower in dairy animals due to vaccination coverage. However, the study of Mathew and Menon (2008) reported that mortality losses were lower compared to milk loss.

4.2.2.5. Miscellaneous Cost

The mean cost of miscellaneous charges per animal per year was almost the same in cross bred and indigenous cattle of Rs. 177.9 ± 34.11 and 162.89± 30.01, ranged between Rs. 113.58 (Zone I) to Rs. 309.31 (Zone II) and Rs. 162.89 ± 30.01 and ranged between Rs. 86.38 (Zone VI) to Rs. 288.83 (Zone III) respectively (Table 29). However, in buffaloes, the mean value of miscellaneous charges was around half to the cattle Rs. 86.89± 22.12/animal/year, ranged from Rs. 13.01 (Zone V) to Rs. 153.44 (Zone II). Differences in miscellaneous cost among the different categories could be due to treatment charges of affected animals, herd size, value of animals etc.

The highest proportional loss (Fig 5) due to FMD in different categories of dairy animals was due to mortality loss (especially young ones) followed by reduction in milk yield, treatment cost of affected animals, labour cost during the illness period and other miscellaneous cost during and after the occurence of FMD in a year (2016-2017). In buffaloes, losses due to milk yield was lower compared to cattle, hence the treatment cost was followed after mortality loss of the affected animals.

Table 29: Components of annual economic losses per animal due to FMD of dairy animals in different ACZ's of Punjab.

	Agro-climatic Zones	Losses (component-wise) (Rs.)					Total loss /animal/year (Rs.)
		Milk yield loss	Treatment cost	Extra Labour charges	Mortality loss	Misc.	
Cross bred cattle	I	8848.06	906.84	202.72	13120	113.58	22823.82
	II	8175.32	2122.86	528.4	27500	309.31	38635.87
	III	4962.1	1121.1	276.08	13996	157.69	15512.97
	IV	6155.78	894.09	210.04	10972.5	113.89	18346.3
	V	9188.56	920.43	203.08	13776.5	114.78	24203.35
	VI	7009.4	1793.4	445.92	21868	253.06	31369.78
	Mean± S.E	7389.1± 643.57	1293.12± 214.78	312.40± 57.31	16872.17± 4932.45	177.9± 34.11	32406.77± 3492.96
% Contribution		29.38	5.14	1.23	67.08	0.70	
Indigenous cattle	I	2105.24	1088.89	296.64	8567.6	169.53	12227.94
	II	1427.81	956.38	273.68	6963.2	150.61	11991.68
	III	1446.92	1796.85	527.68	9734	288.83	13794.28
	IV	774.7	548.27	163.84	4267.8	86.38	5840.99
	V	1796.05	1178.2	319.28	6877	186.64	10357.16
	VI	1142.94	614.55	177.6	5539	95.38	4380.15
	Mean± S.E	1448.94± 191.47	1030.51± 184.70	293.12± 53.58	6991.43± 2676.96	162.89± 30.01	9765.36± 1549.24
% Contribution		14.83	10.55	3.00	71.59	1.66	
Buffaloes	I	182.65	266.01	81.56	2754.9	43.59	3328.71
	II	573.3	930.24	270.2	7562.1	153.44	13297.28
	III	265.85	693	203.68	4278	114.26	5554.79
	IV	233.35	411.09	120.36	4857.1	67.71	5689.61
	V	104.65	78.9	22.8	1158	13.01	1377.36
	VI	382.2	725.82	235.2	9408	129.36	10948.56
	Mean± S.E	290.33± 67.92	517.51± 130.57	155.63± 39.21	5003.01± 1459.85	86.89± 22.12	6699.38± 1858.34
% Contribution		4.33	7.72	2.32	74.67	1.29	

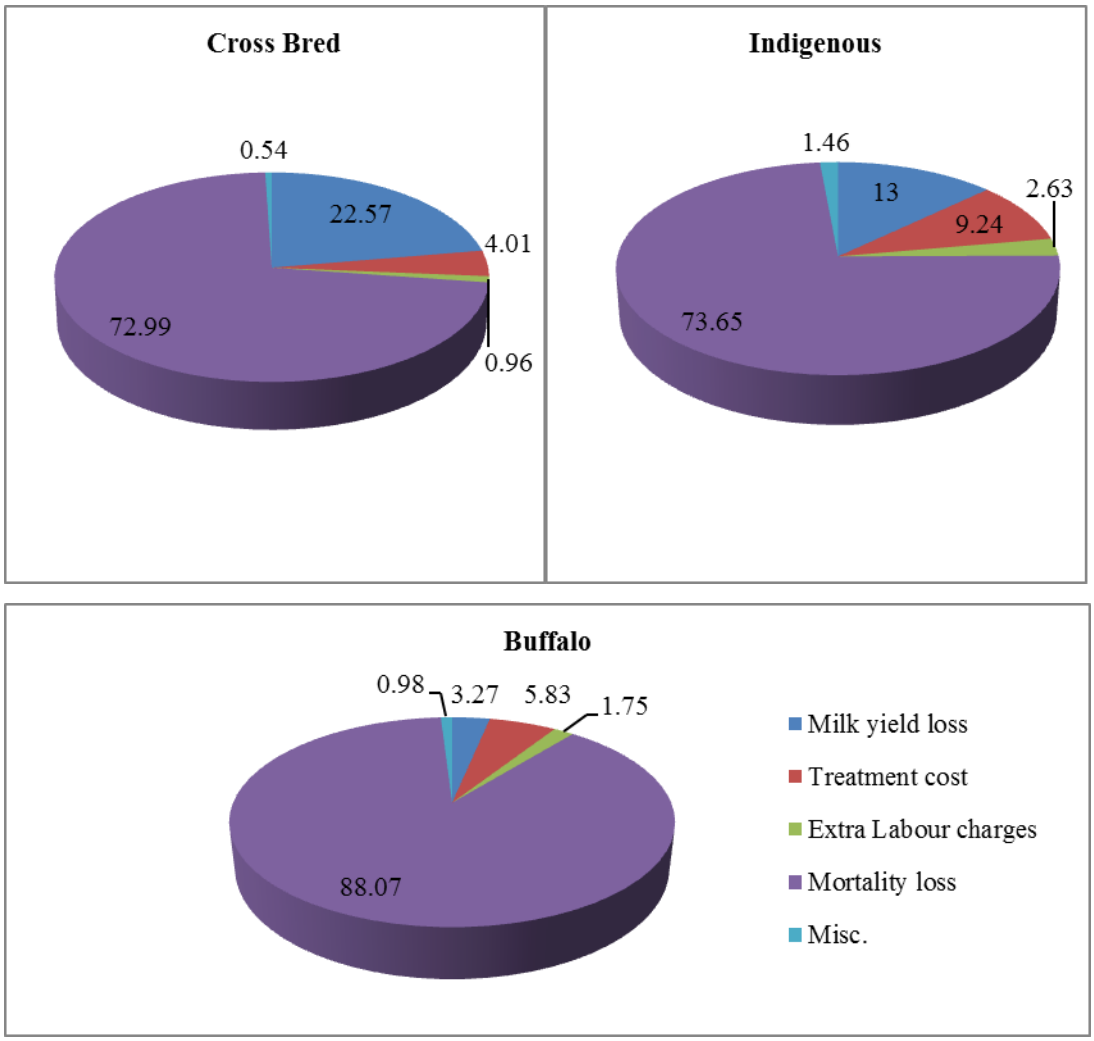


Fig. 5: Proportion of different component losses (%) – FMD

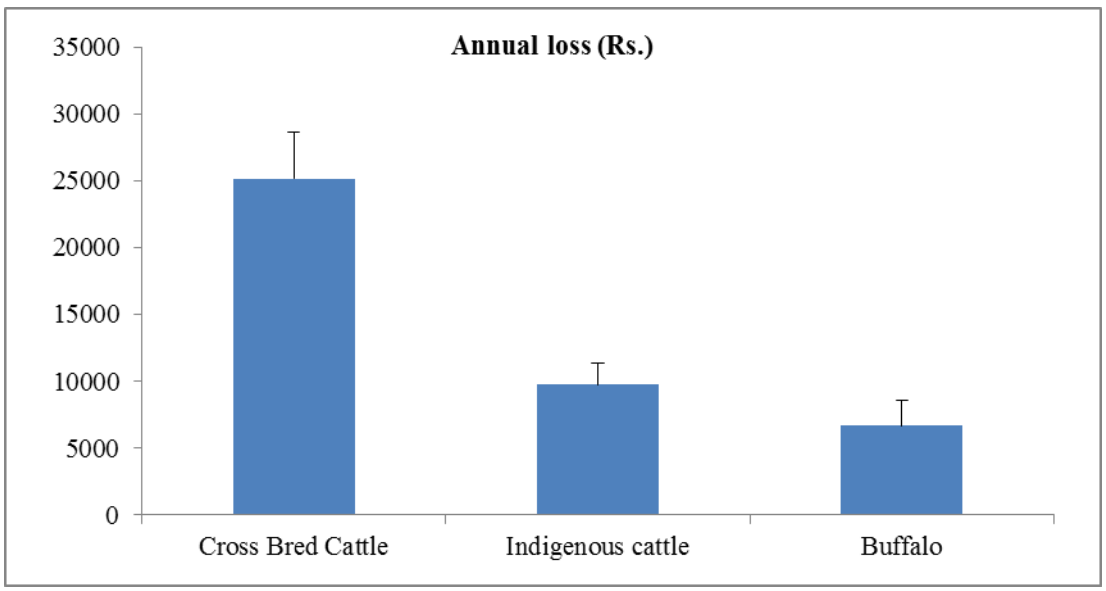


Fig. 6: Overall annual losses per animal in different species due to FMD

4.2.3. Total economic losses of dairy animals due to FMD in different ACZ's of Punjab

From Table 30, the overall loss from the affected animal due to FMD was Rs 13,871.14± 5707.80. However, the mean total of economic losses per animal per year affected due to FMD from different categories of animals were significant ($p<0.01$), higher in crossbred animals (Rs. 25148.68±3492.9), followed by indigenous cattle (Rs. 9765.36±1549.2) and buffaloes (Rs. 6699.38±1858.3). The losses were variable among the different Zones and categories of animals, skewed towards the cross bred animals followed by indigenous cattle and buffaloes (Fig 6). Losses per animal per year due to FMD, between the different ACZ's of Punjab varied among the different categories of animals. In cross bred cattle, the highest loss per animal per year was observed in Zone II (Rs. 38,635.87) and lowest in Zone III (Rs. 15,512.97). For indigenous cattle, the highest loss per animal per year was observed in Zone I (Rs. 12227.94) and lowest in Zone IV (Rs 4380.15). In buffaloes, the highest loss per animal affected due to FMD was in Zone II (Rs. 13297.28) and lowest in Zone V (Rs. 1377.36). Overall mean losses of animals didn't varied significantly between the Zones ($F=0.40$; $p>0.5$) and it ranged from Rs 9958.96±4193.89 (Zone VI) to Rs 21308.27±8671.99 (Zone II). It may be concluded that at species level, the largest component of the economic losses were due to mortality loss of animals (73%) followed by milk loss and treatment cost in cattle, while in buffalo, mortality loss (88%) was followed by treatment cost and milk loss (Table 29).

Similar findings were observed in different studies like Yalcin and Senturk (1999), who estimated the average financial losses per infected animal were estimated to be US $294 (Rs. 19110) for milking cow, US $152 (Rs. 9880) for dairy heifer, US $197 (Rs. 12805) for beef cattle, US $69 (Rs. 4485) for sheep and US $64 (Rs. 4160) for goat. Young *et al* (2012) estimated loss of 216 to 370 USD (Rs. 14040 to 24050) per animal per year. Furthermore, Singh *et al* (2013) estimated that the total losses per infected animal due to FMD in cattle and buffaloes were Rs. 12,532 and Rs. 21,682, respectively and Govindaraj *et al* (2017) estimated the mean total loss per affected animal in local and upgraded buffaloes 440 USD (Rs. 28,000) and 513 USD (Rs. 33,345), respectively.

Table 30: Annual economic losses per animal due to FMD of dairy animals in different ACZ's of Punjab.

Per animal per year	Category	Agro-climatic Zones of Punjab						
		I	II	III	IV	V	VI	Mean±SE
Annual loss (Rs.)	Cross Bred Cattle	22823.82	38635.87	15512.97	18346.3	24203.35	31369.78	25148.68^{b} ± 3492.96
	Indigenous cattle	12227.94	11991.68	13794.28	5840.99	10357.16	4380.15	9765.36^{ab} ± 1549.24
	Buffalo	3328.71	13297.28	5554.79	5689.61	1377.36	10948.56	6699.38^{a} ±1858.34
	Overall	12793.49± 5634.85	21308.27± 8671.99	11620.68±3073.25	15566.16± 8126.12	11979.28± 6639.02	9958.96± 4193.89	13871.14± 5707.80

Different superscripts (a,b,…) indicate significant ($p<0.05$) difference.

Jemberu *et al* (2014) estimated the average economic losses of FMD outbreak due to milk loss, draft power loss and mortality were USD 76 (Rs. 4940) per affected herd and USD 9.8 (Rs. 637) per head of cattle in the affected herds in crop–livestock mixed system; and USD 174 (Rs. 11,310) per affected herd and USD 5.3 (Rs. 344.5) per head of cattle in the affected herds in the pastoral system. The authors in these studies had considered milk loss only during the illness period and haven't considered the replacement cost of dead animals. Because of milk loss and mortality loss in the present study results our estimate larger compared to the above said finding.

From the Table 7-12, the benefit cost analysis of intervention of control measures like effective vaccination, biosafety measures taken at farm level and segregation of affected animals indicated that higher benefits cost ratio in case of crossbred cattle due to their higher occurences. These control measures were assmed to cost Rs 1000 for each animal annually for estimation of BC ratio of FMD in dairy animals. Punjab, the BCA indicated that the benefits outweigh the cost incurred for vaccination under all the incidence (crossbred, indigenous and buffalo) scenarios. Even under low incidence scenario, the benefits realized will be much higher over the cost and thereby it is suggested to vaccinate the entire dairy animal population in the state. BCA ratio was highest in cross bred cattle followed by buffaloes and indigenous cattle in different agroclimatic zones of Punjab. It indicates that net benefits forgone from the non-affected animals could be higher once the intervention of effective FMD control measures (vaccination and proper biosafety measures etc) at farm level could be undertaken and the dairy farming would be profitable once this disease is controlled.

It may be concluded that the losses were more skewed towards cross bred animals followed by indigenous cattle and buffaloes (Fig 6). The largest components contributing the losses due to FMD in dairy animals were the mortality loss, milk yield reduction and treatment cost (Fig 5). Among the different ACZ's, major impact due to disease loss were observed in Zone II & IV, while the least affected Zones were the Zone VI & III. On benefit cost analysis of intervention of FMD vaccination and proper biosafety measures to control FMD at farm level was highest in cross bred cattle followed by indigenous cattle and buffaloes.

4.2.2.1. Epidemiological aspect of Hemorrhagic septicemia (HS) in different ACZ's of Punjab

Hemorrhagic septicemia (HS) cases were reported by dairy farmers in different ACZ's of Punjab and were severely affected by outbreaks in terms of their financial losses due to the sudden loss of milk, veterinary charges and mortality of animals (Table 31-42). Information about the occurrence of HS in their farms was received from the past recall period of one (2016-17), as locally named as "Gal Ghotu". The overall incidence and CFR risk due to HS among the dairy animals in Punjab were 5.45 and 45.15 percent respectively (Table 43-44).

The overall incidence of HS as presented in Table 43 among the different species of cross bred cattle, indigenous cattle and buffaloes (4.67%, 3.91%, and 6.27% respectively) varied significantly (χ^2=13.06; p<0.01). The incidence risk of HS among the cross bred and indigenous cattle between the different ACZ's of Punjab didn't vary significantly (χ^2=10.09 & 9.80; p>0.05), ranged between 3.18% (Zone V) to 5.76% (Zone VI) and 2.22% (Zone II) to 8.62% (Zone V) respectively. However, in buffaloes, it varied significantly (χ^2=16.20; p<0.01) ranged between 4.58% (Zone II) to 8.49% (Zone I). Similarly, the CFR among the different categories of animals and between the different ACZ's of Punjab didn't vary significantly (p>0.05). The overall CFR (Fig 8) among the different species of animals was higher in buffaloes (46.77%) ranged between 38.70% (Zone V) to 53.70% (Zone I), followed by cross bred cattle (42.85%) ranged between 35.29% (Zone II) to 50% (Zone V) and indigenous cattle (41.67%) ranged between 33.33% (Zone III) to 57.14% (Zone IV).

From the Table 44, among the different herd sizes, higher incidence risk of HS in dairy animals was observed in small herd size (10.52%) followed by medium (5.44%) and large (3.01%) and were statistically significant among the different herd groups (χ^2=195.95; p<0.01). Further, between the different ACZ's of Punjab for small herd size (χ^2=12.75; p<0.05), medium herd (χ^2=10.33; p>0.05), and large herd size (χ^2=25.04; p<0.01). The incidence risk among the different herd groups, was observed highest in small herd size ranged between 6.72% (Zone VI) to 13.79% (Zone I), followed by medium herd size ranged between 3.11% (Zone IV) to 6.62% (Zone III) and large herd size (3.01%) with the highest prevalence of 5.61% in Zone III and no cases were observed in Zone I & V. Further, the overall prevalence (5.45%) due to HS among the dairy animals between the different ACZ's of Punjab varied significantly (p<0.01) and ranged between 3.31% (Zone VI) to 9.61% (Zone V).

Similarly, the case fatality rate (CFR) due to HS among the different herd sizes of small, medium and large (49.28%, 44.32%, and 39.15% respectively) was not significant (χ^2=4.39; p>0.05), among the different herd size and between the ACZ's of Punjab. In small herd size, it didn't vary significantly (χ^2=0.98; p>0.05), ranged between 43.75% (Zone VI) to 54.90% (Zone II), for medium herd size, incidence risk didn't vary significantly (χ^2=1.61; p>0.05), ranged between 38.89% (Zone I) to 51.61% (Zone III). Further, for large herd groups, it also didn't vary significantly (p>0.05) with the highest occurrence of 46.67% (Zone II) and no mortality observed in Zone I & V, respectively. The overall CFR (45.15%) due to HS among the dairy animals of different ACZ's of Punjab didn't vary significantly (p>0.05) and ranged between 41.67% (Zone VI) to 49.47% (Zone II).

The highly endemic nature of the disease indicates it is contagious due to high mortality than other diseases. This may be the first report on epidemiological aspect and economic impact of HS in Punjab using primary data collected from the dairy farmers. The significant difference in incidence risk of HS was observed between the species among the different ACZ's of Punjab with higher occurrence in buffaloes followed by crossbred and indigenous cattle and was concurred with previous reports of (Verma *et al* 2004, Khan *et al* 2006, Farooq *et al* 2011, Mondal and Yamage 2014, Singh *et al* 2014b and Govindaraj *et al* 2017), might be due to the inherent disease resistance in indigenous cattle and the susceptibility of HS more towards buffaloes than cattle. The young animals of indigenous cattle suffered higher mortality and morbidity risk, whereas, the adults of crossbred cattle and buffaloes were at higher risk.

Among the different ACZ's of Punjab, Zone I, III and VI following the highest incidence risk than other Zone II & IV (Fig 9). In these Zones, farmers may be engaged in agricultural operations and had less attention to animal husbandry during monsoon also leads to HS occurrence. In some cases, there was a failure in prophylactic vaccination of HS in animals and its occurrence was accompanied with FMD. Further, it was observed that the peak HS occurrence was mainly towards the border districts of the state than the interior districts of the state, indicating the need for different and strong vaccination programme for different regions.

The significant difference of incidence risk and case fatality rate was observed among herd sizes Fig 11), particularly higher proportion in small and medium farms than large farms (Govindaraj *et al* 2017). It may be attributed to the lack of resources

with small and medium farms to rear the animals under reduced stress levels mainly through adequate spacing, appropriate housing, poor veterinary service during an emergency and allocating monetary resources for treatment. Few small farmers had a wrong myth over the vaccination of their animals. Small and medium dairies reared mostly buffaloes and were more susceptible to HS compared to cattle population. The overall incidence risk of HS was 5.45 percent (ranged 2.96–10.28%) observed among the herd sizes was concurred with the results from Bangladesh, Cambodia, India, Pakistan and Srilanka (De Alwis and Vipulassiri 1981, Farooq *et al* 2011, Khan *et al* 2011, Mondal and Yamage 2014, Kawasaki *et al* 2015 and Govindaraj *et al* 2017).

Among the different herds, the estimated CFR 45.15 percent (ranged 41.67–49.47%) in Punjab was contrary to the earlier reports of 50-100% in Karnataka (Govindaraj *et al* 2017), 51.4% in Assam (Krishnamoorthy *et al* 2015) and 89.5% in Tamil Nadu (Krishnamoorthy *et al* 2016). This variation in CFR might be due to better awareness about HS in dairy farmers of Punjab, good coverage and effectiveness of HS vaccination programme by the state animal husbandry department and rearing of more indigenous resistant breeds in this state than the states of Karnataka and Tamil Nadu, where more crossbred animals are reared and non-participation of farmers obstacle the vaccination efforts to control the disease.

Since the overall incidence and CFR risk due to HS among the dairy animals in Punjab was 5.45 and 45.15 percent respectively and was observed higher in buffaloes and small herd size groups among the species and the herd size of animals respectively. Similarly, the mortality risk or CFR due to HS was higher in buffaloes (especially young animals) and in small herd groups. Among the different ACZ's of Punjab, Sub-Mountain Undulating region and Flood plain region had the highest occurrence of incidence risk of HS. Where as, the Western plain region had the lowest occurrence of incidence risk of HS among the dairy animals. Hence, the study concludes that all the cattle and water buffaloes irrespective of age should be vaccinated to mitigate the incidence of HS. However, previous studies (De Alwis 1999 and Shivachandra *et al* 2011) had suggested vaccination of young animals (≤1 year) on priority, but, it would not be sufficient to prevent the disease incidence in the endemic regions (Punjab) where more adult animals were affected.

Table 31: Incidence and CFR risk due to HS across herd sizes, species and categories of dairy animals in Zone I of Punjab.

	Category	Total animals	Affected animals	Incidence risk (%)	No. of animals died	Mortality rate (%)
Herd size	**Small**	406	56	13.79	27	48.21
	Medium	836	54	6.45	21	38.89
	Large	122	0	0	0	0
	Overall	1264	110	8.70	48	43.63
			$\chi^2 = 4.65^{**}$		$\chi^2 = 1.21^{ns}$	
Cross Bred	**Lactating Cow**	360	15	4.17	6	40
	Heifer	59	4	6.77	2	50
	Calf	135	5	3.70	2	40
	Overall	554	24	4.33	10	41.67
			$\chi^2 = 1.46^{ns}$		$\chi^2 = 0.90^{ns}$	
Local	**Lactating cow**	33	1	3.03	0	0
	Heifer	9	1	11.11	1	100
	Calf	21	2	9.52	1	50
	Adult Bull	11	0	0	0	0
	Overall	74	4	5.40	2	50
			$\chi^2 = 0.35^{ns}$		$\chi^2 = 0.01^{ns}$	
Buffalo	**Lactating buffalo**	426	33	7.74	16	48.48
	Heifer	67	8	11.94	5	62.5
	Calf	137	12	8.75	8	66.67
	Buffalo bull	6	1	16.67	0	0
	Overall	636	54	8.49	29	53.70
			$\chi^2 = 2.48^{ns}$		$\chi^2 = 3.05^{ns}$	

$^{*}(p<0.01)$ and ** $(p<0.05)$ indicate significant difference; ^{ns} $(p>0.05)$ indicate no significant difference.

Table 32: Incidence and CFR risk due to HS across herd sizes, species and categories of dairy animals in Zone II of Punjab.

	Category	Total animals	Affected animals	Incidence risk (%)	No. of animals died	Mortality rate (%)
Herd size	**Small**	488	51	10.45	28	54.90
	Medium	606	29	4.78	12	41.37
	Large	583	15	2.57	7	46.67
	Overall	1677	95	5.66	47	49.47
			$\chi^2 = 28.13^{*}$		$\chi^2 = 8.40^{**}$	
Cross Bred	**Lactating cow**	348	11	3.16	3	27.27
	Heifer	83	2	2.40	1	50
	Calf	78	3	3.84	2	66.67
	Bull	3	1	33.33	0	0
	Overall	512	17	3.32	6	35.29
			$\chi^2 = 5.99^{ns}$		$\chi^2 = 1.52^{ns}$	
Local	**Lactating cow**	158	3	1.89	0	0
	Heifer	43	1	2.32	0	0
	Calf	51	2	3.92	1	50
	Adult Bull	18	0	0	0	0
	Overall	270	6	2.22	1	16.67
			$\chi^2 = 0.94^{ns}$		$\chi^2 = 2.21^{ns}$	
Buffalo	**Lactating buffalo**	612	24	3.92	11	45.83
	Heifer	125	6	4.8	3	50
	Calf	137	9	6.56	6	66.67
	Buffalo bull	21	2	9.52	1	50
	Overall	895	41	4.58	21	51.21
			$\chi^2 = 0.76^{ns}$		$\chi^2 = 0.73^{ns}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 33: Incidence and CFR risk due to HS across herd sizes, species and categories of dairy animals in Zone III of Punjab.

	Category	Total animals	Affected animals	Incidence risk (%)	No. of animals died	Mortality rate (%)
Herd size	**Small**	397	46	11.58	23	50
	Medium	468	31	6.62	16	51.61
	Large	470	32	6.80	11	34.36
	Overall	1792	109	6.08	50	45.87
			$\chi^2 = 8.83^{**}$		$\chi^2 = 13.84^{ns}$	
Cross Bred	**Lactating cow**	587	21	3.57	8	38.09
	Heifer	134	9	6.71	4	44.44
	Calf	186	11	5.91	6	54.54
	Bull	8	0	0	0	0
	Overall	915	41	4.48	18	43.90
			$\chi^2 = 3.54^{ns}$		$\chi^2 = 4.85^{ns}$	
Local	**Lactating cow**	72	2	2.78	0	0
	Heifer	9	0	0	0	0
	Calf	8	1	12.5	1	100
	Adult Bull	6	0	0	0	0
	Overall	95	3	3.15	1	33.33
			$\chi^2 = 6.52^{ns}$		$\chi^2 = 0.13^{ns}$	
Buffalo	**Lactating buffalo**	391	27	6.90	9	33.33
	Heifer	94	8	8.51	4	50
	Calf	116	10	8.62	6	60
	Buffalo bull	24	2	8.33	1	50
	Overall	625	47	7.52	20	42.55
			$\chi^2 = 8.56^{**}$		$\chi^2 = 2.3^{ns}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 34: Incidence and CFR risk due to HS across herd sizes, species and categories of dairy animals in Zone IV of Punjab.

	Category	Total animals	Affected animals	Incidence risk (%)	No. of animals died	Mortality rate (%)
Herd size	**Small**	470	40	8.51	19	47.5
	Medium	610	19	3.11	9	47.36
	Large	373	15	4.02	6	40
	Overall	1453	74	5.09	34	45.94
			$\chi^2 = 26.05^{**}$		$\chi^2 = 22.54^{**}$	
Cross Bred	**Lactating cow**	287	6	2.09	2	33.33
	Heifer	31	2	6.45	1	50
	Calf	63	5	7.93	2	40
	Bull	5	1	20	0	0
	Overall	386	14	3.62	5	35.71
			$\chi^2 = 4.67^{ns}$		$\chi^2 = 10.01^{**}$	
Local	**Lactating cow**	167	4	2.39	2	50.0
	Heifer	32	1	3.12	1	100.0
	Calf	48	2	4.16	1	50.0
	Adult Bull	5	0	0	0	0
	Overall	252	7	2.77	4	57.14
			$\chi^2 = 2.35^{ns}$		$\chi^2 = 1.59^{ns}$	
Buffalo	**Lactating buffalo**	578	21	3.63	8	38.09
	Heifer	102	6	5.88	4	66.67
	Calf	118	9	7.62	6	66.67
	Buffalo bull	17	2	11.76	0	0
	Overall	815	38	4.66	18	47.36
			$\chi^2 = 7.27^{ns}$		$\chi^2 = 4.38^{ns}$	

$^{*}(p<0.01)$ and ** $(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 35: Incidence and CFR risk due to HS across herd sizes, species and categories of dairy animals in Zone V of Punjab.

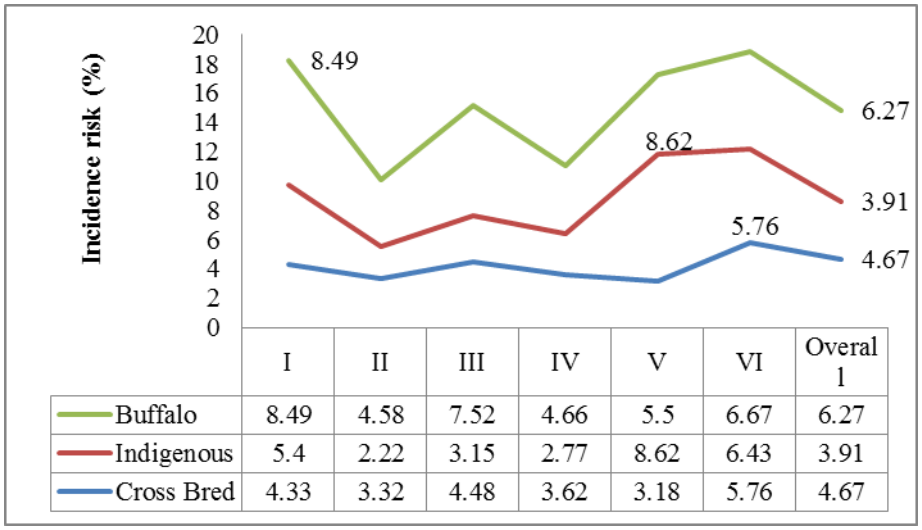
	Category	Total animals	Affected animals	Incidence risk (%)	No. of animals died	Mortality rate (%)
Herd size	**Small**	662	71	10.72	34	47.88
	Medium	452	25	5.53	11	44
	Large	84	0	0	0	0
	Overall	998	96	9.61	45	46.87
			$\chi^2 = 3.37^{ns}$		$\chi^2 = 1.08^{ns}$	
Cross Bred	**Lactating cow**	219	7	3.19	3	42.85
	Heifer	71	2	2.81	1	50
	calf	87	3	3.44	2	66.67
	Bull	377	12	3.18	6	50
	Overall	915	77	8.41	17	22.07
			$\chi^2 = 4.95^{ns}$		$\chi^2 = 4.33^{ns}$	
Local	**Lactating cow**	29	2	6.89	1	50
	Heifer	15	1	6.67	0	0
	Calf	8	1	12.5	1	100
	Adult Bull	6	1	16.67	0	0
	Overall	58	5	8.62	2	40
			$\chi^2 = 0.5^{ns}$		$\chi^2 = 0.33^{ns}$	
Buffalo	**Lactating buffalo**	309	18	5.82	5	27.78
	Heifer	119	5	4.20	3	60
	calf	125	6	4.8	3	50
	Buffalo bull	10	2	20	1	50
	Overall	563	31	5.50	12	38.70
			$\chi^2 = 5.97^{ns}$		$\chi^2 = 0^{ns}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 36: Incidence and CFR risk due to HS across herd sizes, species and categories of dairy animals in Zone VI of Punjab

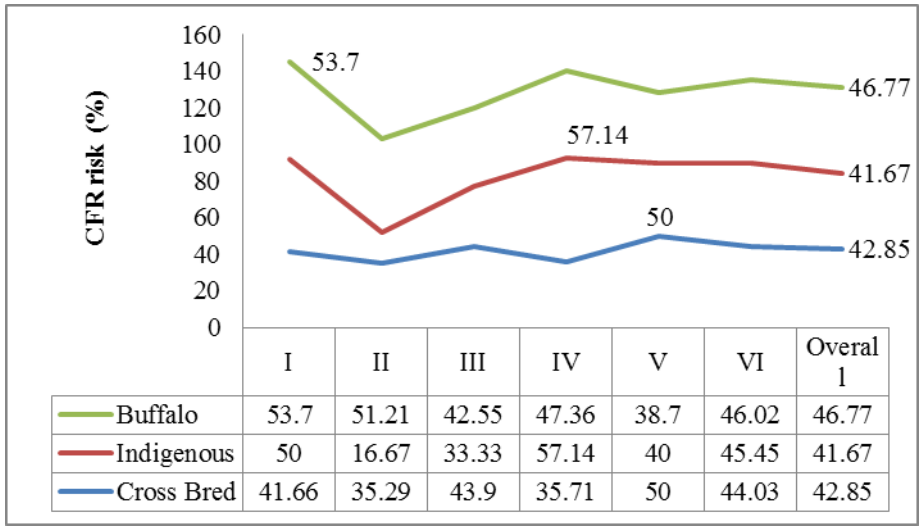
	Category	Total animals	Affected animals	Incidence risk (%)	No. of animals died	Mortality rate (%)
Herd size	**Small**	238	16	6.72	7	43.75
	Medium	594	36	6.06	17	47.22
	Large	3872	104	2.68	41	39.42
	Overall	4704	156	3.31	65	41.66
			$\chi^2 = 2.60^{ns}$		$\chi^2 = 1.20^{ns}$	
Cross Bred	**Lactating cow**	1262	68	5.38	24	35.29
	Heifer	215	12	5.58	6	50
	Calf	418	29	6.93	18	62.06
	Adult Bull	1895	109	5.75	48	44.03
	Overall	1262	68	5.38	24	35.29
			$\chi^2 = 7.18^{**}$		$\chi^2 = 8.46^{**}$	
Local	**Lactating cow**	112	5	4.46	1	20
	Heifer	26	3	11.53	2	66.67
	Calf	18	2	11.11	2	100
	Adult Bull	15	1	6.67	0	0
	Overall	171	11	6.43	5	45.45
			$\chi^2 = 3.93^{ns}$		$\chi^2 = 1.78^{ns}$	
Buffalo	**Lactating buffalo**	2056	191	9.28	98	51.30
	Heifer	248	12	4.83	7	58.33
	Calf	316	47	14.87	31	65.95
	Buffalo bull	18	3	16.67	0	0
	Overall	2638	176	6.67	81	46.02
			$\chi^2 = 2.89^{ns}$		$\chi^2 = 12.32^{**}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.



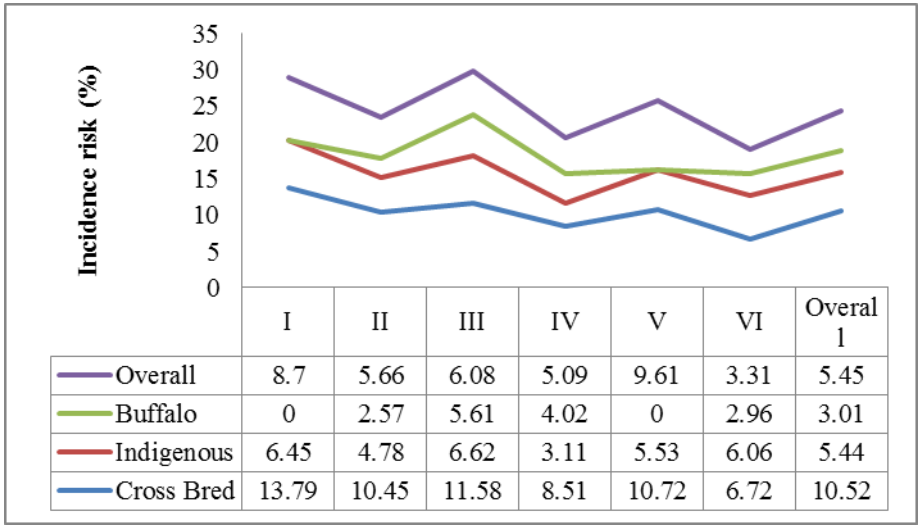
	I	II	III	IV	V	VI	Overal l
Buffalo	8.49	4.58	7.52	4.66	5.5	6.67	6.27
Indigenous	5.4	2.22	3.15	2.77	8.62	6.43	3.91
Cross Bred	4.33	3.32	4.48	3.62	3.18	5.76	4.67

Fig. 7: Incidence risk of HS on Species basis



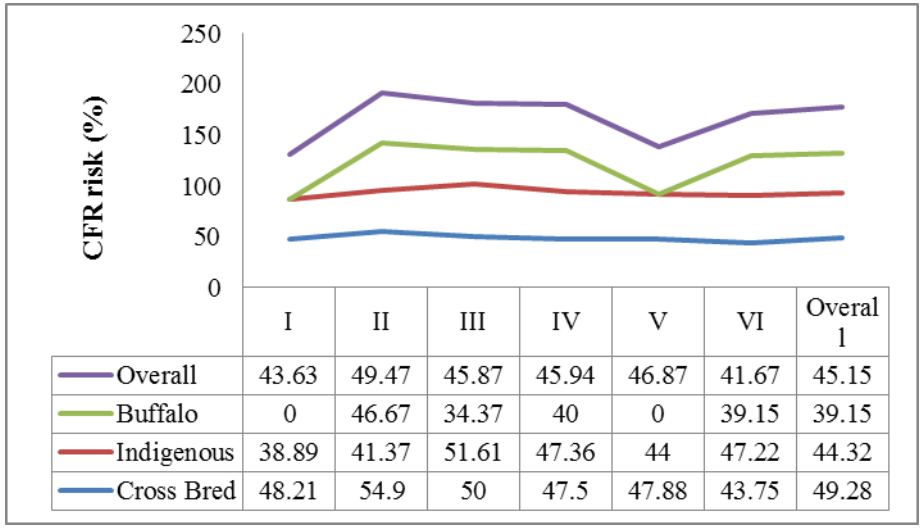
	I	II	III	IV	V	VI	Overal l
Buffalo	53.7	51.21	42.55	47.36	38.7	46.02	46.77
Indigenous	50	16.67	33.33	57.14	40	45.45	41.67
Cross Bred	41.66	35.29	43.9	35.71	50	44.03	42.85

Fig. 8: CFR risk of HS on Species basis



	I	II	III	IV	V	VI	Overal l
Overall	8.7	5.66	6.08	5.09	9.61	3.31	5.45
Buffalo	0	2.57	5.61	4.02	0	2.96	3.01
Indigenous	6.45	4.78	6.62	3.11	5.53	6.06	5.44
Cross Bred	13.79	10.45	11.58	8.51	10.72	6.72	10.52

Fig. 9: Incidence risk of HS on Herd basis



	I	II	III	IV	V	VI	Overal l
Overall	43.63	49.47	45.87	45.94	46.87	41.67	45.15
Buffalo	0	46.67	34.37	40	0	39.15	39.15
Indigenous	38.89	41.37	51.61	47.36	44	47.22	44.32
Cross Bred	48.21	54.9	50	47.5	47.88	43.75	49.28

Fig. 10: CFR risk of HS on Herd basis

Table 43: Incidence risk and CFR due to HS on species basis of dairy animals in different ACZ's of Punjab.

