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CONTENTS

Studies on replacement rate and its components in crossbred cattle

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ABSTRACT: Data for the present investigation were collected from a history sheet of crossbred cattle at the Instructional Dairy Farm of G. B. Pant University of Agriculture and Technology, Pantnagar. The data about 1000 crossbred cattle with a total of 3583 calving records from 87 sires were distributed over 32 years from 1988 to 2019. The estimated average percentages for various parameters, including abnormal births, sex ratio (percent male birth), mortality and culling of female calves up to the age of first calving (AFC), and replacement rate (based on female calf and total calf), were 6.0%, 52.33%, 14.80%, 17.53%, 67.67%, and 30.32% respectively. The effect of the FLMY (first lactation milk yield) group was found to be non-significant on abnormal births, overall mortality rate, overall female calf culling, and replacement rate based on the female calf basis. However, there was a significant effect of the FLMY group on the sex ratio and the replacement rate based on the total calf basis. 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 as 0.18±0.011, 0.045±0.056, 0.15±0.019, 0.08±0.078, 0.35±0.071, and 0.05±0.085, respectively. The lower values of heritability suggest a higher influence of environmental factors on these traits. Therefore, the future selection of dairy cattle for replacement and its components will require a fully integrated and balanced breeding model.

Key words: Abnormal birth, heritability, female calf mortality, female calf culling, replacement rate, sex ratio

The primary obstacle to genetic progress and big herd size is animal disposal. Therefore, increasing the number of female calves by improving fertility and reducing the involuntary culling. Optimal strategies for improving herd size and genetic quality while ensuring profitability involve minimizing animal disposal during both prenatal and postnatal stages. Therefore, determining the causes of increased mortality; identifying and addressing the factors contributing to the unintentional disposal of calves and heifers are essential for mitigating genetic and financial losses (Upadhyay *et al.,* 2017).

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 (Pandey *et al.*, 2016). The degree of genetic diversity in a herd of cattle greatly influences the probability of genetic improvement. Therefore, the present study has been carried out to quantify the replacement rate and its components.

MATERIALS AND METHODS

Data sets and sources

Data for the present investigation were collected from the history sheet of crossbred cattle maintained at the instructional dairy farm of G. B. Pant University of Agriculture and Technology, Pantnagar. The data pertained to 1000 crossbred cattle with a total of 3583 calving records from 87 sires distributed over 32 years from 1988 to 2019. The crossbreds were HF x S, J x S, RD x S, HF x S x RD, RD x S x J, HF x R x J and HF x S x RD x J. The sires having records minimum of at least 5 daughters were included in the present study. The records of only those animals with known pedigree and normal lactation were considered. The lactation records of less than 150 days were considered abnormal and were not included in the analysis. The total duration of the present study was divided into 6 periods, out of which the first period is 7 years and the rest five periods are five years each. The first lactation group was divided into 6 groups. Each year was divided into three seasons namely winter

(November-February), Summer (March–June), and Rainy (July – October). To classify the data for the first lactation milk yield group, periods and seasons of calving were considered for all the traits. The traits considered in the present study were abnormal births, sex ratio (percent male birth), mortality and culling of female calves up to the age of first calving (AFC), and replacement rate (based on female calf and total calf).

Statistical Analysis

As the data in the present study were non-orthogonal with unequal subclass numbers, they were subjected to least squares analysis of variance without interactions using different models to examine the effect of non-genetic factors on various abnormal births, sex ratio (percent male birth), mortality and culling of female calves up to the age of first calving (AFC), and replacement rate (based on female calf and total calf), traits as per standard procedures of Harvey (1990). The model was based on the assumption that different components fitting in the model were linear, independent, and additive. The non-genetic factors (first lactation milk yield groups, periods, and seasons of calving) were taken as fixed effects in the model. The paternal half-sib correlation method was used to estimate the heritability of different traits (Becker, 1985).

Heritability (h^2)

$$h^2 = \frac{\frac{1}{NR1} \cdot \hat{\sigma}_s^2}{\frac{1 - NW}{NR1} \cdot \hat{\sigma}_s^2 + \hat{\sigma}_e^2}$$

Where,

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

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

NR1 is the decimal percentage of additive genetic variance in , and NW is the decimal percentage of additive genetic variance in, NR1 is between variance component and is equal to 0.25 and NW is within variance component and is equal to 0.75.

