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# Studies on replacement rate, Productive herd life, longevity, selective value and their components in different Indian and crossbred cattle-A review

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## ABSTRACT

*The prevalence of abnormal births varied across various cattle breeds, with estimates ranging from 3.14 percent in Sahiwal cattle to 14.28 percent in crossbred cattle. The average sex ratio of 44.15%, (female calf) and 57.42% (male calf). The mean mortality rate in female calves from birth to age at first calving ranged between 13.70% inFrieswal (and 45.60 in crossbred cattle. The mortality rate during the first month of life varied among different breeds of calves and ranged from 4.22% to 16.92% in various breeds. During the age range of 1-3 months ranged from from2.3% to to12.90%, in the group of 3-6 months age mortality was found as 1.34% to 7.06%, in the group of 6-12 months age was found to be 0.81% to 5.06% and, from 12 months to age at first calving (AFC) ranged from 3.00% to 4.3% in different breeds calves. The mean culling rate in female calves from birth to age at first calving ranged between 3.72% and 31.05%. The replacement rate basis on female calves varied from 48.40% in Hariana cattle to 74.72% in Frieswal cattle. The effects of the calving period on abnormal calving have been observed-significant in various studies. However, other studies have also observed significant effects of the calving period on the occurrence rate of abnormal calving. Non-significant effects of the season were found in different studies. However, other studies have reported significant effects of the season. Heritability estimates for abnormal birth, sex ratio, female calf mortality, female calf culling, replacement rate from total female calf basis, and replacement rate from total calf based were reported to be very low. Productive herd life (PHL) ranged from3.06±0.09 years in Karan Fries cattle to 6.43±0.21 years in Sahiwal x Jersey crossbred cattle. The range of longevity is from 3.06±0.09 years in Karan Friesto to 8.76±0.28 years in the Sahiwal breed. The number of calves produced per cow was reported to be 2.91±0.07 in Frieswal' 3.07±0.91 in Karan Fries 4.09±0.25 calves produced per cow in Sahiwal x Jersey crossbred cattle and 5.20±0.16 in Haryana. The maximum average of total alive calves born ranged from 2.71±0.15 in Frieswal cattle to 4.9±0.15 in Hariana cattle. The total number of female calves per cow ranged from 1.23±0.04 to 2.38±0.15. The number of replacement daughters per cow was observed from 0.74±0.05 to 1.61±0.11. The heritability estimates for productive herd life, longevity, total calves produced per cow, total calves produced per cow, total alive calves born, Selective value, and lactation-specific survival rate, for survivorship or stay-ability were observed from very low to high in different studies. It was found that around 1/4 of the total females left the herd after completing their first lactation. The percentage of cows in the herd was estimated and one-third of the total herd consisted of first-time calvers. A meager percentage (about 1.94%) of females in the herd were of 10th or more lactations. The anticipated herd life during the first parity was 1.47 lactations to 3.52 lactations, with a decreasing trend as the lactation number increased. The mean age of cows in the herd varied across cattle breeds from 2.54 lactations to 4.49 lactations. The average age of cows lost from the herd varied among the different breeds from 2.91 to 4.68 lactations. The mean loss rate per cow per lactation was from 0.21 lactations to 0.52 lactations. The replacement index in other studies was observed at 0.84 over 34 years and 1.4 over 20 years.*

**Keywords:** *replacement rate, Productive herd life, longevity, selective value, heritability, Indian and crossbred cattle.*

## Introduction

The relative contribution of female offspring to the subsequent generation is related to lifetime calf production and is an individual's selective value. Planning, running, and assessing breeding programs and maximizing dairy farms' profitability require knowledge of selective values and their constituent parts. For the genetic advancement of the animals, knowledge of gene diversity in replacement rate, selective values, and their components is also required. From the time when a dairy cow's female offspring reaches maturity, its genetic contribution to the following generation is calculated. There is limited information on various variables, including the breed of the sire and dam, season, and period, which are said to affect these critical traits. Two crucial strategies for genetic improvement in dairy cattle features of economic value are correct selection and effective breeding systems. In a cow herd, the replacement rate is a function of calf production, which is affected by post-natal mortality, culling of heifers from birth to the age of first calving, abnormal birth rate, and sex ratio [1]. The primary factor supporting the elimination of inferior females is the number of replacement heifers. The success of this process is influenced by two important factors: the trait's heritability and the selection level, which is largely determined by the number of replacement female calves introduced into the herd.

These factors collectively contribute significantly to achieving genetic gain in the breeding program [2]. The main objectives of a dairy farm are to reduce mortality and involuntary culling among its herd. High involuntary culling and death rates can limit the farm's genetic progress since fewer replacements are available to improve the herd's overall quality. Therefore, understanding the replacement rate is crucial to maintaining a well-structured herd. The survival of newborn calves is of utmost importance for successful livestock reproduction. Unfortunately, a considerable number of calves do not survive beyond their first year, leading to significant negative economic implications for livestock production. Addressing calf mortality is essential to ensure the long-term sustainability and profitability of the dairy farm [3].

The primary obstacle to genetic progress and big herd size is animal disposal. Therefore, getting a greater number of heifers by improving the fertility status and reducing the unintended culling. The best way to enhance the size of the herd for genetic improvement and an economically viable dairy business is by reducing disposal in both prenatal and postnatal phases. Therefore, determining the causes of increased mortality and unintentional disposal of female calves is an essential component in preventing genetic and financial losses [4]. The quantity of replacement heifers that become available over a long period affects the number of low-producing cows that are eliminated. To maintain the herd size, an equivalent number of heifers ought to accompany the milking herd each year to replace the number of cows lost to death or culling for various reasons [5].

