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Influence of non-genetic factors on first lactation and lifetime performance traits in Nili-Ravi buffaloes

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The objective of this research was to evaluate the effects of various non-genetic factors on first lactation and lifetime productivity in Nili-Ravi buffaloes, including season of birth, period of birth, age at first calving, season of first calving, period of first calving, and number of lactations completed. The livestock data on first lactation and lifetime performance traits relevant to 501 Nili-Ravi buffaloes were collected from the history sheet of the animal for a period from 1983 to 2017 (i.e., 35 years) and maintained at the Indian Council of Agricultural Research—Central Institute for Research on Buffaloes (ICAR-CIRB) sub-campus, in Nabha, Punjab, India. To evaluate the least-squares means (LSMs) and the effect of non-genetic factors on performance traits, a least-squares analysis model was applied. The overall LSM for age at first calving (AFC) was 45.03 ± 0.40 months and ranged from 34 to 54 months. The results indicated that the effect of AFC was highly significant ($p \leq 0.01$) on first lactation total milk yield (FLTMY), first lactation standard milk yield (305 days or less) (FLSMY), first peak milk yield (FPY), and first lactation length (FLL) in the Nili-Ravi breed of buffaloes. FLTMY, FLSMY, and FPY were highest (2,250.08 ± 48.16 kg, 1,944.68 ± 31.20 kg, and 9.32 ± 0.16 kg/day, respectively) for animals with an AFC of 42–48 months. Furthermore, FLTMY, FLSMY, and FLL were highest (2,411.02 ± 68.68 kg, 2,008.81 ± 44.49 kg, and 357.43 ± 8.13 days, respectively) in animals that first calved in the autumn season. However, the lowest first dry period (FDP), first service period (FSP), and first calving interval (FCI) (110.63 ± 7.42 days, 125.48 ± 9.04 days, and 443.63 ± 9.00 days, respectively) were found for animals that first calved in the rainy season. The overall LSM for herd life (HL), productive life (PL), productive days (PDs), unproductive days (UDs), total lifetime milk yield (total LTMY), standard lifetime milk yield (standard LTMY), milk yield per day of productive life (MY/PL), milk yield per day of productive days (MY/PDs), and milk yield per day of herd life (MY/HL) were estimated as 3,779.84 ± 31.86 days, 2,078.55 ± 24.32 days, 1,552.74 ± 20.06 days, 525.81 ± 12.44 days, 10,229.71 ± 195.31 kg, 9,203.64 ± 173.52 kg, 4.86 ± 0.08 kg/day, 6.46 ± 0.08 kg/day, and 2.66 ± 0.04 kg/day, respectively. The effect of AFC on HL, PDs, UDs, total LTMY, and standard LTMY was highly significant ($p \leq 0.01$). Furthermore, the effect of season of first calving on HL, PL, and PDs was significant ($p \leq 0.05$). In addition, the effect of the period of first calving on HL, PDs, standard LTMY, and total LTMY was significant ($p \leq 0.05$). In these contexts, it can be concluded that the buffaloes of the Nili-Ravi breed with an AFC of 42–48 months performed better than animals with a later AFC in terms of production, reproduction, and lifetime traits.

KEYWORDS

buffalo, breed, Nili-Ravi, AFC, season, first lactation traits, and lifetime traits

1 Introduction

India has the world's largest buffalo population, accounting for 56.7% of the total global buffalo population. Furthermore, India is the largest producer of milk, accounting for approximately 20% of total world milk production. In addition, buffaloes contribute approximately 45% of the total milk production of India (DAHD Annual Report, 2021-22). Buffaloes are called India's black gold and have dispersed over almost all parts of the nation, with varying population densities, with the majority being concentrated in the north and west. The Nili-Ravi breed of buffalo is found in Bangladesh, China, India, Pakistan, the Philippines, and Sri Lanka but mainly in Pakistan and India. The home tract of the breed is along the belt between the Ravi and Sutlej rivers of the Punjab. Buffaloes are first milked at a young age, have a short calving interval, and are healthy enough to last several lactations will have a much higher lifetime milk yield (LTMY) than those who are older at first calving, do not calve regularly, and have poor longevity (Eastham et al., 2018). Furthermore, the genetic correlation of age at first calving (AFC) was found to be low and negative in both Murrah and Nili-Ravi buffaloes in terms of productive life (PL), productive days (PDs), and lifetime milk production performance (Tamboli et al., 2021; Tamboli et al., 2022). It is important to analyze first lactation and lifetime performance traits because the selection criteria for genetic gain and lifetime production of animals are primarily based on traits expressed in earlier lactation periods. Furthermore, first lactation total milk yield (FLTMY), first lactation standard milk yield (FLSMY) (i.e., 305 days or less), and first peak milk yield (FPY) were found to be significantly and positively associated with herd life (HL), as well as lifetime production performance in Nili-Ravi buffaloes (Tamboli et al., 2021). This information is helpful in designing cost-effective management practices and selection strategies to augment the economic traits of the buffaloes. Lifetime performance determines the economic efficiency of the dairy farm. According to Bashir et al. (2007), the lifetime milk yield, HL, and PL of Nili-Ravi buffaloes were 7,723 ± 164 kg, 3,990 ± 41 days, and 1,061 ± 19 days, respectively. AFC is one of the important attributes that influence herd performance, and it was observed that HL was significantly ($p < 0.01$) affected by the AFC. Moreover, the success of a livestock farm relies primarily on milk production and calving intervals; hence, dairy farmers mainly focus on boosting the productive and reproductive attributes of the animals (Bashir et al., 2007; El-Tarabany and Nasr, 2015). It is critical to comprehend the various physiological and environmental factors that influence livestock performance in order to improve the production potential of dairy buffaloes. Physiological factors are particularly driven by the genetic constitution of the animals. Nonetheless, diverse environmental attributes have a greater impact on buffalo productivity than genetic factors (Zicarelli, 1997). The AFC (Penchev et al., 2014), the season of calving (Khosroshahi et al., 2011), and the number of lactations (Bampidis et al., 2012) are among the non-genetic factors mentioned. Analysis of the literature revealed that observations on the effect of non-genetic factors on the first lactation and lifetime performance of Nili-Ravi buffaloes are scarce, especially in the humid subtropical climate of northern India. Thus, in order to suggest appropriate management practices and selection and breeding strategies for genetic improvement of Nili-Ravi buffaloes, this study was conducted to evaluate the influence of various non-genetic factors, such as season of birth, period of birth, AFC, season of first calving, period of first calving, and number of lactations completed, on first lactation and lifetime productivity in the Nili-Ravi buffaloes.