Species basis	Category	Agro-climatic Zones of Punjab									
		I	II	III	IV	V	VI	χ^2 Value	Total Animals	Affected Animals	Prevalence (%)
Incidence rate (%)	Cross- bred Cattle	4.33	3.32	4.48	3.62	3.18	5.76	10.09 ^{ns}	4639	217	4.67
	Indigenous cattle	5.40	2.22	3.15	2.77	8.62	6.43	9.80 ^{ns}	920	36	3.91
	Buffalo	8.49	4.58	7.52	4.66	5.50	6.67	16.20*	6472	387	6.27
									Overall χ^2 Value = 13.06*		
CFR (%)	Cross- bred Cattle	41.66	35.29	43.90	35.71	50.0	44.03	1.03 ^{ns}	217	93	42.85
	Indigenous cattle	50.0	16.67	33.33	57.14	40.0	45.45	2.50 ^{ns}	36	15	41.67
	Buffalo	53.70	51.21	42.55	47.36	38.70	46.02	2.55 ^{ns}	387	181	46.77
									Overall χ^2 Value = 1.04 ^{ns}		

*(p<0.01) and **(p<0.05) indicate significant difference; ^{ns}(p>0.05) indicate no significant difference.

Table 44: Incidence risk and CFR due to HS on herd basis of dairy animals in different ACZ's of Punjab.

Herd size (%)	Category	Agro-climatic Zones of Punjab									
		I	II	III	IV	V	VI	χ^2 Value	Total Animals	Affected Animals	Prevalence (%)
Incidence risk (%)	Small	13.79	10.45	11.58	8.51	10.72	6.72	12.75**	2661	280	10.52
	Medium	6.45	4.78	6.62	3.11	5.53	6.06	10.33 ^{ns}	3566	194	5.44
	Large	0	2.57	5.61	4.02	0	2.96	25.04*	5504	166	3.01
									Overall χ^2 Value = 195.95*		
CFR (%)	Small	48.21	54.90	50.0	47.5	47.88	43.75	0.98 ^{ns}	280	138	49.28
	Medium	38.89	41.37	51.61	47.36	44.0	47.22	1.61 ^{ns}	194	86	44.32
	Large	0	46.67	34.37	40.0	0	39.15	0.67 ^{ns}	166	65	39.15
									Overall χ^2 Value = 4.39 ^{ns}		

*(p<0.01) and **(p<0.05) indicate significant difference; ^{ns}(p>0.05) indicate no significant difference.

4.2.2.2. Economic losses due to HS

Only the direct loss due to HS which were visible to the dairy farmer was estimated viz. milk yield reduction, treatment cost, extra labour charges to nurse animal, mortality loss of an affected animal, and miscellaneous cost and had been presented in Table (37-42). The assumptions used in FMD for estimation of economic losses were almost the same in HS (Annexure I).

4.2.2.2.1. Loss of milk yield

From the Tables 45, milk loss implies a perceptible milk yield loss due to HS during the illness period. The average duration of illness among the different Zones varies between different categories of crossbred cattle, indigenous cattle and buffaloes (7, 5 and 9 days respectively) with an average milk yield (18, 10 and 8 liters of milk respectively). During the disease period, it was assumed that milk drastically reduced (up to 80 % in Cattle and 70% in Buffaloes) and farmers maintain their herd size after the mortality of affectd animal due to HS.

The highest mean value of milk yield loss per animal per year across the species was highest in cross bred animals (7.38%) of Rs. 428.46±67.42 ranged from Rs.237 (Zone IV) to Rs. 646.9 (Zone V), followed by buffaloes (5.38%) of Rs. 391.02±56.95 ranged from Rs. 236.52 (Zone-IV) to Rs.575.28 (Zone V) and indigenous cattle (4.20%) of Rs. 95.42±28.77 ranged from Rs. 32.26 (Zone IV) to Rs. 232.74 (Zone VI) as presented in Table 45. Since milk loss was considered only during the illness period, hence its impact was higher in high yielder cross bred animals than indigenous animals. However, in case of buffaloes, the impact on milk reduction was more compared to cattle due to the higher incidence of HS in buffaloes. Similar findings were reported by Govindaraj *et al* (2017) that higher milk losses were from cross bred animals due to high milk yield followed by buffaloes and indigenous cattle and estimated the mean milk loss per animal was $2 (Rs 130), $11(Rs 715) and $50 (Rs 3250) in indigenous cattle, water buffaloes, and crossbred cattle, respectively.

4.2.2.2.2. Treatment cost

From the Tables 45, the treatment cost incurred by the farmers was the second major cost after mortality loss among the different species of crossbred (17.50%), indigenous cattle (25.30%) and buffaloes (17.03%). Total mean value of treatment cost per animal per year was maximum in buffaloes of Rs. 1237.7±140.06 ranged from Rs.

794.9 (Zone II) to Rs 1723.9 (Zone V), followed by cross bred cattle of Rs. 1015.0±107.52 ranged from Rs. 673.35 (Zone VI) to Rs 1444.13 (Zone II) and indigenous cattle Rs. 574.52±132.53 ranged from Rs. 179.35 (Zone IV) to Rs. 1099.8 (Zones V). The differences in treatment cost in the various Zones were due to the variation in the number of days of illness, prevalence rate, treatment charges and recovery level. Govindaraj *et al* (2017) estimated the treatment expenses incurred among the bovines due to HS per animal was $24 (Rs 1560) which was almost to our estimated values of treatment cost. Singh *et al* (2014b) reported that among the morbidity losses, the highest loss was treatment cost followed by other losses, as they didn't consider the replacement values of animal losses due to CFR of HS affected animal.

4.2.2.2.3. Extra labor engagement cost

Charges of additional labour used to nurse the infected animals during the disease condition varied across the different ACZ's of Punjab (Table 45). It was found highest in buffalo (4.30%) with a mean total loss per animal per year of Rs.312.56±37.99 ranged from Rs.442.69 (Zone V) to Rs 201.27 (Zone II), followed by cross bred animals Rs 176.93 ± 23.72 ranged from Rs 111.1 (Zone VI) to Rs 260.82 (Zone II) and indigenous cattle of Rs.55.59±11.70 ranged from Rs. 18.2 (Zone IV) to Rs. 97.64 (Zone V). The differences in additional labor cost incurred in the surveyed Zones was due to differences in duration of illness, recovery period, variation in wage rates and proportion of different category of animals owned by the farmer. Its value was higher in buffaloes than cattle due to their higher prevalence of this disease. Similar findings were observed by Govindaraj *et al* (2017) and estimated the extra labor expenses incurred per animal was $7(Rs 455).

4.2.2.2.4. Loss due to mortality of animals

From the Table 45, mortality of animals (especially the young) due to the occurrence of HS contributes the highest percentage loss from the total mean losses in the present study among the various categories of animals viz. crossbred (69.42%), indigenous (63.15%) and buffaloes (70.40) in different ACZ's of Punjab. The total mean value due to mortality was highest in buffaloes Rs. 5115.0±525.40 ranged from Rs.3305.43 (Zone IV) to Rs 6962.63 (Zone III), followed by crossbred cattle Rs. 4026.3±486.10 ranged from Rs.2547.14 (Zone II) to Rs.5298.62 (Zone I) and

indigenous cattle Rs 1433.7 ± 308.26 of which no cases were found in Zones VI and highest loss of Rs. 2068 (Zone VI). Mortality among the animals was higher in buffaloes and cross bred animals (especially their young ones) and similar findings were reported by Ahmed 1996a, De Alwis 1999 and Farooq *et al* 2011. The variation in mortality loss among the different categories of animals depends on several factors like age and sex of animal (Khan *et al* 2006), there were very few cases observed affecting male animals. Loss due to mortality of animals exaggerates the condition of farmers to replace a new batch of animals. Some previous studies (Dutta *et al* 1990, Singh *et al* 1996 and Dua 2003) also reported that HS accounts for 58.8% of the aggregate bovine mortalities due to five major diseases and causes Rs 50,000–55,000 deaths in animals causing significant financial losses to farmers.

Mortality losses estimated from the different categories of animals in our study ranged between 63.15 to 70.40 percent. Similar findings were reported by Verma *et al* (2004) and estimated 58.9% mortality loss. Few studies contradict to our result due to higher mortality loss like Farooq *et al* (2011) reported 90% mortality, Singh *et al* (2014a) 77%, Singh *et al* (2014b) 94% and Govindaraj *et al* (2017) reported highest mortality loss of 86% due to HS respectively. Because in our study area, HS vaccination coverage and its effectiveness were good as compared to other states of this country due to awareness of farmers about this dreadful nature of disease and people used to treat their affected animals on a priority basis.

4.2.2.2.5. Miscellaneous Cost

From the Table 45, the total mean value of miscellaneous charges per animal per year in cross bred cattle (2.63%) was Rs. 152.84 ±21.17 ranged from Rs. 94.3 (Zone VI) to Rs. 229.03 (Zone II). For indigenous cattle (4.89%), it was Rs. 111.02 ± 24.25 ranged from Rs 35.87 (Zone IV) to Rs. 203.3 (Zone V). However, in buffaloes (2.87%), the total mean value of miscellaneous charges was Rs. 208.88±25.24 /animal/year and ranged from Rs. 135.4 (Zone II) to Rs. 295.36 (Zone V). Differences in miscellaneous cost among the different categories were due to the distance of treatment charges animals, discard of animal bedding and utensils etc.

It may be concluded (Fig 11) that among the various categories of losses associated with HS in dairy animals, highest loss was due to mortility of animals followed by treatment expenses, sudden reduction in milk, extra labour charges during the illness period and miscellaneous cost among all the species.

Table 37: Economic losses due to HS and BCA of different species and categories of dairy animals in Zone I of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. cost (Rs.)	Total loss (Rs.)	Vaccine Effectiveness (%)	Vaccine coverage (%)	Total benefits of vaccination per year (Rs.)	Total cost of control (Rs.)	BCA (B/C)
Cross Bred	**Lactating cow**	503.496	355.2	49.72	45000	44.4	8056.82	91.12	94	6607.23	1000	10.35
	Heifer		415.1	66.41	12855	59.3	4098.81	88.14	94	3251.42		
	Calf		79.92	18.64	3330	13.32	444.88	93.34	94	373.72		
	Overall	503.496	850.22	134.78	61185	117.02	12600.51	91.34	94	10358.38		
Local	**Lactating cow**	81.81	151.5	14.54	-	30.3	3308.15	93.94	94	2796.90	1000	5.28
	Heifer		277.75	26.66	20000	55.55	2581.96	88.89	94	2065.59		
	Calf		95.2	11.42	3000	19.04	411.26	90.48	94	334.89		
	Adult Bull		-	-	-	-	-	-	-	-		
	Overall	81.81	524.45	52.62	23000	104.89	6301.37	93.25	94	5288.42		
Buffalo	**Lactating buffalo**	456.12	380.1	91.22	28884	63.35	8592.79	87.33	94	6753.67	1000	15.44
	Heifer		402.9	96.69	7692	67.15	3252.74	86.57	94	2534.30		
	Calf		153.2	55.15	1999.8	30.64	735.36	84.68	94	560.43		
	Buffalo bull		499.8	119.95	-	83.3	7367.05	83.34	94	5525.73		
	Overall	456.12	1436	363.01	38575.8	244.44	19947.94	86.01	94	15441.5		

Table 38: Economic losses due to HS and BCA of different species and categories of dairy animals in Zone II of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. cost (Rs.)	Total loss (Rs.)	Vaccine effectiveness (%)	Vaccine coverage (%)	Total benefits of vaccination per year (Rs.)	Total cost of control (Rs.)	BCA (B/C)
Cross Bred	**Lactating cow**	260.25	183.6	25.70	30000	22.95	4164.50	94	95.41	3576.02	1000	17.92
	Heifer		168.35	26.93	15000	24.05	1662.33	94	95.19	1424.14		
	Calf		92.28	21.53	3333	15.38	513.69	94	92.31	426.77		
	Bull		999.9	186.64	-	166.65	14685.21	94	66.67	8811.56		
	Overall	260.25	1444.13	260.82	48333	229.03	21025.21	94	94.73	17925.91		
Local	**Lactating cow**	59.80	110.75	10.63	14285	22.15	2418.33	94	95.57	2080.08	1000	3.28
	Heifer		116.25	11.16	20000	23.25	1080.67	94	95.35	927.36		
	Calf		78.4	9.40	2250	15.68	338.68	94	92.16	280.92		
	Adult Bull	-	-	-	-	-	-	-				
	Overall	59.80	305.4	31.2	36535	61.08	3837.68	94	95.19	3287.78		
Buffalo	**Lactating buffalo**	246.96	205.8	49.39	35712	34.3	4652.45	94	93.14	3899.96	1000	9.20
	Heifer		216	51.84	8880	36	1743.84	94	92.8	1456.45		
	Calf		87.5	31.5	1749.9	17.5	420	94	91.25	344.92		
	Buffalo bull		285.6	68.54	20000	47.6	4209.74	94	90.48	3428.09		
	Overall	246.96	794.9	201.27	66341.9	135.4	11026.03	94	92.74	9202.99		

Table 39: Economic losses due to HS and BCA of different species and categories of dairy animals in Zone III of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. cost (Rs.)	Total loss (Rs.)	Vaccine effectiveness (%)	Vaccine coverage (%)	Total benefits of vaccination per year (Rs.)	Total cost of control (Rs.)	BCA (B/C)
Cross Bred	**Lactating cow**	550.55	388.43	54.37	30872	48.55	8809.88	90.29	94	7158.99	1000	10.98
	Heifer		391.65	62.66	13998	55.95	3867.26	88.81	94	3091.06		
	calf		187.08	43.65	2586	31.18	1041.41	84.41	94	791.14		
	Bull		-	-	-	-	-	-	-			
	Overall	550.55	967.13	160.69	47456	135.68	13718.55	88.97	94	10984.85		
Local	**Lactating cow**	93.69	173.55	16.65	20000	34.7	3788.54	93.06	94	3173.05	1000	6.14
	Heifer		277.75	26.66	-	55.55	2581.96	88.89	94	2065.59		
	Calf		250	30	3000	50	1080	75	94	729		
	Adult Bull		-	-	-	-	-	-	-			
	Overall	93.69	701.25	73.31	23000	140.25	7450.5	91.58	94	6140.85		
Buffalo	**Lactating buffalo**	497.16	414.31	99.43	28884	69.05	9365.94	86.19	94	7265.25	1000	13.85
	Heifer		510.62	122.54	10000	85.1	4122.24	82.98	94	3078.57		
	calf		232.74	83.77	1555.5	46.54	1116.96	76.73	94	771.33		
	Buffalo bull		249.91	59.97	20000	41.65	3683.52	91.67	94	3039.01		
	Overall	497.16	1407.51	365.72	60439.5	242.34	18288.66	84.16	94	13852.56		

Table 40: Economic losses due to HS and BCA of different species and categories of dairy animals in Zone IV of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. cost (Rs.)	Total loss (Rs.)	Vaccine effectiveness (%)	Vaccine coverage (%)	Total benefits of vaccination per year (Rs.)	Total cost of control (Rs.)	BCA (B/C)
Cross Bred	**Lactating cow**	237.00	167.2	23.40	33328	20.9	3792.51	95.82	94	3270.58	1000	7.88
	Heifer		225.75	62.66	30000	55.95	3867.26	93.55	94	3256.04		
	Calf		152.28	35.53	3750	25.38	847.69	87.31	94	666.10		
	Bull		600	112	0	100	812	80	94	584.64		
	Overall	237	1145.23	233.60	67078	202.23	9319.46	94.05	94	7888.46		
Local	**Lactating cow**	32.26	59.75	5.73	25000	11.95	1304.70	97.61	94	1146.16	1000	1.93
	Heifer		78	7.48	20000	15.6	725.08	96.875	94	632.17		
	Calf		41.6	4.99	1500	8.32	179.71	95.84	94	155.01		
	Adult Bull		-	-	-	-	-					
	Overall	32.26	179.35	18.2	46500	35.87	2209.49	97.23	94	1933.45		
Buffalo	**Lactating buffalo**	236.52	197.1	47.30	34734	32.85	4455.77	93.43	94	3746.72	1000	6.61
	Heifer		323.4	77.61	5454	53.9	2610.91	89.22	94	2096.50		
	Calf		118.6	42.69	1285.5	23.72	569.28	88.14	94	451.58		
	Buffalo bull		352.8	59.97	-	41.65	351.52	88.24	94	279.16		
	Overall	236.52	991.9	227.58	41473.5	152.12	7987.48	92.03	94	6615.79		

Table 41: Economic losses due to HS and BCA of different species and categories of dairy animals in Zone V of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. cost (Rs.)	Total loss (Rs.)	Vaccine effectiveness (%)	Vaccine coverage (%)	Total benefits of vaccination per year (Rs.)	Total cost of control (Rs.)	BCA (B/C)
Cross Bred	**Lactating cow**	646.97	456.4	63.89	41600	57.05	10325.29	88.59	94	8232.45	1000	12.25
	Heifer		443.45	70.95	23331	63.35	4378.75	87.33	94	3441.56		
	calf		110.28	25.7	3750	18.38	613.89	90.81	94	501.72		
	Overall	646.97	1010.13	160.57	68681	138.78	15317.93	88.86	94	12250.36		
Local	**Lactating cow**	232.74	431	41.37	20000	86.2	9411.31	82.76	94	7009.92	1000	7.79
	Heifer		166.5	15.98	-	33.3	215.78	93.34	94	181.26		
	Calf		2.5	0.3	-	0.5	3.3	99.75	94	2.96		
	Adult Bull		499.8	39.98	0	83.3	623.08	83.34	94	467.34		
	Overall	232.74	1099.8	97.64	20000	203.3	10253.47	84.49	94	7796.84		
Buffalo	**Lactating buffalo**	575.28	479.4	115.05	34284	79.9	10837.63	84.02	94	8195.19	1000	17.43
	Heifer		403.2	96.76	7500	67.2	3255.16	86.56	94	2535.9		
	calf		241.3	86.86	1428.3	48.26	1158.24	75.87	94	790.88		
	Buffalo bull		600	144	20000	100	8844	80	94	6367.68		
	Overall	575.28	1723.9	442.69	63212.3	295.36	24095.03	80.38	94	17430.83		

Table 42: Economic losses due to HS and BCA of different species and categories of dairy animals in Zone VI of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Mortality Loss of animal (Rs.)	Misc. cost (Rs.)	Total loss (Rs.)	Vaccine effectiveness (%)	Vaccine coverage (%)	Total benefits of vaccination per year (Rs.)	Total cost of control (Rs.)	BCA (B/C)
Cross Bred	**Lactating cow**	372.51	262.8	36.79	37584	32.85	5960.96	93.43	94	5012.39	1000	7.91
	Heifer		292.95	46.87	16665	41.85	2892.67	91.63	94	2385.49		
	Calf		117.6	27.44	3048.5	19.6	654.64	90.2	94	531.43		
	Overall	372.51	673.35	111.1	57297.5	94.3	9508.27	92.51	94	7916.49		
Local	**Lactating cow**	72.22	133.75	12.84	16665	26.75	2920.56	94.65	94	2487.87	1000	4.89
	Heifer		192.25	18.45	13332	38.45	1787.15	92.31	94	1484.74		
	Calf		111.1	13.33	3000	22.22	479.95	88.89	94	383.96		
	Adult Bull		199.8	15.98	-	33.3	249.084	93.34	94	209.24		
	Overall	72.22	636.9	60.6	32997	120.72	5436.74	100	94	4893.07		
Buffalo	**Lactating buffalo**	334.08	278.4	66.81	30780	46.4	6293.69	90.72	94	5138.67	1000	7.22
	Heifer		144.9	34.77	11666	24.15	1169.82	95.17	94	1001.98		
	Calf		148.7	53.53	1978.5	29.74	713.76	85.13	94	546.86		
	Buffalo bull		499.8	119.95	-	83.3	703.02	83.34	94	527.30		
	Overall	334.08	1071.8	275.06	44424.5	183.59	8880.29	90.41	94	7225.80		

4.2.2.3. Total economic losses of dairy animals due to HS in different ACZ's

From the Table 46, the overall mean economic losses per affected animal per year of Rs. 5,111.64±1482.32 due to HS was significant at the species level ($F=21.84$; $p<0.05$), but didn't vary significantly between the different ACZs ($F= 0.433$; $p>0.05$). The total mean economic losses per animal per year in crossbred cattle, indigenous cattle and buffaloes were Rs. 5799.55±1096.1, Rs. 2270.30±992.6 and Rs. 7265.08±1801 respectively. Maximum losses were skewed towards buffaloes, followed by cross bred and indigenous cattle due to higher prevalence among these animals (Fig 12). The overall mean value per animal per year among all the different categories of animals between the different ACZ's was the highest loss in Zone VI (Rs 6641.66±2692.01) and lowest in Zone IV (Rs. 4092.16±2243.49). In cross bred cattle, among the different ACZ's, highest loss per animal per year was observed in Zone V (Rs.7238.02) and lowest in Zone III (Rs 4561.75). In indigenous cattle, it ranged between Rs 890.44 (Zone VI) to Rs.3701.48 (Zone V). Further, in buffaloes, the maximum loss per animal per year was observed in Zone III (Rs 9475.35) and minimum in Zone IV (Rs 4913.55).

HS causes huge losses to the dairy farmers through production impediments and mortality of dairy animals. Since the overall economic loss was Rs 5,111.64±1482.32 per animal per year and the major losses were estimated in buffaloes followed by cross bred and indigenous cattle due to their more susceptibility to the pathogenic organism of HS. Major losses were from the mortality of animals (63-70%) followed by treatment cost (17-25%), milk yield loss (4.2-7.38%), extra labour charges (2.4-4.3%) and miscellaneous charges (2.63-4.89%). Various studies in India coincide to present findings like Singh *et al* (2014a) estimated total economic loss per infected animal due to Haemorrhagic Septicaemia was highest in buffaloes (Rs 4, 262.57), followed by crossbred cattle (Rs 2355.78) and ND cattle (Rs 3228.52). Singh *et al* (2014b) estimated the total economic loss per infected animal due to Haemorrhagic Septicaemia has been estimated as Rs. 6816 in case of cattle and Rs. 10901 in buffalo.

Recent study reported by Govindaraj *et al* (2017) in Karnataka state contradicts to our study that the average loss per animal due to mortality loss was $275 (Rs 17875), $284 (Rs 18480), and $415 (Rs 26975), in case of indigenous cattle, water buffaloes, and crossbred cattle, respectively. Because in our study, the buffalo population constitutes almost double to the cattle population and highest loss was observed in buffaloes due to the higher prevalence of this disease and case fatality rate due to HS in our study was lower compared to this study.

The major impact of economic losses due to HS was observed in Zone VI (Flood plain region), followed by Zone I (Sub-Mountain undulating region) and minimum impact on Zone IV (Western plain region) due to higher HS incidence risk in these regions and higher buffalo population. These areas were lying towards the border side and these farmers suffer due to their poor awareness of this disease and various myths towards vaccinating their farm animals and also may be due to poor coverage of vaccination. However, in Flood plain Zone, mostly the disease outbreaks due to HS results in such losses, especially in medium-sized dairy herds. Other reasons might be due to due to poor farm management practices, poor biosafety measures. This epidemiological scenario of HS in Punjab, indicate the importance of HS and warrants timely vaccination to prevent the disease.

From the benefit cost analysis of intervention of control measures like effective vaccination, biosafety measures taken at farm level and segregation of affected animals indicated that higher benefits cost ratio in case of buffaloes due to their higher occurences. These control measures were assmed to cost Rs 1000 for each animal annually for estimation of BC ratio of FMD in dairy animals. In Punjab, the BCA indicated that the benefits outweigh the cost incurred for vaccination under all the incidence (crossbred, indigenous and buffalo) scenarios. Even under low incidence scenario, the benefits realized will be 3.5 times over the cost and thereby it is suggested to vaccinate the entire dairy animal population in the state. It indicates that net benefits forgone from the non-affected animals could be higher once the intervention of effective HS control measures (vaccination and proper biosafety measures etc) at farm level could be undertaken and the dairy farming would be profitable once this disease is controlled.

The overall financial loss due to HS per affected animal per year was Rs. 5,111.64±1482.32. However, the mean economic losses per animal per year affected varied significantly ($p<0.05$) among different categories of animals, and was highest in buffalo (Rs. 7265.08±735.27), followed by cross bred (Rs. 5799.55±447.48) and lowest in buffaloes (Rs. 2270.30±405.22). At species level, the largest component of the economic losses were due to mortality loss of animals (69.42% in cross bred, 63.15% in indigenous cattle and 70.40% in buffaloes), followed by treatment cost and milk loss. The major impact of economic losses due to HS was observed in Flood plain region. On benefit cost analysis of intervention of control measures, higher BCA ratio was observed in buffalo, followed by crossbred and indigenous cattle.

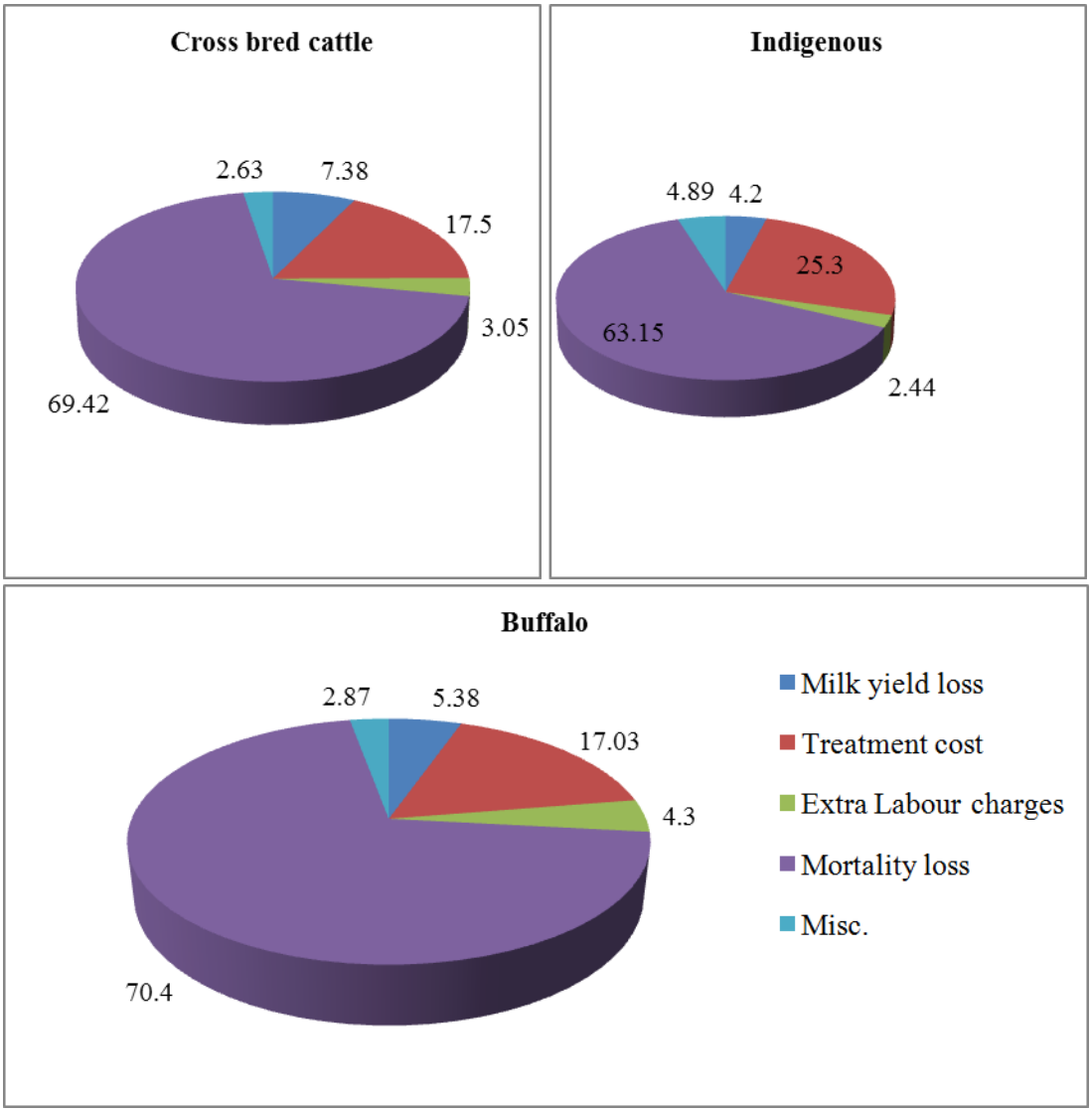


Fig. 11: Proportion of different component losses (%) – HS

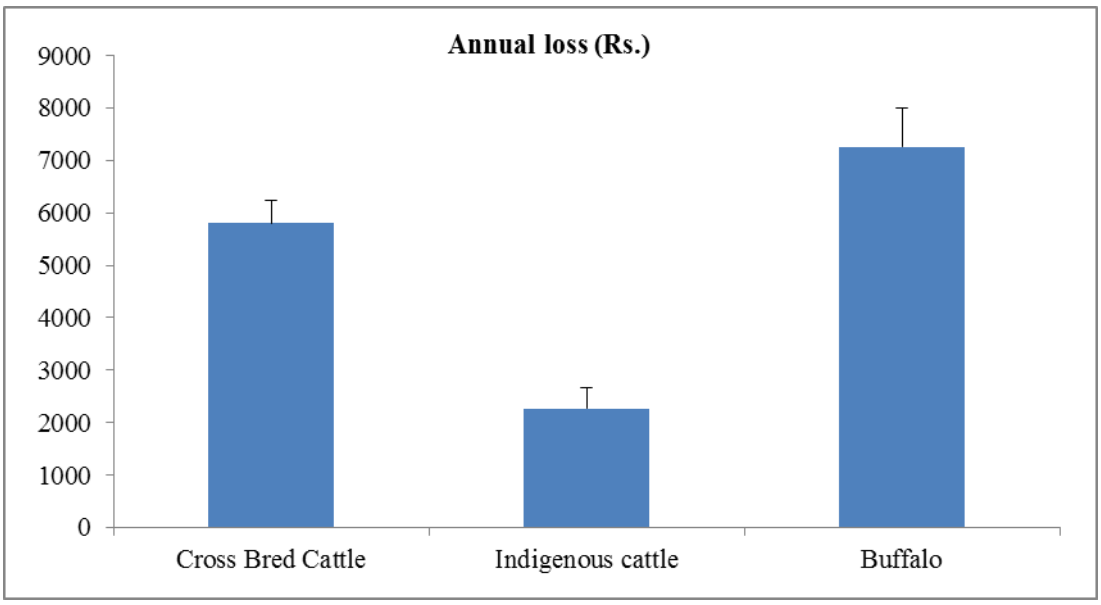


Fig. 12: Overall annual losses per animal in different species due to HS

Table 45: Components of annual economic losses per animal due to HS of dairy animals in different ACZ's of Punjab.

		Losses (component-wise) (Rs.)					Total loss /animal/year (Rs.)
	Agro-climatic Zones	Milk yield loss	Treatment cost	Extra Labour charges	Mortality loss	Misc.	
Cross bred cattle	I	503.496	850.22	134.78	5298.62	117.02	6904.14
	II	260.253	1444.13	260.82	2547.14	229.03	4741.38
	III	550.55	967.13	160.69	2747.70	135.68	4561.75
	IV	237	1145.23	233.60	3991.14	202.23	5809.20
	V	646.97	1010.13	160.57	5281.56	138.78	7238.02
	VI	372.51	673.35	111.1	4291.58	94.3	5542.84
	Mean±S.E	428.46±67.42	1015.0±107.52	176.93±23.72	4026.3±486.10	152.84±21.17	5799.6±447.48
% Contribution		7.38	17.50	3.05	69.42	2.63	
Indigenous cattle	I	81.81	524.45	52.62	1552.5	104.89	2316.27
	II	59.805	305.4	31.2	1757.334	61.08	2214.81
	III	93.69	701.25	73.314	1936.6	140.25	2945.10
	IV	32.26	179.35	18.2	1288.05	35.87	1553.73
	V	232.74	1099.8	97.644	2068	203.3	3701.48
	VI	72.225	636.9	60.6	0	120.72	890.44
	Mean±S.E	95.42±28.77	574.52±132.53	55.59±11.70	1433.7±308.26	111.02±24.25	2270.3±405.22
% Contribution		4.20	25.30	2.44	63.15	4.89	
Buffaloes	I	456.12	1436	363.01	5396.754	244.44	7896.32
	II	246.96	794.9	201.276	4816.422	135.4	6194.95
	III	497.16	1407.5	365.72	6962.63	242.34	9475.35
	IV	236.52	991.9	227.582	3305.438	152.12	4913.55
	V	575.28	1723.9	442.692	5948.277	295.36	8985.50
	VI	334.08	1071.8	275.06	4260.31	183.59	6124.83
	Mean±S.E	391.02±56.95	1237.7±140.06	312.56±37.99	5115.0±525.40	208.88±25.24	7265.1±735.27
% Contribution		5.38	17.03	4.30	70.40	2.87	

Table 46: Annual economic losses per animal due to HS of dairy animals in different ACZ's of Punjab.

Per animal per year	Category	Agro-climatic Zones of Punjab						
		I	II	III	IV	V	VI	Mean±SE
Annual loss (Rs.)	Cross Bred Cattle	6904.14	4741.38	4561.75	5809.2	7238.02	5542.84	5799.55^{b} ±447.48
	Indigenous cattle	2316.27	2214.81	2945.10	1553.73	3701.48	890.44	2270.30^{a} ±405.22
	Buffalo	7896.32	6194.95	9475.35	4913.55	8985.50	6124.83	7265.08^{b} ±735.27
	Overall	5705.57 ±2976.85	4383.71 ±2014.03	5660.73 ±3401.0	4092.16 ±2243.49	6641.66 ±2692.01	4186.03 ±2868.86	5111.64±1482.32

Different lowercase superscripts (a,b,c) indicate significant ($p<0.05$) difference.

4.2.3.1. Epidemiological aspect of Mastitis in different ACZ's of Punjab

The distribution of Mastitis observed in dairy animals of different ACZ's of Punjab has been presented in Table 47-52. Dairy farmers were severely affected by this disease due to heavy economic impact on their milk production. The overall prevalence of Mastitis among the dairy animals was 27.10 percent and was significant among the different species and between the different ACZ's of Punjab of different herd size and species. It was assumed that the animals suffer from chronic Mastitis would be culled depends on the average number of quarters affected. Since the study was survey based, therefore all the three forms of Mastitis in lactating animals were studied during 2016-17.

Table 59, illustrates the prevalence of Mastitis among the different categories of animals viz. cross bred cattle, indigenous cattle and buffaloes varied significantly (χ^2=377.29; p<0.01). Among the different categories of animals on species basis, the highest prevalence was observed in cross bred cattle (38.75%), followed by indigenous cattle and buffaloes (30.47% & 18.50% respectively). Prevalence of Mastitis among the cross bred cattle in different ACZ's of Punjab varied significantly (χ^2=13.8; p<0.05), and its prevalence was observed highest in Zone III (43.95%) and lowest in Zone II (31.70%). Similarly, among the indigenous cattle, it didn't vary significantly (χ^2=7.9; p>0.05) between the different ACZ's and ranged between 25.14% (Zone IV) to 43.05% (Zone III). Further, the prevalence of Mastitis in buffaloes didn't vary significantly (χ^2=8.25; p<0.05) between the different ACZ's and ranged between 15.22% (Zone IV) to 21.07% (Zone II).

Among the different herd groups, the prevalence of Mastitis in small, medium and large herds was 28.20, 30.14 and 24.59 percent respectively and was significant among the different categories of animals (χ^2=25.14; p<0.01). Between the different ACZ's, the prevalence of Mastitis was significant (p<0.05). Among the small herd group, its prevalence was observed lowest in Zone I (20.47%) and highest in Zone VI (36.64%). For medium herd size, it ranged between 20.75% (Zone IV) to 39.39% (Zone III). Further, in large herd size, the prevalence of Mastitis ranged between 14.75% (Zone VI) to 43.39 % (Zone V).

Indeed both at the species level and herd level, the prevalence of Mastitis observed in the current study was high since there was no such study studied before

on an epidemiological aspect of Mastitis at field level collecting a surveyed data from the farmers. But, due to the popularity of dairy farming on a commercial level in Punjab with an excellent potential for milk production due to the availability of forage and rearing of high yielder animals for milk production. Perhaps, the prevailing high prevalence of Mastitis could either be due to less attention or casual approach, a poor hygienic environment at their farms, lack of implementation of regular Mastitis prevention and control strategies rather than treating clinical cases. The fact that most of the dairy farmers were not implementing routine Mastitis prevention practices such as pre and post-milking teat disinfection, wearing of gloves during milking, treatment of Mastitis during the non-lactating period, early diagnostic tests like CMT, SCC etc. at the farm level to screen animals at subclinical Mastitis, dry cow therapy and culling of chronically infected animals. The incidence of Mastitis was influenced by various managerial and environmental factors, such as the poor housing of cows, soiled milking equipment, odd feeding regime, unhygienic quality of feed and water, cleanliness of cows, early diagnostic techniques used to check subclinical Mastitis, implementation of preventive measures, and general practices related to, for instance, drying-off (Nyman *et al* 2007 and Swami *et al* 2017).

Table 59 illustrates that prevalence of Mastitis was higher in high yielder cross bred animals that reveals a significant association between breed and the presence of Mastitis. Among the cattle, indigenous cattle were resistant than cross bred or pure HF breeds, similar findings were observed by Abebe *et al* (2016) that pure local breeds are more resistant to reduce Mastitis than the European. Kvapilík (2015) reported the clinical Mastitis attacks 17–48% in cows. Sachin *et al* (2015) reported that the overall quarter-wise prevalence of subclinical Mastitis in crossbred cows and buffaloes were 49.16% and 45.83% respectively. Bangar *et al* (2015) observed that the prevalence of subclinical Mastitis on cow basis varied from 20.73 to 78.55 %. NAAS (2013) reported that the prevalence of bovine clinical Mastitis varying from 10 to 50% in cows and 5 to 20% in buffaloes. Joshi and Gokhale (2006) reported that high incidences of subclinical Mastitis have been reported from various parts of the country with figures ranging from 18.40% to 72.60% in cross bred cows and 15.78% to 81.60%, in local cows.