The purpose of this paper is to review how these replacement components may affect dairy cows' productive lifespan. The literature on Replacement rate and their component, Productive herd life, longevity, and selective value and their components is vast, and the references in this article include only a fraction of the available literature. The emphasis of this paper is on the Replacement rate and productive lifespan of milk-producing cows in India.

**Replacement rate and their component**

The replacement rate refers to the ratio of young heifers that are selected as replacements compared to the total number of female calves born and pregnancies in a given year. It has a significant role in determining the genetic progress and profitability viability of a herd. Several factors, including the number of births, female calf mortality, sex ratio, prenatal calf losses, and culling before reaching the age at which cow calves for the first time, contribute to the calculation of the replacement rate.

**Average value for replacement rate and their components**

**Abnormal births**

Abnormal births are determined by calculating the proportion of unsuccessful births, including abortions, stillbirths, and premature births, among the total number of pregnancies. The prevalence of abnormal births varied across different cattle breeds, with estimates ranging from 3.14 percent in Sahiwal cattle [6] to 14.28 percent in crossbred cattle [5]. In Bos indicus breeds, the average values of abnormal births varied from 3.14 to 7.10 percent, while in the case of crossbred cattle, the average values ranged from 4.86 to 14.28 percent.

**Sex Ratio (Percent male birth)**

The sex ratio refers to the proportion of male births out of the total number of normal births. Ideally, the male and female birth ratio is envisaged to be 50:50, with an equal proportion of male and female births. While in other reports suggest that the sex ratio can deviate due to genetic factors significantly. The mean sex ratio in different studies has provided insights into the average values of the sex ratio in different breeds. For instance, in Sahiwal cattle, [7] reported an average sex ratio of 44.15%, (female calf) while [1] found a higher value of 57.42% (male calf) in the same breed.

Interestingly, some breeds show a sex ratio closer to the mid-value range. Singh [8] observed a sex ratio in Holstein Friesian (HF) cattle that fell within this range. Similarly, [9] reported a comparable sex ratio in Karan Fries cattle, and [10] documented a similar trend in Jersey x Sahiwal crossbred cattle.

**Female calf mortality rate**

The mortality rate refers to the rate at which female calves experience death from the time of birth until they reach the age of first calving. It is a measure of the proportion of female calves that do not survive to reproductive age. The mean mortality rate in heifers from birth to age at first calving estimated by various workers ranged between 13.70% in Frieswal [11] and 45.60 in crossbred cattle [12]. The highest mortality in Indigenous cattle was observed at 35.38% in Sahiwal cattle [Banik and Naskar, 1] as well as in crossbred cattle at 45.60% [12]. [13] observed that maximum mortality occurred during the first month of life and declined with the advancement of age in Gir cattle.

**Age-specific calf mortality**

hend mortality rate varied among different breeds of calves during the first month of life. [13] reported the highest mortality rate of 16.92% in Gir calves, followed by [14] who reported a mortality rate of 16.36% in Karan Fries calves. On the other hand, [9] and [15] in Karan Fries calves as well as [16] Gir calves were estimated the lowest mortality rates as 5.00%, 4.22%, and 5.10%, respectively. While [17] reported a mortality rate of 14.00% in Sahiwal female calves.

During the age range of 1-3 months, different studies have reported varying mortality rates in different breeds of calves. [19] reported the highest mortality rate of 12.90% in crossbred calves. In contrast, [13] and [14] reported zero mortality in Gir and KF calves, respectively. [9] and [19] reported lower mortality rates of 2.3% and 4.35% in Karan Fries (KF) and Sahiwal calves, respectively.

In the age range of 3-6 months, [18] reported the highest mortality rate of 6.35%, followed by the finding of [20] who reported 7.06% in crossbred calves. On the other hand, [15] and [21] estimated lower mortality rates of 1.51% and 1.34%, respectively, in Karan Swiss (KS) calves. [19] reported a mortality rate of 2.00% in Sahiwal calves.

For the age range of 6-12 months, [16] and [20] reported the highest mortality rates of 5.02% and 5.06% in Gir and crossbred calves, respectively. [21], [14], and [19] analysed mortality rates of 0.81%, 4.33%, and 2.06% in KS, KF, and Sahiwal calves, respectively.

From 12 months to age at first calving (AFC), [15]) in KS calves, [14] in KF calves as well, and [19] in Sahiwal, calves reported mortality rates below 3.00%. However, [9] reported a mortality rate of 4.3% in KF calves.

**Female calf culling rate**

The culling in female calves refers to the process of removing female calves from the herd for different reasons before reaching the age at first calving. The mean culling rate in heifers from birth to age at first calving estimated by different workers ranged between 3.72% in Sahiwal cattle [4] and 31.05% in HF cattle [3]. [17] on Sahiwal cattle reported that the highest culling rate occurred during the 12 months of AFC. This suggested that culling of animals was done at maturity age. So, an early-age culling rate was always low.

**Age-specific female calf culling rate**

The culling rate, which represents the percentage of female calves removed from the herd, varied across different age groups and breeds. At the age of 0-1 months, [21] reported the highest culling rate of 0.50% in KS calves, followed by 0.64% in Sahiwal calves [17]. However, [15], [9], [22], and (2017a) reported lower culling rates below 0.15% in KF and Sahiwal calves.

For calves aged 1-3 months, [21] reported relatively high culling rates of 0.75% in KS calves, while [17] reported 0.68% in Sahiwal calves. [14], and [19] reported no culling in KF and Sahiwal calves.