2 Materials and methods

2.1 Study location and the collection of data and its classification

The livestock data on first lactation and lifetime performance traits relevant to Nili-Ravi buffaloes were collected from the history sheet of the animal for the period from 1983 to 2017 (35 years) maintained at the Indian Council of Agricultural Research—Central Institute for Research on Buffaloes (ICAR-CIRB) sub-campus, in Nabha, Punjab, India. The performance records of 501 Nili-Ravi buffaloes that remained in the herd for a minimum of three lactations were considered. The records for all the buffaloes born and calved at the farm were collected up to the date of disposal. First, the availability of all the records pertinent to the date of birth, date of first calving, date of death/culling, and all the lactations was ascertained. Animals with a lactation length of at least 150 days and a production of at least 1,000 kg for the first parity were included. Incomplete and abnormal animal data could be the result of a disease that was excluded from the study.

Our study included first lactation traits such as AFC in months, FLTMY in kg, FLSMY (i.e., 305 days or less) in kg, FPY in kg/day, first lactation length (FLL) in days, first dry period (FDP) in days, first service period (FSP) in days, first calving interval (FCI) in days, and lifetime traits, namely herd life (HL) in days, PL in days, productive days (PDs) in days, unproductive days (UDs) in days, total lifetime milk yield (total LTMY) in kg, standard lifetime milk yield (standard LTMY) in kg, milk yield per day of productive life (MY/PL) in kg/day, milk yield per day of productive days (MY/PDs) in kg/day, and milk yield per day of herd life (MY/HL) in kg/day.

The data were categorized based on the season of birth (SOB), period of birth (POB), AFC, season of first calving (SOC), period of first calving (POC), and lactation completed (LC). The year was specified into four seasons of birth on the basis of geoclimatic conditions in the area, namely summer (April to June), rainy season (July to September), autumn (October to November), and winter (December to March). For the POB (1979 to 2008), the particulars were classified into six groups, each consisting of 5 consecutive years. AFC was further classified into six categories: 36, > 36–42, > 42–48, > 48–54, > 54–60, and > 60 months. Consistent with the SOB, each year was extended into four seasons of first calving, namely summer (April to June), rainy season (July to September), autumn (October to November), and winter (December to March). The POC (1983 to 2012) was further divided into six groups, each comprising 5 consecutive years. AFC was the duration between date of birth and the date of first calving of animals. FLTMY was the total amount of milk produced by the animal in the first lactation. FLSMY (i.e., 305 days or less) was the amount of milk produced for 305 days or less in the first lactation. FPY was the highest amount of daily milk yield in the first lactation. FLL was the sum of the number of days in milk in the first lactation. FDP was the duration between last day in milk in the first lactation to the next calving of animals. FSP was the duration between the date of first calving to the next successful conception. FCI was the time period between the first and second calving. The HL was defined as the duration between the birth and the disposal of the livestock. PL was calculated as the total number of days from the date of first calving to the date of the last dry day or date of disposal if animals were disposed of in the lactation stage. PDs were estimated as the sum of the number of days in milk in different lactations in the same herd. UDs were defined as the sum of the number of dry periods in different lactations in the same herd. Total LTMY was computed as the total amount of milk produced by a buffalo from the initiation of the first lactation until the last day of milk in the herd. Standard LTMY was defined as the sum of milk yield for 305 days or less in different lactations of an animal in its lifetime. MY/PL was calculated as the lifetime milk yield divided by the productive life. MY/PDs was measured as lifetime milk yield divided by the PDs. MY/HL was evaluated as lifetime milk yield divided by herd life.

2.2 Statistical analysis

A least-squares analysis model and IBM SPSS Statistics (IBM Corporation, Armonk, NY, USA) version 20.0 software (Snedecor and Cochran, 1994) were used to ascertain the effects of non-genetic factors and estimates of least-squares means (LSMs). The following general linear model was applied:

$Y_{ijklm} = \mu + A_i + T_j + P_k + R_l + e_{ijklm}$.