Biffa *et al* (2005) reported that high rate of development of Mastitis in Holstein-Friesian (56.5%) as compared to local zebu (30.9%) and Jersey cows (28.9%). Shukla *et al* (2005) recorded the prevalence of clinical and sub-clinical Mastitis in crossbred and Sahiwal cows and Murrah buffaloes as 8.97% and 67.94%, 8.33% and 47.22% and 7.50% and 42.50%, respectively. Breed difference susceptibility to Mastitis had also been reported by other studies like Shittu *et al* (2012), Iraguha *et al* (2015), Sanotharan *et al* (2016) and Swami *et al* (2017). Since mastitic cows tend to have higher milk yield than non-mastitic cows before they develop CM (Grohn *et al* 2004 and Wilson *et al* 2004), indicating that high milk yield as a risk factor for Mastitis. In this study, dairy farmers especially the medium herd size of commercial dairy farmers were rearing cross bred HF animals for higher milk production but were less concerned about their udder health. There was indiscriminate use of multiple antibiotics once the Mastitis symptoms appear and without consulting the veterinarian or going for the diagnostic test like SSC, CMT and antibiotic sensitive test for bacteriological bio gram for effectively treating the mastitic animals. One more reason might be due to yield stress and environmental stress, where an animal could not withstand the opportunistic pathogens causing Mastitis. Even though, the poor managemental conditions, buffaloes were less affected due to well adopted climatic conditions, and having thick and compact epithelium, thick keratin layer and thick muscle sphincter in streak canal of teats in buffaloes as compared to cows (Uppal *et al* 1994, Thapa and Kaphle 2002 and Sharma *et al* 2012).

The overall incidence of Mastitis among dairy animals was 27.10 percent. Incidence of Mastitis on the species basis varied significantly and was observed highest in cross bred (38.75%), followed by indigenous cattle (30.47%) and least in buffalo (18.50%). The incidence of Mastitis among the different ACZ's of Punjab was observed highest in Central plain and Western plain regions (Fig 13). Its occurence varied significantly ($p<0.05$) in cross bred aniamls, but no difference was found within different ACZ's in either indigenous cattle or buffalo. Within different herd sizes (Fig 14), the incidence of Mastitis varied significantly and was highest in medium herd size (30.14%) followed by small (28.20%) and large herd size (24.59%). Incidence risk varied significantly ($p<0.01$) between the different ACZ's of Punjab within small, medium as well as large sized herds

Table 47: Prevalence and culling rate of Mastitis across herd sizes, species and categories of dairy animals in Zone I of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate %
Herd size	**Small**	254	52	20.47	18	13.46
	Medium	487	148	30.39	25	16.89
	Large	78	25	32.05	11	44.00
	Overall	819	227	27.71	54	18.94
			$\chi^2 = 9.14^{**}$		$\chi^2 = 111.56^{*}$	
Cross Bred	**Lactation (<2)**	65	21	32.30	4	19.04
	Lactation (2-5)	177	65	36.72	17	26.15
	Lactation (>5)	118	46	38.98	15	32.60
	Overall	360	132	36.66	36	27.27
			$\chi^2 = 0.80^{ns}$		$\chi^2 = 0.54^{ns}$	
Local	**Lactation (<2)**	8	2	25.00	0	0
	Lactation (2-5)	14	4	28.57	1	25
	Lactation (>5)	11	4	36..36	1	25
	Overall	33	10	30.30	3	30
			$\chi^2 = 0.31^{ns}$		$\chi^2 = 0.05^{ns}$	
Buffalo	**Lactation (<2)**	105	18	17.14	2	11.11
	Lactation (2-5)	203	41	20.19	7	17.07
	Lactation (>5)	118	26	22.03	6	23.07
	Overall	426	85	19.95	15	17.64
			$\chi^2 = 0.84^{ns}$		$\chi^2 = 1.06^{ns}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 48: Prevalence and culling rate of Mastitis across herd sizes, species and categories of dairy animals in Zone II of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate %
Herd size	**Small**	319	78	24.45	28	27.18
	Medium	458	130	28.38	22	12.64
	Large	341	101	29.61	15	10.41
	Overall	1118	309	27.63	65	15.43
			$\chi^2 = 6.97^{**}$		$\chi^2 = 14.70^{**}$	
Cross Bred	**Lactation (<2)**	116	36	31.03	5	13.88
	Lactation (2-5)	154	57	37.01	12	21.05
	Lactation (>5)	78	41	52.56	16	39.02
	Overall	348	134	38.50	33	24.62
			$\chi^2 = 9.38^{**}$		$\chi^2 = 7.20^{**}$	
Local	**Lactation (<2)**	45	8	17.77	2	25
	Lactation (2-5)	71	21	29.57	4	19.04
	Lactation (>5)	42	17	40.47	6	35.29
	Overall	158	46	29.11	12	26.08
			$\chi^2 = 5.43^{ns}$		$\chi^2 = 1.29^{ns}$	
Buffalo	**Lactation (<2)**	165	24	14.54	2	8.33
	Lactation (2-5)	316	63	19.93	7	11.11
	Lactation (>5)	131	42	32.06	11	26.19
	Overall	612	129	21.07	20	15.50
			$\chi^2 = 15.09^{**}$		$\chi^2 = 5.53^{ns}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 49: Prevalence and culling rate of Mastitis across herd sizes, species and categories of dairy animals in Zone III of Punjab.

	Category	Total animals	Affected animals	Prevalence Rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	312	114	36.53	13	11.40
	Medium	363	143	39.39	26	18.18
	Large	375	109	29.06	34	31.19
	Overall	1050	366	34.85	73	19.94
			$\chi^2 = 9.21^{**}$		$\chi^2 = 14.12^{**}$	
Cross Bred	**Lactation (<2)**	157	61	38.85	6	9.83
	Lactation (2-5)	279	119	42.65	18	15.12
	Lactation (>5)	151	78	51.65	24	30.76
	Overall	587	258	43.95	48	18.60
			$\chi^2 = 5.48^{ns}$		$\chi^2 = 11.67^{**}$	
Local	**Lactation (<2)**	16	5	31.25	0	0
	Lactation (2-5)	37	14	37.83	2	14.28
	Lactation (>5)	19	12	63.15	5	41.66
	Overall	72	31	43.05	7	22.58
			$\chi^2 = 4.45^{ns}$		$\chi^2 = 2.85^{ns}$	
Buffalo	**Lactation (<2)**	123	18	14.63	1	5.55
	Lactation (2-5)	176	33	18.75	5	15.15
	Lactation (>5)	92	26	28.26	12	46.15
	Overall	391	77	19.69	18	23.37
			$\chi^2 = 6.35^{**}$		$\chi^2 = 11.96^{**}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 50: Prevalence and culling rate of Mastitis across herd sizes, species and categories of dairy animals in Zone IV of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	311	86	27.65	18	20.93
	Medium	477	99	20.75	30	30.30
	Large	244	36	14.75	21	58.33
	Overall	1032	421	37.65	65	15.43
			$\chi^2 = 13.74^{**}$		$\chi^2 = 16.60^{**}$	
Cross Bred	**Lactation (<2)**	91	19	20.879	3	15.78
	Lactation (2-5)	124	35	28.225	12	34.28
	Lactation (>5)	72	37	51.38	19	51.35
	Overall	287	91	31.70	34	37.36
			$\chi^2 = 18.50^{**}$		$\chi^2 = 7.01^{**}$	
Local	**Lactation (<2)**	51	11	21.56	1	9.090
	Lactation (2-5)	78	18	23.07	5	27.77
	Lactation (>5)	38	13	34.21	5	38.46
	Overall	167	42	25.14	11	26.19
			$\chi^2 = 2.18^{ns}$		$\chi^2 = 2.69^{ns}$	
Buffalo	**Lactation (<2)**	171	22	12.86	5	22.72
	Lactation (2-5)	272	40	14.70	15	37.5
	Lactation (>5)	135	26	19.25	14	53.84
	Overall	578	88	15.22	24	27.27
			$\chi^2 = 2.49^{ns}$		$\chi^2 = 4.90^{ns}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 51: Prevalence and culling rate of Mastitis across herd sizes, species and categories of dairy animals in Zone V of Punjab.

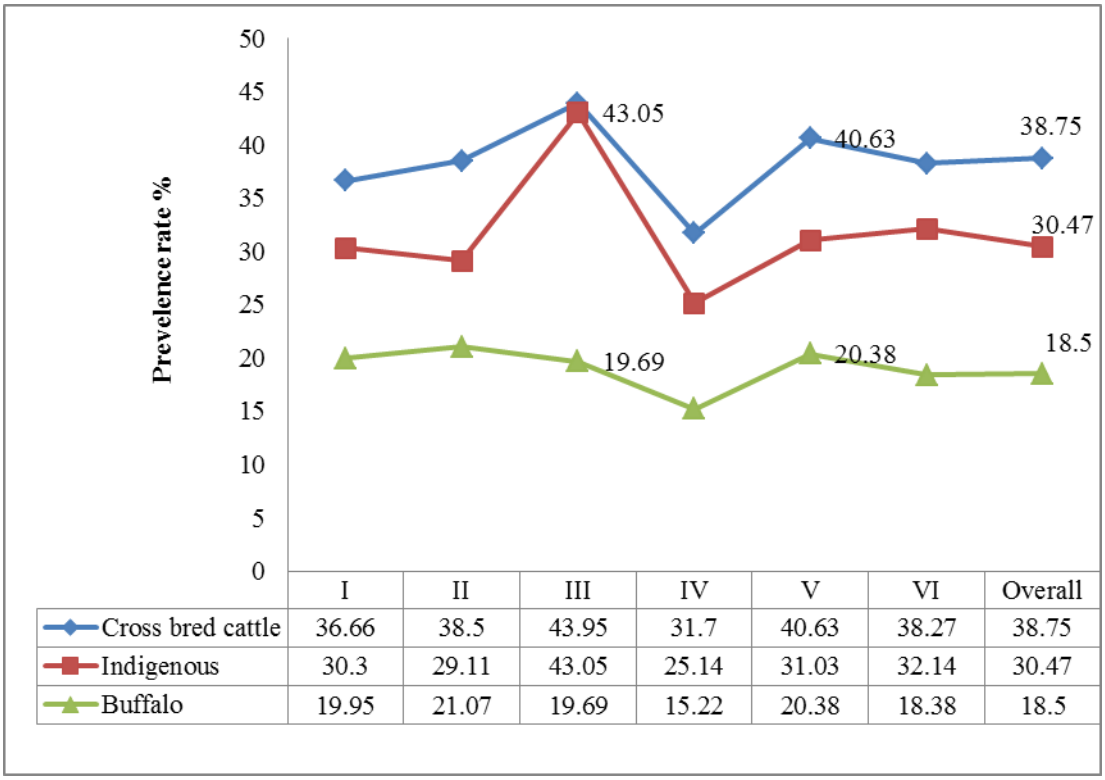
	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	281	73	28.82	16	19.75
	Medium	223	68	33.18	19	25.67
	Large	53	27	43.39	4	17.39
	Overall	557	161	33.75	57	21.91
			$\chi^2 = 19.40^{*}$		$\chi^2 = 14.73^{**}$	
Cross Bred	**Lactation (<2)**	31	9	29.03	2	9.09
	Lactation (2-5)	130	53	40.76	16	20.77
	Lactation (>5)	58	27	46.55	16	51.61
	Overall	219	89	40.63	34	26.15
			$\chi^2 = 6.73^{**}$		$\chi^2 = 6.80^{**}$	
Local	**Lactation (<2)**	6	1	33.33	0	0
	Lactation (2-5)	14	3	21.42	1	33.33
	Lactation (>5)	9	5	44.44	2	40.00
	Overall	29	9	31.03	3	30
			$\chi^2 = 6.03^{**}$		$\chi^2 = 0.03^{ns}$	
Buffalo	**Lactation (<2)**	72	9	12.5	1	11.11
	Lactation (2-5)	129	23	17.82	4	17.39
	Lactation (>5)	108	31	28.70	15	48.38
	Overall	309	63	20.38	20	38.09
			$\chi^2 = 7.88^{**}$		$\chi^2 = 7.91^{**}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 52: Prevalence and culling rate of Mastitis across herd sizes, species and categories of dairy animals in Zone VI of Punjab.

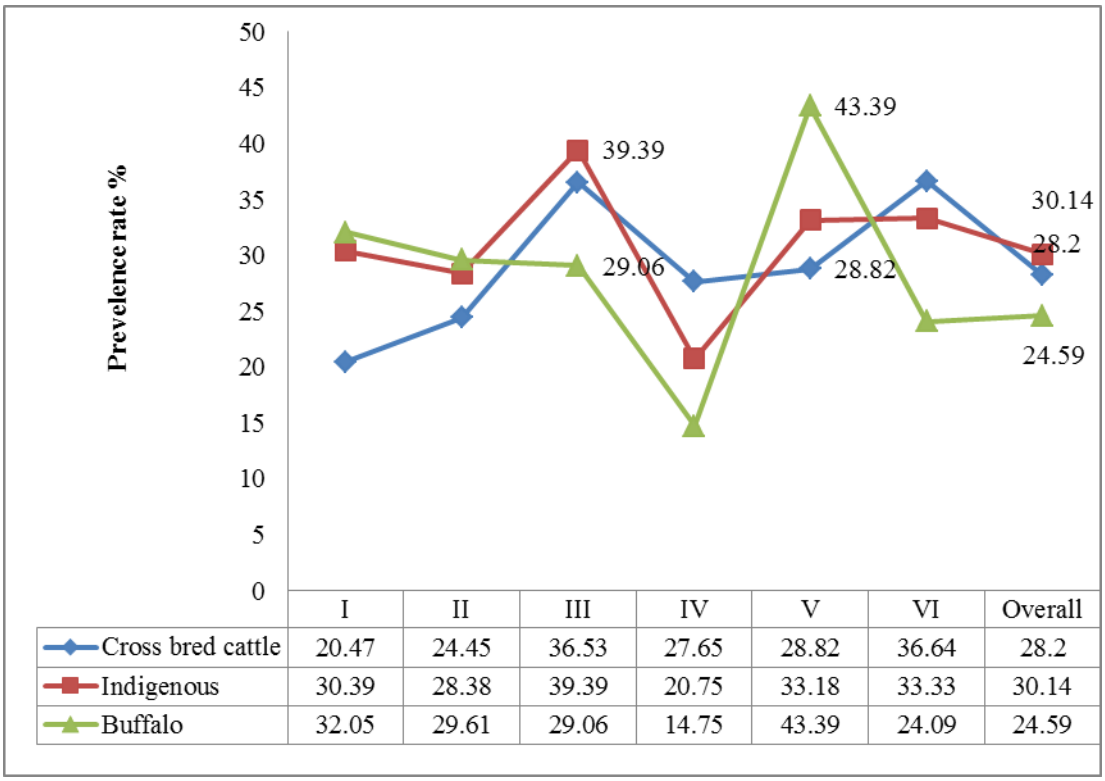
	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	161	59	36.64	16	31.37
	Medium	546	182	33.33	44	19.29
	Large	2723	656	24.09	116	15.71
	Overall	3430	897	26.15	176	17.30
			$\chi^2 = 47.16^{*}$		$\chi^2 = 8.98^{**}$	
Cross Bred	**Lactation (<2)**	264	72	27.27	8	11.11
	Lactation (2-5)	679	247	36.37	36	14.57
	Lactation (>5)	319	164	51.54	73	44.51
	Overall	1262	483	38.27	117	24.22
			$\chi^2 = 37.86^{*}$		$\chi^2 = 56.04^{*}$	
Local	**Lactation (<2)**	23	4	17.39	1	25
	Lactation (2-5)	52	15	28.84	2	13.33
	Lactation (>5)	37	17	45.94	12	70.58
	Overall	112	36	32.14	15	41.60
			$\chi^2 = 6.22^{**}$		$\chi^2 = 11.26^{**}$	
Buffalo	**Lactation (<2)**	498	71	14.25	4	5.6
	Lactation (2-5)	1256	232	18.47	19	8.18
	Lactation (>5)	302	64	21.19	21	32.81
	Overall	2056	378	18.38	44	11.64
			$\chi^2 = 7.0^{**}$		$\chi^2 = 34.22^{**}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.



	I	II	III	IV	V	VI	Overall
Cross bred cattle	36.66	38.5	43.95	31.7	40.63	38.27	38.75
Indigenous	30.3	29.11	43.05	25.14	31.03	32.14	30.47
Buffalo	19.95	21.07	19.69	15.22	20.38	18.38	18.5

Fig. 13: Prevalence of Mastitis on Species basis



	I	II	III	IV	V	VI	Overall
Cross bred cattle	20.47	24.45	36.53	27.65	28.82	36.64	28.2
Indigenous	30.39	28.38	39.39	20.75	33.18	33.33	30.14
Buffalo	32.05	29.61	29.06	14.75	43.39	24.09	24.59

Fig. 14: Prevalence of Mastitis on Herd basis

Table 59: Prevalence of Mastitis on species basis and herd basis of dairy animals in different ACZ's of Punjab.

Prevalence (%)	Category	Agro-climatic zones of Punjab									
		I	II	III	IV	V	VI	χ^2 Value	Total Animals	Affected Animals	Prevalence (%)
Species basis	Cross- bred Cattle	36.66	38.50	43.95	31.70	40.63	38.27	13.8^{**}	3063	1187	38.75
	Indigenous cattle	30.30	29.11	43.05	25.14	31.03	32.14	7.90^{ns}	571	174	30.47
	Buffalo	19.95	21.07	19.69	15.22	20.38	18.38	8.25^{ns}	4372	809	18.50
									Overall χ^2 Value = 377.29^{*}		
Herd size basis	Small	20.47	24.45	36.53	27.65	28.82	36.64	26.8^{*}	1638	462	28.20
	Medium	30.39	28.38	39.39	20.75	33.18	33.33	38.1^{*}	2554	770	30.14
	Large	32.05	29.61	29.06	14.75	43.39	24.09	43.1^{*}	3814	938	24.59
	Overall	27.71	27.63	34.85	37.65	33.75	26.15	52.9^{*}	8006	2170	27.10
									Overall χ^2 Value = 25.14^{*}		

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Our study contradicts the study of Kurjogi and Kaliwal (2014) conducted in Karnataka about the prevalence of clinical Mastitis 4.7-8%, based on diagnostic tests; Firat *et al* (1993) 16-65% and Miltenburg *et al* (1996) 10-12% on the herd basis. Kaur *et al* (2014) reported the prevalence of 9.8% sub clinical Mastitis (SCM) in buffaloes in Punjab on the quarter level. Mpatswenumugabo *et al* (2017) reported SCM prevalence at cow level was 50.4%. The reason for the higher prevalence of Mastitis in our study was survey based during one year hence our results were based on the information perceived by the dairy farmers during a year. Secondly, most of the cases were treated by farmer themselves or taking help from nearby veterinary field assistants hence not recorded at veterinary clinics. Sub clinical Mastitis is 3–40 times more common than clinical Mastitis Bachaya *et al* (2011). Few reported the incidence of sub-clinical Mastitis at quarter wise and animal wise by Anusha *et al* (2017) 35.02% and 66.18%, respectively and Shittu *et al* (2012) reported 85.33% and 43.25% respectively.

The findings of clinical Mastitis in the study area were predominant in medium herd size (30.14%) giving a clear evidence of huge economic loss this sector is suffering from. Medium herds of central plain and western plain regions of dairy farmers preferred to rear the cross bred animals to commercialize their business, hence higher occurrence of Mastitis in their animals was observed due to their more susceptibility. While as large herds of the sub-mountain undulating region and undulating plain region mainly reared buffaloes and indigenous cows showing lower incidences of Mastitis due to their natural resistance and well adaptability to their stressful habitat. Similar findings were agreed by Oliveira *et al* (2013) that in large herds in the United States, the proportion of CM caused by contagious organisms is much lower than those in smaller herds. In Punjab, Mir *et al* (2014) reported 30.7% on the quarter level through machine milking. Sharma *et al* (2014) conducted a study of organized dairy farms in Haryana and reported 39.8 and 64.2% of sub clinical Mastitis on cow level and on quarter level respectively. Few more previous studies on the herd basis, reported the 50% dairy herd population in India (Garg 2001) and Srivastava *et al* (2008) of 28.5%, Rahman and Samad (2008) of 30% in Bangladesh, and Jalil *et al* (2003) of 27% in Pakistan, Sharma and Sindhu (2007) 32.9% on the

quarter level in buffaloes, Sinha *et al* (2014) 46% and Zeryehun and Abera (2017) 12.5-51.8%, Getaneh *et al* (2017) 0-50% and Sarba and Tola (2017) 41.7%.

A study from Abebe *et al* (2016) contradicts to our study that the prevalence of Mastitis at herd-level was 74.7 percent and at cow-level was 62.6 percent of which 59.2 and 3.4 percent were sub-clinical and clinical Mastitis cases, respectively. Chishty *et al* (2001) reported 47.5% herd population in Pakistan and 51.3% cows in Bangladesh (Rahman *et al* 2010). On cow basis Mastitis affects 54.3% dairy cows in Zhejiang province of China by Li *et al* (2009) and 52.5% dairy cows in Egypt by Abde and Mohammed (2009). Because our result was based on herd size of an animal rather than the dairy farmer and also due to better awareness of dairy farmers against this disease in Punjab leads to lower prevalence compared to other previous studies. Role of institutions and cooperative societies to display disease control measures and provide necessary inputs to dairy farmers about scientific management of feeding, breeding and health management.

The overall prevalence of Mastitis was significantly associated with among the different ACZ's of Punjab, the most affected Zone was Zone IV (Western plain region) including the Barnala and Bathinda district of Punjab, where farmers were having less awareness about the control of Mastitis and follow poor animal health management practices at the farm level. Also, the farmers in the Western plain region remain engaged with their agricultural lands during the summer season and were less involved to their subsidiary business of dairy farming. Secondly, due to summer stress and yield stress, milking animals remain immunologically weak, making an opportunity to Mastitis pathogens to cause the disease (Ranjan *et al* 2011).

The least affected region in the state was the Flood plain region and the western region includes Ludhiana, Pathankot, Faridkot, and Sri Muktsar Sahib districts. Dairy farming in these districts was undertaken by sub urban commercialized dairy farmers and had awareness about the disease control measures from regular teaching and training programme conducted by various veterinary institutions (GADVASU, KVK etc.) and dairy cooperative societies like Verka and PDDB etc.

Thus, it is obvious that the prevalence of Mastitis is high in the current study area which is a serious problem that not only reduces milk production but adversely affects the quality of milk, reduces profitability and has a public health hazard.

4.2.3.2. Economic losses due to Mastitis

Various losses were associated due to Mastitis including both visible and an invisible cost has been presented in Table 53-58. The visible cost due to Mastitis perceive by the dairy farmer viz. milk yield reduction, treatment cost, extra labour charges to nurse animal and miscellaneous cost while as invisible cost include the loss due to milk production throughout the lactation due to the occurrence of Mastitis, depreciation value of an animal, replacement cost perceived by farmers. Economic losses of different categories due to Mastitis of dairy animals in Punjab under this study was based on few assumptions or simulations like to estimate milk loss for whole lactation, veterinary charges only during illness period, extra labour charges @ Rs 40 per hour during the illness period and replacement cost of animals was calculated to assume that their was no salvage value of cattle in the study area but 50% value in case of buffalo when animals suffer chronic Mastitis. Another assumption about the depreciation value of animals suffering from Mastitis was taken 10% of 4^{th} and 5^{th} lactation and 20% after 5^{th} lactation. Average illness period varied in different species of 7 days in crossbred cattle and 6 days in indigenous cattle and buffaloes.

4.2.3.2.1. Loss of milk yield

From the Tables 53-58, milk yield loss implies the reduction of milk from the lactating animals affected due to Mastitis during the whole lactation period in different categories of animals from the different ACZ's of Punjab. A perceptible milk yield loss due to Mastitis was observed on short term and long term basis. For short term basis, the average duration of illness among the different Zones varied between different categories of cross bred cattle, indigenous cattle and buffaloes (7, 6 & 6 days respectively) with an average milk yield (18, 10 and 8 liters of milk respectively). The average quarters affected (Ratio of average number of quarters affected to 4) in cross bred cattle, indigenous cattle and buffaloes were 2.2, 1.6 & 1.4 and the reduction of milk of 5, 2.5 & 2 liters per day per average quarter affected, respectively. However, the long term reduction in milk yield for the whole lactation was estimated based on the estimation of Juliana *et al* (2017) that reduction in milk production due to clinical Mastitis for the whole lactation was about 18.5%.

Table 53: Economic losses due to Mastitis and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone I of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment coverage (%)	Total benefits per year (Rs)	Total cost of control (Rs)	BCA
Cross Bred	**Lactation (<2)**	10552.41	1130.5	155.04	6092.8	161.5	18092.25	67.7	80.95	9915.41	1200	7.91
	Lactation (2-5)	11996.42	1285.2	176.25	7322	183.6	20963.48	63.28	73.84	9796.20		
	Lactation (>5)	12734.76	1364.3	187.10	8345.6	194.9	22826.67	61.02	67.39	9386.82		
	Overall	11761.2	1260	172.8	7253.46	180	20627.46	63.34	72.72	9502.13		
Local	**Lactation (<2)**	3937.5	750	120	-	125	4932.5	75	100	3699.37	1200	3.55
	Lactation (2-5)	4499.77	857.1	137.13	4500	142.85	10136.86	71.43	75	5430.56		
	Lactation (>5)	4721.32	899.3	143.88	4250	149.88	8747.72	63.64	50	3555.51		
	Overall	4386.19	835.46	133.67	4375	139.24	7939.02	69.7	70	3873.44		
Buffalo	**Lactation (<2)**	1319.78	428.5	82.27	999.9	85.7	2916.15	82.86	88.88	2147.84	1200	1.95
	Lactation (2-5)	1554.63	504.75	96.91	1382.67	100.95	3639.91	79.81	82.92	2409.03		
	Lactation (>5)	1696.31	550.75	105.74	1661.04	110.15	4123.99	77.97	76.92	2473.44		
	Overall	1523.57	494.66	94.97	1347.87	98.93	3560.01	80.05	82.35	2346.88		

Table 54: Economic losses due to Mastitis and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone II of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment Coverage (%)	Total benefits Per year (Rs)	Total cost of control (Rs)	BCA
Cross Bred	**Lactation (<2)**	10137.5	1086.05	148.94	4441.6	155.15	15969.25	68.97	86.11	9484.27	1200	11.92
	Lactation (2-5)	12091.17	1295.35	177.64	5894	185.05	19643.22	62.99	78.94	9768.36		
	Lactation (>5)	17171.35	1839.6	252.28	9989.12	262.8	29515.16	47.44	60.97	8537.82		
	Overall	13133.34	1407	192.95	6774.90	201	21709.21	61.5	75.37	10063.19		
Local	**Lactation (<2)**	2798.77	533.1	85.29	5000	88.85	8506.02	82.23	75	5245.87	1200	4.56
	Lactation (2-5)	4657.27	887.1	141.93	3427.2	147.85	9261.36	70.43	80.95	5280.34		
	Lactation (>5)	6374.025	1214.1	194.25	5646.4	202.35	13631.13	59.53	64.70	5250.63		
	Overall	4610.02	878.1	140.49	4691.2	146.35	10466.17	70.89	73.91	5483.95		
Buffalo	**Lactation (<2)**	1119.58	363.5	69.79	749.7	72.7	2375.27	85.46	91.66	1860.74	1200	2.03
	Lactation (2-5)	1534.61	498.25	95.66	899.91	99.65	3128.08	80.07	88.88	2226.35		
	Lactation (>5)	2468.62	801.5	153.88	1885.68	160.3	5469.98	67.94	73.80	2742.98		
	Overall	1707.60	554.416	106.44	1178.43	110.88	3657.77	78.93		2439.47		

Table 55: Economic losses due to Mastitis and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone III of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment coverage (%)	Total benefits Per year (Rs)	Total cost of control (Rs)	BCA
Cross Bred	**Lactation (<2)**	12692.29	1359.75	186.48	3145.6	194.25	17578.37	61.15	90.16	9691.87	1200	8.26
	Lactation (2-5)	13933.75	1492.75	204.72	4233.6	213.25	20078.07	57.35	84.87	9773.04		
	Lactation (>5)	16874.05	1807.75	247.92	7874.56	258.25	27062.53	48.35	69.23	9058.66		
	Overall	14500.03	1553.41	213.04	5084.58	221.91	21572.99	56.05	81.39	9842.04		
Local	**Lactation (<2)**	4921.87	937.5	150	-	156.25	6165.62	68.75	100	4238.86	1200	4.32
	Lactation (2-5)	5958.22	1134.9	181.58	2570.4	189.15	10034.25	62.17	85.71	5347.10		
	Lactation (>5)	9946.12	1894.5	303.12	6665.6	315.75	19125.09	36.85	58.33	4111.09		
	Overall	6942.07	1322.3	211.56	4618	220.38	11774.98	56.95	77.41	5191.62		
Buffalo	**Lactation (<2)**	1126.51	365.75	70.22	499.5	73.15	2135.13	85.37	94.44	1721.49	1200	2.04
	Lactation (2-5)	1443.75	468.75	90	1227.15	93.75	3323.4	81.25	84.84	2291.13		
	Lactation (>5)	2176.02	706.5	135.64	3322.8	141.3	6482.26	71.74	53.84	2504.04		
	Overall	1582.09	513.66	98.62	1683.15	102.73	3980.26	80.31	76.62	2449.30		

Table 56: Economic losses due to Mastitis and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone IV of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment Coverage (%)	Total benefits Per year(Rs)	Total cost of control (Rs)	BCA
Cross Bred	**Lactation (<2)**	6818.22	730.45	100.17	5049.6	104.35	12802.80	79.121	84.21	8530.27	1200	7.73
	Lactation (2-5)	9219.47	987.7	135.45	9598.4	141.1	20082.13	71.775	65.71	9472.02		
	Lactation (>5)	16785.84	1798.3	246.62	13145.6	256.9	32233.27	48.62	48.64	7624.12		
	Overall	10941.17	1172.1	160.74	9264.53	167.45	21706.06	68.3	62.63	9286.14		
Local	**Lactation (<2)**	3395.7	646.8	103.48	1818	107.8	6071.78	78.44	90.90	4329.73	1200	4.37
	Lactation (2-5)	3633.52	692.1	110.73	4998.6	115.35	9550.31	76.93	72.22	5306.20		
	Lactation (>5)	5388.07	1026.3	164.20	6153.6	171.05	12903.23	65.79	61.53	5224.02		
	Overall	4139.09	788.4	126.13	4323.4	131.4	9508.44	74.86	73.80	5253.77		
Buffalo	**Lactation (<2)**	990.22	321.5	61.728	2044.8	64.3	3482.54	87.14	77.27	2344.98	1200	2.43
	Lactation (2-5)	1131.9	367.5	70.56	3037.5	73.5	4680.96	85.3	62.5	2495.53		
	Lactation (>5)	1482.25	481.25	92.4	3876.48	96.25	6028.63	80.75	46.15	2246.82		
	Overall	1201.47	390.08	74.89	2986.26	78.01	4730.71	84.78	72.72	2916.86		

Table 57: Economic losses due to Mastitis and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone V of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment coverage (%)	Total benefits Per year (Rs)	Total cost of control (Rs)	BCA
Cross Bred	**Lactation (<2)**	9484.10	1016.05	139.34	2908.82	145.15	13693.44	70.97	77.77	7558.62	1200	5.31
	Lactation (2-5)	13316.29	1426.61	195.64	5815.65	203.85	20957.94	59.24	69.81	8667.41		
	Lactation (>5)	15207.88	1629.25	223.44	13212.16	232.75	30505.48	53.45	40.74	6642.85		
	Overall	12669.42	1357.34	186.14	7312.18	193.93	21718.95	59.37	61.79	7968.53		
Local	**Lactation (<2)**	5249.47	999.91	159.98	-	166.65	6576	100	100	4384.21	1200	3.26
	Lactation (2-5)	3373.65	642.62	102.81	5999.41	107.12	10225.52	66.67	66.67	5356.79		
	Lactation (>5)	6999.32	1333.20	213.31	6400	222.21	15168.01	78.58	60	5056.40		
	Overall	5207.47	991.91	158.70	6199.72	165.31	10656.53	55.56	66.67	4899.86		
Buffalo	**Lactation (<2)**	962.51	312.52	60	999.92	62.52	2397.42	100	88.88	1864.64	1200	1.50
	Lactation (2-5)	1372.14	445.53	85.53	1408.59	89.11	3400.86	100	82.60	2308.77		
	Lactation (>5)	2209.90	717.51	137.76	3483.36	143.52	6692.02	87.51	51.61	2462.66		
	Overall	1514.84	491.83	94.43	1963.95	98.36	4163.42	82.18	68.25	2262.56		

Table 58: Economic losses due to Mastitis and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone VI of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment Coverage (%)	Total benefits Per year (Rs)	Total cost of control (Rs)	BCA
Cross Bred	**Lactation (<2)**	8909.10	954.45	130.89	3555.2	136.35	13686.00	72.73	88.88	8847.84	1200	6.42
	Lactation (2-5)	11882.07	1272.95	174.57	4079.6	181.85	17591.05	63.63	85.42	9561.79		
	Lactation (>5)	16838.11	1803.9	247.39	11394.56	257.7	30541.67	48.46	55.48	8212.46		
	Overall	12543.09	1343.76	184.28	6343.12	191.96	20606.24	61.73	75.77	9638.93		
Local	**Lactation (<2)**	2738.92	521.7	83.47	5000	86.95	8431.0	82.61	75.01	5223.63	1200	3.24
	Lactation (2-5)	4542.3	865.2	138.43	2399.4	144.2	8089.5	71.16	86.66	4988.95		
	Lactation (>5)	7235.55	1378.2	220.51	11292.8	229.7	20356.76	54.06	29.41	3236.72		
	Overall	4838.92	921.7	147.47	6230.73	153.61	12292.42	67.86	58.33	4865.95		
Buffalo	**Lactation (<2)**	1097.25	356.25	68.4	504	71.25	2097.15	85.75	109.85	1975.60	1200	1.53
	Lactation (2-5)	1422.19	461.75	88.65	662.58	92.35	2727.52	81.53	91.81	2041.62		
	Lactation (>5)	1631.63	529.75	101.71	2362.32	105.95	4731.36	78.81	67.18	2505.27		
	Overall	1383.69	449.25	86.25	1176.3	89.85	3185.34	81.62	88.35	2297.24		

From the Table 60, the maximum reduction in mean value of milk yield per animal annually across the different categories of species of cross bred cattle (59.04%) of Rs. 12591.37±495.22) followed by indigenous cattle (44.48%) of Rs. 5076.48±399.01 and buffaloes (38.29%) Rs. 1485.29±71.18 per animal annually. Between the different ACZ's of Punjab, milk yield loss in cross bred cattle ranged between Rs. 10,941.18 to Rs. 14,500.03 in Zone IV and Zone III respectively. In indigenous cattle, it ranged between Rs. 4139.09 to Rs. 6942.07 in Zones IV & III respectively. However, in case of buffaloes, it ranged between Rs. 1201.45 to Rs. 1707.60 in Zone IV to Zone II, respectively. Since milk loss was considered during the whole lactation period, hence its impact was highest among the various categories of losses in cross bred cattle followed by indigenous cattle and buffaloes. Similar findings were agreed with previous studies of milk loss upto 70-85% by DeGraves *et al* (1993), Hortet and Seegers (1998) and Bhikane and Kawitkar (2000). Seegers *et al* (2003) reported that reduction in milk production was the major economic loss caused by Mastitis and the largest portion of total costs, contributing $135.68± 44.24 (Rs 8819.2±2875.6) in Primiparous cows and $137.88 ± 39.94 (8962.2±2596.1) in multiparous cows. Sinha *et al* (2014) reported that the yield losses (49%) due to Mastitis were estimated to be Rs 1390 per lactation. Kvapilík *et al* (2015) reported almost the similar results from the sale of milk (53%).

Few studies contradicted to our findings for estimation of milk loss due to Mastitis in dairy animals by Rollin *et al* (2015) estimated the Future milk production loss of $125 (Rs 8125) was a substantial fraction of the economic impact of CM of 28% of total cost per case. Juliana *et al* (2017) estimated the reduction in milk production 32.3% due to clinical Mastitis. Previous studies estimated milk production loss as a consequence of CM only during the illness period, but in our study, we estimated it during the whole lactation including both short term effects during illness period and the long term effects on milk production loss as the future expected loss.

4.2.3.2.2. Treatment cost

The total mean value of treatment cost per animal per year (Table 60) incurred by dairy farmers to treat affected animals due to clinical Mastitis constitutes the third major cost in cross bred cattle (6.32%) of Rs. 1348.95±53.04 ranged between Rs.1172.2 (Zone IV) to Rs. 1553.4 (Zone III). In case of indigenous cattle, treatment loss constitutes (8.47%) Rs. 966.95±76.0 and ranged between Rs. 788.4 (Zone IV) to

Rs 1322.3 (Zone III). Further, treatment cost in buffaloes constitutes (12.43%) Rs. 483.31±23.11 and ranged between Rs. 390.08 (Zone IV) to Rs. 554.41(Zone II).

The treatment cost of clinical cases was an important element in the expenditure due to Mastitis. Its total contribution varied among the species from 6.32-12.43% and was highest in cross bred cattle followed by indigenous cattle and buffaloes. The difference was due to variation in the number of illness days, stage of Mastitis, incidence rate, medication charges etc. Similar results were agreed by Bhikane & Kawitkar (2000) economic losses associated due to veterinary service were upto 7% and Liang *et al* (2013) estimated $77.13 ± 32.58 (Rs 5013.45±2117.7) per case. Kvapilík *et al* (2015) reported costs for drugs and cow cure (14%). Jingar *et al* 2017 reported the total average treatment cost in 4th parity (Rs. 470.52) and less in 2nd parity (Rs. 250.00).

Our study contradicts the economic assessment by Heikkila *et al* (2012), in which veterinary service and drugs represent 24% to 31% of the cost of CM and Sinha *et al* (2014) estimated the cost of treating an animal to be Rs 509 which includes the cost of medicine (31.10%) and services (5.47%). Because the percentage of milk loss and replacement cost corresponds to the maximum percentage loss in terms of monetary loss in our study but and in these findings, treatment charges were calculated only during the illness period.