At 3-6 months of age, higher culling rates were observed. [21] reported 2.24% in KS calves, [22] reported 2.10% in Sahiwal calves, and [17] reported 2% in Sahiwal calves. [9], [14], and [19] estimated culling rates of 1.7%, 1.23%, and 0.80% in KF, KF, and Sahiwal calves, respectively.

Among the age group of 6-12 months, [17] reported the highest culling rate of 5.71% in Sahiwal calves. [15], [9], and [22] also reported culling rates above 2% in KF, KF, and Sahiwal calves, respectively. [14] reported a lower culling rate of 0.80% in KF calves.

At the age of 12 months to AFC, different researchers reported varying levels of culling. [21] recorded the highest culling rate of 24.01% in KS calves. [15] and [17] reported culling rates of 14% in KF and Sahiwal calves, respectively. [19] reported a lower culling rate of 1.88% in Sahiwal calves.

**Replacement rate on female calf basis**

Replacement rate on a heifers basis refers to the mean number of heifers that survive until reaching the age at first calving. The replacement rate estimated by various workers based on female calves varied from 48.40% in Hariana cattle [23] to 74.72% in Frieswal cattle [11]. The lowest replacement value was estimated in crossbred cattle by [7]. The rate of replacement can differ across herds due to various environmental factors and the management conditions provided to the herds.

**Replacement rate on total calf basis**

It represents the percentage of heifers that have successfully survived until the age at first calving, out of the total number of pregnancies. The percentage of total calves that serve as replacements in the herd varied from 22.60% in Hariana cattle [23] to 37.55% in Sahiwal cattle [4]. [11] and [7] observed replacement rates of 31.65% and 25.27% in Frieswal and crossbred cattle, respectively.

**Effect of non-genetic Factors on Replacement Rate and their Components**

Factors unrelated to genetics that influence the replacement rate can be categorized into two main factors: the period and the season of calving. The impact of the period can be imputed to variations in environment, feed and fodder availability, disease prevalence, and overall herd management practices. The effects of the calving period on abnormal calving have been observed non-significant in various studies. These studies include [23] in Hariana cattle, [8] and [3] in Holstein Friesian cattle, and [4] in Sahiwal cattle. However, significant effects of the calving period on the occurrence of abnormal calving have been also reported in other studies. These studies include [24] and [7] in crossbred cattle, [6] in Sahiwal cattle, and [11] in Frieswal cattle. Furthermore, higher significant effects of the calving period on the incidence of abnormal calving have been reported in other studies. These studies include [9] in Karan Fries cattle, [10] in Jersey x Sahiwal cattle, [1], and [25] in Sahiwal cattle.

Seasonal effects can be attributed to factors such as rainfall and temperature, which directly impact vegetation growth and the reproduction of diseases and parasites. Several studies have examined the effects of season on various cattle breeds. Non-significant effects of the season were found in studies conducted by [23] in Hariana cattle, [10] in Jersey x Sahiwal cattle, and [25] in Holstein Friesian cattle. Similarly, [6] and [1] estimated non-significant effects of the season in Sahiwal cattle. However, significant effects ($P<0.05$) of the season were reported in other studies by [8] in Holstein Friesian cattle, [9] in Karan Fries cattle, and [7] in crossbred cattle. Furthermore, effects ($P<0.01$) of the season on abnormal births were recorded higher significantly by [3] in Holstein Friesian cattle and [4] in Sahiwal cattle.

[6] and [1] reported a higher occurrence of abnormal births in Sahiwal cattle during the rainy season. Similarly, [7] observed a higher incidence of abnormal births in crossbred cattle during the same season. On the other hand, [4]in Sahiwal cattle and [1] in Sahiwal cattle reported a lower occurrence of abnormal births during the summer season.

**Effect of non-genetic factors on sex ratio**

[23] in Hariana cattle, [8] in Holstein Friesian (HF) cattle, [9] in Karan Fries (KF) cattle, [3] in Holstein Friesian (HF) cattle, [24] in crossbred cattle, [11] in Frieswal cattle, and [1] in Sahiwal cattle sex ratio is not affected by the effect of the period. In contrast, [7]) in crossbred cattle reported a significant effect of the period. Moreover, [25] in Holstein Friesian cattle sex ratio was affected highly significantly by the effect of the period.

[23] in Hariana cattle, [8] in Holstein Friesian (HF) cattle, [9] in Karan Fries (KF) cattle, [ 3] in Holstein Friesian (HF) cattle, [24] in crossbred cattle, and [6] in Frieswal cattle, and [1] in Sahiwal cattle reported a non-significant effect of season on sex ratio. However, [7] in crossbred cattle reported a significant effect ($P<0.05$) of season on sex ratio.

**Effect of non-genetic factors on female calf mortality**

[23] in Hariana cattle, [6] in crossbred cattle, [11], in Frieswal cattle, and [19] in Sahiwal cattle reported a highly significant effect ($P<0.01$) of the period on overall mortality. [8] and [3] in Holstein Friesian (HF) cattle reported a significant effect of the period of birth on the overall mortality rate of heifers. On the other hand, [24] crossbred cattle reported a non-significant effect of period of birth on overall mortality.

[24] in crossbred cattle and [11] in Frieswal cattle reported a higher significant effect of season of birth on overall mortality. However, [23] in Hariana cattle, [8] in Holstein Friesian cattle, [1] in Sahiwal cattle, and [10] in Jersey x Sahiwal cattle reported a non-significant effect of season of birth on overall mortality.