Y_{ijklm} = the mth observation in ith AFC, jth season, kth period and lth parity.

μ = overall population mean.

A_i = fixed effect of ith AFC (i = 1–6).

T_j = fixed effect of jth season of first calving (j = 1–4).

P_k = fixed effect of kth period of first calving (k = 1–6).

R_l = fixed effect of lth parity (l = 1–5).

e_{ijklm} = random/residual effect assumed to be normally and independently distributed (NID) $(0, \sum_1^2)$.

The following model was applied to analyze the effect of the SOB and POB on AFC:

$Y_{ijk} = \mu + T_i + P_j + e_{ijk}$.

Y_{ijk} = kth observation in ith season, jth period.

μ = overall population mean.

T_i = fixed effect of ith season of birth (i = 1–4).

P_j = fixed effect of jth period of birth (j = 1–6).

e_{ijk} = random/residual effect assumed to be NID $(0, \sum_1^2)$.

Duncan's multiple range test (DMRT), as modified by Kramer (1957), was used to compare LSM for significant differences.

3 Results

3.1 First lactation performance traits

3.1.1 Overall means and factors affecting AFC in Nili-Ravi buffaloes

The LSMs [with standard errors (SEs)] for the AFC in Nili-Ravi buffaloes are presented in Figure 1. The overall LSM for the AFC was 45.03 ± 0.40 months. The effect of birth season on the AFC was not found to be significant in this study.

In our results, the POB was found to affect the AFC: a decreasing trend across different periods with an increase in period of time was

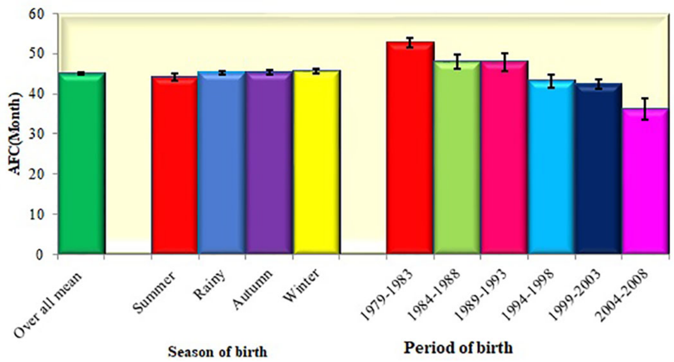

FIGURE 1
Least-squares means (LSMs) with standard errors (SEs) for age at first calving (AFC) in Nili-Ravi buffaloes.

noticed (Figure 1). It was significantly ($p \le 0.05$) higher from 1979 to 1983 (52.80 ± 1.22 months) and lower from 2004 to 2008 (36.22 ± 2.75 months).

3.1.2 Overall means and factors affecting first lactation production and reproduction traits in Nili-Ravi buffaloes

The LSMs for first lactation production and reproduction traits in Nili-Ravi buffaloes are given in Table 1. The overall LSM for FLTMY, FLSMY, FPY, FLL, FDP, FSP, and FCI were estimated as 2,033.20 ± 40.07 kg, 1,699.96 ± 25.96 kg, 8.71 ± 0.13 kg/day, 347.97 ± 4.75 days, 121.77 ± 6.11 days, 152.45 ± 7.45 days, and 469.74 ± 7.41 days, respectively.

3.1.2.1 Effect of age at first calving

The results (see Table 1) indicated that the effect of AFC was highly significant ($p \le 0.01$) for FLTMY, FLSMY, FPY, and FLL. FLTMY, FLSMY, and FPY were highest (2,250.08 ± 48.16 kg, 1,944.68 ± 31.20 kg, and 9.32 ± 0.16 kg/day, respectively) for the buffaloes with an AFC of 42–48 months and lowest (1,786.14 ± 88.67 kg, 1,503.12 ± 57.44 kg, and 7.96 ± 0.29 kg/day) for those with an AFC of ≤ 36 months. FLL was also higher (360.91 ± 5.70 days) in buffaloes with an AFC of 42–48 months and lowest (331.08 ± 7.65 days) in those with an AFC of 48–54 months. However, the effect of AFC on all reproductive traits under study, namely FDP, FSP, and FCI, was non-significant ($p > 0.05$).

3.1.2.2 Effect of season of first calving

Table 1 shows that the effect of season of first calving was highly significant ($p \le 0.01$) for FLTMY, FLSMY, and FLL, whereas the effect on FPY was non-significant ($p > 0.05$). FLTMY, FLSMY, and FLL were highest (2,411.02 ± 68.68 kg, 2,008.81 ± 44.49 kg, and 357.43 days ± 8.13 days, respectively) in buffaloes first calved in the autumn season, whereas FLTMY and FLSMY were lowest (1,778.14 ± 69.32 kg and 1,498.18 ± 44.90 kg) in buffaloes first calved in the summer season. FLL was lower for those buffaloes calved in the rainy season (333.00 ± 5.76 days) and those first calved in the summer (345.62 ± 8.21 days). Furthermore, a highly significant ($p \le 0.01$) effect of the season of first calving was observed for FDP, FSP, and FCI. The buffaloes that calved for the first time during the rainy season had the lowest FDP, FSP, and FCI (110.63 ± 7.42 days,

TABLE 1 Least-squares means (LSMs) with standard errors (SEs) for first lactation production and reproduction traits in Nili-Ravi buffaloes.