The standard error of heritability was estimated by the formula given by Swiger *et al.* (1964) as detailed below:

$$\text{S.E. } (h^2) = \frac{\sqrt[4]{2(n-1)(1-t^2)(1+(k-1)t^2)}}{\sqrt{K^2(N-S)(S-1)}}$$

RESULTS AND DISCUSSION

Replacement rate and its component

The overall mean values of the replacement rate and its components are given in Table 1 and the analysis of variance is in Table 2.

Abnormal births

The overall incidence of abnormal births was found to be 6.02 percent. 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 to 14.28 percent in crossbred cattle. 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. This result closely aligns with the findings of Shahi and Kumar (2006) in Jersey x Sahiwal cattle and Upadhyay *et al.* (2017) in Sahiwal cattle. Comparing these results with previous studies, Singh (1999) and Singh *et al.* (2002) reported higher rates of abnormal births in HF cattle, Singh (2001) in KF cattle, Atrey *et al.* (2005) and Goshu and Singh (2013) in Frieswal cattle, as well as Pandey *et al.* (2016) and Panwar *et al.* (2022) in crossbred cattle. On the other hand, Kumar (1999) in Hariana cattle, Abbas (2005), Banik and Naskar (2006), and Singh *et al.* (2023) in Sahiwal cattle, reported lower rates of abnormal births.

The analysis of variance revealed that in the current study, there was no significant impact of season, on abnormal births. The Least Squares Means of abnormal births were observed highest in the rainy season and lowest in the summer season. This finding is consistent with the results reported by Kumar (1999) in Hariana cattle, where season also showed non-significant effects on abnormal births. Furthermore, the lack of a significant effect of season on abnormal births aligns with the findings of Abbas (2005) and Banik and Naskar (2006) in Sahiwal cattle and Goshu and Singh (2013) in HF cattle. However, Singh *et al.* (2002) in HF cattle, where they reported a highly significant effect of season on abnormal births. Similarly, Singh (1999) in HF cattle, Pandey (2003), and Panwar *et al.* (2022) in crossbred cattle, as well as Atrey *et al.* (2005) in Frieswal cattle, found significant differences in abnormal birth rates across different seasons. These studies suggest that seasonal variations may not play a significant role in influencing abnormal birth rates in these specific breeds.

The non-significant effect of the season in the present study suggests that these factors may not play a substantial role in influencing the occurrence of abnormal births in the cattle population under investigation. However, it is important to interpret these findings cautiously, as other factors not considered in this study might still contribute to the incidence of abnormal births.

The analysis of variance revealed that in the current study, there was no significant impact of periods on abnormal births. The least squares mean reveals that period VI (2015-2019) had the highest abnormal births followed by period II (1995-1999) and period IV (2005-2009), respectively. Whereas period I (1988-1994) had the lowest value for abnormal births. The difference between mean values over the periods might be due to differences in management practices followed at the farm during the study period. This finding is consistent with the results reported by Kumar (1999) in Hariana cattle, where season and period also showed non-significant effects on abnormal births. Singh (1999) and Singh *et al.* (2002) in HF cattle, as well as Upadhyay (2017) in Sahiwal cattle, reported a non-significant effect. Shahi and Kumar (2006) in Jersey x Sahiwal cattle, Banik and Naskar (2006) in Sahiwal cattle, and Goshu and Singh (2013) in HF cattle found a highly significant effect of the period on abnormal birth rates.

The analysis of variance revealed that in the current study, there was no significant impact of the First Lactation Milk Yield (FLMY) Group on abnormal births. For the comparison of these results, reports are not available in the literature.