**Effect of non-genetic Factors on culling Rate among Female calves**

[8] in Holstein Friesian cattle, [23] in Hariana cattle, [1]in Sahiwal cattle, and Shahi and [10] in Jersey-Sahiwal cattle

estimated a significant effect (P<0.05) of period of birth on overall culling rate. Additionally, [9] in Karan Friesian cattle, [25] in Holstein Friesian cattle, and [4] in Sahiwal cattle reported a higher significant effect of year of birth on the overall culling rate. However, [24] in crossbred cattle and [6] in Frieswal cattle reported a non-significant effect of year of birth on the overall culling rate. [23] in Hariana cattle and [24] in crossbred cattle reported a higher significant effect of season of birth on the overall culling rate. On the other hand, [8] in Holstein Friesian cattle, [11] in Frieswal cattle, [10] in Jersey-Sahiwal cattle, and [7]in crossbred cattle reported a non-significant effect of season of birth on the overall culling rate.

**Effect of non-genetic factors of the calf on replacement rate on total female calf basis**

Significant effects of year of birth were estimated by (23) and.[7] in Holstein Friesian cattle, [6], [1] in Sahiwal cattle, and [10] in Jersey x Sahiwal cattle. Additionally, a higher significant effect of the period was recorded [23] in Hariana cattle, [9] in Karan Friesian cattle, and [25]in Holstein Friesian cattle. However, [24] reported a non-significant effect of the period in crossbred cattle. [7] reported a significant effect (P<0.05) of season in crossbred cattle. [23] in Hariana cattle, [24] in crossbred cattle, and [11] in Frieswal cattle reported a higher significant effect of season. On the other hand, [8] and [3] in Holstein Friesian cattle, [6] and [1] in Sahiwal cattle, and [25] in Holstein Friesian cattle reported a non-significant effect of season.

[1] estimated a higher replacement rate on a total female calf basis during the winter season in Sahiwal cattle. On the other hand, [7] in crossbred cattle and [1] in Sahiwal cattle found a lower replacement rate on a total female calf basis during the summer season. This suggests that there may be a seasonal variation in the replacement rate, with a higher rate observed during winter and a lower rate during the summer season. Further investigation into the underlying factors contributing to this seasonal variation would be beneficial to better understand the dynamics of replacement rates in these cattle breeds.

**Effect of non-genetic factors on replacement rate from total calf basis**

[8] and [3] observed a significant effect (P<0.05) of the period in Holstein Friesian cattle, indicating that the period influenced certain characteristics or outcomes. Similarly, [6] in Sahiwal cattle and [10] in Jersey x Sahiwal cattle also estimated a significant effect (P<0.05) of the period. On the other hand, [23] in Hariana cattle and [25] in Holstein Friesian cattle reported a higher significant effect (P<0.01) of the period, indicating a stronger impact of the period on the studied variables. In contrast,[24] reported a non-significant effect of the period in crossbred cattle.

A significant effect (P<0.05) of season of birth was observed in Frieswal cattle, as reported by [11]. Furthermore, [23] in Hariana cattle and [24] in crossbred cattle found a higher significant effect (P<0.01) of season of birth. However, [3]in Holstein Friesian cattle, [6] in Sahiwal cattle, and [25] in Holstein Friesian cattle reported a non-significant effect (P<0.05) of the season of birth. [1] reported a higher replacement rate on a total calf basis during the winter season in Sahiwal cattle. This suggested that more female calves were able to survive and become replacements during this season. On the other hand, [26] observed a lower replacement rate on a total calf basis during the summer season in crossbred cattle, as well as in Sahiwal cattle according to [1].

The differences in replacement rates between seasons might have been influenced by various factors such as temperature, availability of resources, and management practices during different seasons.

**Heritability of replacement rate and their components**

The heritability estimates for the replacement rate and its components give us an understanding of the genetic influence on the replacement rate and its various factors. The heritability estimates allow us to determine the proportion of the total variation in the replacement rate that can be accredited to genetic factors.

**Abnormal births**

The estimates of heritability for abnormal births were comparatively low, announcing that there was limited additive genetic variance related to this trait. [27] reported a heritability estimate of 0.042 for Red Sindhi cattle, while [28] found a heritability estimate of 0.056 for crossbred cattle. In Hariana cattle, [23] reported a heritability estimate of 0.285, while [9] reported a similar estimate. For Sahiwal cattle, [6] reported a heritability estimate of 0.28, and for Holstein Friesian cattle, [25] reported a heritability estimate of 0.16. These estimates suggest that genetic factors have a limited influence on the incidence of abnormal births in these cattle breeds.

**Sex ratio**

The estimates of heritability for various cattle breeds have been estimated by other workers. [27] found a heritability estimate of 0.016 in Red Sindhi cattle, while [9] estimated heritability as 0.013 in Hariana cattle. [6] estimated a heritability estimate of 0.01 in Sahiwal cattle. On the other hand, [25] reported a moderate level of additive genetic variance in Holstein Friesian cattle. These heritability estimates provided insight into the genetic influence on the traits under investigation in the respective cattle breeds.

**Female calf mortality**

The estimates of heritability of mortality rate were low in magnitude, as reported by [27] in Red Sindhi, [9] in Hariana, and [5] in crossbred cattle to be 0.001, 0.028, and 0.096, respectively. [28] in Crossbred and [29] in Frieswal cattle have been estimated with modest heritability estimates as 0.137, and 0.193, respectively. These heritability estimates provide a perception of the genetic influence on the mortality rate, showing the extent to which genetic factors contribute to this trait in the respective cattle breeds.