Source of variation	FLTMY (kg)	FLSMY (kg)	FPY (kg/day)	FLL (days)	FDP (days)	FSP (days)	FCI (days)
Overall mean (501)	**2,033.20 ± 40.07**	**1,699.96 ± 25.96**	**8.71 ± 0.13**	**347.97 ± 4.75**	**121.77 ± 6.11**	**152.45 ± 7.45**	**469.74 ± 7.41**
AFC							
< 36 months (43)	1,786.14^{a} ± 88.67	1,503.12^{a} ± 57.44	7.96^{a} ± 0.29	342.48^{ab} ± 10.50	126.09 ± 13.53	152.54 ± 16.49	468.57 ± 16.41
> 36–42 months (169)	1,936.82^{ab} ± 50.99	1,655.80^{b} ± 33.03	8.72^{b} ± 0.17	339.51^{a} ± 6.04	141.93 ± 7.78	164.60 ± 9.48	481.44 ± 9.43
> 42–48 months (165)	2,250.08^{c} ± 48.16	1,944.68^{c} ± 31.20	9.32^{c} ± 0.16	360.91^{b} ± 5.70	112.84 ± 7.35	155.38 ± 8.95	473.75 ± 8.91
> 48–54 months (81)	2,001.82^{b} ± 64.57	1,735.18^{b} ± 41.83	8.69^{b} ± 0.21	331.08^{a} ± 7.65	116.24 ± 9.85	130.62 ± 12.01	447.32 ± 11.95
> 54–60 months (26)	2,044.31^{abc} ± 112.74	1,689.40^{ab} ± 73.03	8.74^{abc} ± 0.37	352.61^{ab} ± 13.35	128.83 ± 17.20	161.35 ± 20.96	481.44 ± 20.86
> 60 months (17)	2,180.03^{bc} ± 142.57	1,671.59^{ab} ± 92.36	8.81^{abc} ± 0.47	361.22^{abc} ± 16.89	104.69 ± 21.75	150.21 ± 26.51	465.91 ± 26.38
Season of first calving							
Summer (April–June) (76)	1,778.14^{a} ± 69.32	1,498.18^{a} ± 44.90	8.88 ± 0.23	345.62^{ab} ± 8.21	112.95^{a} ± 10.58	140.36^{ab} ± 12.89	458.58^{ab} ± 12.83
Rainy (July–September) (223)	1,880.35^{a} ± 48.64	1,632.70^{b} ± 31.50	8.67 ± 0.16	333.00^{a} ± 5.76	110.63^{a} ± 7.42	125.48^{a} ± 9.04	443.63^{a} ± 9.00
Autumn (October–November) (88)	2,411.02^{c} ± 68.68	2,008.81^{c} ± 44.49	8.71 ± 0.23	357.43^{b} ± 8.13	118.65^{a} ± 10.48	160.01^{bc} ± 12.77	476.08^{bc} ± 12.71
Winter (December–March) (114)	2,063.30^{b} ± 58.52	1,660.15^{b} ± 37.91	8.56 ± 0.19	355.82^{b} ± 6.93	144.84^{b} ± 8.93	183.95^{c} ± 10.88	500.66^{c} ± 10.83
Period of first calving							
1983–87 (76)	1,814.71 ± 90.01	1,488.78^{a} ± 58.31	7.66^{a} ± 0.30	335.65^{ab} ± 10.66	100.87 ± 13.73	122.00^{a} ± 16.74	436.52^{a} ± 16.65
1988–92 (44)	1,876.46 ± 147.43	1,544.69^{ab} ± 95.50	7.80^{a} ± 0.49	362.11^{bc} ± 17.46	83.79 ± 22.49	128.40^{ab} ± 27.41	445.89^{ab} ± 27.28
1993–97 (84)	2,084.19 ± 156.83	1,657.73^{ab} ± 101.59	8.95^{ab} ± 0.52	365.30^{bc} ± 18.58	155.02 ± 23.93	204.62^{b} ± 29.16	520.32^{b} ± 29.02
1998–2002 (84)	2,074.93 ± 105.24	1,894.83^{c} ± 68.17	9.21^{b} ± 0.35	311.35^{a} ± 12.46	121.06 ± 16.06	112.89^{a} ± 19.57	432.41^{a} ± 19.47
2003–07 (110)	2,060.27 ± 91.97	1,784.61^{bc} ± 59.58	9.05^{b} ± 0.30	326.24^{ab} ± 10.89	145.94 ± 14.03	153.38^{ab} ± 17.10	472.18^{ab} ± 17.02
2008–12 (103)	2,288.63 ± 157.37	1,829.13^{bc} ± 101.94	9.57^{b} ± 0.52	387.17^{c} ± 18.64	123.94 ± 24.01	193.41^{b} ± 29.26	511.12^{b} ± 29.12

Means bearing different superscripts in a column differ significantly.