4.2.3.2.3. Extra labor engagement cost

From Table 60, the overall mean value of additional labour per animal per year on the basis average daily wage rate (Rs.330) was assumed to spend almost two hours per day to nurse affected animal during the disease condition. It was found highest in cross bred animals (0.86%) costs Rs.184.99 ± 7.27 ranged from Rs 160.74 (Zone IV) to Rs 213.04 (Zone III) followed by indigenous cattle (1.35%) of Rs 154.70 ± 12.16 ranged from Rs.126.13 (Zone IV to Rs. 211.56 (Zone III) and buffaloes (2.38%) with overall mean loss of Rs.92.60±4.43 ranged from Rs.74.89 (Zone IV to Rs. 106.44 (Zone II). The differences in additional labor cost incurred in different Zones and categories were due to differences in duration of illness, recovery period, variation in the wage rate.

Table 60: Components of annual economic losses per animal due to Mastitis of dairy animals in different ACZ's of Punjab.

	Agro-climatic Zones	Losses (component-wise) (Rs.)					Total loss /animal/year (Rs.)
		Milk yield loss	Veterinary charges	Labour charges	Replacement cost	Misc. charges	
Cross bred cattle	I	11761.2	1260	172.8	7253.467	180	20627.47
	II	13133.34	1407	192.9533	6774.907	201	21709.21
	III	14500.03	1553.4	213.04	5084.587	221.92	21572.99
	IV	10941.18	1172.2	160.748	9264.533	167.45	21706.07
	V	12669.42	1357.3	186.144	7312.187	193.9	21718.96
	VI	12543.1	1343.8	184.286	6343.12	191.97	20606.24
	Mean± S.E	12591.37± 495.22	1348.95± 53.04	184.99± 7.27	7005.46± 560.96	192.70± 7.57	21323.49± 224.55
% Contribution		59.04	6.32	0.86	32.85	0.90	
Indigenous cattle	I	4721.323	899.3	143.8853	4250	149.8833	8747.73
	II	4610.022	878.1	140.492	4691.2	146.35	10466.17
	III	6942.07	1322.3	211.5667	4618	220.3833	11774.99
	IV	4139.097	788.4	126.1393	4323.4	131.4	9508.44
	V	5207.473	991.9	158.7007	6199.7	165.3167	10656.5
	VI	4838.923	921.7	147.47	6230.733	153.6167	12292.42
	Mean± S.E	5076.48± 399.01	966.95± 76.00	154.70± 12.16	5052.172± 374.13	161.15± 12.66	10574.37± 544.19
% Contribution		44.48	8.47	1.35	44.27	1.41	
Buffaloes	I	1523.573	494.6667	94.97467	1347.87	98.93333	3560.018
	II	1707.603	554.4167	106.4433	1178.43	110.8833	3657.777
	III	1582.093	513.6667	98.62	1683.15	102.7333	3980.263
	IV	1201.457	390.0833	74.896	2986.26	78.01667	4730.71
	V	1514.847	491.8333	94.43	1963.95	98.36667	4163.427
	VI	1383.69	449.25	86.25333	1176.3	89.85	3185.343
	Mean± S.E	1485.54± 71.18	482.31± 23.11	92.60± 4.43	1722.66± 282.34	96.46± 4.62	3879.58± 219.72
% Contribution		38.29	12.43	2.38	44.40	2.48	

Table 61: Annual economic losses per animal due to Mastitis of dairy animals in different ACZ's of Punjab.

Per animal per year	Category	Agro-climatic zones of Punjab						
		I	II	III	IV	V	VI	Mean ±SE
Annual loss (Rs.)	Cross Bred Cattle	20627.46	21709.21	21572.99	21706.06	21718.95	20606.24	21323.48^{c} ± 224.55
	Indigenous cattle	8747.72	10466.17	11774.98	9508.44	10656.5	12292.42	10574.37^{b} ± 544.19
	Buffalo	3560.01	3657.77	3980.263	4730.71	4163.42	3185.34	3879.58^{a} ± 219.728
	Overall	10978.39±5051.61	11944.38±5263.15	12442.74±5089.54	11981.73±5053.99	12179.62±5124.74	12028.0±5030.71	12028.0±5030.71
Total benefits perceived by farmers controlling Anestrus (Rs.)	Cross Bred Cattle	9502.13	10063.19	9842.04	9286.14	7968.53	9638.93	9383.49^{b} ± 303.48
	Indigenous cattle	3873.44	5483.95	5191.62	5253.77	4899.86	4865.95	4928.09^{ab} ± 231.04
	Buffalo	2346.88	2439.47	2449.30	2916.86	2262.565	2297.24	2452.05^{a} ± 97.83
	Overall	5240.81±2175.75	5995.53±2215.59	5827.65±2157.66	5818.92±1860.24	5043.65±1648.73	5600.70±2150.96	5587.88 ±389.1

Different lowercase superscripts (a,b,…) indicate significant ($p<0.05$) difference.

The estimation of the labour charges per case was variable and relied upon various factors, such as the type of Mastitis, milk yield, farm size, hired labour and farm owner. Few studies contradict our findings due to cheap availability of labour force in India and its value was estimated only during the illness period. Seegers *et al* (2003) reported increased labor 2% of the total loss. Liang *et al* (2013) agreed to our study with the cost of labour was $12.13 ± 6.18 (788.45±401.7) per case. Kvapilík *et al* (2015) reported that labour cost during treatment of ill cows (7%) and costs between 19 and 34 € (Rs 1458.44 and 2609.84).

4.2.3.2.4. Replacement cost of culled animals

From Table 60, the replacement cost of animals culled due to the occurrence of recurrent Mastitis or chronic Mastitis (especially the older animals greater than 5th lactation) contributes the second major percentage loss among the cattle population viz. crossbred (32.85%) & indigenous cattle (44.27%) and third major loss (44.40%) due to Mastitis in buffaloes. The total mean value per animal per year due to the replacement of culled animals was highest in cross bred animals Rs. 7005.46±560.96 ranged between Rs. 5084.58 (Zone III) to Rs. 9264.53 (Zone IV), followed by indigenous cattle Rs. 5052.17±374.13 ranges between Rs. 4250 (Zone I) to Rs. 6230.73 (Zone VI) and buffaloes of Rs.1722.66 ±282.34 ranges between Rs. 1176.3 (Zone VI) to Rs. 2986.26 (Zone IV) in different ACZ's of Punjab.

The replacement cost of affected animals was calculated based on the average number of quarters affected, depreciation value of animal and age of the lactating animal. Since the animals were culled due to their risk of transmission of contagious pathogens to herd mates (Down *et al* 2013) and their lower productivity. The premature culling of potentially profitable cows due to chronic Mastitis is also a significant loss. Few previous studies which agreed to our findings were: Mustafa (2003) confirms his opinion that only 6 – 8% herds of cows show chronic Mastitis from 40 to 50% of all clinical Mastitis. A similar view was observed from the calculation of Leslie (1995), Jones and Bailey (2009), Hogeveen *et al* (2011), Schroeder (2012), Down *et al* (2013) and Kitschen (2013). Rollin *et al* (2015) calculated the cost of premature culling and replacement of chronic animals represents the maximum proportion (41%) of all categories of total costs of $182 (Rs 11830). Juliana *et al* (2017) estimated cow culling costs in clinical Mastitis of 39.4% of the total loss.

However, few studies didn't agree to our findings like Bhikane and Kawitkar (2000) that economic losses associated due to premature culling was upto 14% and Kvapilík *et al* (2015) reported higher culling (21%) of cows 1800 CzC (Rs 5292). Because our study was based on all the different categories of animals and we estimate its value from the depreciation of animal value as per their parity of their market value and secondly, the beef ban in India depreciate their salvage value of affected animal of chronic Mastitis.

4.2.3.2.5. Miscellaneous Cost

From the Table 60, the overall mean value per animal per year of miscellaneous charges in cross bred cattle was Rs. 192.70 ±7.57 and ranged between Rs. 167.45 (Zone IV) to Rs. 221.92 (Zone III). In indigenous cattle with the total mean value per animal per year of Rs. 161.15 ±12.66 ranged between Rs 131.4 (Zone IV) to Rs 220.38 (Zone III). However, in buffaloes, the total mean value of miscellaneous charges was Rs. 96.46±5.13/animal/year, ranged from Rs. 78.01 (Zone IV) to Rs. 110.88 (Zone II). It was observed that highest loss was found in cross bred cattle (0.90%) followed by indigenous cattle (1.41%) and buffaloes (2.48%). Variation among the different ACZ's were due to the difference in herd size, transportation cost and occurrence of Mastitis across the different Zones and categories of animals. Since affected animals in the study couldn't move longer distances, hence they had to carry in load carriers to veterinary clinics for diagnostic investigation. Sometimes they call veterinarians to visit their farm for treatment of their affected animals.

Among the different components of economic losses due to Mastitis of dairy animals in Punjab, it may be concluded that in dairy cattle highest losses were from the reduction in milk yield (Fig 15) followed by replacement cost of culled animals, treatment charges, miscllaneous charges and labour expenses during the veterinary intervention. However, in buffaloes, highest losses were from the replacement of culled animals followed by reduction in milk yield, treatment charges and labour expenses.

4.2.3.3. Total economic losses of dairy animals due to Mastitis in different ACZ's of Punjab

From the Table 61, the overall mean economic losses per animal per year of Rs.12028 affected due to Mastitis at species level of different categories were

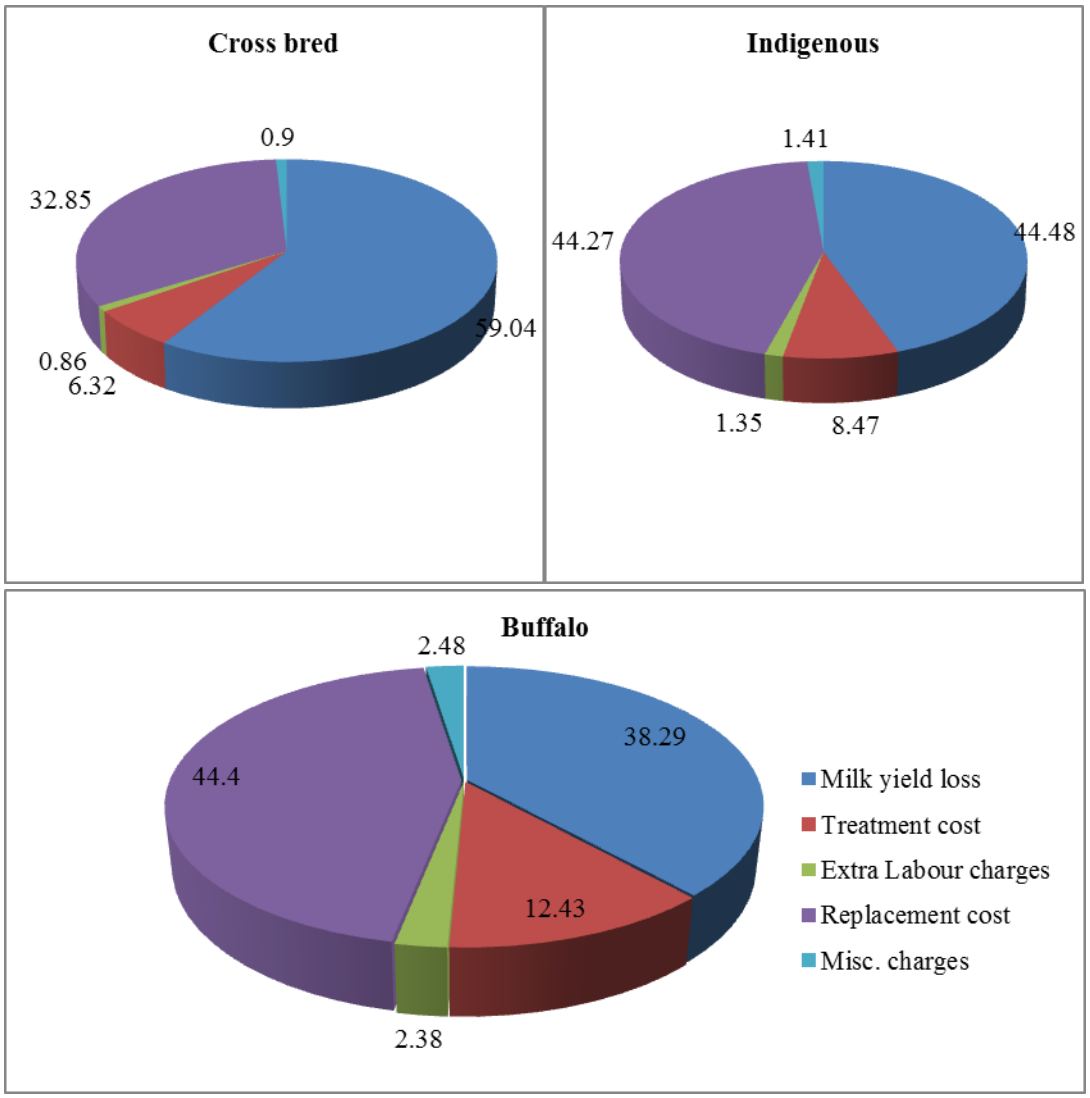


Fig. 15: Proportion of different component losses (%) – Mastitis

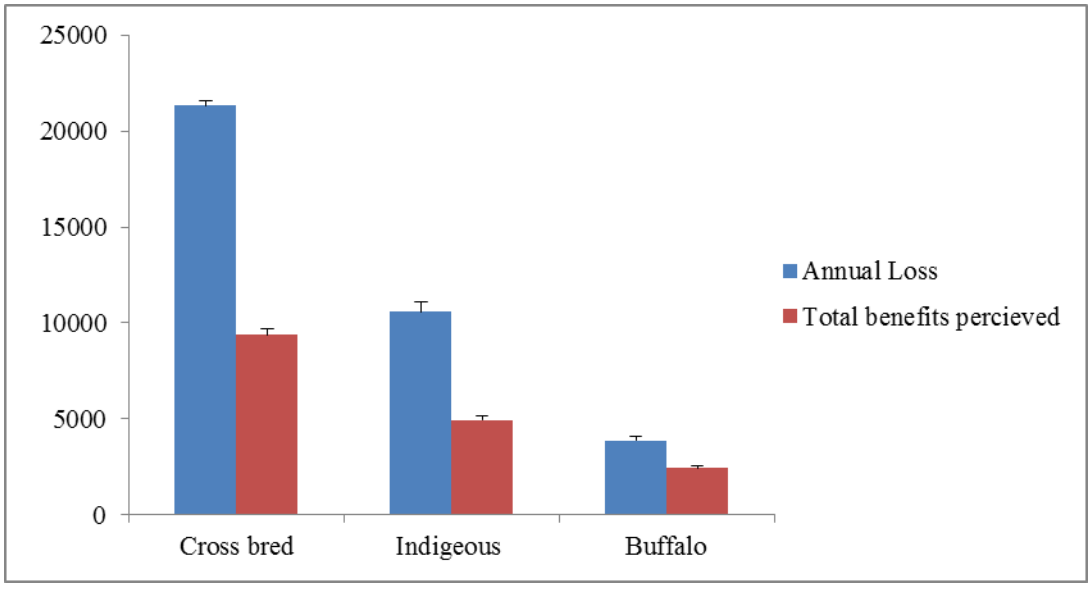


Fig. 16: Mastitis Economic Losses vs Total Benefits perceived per animal per year

statistically significant (F=588.39; p<0.01) but non-significant between the different ACZ's (F=0.028; p>0.05). The total mean economic losses per animal per year in crossbred cattle, indigenous cattle and buffaloes were Rs. 21323.48±224.55, Rs. 10574.37±544.19 and Rs. 3879.58±219.72 respectively. Maximum losses were skewed towards cross bred animals, followed by indigenous cattle and buffaloes due to the higher prevalence and maximum loss in milk yield during the whole lactation. From the post hoc test between the different ACZ's, the overall mean values per animal per year were not significant (p>0.05) with maximum loss observed in Zone III (Rs. 12442.74±5089.54) and lowest in Zone I (Rs. 10978.39±5051.61). Because in Zone III, due to higher prevalence of Mastitis and farmers unawareness about the preventive measure and returns forgone to their income. In cross bred cattle, between the different ACZ's, highest loss per animal per year were observed in Zone V (Rs. 21718.95) and lowest in Zone VI (Rs. 20606.24). Maximum loss per animal per year in indigenous cattle was found in Zone VI (Rs.12292.42) and lowest in Zone I (Rs. 8747.72). Further, the maximum loss per animal per year in buffaloes was noticed in Zone IV (Rs. 4730.71) and minimum in Zone VI (Rs. 3185.34).

The economic impact was simulated for clinical Mastitis and was estimated as the total losses plus the expenses for the prevention and treatment of clinical cases. Losses due to Mastitis were calculated based on the long term effects of Mastitis during the whole lactation period and the expected loss that farmers underestimated at the field level. In India, Project Directorate on Cattle (PDC) Meerut, (2012) estimated the economic losses due to Mastitis Rs. 16,702 million and PDADMAS (2011) reported for cows (Rs 3649.56 crores) and buffaloes (Rs 3515.95 crores). Few more studies estimated the losses due to Mastitis in India viz. Bansal and Gupta (2009) estimated Rs 71,655 million; Varshney and Naresh (2004) estimated about 526 million dollars of which 70 percent are due to subclinical Mastitis; Dua (2001) estimated the losses amounting to Rs. 6053.21 crore with Rs. 4365.32 crore (70-80%) due to sub clinical Mastitis.

Several similar findings were calculated by Steeneveld *et al* (2008), Bar *et al* (2008), and Huijps *et al* (2008) assessed that the cost per case of Mastitis ranged between €71 (Rs. 5385.35) and €519 (Rs. 39366.15). Rollin *et al* (2015) estimated the average case of clinical Mastitis resulted in a total economic cost of $444 (Rs 28860). Kvapilík *et al* (2015) reported the total costs of clinical Mastitis 9000 CzC (Rs.

26,730). Van Soest *et al* (2016) estimated the total costs of Mastitis to be €240/lactating cow per year (Rs 18204).

Among the different species (Fig 16), economic losses due to Mastitis were higher in cross bred cattle followed by indigenous cattle and buffalo with the exception of few studies which contradict to our findings like Jingar *et al* (2017) estimated the total loss in indigenous Sahiwal and Tharparkar cows was more (Rs 1695.00) in this study than the crossbred (Rs 1597.64) cows and Murrah buffaloes (Rs 1498.44). Sinha *et al* (2014) estimated Rs 1390 of which loss due to Mastitis in cattle and buffaloes was Rs.1592.87 and Rs 892.42 per lactation, respectively. Singh *et al* (2014) estimated the economic loss per animal per lactation to be Rs 2182.44 and Rs 1272.36 for cattle and buffaloes respectively. Another study by John (2014) estimated the direct losses due to clinical Mastitis in cows to be Rs. 2086.96 per clinical case. The higher proportion of total loss from our findings includes the reduction in milk yield throughout the whole lactation period, replacement of culled animals, extra labour charges which above studies hadn't taken into consideration.

The mean economic losses per animal per year affected varied significantly ($p<0.05$) among different categories of animals but not between the different ACZ's of Punjab and was highest in cross bred followed by indigenous cattle and lowest in buffaloes. At species level (Fig 15), the largest component of the economic losses were due to milk loss (59.04% in cross bred, 44.48% in indigenous cattle and 38.29% in buffaloes), followed by treatment cost (32.85% in cross bred, 44.27% in indigenous cattle and 44.40% in buffaloes). Among the different agroclimatic zones, highest losses were observed in Central plain region (12442.74±5089.54) and Western region (12179.62±5124.74). The tool used to evaluate the economic impact of Mastitis at the species level can be applied to the other herds and it should be useful to define priorities in relation to Mastitis control and prevention procedures. The estimated loss in Rupees of each component on the total economic impact of Mastitis at the species level combined with clinical, chronic and subclinical Mastitis indicators can assist in decision-making focused on the economic aspects of the disease and define the priorities in terms of the cost-benefit of the control procedures (Huijps *et al* 2010).

4.2.3.4. Total benefits forgone and benefit cost analysis of controlling Mastitis

From the Table 61, the overall benefits forgone simulated for the dairy farmers controlling Mastitis through various preventive measures of different species of

animals in different ACZ's of Punjab was Rs. 5587.88. From the post hoc test, It varies significantly ($F=238.7168$; $p<0.01$) across the species with highest returns estimated in cross bred cattle Rs 9383.49±303.48, followed by indigenous cattle and buffaloes of Rs. 4928.09±231.04 and 2452.05±97.83 respectively in the ratio of almost 4:2:1. Between the different ACZ's, it did not vary significantly ($F=0.03$; $p>0.05$) and the highest returns forgone was estimated in Zone III (Rs 2215.591± 2215.5) followed by Zone II (Rs. 9200.33±1896.25), while as the lowest returns forgone was simulated in Zone V (5043.65±1648.73) followed by Zone III (8758.11±747.14). From Table (53-58), if the interventions of control measure were taken to check Mastitis at sub clinical level, that may cost Rs. 1200 per animal per year including use of teat dips, wet towels, dry cow and use of other disinfectants. Through this intervention, the maximum benefits were estimated to be observed in the ration of 3:2:1 in cross bred animals followed by indigenous cattle and buffalo respectively. It might be due to higher impact of this disease on cross bred animals and maximum returns were foregone, if such control measure were taken.

From the above foregoings, it can be concluded that return forgone was highest in crossbred cattle due to their heavy returns if managed properly and prevent Mastitis at the gross root level. However, in buffaloes, returns forgone were the least because the losses from them were not too much compared to cattle and secondly due to natural adoptability with better immunity. This indicates that for a large proportion of farms benefits forgone appear highest when the avoidable losses could be more than control losses. Expenditure on Mastitis control can be determined by various control measures viz. educational costs, blanket use of dry-cow therapy, keeping cows standing after milking, milking of an affected animal at the end, pre-milking preparation of the udders, teat disinfection, monitoring measures, and maintenance of the milking machine. The early prevention and treatment of cow Mastitis with respect to the specific conditions of the herd can significantly reduce the production and economic losses associated with the illness. (Kvapilík *et al* 2015). DeGraves and Fetrow (1993) estimated the benefit of $57 (Rs 3705) per cow if the herd is vaccinated, assuming that 1 % of the cows would normally contract coliform Mastitis during the season. According to Kron (2002) calculation, there is an apparent benefit of preventive treatment of cow group against mammary gland inflammation in the amount 136 € (Rs 10350) per cow during the first 100 days of lactation.

In order to provide good support to farmers' decision-making, it was important to describe the Mastitis setting not only in terms of disease but also in monetary terms. To make good decisions, it is necessary to provide the dairy farmer with information on the additional expenditure and reduced losses associated with alternative decisions. Bar *et al* (2008) Relevant estimations about disease costs can be used in evaluating the benefits of applying preventive measurements to decrease disease incidence, disease losses, or both, and in the process allow the evaluation of individual cow disease treatment options. Schroeder (2012) reported about reduced losses from the sale of milk by 136 US$ (Rs 8840) at the costs of preventive measures US$ 24 (Rs 1560). Kvapilík *et al* (2015) reported the reduced losses from the preventive measures are relatively low, varying between € 8 and 36 (Rs 608 to Rs 2736) per cow per year.

The overall benefit forgone for the animals not affected due to Mastitis through various preventive measures was Rs. 5587.88. It varied significantly ($p<0.01$) across the species with highest returns estimated in crossbred cattle followed by indigenous cattle and buffaloes. To estimate the BCA for intervention of control measure like teat dips, use of disfectants for udder wash, early diagnostic tests etc. were assumed to cost Rs 1200 for each category of animals. Through this intervention to control Mastitis, the maximum benefits were estimated to be observed in the ratio of 3:2:1 in cross bred animals followed by indigenous cattle and buffalo respectively.

This study help to present the economic aspects of Mastitis that will help farmers to make management decisions on Mastitis control having a negative impact on the development of the dairy sector within the state. To develop proper prevention and control strategies, it was imperative to know the prevalence and etiology of Mastitis at the earliest. Further, the extensive and indiscriminate use of antibiotics in the treatment and control of Mastitis may lead to the undesirable presence of drug residues in milk and emergence of antibiotic resistant bacteria. But these data or calculations are only useful if the information reaches to the farmers at gross root level.

4.2.4.1. Epidemiological aspect of Repeat Breeding in different ACZ's of Punjab

The distribution of RB observed in dairy animals of different ACZ's of Punjab has been presented in Table 62-67. The impact of RB had overburdened the dairy farming due to various losses associated with it. The overall prevalence of RB

observed was 27.63 percent (Table 70). The prevalence of RB was statistically significant among the herd size ($p<0.01$) and different categories of animals species ($p<0.01$). Between the different ACZ's of Punjab, prevalence of RB varied significantly among the different herds ($p>0.05$) and categories of animals on species basis ($p<0.05$) except in buffaloes ($p<0.10$).

Table 70, illustrates that among the herd sizes, the prevalence rate of RB in small, medium and large were 39.35, 28.97 and 21.78 percent respectively and was statistically significant among the different categories of animals ($\chi^2=186.76$; $p<0.01$). Between the different ACZ's, the prevalence of RB was non-significant ($P>0.05$). Among the small herd group, its prevalence was significant 39.35% ($\chi^2= 17.9$) and ranges between 34.72% (Zone I) to 52.17% (Zone VI). Whereas, among the medium herd size, the prevalence of RB was highly significant between the different Zones 28.97% ($\chi^2= 93.4$; $p<0.01$) and ranges from 21.17% (Zone I) to 44.87% (Zone VI). In case of large herd size, the prevalence of RB was significantly different 21.78% ($\chi^2= 32.8$; $p<0.01$) and ranged between 14.36 to 30.66 percent in Zone II & III, respectively.

Prevalence of RB (Table 70) among the different categories of animals viz. cross bred cattle, indigenous cattle and buffaloes varies significantly ($\chi^2=533.80$; $p<0.01$). The highest prevalence was observed in cross bred cattle (41.77 %), followed by indigenous cattle and buffaloes (32.05 % & 17.59 %) respectively.

Prevalence of RB among the cross bred cattle in different ACZ's of Punjab varied significantly ($\chi^2=20.2$; $p<0.01$) and ranged between 34.48% (Zone II) to 45.40% (Zone VI). Similarly, among the indigenous cattle, it varied significantly ($\chi^2=11.8$; $p<0.05$) and ranged between 20.68% (Zones V) to 38.92% (Zone IV). However, the prevalence of RB in buffaloes didn't varied significantly ($\chi^2=9.83$; $p>0.05$) and ranges between 16.78% (Zone VI) to 23.94% (Zone VI). From the post hoc interaction test, there was no significant interaction among the different ACZ's with each other, but interaction was observed between the different categories of animals.

Table 62: Prevalence and culling rate of Repeat Breeding across herd sizes, species and categories of dairy animals in Zone I of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	311	108	34.72	21	19.44
	Medium	477	101	21.17	34	33.66
	Large	244	41	16.80	19	46.34
	Overall	1032	250	24.22	74	29.6
			χ^2 =28.42*		χ^2 = 11.66**	
Cross Bred	**Lactation (<2)**	91	21	23.07	3	14.28
	Lactation (2-5)	124	47	37.90	9	19.14
	Lactation (>5)	72	35	48.61	15	42.85
	Overall	287	103	35.88	27	26.21
			χ^2 = 11.77**		χ^2 = 7.77**	
Local	**Lactation (<2)**	51	8	15.67	1	12.5
	Lactation (2-5)	78	23	29.48	5	21.73
	Lactation (>5)	38	18	47.36	12	66.66
	Overall	167	49	29.34	18	36.73
			χ^2 = 10.54**		χ^2 = 11.18**	
Buffalo	**Lactation (<2)**	171	16	9.3567	2	12.5
	Lactation (2-5)	272	48	17.64	9	18.75
	Lactation (>5)	135	34	25.18	18	52.94
	Overall	578	98	16.95	29	29.59
			χ^2 = 13.59**		χ^2 = 13.84**	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 63: Prevalence and culling rate of RB across herd sizes, species and categories of dairy animals in Zone II of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	319	114	35.73	34	29.82
	Medium	458	102	22.27	15	14.70
	Large	341	49	14.36	27	55.10
	Overall	1118	265	23.70	76	28.67
			$\chi^2 = 42.48^{**}$		$\chi^2 = 26.53^{**}$	
Cross Bred	**Lactation (<2)**	116	28	24.13	5	17.85
	Lactation (2-5)	154	59	38.31	12	20.33
	Lactation (>5)	78	33	42.30	17	51.51
	Overall	348	120	34.48	34	28.33
			$\chi^2 = 8.60^{**}$		$\chi^2 = 12.10^{**}$	
Local	**Lactation (<2)**	45	5	11.11	1	20
	Lactation (2-5)	71	18	25.35	3	16.66
	Lactation (>5)	42	16	38.09	9	56.25
	Overall	158	39	24.68	13	33.333
			$\chi^2 = 8.53^{**}$		$\chi^2 = 6.43^{**}$	
Buffalo	**Lactation(<2)**	165	14	8.48	3	21.42
	Lactation (2-5)	316	57	18.03	8	14.03
	Lactation (>5)	131	35	26.71	18	51.42
	Overall	612	106	17.32	29	27.35
			$\chi^2 = 17.18^{**}$		$\chi^2 = 15.54^{**}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 64: Prevalence and culling rate of Repeat Breeding across herd sizes, species and categories of dairy animals in Zone III of Punjab.

	Category	Total animals	Affected animals	Prevalence Rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	312	131	41.98	9	6.870
	Medium	363	96	26.44	12	12.5
	Large	375	115	30.66	38	33.04
	Overall	1050	342	32.57	59	17.25
			χ^2 =19.41**		χ^2 = 31.49**	
Cross Bred	**Lactation (<2)**	157	48	30.57	4	8.33
	Lactation (2-5)	279	124	44.44	12	9.67
	Lactation (>5)	151	71	47.01	16	22.53
	Overall	587	243	41.39	32	13.16
			χ^2 = 10.04**		χ^2 = 7.75**	
Local	**Lactation (<2)**	16	6	37.5	1	16.66
	Lactation (2-5)	37	13	35.13	1	7.69
	Lactation (>5)	19	9	47.36	3	33.33
	Overall	72	28	38.88	5	17.85
			χ^2 = 0.80 ns		χ^2 = 2.39 ns	
Buffalo	**Lactation (<2)**	123	16	13.00	3	18.75
	Lactation (2-5)	176	31	17.61	6	19.35
	Lactation (>5)	92	24	26.08	13	54.16
	Overall	391	71	18.15	22	30.98
			χ^2 = 6.12**		χ^2 = 9.11**	

**(p<0.01) and **(p<0.05) indicate significant difference; ns(p>0.05) indicate no significant difference.*

Table 65: Prevalence and culling rate of Repeat Breeding across herd sizes, species and categories of dairy animals in Zone IV of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	311	114	36.65	16	14.03
	Medium	477	128	26.83	27	21.09
	Large	244	51	20.90	21	41.17
	Overall	1032	293	28.39	64	21.84
			$\chi^2 = 17.74^{**}$		$\chi^2 = 15.27^{**}$	
Cross Bred	**Lactation (<2)**	91	37	40.65	4	10.8
	Lactation (2-5)	124	54	43.54	10	18.51
	Lactation (>5)	72	35	48.61	19	54.28
	Overall	287	126	43.90	29	23.01
			$\chi^2 = 6.73^{**}$		$\chi^2 = 20.46^{**}$	
Local	**Lactation (<2)**	51	18	35.29	2	11.11
	Lactation (2-5)	78	30	38.46	4	13.33
	Lactation (>5)	38	17	44.73	8	47.05
	Overall	167	65	38.92	14	21.53
			$\chi^2 = 0.82^{ns}$		$\chi^2 = 8.90^{**}$	
Buffalo	**Lactation (<2)**	171	22	12.86	1	4
	Lactation (2-5)	272	42	15.44	8	16.66
	Lactation (>5)	135	38	28.14	12	41.37
	Overall	578	102	17.64	21	20.58
			$\chi^2 = 23.38^{**}$		$\chi^2 = 12.32^{**}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 66: Prevalence and culling rate of Repeat Breeding across herd sizes, species and categories of dairy animals in Zone V of Punjab.

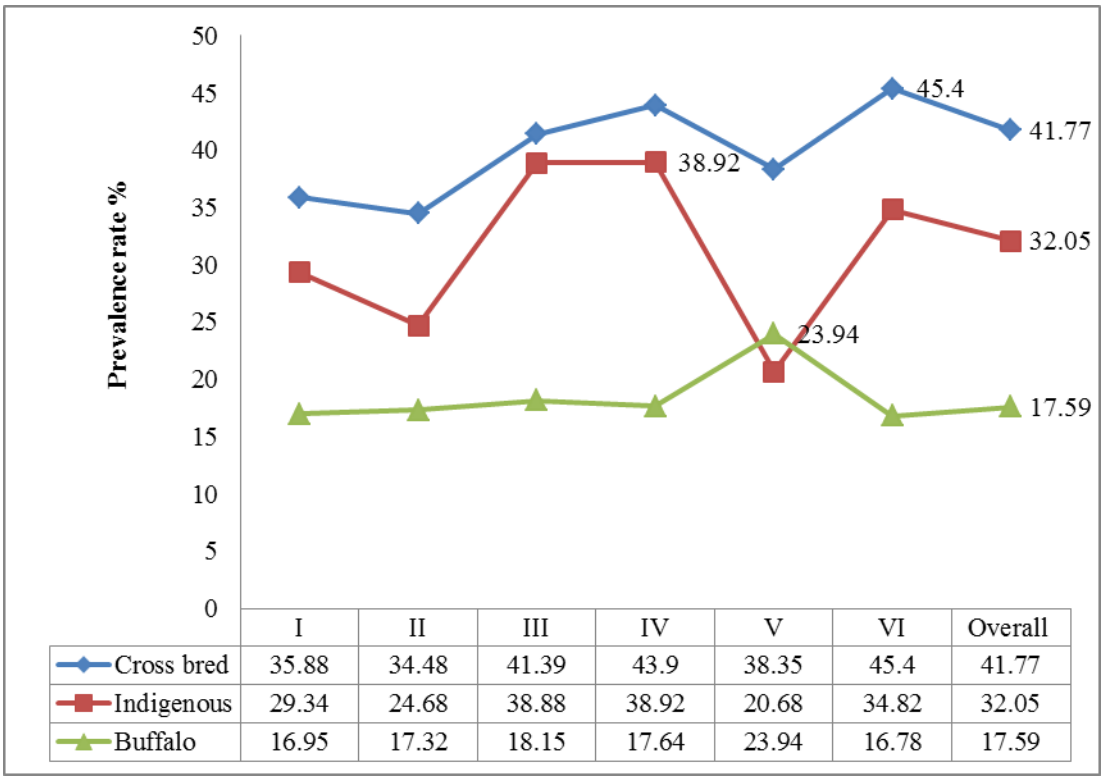
	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	281	116	41.28	23	19.82
	Medium	223	65	29.14	24	36.92
	Large	53	11	20.75	6	54.54
	Overall	557	194	34.47	53	27.60
			$\chi^2 = 12.98^{**}$		$\chi^2 = 10.33^{**}$	
Cross Bred	**Lactation (<2)**	31	6	19.35484	1	16.66
	Lactation (2-5)	130	50	38.46154	14	28
	Lactation (>5)	58	28	48.27586	13	46.42
	Overall	219	84	38.35616	28	33.33
			$\chi^2 = 7.14^{**}$		$\chi^2 = 12.08^{**}$	
Local	**Lactation (<2)**	6	1	16.6666	1	100
	Lactation (2-5)	14	3	14.2857	1	25
	Lactation (>5)	9	3	33.3333	1	33.33333
	Overall	29	6	20.6896	3	37.5
			$\chi^2 = 0.51^{ns}$		$\chi^2 = 0.05^{ns}$	
Buffalo	**Lactation (<2)**	72	13	18.05	2	15.38
	Lactation (2-5)	129	32	24.80	5	15.62
	Lactation (>5)	108	29	26.85	15	51.72
	Overall	309	74	23.94	22	29.72
			$\chi^2 = 1.92^{ns}$		$\chi^2 = 11.04^{**}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 67: Prevalence and culling rate of Repeat Breeding across herd sizes, species and categories of dairy animals in Zone VI of Punjab.

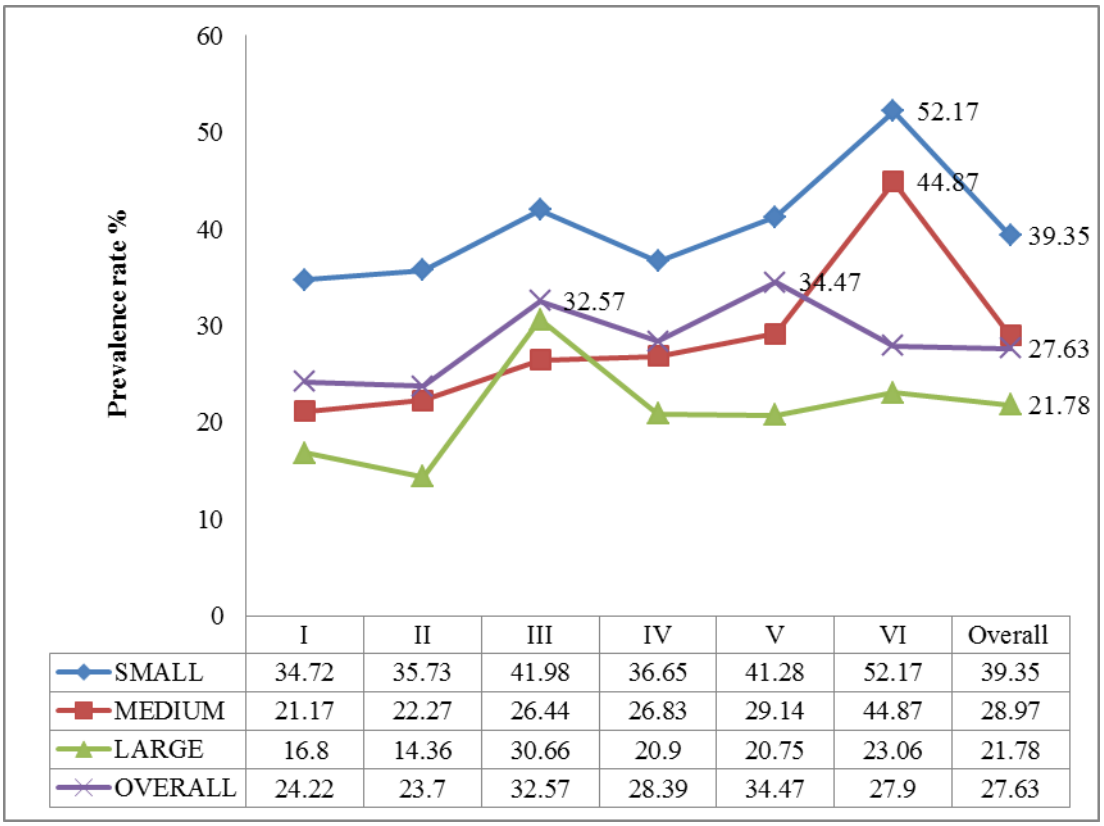
	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	161	84	52.17	11	13.09
	Medium	546	245	44.87	41	16.73
	Large	2723	628	23.06	124	19.74
	Overall	3430	957	27.90	176	18.39
			$\chi^2 = 157.02^{**}$		$\chi^2 = 1.77^{ns}$	
Cross Bred	**Lactation (<2)**	264	98	42.42	4	4.08
	Lactation (2-5)	679	316	44.46	22	6.96
	Lactation (>5)	319	159	49.84	27	16.98
	Overall	1262	573	45.40	53	9.24
			$\chi^2 = 10.19^{**}$		$\chi^2 = 16.41^{**}$	
Local	**Lactation (<2)**	23	6	26.08	0	0
	Lactation (2-5)	52	18	34.61	1	5.55
	Lactation (>5)	37	15	40.54	4	26.66
	Overall	112	39	34.82	5	12.82
			$\chi^2 = 1.30^{ns}$		$\chi^2 = 2.86^{ns}$	
Buffalo	**Lactation (<2)**	498	58	11.64	5	8.6
	Lactation (2-5)	1256	211	16.79	27	12.79
	Lactation (>5)	302	76	25.16	23	30.26
	Overall	2056	345	16.78	55	15.94
			$\chi^2 = 24.60^{**}$		$\chi^2 = 15.92^{**}$	

$^{*}(p<0.01)$ and ** $(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.