Sex Ratio (Percent male birth)

The average sex ratio, representing the frequency of male births among normal calves, was found to

Table 1: Least-squares mean ± SE and effect of non-genetic factor on replacement rate and its components in crossbred cattle

Effect	Total Calving	Abnormal birth	Normal calves for sex ratio			Female calves			Replacement rate	
			Total	Males	Females	Died	Culled	Retained	Female calf basis	Total calf basis
Overall	4749	6.02 (285)	4464(93.99)	2336(52.33)	2128(47.67)	14.80(315)	17.53(373)	1440	67.67	30.32
SEASON										
S_1 (Winter)	1545	6.34(98)	93.66(1447)	53.28(771)	46.72(676)	14.94(101)	14.05(95)	480	71.00	31.07
S_2 (Summer)	1622	5.12(83)	94.88(1539)	51.98(800)	48.02(739)	14.34(106)	21.11(156)	477	64.55	29.41
S_3 (Rainy)	1582	6.57(104)	93.43(1478)	51.76(765)	48.24(713)	15.15(108)	17.11(122)	483	67.74	30.53
PERIOD										
P_1 (1988-1994)	711	5.06 (36)	94.94(675)	49.78(336)	50.22(339)	15.34(52)	17.40(59)	228	67.26	32.06
P_2 (1995-1999)	754	6.37 (48)	93.63(706)	51.13(361)	48.87(345)	13.04(45)	17.10(59)	241	69.85	31.96
P_3 (2000-2004)	792	5.43 (43)	94.57(749)	51.00(382)	49.00(367)	9.26(34)	20.16(74)	259	70.57	32.7
P_4 (2005-2009)	823	6.32(52)	93.68(771)	54.86(423)	45.14(348)	19.25(67)	2.59(9)	224	64.37	27.22
P_5 (2010-2014)	806	6.08(49)	93.92(757)	50.46(382)	49.54(375)	19.20(72)	13.87(52)	251	66.93	31.14
P_6 (2015-2019)	863	6.61(57)	93.51(807)	56.13(452)	43.87(354)	12.71(45)	20.34(72)	237	66.95	27.46
FLMY group										
G_1(≤ 2400)	1044	5.74(60)	94.25(984)	54.37(535)	45.63(449)	15.37(69)	16.93(76)	304	67.70	29.12
G_2 (2401-2900)	1125	4.35(49)	95.64(1076)	52.42(564)	45.58(512)	15.03(77)	18.16(93)	342	66.98	30.40
G_3 (2901-3400)	874	4.62(39)	95.54(835)	54.37(454)	45.63(381)	20.73(79)	13.91(53)	249	65.35	28.49
G_4 (3401-3900)	740	3.92(29)	96.08(711)	48.38(344)	51.62(367)	11.99(44)	18.26(67)	256	69.75	34.59
G_5(3901-4400)	599	4.84(29)	95.49(572)	54.37(311)	45.63(261)	13.41(35)	20.31(53)	173	66.28	28.88
G_6 (≥4401)	367	6.54(24)	93.46(343)	48.98(168)	51.02(175)	15.43(27)	18.58(32)	116	66.29	31.61

be 52.33 percent in the overall study. The chi-square test indicated that the deviation in sex ratio from the normal expected ratio of 50: 50 was significant. This finding is consistent with similar studies conducted by Abbas (2005) in Sahiwal cattle, as well as Atrey *et al.* (2005) and Goshu and Singh (2013) in Frieswal cattle, which also reported similar sex-ratio values. Banik and Naskar (2006) in Sahiwal cattle reported a higher sex-ratio value compared to the present study. Conversely, Kumar (1999) in Hariana cattle, Singh (1999) and Singh *et al.,* (2002) in HF cattle, Shahi and Kumar (2006) in Jersey x Sahiwal cattle, Upadhyay *et al.* (2017) and Singh *et al.* (2023) in Sahiwal cattle, and Panwar *et al.,* (2022) in crossbred cattle reported lower sex-ratio values. The effect of season on the sex ratio in the cattle population under study aligns with previous research in certain cattle breeds. Kumar (1999) in Hariana cattle, Singh (1999), Singh *et al.* (2002), Goshu and Singh (2013) in HF cattle, Abbas (2005) and Banik and Naskar (2006) in Sahiwal cattle, as well as Shahi and Kumar (2006) in Jersey x Sahiwal cattle, all reported similar findings, indicating a non-significant influence of season on the sex ratio in their respective breeds. However, it's worth noting that Panwar *et al.* (2022) reported a significant difference in the sex ratio based on the season in crossbred cattle. The Least Squares Means of sex ratio was observed highest in the winter season and lowest in the rainy season.