125.48 ± 9.04 days, and 443.63 ± 9.00 days, respectively). Those buffaloes first calving in the summer and autumn seasons also had significantly ($p \leq 0.05$) lower FDP, FSP, and FCI than winter-calved heifers, whereas FDP (144.84 ± 8.93 days), FSP (183.95 ± 10.88 days), and FCI (500.66 ± 10.83 days) were on the higher side.

3.1.3 Effect of period of first calving

It is clear from Table 1 that the effect of the period of first calving was highly significant ($p \leq 0.01$) for FLSMY, FPY, and FLL, but non-significant ($p > 0.05$) for FLTMY. FLSMY was highest (1,894.83 ± 68.17 kg) in the period 1998–2002, followed by the period 2008–12 (1,829.13 ± 101.94 kg), and was lowest (1,488.78 ± 58.31 kg) in the period 1983–87. FPY was highest (9.57 ± 0.52 kg/day) in 2008–12 and lowest (7.66 ± 0.30 kg/day) in 1983–87. FLSMY and FPY showed an increasing trend across time periods. FLL was highest (387.17 ± 18.64 days) for the period 2008–12 and lowest (311.35 ± 12.46 days) for the period of first calving in 1998–2002. Moreover, the effect of the period of first calving was significant ($p \leq 0.05$) on FSP and FCI, but non-significant ($p > 0.05$) on FDP. The FDP ranged from 83.79 ± 22.49 days to 155.02 ± 23.93 days, the FSP ranged from 112.89 ± 19.57 days to 204.62 ± 29.16 days, and the FCI ranged from 432.41 ± 19.47 days to 520.32 ± 29.02 days.

3.2 Lifetime performance traits

3.2.1 Least squares means and factors affecting lifetime performance traits in Nili-Ravi buffaloes

The LSMs along with the SEs for different lifetime performance traits in Nili-Ravi buffaloes are presented in Tables 2A, B. The overall LSM for HL, PL, PDs, UDs, total LTMY, standard LTMY, MY/PL, MY/PDs, and MY/HL were estimated as 3,779.84 ± 31.86 days, 2,078.55 ± 24.32 days, 1,552.74 ± 20.06 days, 525.81 ± 12.44 days, 10,229.71 ± 195.31 kg, 9,203.64 ± 173.52 kg, 4.86 ± 0.08 kg/day, 6.46 ± 0.08 kg/day, and 2.66 ± 0.04 kg/day, respectively.

3.2.1.1 Effect of age at first calving

The results (Table 2A) indicated that the effect of AFC was highly significant ($p \leq 0.01$) for HL, PDs, UDs, total LTMY, standard LTMY, MY/PL, MY/PDs, and MY/HL, but non-significant ($p > 0.05$) for PL. Among the groups based on AFC, significantly ($p \leq 0.05$) higher HL (4,252.66 ± 111.96 days) was observed in buffaloes with an AFC of > 60 months and lower HL (3,398.00 ± 68.88 days) was observed for animals with an AFC of less than 36 months. Furthermore, the PDs were significantly ($p \leq 0.05$) higher (1,670.67 ± 23.72 days) for the group of heifers first calving at 42–48 months and lower (1490.65 ± 25.06 days) for those buffaloes with an AFC of 36–42 months. UDs were also significantly ($p \leq 0.05$) lower (451.14 ± 14.71 days) for those with an AFC of 42–48 months and higher (551.35 ± 26.90 days) for those with an AFC of ≤ 36 months. Total LTMY, standard LTMY, MY/PL, and MY/PDs were significantly ($p \leq 0.05$) higher in animals with an AFC of 42–48 months and lower in animals with an AFC of ≤ 36 months. MY/HL was significantly ($p \leq 0.05$) higher (3.04 ± 0.05 kg/day) in animals with an AFC of 42–48 months and lower (2.36 ± 0.12 kg/day) in animals with an AFC of 54–60 months.

3.2.1.2 Effect of season of first calving

Table 2A reveals that the effect of the season of first calving was highly significant ($p \leq 0.01$) for HL and significant ($p \leq 0.05$ for) PL and PDs, whereas it was non-significant ($p > 0.05$) for UDs, total LTMY, standard LTMY, MY/PL, MY/PDs, and MY/HL. Depending on the season of first calving, HL varied from 3,697.42 ± 38.23 days in the rainy season to 3,868.26 ± 45.83 days in the winter, and the result was significant (Table 2A). PL was significantly ($p \leq 0.05$) higher in the winter (2,116.06 ± 34.99 days) and autumn (2111.36 ± 41.47 days) than for rainy season calving (2008.56 ± 29.18 days). PDs were 1,499.03 ± 24.07 days for the rainy season and 1,580.87 ± 28.86 days for winter season calving.

3.2.1.3 Effect of period of first calving

The results showed (Table 2B) that the effect of the period of first calving was highly significant ($p \leq 0.01$) for HL, PDs, standard LTMY, MY/PL, MY/PDs, and MY/HL, significant ($p \leq 0.05$) for total LTMY, and non-significant ($p > 0.05$) for PL and UDs. The HL was lowest (3,557.42 ± 72.97 days) in the period 2003–07 and highest (4,250.05 ± 70.08 days) in 1983–87. The PDs were highest (1,655.50 ± 44.13 days) in the period 1983–87 and lowest (1,437.01 ± 45.95 days) in the period 2003–07. Total LTMY and standard LTMY were higher in the last three periods starting from 1998–2002 to 2008–12 than in the first three periods from 1983–87 to 1993–97. The MY/PL and MY/HL were lowest (4.28 ± 0.17 kg/day and 2.10 ± 0.10 kg/day, respectively) in the period 1983–87 and highest (5.39 ± 0.20 kg/day and 3.03 ± 0.11 kg/day) for the period 1998–2002. The MY/PDs were lowest (5.42 ± 0.18 kg/day) in 1983–87 and highest (7.22 ± 0.32 kg/day) in 2008–12.