	I	II	III	IV	V	VI	Overall
Cross bred	35.88	34.48	41.39	43.9	38.35	45.4	41.77
Indigenous	29.34	24.68	38.88	38.92	20.68	34.82	32.05
Buffalo	16.95	17.32	18.15	17.64	23.94	16.78	17.59

Fig. 17: Prevalence of Repeat Breeding on Species basis



	I	II	III	IV	V	VI	Overall
SMALL	34.72	35.73	41.98	36.65	41.28	52.17	39.35
MEDIUM	21.17	22.27	26.44	26.83	29.14	44.87	28.97
LARGE	16.8	14.36	30.66	20.9	20.75	23.06	21.78
OVERALL	24.22	23.7	32.57	28.39	34.47	27.9	27.63

Fig. 18: Prevalence of Repeat Breeding on Herd basis

Table 70: Prevalence of Repeat Breeding on species basis and herd basis of dairy animals in different ACZ's of Punjab.

Prevalence (%)	Category	Agro-climatic zones of Punjab									
		I	II	III	IV	V	VI	χ^2 value	Total Animals	Affected Animals	Prevalence (%)
Species basis	Cross- bred Cattle	35.88	34.48	41.39	43.90	38.35	45.40	20.2^{**}	2990	1249	41.77
	Indigenous cattle	29.34	24.68	38.88	38.92	20.68	34.82	11.8^{*}	705	226	32.05
	Buffalo	16.95	17.32	18.15	17.64	23.94	16.78	9.83^{ns}	4524	796	17.59
									Overall χ^2 Value= 533.80^{**}		
Herd size basis	Small	34.72	35.73	41.98	36.65	41.28	52.17	17.9^{**}	1695	667	39.35
	Medium	21.17	22.27	26.44	26.83	29.14	44.87	93.4^{**}	2544	737	28.97
	Large	16.80	14.36	30.66	20.90	20.75	23.06	32.8^{**}	3980	867	21.78
	Overall	24.22^{**}	23.70^{**}	32.57^{**}	28.39^{**}	34.47^{**}	27.90^{**}	40.1^{**}	8219	2271	27.63
									Overall χ^2 Value= 186.76^{**}		

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

From the Table 70, it is clear that prevalence of RB was observed highest in high yielder cross bred animals, followed by indigenous cattle and buffaloes because the high-producing Holstein cows and cross bred cows were mainly reared for higher milk production but have reduced fertility (Butler 2000) because of intensive selection for high yields (Dobson *et al* 2007 and Roy and Prakash 2007) and facing negative energy balance due to high milk yield, causes of the RB mainly include pathological endometritis (Sheldon *et al* 2009), nutritional deficiency, specially trace minerals and vitamin A, age of the dam, improper heat detection and endocrine dysfunction (Ahmed 2009) and uncomfortable condition were risk factors for several reproductive disorders, which in turn delayed insemination and conception in dairy cows Grohn *et al* (2000). Present study is supported from the study of Patel *et al* (2007) and Purohit *et al* (2008) that the incidence of RB is lower in buffaloes compared to cattle and contradicts with the study of Sharma and Karwani (2003) that RB was higher in indigenous cattle Sahiwal (21.67%) than cross bred HF cattle (14.28%) due to use of Sahiwal as breeding programmes using frozen semen which on thawing has lower motility. Marai *et al* (1992) reported that Repeat breeder buffaloes in the lactation herd revealed that lactating animals with high milk production required higher number of services per conception than non-lactating and low producing buffaloes.

Among the Zones, the most affected Zone was Zone V (34.47%) & III (32.57%) and least affected Zone was Zone II (23.70%), because the animals reared were mainly cross bred animals with small herd units with little awareness about the animals health and breeding management and however in Zone II the animals reared were mainly buffaloes having lower prevalence compared to cows in this region. Among the herd size, small herd was affected highest followed by medium and large herd groups. Compared to cattle, buffalo shows lower incidence of RB because buffaloes are well adopted to their natural habitat and have lower production capacity compared to cross bred animals, however they shows reproductive inefficacy because of silent heat during summer season, unable to detect estrous during night hours and fertility problems in them are often not easily recognized due to seasonal suppression of fertility during hot summer months (Azawi *et al* 2008).

Different previous studies had reported the incidence of RB of dairy animals in Punjab viz. Kodagali (1968) reported 10.11% incidence in buffaloes. Bhosrekar (1973) reported in Sahiwal breed of cattle 18.1–24.4%; Bansal *et al* (1978) reported (10.76%) in buffalo breeds of Nilli Ravi and Murrah and Sharma and Karwani (2003) reported the

incidence of RB in cattle and buffaloes (19.61% and 15.63% respectively); Singh *et al* (2003) reported incidence of RB in cattle (12.30 to 18.20%); Singh *et al* (2003) reported the prevalence (12.20%) in buffaloes and Kaur *et al* (2011) reported the incidence of RB in cattle and buffalo as 11.67 and 11.04 percent respectively in central Zone of Punjab. Kumar *et al* (2011) reported the incidence of RB of buffaloes in commercial dairy farms was found 8.82%. Our study coincide from the study of Saxena (2004) that the incidence of RB in India ranges from 5.5 to 33.33% in cattle and from 6 to 30 % in buffaloes. Gupta and Deopurkar (2005) reported the incidence of RB 5-32% in cows and 6-30% in buffaloes.

The overall incidence of RB among dairy animals was 27.63 percent. Incidence of RB on the species basis varied significantly (χ^2=533.80; $p<0.05$) and was observed highest in cross bred (41.77%), followed by indigenous cattle (32.05%) and least in buffalo (17.59%). From the Fig 17, the incidence of RB among the different ACZ's of Punjab in cross bred cattle varied significantly ($p<0.05$) and ranged from 34.48% (Zone II) to 45.40% (Zone VI). Similarly, the incidence of RB among the different ACZ's of Punjab in indigenous cattle varied significantly ($p<0.05$) and ranged from 20.68% (Zone V) to 38.90% (Zone IV), whereas no difference was found within different ACZ's in case of buffalo. Within different herd sizes (Fig 18), the incidence of RB varied significantly (χ^2=186.76; $p<0.05$) and was highest in small herd size (39.35%) followed by medium (28.97%) and lowest in large herd size (21.78%). Orthogonal comparisons revealed that the incidence of RB varied respect to different ACZ in each herd size and also with respect to species of animal in all ACZ's.

4.2.4.2. Economic losses due to Repeat Breeding

Various losses were associated due to RB including both visible and invisible costs. The visible cost due to RB perceived by the dairy farmer viz. veterinary expenses (including treatment cost, veterinarian charges and cost of AI), extra feeding cost, extra labour charges and miscellaneous cost while as invisible cost include reduction in milk yield during the open days, depreciation value of animal, expected calf loss, replacement cost perceived indirectly by farmers, presented in Table (68-69).

Table 68: Economic losses and BCA due to Anestrus of dairy animals in Zone I, II and III of Punjab.

Category	Expected Milk yield loss (Rs.)	Extra feeding cost (Rs)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Future calf reduction (Rs)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Recovered animals after Treatment coverage (%)	Total benefits per year (Rs)	Total cost of control (Rs)	BCA
Zone I													
Cross Bred	7147.29	3918.09	538.23	114.81	10484	502.32	107.64	22812.37	64.12	73.78	10792.01	2000	5.39
Local	4295.37	2957.47	440.17	93.88	9182.5	410.76	88.02	17468.12	70.66	63.26	7808.16	2000	3.90
Buffalo	2481.48	1708.56	254.28	54.24	8877	237.3	50.85	13663.68	83.05	70.4	7988.77	2000	3.99
Zone II													
Cross Bred	6868.41	3765.21	517.2	110.336	11332	482.72	103.44	23179.33	65.52	71.66	10883.07	2000	5.44
Local	3613.15	2487.74	370.2	78.976	8333.25	345.52	74.04	15302.88	75.32	66.66	7683.31	2000	3.84
Buffalo	2535.64	1745.85	259.8	55.424	8205	242.48	51.96	13096.17	82.68	72.26	7824.24	2000	3.91
Zone III													
Cross Bred	6868.41	3765.21	517.2	110.336	11332	482.72	103.44	23179.33	65.52	71.66	10883.07	2000	5.44
Local	3613.15	2487.74	370.2	78.976	8333.25	345.52	74.04	15302.88	75.32	66.66	7683.31	2000	3.84
Buffalo	2535.64	1745.85	259.8	55.424	8205	242.48	51.96	13096.17	82.68	72.26	7824.24	2000	3.91

Table 69: Economic losses due to Anestrus and BCA of dairy animals in Zone IV, V and VI of Punjab.

Category	Expected Milk yield loss (Rs.)	Extra feeding cost (Rs)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Future calf reduction (Rs)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Recovered animals after Treatment coverage (%)	Total benefits per year (Rs)	Total cost of control (Rs)	BCA
Zone IV													
Cross Bred	8744.88	4793.88	658.5	140.48	9204	614.6	131.7	24288.04	56.09	76.98	10487.11	2000	5.24
Local	5697.88	3923.13	583.8	124.54	5382.5	544.88	116.76	16373.51	61.07	78.46	7845.45	2000	3.92
Buffalo	2582.49	1778.11	264.6	56.44	6174	246.96	52.92	11155.54	82.35	79.41	7295.06	2000	3.64
Zone V													
Cross Bred	7640.54	4188.49	575.34	122.73	13332	536.98	115.06	26511.18	61.64	66.66	10893.24	2000	5.44
Local	3028.95	2085.51	310.34	66.20	9375	289.65	62.06	15217.74	72.41	83.35	9184.47	2000	4.59
Buffalo	3504.81	2413.15	359.1	76.60	8916	335.16	71.82	15676.66	76.05	70.27	8377.65	2000	4.18
Zone VI													
Cross Bred	7640.54	4188.49	575.34	122.73	13332	536.98	115.06	26511.18	61.64	66.66	10893.24	2000	5.44
Local	3028.95	2085.51	310.34	66.20	9375	289.65	62.06	15217.74	72.41	83.35	9184.47	2000	4.59
Buffalo	3504.81	2413.15	359.1	76.60	8916	335.16	71.82	15676.66	76.05	70.27	8377.65	2000	4.18

For estimation of losses due to RB, following assumptions and simulations were incorporated to calculate the exact figures. Losses after calving period from 60 to 90 days were not incorporated for its calculation: average feed cost @ Rs 100 per day extended period, market value of calf @ Rs 5000, milk yield loss during the extended period of open days and average extended days open was 84 days (Average number of misconceptions); extra labour utilized only during the veterinary intervention period (charged @ Rs 40 per hour).

4.2.4.2.1. Loss of milk yield

From the Table 71, reduction in milk yield was calculated from the study of Ribeiro *et al* (2012) for high producers and low producers animals during their extended days of RB. It constitute the second highest loss, the reduction of mean value of milk yield per animal annually across the different categories of species was observed highest in cross bred animals (35.17 %) of Rs. 7948.28±357.06 ranged between Rs 9043.68 (Zone VI) to Rs. 6868.416 (Zone II), followed by indigenous cattle (29.53%) of Rs. 4074.41±404.42 ranged between Rs 5697.88 (Zone IV) to Rs 3028.95 (Zone V) and buffaloes (20.91%) Rs. 2677.18±16 ranged between Rs 3504.81 (Zone V) to Rs 2456.52 (Zone VI).

Major impact on milk reduction was higher in cross bred animals due to their higher yield potential and highest occurrence of this disease. Due to non-proportionality of increase in marginal loss of milk yield during the estrous period, per extra day open and persistency as a consequence of long calving intervals (Olds *et al* 1979). De Vries (2006) estimated that changes in milk sales ranged from an increase of $0.51(Rs 33.15) to a decrease of $1.24 (Rs 80.6) per extra day open.

4.2.4.2.2. Extra feeding cost

From the Table 71, extra feeding cost was one of the major loss during the RB of dairy animals for their maintenance, it was calculated on an average daily basis i.e. the cost of amount of feed per day per animal on the basis of available market rate. Major cost of feed and fodder was observed in cross bred cattle (19.28%) due to higher requirement of energy Rs 4357.19±195.73 ranged from Rs 4957.68 (Zone VI) to Rs. 3765.21 (Zone II), followed by indigenous cattle (20.33%) Rs. 3147.13±312.38 ranged between Rs. 3509.85 (Zone VI) to Rs. 2085.51 (Zone V) and in buffaloes (14.40%) Rs. 1550.92±93.53 ranges from Rs. 2413.15 (Zone V) to Rs. 1691.42 (Zone VI).

4.2.4.2.3. Cost involved in Veterinary intervention

The total mean value of treatment cost (Table 71) incurred by dairy farmers to treat affected animals and cost involved in insemination of animals. Major contribution to the total cost was observed in cross bred cattle (2.64%) Rs. 598.51±26.88 ranged from Rs 681 (Zone VI) to Rs 517.2 (Zone II) followed by indigenous cattle (3.02%) of Rs. 468.25.43±61.98, ranged between Rs 583.8 (Zone III & IV) to Rs 310.34 (Zone V), followed by and buffaloes (2.14%) of Rs. 276.95±22.27 ranged from Rs 359.1 (Zone V) to Rs 251.7 (Zone VI). The difference was due to variation in average number of inseminations per conception, incidence rate, medication charges etc.

4.2.4.2.4. Extra labor engagement cost

From Table 71, the overall mean value of additional labour cost per animal per year on the basis of average daily wage rate (Rs.350) and was assumed to spend extra one hour per day to nurse affected animal during the veterinary intervention only. In cross bred animals, the Extra labor engagement was Rs. 127.68±5.73, followed by indigenous cattle of Rs. 99.90±4.35 ranged and buffaloes with overall mean loss of Rs. 59.08±3.30. The differences in additional labor cost incurred in different Zones and categories were due to differences in recovery period, cost of insemination, prevalence rate and variation in wage rate. The proportion of extra labour cost was observed highest in indigenous cattle (0.64%), followed by cross bred cattle and buffalo (0.56% & 0.45% respectively).

4.2.4.2.5. Replacement cost of culled animals

From Table 71, replacement cost per animal per year contributes the largest proportion loss due to RB especially the older (>5 lactation) and unproductive animals (Hodel *et al* 1995). It contributed the major proportion loss in crossbred (39.23%) & indigenous cattle (43.01%) and buffaloes (59.64%). The total mean value due to replacement of culled animals was highest in cross bred animals Rs. 8885.33±1510.62 ranges between Rs. 3696 (Zone VI) to Rs. 13332 (Zone V), followed by buffaloes Rs. 7708±741.68 ranges between Rs. 4782 (Zone VI) to Rs. 9294 (Zone III) and indigenous cattle of Rs.6656.67 ±588.81 ranges between Rs. 3931.02 (Zone V) to Rs. 7394.8 (Zone IV) in different ACZ's.

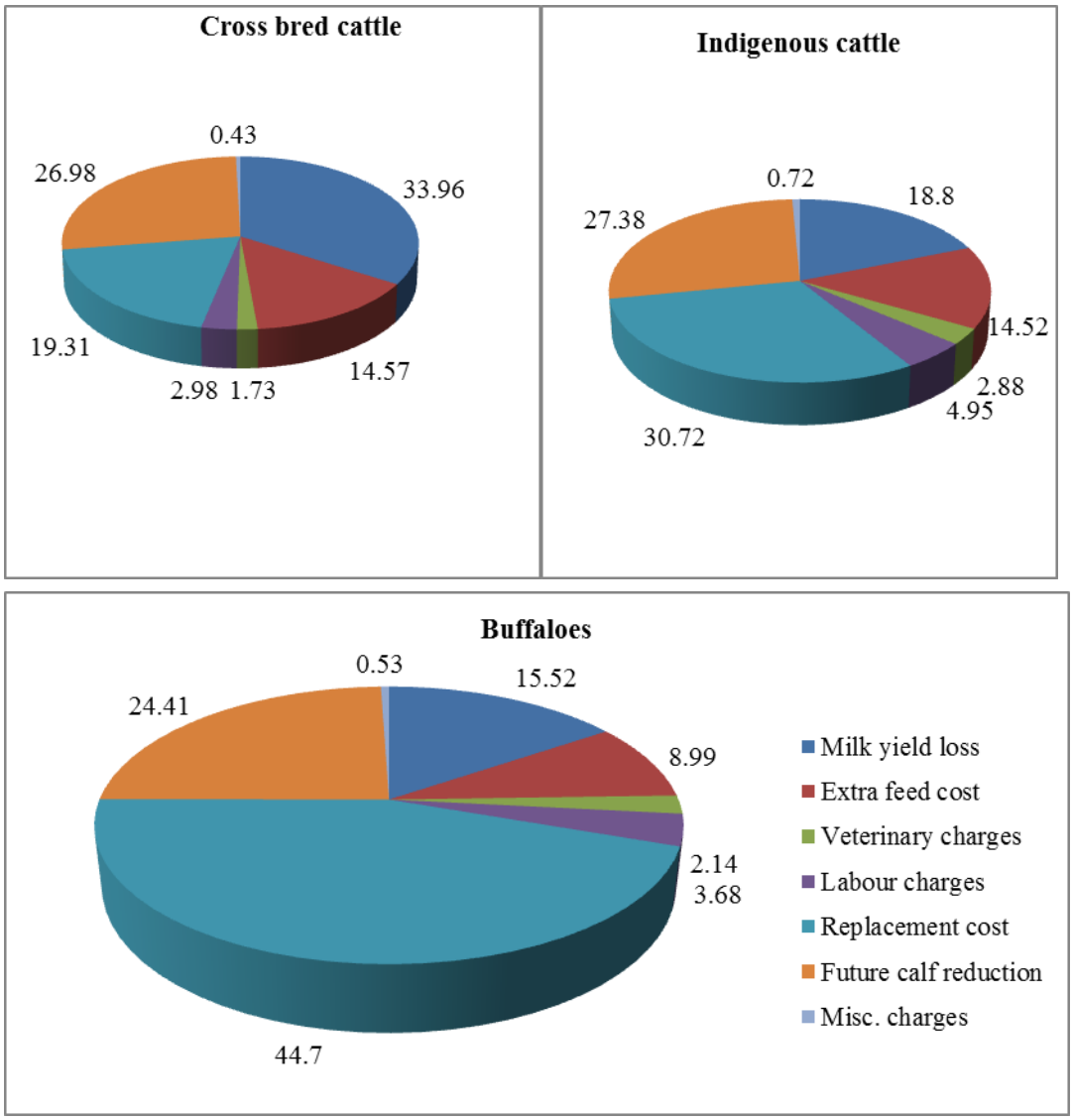


Fig. 19: Different losses associated with Repeat Breeding

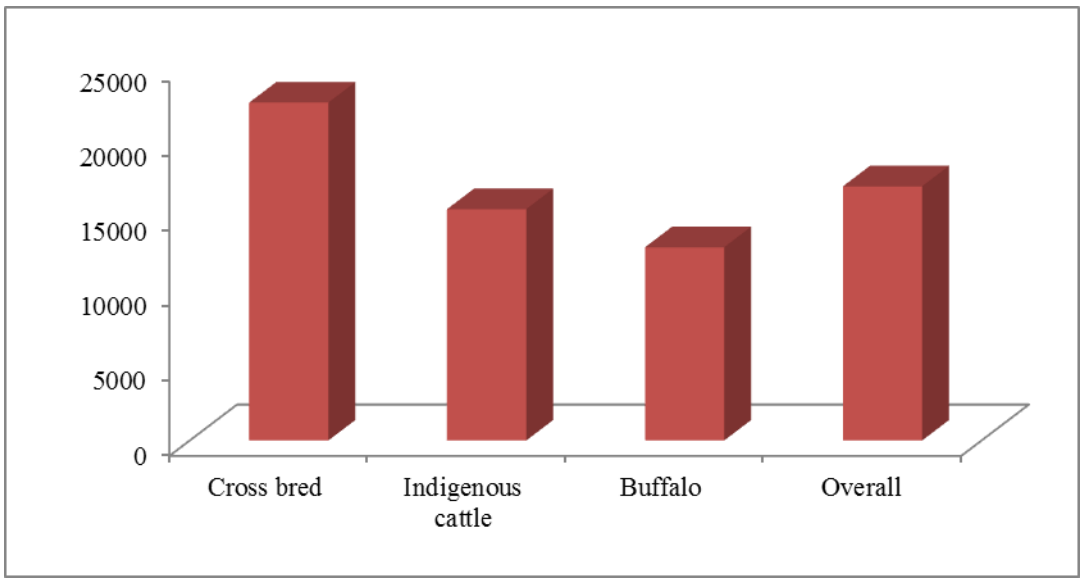


Fig. 20: Annual loss per animal due to Repeat Breeding

Total mean values of replacement cost due to RB was observed higher in high yielders of cross bred animals than local animals and constitute the major proportion of total loss per animal annually. Variation among the animals was due to zero salvage value of cross bred animals, higher replacement values and further due to their higher prevalence of RB. Such inefficient reproductive animals were supposed to be culled when the marginal net profit expected keeping her in herd will become lower than the average profit provided by the average cow, allow farmers to take a planned decisions based on economic aspects rather than biological considerations (Groenendaal *et al* 2004) as large part of economic consequences of poor reproduction is attributable to culling (Sol *et al* 1984). Gupta *et al* (2015) reported that about 30.4% of cattle and buffaloes were culled mainly due to infertility, which incriminates direct losses to the farmers as well as to the genetic resource.

One study by De Vries (2006) estimated the replacement cost of culled animals as a major cost determinant, ranging from an increase of $2.11 to $7.46 (Rs 137.15 to Rs 484.9) per cow per year for each extra day open and cow sales increased from $0.80 to $2.20 (Rs 52 to Rs 143) per extra day open.

4.2.4.2.6. Future calf reduction

The expected future calf crop loss due to RB was estimated on the basis of calving interval of 17 months instead of 13 months results quantitative loss of 0.30 times the market value of calf. As presented in Table 71, the highest future calf loss was observed in cross bred cattle Rs. 558.61±25.09 ranges from Rs. 482.72 (Zone II) to Rs. 635.6 (Zone VI) followed by indigenous cattle Rs. 437.10±58.81 ranges from Rs. 289.65 (Zone V) Rs. 544.88 (Zone IV) and buffaloes Rs. 258.85±25.89 ranges between Rs. 234.92 (Zone VI) to Rs. 335.16 (Zone V). De Vries (2006) studied that calf sales decreased from -$0.43 to -$0.23 (Rs 27.95 to Rs 14.95) per extra day open. Reduced calf crop hamper the selection efficiency in long term dairy herd improvement (Baghel 2006).

Table 71: Annual economic losses per animal due to Repeat Breeding of dairy animals in different ACZ's of Punjab.

Per animal per year	Category	Agro-climatic zones of Punjab						
		I	II	III	IV	V	VI	Mean±SE
Annual loss (Rs.)	Cross Bred Cattle	22812.37	23179.33	19485.6	24288.04	26511.18	19295.44	22595.32^{b} ± 965.43
	Indigenous cattle	17468.12	15302.88	15442.21	16373.51	15217.74	13038.17	15473.77^{a} ± 507.44
	Buffalo	13663.68	13096.17	14419.56	11155.54	15676.66	9520.67	12922.04^{a} ± 773.06
	Overall	17981.38± 2653.43	17192.79± 3060.30	16449.12± 1546.67	17272.36± 3817.57	19135.19± 3690.37	13951.42± 2858.44	**16997.04± 2894.44**
Total benefits perceived by farmers controlling Anestrus (Rs.)	Cross Bred Cattle	10792.01	10883.07	9852.958	10487.11	10893.24	9560.79	10411.53^{b} ±233.85
	Indigenous cattle	7808.163	7683.319	7831.819	7845.452	9184.47	7408.74	7960.32^{a} ± 253.79
	Buffalo	7988.771	7824.249	8098.106	7295.066	8377.65	6659.92	7707.29^{a} ± 255.73
	Overall	8862.98± 965.92	8796.88± 1043.88	8594.29± 634	8542.54± 985.17	9485.12± 741.58	7876.47± 869.45	**8693.05± 862.33**

Different superscripts (a,b,…) indicate significant ($p<0.05$) difference.

Table 72: Components of annual economic losses per animal due to Repeat Breeding of dairy animals in different ACZ's of Punjab.

		Losses (component-wise) (Rs.)							Total loss /animal/year (Rs.)
	Agro-climatic Zones	Milk yield loss	Extra feed cost	Veterinary charges	Labour charges	Replacement cost	Future calf reduction	Misc. charges	
Cross bred cattle	I	7147.29	3918.09	538.2	114.81	10484	502.32	107.64	22812.37
	II	6868.41	3765.21	517.2	110.33	11332	482.72	103.44	23179.33
	III	8244.88	4519.78	620.85	132.44	5264	579.46	124.17	19485.6
	IV	8744.88	4793.88	658.5	140.48	9204	614.6	131.7	24288.04
	V	7640.54	4188.49	575.34	122.73	13332	536.98	115.06	26511.18
	VI	9043.68	4957.68	681	145.28	3696	635.6	136.2	19295.44
	Mean± S.E	7948.28±357.06	4357.19± 195.73	598.51± 26.88	127.68± 5.73	8885.33± 1510.62	558.61± 25.09	119.70± 5.37	22595.32± 965.43
% contribution		35.17	19.28	2.64	0.56	39.32	2.47	0.52	100
Indigenous cattle	I	4295.37	2957.47	440.1	93.88	9182.5	410.76	88.02	17468.12
	II	3613.15	2487.74	370.2	78.97	8333.25	345.52	74.04	15302.88
	III	5692.03	3919.10	583.2	124.41	4462.5	544.32	116.64	15442.21
	IV	5697.88	3923.13	583.8	124.54	5382.5	544.88	116.76	16373.51
	V	3028.95	2085.51	310.34	66.20	9375	289.65	62.06	15217.74
	VI	5097.64	3509.85	522.3	111.42	3205	487.48	104.46	13038.17
	Mean± S.E	4074.41±404.42	3147.13± 312.38	468.25.43±61.98	99.90±4.35	6656.66±1079.03	437.10±58.81	93.66±15.49	15473.77±507.44
% contribution		29.53	20.33	3.02	0.64	43.01	2.84	0.60	100
Buffaloes	I	2481.48	1708.56	254.25	54.24	8877	237.3	50.85	13663.68
	II	2535.64	1745.85	259.8	55.42	8205	242.48	51.96	13096.17
	III	2657.16	1829.52	272.25	58.08	9294	254.1	54.45	14419.56
	IV	2582.49	1778.11	264.6	56.44	6174	246.96	52.92	11155.54
	V	3504.81	2413.15	359.1	76.60	8916	335.16	71.82	15676.66
	VI	2456.59	1691.42	251.7	53.69	4782	234.92	50.34	9520.67
	Mean± S.E	2677.18±161.46	1550.92±93.53	276.95±22.27	59.08±3.30	7708.0±741.68	258.85±25.89	55.39±5.56	12922.04± 773.06
% contribution		20.91	14.40	2.14	0.45	59.64	2.0	0.42	100

4.2.4.2.7. Miscellaneous Cost

From the Table 71, the overall mean value of miscellaneous charges per animal annually in cross bred cattle was Rs. 119.70±5.37 followed by indigenous cattle Rs 93.66±15.49 and buffaloes Rs 55.39±5.56 and cross bred cattle. Variation among the Zones was due to difference in herd size, transportation cost and occurrence of Repeat Breeding across the different Zones and categories of animals.

It may be concluded from the Fig 19 that, at species level, the largest component of the economic losses were due to replacement cost (39.32% in cross bred, 43.01% in indigenous cattle and 59.64% in buffalo). The highest losses were associated due to reduction in milk yield in cross bred animals followed by replacement cost of culled animals and extra feeding cost during the open days, veterinary intervention, expected future calf loss, labour expenses during the veterinary intervention and miscellaneous charges. However, in indigenous catle and buffaloes, highest losses were associated with replacement cost of culled animals followed by loss due to milk reduction, extra feeding cost during the extended period and so on.

4.2.4.3. Total economic losses of dairy animals due to RB in different ACZ's of Punjab

Table 72, illustrates the overall mean economic losses per animal per year among the different species due to RB was statistically significant Rs. 16997.04±2894.44 ($F=42.18$; $p<0.05$) but non-significant between the different ACZ's ($F=0.33$; $p>0.05$). The total mean economic losses in crossbred cattle, indigenous cattle and buffaloes were Rs. 22595.32±965.43, Rs. 15473.77±507.44 and Rs. 12922.04±773.06 per animal per year respectively. Maximum losses during the whole lactation were skewed towards cross bred animals, followed by indigenous cattle and buffaloes due to maximum reduction in milk yield, lower replacement value and due to their higher prevalence. From the post hoc test between the different ACZ's, the overall mean annual loss per animal in different categories of animals does not vary significantly ($p>0.05$) with maximum loss observed in Zone V (Rs. 19135.19 ± 3690.37) and lowest in Zone VI (Rs. 13951.42 ± 2858.44). In cross bred cattle, between the different ACZ's, maximum loss per animal per year was observed in Zone V (Rs. 26511.18) and lowest in Zone VI (Rs. 19295.44). In indigenous cattle,

maximum loss per animal per year was observed in Zone I (Rs. 17468.12) and lowest in Zone VI (Rs. 13038.17). However, in buffaloes, the maximum loss per animal per year was observed in Zone V (Rs. 15676.66) and minimum in Zone VI (Rs. 9520.67). Among the different species, cross bred animals were more affected. Similar findings were estimated by De Vries (2006) that the cost of pregnancy loss is greater for high yielder animals (early in lactation). The average value cost of pregnancy loss for a Holstein cow in the United States was estimated to $555 (Rs 36075), but the cost per extra day open varied from $3.19 to $5.41 (Rs 207.35 to Rs 351.65) per cow per year. The major cost determinant was heifer purchase cost, ranging from an increase of $2.11 to $7.46 (Rs 137.15 to Rs 484.9) per cow per year for each extra day open. In another study De Vries (2011) estimated that the cost of a day open varies from $0 at the optimal day postpartum at pregnancy to as much as $6.00 (Rs 390) according to several factors such as the days postpartum, culling policies, availability of replacement heifers, milk production, persistency, and lactation number. Groenendaal *et al* (2004) calculated the cost of a day open increases as calving interval increases and has been estimated to average $1.25 (Rs 81.25), $2.10 (Rs 136.5) and $2.75 (Rs 178.75) at 90, 150 and 210 days in milk, respectively.

However, among the different ACZ's of Punjab, the major impact of RB was observed in Zone V followed by Zone I & II, and the minimum impact on Zone VI was observed (Fig 20). Because majority of the affected Zones were small herd groups and reared few animals and were much engaged in their agricultural practices, there might be possibility of missing heat or poor heat detection in their animals. Further, they were also not practicing the scientific way of feeding and other managemental practices at their farms.

The overall economic loss incurred by dairy farmers due to RB irrespective of species of animals was Rs. 16997±2894.44. The mean economic losses per animal per year affected varied significantly ($p<0.05$) among different categories of animals, and was highest in cross bred (Rs. 22595.32± 965.43), followed by indigenous (Rs. 15473.77± 507.44) and lowest in buffalo (Rs. 12922.04± 773.06). Among the different ACZ's of Punjab, the major impact of RB was observed in Western region (Rs. 19135.19±3690.37) followed by Sub Mountain Undulating region and Undulating Plain region, and the minimum impact on Flood plain region (Rs. 13951.42 ± 2858.44) was observed.

4.2.4.3. Total benefits perceived by farmers controlling RB per animal per year in different ACZ's of Punjab

From the Table 72, the overall mean of benefits forgone per animal per year in controlling RB was statistically significant Rs. 8693.05±862.33 ($F=36.27$; $p<0.01$) but non-significant between the different ACZ's of Punjab ($F=0.34$; $p>0.5$). The total mean of benefits forgone per animal per year in crossbred cattle, indigenous cattle and buffaloes were Rs. 10411.53±233.85, Rs. 7960.32±253.79 and Rs. 7707.29±255.73 with the benefit cost ratio while intervening the control measures of RB (like mineral mixture, qualified inseminator and good quality semen and comfort zone of animals) in different categories of dairy animals (assuming Rs 2000 per animal per year) of 6.94, 5.3 and 5.13 respectively. Maximum benefits were skewed towards cross bred animals (Fig 20), followed by indigenous cattle and buffaloes due to higher their higher prevalence. From the post hoc test between the different ACZ's, the overall mean values of benefits simulated in different categories of animals does not vary significantly ($p>0.05$) with maximum benefits perceived in Zone V (Rs. 9485.12± 741.58) and lowest in Zone VI (Rs. 7876.47 ± 869.45). In cross bred cattle, among the different ACZ's, highest benefits perceived per animal per year was observed in Zone V (Rs. 10893.24) and lowest in Zone VI (Rs. 9560.79). In indigenous cattle, maximum loss per animal per year was observed in Zone V (Rs. 9184.47) and lowest in Zone VI (Rs. 7408.74). However, in buffaloes, the maximum loss per animal per year was observed in Zone V (Rs. 8377.65) and minimum in Zone VI (Rs. 6659.92). Inchaisri *et al* (2010) estimated the mean net economic loss compared with the good scenario was €34 (Rs 2584) and €231 per cow per year (Rs 17556) and poor reproductive performance scenario, respectively.

From the benefit cost analysis of intervention of control measures againt RB (Table 68 & 69) was highest in cross bred cattle followed by indigenous cattle and buffalo. BCA of latter two was almost same and indicated that the benefits outweigh the cost incurred for controlling RB under the prevalence of species wise scenario of Punjab. Further, the benefits outweigh the cost indicating the feasibility of control RB if possible through proper intervention of control measures.

It may be concluded, that the RB is a great challenge while economic losses were considered and had a huge impact on dairy farmers turn over especially those rearing cross bred animals. But from the benefit cost analysis, if proper control

measures were followed at farm level, it may provide handful profitability to their dairy business. The overall benefits forgone simulated for the dairy farmers controlling RB through various preventive measures was Rs. 5693. It varied significantly ($p<0.01$) across the species with highest returns estimated in cross bred cattle (Rs. 10411.53±233.85), followed by indigenous cattle (Rs. 7960.32± 253.79) and buffaloes (Rs. 7707.29± 255.73). From the benefit cost analysis of intervention of control measures againt RB was highest in cross bred cattle followed by indigenous cattle and buffaloes.

4.2.5.1. Epidemiological aspect of Anestrus in different ACZs of Punjab

The epidemiology of Anestrus observed in dairy animals of different ACZ's of Punjab has been presented from Table 73-78. The incidence of Anestrus had put a lot of economic burden on dairy farming to the livestock owners due to various financial losses associated with it. The overall prevalence of Anestrus observed in the study area was 25.78 percent. The prevalence of Anestrus was statistically significant among the different categories of animals species (χ^2= 738.26; $p<0.01$) and different herd size (χ^2= 370.33; $p<0.01$). Also, the overall total animals of different categories were significant (χ^2=60.0; $p<0.01$) between the different ACZ's of Punjab.

Table 85 illustrates the prevalence of Anestrus between the different categories of animals viz. cross bred cattle, indigenous cattle and buffaloes varied significantly. The highest prevalence was observed in buffaloes (36.54%), followed by cross bred cattle and indigenous (13.34% & 13.10 % respectively). Prevalence of Anestrus among the cross bred cattle in different ACZ's of Punjab varied significantly (χ^2=61.86; $p<0.01$) and ranged between 9.28% (Zone VI) to 20.24% (Zone III). However, in indigenous cattle and buffaloes, it didn't vary significantly (χ^2=6.22; $p>0.05$), ranged from 9.35% (Zones VI) to 17.08% (Zone IV) and (χ^2=6.96; $p>0.05$) and ranged from 33.38% (Zone I) to 39.79% (Zone III) respectively.

Among the herd sizes, the prevalence rate of Anestrus in the small, medium and large herd were 41.05, 24.21 and 20.90 percent respectively and varied significantly among the different herd groups and between the different ACZ's ranging from 26.81% (Zone IV) to 35.1% (Zone III). Among the small herd group, its prevalence was not significant between the different Zones (χ^2= 6.98; $p>0.05$) and ranged between 36.22% (Zone V) to 45.10% (Zone III). Whereas, in medium herd

size, the prevalence of Anestrus was highly significant between the different ACZ's (χ^2= 20.8; p<0.01) and ranged between 22.58% (Zone I) to 30.63% (Zone VI). Further, in case of large herd size, the prevalence of Anestrus was significant (χ^2= 28.4; p<0.01) and ranged from 13.79 % (Zone V) to 23.34 % (Zone I).

Various studies support this fact that incidence of Anestrus was higher in buffaloes and indigenous cattle than exotic or cross bred cattle like Singh *et al* (2003) reported 25-67% and Pandit (2004) reported 2-20%, respectively. Siddiquee *et al* (2007) reported the incidence of Anestrus in northern Gujarat in cattle and buffalo as 34.71 % and 41.49 % respectively. In Punjab, our study coincides with the study of Singh *et al* (2006) that the incidence of Anestrus in cattle and buffalo was 17.28 percent and 31.98 percent respectively. Few studies in Punjab which contradict our findings were Singh *et al* (2003) reported the incidence of Anestrus in cattle as 43–67%; Dua (2003) estimated the prevalence of Anestrus in cattle and buffaloes as 43.5% and 55.5%, while Kaur *et al* (2011) 1.20 and 3.82 %, respectively in the central Zone of Punjab. Other studies which didn't agree to our findings were Rabbani *et al* (2010) reported an incidence of 9.74 percent among buffaloes in Pakistan and Khair *et al* (2013) reported that the cumulative incidence of Anestrus (20.69%) in cross bred dairy cattle. Maji and Samanta (2013) reported that the overall incidence of anestrous was 67.68 % that too higher in non-descript cattle (53.86 %) than that crossbred Jersey cattle (46.14 %).