**The culling rate among female calves**

The very low heritability estimates of 0.059 for the culling rate in Holstein Friesian (HF) cattle were reported by [8], while [9] found a similarly low estimate of 0.013 in Hariana cattle. [6] reported an extremely low heritability estimate of 0.001 in Sahiwal cattle, and [5] reported a relatively low estimate of 0.038 in Crossbred cattle. On the other hand, [27] reported a moderate heritability of 0.347 in Red Sindhi cattle, and [25] found a high heritability estimate of 0.71 in Holstein Friesian cattle. These heritability estimates reflect the extent to which genetic factors contribute to the culling rate in the respective cattle breeds, with some breeds showing higher heritability than others.

**Replacement rate from total female calf basis**

[9] and [6] estimated very small heritability estimates for replacement rate in cattle, with values of 0.02 in Haryana and 0.01 in Sahiwal breeds, respectively. [28] reported a moderate heritability estimate of 0.225 in crossbred cattle, while [27] reported a similar level of 0.230 in Red Sindhi cattle. [23] observed a higher heritability estimate of 0.571 in Hariana cattle, and [25] reported an even higher estimate of 0.66 in Holstein Friesian (HF) cattle.

**Replacement rate from total calf basis**

[30] in Tharparkar, [9] in Haryana, [6] in Sahiwal, and [25]in Holstein Friesian (HF) cattle reported very low heritability estimates for the respective breeds, with values of 0.031, 0.01, 0.01, and 0.01, respectively. On the other hand, [27] reported a moderately low heritability estimate of 0.10 in Red Sindhi cattle. These heritability estimates reflect the limited contribution of genetic factors to the variation observed in the traits being studied within the mentioned cattle breeds.

**Productive herd life, longevity, and selective value and their components**

**Productive herd life (PHL)**

Productive herd life (PHL) is the number of years a cow stays in the herd after first calving. [9] reported a PHL of 3.06±0.09 years in Karan Fries cattle, while [31] observed a PHL of 6.43±0.21 years in Sahiwal x Jersey crossbred cattle. [6] reported a PHL range of 3.89±0.24 years in Sahiwal cattle to 5.38±0.18 years in Hariana cattle for Indian breeds. [32] reported a PHL of 4.87±0.29 years in Holstein Friesian cattle.

**Longevity**

The number of years from the date of birth to the date of removal of cows from the herd either due to culling or death is called longevity. [9] and [31] reported the range of longevity to be from 3.06±0.09 years in Karan Fries cattle to 6.43±0.21 years in Sahiwal x Jersey crossbred cattle. In Sahiwal cattle, [6] estimated longevity as 6.98±0.25 years, and [33] reported as 8.76±0.28 years. For Frieswal cattle, estimates of longevity ranged between 6.20±0.09 years [11] and 6.43±0.09 years [34]. [35] estimated longevity as 6.43±0.09 years in Holstein Friesian cattle.

**Selective value and its components**

The selective value of an individual cow, which determines its genetic contribution to future generations, is determined by the number of calves it produces and that survive to produce milk. The production of replacement female calves by per adult cow is a key factor in deciding its subscription to the next generation.

**Total calves produced by each cow**

The mean values of calves produced per cow were found to be 3.07±0.91 in Karan Fries and 2.91±0.07 in Frieswal. [31] observed an average of 4.09±0.25 calves produced per cow in Sahiwal x Jersey crossbred cattle. In Indian cattle breeds, the average number of calves produced per cow ranged between 3.21±0.25 in Kankrej [36] and 5.20±0.16 in Haryana [23].

**Total alive calves born**

The maximum mean values of total alive calves born were reported by [23] as 4.9±0.15 in Hariana cattle while minimum estimates of total alive calves born have been reported by [34] as 2.71±0.15 in Frieswal cattle. In addition, Goshu [35] reported 3.20±0.10 in Holstein Friesian cattle. [6], [37], and [36] were reported as the average of total alive calves born as 3.48±0.17, 3.70±0.15, and 2.93±0.21 in Sahiwal, Hariana, and Kankrej cattle, respectively.

**Total Female calves per cow**

[11] provided the lowest estimates of the total number of female calves by each cow in Frieswal cattle, with an average of 1.23±0.04. On the other hand, [23] reported the highest number of female calves by each cow in Hariana cattle, with an average of 2.38±0.15. Other researchers, such as [9], [31], [6], [37], [35], and [34], reported a range of values between 1.30 and 2.10 for the total number of heifers calves per cow in various breeds of cattle.

**The total number of female calves reached to milking herd (Selective value)**

The production and provision of live female calves from each mature cow have significant implications in dairy animals as these females serve as replacements for the aging and unproductive cows in the milking herd.

[6] reported that in Sahiwal cattle, the number of replacement daughters per cow was 1.61±0.11, indicating that each cow was producing more than one replacement, leading to an overall increase in the herd size. This finding was supported by [23] in Hariana cattle, [31] in Sahiwal x Jersey crossbred cattle, [35] in Holstein Friesian cattle, and [36] in Kankrej cattle, who reported replacement daughter values of 1.2±0.21, 1.37±0.89, 1.12±0.06, and 1.09±0.14, respectively. On the other hand, Singh [9]in Karan Fries cattle, [11] in Frieswal cattle, and [37] in Hariana cattle observed values of less than one replacement, with 0.86±0.44, 0.92±0.04, and 0.74±0.05 replacement daughters per cow, respectively.

**Coefficient of gene replication (CGR)**

The maximum CGR value of 0.81±0.06 in Sahiwal has been reported by [6], while the minimum of 0.38±0.02 in Hariana cattle was found by [37]. [23] in the case of Hariana, [35] in Sahiwal x Jersey, [35] in Holstein Friesian, and [36] in Kankrej cattle also reported the replacement daughter as 0.60±0.11, 0.69±0.04, 0.56±0.03, and 0.56±0.08, respectively. [11] in Frieswal and [37] in Hariana cattle estimated lower CGR as 0.47±0.02 and 0.38±0.02, respectively.