3.2.1.4 Effect of lactation completed

A highly significant ($p \leq 0.01$) effect of LC was found on all the lifetime traits (Table 2B). Furthermore, with a greater number of parities, all lifetime traits showed a tendency to increase with parity.

4 Discussion

In our study, the observed overall LSM for AFC (45.03 ± 0.40 months) was in accordance with the findings of Parmar et al. (2019), who observed that the LSM for AFC was 45.47 ± 0.12 months in Mehsana buffaloes. Similar LSMs for AFC were also reported by Chaudhari (2016) and Prajapati et al. (2018) in Mehsana buffaloes and by Jamal et al. (2018) in Murrah buffaloes. By contrast, a higher AFC, of 55.39 months, was reported by Chaudhari (2015), whereas a lower AFC (of 42.44 months) was reported by Naqvi and Shami (1999) in Nili-Ravi buffaloes. Similar to our results, a non-significant ($p > 0.05$) effect of SOB on AFC was also reported by Gogoi et al. (1985); Rege et al. (1992); Chaudhary et al. (1995); Barwe et al. (1996); Sharma (1996); Nath (1998); Dahlin et al. (1998); Gajbhiye and Tripathi (1999); Javed et al. (2000); Kumar (2000); Mustafa et al. (2003); Singh et al. (2005); Kumar (2007); Kathiravan et al. (2009); Manoj (2009); Raja (2010), and Pawar et al. (2018). By contrast, a significant ($p \leq 0.05$) effect of SOB on AFC was reported by Prajapati et al. (2017) in Mehsana buffalo. The decreasing trend in AFC with time may be due to variation in management practices, such as

TABLE 2A A Least-squares means (LSDs) with standard errors (SEs) for lifetime performance traits in Nili-Ravi buffaloes.

Source of variation	HL (days)	PL (days)	PDs (days)	UDs (days)	Total LTMY (kg)	Standard LTMY (kg)	MY/PL (kg/day)	MY/PD (kg/day)	MY/HL (kg/day)
AFC									
< 36 months (43)	3,398.00^{a} ± 68.88	2,123.89 ± 52.58	1,572.55^{a} ± 43.37	551.35^{b} ± 26.90	9,617.91^{a} ± 422.25	8,476.15^{a} ± 375.13	4.39^{a} ± 0.17	5.90^{a} ± 0.18	2.72^{b} ± 0.09
> 36–42 months (169)	3,447.59^{a} ± 39.80	2,037.07 ± 30.38	1,490.65^{a} ± 25.06	546.42^{b} ± 15.55	9,739.34^{a} ± 244.00	8,872.14^{a} ± 216.78	4.66^{ab} ± 0.10	6.40^{b} ± 0.10	2.72^{b} ± 0.05
> 42–48 months (165)	3,723.01^{b} ± 37.67	2,121.80 ± 28.76	1,670.67^{b} ± 23.72	451.14^{a} ± 14.71	11,581.67^{b} ± 230.94	10,679.71^{b} ± 205.17	5.47^{c} ± 0.09	6.87^{c} ± 0.10	3.04^{c} ± 0.05
> 48–54 months (81)	3,806.40^{b} ± 50.54	2,056.89 ± 38.58	1,538.54^{a} ± 31.82	518.36^{b} ± 19.74	10,246.55^{a} ± 309.82	9,344.84^{a} ± 275.25	4.95^{b} ± 0.12	6.62^{bc} ± 0.13	2.64^{b} ± 0.07
> 54–60 months (26)	4,051.36^{c} ± 88.45	2,071.25 ± 67.52	1,527.37^{a} ± 55.69	543.88^{b} ± 34.54	9,640.10^{a} ± 542.22	8,566.49^{a} ± 481.72	4.62^{ab} ± 0.22	6.18^{ab} ± 0.23	2.36^{a} ± 0.12
> 60 months (17)	4,252.66^{c} ± 111.96	2,060.40 ± 85.47	1,516.67^{a} ± 70.49	543.74^{b} ± 43.73	10,552.71^{ab} ± 686.38	9,282.52^{a} ± 609.79	5.05^{bc} ± 0.28	6.79^{bc} ± 0.29	2.50^{ab} ± 0.15
Season of first calving									
Summer (April–June) (76)	3,742.24^{ab} ± 54.26	2,078.23^{ab} ± 41.43	1,568.22^{ab} ± 34.17	510.01 ± 21.19	10,252.11 ± 332.66	9,297.90 ± 295.55	4.77 ± 0.13	6.30 ± 0.14	2.66 ± 0.07
Rainy (July–September) (223)	3,697.42^{a} ± 38.23	2,008.56^{a} ± 29.18	1,499.03^{a} ± 24.07	509.52 ± 14.93	9,935.46 ± 234.35	9,079.06 ± 208.20	4.91 ± 0.09	6.50 ± 0.10	2.64 ± 0.05
Autumn (October–November) (88)	3,811.43^{bc} ± 54.32	2,111.36^{b} ± 41.47	1,562.83^{ab} ± 34.20	548.53 ± 21.22	10,354.14 ± 333.01	9,237.96 ± 295.85	4.89 ± 0.13	6.58 ± 0.14	2.70 ± 0.07
Winter (December–March) (114)	3,868.26^{c} ± 45.83	2,116.06^{b} ± 34.99	1,580.87^{b} ± 28.86	535.19 ± 17.90	10,377.13 ± 280.96	9.199.65 ± 249.61	4.85 ± 0.11	6.45 ± 0.12	2.64 ± 0.06