The overall incidence of Anestrus among dairy animals was 25.78 percent. Incidence of Anestrus (Fig 21) on the species basis varied significantly and was observed highest in buffaloes (36.54%), followed by cross bred (13.34%) and least in indigenous cattle (13.10%). The incidence of Anestrus among the different ACZ's of Punjab in cross bred cattle varied significantly (p<0.05) and ranged from 92.8% (Zone VI) to 20.24% (Zone III). However, no difference was found within different ACZ's in case of indigenous cattle and buffaloes. Within different herd sizes (Fig 22), the incidence of Anestrus varied significantly and was highest in small herd size (41.05%) followed by medium (24.21%) and lowest in large herd size (20.90%). Orthogonal comparisons revealed that the incidence of Anestrus varied respect to different ACZ in each herd size and also with respect to species of animal in all ACZ's, except between different ACZ's within small herd size.

Table 73: Prevalence and culling rate of Anestrus across herd sizes, species and categories of dairy animals in Zone I of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	361	157	43.49	22	14.01
	Medium	549	109	22.58	34	27.41
	Large	287	32	23.34	29	43.28
	Overall	1197	298	29.07	85	24.42
			$\chi^2 = 103.22^{*}$		$\chi^2 = 19.06^{**}$	
Cross Bred	**Lactating cow**	287	46	16.02	21	45.65
	Heifer	31	3	9.67	1	33.33
	Overall	318	49	15.4	22	44.89
			$\chi^2 = 0.86^{ns}$		$\chi^2 = 0.17^{ns}$	
Local	**Lactating cow**	167	19	11.37	11	57.89
	Heifer	32	3	9.37	1	33.33
	Overall	199	22	11.05	12	54.54
			$\chi^2 = 0.10^{ns}$		$\chi^2 = 0.63^{ns}$	
Buffalo	**Lactating buffalo**	578	204	35.29	92	45.09
	Heifer	102	23	22.54	5	21.73
	Overall	680	227	33.38	97	42.73
			$\chi^2 = 6.33^{**}$		$\chi^2 = 4.60^{ns}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 74: Prevalence and Culling rate of Anestrus across herd sizes, species and categories of dairy animals in Zone II of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	378	154	40.74	21	13.207
	Medium	512	127	24.80	31	23.66
	Large	479	93	19.41	46	44.23
	Overall	1369	374	27.31	98	24.87
			$\chi^2 = 50.99^{*}$		$\chi^2 = 142.13^{*}$	
Cross Bred	**Lactating cow**	348	61	17.52	33	54.09
	Heifer	83	7	8.43	1	14.28
	Overall	431	68	15.77	34	50.0
			$\chi^2 = 4.17^{**}$		$\chi^2 = 12.68^{**}$	
Local	**Lactating cow**	158	22	13.92	8	36.36
	Heifer	43	5	11.62	1	20
	Overall	201	27	12.93	9	33.33
			$\chi^2 = 0.15^{ns}$		$\chi^2 = 0.49^{ns}$	
Buffalo	**Lactating buffalo**	612	253	41.33	94	37.15
	Heifer	125	26	20.8	4	15.38
	Overall	737	279	37.85	98	35.12
			$\chi^2 = 18.61^{**}$		$\chi^2 = 4.90^{**}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 75: Prevalence and Culling rate of Anestrus across herd sizes, species and categories of animals in Zone III of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate %
Herd size	**Small**	337	152	45.10	34	22.36
	Medium	463	106	22.89	73	68.86
	Large	485	93	19.17	53	56.98
	Overall	1285	351	27.31	160	
			$\chi^2 = 74.45^{**}$		$\chi^2 = 61.07^{**}$	
Cross Bred	**Lactating cow**	587	128	21.80	69	53.90
	Heifer	134	18	13.43	6	33.33
	Overall	721	146	20.24	75	51.36
			$\chi^2 = 4.73^{**}$		$\chi^2 = 2.67^{ns}$	
Local	**Lactating cow**	72	9	12.5	4	44.44
	Heifer	9	2	22.22	1	50
	Overall	79	12	15.18	5	41.66
			$\chi^2 = 0.64^{ns}$		$\chi^2 = 0.02^{ns}$	
Buffalo	**Lactating buffalo**	391	167	42.71	72	43.11
	Heifer	94	26	27.65	8	30.76
	Overall	485	193	39.79	80	41.45
			$\chi^2 = 7.16^{**}$		$\chi^2 = 1.41^{ns}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 76: Prevalence and Culling rate of Anestrus across herd sizes, species and category of animals in Zone IV of Punjab.

	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate (%)
Herd size	**Small**	361	145	40.1662	22	14.01
	Medium	549	128	23.31512	34	27.41
	Large	287	48	16.72474	29	43.28
	Overall	1197	321	26.81704	85	24.42
			$\chi^2 = 51.10^{**}$		$\chi^2 = 28.02^{**}$	
Cross Bred	**Lactating cow**	287	41	14.28	18	43.90
	Heifer	31	4	12.90	1	25
	Overall	318	45	14.15	19	42.22
			$\chi^2 = 0.04^{ns}$		$\chi^2 = 0.15^{**}$	
Local	**Lactating cow**	167	29	17.36	14	48.27
	Heifer	32	5	15.62	2	40.0
	Overall	199	34	17.08	16	47.05
			$\chi^2 = 0.05^{ns}$		$\chi^2 = 0.11^{ns}$	
Buffalo	**Lactating buffalo**	578	218	37.71	104	47.70
	Heifer	102	24	23.52	5	20.83
	Overall	680	242	35.58	109	45.04
			$\chi^2 = 7.61^{**}$		$\chi^2 = 6.30^{**}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 77: Prevalence and culling rate of Anestrus across herd sizes, species and categories of animals in Zone V of Punjab.

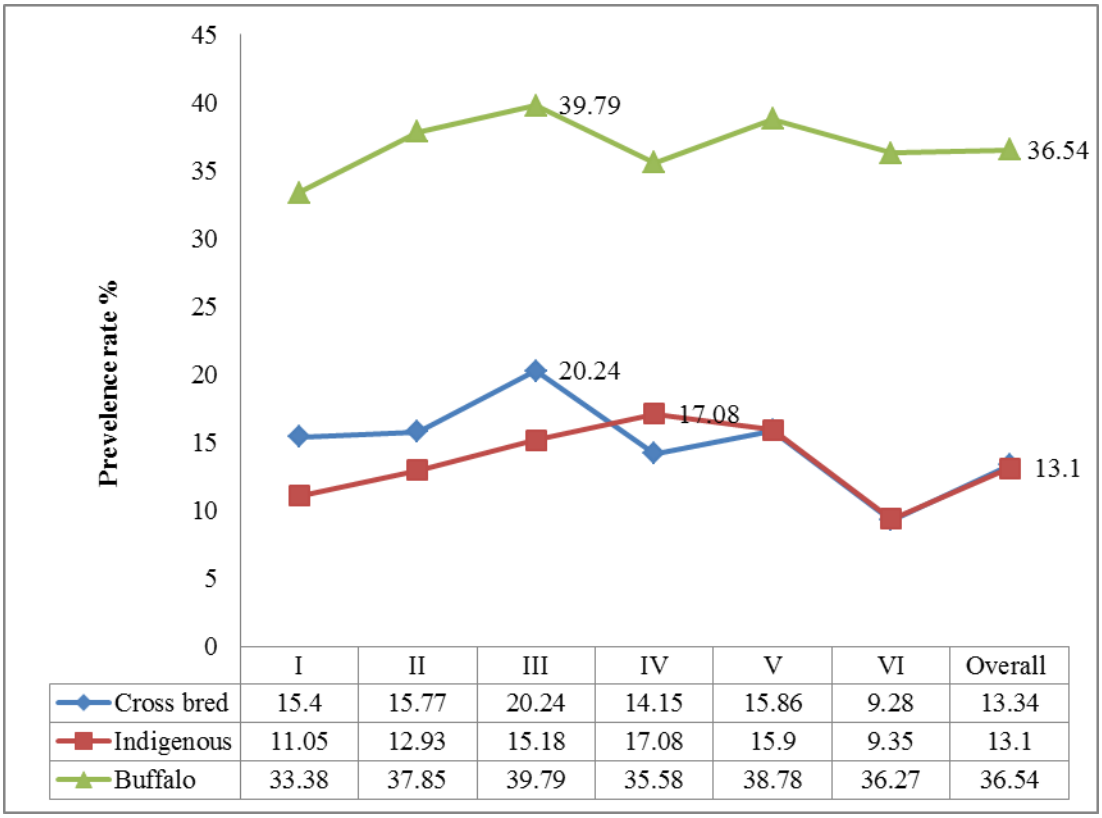
	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate %
Herd size	**Small**	381	138	36.22	61	44.20
	Medium	323	73	22.60	44	60.27
	Large	58	8	13.79	5	62.5
	Overall	762	219	28.74	110	50.22
			$\chi^2 = 13.69^{**}$		$\chi^2 = 4.93^{**}$	
Cross Bred	**Lactating cow**	219	38	17.35	17	44.73
	Heifer	71	8	11.26	3	37.5
	Overall	290	46	15.86	20	43.47
			$\chi^2 = 1.48^{ns}$		$\chi^2 = 0.05^{ns}$	
Local	**Lactating cow**	29	5	17.24	2	40.00
	Heifer	15	2	13.33	1	50.0
	Overall	44	7	15.90	3	42.85
			$\chi^2 = 0.11^{ns}$		$\chi^2 = 0.05^{ns}$	
Buffalo	**Lactating buffalo**	309	145	46.92	81	55.86
	Heifer	119	21	17.64	6	28.57
	Overall	428	166	38.78	87	52.40
			$\chi^2 = 3.10^{**}$		$\chi^2 = 5.47^{**}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

Table 78: Prevalence and culling rate of Anestrus across herd sizes, species and categories of animals in Zone VI of Punjab.

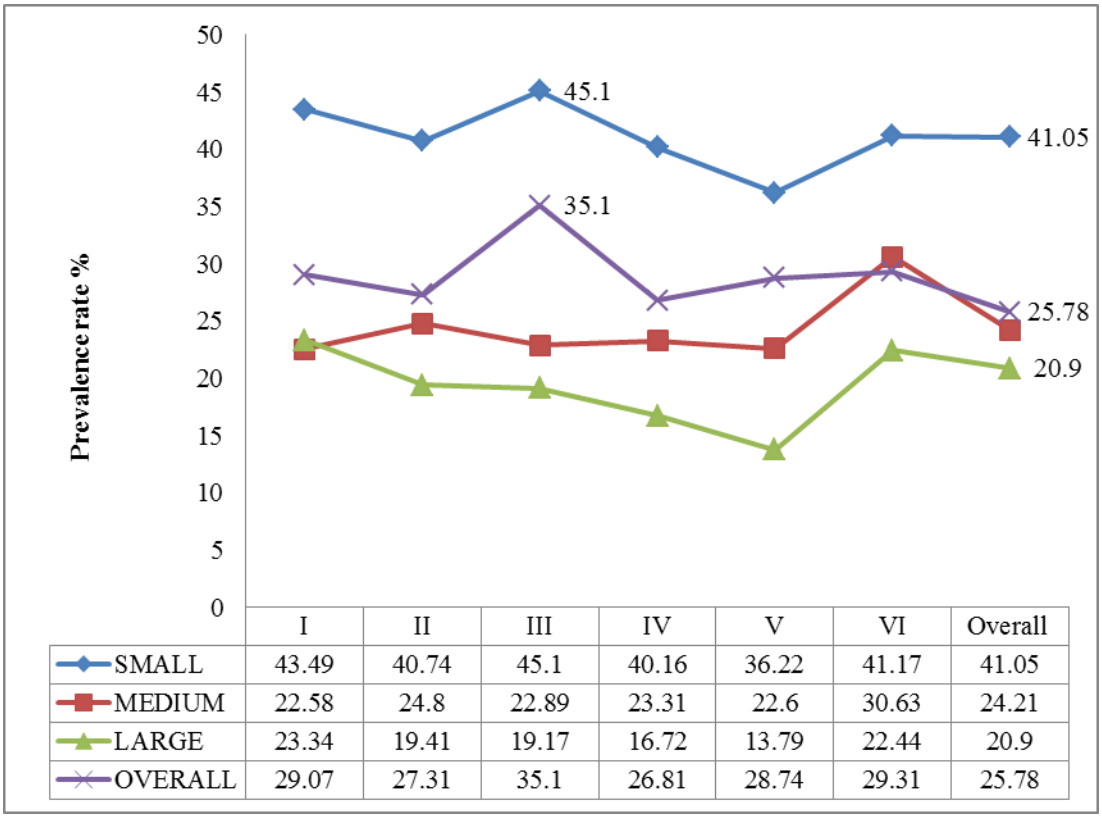
	Category	Total animals	Affected animals	Prevalence rate (%)	No. of culled animals	Culling rate %
Herd size	**Small**	238	98	41.17	21	21.42
	Medium	594	182	30.63	70	38.46
	Large	3872	869	22.44	374	43.03
	Overall	3919	1149	29.31	465	40.46
			$\chi^2 = 56.84^{**}$		$\chi^2 = 17.23^{**}$	
Cross Bred	**Lactating cow**	1262	161	14.81	42	26.08
	Heifer	215	15	8.3	2	13.33
	Overall	1895	176	9.28	44	25.0
			$\chi^2 = 5.848^{**}$		$\chi^2 = 1.19^{ns}$	
Local	**Lactating cow**	112	14	12.5	3	21.42
	Heifer	26	2	7.69	1	50.0
	Overall	171	16	9.35	4	25.0
			$\chi^2 = 0.47^{ns}$		$\chi^2 = 0.76^{ns}$	
Buffalo	**Lactating buffalo**	2056	893	43.43	412	46.13
	Heifer	248	64	25.80	5	7.81
	Overall	2638	957	36.27	417	43.57
			$\chi^2 = 28.31^{**}$		$\chi^2 = 35.67^{**}$	

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.



	I	II	III	IV	V	VI	Overall
Cross bred	15.4	15.77	20.24	14.15	15.86	9.28	13.34
Indigenous	11.05	12.93	15.18	17.08	15.9	9.35	13.1
Buffalo	33.38	37.85	39.79	35.58	38.78	36.27	36.54

Fig. 21: Prevalence of Anestrus on Species basis



	I	II	III	IV	V	VI	Overall
SMALL	43.49	40.74	45.1	40.16	36.22	41.17	41.05
MEDIUM	22.58	24.8	22.89	23.31	22.6	30.63	24.21
LARGE	23.34	19.41	19.17	16.72	13.79	22.44	20.9
OVERALL	29.07	27.31	35.1	26.81	28.74	29.31	25.78

Fig. 22: Prevalence of Anestrus on Herd basis

Table 85: Overall Prevalence of Anestrus on species basis and herd basis of dairy animals in different ACZs of Punjab.

Prevalence (%)	Category	Agro-climatic Zones of Punjab									
		I	II	III	IV	V	VI	χ^2 Value	Total animals	Affected animals	Prevalence (%)
Species basis	Cross- bred Cattle	15.40	15.77	20.24	14.15	15.86	9.28	61.86^{**}	3973	530	13.34
	Indigenous cattle	11.05	12.93	15.18	17.08	15.90	9.35	6.22^{ns}	893	118	13.10
	Buffalo	33.38	37.85	39.79	35.58	38.78	36.27	6.96^{ns}	5648	2064	36.54
									Overall χ^2 Value = 738.26^{**}		
Herd size basis	Small	43.490	40.74	45.10	40.16	36.22	41.17	$^{ns}6.98$	1956	844	41.05
	Medium	22.58	24.80	22.89	23.31	22.60	30.63	20.8^{**}	2890	724	24.21
	Large	23.34	19.41	19.17	16.72	13.79	22.44	28.41^{**}	5463	1143	20.90
	Overall	29.07^{*}	27.31^{*}	35.1^{*}	26.81^{*}	28.74^{*}	29.31^{*}	60.0^{**}	9729	3646	25.78
									Overall χ^2 Value = 370.33^{**}		

$^{*}(p<0.01)$ and $^{**}(p<0.05)$ indicate significant difference; $^{ns}(p>0.05)$ indicate no significant difference.

The occurrence of Anestrus in the study area might be due to inadequate well-balanced ration, silent heat, longer postpartum Anestrus, lactational stress, high ambient temperature, high parasitic burden and other diseases exacerbate the condition. Silent heat in buffaloes due to heat stress in the tropics and subtropics reduces the fertility and poor estrus expression (Flores *et al* 2004) as a result of reduced estradiol secretion from the dominant follicle developed in a low luteinizing hormone environment (De Rensis and Scaramuzzi 2003). The period of postpartum Anestrus is usually longer in buffalo than the cattle under similar management conditions (Dobson and Kamonpatana, 1986; Jainudeen and Hafez, 1993). In comparison to cows, buffaloes have lesser number of preantral and antral follicles, smaller sized pre– ovulatory follicle and greater tendency of follicular atresia (Samad and Nasseri, 1979; Baruselli *et al* 1997) which might be responsible for high incidence of Anestrus in buffaloes. The incidence of Anestrus was higher in adult cattle and buffaloes than their heifers (Bharkad and Markandeya 2003).

Among the Zones, the most affected Zones were the Central plain region followed by Flood plain region and sub-mountain undulating region. The least affected Zones were Western plain and western region. The highly affected regions were having small herd size, mostly they rear buffaloes as a subsidiary business to their primary agricultural farming. Other reasons might be due to lack of record keeping, poor necessary inputs for maintaining animal health, poor awareness about the importance of well-balanced nutritious diet, the high cost of branded feed and poor management exaggerate this Anestrus problem. However, the least affected Zones were having a larger land holding, large herd size, rearing cross bred animals and furnish good nutritive branded feed to their animals. Among the herd size, small herd was severely affected followed by medium and large herd groups because as the herd size increases, animals were reared mainly for commercial purposes especially the cross bred animals, hence proper care and management of feeding, health care and breeding of these animals were undertaken.

The overall incidence of Anestrus among dairy animals was 25.78 percent. Incidence of Anestrus on the species basis varied significantly (χ^2=738.26; $p<0.05$) and was observed highest in buffaloes (36.54%), followed by cross bred (13.34%) and

least in indigenous cattle (13.10%). The incidence of Anestrus among the different ACZ's of Punjab in cross bred cattle varied significantly ($p<0.05$) and ranged from 92.8% (Zone VI) to 20.24% (Zone III). However, no difference was found within different ACZ's in case of indigenous cattle and buffaloes. Within different herd sizes, the incidence of Anestrus varied significantly ($\chi^2=370.33$; $p<0.05$) and was highest in small herd size (41.05%) followed by medium (24.21%) and lowest in large herd size (20.90%). Orthogonal comparisons revealed that the incidence of Anestrus varied respect to different ACZ in each herd size and also with respect to species of animal in all ACZ's, except between different ACZ's within small herd size.

4.2.5.2. Economic losses due to Anestrus

Losses associated with Anestrus were not visible to the dairy farmers and were underestimated due to indirect impact on their financial returns. Various losses associated with Anestrus include veterinary expenses (treatment cost, veterinarian charges and diagnostic cost), extra labour charges and miscellaneous cost, the impact of yield loss throughout the lactation during the Anestrus period, depreciation value of an animal, expected calf loss, replacement cost perceived by farmers are presented in Tables (79-84). Economic losses from post-partum period 60-90 days were not considered in lactating animals, milk loss was estimated for whole lactation period (290 days) considering the previous study of DeVries (2011) for low (local cow and buffalo) and high producers(crossbred cow), future calf crop expected was estimated for whole year from its market value and extra labour charges were calculated only during the veterinary intervention @ Rs 40 per hour (wage rate per day @Rs 330) and extra feed cost during Anestrus period wasn't taken into account but was considered in the miscellaneous charges as maintaniance cost of animal. Intervention of control measures for measuring benefit cost analysis was Rs. 2500 for cross bred cattle and Rs. 2000 in indigenous cattle and buffaloes.

Table 79: Economic losses due to Anestrus and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone I of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Future calf reduction value (Rs.)	Misc. cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment coverage (%)	Total benefits per year (Rs)	Cost of control per year (Rs)	BCA
Cross Bred	**Lactating cow**	3590.08	400.5	12.81	18260	801	64.08	23128.47	83.97	54.34	10553.35	2500	5.37
	Heifer		193.4	7.73	4999.5	483.5	29.01	5713.14	90.32	66.66	3439.72		
	Overall	3590.08	593.9	20.546	23259.5	1284.5	93.09	28841.61	84.59	55.1	13442.81		
Local	**Lactating cow**	1872.63	272.88	9.09	14472.5	341.1	56.85	17025.07	88.62	42.1	6352.87	2000	4.21
	Heifer	0	187.4	7.496	3333	281.1	28.11	3837.1	90.62	66.66	2318.24		
	Overall	1872.63	460.28	16.586	17805.5	622.2	84.96	20862.17	88.94	45.45	8434.45		
Buffalo	**Lactating buffalo**	6458.07	846.96	28.232	13527	1058.7	176.45	22095.41	64.7	54.9	7849.35	2000	4.86
	Heifer		450.8	18.032	2173	676.2	67.62	3385.65	77.45	78.26	2052.17		
	Overall	6458.07	1297.76	46.264	15700	1734.9	244.07	25481.06	66.61	57.26	9721.29		

Table 80: Economic losses due to Anestrus and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone II of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Future calf reduction value (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment coverage (%)	Total benefits per year (Rs)	Cost of control per year (Rs)	BCA
Cross Bred	**Lactating cow**	3926.23	438	14.016	21636	876	70.08	26960.33	82.47	45.90	10205.49	2500	5.0
	Heifer		168.6	6.744	2142	421.5	25.29	2764.134	91.56	85.71	2169.18		
	Overall	3926.23	606.6	20.76	23778	1297.5	95.37	29724.46	84.22	50	12516.97		
Local	**Lactating cow**	2292.62	334.08	11.136	9090	417.6	69.6	12215.04	86.70	61.90	6556.65	2000	4.22
	Heifer		232.4	9.296	2000	348.6	34.86	2625.15	88.37	80	1855.92		
	Overall	2292.62	566.48	20.432	11090	766.2	104.46	14840.19	87.06	65.38	8448.06		
Buffalo	**Lactating buffalo**	7563.39	991.92	33.064	11145	1239.9	206.65	21179.92	58.66	86.56	10754.52	2000	6.39
	Heifer		416	16.64	1538	624	62.4	2657.04	79.2	84.61	1780.62		
	Overall	7563.39	1407.92	49.704	12683	1863.9	269.05	23836.96	62.14	86.37	12795.63		

Table 81: Economic losses due to Anestrus and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone II of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Future calf reduction value (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment Coverage (%)	Total benefits [er year (Rs)	Cost of control per year (Rs)	BCA
Cross Bred	**Lactating cow**	4885.38	545	17.44	21560	1090	87.2	28185.02	78.2	46.09	10158.55		
	Heifer		268.6	10.74	4999.5	671.5	40.29	5990.63	86.57	66.66	3457.04	2500	5.32
	Overall	4885.38	813.6	28.18	26559.5	1761.5	127.49	34175.65	79.76	48.63	13255.81		
Local	**Lactating cow**	2058.75	300	10	11110	375	62.5	13916.25	87.5	55.55	6764.84		
	Heifer		444.4	17.77	5000	666.6	66.66	6195.43	77.78	50	2409.40	2000	4.97
	Overall	2058.75	744.4	27.77	16110	1041.6	129.16	20111.69	84.82	58.33	9950.92		
Buffalo	**Lactating buffalo**	7815.93	1025.04	34.16	12933	1281.3	213.55	23302.99	57.29	56.88	7594.47		
	Heifer		553	22.12	3076	829.5	82.95	4563.57	72.35	69.23	2285.82	2000	4.81
	Overall	7815.93	1578.04	56.28	16009	2110.8	296.5	27866.56	60.21	58.54	9823.66		

Table 82: Economic losses due to Anestrus and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone IV of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Future calf reduction value (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment Coverage (%)	Total benefits per year (Rs)	Cost of control per year (Rs)	BCA
Cross Bred	**Lactating cow**	3200.14	357	11.42	17560	714	57.12	21899.68	57.29	56.88	7136.35	2500	3.75
	Heifer		258	10.32	3750	645	38.7	4702.02	72.35	69.23	2355.14		
	Overall	3200.14	615	21.74	21310	1359	95.82	26601.7	60.21	58.54	9376.28		
Local	**Lactating cow**	2859.19	416.64	13.88	12067.5	520.8	86.8	15964.82	85.71	56.09	4833.21	2000	3.65
	Heifer		312.4	12.49	4000	468.6	46.86	4840.35	87.09	75	3071.48		
	Overall	2859.19	729.04	26.38	16067.5	989.4	133.66	20805.17	85.84	57.77	7318.08		
Buffalo	**Lactating buffalo**	6900.93	905.04	30.16	14310	1131.3	188.55	23465.99	82.63	51.72	6823.79	2000	4.56
	Heifer		470.4	18.81	2083	705.6	70.56	3348.376	84.37	60	2450.42		
	Overall	6900.93	1375.44	48.98	16393	1836.9	259.11	26814.37	82.91	52.94	9132.62		

Table 83: Economic losses due to Anestrus and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone V of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Future calf reduction value (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment Coverage (%)	Total benefits per year (Rs)	Cost of control per year (Rs)	BCA
Cross Bred	**Lactating cow**	3888.13	433.75	13.88	17892	867.5	69.4	23164.66	82.64	55.26	10578.57	2500	5.63
	Heifer		225.2	9.00	5625	563	33.78	6455.98	88.73	62.5	3580.24		
	Overall	3888.13	658.95	22.88	23517	1430.5	103.18	29620.65	84.13	56.52	14084.7		
Local	**Lactating cow**	2839.42	413.76	13.79	10000	517.2	86.2	13870.38	82.75	60	6887.36	2000	4.70
	Heifer		266.6	10.66	5000	399.9	39.99	5717.15	86.66	50	2477.43		
	Overall	2839.42	680.36	24.45	15000	917.1	126.19	19587.53	84.09	57.14	9412.19		
Buffalo	**Lactating buffalo**	8586.36	1126.08	37.53	16758	1407.6	234.6	28150.18	53.07	44.13	6594.44	2000	4.65
	Heifer		352.8	14.11	2857	529.2	52.92	3806.03	82.35	71.42	2238.84		
	Overall	8586.36	1478.88	51.64	19615	1936.8	287.52	31956.21	61.21	47.59	9309.61		

Table 84: Economic losses due to Anestrus and BCA of Crossbred cattle, Indigenous cattle and Buffalo in Zone VI of Punjab.

	Category	Expected Milk yield loss (Rs.)	Treatment cost (Rs.)	Labour charges (Rs.)	Replacement of animal (Rs.)	Future calf reduction value (Rs.)	Misc. Cost (Rs.)	Total loss (Rs.)	Control measures (%)	Treatment Coverage (%)	Total benefits per year (Rs)	Total cost of control per year (Rs)	BCA
Cross Bred	**Lactating cow**	3318.92	370.25	11.84	10432	740.5	59.24	14932.76	85.19	73.91	9402.25	2500	4.77
	Heifer		166	6.64	1999.5	415	24.9	2612.04	91.7	86.66	2075.71		
	Overall	3318.92	536.25	18.48	12431.5	1155.5	84.14	17544.8	90.72	75	11937.48		
Local	**Lactating cow**	2058.75	300	10	5355	375	62.5	8161.25	87.5	78.57	5610.85	2000	4.61
	Heifer		153.8	6.15	5000	230.7	23.07	5413.72	92.31	50	2498.70		
	Overall	2058.75	453.8	16.15	10355	605.7	85.57	13574.97	90.65	75	9229.28		
Buffalo	**Lactating buffalo**	7947.69	1042.32	34.74	13839	1302.9	217.15	24383.8	56.57	53.86	7429.86	2000	4.72
	Heifer		516	14.11	781	529.2	52.92	1893.23	74.2	92.18	1295.03		
	Overall	7947.69	1558.32	48.85	14620	1832.1	270.07	26277.03	63.73	56.42	9449.35		

4.2.5.2.1. Loss of milk yield

From the Tables 79-84, milk yield loss implies the reduction of milk from the lactating animals during the whole lactation (290 days) due to Anestrus. The average market value of milk received by farmers was about Rs. 37.5 per liter of cow milk and Rs. 47.5 of buffalo milk. Losses due to milk yield constitute the second largest component due to Anestrus. Table 86, illustrates the reduction of mean value of milk yield per animal annually in different species was observed highest in buffaloes (27.90%) of Rs. 7545.39±311.79 ranged between Rs. 3200.14 (Zone IV) to Rs. 4885.38 (Zone III), followed by cross bred cattle (13.69%) of Rs. 3801.48±247.45, ranged from Rs. 1872.63 (Zone I) to Rs. 2859.192 (Zones IV) and indigenous cattle (12.73%) of Rs. 2330.22±172.94 ranged from Rs. 6458.07 (Zone I) to Rs. 8586.36 (Zone V).

Since milk loss was considered during the whole lactation period after 90 days of calving, still it constitutes the second largest proportion in buffaloes due to better returns of their milk sold and higher prevalence than cattle. Similar findings in were reported by DeVries (2011), he estimated loss of 1.51 Kg/cow/day of calving interval or 498 Kg of milk/cow/year for high producing animals and 1.11 Kg of milk/cow/day of calving interval or approximately 366 Kg/cow/year for moderate producing animal. Cattaneo *et al* (2015) estimated that the period of 340-370 days, milk yield loss per day US$ 1.8/cow/day (Rs 117).

4.2.5.2.3. Treatment cost

From the Tables 86, the total mean value of treatment cost per animal per year incurred by dairy farmers to treat affected animals was calculated during the Anestrus period after postpartum period of 90 days in case of lactating animals. Table 90 illustrates the total mean value of treatment cost per animal per year was in cross bred cattle (2.29%) was Rs. 637.38±38.76, ranged from 536.25 (Zone VI) to Rs. 813.6 (Zone III); indigenous cattle (3.31%) of Rs. 605.72±53.47 ranged from Rs. 453.8 (Zone VI) to Rs. 744.4 (Zone III); and buffaloes (5.36%) of Rs. 1449.39±44.52, ranged from Rs. 1297.76 (Zone I) to Rs. 1578.04 (Zone III). Since the total mean value of treatment cost per animal per year was calculated during the Anestrus period and was higher in buffaloes followed by cross bred and indigenous cattle due to the

higher occurrence in the study area, higher medication charges and poor recovery from the Anestrus condition. Kutty (2000) reported that every missed heat leads to a loss of Rs. 500 per animal, in case of lactating cows and the loss becomes almost double in case of heifers of the poor farmers under Indian condition.

4.2.5.2.4. Extra labor engagement cost

From Table 86, the overall mean value of additional labour on the basis of average daily wage rate (Rs.330) was assumed to spend extra one hour per day to nurse affected animal during treatment period only. It was highest in buffaloes (0.18%) costs Rs. 50.29±1.39/animal/year followed by cross bred cattle (0.07%) of Rs. 1074.02±106.60/animal/year and indigenous cattle (0.12%) of Rs. 635.138± 38.30/animal/year. The differences in additional labor cost incurred in different Zones and categories were due to differences in recovery period, prevalence rate and variation in wage rate. The proportion of extra labour cost was observed highest in buffaloes followed by indigenous and cross bred cattle due to higher occurrence of Anestrus in buffaloes compared to cattle which leads to more veterinary interventions and treatment charges.

4.2.5.2.5. Replacement cost of culled animals

From Table 86, replacement cost of animals due to Anestrus especially in older and unproductive animals (>5 lactation) contributed the major percentage loss among different categories of animals viz. crossbred (78.78%), indigenous cattle (78.72%) and buffaloes (58.57%). The total mean value due to replacement of culled animals was highest in cross bred animals (Rs. 21809.25±1997.09) ranged between Rs. 12431.5 (Zone VI) to Rs. 26559.5 (Zone III), followed by buffaloes (Rs. 15836.66±932.01) ranged between Rs. 12683.0 (Zone II) to Rs. 19615.0 (Zone V) and indigenous cattle of (Rs. 14404.66±1224.47) ranged between Rs. 10355.0 (Zone VI) to Rs. 17805.5 (Zone VI) /animal/year in different ACZs.

Total mean values of replacement cost due to Anestrus was higher in high yielders of cross bred animals than local animals and constituted the major proportion of total loss per animal annually. In cattle, it contributed the highest proportion due to the higher replacement cost of animals due to their zero salvage value. However, in buffaloes, farmers were able to get the price of their unproductive animals from the

organized slaughter houses. Our findings concurred with the study of De Vries (2006) that cow replacement cost due to infertility represented the highest proportion of the total cost. Since the unproductive and older animals were mainly culled to maintain the dairy herd and avoid loss from these unproductive animals. Beaudeau *et al* (1995) reported that probability for a cow to be culled in first and second lactation increases with the parity and it depends according to the days open observed in the same lactation. Groenendaal *et al* (2004) concluded that replacement of animals is favorable when the marginal net profit expected keeping cows in a herd will become lower than the average profit provided by the average cow. Sharma *et al* (1993) reported that about 18-40% of cattle and buffaloes were culled mainly due to infertility which incriminates direct losses to the farmer as well as to the genetic resource.

4.2.5.2.6. Future calf reduction

The expected future calf crop loss per animal per year due to Anestrus was estimated on the basis of an average number of open days to the total number of days of pregnancy with its marketed calf value for the next replacement. As presented in Table 86, the highest future calf loss was observed in buffaloes Rs. 1885.9±52.20 ranged from Rs. 1734.9 (Zone I) to Rs. 2110.8 (Zone III) followed by cross bred cattle Rs. 1381.41±84.62 ranged from Rs. 1155.5 (Zone VI) Rs. 1761.5 (Zone III) and indigenous cattle Rs. 823.7±76.39 ranged between Rs. 605.7 (Zone VI) to Rs. 1041.6 (Zone III). It constituted the third major loss due to Anestrus in different categories of dairy animals. The proportion of future calf reduction in cattle was almost same in both cross bred and indigenous animals but lower than buffaloes.

4.2.5.2.7. Miscellaneous Cost

From the Table 86, the overall mean value per animal per year of miscellaneous charges include maintenance cost, transportation cost, change in bedding, ropes, utensils etc. The overall mean value per animal per year in cross bred cattle (1.0%) was Rs. 99.84±6.06 ranged between Rs. 84.14 (Zone VI) to Rs. 127.4 (Zone III); indigenous cattle, it was (0.6%) of Rs. 110.66±9.02/animal/year ranged from Rs 84.96 (Zone I) to Rs. 133.66 (Zone IV) and in buffaloes (0.35%) of Rs. 271.05±7.73/animal/year ranged from Rs. 244.07 (Zone I) to Rs. 296.5 (Zone III). Largest cost was observed in buffaloes followed by indigenous cattle and cross bred

cattle between the different Zones and categories of animals was due to the difference in herd size, transportation cost depends on the distance of polyclinic from the farmer's house and occurrence of Anestrus across the different Zones and categories of animals.

It may be concluded from the Fig 23 that among the different categories of losses associated with Anestrus of dairy animals in the study area highest loss was observed due to replacement cost of animals which were culled due to Anestrus, followed by loss in the milk yield during the open days of Anestrus. Future calf reduction estimated had a major impact on economics of dairy business, it was followed by veterinary expenses to treat their affected animals followed by labour charges during the treatment period and miscelanoes charges.

4.2.5.3. Total economic losses of dairy animals due to Anestrus in different ACZs of Punjab

Table 87 presents the overall mean economic losses per animal per year due to Anestrus. The loss varied significantly among the different categories of animals ($F=20.72$; $p<0.01$) but non-significant between the different ACZ's ($F=0.52$; $p>0.5$). The total mean economic losses in crossbred cattle, indigenous cattle and buffaloes were Rs. 27511.48±1227.60, Rs. 18296.95±1317.53 and Rs. 27038.69±1128.05 per animal per year, respectively (Fig 24). Maximum losses were skewed towards buffaloes followed by indigenous cattle and cross bred cattle because of better value of milk in the market and higher prevalence in case of buffaloes. From the post hoc test between the different ACZ's, the overall mean loss per animal annually of different categories of animals was Rs. 24362.93±1273.04 and didn't vary significantly ($p>0.05$), ranged from Rs. 19135.6±4326.50 (Zone VI) to Rs 27384.63±2407.03 (Zone III) to. The overall mean loss per animal annually in cross bred cattle between the different ACZ's was Rs. 17554.81 (Zone VI) to Rs. 34175.65 (Zone III), indigenous cattle of Rs. 13574.97 (Zone VI) to Rs. 20862.17 (Zone I) and in buffaloes of Rs. 23836.96 (Zone II) to Rs. 31956.21 (Zone V).

Table 86: Component wise economic losses due to Anestrus of different species of dairy animals in different ACZ's of Punjab.