**Effect of non-genetic Factors on Productive Herd Life, longevity, and Selective Value and their components**

**Productive herd life (PHL)**

[38] found that season had a non-significant effect on productive herd life (PHL) in Tharparkar cattle. Similarly, [3], [32], and [35] reported a non-significant effect of season on PHL in Holstein Friesian cattle. [33] also reported a non-significant effect of season on PHL in Sahiwal cattle.

On the other hand, [23] and [37] estimated a highly significant effect of the period on PHL in Hariana cattle, and [32] and [35] estimated a highly significant effect of the period on PHL in Holstein Friesian cattle. [33] and [34] also found a highly significant effect of the period on PHL in Sahiwal and Frieswal cattle, respectively. However, [38], [31]), and [6] found no significant effect of the period on PHL in Tharparkar, Sahiwal-Jersey, and Sahiwal cattle, respectively.

Most of the workers reported a highly significant effect of FLMY on PHL i.e., [28] in Crossbred, [23] in Haryana, [31] in Sahiwal-

 

Jersey, [6] in Sahiwal, [35] in Holstein Friesian cattle, and [34] in Frieswal. Contrarily, the non-significant effect of FLMY on PHL was estimated by [11] in Frieswal cattle.

**Longevity**

[38] found no significant effect of season on longevity in Tharparkar cattle, and [3], [32], and [35] reported a similar non-significant effect of season on longevity in Holstein Friesian cattle. [33] also reported a non-significant effect of season on longevity in Sahiwal cattle.

In contrast, [23] and [37] observed a highly significant effect of the period on longevity in Hariana cattle, and [32] and [35] reported a highly significant effect of the period on longevity in Holstein Friesian cattle. [38], [33], and [[34] also reported a highly significant effect of the period on longevity in Tharparkar, Sahiwal, and Frieswal cattle, respectively. However, [31] and [6] found no significant effect of the period on longevity in Sahiwal-Jersey and Sahiwal cattle, respectively.

The effect of first lactation milk yield (FLMY) on longevity was reported as highly significant in most of the studies, including [28] in crossbred, [23]in Haryana, [31] in Sahiwal-Jersey, [6] in Sahiwal, [35] in Holstein Friesian cattle, as well as [11] and [34] in Frieswal cattle.

**Selective value and its components**

**Total calves produced by each cow**

[35] found the effect of season non-significant on the total number of calves produced per cow in Holstein Friesian cattle, and [36] found a similar effect in Kankrej cattle. On the other hand, [28] in crossbred cattle, [23] in Hariana, [9] in Karan Fries, [11] in Frieswal, and [35] in Holstein Friesian cattle reported a highly significant effect of period and first lactation milk yield (FLMY) on the total number of calves produced by each cow. However, [6] found a significant effect of the period on the total number of calves produced by each cow in Sahiwal cattle, while [31] reported a non-significant effect of the period in Sahiwal x Jersey cattle.

**Total alive calves born**

[35] found no significant effect of season on the total number of alive calves born in Holstein Friesian cattle, and [36] reported a similar non-significant effect in Kankrej cattle. On the other hand, [28] in crossbred cattle, [23] in Hariana, [9] in Karan Fries, [11] in Frieswal, [35] in Holstein Friesian cattle, and [34]in Frieswal reported a highly significant effect of period and first lactation milk yield (FLMY) on the total number of live calves born. However, [6] found a significant effect of the period on the total number of alive calves born in Sahiwal cattle, while (2004) reported a non-significant effect of the period in Sahiwal x Jersey cattle.

**Total Female calves per cow**

Goshu [35] and Joshi et al. [36] reported a non-significant effect of season on total female calves in Holstein Friesian and Kankrej cattle, respectively. Highly significant effects of period and FLMY on total female calves were reported by [28] in crossbred cattle, [23] in Haryana, [9] in Karan Fries, and [11] in Frieswal, [35] in Holstein Friesian, and [34] in Frieswal cattle. However, [35] and [6] reported a non-significant effect of the period on total female calves in Sahiwal x Jersey and Sahiwal cattle, respectively. [37] reported a significant effect of the period in Hariana cattle.

**The total number of female calves reached to milking herd (Selective value)**

[35] and [36] reported non-significant effects of season on total female calves in Holstein Friesian and Kankrej cattle. A highly significant effect of period and FLMY on total female calves was reported by [28] in crossbred cattle, [23]in Haryana, [9] in Karan Fries, and [11] in Frieswal. However, [31], [6], and [35] reported a non-significant effect of the period on total female calves in Sahiwal x Jersey, Sahiwal, and Holstein Friesian cattle, respectively. However, the period had a significant effect on the case of Hariana cattle as found by [37].

**Heritability of Productive herd life, longevity, and selective value and their components**

**Productive herd life**

Estimates of heritability for productive herd life varied across different cattle breeds. Higher heritability estimates were observed, ranging from 0.44 in Karan Fries cattle [9] to 0.945 in Hariana cattle [23]. On the other hand, lower to moderate heritability estimates were reported, with values of 0.17 in Sahiwal cattle [6] and 0.239 in Sahiwal x Jersey cattle [31]. Additionally, a moderate heritability estimates of 0.32 was reported in Holstein Friesian cattle [35].

Longevity

The heritability estimates for longevity varied across different cattle breeds. Higher heritability estimates were reported, ranging from 0.44 in Karan Fries cattle [9] to 0.975 in Hariana cattle [23]. In contrast, medium heritability estimates were observed, with values of 0.254 in Sahiwal x Jersey cattle [31] and 0.31 in Holstein Friesian cattle [35].