HL, herd life; PDs, productive days; PL, productive life; standard LTMY, standard lifetime milk yield; MY/HL, milk yield per day of herd life; MY/PDs, milk yield per day of productive days; MY/PL, milk yield per day of productive life; UDs, unproductive days, total LTMY, total lifetime milk yield.
Means bearing different superscripts in a column differ significantly.

TABLE 2B Least-squares means LSMs with standard errors SEs for lifetime performance traits in Nili-Ravi buffaloes.

Source of variation	HL (days)	PL (days)	PD (days)	UD (days)	Total LTMY (kg)	Standard LTMY (kg)	MY/PL (kg/day)	MY/PD (kg/day)	MY/HL (kg/day)
Overall mean (501)	**3,779.84 ± 31.86**	**2,078.55 ± 24.32**	**1,552.74 ± 20.06**	**525.81 ± 12.44**	**10,229.71 ± 195.31**	**9,203.64 ± 173.52**	**4.86 ± 0.08**	**6.46 ± 0.08**	**2.66 ± 0.04**
Period of first calving									
1983–87 (76)	4,250.05^{b} ± 70.08	2,124.48 ± 53.50	1,655.50^{b} ± 44.13	468.98 ± 27.37	9,148.76^{a} ± 429.64	7,503.46^{a} ± 381.70	4.28^{a} ± 0.17	5.42^{a} ± 0.18	2.10^{a} ± 0.10
1988–92 (44)	3,813.03^{a} ± 114.84	2,037.93 ± 87.67	1,583.86^{b} ± 72.31	454.07 ± 44.85	9,237.69^{ac} ± 704.00	8,113.27^{ab} ± 625.45	4.42^{ad} ± 0.28	5.59^{ab} ± 0.29	2.34^{ab} ± 0.16
1993–97 (84)	3,671.18^{a} ± 121.97	2,132.37 ± 93.11	1,580.09^{b} ± 76.80	552.28 ± 47.64	10,122.08^{ab} ± 747.76	9,233.68^{bc} ± 664.32	4.53^{acd} ± 0.30	6.21^{b} ± 0.31	2.65^{bc} ± 0.17
1998–2002 (84)	3,720.75^{a} ± 81.93	2,098.55 ± 62.55	1,568.97^{b} ± 51.59	529.57 ± 32.00	11,236.70^{b} ± 502.29	10,340.31^{c} ± 446.24	5.39^{b} ± 0.20	7.13^{c} ± 0.21	3.03^{d} ± 0.11
2003–07 (110)	3,557.42^{a} ± 72.97	1,979.20 ± 55.71	1,437.01^{a} ± 45.95	542.19 ± 28.50	10,530.43^{bc} ± 447.35	9,853.03^{c} ± 397.44	5.25^{bc} ± 0.18	7.18^{c} ± 0.19	2.91^{cd} ± 0.10

(Continued)

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TABLE 2B Continued

Source of variation	HL (days)	PL (days)	PD (days)	UD (days)	Total LTMY (kg)	Standard LTMY (kg)	MY/PL (kg/day)	MY/PD (kg/day)	MY/HL (kg/day)
2008–12 (103)	3,666.59^{a} ± 123.61	2,098.78 ± 94.36	1,491.01^{b} ± 77.83	607.78 ± 48.28	11,102.61^{bc} ± 757.78	10,178.09^{c} ± 673.23	5.26^{bd} ± 0.30	7.22^{c} ± 0.32	2.94^{cd} ± 0.17
Lactation completed									
3 (139)	2,853.55^{a} ± 43.21	1,191.62^{a} ± 32.99	917.53^{a} ± 27.21	274.09^{a} ± 16.88	5,234.70^{a} ± 264.89	4,425.20^{a} ± 235.34	4.47^{a} ± 0.11	5.81^{a} ± 0.11	1.86^{a} ± 0.06
4 (128)	3,301.72^{b} ± 43.52	1,571.47^{b} ± 33.22	1,185.66^{b} ± 27.40	385.81^{b} ± 17.00	7,459.51^{b} ± 266.81	6,682.61^{b} ± 237.04	4.78^{b} ± 0.11	6.28^{b} ± 0.11	2.31^{b} ± 0.06
5 (80)	3,741.22^{c} ± 51.36	2,024.86^{c} ± 39.21	1,524.01^{c} ± 32.34	500.86^{c} ± 20.06	10,064.26^{c} ± 314.87	9,011.42^{c} ± 279.73	4.93^{bc} ± 0.13	6.53^{bc} ± 0.13	2.75^{c} ± 0.07
6 (72)	4,163.74^{d} ± 56.86	2,474.26^{d} ± 43.40	1,846.59^{d} ± 35.80	627.68^{d} ± 22.21	12,354.59^{d} ± 348.55	11,164.47^{d} ± 309.66	4.95^{bc} ± 0.14	6.63^{c} ± 0.15	3.01^{d} ± 0.08
7 and above (82)	4,838.96^{e} ± 53.76	3,130.55^{e} ± 41.04	2,289.92^{e} ± 33.85	840.63^{e} ± 21.00	16,035.51^{e} ± 329.56	14,734.51^{e} ± 292.79	5.15^{c} ± 0.13	7.05^{d} ± 0.14	3.37^{e} ± 0.07