	Agro-climatic Zones	Losses (component-wise) (Rs.)						Total loss /animal/ year (Rs.)
		Milk yield loss	Veterinary charges	Labour charges	Replacement cost	Future calf reduction	Misc. charges	
Cross bred cattle	I	3590.08	593.9	20.546	23259.5	1284.5	93.09	28841.62
	II	3926.23	606.6	20.76	23778.0	1297.5	95.37	29724.46
	III	4885.38	813.6	28.18	26559.5	1761.5	127.49	34175.65
	IV	3200.14	615.0	21.74	21310.0	1359.0	95.82	26601.71
	V	3888.13	658.95	22.88	23517.0	1430.5	103.18	29620.65
	VI	3318.92	536.25	18.48	12431.5	1155.5	84.14	17554.81
	Mean± S.E	3801.48± 247.45	637.38± 38.76	22.10±1.35	21809.25±1997.09	1381.41± 84.62	99.84±6.06	27511.48±1227.60
% Contribution		13.69	2.29	0.07	78.58	4.97	0.35	
Indigenous cattle	I	1872.63	460.28	16.58	17805.5	622.2	84.96	20862.17
	II	2292.62	566.48	20.42	11090.0	766.2	104.46	14840.19
	III	2058.75	744.4	27.77	16110.0	1041.6	129.16	20111.68
	IV	2859.19	729.04	26.38	16067.5	989.4	133.66	20805.17
	V	2839.42	680.36	24.45	15000.0	917.1	126.19	19587.53
	VI	2058.75	453.8	16.15	10355.0	605.7	85.57	13574.97
	Mean± S.E	2330.22±172.94	605.72±53.47	21.96±2.03	14404.66±1224.47	823.7±76.39	110.66±9.02	18296.95±1317.53
% Contribution		(12.73)	(3.31)	(0.12)	(78.72)	(4.50)	(0.60)	
Buffaloes	I	6458.07	1297.76	46.26	15700.0	1734.9	244.07	25481.062
	II	7563.39	1407.92	49.70	12683.0	1863.9	269.05	23836.96
	III	7815.93	1578.04	56.28	16009.0	2110.8	296.5	27866.56
	IV	6900.93	1375.44	48.98	16393.0	1836.9	259.11	26814.36
	V	8586.36	1478.88	51.64	19615.0	1936.8	287.52	31956.21
	VI	7947.69	1558.32	48.85	14620.0	1832.1	270.07	26277.03
	Mean± S.E	7545.39±311.79	1449.39±44.52	50.29±1.39	15836.66±932.01	1885.9±52.20	271.05±7.73	27038.69±1128.05
% Contribution		27.90	5.36	0.18	58.57	6.97	1.0	

Table 87. Economic losses and Total benefits perceived due to Anestrus of different species of dairy animals in different ACZ's of Punjab

Per animal per year	Category	Agro-climatic Zones of Punjab						
		I	II	III	IV	V	VI	Mean±SE
Annual loss (Rs.)	Cross Bred Cattle	28841.62	29724.46	34175.65	26601.71	29620.65	17554.81	27511.48± 1227.60[b]
	Indigenous cattle	20862.17	14840.19	20111.69	20805.17	19587.53	13574.97	18296.95± 1317.53[a]
	Buffalo	25481.06	23836.96	27866.56	26814.37	31956.21	26277.03	27038.69± 1128.05[b]
	Overall	25061.62± 2454.42	22800.54± 2957.13	27384.63± 2407.03	24740.42± 3481.61	27054.8± 4284.25	19135.6± 4326.50	**24362.93± 1273.04**
Total benefits perceived by farmers controlling Anestrus (Rs.)	Cross Bred Cattle	7919.11	6357.32	8275.54	9823.65	8878.10	8870.23	8353.99± 478.99
	Indigenous cattle	8434.45	8448.06	9950.92	7318.08	9412.19	9229.28	8798.83± 380.22
	Buffalo	9721.29	12795.63	9823.66	9132.62	9309.61	9449.35	10038.69± 561.17
	Overall	8691.61± 535.89	9200.33± 1896.25	9350.03± 538.50	8758.11± 747.14	9199.96±1 63.63	9182.95± 168.77	**9063.83±405.6**

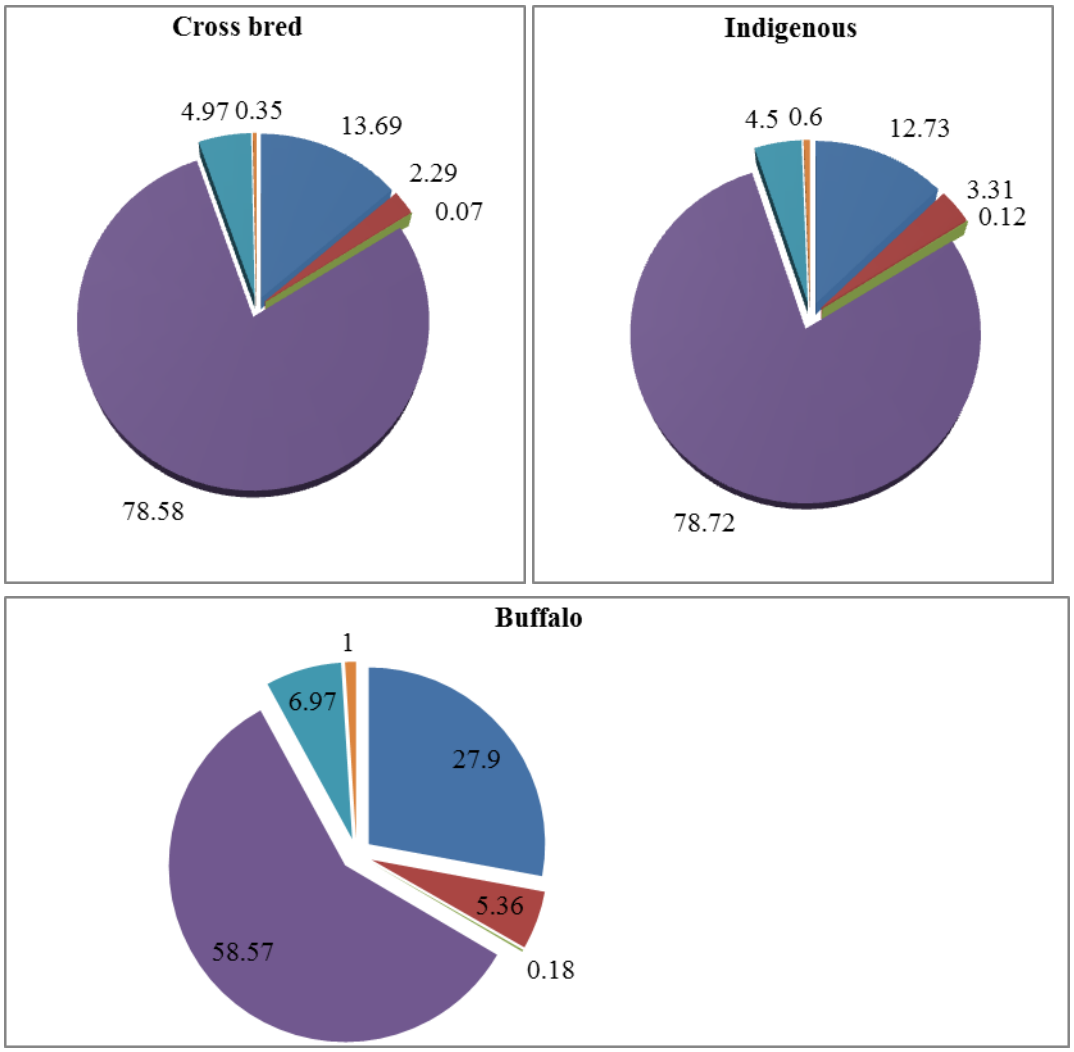


Fig. 23: Different categories of Losses associated with Anestrus

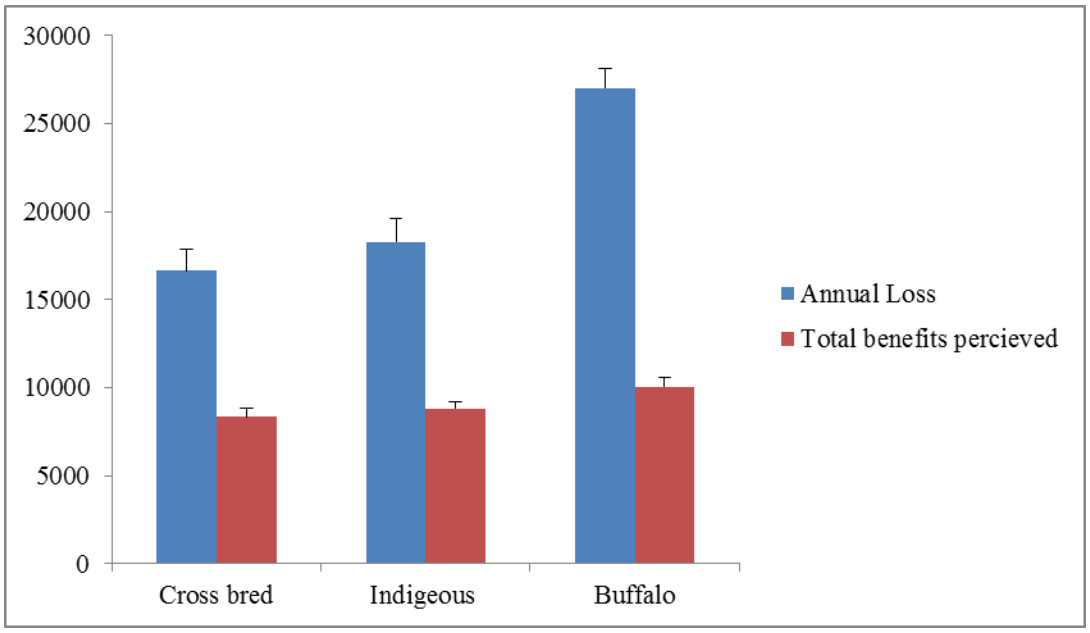


Fig. 24: Economic Losses *vs* Total Benefits perceived per animal

Different studies were conducted to estimate the losses due to extended open days of dairy animals. To compare estimates from different studies, it depends on the values and parameters to be estimated and days open or the calving interval. Methodological differences and economic context differences exists between different areas and time period (Seegers *et al* 1994). In our study, one day delays in conception during the 290 days of lactating animals excluding the post-calving period of 100 days were Rs 78.13. similar finding were calculated from the previous studies focused primarily on the impact of the conception rate, that one day of delay in conception was calculated to cause $2.03 or Rs 131.95 (Lineweaver, 1975), $1.24 or Rs 80.6 (DeVries and Conlin, 2003) loss in the United States and £2.41 (Rs 233.77) loss in the UK (Esslemont *et al* 2000) for an average milking cow, De Vries (2003) €0.28 –1.10 (Rs 21.49 – 84.43; Groenendaal (2004) €0.06 –1.03(Rs 4.6 -79.06); Meadows (2005) €0.47–€0.79 (Rs 36.07- 60.64). Esslemont *et al* (2000) also reported a loss of £6.52 (Rs 606.25) per day for a high producing cow to become pregnant between 206 and 235 days post-calving (Kafi *et al* 2007).

Few studies contradict to our findings, Pawshe *et al* (2011) reported an estimated loss from Anestrus around Rs.193.00 per day in cow while Kumar *et al* (2013) reported Rs. 372.90 per day in buffalo. Plaizier (1997) calculated the loss per day open €2.95(Rs 226.44) and Veerkamp (2002) €2.07 (Rs 158.89). In our study, due to the difference in components taken into account consideration for calculating economic loss annually, the type of farming, the marketing values of animals and milk loss taken into consideration, lower prevalence of Anestrus compared to above said studies and also the extra feeding cost during the open days of Anestrus animals were not considered.

Among the different ACZ's of Punjab, the most affected region was the western region including districts of Faridkot and Muktsar, and other border districts of Punjab were affected by Anestrus due to poor awareness about management of Anestrus animals, poor record keeping, small dairy units hence less care and management, engagement in agricultural lands and providing poor fodder to their animals which remains deficient in important ingredients for maintaining the good reproductive performance of dairy animals. The least affected regions of this state were the Flood plain region, had put dairy business in the urban and sub-urban regions and commercialized their dairy rearing cross bred animals, awareness about

this problem and proper veterinary infrastructure to tackle this problem, hence this problem was not observed much in medium and large dairy herds.

The overall economic loss incurred by dairy farmers due to Anestrus irrespective of species of animals was Rs. 24362 (Fig 24). The mean economic losses per animal per year affected varied significantly ($p<0.05$) among different categories of animals, and was highest in cross bred followed by buffaloes and least in indigenous cattle. At species level (Fig 23), the largest component of the economic losses were due to replacement cost (78.58% in cross bred, 78.72% in indigenous cattle and 58.57% in buffaloes), followed by milk yield loss cost (13.69% in cross bred, 12.73% in indigenous cattle and 27.90% in buffaloes). Among the different agroclimatic zones, highest loss was observed in Central plain region (Rs 27384.63±2407.03) and the least affected zone was Flood plain region (Rs. 19135.6± 4326.50).

4.3.5.3. Total benefits perceived by the dairy farmers per animal per year controlling Anestrus in different agro climatic Zones of Punjab

From the Table 79, the overall benefits simulated for the dairy farmers controlling Anestrus across the different categories of animals in different ACZ's of Punjab were Rs. 9063.83. It didn't vary significantly ($p<0.10$) between the different species and different ACZ's of Punjab with highest returns estimated in buffaloes Rs.10038.69±561.17, followed by indigenous and cross bred cattle of Rs. 8798.83±380.22 and Rs. 8353.99±478.99 respectively. The highest returns forgone was estimated in Zone III (Rs. 9350.03±538.50), followed by Zone II (Rs. 9200.33± 1896.25), while as the lowest returns forgone was simulated in Zone I (8691.61± 535.89) followed by Zone IV (8758.11±747.14). The benefit cost ratio of cross bred cattle, indigenous cattle and buffaloes were in the ratio of 3.54, 4.39 and 5.01 respectively, if the control measures (like mineral mixture, estrus detection, teaser bulls, comfort zone of animals) were assumed to cost Rs 2500 for cross bred cattle and Rs 2000 for indigenous cattle and buffaloes. From the Benefit cost analysis, it may be concluded that the buffaloes may get the highest returns if the control measures could be promoted efficiently to them. From the above facts, it can be summarised that net returns forgone were maximum among the buffaloes due to their highest occurrences among the species and the anticipated control measures taken by farmers level and they will benefit them in future to get their maximum output. However, in cattle, returns forgone will also be higher, if the farmers could take the control measures and maintain good managemental practices. A study by Inchaisri *et al* (2010) estimated the impact of

animals on average reproductive performance and good reproductive performance and reported that the economic losses due to non-optimal fertility in an average reproductive performance cow were €34 per cow per year (Rs 2609.84) as compared to the losses of €231 per cow per year (Rs 17731.56) in a good reproductive situation cow.

The overall benefits forgone simulated for the dairy farmers controlling Anestrus through various preventive measures (Fig 24) was Rs. 9063.83. It did not vary significantly ($p<0.01$) across the species, however was highest in buffaloes (Rs. 10038.69±561.17), followed by indigenous cattle (Rs. 8798.83±380.22) and cross bred cattle (Rs. 8353.99±478.99). Through benefit cost analysis, the intervention of various control measures of Anestrus, the maximum benefits were estimated to be observed in cross bred animals followed by indigenous cattle and buffaloes respectively.

From the Fig 25, the most costly important diseases of dairy animals among the selected five diseases in our study were the Anestrus, followed by RB, FMD, Mastitis and HS with annual losses per animal in Punjab state were Rs. 24362±1273.04, Rs. 16997±2894.44, Rs. 13871.14±5707.80, Rs. 12028.0±5030.71 and Rs. 5111.64± 1482.32, respectively. From this study, we may estimate the projected loss of selected diseases of dairy animals due to Anestrus, RB, FMD, Mastitis and HS were Rs. 213.57 crores, Rs. 159.70 crores, Rs. 110.84 crores, Rs. 775.66 crore and Rs. 211.37 crores respectively.

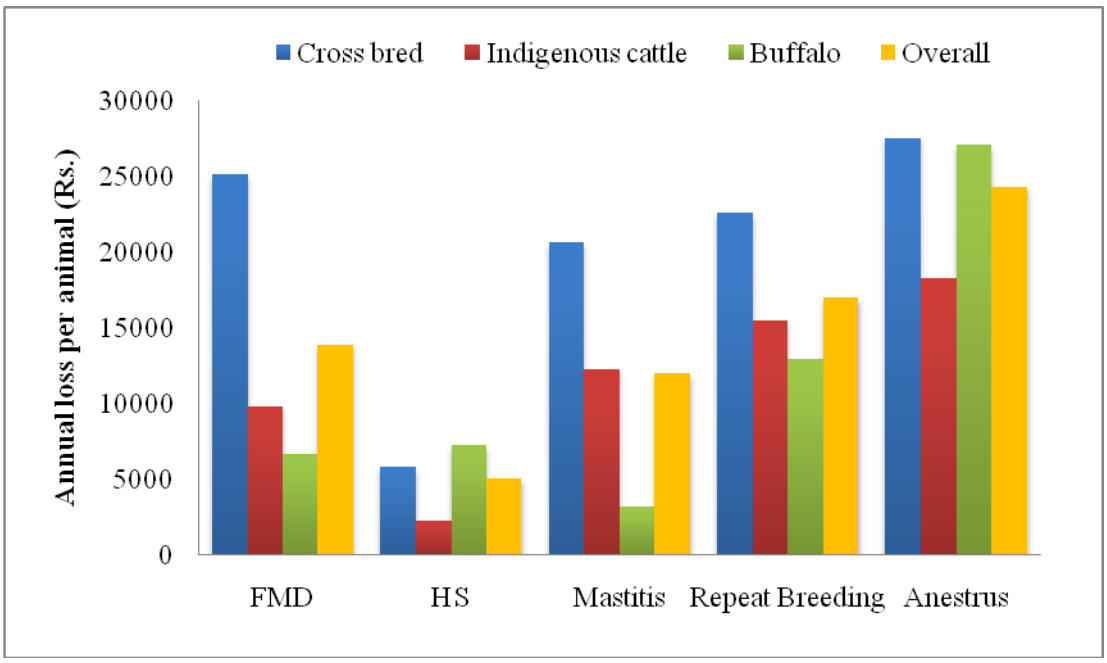


Fig. 25: Projected annual losses per animal due to important diseases of dairy animals in Punjab

4.3. Economic impact on dairy farmers due to economic losses of diseases

From the Table 88, majority (93.47%) of the livestock farmers in the study area opined that their important permanent asset was lost and further asset creation and multiplication was curtailed due to various Government schemes and transportation of animals to sell their unproductive animals. Around 81.80% and 80.97% of farmers experienced psychological stress (financial burden) and affected agricultural productivity (less attention in crop cultivation and lack of cow dung), respectively. A sizable number of affected farmers (67.91%) also lost their employment on their farms due to these diseases. Impact on consumer behavior (57.63%) after the disease occurrence also affected their returns from their milk and milk products due to public health concerns. Most commercial farmers especially rearing cattle were willing to lose dairy farming business (32.08%) due to lesser returns from the farm and sale of their unproductive animals.

The impact of animal diseases losses on dairy farmers due to financial losses and unable for the creation of household assets like building, machineries, gold (17.91%), increased borrowing for meeting consumption needs of the family (12.91%), additional medical expenses for the family (18.88%), Unable to repay the loan to financial institutions (10.83%) and negative impact on the education of their children (8.05%). Other social impacts perceived by the farmers are presented in Table 88.

Besides financial losses, a majority of the farmers opined that the animal diseases caused a huge burden on the family in both the short term and long term. They felt that their important permanent income earning asset is lost due to animal diseases like FMD, HS, and Mastitis, as small holders are highly dependent on livestock for their daily household consumption and income generation on regular basis. They additionally felt that mortality of animals restricted the asset creation and multiplication as they consider livestock as an asset of economic and social value. Around 73.88% of the farmers experienced psychological stress as the majority of them are small holders whose livelihood depends on one or two animals owned by them. Their agricultural productivity is also affected due to the diversion of their managerial and labour resources for nursing the animal than raising crops, thus paying less attention in performing important and timely agricultural operations. Hence, it can be inferred from the findings that animal diseases cause huge financial burden on livestock farmers as well as their social well-being. Thus, the estimated losses and

social impact due to animal diseases signify the importance of the intervention to control the disease and thus socio-economic gain to the dairy farmer and society at large. Similar findings were observed from the study of Govindaraj *et al* (2017) on the farm community impacts of FMD outbreaks in cattle and buffaloes in Karnataka State. They revealed that majority of the livestock owners perceived FMD had caused permanent asset loss, which in turn increased the psychological stress of the family.

It may be concluded that the major impact on dairy farmers due to economic losses by various animal diseases was due to loss of livestock asset of the farm families and its creation, regular income loss affected their savings pattern, affected agricultural productivity, loss of employment of the farmer/farm labour, increased psychological stress and farmers willing to lose dairy farming business.

Table 88: Economic impact on dairy farmers due to losses by various diseases.

Economic impact on dairy farmers due to losses by various diseases		**Number of farmers (%)**
i.	Livestock asset of the farm families and its creation is lost	673 (93.47)
ii.	Farmers willing to lose dairy farming business	231 (32.08)
iii.	Regular income loss affected their savings pattern	589 (81.80)
iv.	Affected medical expenses burden for family	136 (18.88)
v.	Impact on consumers behavior after the disease occurrence	415 (57.63)
vi.	Unable to repay loan to financial institutions	78 (10.83)
vii.	Affected the education of their children	58 (8.05)
viii.	Affected daily food consumption pattern	152 (21.11)
ix.	Affected household asset creation like building, machineries, gold.	129 (17.91)
x.	Increased their borrowing for meeting consumption needs	93 (12.91)
xi.	Increased psychological stress	532 (73.88)
xii.	Affected agricultural productivity (less attention in crop cultivation and lack of cow dung)	583 (80.97)
xiii.	Employment of the farmer/farm labour is lost	489 (67.91)

4.4. Constraints for controlling important diseases using Garrett's ranking technique

Various constraints of controlling important diseases were enlisted to farmers and were ranked as per they perceive and were further analyzed by Garrett's ranking technique in different agroclimatic zones of Punjab to rank them as per the Garrett's mean score value and finally an overall modal value of different Zones were calculated to rank different categories accordingly. Various constraints in controlling important diseases by using Garrett's ranking technique are mentioned as:

4.4.1. Constraints to control FMD in different ACZ's of Punjab

FMD is one of the costly disease causing huge economic losses due to abrupt milk reduction and mortality of animals. Table 89 presents the constraints of controlling FMD in different ACZ's of Punjab. Since the vaccination coverage is not 100% in the state (93.4% by Directorate Animal Husbandry Punjab, 2016), due to failure of prophylactic vaccination and higher cost medication of treating affecting animals were the major constraints across the different ACZ's of Punjab. In Punjab, FMD prevalence was frequently encountered as reported earlier and only sporadic outbreaks may be recorded due to logistic factors in transportation, storage, and administration of the vaccine adversely affecting the vaccination program. The other reason might be that animals may not adequately respond to vaccinations due to host factors like immunosuppression due to parasitic or other such immunosuppressive diseases, nutritional deficiency, genetics and maternal antibody levels.

Strict biosafety and sanitary measure ranks 3rd as per the Garrett's mean value across all the different ACZ's except in Zone I and Zone II (ranks IV with inadequate early disease detection and isolation). Due to overcrowding of animals, regular fumigation and strict movement of men and animals were not practiced and poor drainage system propels its condition.

An inadequate diagnostic tool for early detection and isolation of affected animals at nearby veterinary dispensaries was the major constraint and ranks 4th across the different ACZ's of Punjab. Farmers were not educated enough about the early symptoms of FMD, they come to know once the disease had put its impact on animal health and has clear cut signs among affected animals.

Table 89: Constraints for controlling FMD in dairy animals by Garrett's Ranking Technique from different ACZ of Punjab.

S. No.	Category of control measures	Agro-climatic zone												Overall Rank
		I		II		III		IV		V		VI		
		Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	
1	Failure of prophylactic vaccination	80.5	I	80.5	I	86.37	I	81.09	I	79.7	I	80.76	I	I
2	Higher Cost of treatment	76.37	II	76.37	II	76.83	II	79.11	II	77.11	II	76.48	II	II
3	Strict biosafety and sanitary measures	69.54	IV	69.54	IV	70.49	III	71.78	III	68.02	III	68.17	III	III
4	Inadequate early disease detection and isolation	71.59	III	71.59	III	65.47	IV	65.53	IV	67.75	IV	70.13	IV	IV
5	Poor availability of veterinary service during emergency time	63.59	V	63.59	V	63.63	V	63.56	V	61.52	V	61.3	V	V
6	Poor extension service	56.82	VI	56.82	VI	55.57	VI	57.55	VI	57.17	VI	57.25	VI	VI
7	Segregation of affected animal protocols not followed	54	VII	54	VII	55.5	VII	53.7	VII	53.87	VII	52.44	VII	VII
8	Disposal of affected carcass in the open	47.14	VIII	47.14	VIII	44.11	VIII	43.55	VIII	48.33	VIII	46	VIII	VIII
9	Poor animal health status	38.65	X	38.65	X	41.02	IX	43.34	IX	45.41	IX	44.24	IX	IX
10	Govt. regulations in slaughtering or culling of affected animals	39.4	IX	39.4	IX	37.79	X	38.39	X	38.72	X	40.83	X	X

Poor veterinary service during the outbreak of disease was among the 5th major constraint perceived by dairy farmers across the different ACZ's of Punjab. Since, there is abrupt reduction in milk production during the disease occurrence putting an impact on dairy farmers financial loss. Also due to contagious nature of the disease, it should be controlled as early as possible which needs veterinary service to treat properly the affected animals.

Poor extension service to aware dairy farmers backed up by a good disease reporting or information system was at 6th rank as per the Garrett's mean score value for different ACZ's of Punjab. Farmers were not aware about the FMD control measures and improved farm management practices.

The next major constraint ranked at 7th position from the Garrett's mean score values across the different ACZ's to control FMD was segregation of affected animal protocols not followed except in Zone I and Zone II.

Disposal of affected carcass in the open was ranked at 8th position among the different ACZ's of Punjab and was considered an important constraint to control the FMD at farm level. Similarly, poor animal health status due to deficiency of adequate balanced nutrients in the diet and stressful condition in the farm due to poor hygiene, poor ventilation and heat stress etc. was ranked at 9th position from the overall modal value in Zone III, IV, V & VI, whereas Zone I and Zone II were having problem of culling the affected animals. Government regulations in slaughtering and culling of affected animals was also one of the constraint in controlling FMD and was ranked 10th from the overall modal values of Garrett's mean score value.

Both globally as well as in India, economic consequence is the primary driver to control FMD. Sero-monitoring and sero-surveillance of non-vaccinated and vaccinated animals; animal movement restriction (both inter-state as well as transboundary) are the upmost measures that should be undertaken (Grubman and Buxt 2004, Verma *et al* 2008, Nishiura and Omori 2010 and Longjam *et al* 2011). Due to limited resources, the use of vaccines based on epidemiological data for controlling FMD in India has several challenges that had to be overcome. Recent molecular diagnostic tools, effective disease surveillance/monitoring systems are required to be applied widely for detecting FMD virus and its disease outbreaks in

animals so as to follow appropriate prevention and control measures timely (Madhanmohan *et al* 2012, Xu *et al* 2013 and Chakraborty *et al* 2014).

It may be concluded that the major constraints in controlling the FMD like failure of adhering to prophylactic vaccination, higher cost of treatment, strict biosafety and sanitary measures not followed, inadequate early disease detection and isolation and poor availability of veterinary and extension services be curbed at farmers door step for promoting the dairy farming business in a more profitable manner in the state.

4.4.2. Constraints for controlling HS using Garrets Ranking Technique in different ACZ's of Punjab

Prevalence of HS in this region causing a huge economic loss to the dairy farmers creating an optimum decision to control this disease by planners and other people associated with this sector. Control of diseases and subsequently eradication requires isolation and quarantine of sick animals as well as animals suspected for disease; strengthening disease monitoring and surveillance, vaccines and vaccination strategies along with other control measures (Thrusfield 2007) which is not feasible under Indian perspective due to small units of dairy farming as well as small land holding by rural people. Hence strict and well planned control measure needs to be taken in favour of farmers to overcome its burden. Hence, the various control measures that a dairy farmer perceived in the study area has been presented in Table 90.

First major constraint was the failure of prophylactic vaccination in Zone I, II, III and VI whereas, in Zone V (Western plain), the major constraint was higher cost of treatment of affected animals and in Zone V the first major constraint was inadequate early disease detection. From the previous study, there were sporadic cases of HS outbreak in various regions of the state that might due logistic factors in transportation, storage, administration of the vaccine adversely affecting the vaccination program. The other reason might be that animals may not adequately respond to vaccinations due to host factors like immunosuppression parasitic or other such immunosuppressive diseases, nutritional deficiency, genetics and maternal antibody levels.

Table 90: Constraints for controlling HS in dairy animals by Garrett's Ranking Technique from different ACZ's of Punjab.

S. No.	Category of control measures	Agro-climatic zone												Overall Rank
		I		II		III		IV		V		VI		
		Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	
1	Failure of prophylactic vaccination	88.27	I	82.33	I	88.03	I	62.28	V	81.54	II	81.34	I	I
2	Higher Cost of treatment	81.88	II	77.73	II	58.32	VI	78.71	II	82.83	I	70.48	IV	II
3	Strict biosafety and poor sanitary measures	72.39	III	64.92	III	75.01	II	81.97	I	77.95	III	67.77	V	III
4	Inadequate early disease detection	66.93	IV	64.17	V	61.49	IV	68.47	III	63.19	IV	74.44	II	IV
5	Poor availability of veterinary service during emergency time	65.02	V	64.73	IV	65.92	III	56.18	VIII	56.84	V	71.57	III	V
6	Poor extension service	54.85	VI	56.19	VI	58.69	V	46.66	IX	51.07	VIII	59.47	VI	VI
7	Segregation of affected animal protocols not followed	44.06	VIII	50.88	VIII	52.25	VIII	56.22	VII	51.08	VII	53.94	VIII	VIII
8	Disposal of affected carcass in the open	48.18	VII	57.62	VII	56.03	VII	67.17	IV	53.27	VI	55.58	VII	VII
9	Poor animal health status	42.64	IX	40.53	IX	41.34	IX	40.93	X	43.57	IX	34.53	IX	IX
10	Govt. regulations in slaughtering or culling of affected animals	33.38	IX	38.5	X	40.52	X	62.28	VI	36.26	X	28.48	X	X

The next major constraint across the different Zones of Garrett's mean score value was the higher cost of medication for diseased animals except in Zone I, V and VI (ranks 6^{th}, 1^{st} and 4^{th} respectively). Higher cost of veterinary service during the emergency time and use of costly medicines to treat the animals were percieved by the dairy farmers as the next major constraint in controlling HS in the region.

Strict biosafety measures and poor sanitary condition of dairy farm ranks 3^{rd} from the Garrett's mean value across all the different ACZ's except in Zone III, IV & VI (ranks 2^{nd}, 1^{st} & 5^{th} respectively) with Inadequate early disease detection and its diagnosis in various regional laboratories.

Due to overcrowding of animals, regular fumigation not practiced strict movement of men and animals not followed and poor drainage system accelerates the occurrence of HS due to its contagious nature.

The next major constraint was an inadequate diagnostic tool for early detection at nearby regional diagnostic laboratories and ranks 4^{th} across the different ACZ's of Punjab except in Zone II (ranks 5^{th} and Zone VI (ranks 2^{nd}). Farmers were not aware about the early symptoms of HS, they came to notice once the disease had put its impact on animal health suddenly.

Poor veterinary service during the outbreak of disease was among the 5^{th} major constraint perceived by dairy farmers in Zone I & V. Since, this constraint was not prominent in this region as the farmers were well aware about the outcome of this disease. But, due to contagious nature of the disease, it should be controlled as early as possible which needs veterinary service to treat properly the affected animals and give proper guidance to them as per the requirement.

The 6^{th} major constraint perceived by dairy farmers across different Zones of Punjab (Zone I, II & VI) was the poor extension service to aware dairy farmers backed up by good disease reporting or information system, as the farmers were not acknowledged about the HS control measures and improved farm management practices.

The next major constraint ranked at 8^{th} position from the Garrett's mean score values across the different ACZ's (Zone I, II, III & VI) to control HS was segregation of affected animal protocols not followed except in Zone I and Zone II (ranks 7^{th}).

Affected animals were not isolated from the healthy herd especially in small herd groups. Commercial farmers follow this method of separation of affected animals in a separate shed. Quarantine of newly purchased animals was not followed.

Disposal of affected carcass in the open area was ranked at 7^{th} position among the different ACZ's of Punjab and was considered an important constraint to control the HS at farm level. Affected animals were not buried deep or incinerated to prevent exposure of pathogens to targeted healthy animals. Similarly, poor animal health status due to deficiency of adequate balanced nutrients in the diet and stressful condition at the farm due to poor hygiene, poor ventilation and heat stress etc. was ranked at 9^{th} position from the overall modal value from all the Zones except in Zone IV (ranks 10^{th}). The main reason for this constraint was due to higher cost of branded feed in the market, animal comfort Zones were not sufficient and due to overcrowding of animals.

Government regulations in slaughtering and culling of affected animals impedes the elimination of this disease and was ranked at 10^{th} position from the overall Garrett's mean score value in Zone II, III, V & VI

In India, due to limited resources, the use of vaccines based on epidemiological data for controlling HS has several challenges that have to overcome. In future, recent molecular diagnostic tools, effective disease surveillance/monitoring systems are required to be applied widely for detecting HS virus and its disease outbreaks in animals so as to follow appropriate prevention and control measures timely. Hence, it may be concluded that the major constraints in controlling the HS like Failure of prophylactic vaccination, Higher Cost of treatment, strict biosafety measures and hygienic sanitary conditions not followed, inadequate early disease detection and poor availability of veterinary and extension services could be curbed at farmers door step, it will promote the dairy farming business in a more profitable manner.

4.4.3. Constraints for controlling Mastitis using Garrets Ranking Technique in different ACZ's of Punjab

Table 91 illustrates the control measure against Mastitis in different ACZ's of Punjab. It has been suggested that Mastitis can never be eradicated from dairy operations but its occurrence can only be minimized to the acceptable levels. Major

risk factors predominantly responsible for Mastitis were common in this region viz. large herd size (Abebe *et al* 2016), cross bred and exotic breeds (Sanotharan *et al* 2016), not milking mastitic animals at the end (Belayneh *et al* 2013), absence of bedding material (Radostitis *et al* (2000), a higher proportion of multiparous older cows with four or more parities (Mureithi and Njuguna 2016), early stage of lactation (Iraguha *et al* 2015), and teat end morphology (Bharti *et al* 2015). There were variations in the type of constraints that farmers face related to their ability to comprehend the problem, accessibility to control supplies and sophistication of farming enterprises as well as management routines. The present study was conducted to analyze various major constraints controlling Mastitis due to its higher prevalence in the study area, which makes a major hurdle in dairy production from the different ACZ's of Punjab. From the different Zones, the ranking obtained for different constraints with their respective Garrett's mean score value is presented in Table 91.

Higher cost of treatment due to Mastitis in dairy animals including the cost of medication, veterinary charges etc. were the major constraint and ranks first except in Zone II and Zone V (having cleanliness of animal shed as their major constraint). Since the dairy farmers are trying to treat affected animals using cheap antibiotics without proper recommended dosage that leads to antibiotic resistance to animals and next time they had to use more dosages of antibiotics which are more expensive hence put more burden on dairy farmers. The present is concurred with the study conducted by Christy (2014) that higher cost of treatment rank first due to high resistance of the common and cheap antibiotics (Byarugaba *et al* 2008). Shortage of skilled labour and higher wage rate made it very difficult to practice routine disease preventive measures that might have prevented the occurrence of Mastitis.

Cleanliness of animal and animal shed was second major constraint in almost all the Zones except in Zone II and Zone V (cost of medication as their major constraint). The Garrett's mean score was highest among all these Zones, since the farmers face major hurdle in cleanliness of animal shed regularly due to poor drainage of animal's defecation and urine. Maintaining excellent cow hygiene is an essential practice for controlling Mastitis in the dairy herd as many studies had found a correlation between clean cows and lower bulk tank SCC (Steeneveld *et al* 2008,

Ranjan *et al* 2011). Similarly, some studies have proved that poor hygiene results in udder health problems (National Mastitis Council, 2007). Christy (2014); Byarugaba *et al* (2008) and Mureithi and Njuguna (2016) also reported that Prevalence of poor environmental hygiene and dirty udder and leg as one of the major constraint in Mastitis.

Poor diagnostic tools for early detection of subclinical Mastitis and antibiotic sensitivity report of affected animals was also the third major constraint in all Zones except in Zone I and Zone V (Effective pre milking and post milking teat dips as third major constraint).

Effective pre milking and post milking teat dips and udder wash by proper disinfectant was also found to be the major fourth constraint in controlling Mastitis in all Zones except Zone I and Zone V (Poor diagnostic tools for early detection of Mastitis as their fourth major constraint. Nickerson, (2001) concluded that Pre-milking teat disinfection was developed as a simple, effective and economic method to control environmental pathogens by reducing bacterial populations on teat skin before milking, thus minimizing their penetration into the teat canal. The vast majority of post milking teat dip products have the capability of reducing new intramammary infections by at least 50%, and, in some cases, as much as 95%. However, Oliver *et al* (2001) reported that postmilking teat disinfectants have not proven to be effective in controlling Mastitis due to the environmental pathogens such as coliforms and streptococci other than S. agalactiae.

The fifth major constraint in Zone I, II, III and IV was the lack of extension services to educate farmers about the importance of early diagnosis of sub clinical Mastitis, its economic burden, preventive measures like use of teat dips, and animal hygiene measures. Karimuribo *et al* (2006) reported that lack of knowledge on subclinical Mastitis among smallholder farmers was the major constraint in controlling Mastitis.

Table 91: Constraints for controlling Mastitis in dairy animals by Garrett's Ranking Technique from different ACZ's of Punjab.

S. No.	Category of control measures	Agro-climatic zone												Overall Rank
		I		II		III		IV		V		VI		
		Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	
1	Cost of treatment	85.29	I	79.43	II	82.26	I	83.24	I	76.35	II	80.5	I	I
2	Poor cow hygiene and animal housing	78.83	II	83	I	78.42	II	76.01	II	80.5	I	76.37	II	II
3	Poor diagnostic tools for early detection of Mastitis	70.1	IV	72.48	III	70.6	III	69.18	III	69.54	IV	69.54	III	III
4	Udder wash before and after milking by use of disinfectant or Effective pre-milking teat dips.	70.55	III	69.69	IV	68.63	IV	69.18	IV	71.59	III	71.59	IV	IV
5	Lack of extension service to inform dairy farmers against the control of Mastitis	62.91	V	62.91	V	64.91	V	65.59	V	54	VII	56.82	VI	V
6	Dry cow therapy	58.65	VI	57.35	VI	56.53	VI	56.08	VI	56.82	VI	63.59	V	VI
7	Feeding animals after milking	50.02	VII	50.17	VII	50.48	VII	53.4	VII	63.59	V	54	VII	VII
8	Biosafety measures in the shed	45.34	VIII	43.18	VIII	44.12	VIII	43.2	VIII	47.14	VIII	47.14	VIII	VIII
9	Higher cost of branded feed	37.61	X	38.39	X	39.67	X	40.65	X	38.65	X	38.65	X	X
10	Poor record keeping for Culling of animals with chronic Mastitis or repeated clinical Mastitis	38.3	IX	41	IX	41.98	IX	41.07	IX	39.4	IX	39.4	IX	IX

Practice of dry cow therapy was also poor among the dairy farmers and ranks 6th constraint in controlling Mastitis in all the ACZ's of Punjab except Zone VI (lack of extension service ranks 6th as per the Garrets mean score value) due to commercialized dairy operations. This problem of practicing dry cow therapy might be because of farmers unawareness and cost factor. Bradley and Green (2001) reported that antibiotic dry cow therapy has two functions: remove pre-existing intramammary infections that are present at drying off and to prevent any new intramammary infections from forming during the dry period. Green *et al* (2007) studied about the susceptibility of the bovine mammary gland to infection during the dry period is considered to be greatest in the days after drying off and in the three weeks just prior to calving.