**Selective value and its components**

**Total calves produced by each cow**

The heritability estimates for total calves produced by each cow varied across different cattle breeds. Higher heritability estimates were observed, ranging between 0.52 in Karan Fries cattle [9] and 0.965 in Hariana cattle [23]. On the other hand, there were low to moderate medium heritability estimates, with values ranging from 0.11 in Holstein Friesian cattle [35] to 0.28 in Tharparkar cattle [30]. [6] reported a medium heritability estimate of 0.32 in Sahiwal cattle.

**Total alive calves born**

The heritability estimates for total alive calves born varied among different cattle breeds. The maximum heritability estimate was observed to range between 0.69 in Karan Fries cattle [9] and 0.994 in Hariana cattle [23]. On the other hand, there were low to moderate medium heritability estimates, with values ranging from 0.12 in Holstein Friesian cattle [35] to 0.24 in Tharparkar cattle [30].

**Total Female calves per cow**

The heritability estimates ranged between 0.37 in Tharparkar cattle [30] and 0.761 in Hariana cattle [23]. On the other hand, there were low to medium heritability estimates, with values ranging from 0.10 in Holstein Friesian cattle [35] to 0.30 in Frieswal cattle [29]. However, in contrast, low heritability estimates were reported for total female calves, ranging from 0.043 in Karan Swiss [39] to 0.073 in Sahiwal x Jersey cattle [35].

**The total number of female calves reached to milking herd (Selective value)**

The higher heritability estimates ranged between 0.49 in Karan

Fries cattle [9] and 0.729 in Hariana cattle [23]. Additionally, there were low heritability estimates, such as 0.13 in Sahiwal cattle [6] and 0.17 in Tharparkar cattle [30]. However, in contrast, low heritability estimates were recorded, ranging from 0.014 in Sahiwal x Jersey cattle [35] to 0.036 in Karan Swiss [39].

**Demographic Parameters**

Demographic studies involve the estimation of various parameters related to the population dynamics of livestock, such as loss rate ($Q_x$), survival rate (Px), proportion of cows present in the herd ($p_x$), proportion of cows lost from the herd ($q_x$), and expected herd life (Ex). These parameters provide important information about the overall life statistics of the herd, including the mean age of cows present in the herd, the mean age of cows lost from the herd, the mean rate of loss per cow per lactation, and the mean life expectancy at first lactation.

The results of such analyses have proven valuable in formulating plans for culling and replacement, organizing breeding schemes, and serving as a means to evaluate management practices. Previous studies conducted [40] and [29] have utilized these results to gain insights into livestock population dynamics and inform decision-making processes

**Lactation-specific demographic parameters**

The important lactation-specific demographic parameters are survival rate, survivorship or stability, age distribution in terms of the proportion of cows present and lost in the herd of each lactation group, and expected herd life in years.

**Survival rate (Px)**

[23] in the case of Hariana cattle, found that the lactation-specific survival rate was around 0.80 up to the seventh lactation, after which there was a declining trend as the lactation number upward. Similarly, [9] researched Karan Fries cattle and found that the probability of survival rate was highest (0.72) in the first lactation. However, there was no clear trend observed in the survival rate from the 2nd to the 14th lactation. [41]reported that the survival rate was around 0.74 up to the fourth lactation, after which it showed a decreasing trend with ascending lactation numbers. Additionally, [25] reported that the survival rate of exotic cows was lowest (0.74) in the third lactation and continued to decline. Other studies conducted by [42] in Frieswal cattle,[43] in Sahiwal cattle, [44] in Tharparkar cattle, and [45] in Jersey and Red Sindhi, crossbred cattle found similar trends. They observed that the survival rate was around 0.71 in the third lactation, and then declined with upward lactations. [45] notably highlighted the lowest survival rate of 0.65 in the first lactation for Jersey and Red Sindhi crossbred cattle.

**Survivorship or stay-ability ($L_x$)**

[23] reported survivorship ranging from 1.0 to 0.37 from the first to the sixth parity in Hariana cattle, with a decreasing trend observed thereafter [9] found survivorship of 0.72 at the first lactation in Karan Fries cattle, which decreased with each coming parity. [41], [42], and [25] observed that survivorship was initially unity in the first lactation but decreasing with each coming parity, with values leave below 0.10 after the eighth parity in Sahiwal, Frieswal, and Holstein Friesian cattle, respectively. Similarly, studies by [43], [44], and in Sahiwal, Tharparkar, and Karan Fries cattle, respectively, also unveil a declining trend in survivorship with augmenting age or parity of lactation. [45] found a survivorship of 0.12 at the fifth parity in Jersey and Red Sindhi crossbred cattle.

**Proportion of cows left the herd ($q_x$)**

[23] on Hariana cattle, it was found that around one-fourth of the total cows left the herd after completing their first lactation. Similar findings were reported by [9], [41], [42], and [43] for Karan Fries, Sahiwal, Frieswal, and Sahiwal cattle, respectively. They found that more than half of the females who completed their first lactation left the herd before reaching their third lactation. Additionally, [44], [46], and [45] reported that more than half of the females that completed their first lactation left the herd before reaching their second lactation in Tharparkar, Karan Fries, and Jersey and Red Sindhi crossbred cattle, respectively.