The analysis of variance did show a highly significant effect of the period on the sex ratio. This indicates that there were substantial differences in the sex ratio across different periods. The period under investigation played a significant role in determining the proportion of male births to female births. The least squares mean reveals that period VI (2015-2019) had the highest sex ratio followed by period IV (2005-2009) respectively. Whereas period I (1988-1994) had the lowest value for sex ratio. Goshu and Singh (2013) reported a highly significant period effect in HF cattle. However, contrasting results were reported in other studies. Kumar (1999) in Hariana cattle, Singh (1999), and Singh *et al.* (2002) in HF cattle, Abbas (2005) and Banik and Naskar (2006) in Sahiwal cattle, as well as Shahi and Kumar (2006) in Jersey x Sahiwal cattle, all found a non-significant effect of the period on the sex ratio in their respective cattle breeds.

The analysis of variance revealed that in the current study, there was a significant impact of the First Lactation Milk Yield (FLMY) Group on abnormal births. For the comparison of these results, reports are not available in the literature.

Female calf mortality rate (birth to age at first calving)

It was observed that 14.80% of the total female calves born did not survive to reach the milking herd. The average mortality rate among female calves from birth to age at first calving reported by various workers ranged between 13.70% in Frieswal and 45.60 in crossbred cattle. The highest mortality in indigenous cattle was observed at 35.38% in Sahiwal cattle as well as in crossbred cattle at 45.60%. Gaur *et al.* (2003) 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. Our study's findings closely matched the results reported by Singh (2001) in Karan Fries cattle and Mishra *et al.* (2015) in Gir cattle herd, indicating similar mortality rates in these breeds. However, higher mortality rates were reported by Saha (2001) in Karan Fries and Karan Swiss cattle, as well as Abbas (2005), Shahi and Kumar (2014), and Upadhyay *et al.* (2017) in Sahiwal cattle. Conversely, lower mortality rates

Table 2: Analysis of variance (ANOVA) for replacement rate and its components in crossbred cattle

Source of variation	d.f.	Abnormal Birth	Sex ratio	Mortality	Culling	Replacement rate	
						Female calf basis	Total calf basis
Season	2	0.53	96.02	0.20	0.61	0.46^{*}	0.01
Period	5	0.46	1903.00^{**}	1.46^{**}	0.16	0.06	0.15^{**}
FLMY group	5	0..24	1532.38^{*}	0.42	0.62	0.10	0.12^{*}
Error	987	209.39	600.76	0.29	0.33	0.14	0.05

* $P \leq 0.05$; ** $P \leq 0.01$

Table 3: Heritability of replacement rate and their components in crossbred cattle

Traits	Heritability
Abnormal births	0.18±0.011
Sex ratio	0.045±0.056
Female calf mortality	0.15±0.019
Female calfculling	0.08±0.078
Replacement rate from total female calf basis	0.35±0.071
Replacement rate from total calf basis	0.05±0.085

were recorded in the study by Singh and Gurnani (2004) in Karan Swiss cattle and Atrey *et al.* (2005) in Frieswal cattle, indicating comparatively better survival rates for female calves in these breeds.

The impact of season on the overall mortality rate was not found to be significant in our study. Similar findings for the season were reported by Kumar (1999) in Hariana cattle, Singh (2001) in Karan Fries cattle, Goshu and Singh (2013) in HF cattle, and Panwar *et al.* (2022) in crossbred cattle. In addition, Abbas (2005), Banik and Naskar (2006), and Upadhyay *et al.* (2017) in Sahiwal cattle also reported similar findings. However, in contrast, Atrey *et al.* (2005) found a strong and statistically significant impact of season in Frieswal cattle, while Pandey (2003) reported that the season had no significant effect in crossbred cattle.