The next major constraint was unawareness of farmers about feeding practice before and after milking to keep animal busy in standing position on order to prevent entry of pathogens through teat canal which remains open after milking. This constraint ranks 7th as per the Garrett's mean score value across all the ACZ's except in Zone V (lack of extension service ranks 7th as per the Garrets mean score value).

Poor biosafety measures in the animal shed ranks 8th across all the Zones followed by poor record keeping for animals to be culled due to repeated clinical Mastitis and chronic Mastitis ranks 9th as per Garrett's mean score value across all the ACZ's of Punjab. Poor record keeping of these affected animals may lead to transmission of infection to healthy animals which may be further overpowered by poor biosafety measures undertaken at majority of the dairy farms.

Higher cost of the branded market feed is the cause of triggering the problem of controlling Mastitis and it ranks 10th as per the Garrett's mean score value. Animals were poorly fed to well-balanced nutrients leading them to immunologically weak hence can't cope the infection from environmental opportunistic pathogens leads to unhealthy udder conditions. Chew *et al* (1982) conducted a study on correlation between vitamin A and β- carotene on Mastitis management for the maintenance of functional integrity of epithelial tissues lining the body cavities. This functional state of the epithelium regulates the transfer of immunoglobulins and the production of bactericidal agents such as keratin. Due to this, it is possible that when the epithelium deviates from its healthy state, these would be increasingly susceptibility to the mammary gland due to invasion by pathogens.

Scanning through the literature, no direct references were available to compare the Mastitis ranking as per the farmer's perceptions. From the above facts, it may be concluded that occurrence of Mastitis was based on many factors from diagnosis to lack of extension service, but the higher cost of treatment to the cost of feed were the most important factors to control Mastitis at the farmers based on Garrettes ranking technique. Hence, it is suggested that proper management of clinical and subclinical Mastitis will not only promote the health status of a herd, but ensure high quality of milk produced and the economic viability of a dairy business.

4.4.4. Constraints for controlling Repeat Breeding in cattle and buffaloes using Garrets Ranking Technique in different ACZ's of Punjab

Measures to remove constraints of RB in dairy animals by using Garrett's ranking technique has been presented in Table 92. RB accounted for a considerable financial losses and economic setback to dairy farmers, whereby, it delays in calving period and increases dry period causing low milk production per lactation. In Punjab, the proportion of animals suffering from RB was skewed towards cattle than buffalo that was quite alarming from the economic point of view. Proper allocation of additional resources in dairying, to remove the constraints of controlling RB, in order to increase milk production and generate surplus to the society. Various constraints of controlling RB were enlisted to farmers and were ranked as per they perceive and were further analyzed by Garrett's ranking technique in different ACZ's of Punjab.

The first major constraint perceived across all the Zones in the study area was lack of effective and accurate estrous detection when estrous detection is faulty, standing estrus is less likely to be observed and more cows were inseminated on the basis of signs other than standing estrus. This results an inaccurate timing of insemination, which in turn results failure to conceive. The other reason associated with this constraint was that farmers remain busy with their work schedule, farmers were unable to detect estrus or silent heat during summer season. Nowadays teaser bulls are not used to detect estrus in dairy farms, since natural service was replaced by artificial insemination. Inadequate and inaccurate estrus detection was frequently a cause of cows becoming repeat breeders. Rorie *et al* (2002) reported that estrus detection is less than 50% on many dairy farms and there is a substantial need for accurate and efficient heat detection. Utilizing a combination of estrus detection aids

to improve both accuracy and number of animals getting inseminated in estrus will improve conception rates.

The second major constraint perceived across different ACZ's (III, V & VI) in the study area was the nutritional imbalances due to poor transition and nutritional management and due to higher cost of branded feed available in the market leads to deficiency of essential minerals. Imakawa *et al* (1986) reported that poor nutrition or underfeeding occurs most frequently and results weak estrus expression and reduced ovulation, extended periods of Anestrus following calving, low conception and fertilization rates. Royal *et al* (2000) reported that large negative energy balance during post-partum period was associated with reduced BCS and subfertility

Poor management practices like poor farm hygiene, poor record keeping, inadequate feed provided and concurrent disease issues like endometritis, cervicitis, anatomical defect, Mastitis or lameness etc. ranked at 4^{th} position across different Zones (III, V & VI).

Improper timing of insemination ranked at 3^{rd} position from the overall Garrett's mean score value in different agroclimatic Zones (II, III, V & VI). This constraint was due to improper storage, thawing, post thaw handling of semen, incorrect and inappropriate insemination with respect to stage of estrus. Correctness and precision of these steps were mandatory in achieving high success rate with AI (Salisburry *et al* 1985).

Poor veterinary service was ranked at 5^{th} position across all the ACZ's of Punjab. Proper diagnosis and treatment of affected animals could be made by veterinary doctors who were not showing interest at field level in gynecological cases like pregnancy diagnosis, examination of repeater animal etc. they had put this service to lower staff, who were not expertise of this specialization.

The next major constraint in controlling RB in farm animals was the poor semen quality and this constraint was found across all the Zones (except Zone V) and was ranked at 6^{th} from the overall Garrett's mean score value.

Table 92: Constraints for controlling RB in dairy animals by Garrett's Ranking Technique from different ACZ's of Punjab.

S. No.	Category of control measures	Agro-climatic zone												Overall Rank
		I		II		III		IV		V		VI		
		Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	
1	Lack of Effective and accurate estrous detection	76.3	I	80.02	I	77.87	I	74.18	I	80.27	I	75	I	I
2	Nutritional imbalances	67.56	III	68.32	IV	75.4	II	70.13	IV	73.48	II	74.23	II	II
3	Improper farm management	69	II	71.43	II	72.18	IV	71.01	III	70.39	IV	71.57	IV	IV
4	Improper timing of Insemination	65.38	IV	71.08	III	73.04	III	71.8	II	70.47	III	71.67	III	III
5	Poor veterinary service available	63.52	V	66.23	V	65.79	V	65.73	V	64.71	V	66.2	V	V
6	Poor semen quality	60.88	VI	57.13	VI	58.73	VI	60.08	VI	54.65	VII	57.15	VI	VI
7	Improper cooling and cow comfort/heat stress	53.18	VII	51.38	VII	51.64	VII	54.4	VII	55.98	VI	54.93	VII	VII
8	Inadequate early detection of pregnancy	51.63	VIII	46.38	VIII	43.19	IX	45.96	IX	44.2	IX	47.95	VIII	IX
9	Lack of extension service	44.57	X	43.87	IX	43.64	VIII	47.12	VIII	44.58	VIII	41.17	X	VIII
10	Problem of culling unproductive animals	45.58	IX	41.76	X	36.12	X	37.19	X	38.87	X	37.73	IX	X

Heat stress or improper cooling and cow comfort Zone of animals especially high yielders HF cows was the major cause of RB and was ranked at 7th position in all the agro climatic different Zones of Punjab (except Zone V). Since the temperature remains higher during summer season, farmers were not able to cope the heat stress affecting animal health production and were not able to detect heat during summer especially in buffaloes. This heat stress was also responsible for lower milk production and also responsible for occurrence of various diseases in farm animals.

Poor Extension service ranked at 8th position among the different ACZ's (III, IV & V). Proper extension service was not provided to reach out every corner of the state to aware farmers about the RB management at farm level. Farmers should be made aware about the estrus signs, early pregnancy detection, importance of well-balanced nutritional diet etc.

Inadequate early detection of pregnancy ranked at 9th position from the overall Garrett's mean score value in different ACZ's of Punjab (III, IV & V). Since the early detection of pregnancy at field level was not possible that make livestock owners in a dilemma about their reproductive status of their farm animals.

Culling of affected animals not conceiving repeatedly ranked at 10th position across different agro climatic different Zones of Punjab except Zone I & VI. This constraint arises due to government regulation in trade and slaughter of unproductive animals. Agarwal *et al* (2005) estimated that majority of cattle and buffaloes (18-40%) were culled and reach to slaughter house primarily due to infertility. However, it has been reported that 37.5% buffaloes end up in slaughter houses due to various reproductive problems (Sharma *et al* 1993).

Finally, a comprehensive, ongoing reproductive management program, involving a team effort by the dairy farmers, inseminator and veterinarian, is the key to success in diagnosing, treating and preventing the problem of RB. One of the important measures to remove constraints is to increase the intensity of veterinary institutions which will improve accessibility and veterinary health of dairy animals especially that of crossbred cows that need it more. Overcoming the problem of mineral deficiency among lactating crossbred cows will alone reduce fifty per cent of the losses and any such effort is going to have the highest benefit-cost ratio.

4.4.5. Constraints for controlling Anestrus in cattle and buffaloes using Garrets Ranking Technique in different ACZ's of Punjab

Control measures to remove constraints of Anestrus in dairy animals by using Garrett's ranking technique has been presented in Table 93. Anestrus accounted for a considerable financial losses and economic setback to dairy farmers like increased open days, reducing milk production per lactation, future calf loss etc. In Punjab, the proportion of animals suffering from Anestrus was higher and remained mainly limited to buffaloes than cattle (almost half percentage to buffaloes) due to silent heat during summer season. However, proper allocation of additional resources in dairying to remove the constraints of controlling Anestrus were enlisted by dairy farmers during the survey period and were ranked accordingly which they perceive and latter analyzed by Garrett's ranking technique in different Zones of Punjab to rank them on this basis of Garrett's mean score value.

The first major constraint perceived across different ACZ's of Punjab (I, II, IV, V & VI) in the study area was the Nutritional imbalances due to poor transition and nutritional management and due to higher cost of branded feed in the market leads to deficiency of essential minerals. Farmers couldn't afford the costlier branded mineral mixture at higher rates, makes animal deficient in essential nutrients. Large negative energy balance during post-partum period is associated with reduced BCS and subfertility (Royal *et al* 2000). High Proportion of postpartum anestrum and subestrum cases are indicative of overall deficiency of nutrients (Agarwal *et al* 2001), while postpartum and post service Anestrus are reflections of energy deficiency and/or poor service and obstetrical management (Rao and Naidu 2000).

The second major constraint was the higher cost of veterinary charges including higher cost of medicine, doctor's charge, diagnostic charges etc. in different ACZ's of Punjab except Zone III. There was less veterinary infrastructure to overcome this problem like availability of veterinarians, high cost of treatment, field assistants taking part in controlling this problem without any proper knowledge and expertise.

The third major constraint perceived across the different Zones (I, IV, V & VI) in the study area was poor breeding management including poor semen quality, poor

record keeping of affected animals, lack of skills of inseminator and poor estrous detection. Poor animal health status during breeding season was the chief reason of infertility in animals.

Unawareness about the body score condition of animals ranked at 4th position in different ACZ's of Punjab (I, IV, V & VI) during the breeding season. Body condition of animals was related to many critical aspects of production such as conception rate, days to estrus, calving interval and milk production. When cows were extremely thin (BCS < 4), they were not only reproductively inefficient, but were more susceptible to health problems. Cows at BCS 1 were in a life-threatening situation and need immediate attention. Cows that are over-conditioned (BCS 8-9) were the most costly to maintain. Farmers were unaware about the importance of body score condition in breeding and feeding management to save cost from excess feed provided to over-conditioned animals.

Poor diagnostic tools for detection of pyometra, semen quality, endometritis, estrus detection etc. by ultrasonography and other related diagnostic tools was ranked at 5th position in different ACZ's of Punjab. Inefficient heat detection reduces the fertility status of herd and this problem is more in buffaloes. However, this problem can be sought out by using teaser bulls at herd level for estrus detection especially in buffaloes during summer season. Heat detection also needs proper monitoring of farm regularly.

Poor extension service was ranked at 6th position in different ACZ's of Punjab. Proper extension service was not provided to reach every corner of the state to aware farmers about the Anestrus management at farm level. Educate them about the estrus signs, early pregnancy detection, importance of well-balanced nutritional diet etc.

Problem of culling Anestrus animals was positioned at 7th rank in different ACZ's of Punjab. This constraint arises due to government regulation in trade and slaughter of unproductive animals. Agarwal *et al* (2005) estimated that majority of cattle and buffaloes (18-40%) are culled and reach to slaughterhouse primarily due to infertility. However, it has been reported that 37.5% buffaloes end up in slaughter houses due to various reproductive problems (Sharma *et al* 1993).

Table 93: Constraints for controlling Anestrus in dairy animals by Garrett's Ranking Technique from different ACZ of Punjab.

S. No.	Category of control measures	Agro-climatic zone												Overall Rank
		I		II		III		IV		V		VI		
		Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	Garrett's Mean score	Rank	
1	Nutritional imbalances	80.92	I	79.34	I	75.05	II	77.12	I	80.01	I	78.65	I	I
2	Higher veterinary charges	75.89	II	75.27	II	77.24	I	72.35	II	71.36	II	70.04	II	II
3	Poor breeding management	70.8	III	70.06	IV	70.58	IV	71.41	III	69.99	III	69.27	III	III
4	Unawareness about body score condition of animals	69	IV	70.7	III	71.43	III	68.3	IV	65.3	IV	64.9	IV	IV
5	Lack of extension service	64.64	V	63.5	V	62.63	V	62.52	V	63.91	V	64.63	V	V
6	Poor extension service	54.95	VI	57.76	VI	58.89	VI	61.69	VI	58.03	VI	62.84	VI	VI
7	Problem of culling unproductive anestrus animals	51.69	VII	52.23	VII	52.91	VII	50.47	VII	53.74	VII	51.61	VII	VII
8	Occurrence of postpartum uterine infections and peri-parturient diseases	47.54	VIII	49.85	VIII	50.21	VIII	49.3	VIII	47.21	VIII	45.89	IX	VIII
9	Poor veterinary service	41.37	IX	40.69	IX	39.2	X	41.67	X	45.85	IX	43.06	X	IX
10	Heat ameliorating methods	40.8	X	38.2	X	39.46	IX	42.77	IX	42.2	X	46.71	VIII	X

Occurrence of post-partem uterine infection and periparturient diseases affects half of all dairy cattle after parturition, causing infertility by disrupting uterine and ovarian function and this constraint has been positioned 8th rank from the Garrett's mean score value in all the different Zones except Zone (VI). Cows with uterine infections were less likely to ovulate because they had a slower growth of postpartum dominant follicle in the ovary, lower peripheral plasma estradiol concentrations, and perturbation of hypothalamic and pituitary function. Opsomer (2000) reported that about 50% of dairy cows had irregular ovarian cycles during the postpartum period. LeBlanc (2010) studied that conception rates are about 20% lower for cows with endometritis and there are 3% more animals culled for failure to conceive. This constraint can be solved by controlling poor health status of animals, early embryonic deaths, uterine torsion, retained placenta, secondary disease occurrence, poor management practices etc.

Poor veterinary service ranked at 9th position from the Garrett's mean score value in different ACZ's of Punjab (I, II & V). This problem was perceived by farmers due to lack of veterinary infrastructure viz. veterinary doctors, lack of mobile veterinary van, unskilled persons used to treat affected animals especially in rural area.

Heat ameliorating methods or improper cooling and cow comfort Zone of animals especially high yielders HF cows was the major cause of Anestrus and was ranked at 10th position in agro different ACZ's of Punjab (Zone I, II & V). Since the temperature remains higher during summer season, farmers were not able to cope the heat stress affecting animal health production and were not able to detect heat during summer especially in buffaloes. This heat stress was also responsible for lower milk production and also responsible to occurrence of various diseases in farm animals.

A strategic policy for breeding, feeding and health management of dairy animals should be made to control these reproductive disorders and farmers should be aware about the negative consequences of this problem and cost benefit effect of this problem. Proper management practices adopted by the farmers and efficient veterinary services will help to overcome this problem in this region. Moreover, different dairy associations also play a role in providing extension service to create awareness among farmers of the area regarding the reproductive health management of their dairy animals.

CHAPTER V

SUMMARY AND CONCLUSIONS

India has huge livestock population that contributes enormously to national exchequer. Although, their contribution is not to its fullest potential, as livestock sector in India suffers from major challenges such as shortage of feed and fodder, breed improvement, the poor productivity of native breeds and diseases incidence cause economic losses up to 30% of the annual livestock output in developing countries, thus reducing household incomes. In order to improve the livestock population and their production, the countries have to be free of livestock diseases either through vaccination or other disease control measures. Major challenges include viral disease with wide national and international ramifications such as FMD, bacterial disease such as HS resulting in severe mortality, disease conditions like Mastitis affecting milk production and reproductive disorders resulting in reduced calf crop such as Anestrus and RB. Formulation of control strategies requires proper epidemiological know-how of the disease condition i.e., occurrence, susceptible population, risk factors, spread of disease and economic and social impact of the disease.

The present study was carried out to know the incidence, economic impact as well as constraints faced by farmers in applying control measures against selected disease conditions. The study was carried out in Punjab state, which has been divided in 6 agro climatic zones (ACZ's) viz., ACZ-I (Sub-mountainous undulating region), ACZ-II (Undulating plain region), ACZ-III (Central plain region), ACZ-IV (Western plain region), ACZ-V (Western region) and ACZ-VI (Flood plain region). From each zone, 2 districts were selected randomly. Further, 2 Tehsils were selected from each selected district, and from each Tehsil, three villages were selected and from each village, 10 dairy farmers each having at least 5 dairy animals were selected randomly, thereby making the number of respondents as 720. Dairy farmers were divided into 3 groups based on the herd size, viz., Small (5-10), Medium (11-50) and Large (>50). The information about the occurrence of selected diseases was perceived by farmers during the survey period and no diagnostic techniques or testing was made for confirming the disease.

The dairy farmers were interviewed using specially prepared questionnaires for collection of data with respect to socio economic profile (age, education, occupation, family size, family type, land holding, fodder availability, access to credit facility), extension activities in the area (Training received and Extension agency contacts) and epidemiological aspects of five selected disease conditions (FMD, HS, Mastitis, RB and Anestrus). Farmers were asked to describe the main epidemiological and economic losses due to FMD, HS, Mastitis, RB and Anestrus that they observed in their animals. Thereafter, for each disease condition, the morbidity, culling rate and mortality rates at species level and herd levels were recorded.

Economic losses were estimated for each disease condition. For FMD and HS, losses were calculated considering milk loss, treatment cost, mortality cost, miscellaneous cost (transportation of affected animal, affected bedding, rope, utensils, etc.) and extra labour engagement cost incurred to nurse the affected animals. Similarly, financial losses in mastitic animals included milk reduction, and extra labor engagement cost incurred to nurse the affected animal, treatment cost, replacement cost per culled animal, and other miscellaneous costs. Economic losses vis-à-vis Anestrus and RB were calculated on the basis of milk yield reduction due to extended non-pregnancy, extra labor cost engaged, replacement cost per effected animal, treatment cost, cost of feeding during non-productive phase, and other miscellaneous costs. Finally, constraints for disease control measures for each disease condition were also estimated using Garett's technique. The following results were recorded.

1. Majority of dairy farmers selected in the present study were young upto 40 years (48.27%), male (82.63%), having higher secondary education (27.77%), from joint families (62.63%) of medium family size (47.73%), having agriculture as main occupation (56.80%) and land holding of upto 2 hectares (38.88%).
2. Overall, 56.38% of farmers from different Zones had received training from dairy related Institutional Training Centers/Institutions like GADVASU, KVK's, etc; whereas, others received training and knowledge through cooperative societies like Verka and farmer associations. The mean score value of social participation was highest (55.66±11.23) from the dairy cooperative society followed by institutional centres (51.5±14.78) like GADVASU, KVK's etc. and majority of the dairy farmers (65.69%) had low level of extension contacts.

3. Majority of the dairy farmers (66.67%) had small herd (upto 10 dairy animals), followed by medium herd size (25.69%) rearing 11-50 dairy animals and large herd size (7.63%) rearing more than 50 dairy animals at their farms. Buffaloes constituted maximum proportion of dairy animals (38.83%), followed by cows (30.20%), heifers of cattle and buffalo (6.04% and 7.88%), cattle and buffalo calves (9.31% and 6.27%) and adult cattle and buffalo males (0.64% and 0.79%). The availability of feed and fodder varies significantly ($p<0.05$) among the different categories and between the different Zones. Majority of the farmers were using both cultivable fodder and branded feed to animals (60.69%), followed by market feed (24.30%) and cultivable fodder (15%).
4. The overall incidence and CFR risk of FMD among dairy animals was 7.37 and 21.32 percent, respectively. Incidence of FMD on the species basis varied significantly ($p<0.01$) and was observed highest in cross bred animals (10.30%), followed by indigenous cattle (9.13%) and buffaloes (5.02%). The incidence risk of FMD among the different ACZ's of Punjab in cross bred and indigenous cattle was not significant and ranged from 8.41% (Zone III) to 12.69% (Zone II) in cross bred cattle and 5.84% (Zone VI) to 12.63% (Zone III) in indigenous cattle. However, in buffaloes, it varied significantly ($p<0.01$) and ranged between from 2.75% (Zone V) to 9.38% (Zone II).
5. Within different herd sizes, the incidence risk of FMD varied significantly ($p<0.05$) and was highest in medium herd (8.1%) size followed by small (7.64%) and large herd size (6.76%). Incidence risk varied significantly ($p<0.01$) between the different ACZ's of Punjab within all herd sizes. In small herd size, the incidence ranged from 4.62% (Zone VI) to 12.90% (Zone II); in medium herd size, ranged between 3.26% (Zone V) to 15.67% (Zone II), whereas in large herd size, no case was reported from Zone I and Zone V.
6. The overall financial loss due to FMD per affected animal per year was Rs. 13,871.14± 5707.80. However, the mean economic losses per animal per year affected varied significantly ($p<0.05$) among different categories of animals, and was highest in cross bred animals (Rs. 25148.68±3492.9), followed by indigenous cattle (Rs. 9765.36±1549.2) and lowest in buffaloes (Rs. 6699.38±1858.3). The losses were variable among the different Zones and categories of animals (highest in Zone II and lowest in Zone VI), skewed towards the cross bred animals

followed by indigenous cattle and buffaloes. At species level, the largest proportion of the economic losses among the various categories were due to mortality loss of animals (73% in cross bred and indigenous cattle and 88% in buffalo), followed by milk loss and treatment cost. From the benefit cost analysis of intervention of control measures against FMD was highest in cross bred cattle followed by indigenous cattle and buffalo.

7. The overall incidence and CFR risk of HS among dairy animals was 5.45 and 45.15 percent, respectively. Incidence risk of HS on the species basis varied significantly ($p<0.01$) and was observed highest in buffaloes (6.27%), followed by cross bred (4.67%) and indigenous cattle (3.91%). The incidence risk of HS among the different ACZ's of Punjab in cross bred and indigenous cattle was not significant and ranged from 3.18% (Zone II) to 5.67% (Zone VI) in cross bred cattle, and between 2.22% (Zone II) to 8.62% (Zone IV) in indigenous cattle. However, in buffaloes, it varied significantly ($p<0.01$) and ranged between from 4.58% (Zone II) to 8.49% (Zone I).
8. Within different herd sizes, the incidence risk of HS varied significantly ($p<0.01$) and was highest in small herd size (10.52%) followed by medium (5.44%) and large herd size (3.01%). Incidence risk varied significantly between the different ACZ's of Punjab within small ($p<0.05$) and large ($p<0.01$) sized herds but not in medium sized herds. CFR among the different herds was highest in small herd (49.28%) followed by medium herd (44.32%) and large herd (39.15%).
9. The overall financial loss due to HS per affected animal per year was Rs. 5,111.64±1482.32. However, the mean economic losses per animal per year affected varied significantly ($p<0.05$) among different categories of animals, and was highest in buffaloes (Rs. 7265.08±735.27), followed by cross bred (Rs. 5799.55±447.48) and lowest in indigenous cattle (Rs. 2270.30±405.22). At species level, the largest component of the economic losses were due to mortality loss of animals (63.15% in indigenous cattle, 69.42% in cross bred, and 70.40% in buffaloes), followed by treatment cost and milk loss. From the benefit cost analysis of intervention of control measures against HS was highest in buffaloes followed by cross bred cattle and indigenous cattle.
10. The overall prevalence of Mastitis among dairy animals was 27.10 percent. Prevalence of Mastitis on the species basis varied significantly ($p<0.01$) and was

observed highest in cross bred (38.75%), followed by indigenous cattle (30.47%) and least in buffaloes (18.50%). The prevalence of Mastitis among the different ACZ's of Punjab in cross bred cattle varied significantly ($p<0.05$) and ranged from 31.70% (Zone IV) to 43.95% (Zone III) in cross bred cattle, Whereas no difference was found within different ACZ's in either indigenous cattle or buffalo. Within different herd sizes, the incidence of Mastitis varied significantly ($p<0.01$) and was highest in medium herd size (30.14%) followed by small (28.20%) and large herd size (24.59%). Prevalence varied significantly ($p<0.01$) between the different ACZ's of Punjab within small, medium as well as large sized herds.

11. The mean economic losses per affected animal per year due to Mastitis was Rs. 12028.0±5030.71, varied significantly ($p<0.05$) among different categories of animals, and was highest in cross bred (Rs. 20606.24± 224.55), followed by indigenous (Rs. 12292.42± 544.19) and lowest in buffaloes (Rs. 3185.34± 219.728). At species level, the largest component of the economic losses were due to milk loss (59.04% in cross bred, 44.48% in indigenous cattle and 38.29% in buffaloes), followed by replacement cost (32.85% in cross bred, 44.27% in indigenous cattle and 44.40% in buffaloes) and treatment cost. The overall benefits forgone per animal per year simulated for the dairy farmers controlling Mastitis through various preventive measures was Rs. 5600.70±2150.96. It varied significantly ($p<0.01$) across the species with highest returns estimated in cross bred cattle (Rs. 9638.93±303.48), followed by indigenous cattle (Rs. 4865.95 ±231.04) and buffaloes (Rs. 2297.24±97.83). Through the intervention of various control measures of Mastitis, the maximum benefits were estimated to be observed in the ratio of 3:2:1 in cross bred animals followed by indigenous cattle and buffaloes respectively.
12. The overall incidence of RB among the dairy animals was 27.63 percent and Western region was the most affected region of Punjab having 34.47 percent. Incidence of RB on the species basis varied significantly ($p<0.05$) and was observed highest in cross bred (41.77%), followed by indigenous cattle (32.05%) and least in buffaloes (17.59%). The incidence of RB among the different ACZ's of Punjab varied significantly ($p<0.05$) in cross bred cattle (ranged from 34.48% in Zone II to 45.4% in Zone VI), indigenous cattle (ranged from 20.68% in Zone V to 38.92% in Zone IV) and buffaloes (ranged from 16.78% in Zone VI to

23.94% in Zone V). Within different herd sizes, the incidence of RB varied significantly ($p<0.05$) and was highest in small herd size (39.35%) followed by medium (28.97%) and lowest in large herd size (21.78%). Orthogonal comparisons revealed that the incidence of RB varied respect to different agro climatic zone in each herd size and also with respect to species of animal in all ACZ's.

13. The overall annual economic loss per animal incurred by dairy farmers due to RB irrespective of species of animals was Rs. 16997±2894.44. The mean economic losses per animal per year affected varied significantly ($p<0.05$) among different categories of animals, and was highest in cross bred (Rs. 22595.32± 965.43), followed by indigenous (Rs. 15473.77± 507.44) and lowest in buffaloes (Rs. 12922.04± 773.06). At species level, the largest component of the economic losses were due to replacement cost (39.32% in cross bred, 43.01% in indigenous cattle and 59.64% in buffalo), followed by milk yield loss cost (35.17% in cross bred, 29.53% in indigenous cattle and 20.91% in buffalo). The overall benefits forgone simulated for the dairy farmers controlling RB through various preventive measures was Rs. 8693.05±862.33. It varied significantly ($p<0.01$) across the species with highest returns estimated in cross bred cattle (Rs. 10411.53±233.85), followed by indigenous cattle (Rs. 7960.32± 253.79) and buffaloes (Rs. 7707.29± 255.73). From the benefit cost analysis of intervention of control measures against RB was highest in cross bred cattle followed by indigenous cattle and buffaloes. BCA of latter two was almost same and indicated that the benefits outweigh the cost incurred for controlling RB under the prevalence of species wise scenario of Punjab.
14. The overall incidence of Anestrus among dairy animals was 25.78 percent and the most affected region was Central plain region of Punjab. Incidence of Anestrus on the species basis varied significantly ($p<0.05$) and was observed highest in buffaloes (36.54%), followed by cross bred (13.34%) and least in indigenous cattle (13.10%). The incidence of Anestrus among the different ACZ's of Punjab in cross bred cattle varied significantly ($p<0.05$) and ranged from 9.28% (Zone VI) to 20.24% (Zone III). However, no difference was found within different ACZ's in case of indigenous cattle and buffaloes. Within different herd sizes, the incidence of Anestrus varied significantly and was highest in small herd size

(41.05%) followed by medium (24.21%) and lowest in large herd size (20.90%). Orthogonal comparisons revealed that the incidence of Anestrus varied respect to different ACZ in each herd size and also with respect to species of animal in all ACZ's, except between different ACZ's within small herd size.

15. The overall annual economic loss per animal incurred by dairy farmers due to Anestrus irrespective of species of animals was Rs. 24362±1273.04. The mean economic losses per animal per year affected varied significantly ($p<0.05$) among different categories of animals, and was highest in cross bred (Rs. 27511.48±1227.60), followed by buffaloes (Rs. 27038.69±1128.05) and least in indigenous cattle (Rs. 18296.95±1317.53). At species level, the largest component of the economic losses were due to replacement cost (78.58% in cross bred, 78.72% in indigenous cattle and 58.57% in buffaloes), followed by milk yield loss cost (13.69% in cross bred, 12.73% in indigenous cattle and 27.90% in buffaloes). Between the different agroclimatic zones, overall losses due to Anestrus didn't vary significantly, highest loss was observed in Central plain region (Rs 27384.63±2407.03) and the least affected zone was Flood plain region (Rs. 19135.6± 4326.50).The overall benefits forgone simulated for the dairy farmers controlling Anestrus through various preventive measures was Rs. 9063.83±405.6. It did not vary significantly ($p<0.01$) across the species, however was highest in buffaloes (Rs. 10038.69±561.17), followed by indigenous cattle (Rs. 8798.83±380.22) and cross bred cattle (Rs. 8353.99±478.99). Through the intervention of various control measures of Anestrus, the maximum benefits were estimated to be observed in cross bred animals followed by buffaloes and indigenous cattle.
16. Major impact on dairy farmers due to economic losses by various animal diseases was due to loss of livestock asset of the farm families and its creation (93.47%), regular income loss affected their savings pattern (81.80%), affected agricultural productivity (80.97%), increased psychological stress (73.88%), loss of employment of the farmer/farm labour (67.91%), and farmers willing to lose dairy farming business (32.08%).
17. The constraints faced by dairy farmers in controlling these disease conditions as analysed by Garrett's ranking technique from different agro-climatic conditions of Punjab varied with respect to disease condition. The highest ranking constraint

with respective to each disease condition was an ineffective prophylactic vaccination for controlling FMD and HS, inability to bear the cost of treatment in control of Mastitis and Anestrus, and lack of effective and accurate estrus detection technique for control of RB.

18. The major constraints in controlling the FMD like failure of adhering to prophylactic vaccination, higher cost of treatment, strict biosafety and sanitary measures not followed, inadequate early disease detection and isolation, poor availability of veterinary and extension services be curbed at farmers door step for promoting the dairy farming business in a more profitable manner in the state.
19. The major constraints in controlling the HS like failure of prophylactic vaccination, cost of treatment, strict biosafety measures and hygienic sanitary conditions not followed, inadequate early disease detection and poor availability of veterinary and extension services
20. The major constraints in controlling the occurrence of Mastitis was based on many factors from cost of treatment, poor cow hygiene and animal housing, early detection of Mastitis, udder wash before and after milking by use of disinfectant or effective pre-milking teat dips, poor diagnosis to lack of extension service, dry cow therapy and biosafety measures in the shed were the most important factors to control Mastitis at the farmers level based on Garrett's ranking technique.
21. The major constraints perceived for controlling RB across all the Zones in the study area was lack of effective and accurate estrus detection, nutritional imbalances due to poor transition and nutritional management, poor management practices, improper timing of insemination, poor veterinary services, semen quality, heat stress or improper cooling and cow comfort Zone of animals, poor extension service, inadequate early detection of pregnancy and culling of affected animals not conceiving repeatedly. A strategic policy for breeding, feeding and health management of dairy animals should be made to control these reproductive disorders and farmers should be aware about the negative consequences of this problem and cost benefit effects of this problem.
22. Major constraints in controlling Anestrus among the dairy animals was a nutritional imbalances due to poor transition and nutritional management and due to higher cost of branded feed. Cost of veterinary charges, poor breeding management, unawareness about the body condition score of animals, poor

diagnostic tools (for detection of metritis, endometritis, semen quality, estrus detection etc.), poor extension services and problem of culling Anestrus animals.

CONCLUSIONS

Findings are on the basis of information perceived by the dairy farmers about the epidemiological aspect of the diseases and the losses associated with them during the year (2016-17). Diseases had been reported by the dairy farmers and no testing or diagnostic procedures had been undertaken to confirm the disease.

- Majority of dairy farmers selected in the present study were young, male, having higher secondary education, from the joint families, of medium family size, having agriculture as main occupation and were small herds rearing mainly buffaloes.
- Dairy animals mainly suffer from Mastitis (27.10%) and reproductive disorders like Anestrus (25.78%) and RB (27.63%).
- Small herd group farmers were mainly affected due to different livestock diseases.
- Mastitis occurrence is significantly increasing ($p<0.05$) in both cattle and buffaloes, however cross bred animals were more affected (38.75%).
- Major losses were from the mortality of animals or their replacement values followed by reduction in milk yield.
- Among the different diseases selected, largest losses were observed in Anestrus (Rs. 24362±1273.04) followed by RB (Rs. 16997±2894.44), FMD (Rs. 13871.14±5707.80), Mastitis (Rs. 12028.0±5030.71) and HS (Rs. 5111.64± 1482.32).
- Benefit cost analysis of any intervention in controlling dairy animal diseases play an important role to intervene the benefits forgone from these interventions. Highest BC ratio was observed in crossbred cattle followed by indigenous cattle and buffaloes.
- Among the different regions of Punjab, mainly the border areas of the state were more affected due to poor knowledge and awareness about the disease control measures and lack of good veterinary infrastructure.

- Major impact due to economic losses was due to loss of livestock asset of the farm families and its creation (93.47%).
- Major constraints in controlling diseases were the failure of prophylactic vaccination, higher cost of treatment, nutritional imbalances and poor cow hygiene and animal management.

The most costly disease of dairy animals among the selected five diseases in present study was Anestrus, followed by RB, FMD, Mastitis and HS. The total estimated annual losses per animal in Punjab state were Rs. 24362±1273.04, Rs. 16997±2894.44, Rs. 13871.14±5707.80, Rs. 12028.0±5030.71 and Rs. 5111.64±1482.32, respectively.

The projected annual losses associated with these important diseases in Punjab are FMD (Rs. 775.67crores), HS (Rs. 211.37 crores), Mastitis (Rs. 1108.47 crores), RB (Rs. 1597.04 crores) and Anestrus (Rs. 2135.79 crores). Impact of these diseases on dairy farmers should be tackled for improving the socio economic status of the dairy farmers. There has to be the strong extension efforts along with streamlining the treatment services either through mobile vans or modern extension tools to give a push to the livestock sector for making it more profitable. The different extension tools should be chosen based on agroclimatic conditions and analysing farmers in respect of education, herd size, extension contacts, teledensity and training etc.

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ANNEXURE I

Simulations for estimation of economic losses associated with important diseases of dairy animals in Punjab

Findings are perceived information by the dairy farmers about the epidemiological aspect of diseases and the losses associated with them during the year (2016-17). On the basis of diseases reported by the dairy farmers and no testing or diagnostic procedures had been undertaken to confirm the diseases.

1. Maintenance of herd size whether animals were died or culled due to disease affection to maintain lactation of milk yield in a year.
2. Replaced animal was assumed at the same stage of lactation milk yield.
3. Replacement of affected animals was taken to its half value for maintenance of herd size.
4. Milk loss was estimated for the whole lactation period,
5. Affected animals suffereing with FMD and HS were assumed to be not vaccinated.
6. Analysis of BC ratio for cost of intervention of different diseases were assumed like FMD (Rs 1000), HS (1000), Mastitis (Rs 1200), RB (Rs. 2000) and Anestrus (Rs. 2500 in crossbred and Rs. 2000 in indigenous cattle and buffaloes)

S. No.	Categories	Cross bred cattle	Indigenous cattle	Buffalo
1	Average market value of milk (Rs)	37.5	37.5	47.5
2	Average value of adult animals upto 3rd lactation (Rs)	80,000	50,000	60,000
3	Average value of adult animals from 4-5th lactation (Rs)	72,000	45,000	54,000
4	Average value of adult animals >5th lactation (Rs)	64,000	40,000	48,000
5	Average market value of adult bull (Rs.)	60000	30000	30000
6	Average market value heifer (Rs)	25,000	20000	20000
7	Average market value of calf (Rs.)	5000	5000	5000
8	Salvage value of culled animal (Rs.)	0	0	50%
9	Replacement cost of culled animal (Rs.)	50%	50%	50%
10	Average extra labour charges per hour (Rs.)	40	40	40
11	Average Days of illness in FMD	12	12	12
14	Average Days of illness in HS	7	5	9
15	Average Days of illness in Mastitis	7	6	6
16	Average open Days in RB	84	84	84
17	Average open Days in Anestrus	150	180	220
18	Postpartem period (days)	90	90	90
19	*Average intercalving interval (days)	390	450	453
20	*Average lactation production (lt)	3,926-4,568	2325	1,751
21	*Average daily milk yield (lt.)	18	8	10
22	**Vaccination of FMD & HS (%)	93.4	93.4	93.4

Assumed values for the present study (1-14)

**Administrative Report 2009-10, Department of Animal Husbandry, Govt. of Punjab and Nivsarkar et al (2000), Animal Genetic Resources of India, Cattle and Buffalo, ICAR publication.*

**Directorate of AH Punjab report (2016)*

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