Percentage of cow's present in the herd ($p_x$). [23] on Hariana cattle; reported that around one-fifth of the herd comprise of first calvers. [9] observed in Karan Fries cattle that one-third of the total herd consisted of first calvers, while the majority (70.3%) belonged to the 10th lactation. A small percentage (about 1.94%) of females in the herd were in their 10th or more lactations. [31] studied Sahiwal cattle and reported that around one-fourth of the total cows in the herd were in their first parity, and two-thirds of the total cows belonged to the first through third parity. In Frieswal cattle, [42] found that approximately 88% of the herd consisted of cows in their first to fourth lactation. Similarly, [44], [46] and [45] reported that around 30% of the total cows in the herd were in their first parity in Tharparkar, Karan fries, and Jersey and Red Sindhi crossbred cattle, respectively.

**Expected herd life ($E_x$)**

In the study by [23] and [41] on Hariana and Sahiwal cows, respectively, the anticipated herd life during the first parity was found to be 3.52 and 3.14 lactations, with a decreasing trend as the lactation number increased. [9] reported an expected herd life of 2.14 lactations at first parity, which remained relatively comprised up to the sixth lactation and then decreased with increasing lactations of cattle. [42] in Frieswal cattle, [25] in Holstein Friesian cattle, and [43] in Sahiwal cattle reported anticipated herd life at first parity to be 2.05, 2.45, and 2.59 lactations, respectively, with a decreasing trend observed in subsequent lactations.[46] found the lowest expected herd life at first parity in Karan Fries cattle to be 1.80 lactations, while [45] estimated an expected herd life of 1.47 lactations in Jersey and Red Sindhi crossbred cattle.

**Overall lifetime statistics**

The average age of cows in the herd varied across different cattle breeds. [23] found an average age of 4.49 lactations in Hariana cattle, while [35] found a mean age of 3.49 lactations in Holstein Friesian (HF) cattle. [41] observed a mean age of 2.93 lactations in Sahiwal cattle, and [29]) reported a mean age of 2.54 lactations in Frieswal cattle.

The average age of cows lost from the herd varied among the different breeds. [23] reported an average age of 4.68 lactations in Hariana cattle, while [29] reported an average age of 2.91 lactations in Frieswal cattle. [47] reported a mean age of 3.43 lactations in Tharparkar cattle, [41] observed a mean age of 4.14 lactations in Sahiwal cattle, [9] reported a mean age of 3.13 lactations in Karan Fries (KF) cattle, and [35] found a mean age of 4.35 lactations in HF cattle.

The mean loss rate per cow per lactation ranged from 0.21 lactations [23] to 0.52 lactations [29] in Frieswal cattle. [47],

[41], [9], and [35] reported mean rates of 0.26, 0.32, 0.46, and 0.32 lactations per cow per lactation in Tharparkar, Sahiwal, KF, and HF cattle, respectively.
The mean life expectancy at first lactation also varied, with Goshu [35] reporting a minimum of 1.28 lactations in HF cattle and [23] finding a maximum of 4.19 lactations in Hariana cattle. [47], [41], [9], and [28] reported mean life expectancies of 3.32, 2.64, 1.64, and 1.41 lactations in Tharparkar, Sahiwal, KF, and Frieswal cattle, respectively.

**Annual replacement index**

The annual replacement index is used to assess the changes in herd size over some time. (1989) observed a replacement index of 0.84 over 34 years (1950-1986) in a Red Sindhi cattle herd, indicating a decrease in herd size. [28] reported an overall replacement index of 1.07 over 22 years (1970-1991) in a Zebu crossbred cow herd, suggesting a relatively stable herd size. [48] and [49] studied Sahiwal and Tharparkar cattle herds and found the replacement index to be close to one in the Sahiwal herd and 0.92 in the Tharparkar cattle herd. Significant differences were observed among different years in both herds. [23] estimated a replacement index of 1.2 in a herd of Hariana cattle in Hisar, with significant variations over the years. (2001) reported an overall replacement index of 1.06 for Karan Fries cattle during the period 1973-1994. [31] observed a replacement index of 1.09 over 25 years (1977-2001) in a Sahiwal cattle herd. [6] reported a replacement index of 1.4 over 20 years (1983-2002) in another Sahiwal cattle herd. [5] estimated an overall replacement index of 1.37 for 9 years (1994-2002) in a crossbred cattle herd.
Based on the findings of these studies, the following conclusions are drawn.

- In Bos indicus breeds, the average values of abnormal births varied from 3.14 to 7.10 percent, while among crossbred cattle, the average values varied from 4.86 to 14.28 percent.
- Observed that maximum mortality occurred during the first month of life and the mortality rate decreased with the advancement of the age in Gir cattle.
- It is reported that the highest culling rate occurred during the 12 months of AFC. This suggested that culling of animals was done at maturity age. So, an early-age culling rate was always low.
- The replacement rate can differ across herds due to various environmental factors and the management conditions provided to the herds.
- The heritability estimates for abnormal birth, sex ratio, female calf mortality, female calf culling, replacement rate from total female calf basis, and replacement rate from total calf basis were reported very low.
- Productive herd life (PHL) ranged from 3.06±0.09 years to 6.43±0.21 years in different cattle breeds.
- The range of longevity ranges from 3.06±0.09 years to 8.76±0.28 years in different breeds of cattle.
- The average number of calves produced by each cow was reported to be 2.91±0.07 in Frieswal' 3.07±0.91 in Karan Fries 4.09±0.25 calves produced per cow in Sahiwal x Jersey crossbred cattle and 5.20±0.16 in Hariana.
- The maximum average of total alive calves born ranged from 2.71±0.15 in Frieswal cattle to 4.9±0.15 in Hariana cattle.
- The number of replacement daughters per cow ranged from 0.74±0.05 to 1.61±0.11 in different cattle breeds.

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