The period had a significant effect on overall female calf mortality. Similar findings for the period were reported by Kumar (1999) in Hariana cattle, Singh (2001) in Karan Fries cattle, Goshu and Singh (2013) in HF cattle, and Panwar *et al.* (2022) in crossbred cattle. In addition, Abbas (2005), Banik and Naskar (2006), and Upadhyay (2017) in Sahiwal cattle also reported similar findings. However, in contrast, Atrey *et al.* (2005) found a strong and statistically significant impact of season in Frieswal cattle, while Pandey (2003) reported that the period had no significant effect in crossbred cattle. The analysis of variance revealed that in the current study, there was no significant impact of the First Lactation Milk Yield (FLMY) Group on overall female calf mortality. For the comparison of these results, reports are not available in the literature

Female calf culling rate (birth to age at first calving)

The overall mean culling rate among female calves was found to be 17.53 per cent. This result is consistent with earlier findings reported by Saha (2001) in Karan Swiss cattle and Pandey *et al.* (2016) in crossbred cattle. However, higher culling rates than present finding were also reported in other studies, such as those conducted by Singh (2001) in Karan Fries cattle, Singh and Gurnani (2004) in Karan Swiss cattle, Shahi and Kumar (2014) in Sahiwal cattle, as well as Pandey *et al.* (2016) and Panwar *et al.* (2022) in crossbred cattle. Conversely, some studies estimated lower values of culling rates as compared to this study. Nehra (2011) on Karan Fries cattle, Abbas (2005), Upadhyay (2013), and Upadhyay *et al.* (2017) on Sahiwal cattle, and Goshu and Singh (2013) on Frieswal cattle reported lower culling rates in their breed populations. The variations in culling rates can be attributed to various factors, including management practices, and herd health status.

The impact of season on overall female calf culling was found to be non-significant. Similar results for the season were reported in Sahiwal cattle by Abbas (2005). Singh (1999) and Singh *et al.* (2002) in HF cattle, Panwar *et al.* (2022) in crossbred cattle, Banik and Naskar (2006), and Upadhyay (2017) in Sahiwal cattle. However, Pandey (2003) in crossbred cattle reported a highly significant effect for the season, and Goshu and Singh (2013) in HF cattle reported a highly significant effect for the season.

The impact of the period on overall female calf culling was found to be non-significant. Similar results for the period were reported in Sahiwal cattle by Abbas (2005). Singh (1999) and Singh *et al.* (2002) in HF cattle, Panwar *et al.* (2022) in crossbred cattle, Banik and Naskar (2006) and Upadhyay (2017) in Sahiwal cattle also reported comparable findings for period effects. However, Pandey (2003) in crossbred cattle reported a highly significant effect for the period, and Goshu and Singh (2013) in HF cattle reported a highly significant effect for the period.

The analysis of variance revealed that in the current study, there was no significant impact of the First Lactation Milk Yield (FLMY) Group on overall female calf culling. For the comparison of these results, reports are not available in the literature.

Heritability

Heritability of replacement rate and their components in crossbred cattle are presented in Table 3. 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 as 0.18±0.011, 0.045±0.056, 0.15±0.019, 0.08±0.078, 0.35±0.071, and 0.05±0.085, respectively. The lower values of heritability suggest a higher influence of environmental factors on these traits. Similar results were also reported by Kumar (1999) in Hariana cattle and Atrey (2003) in Frieswal cattle. On the other hand, Pandey *et al.* (2016) in crossbred cattle reported a higher heritability estimate compared to the present study. However, very low heritability estimates were reported by Singh (2001) on Hariana cattle, Abbas (2005) on Frieswal cattle, and Goshu and Singh (2013) on HF cattle. To effectively manage and improve the replacement rate in cattle herds, a comprehensive approach considering both genetic selection and non-genetic factors is necessary. Proper herd management practices and environmental conditions should be optimized to maximize the replacement rate, particularly in breeds where genetic factors have a minor influence.

CONCLUSION

This suggests that approximately 3-4 pregnancies are required for one heifer to enter the milking herd in crossbred cattle. The relatively low replacement rate indicates that a considerable number of pregnancies do not result in heifers entering the milking herd due to various reasons such as unfavourable sex ratios and calf health issues. The impact of the season was found to be non-significant on abnormal births, sex ratio, overall mortality rate, overall female calf culling, and replacement rate based on the total calf basis. However, there was a significant effect of season on the replacement rate when considering the female calf basis. The period had a highly significant effect on the sex ratio, overall mortality rate, and replacement rate based on the total calf basis. However, it did not show a significant effect on abnormal births, overall female calf culling, and replacement rate based on the female calf basis.

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