HL, herd life; PDs, productive days; PL, productive life; standard LTMY, standard lifetime milk yield; MY/HL, milk yield per day of herd life; MY/PDs, milk yield per day of productive days; MY/PL, milk yield per day of productive life; UDs, unproductive days, total LTMY, total lifetime milk yield.
Means bearing different superscripts in a column differ significantly.

feeding, reproduction, and so on, over time (Kakati et al., 2017), which influences growth rate and AFC in heifers. This is in line with the findings of Reddy and Mishra (1980) in Murrah buffaloes, Cady et al. (1983) in Nili-Ravi buffaloes, Gogoi et al. (2002); Meena et al. (2003), and Rathod et al. (2018) in Surti buffaloes, and Parmar et al. (2019) in Mehsana buffaloes, which also observed a decreasing age in the AFC over time.

The increase in FLTMY with an increase in AFC up to 42–48 months could be attributed to the optimum development of the mammary glands; insufficient growth of heifers, if calved too early, may lead to a negative effect on production (Teke and Murat, 2013). Batra and Desai (1964) and Nagpal and Acharya (1970) reported significant ($p \leq 0.05$) effects of AFC on FLTMY in Sahiwal cows, lending support to the findings. Chaudhari (2015) in Nili-Ravi buffaloes and Chakraborty et al. (2010) in Murrah buffaloes reported significant ($p \leq 0.05$) effects of AFC on FLSMY. Furthermore, a significant ($p \leq 0.05$) effect of AFC on FPY was observed by Singh and Tiwana (1981) in Murrah buffaloes and by Verma and Yadav (1990) in Nili-Ravi buffaloes. Other workers reported a significant ($p \leq 0.05$) effect of AFC on FLL (Ragab et al., 1953; Venkayya and Anantakrishnan, 1957; and Kanaujia et al., 1975). Contrary to our findings, a non-significant ($p > 0.05$) effect of AFC on FLTMY was found by El-Arian (1986) and Dass and Sharma (2000) in Murrah buffaloes. Neog et al. (1993) reported a non-significant ($p > 0.05$) effect of AFC on FPY and Roychaudhary et al. (1971); El-Arian (1986), and Chhikara (1993) reported a non-significant (p > 0.05) effect of AFC on FLL in Murrah buffaloes. Heat stress has a negative impact on livestock production, both directly and indirectly. Owing to heat stress, buffaloes reduce their milk production in summer, and have shorter lactation lengths (Upadhayay et al., 2007). Furthermore, those buffaloes calved in the summer season are more influenced by heat stress in early lactation, thereby adversely affecting the total LTMY. Similar to our results, Hassan et al. (2017) observed a significant ($p \leq 0.05$) effect of the season of first calving on FLTMY. Other findings revealed that animals first calved in the spring had the highest, and those calved in summer had the lowest, FLTMY (Afzal et al., 2007). A non-significant ($p > 0.05$) effect of season of first calving on FPY was observed by Galsar et al. (2016) in Mehsana buffaloes, and by Prakash and Tripathi (1987); Sethi and Khatkar (1997); Kumar (2000), and Chakraborty et al. (2010) in Murrah buffaloes. By contrast, a non-significant ($p > 0.05$) effect of season of first calving on FLTMY, FLSMY, and FLL was reported by Chaudhari (2015) in Nili-Ravi buffaloes and on FLTMY and FLL by Galsar et al. (2016) in Mehsana buffaloes. A significant ($p \leq 0.05$) effect of season of first calving on FPY was noted by Tekerli et al. (2001) in Anatolian buffaloes, by Singh et al. (2011); Thiruvenkadan et al. (2014), and Dev et al. (2016) in Murrah buffaloes, and by Chaudhari (2015) in Nili-Ravi buffaloes. Furthermore, differences in the performance of buffaloes throughout different periods might be attributed to differences in management practices, sires used for breeding, environmental conditions, and variations in feed and fodder availability. Similar to our findings, Gupta (2009) and Jamuna et al. (2015) in Murrah buffaloes and Ratwan et al. (2016) in Jersey crossbreds observed a significant ($p \leq 0.05$) effect of the period of first calving on FLSMY. In addition, Chaudhari (2015) found that the period of first calving had a significant ($p \leq 0.05$) effect on FPY in both Murrah and Nili-Ravi buffaloes By contrast, Chaudhari (2015) and Galsar et al. (2016) reported a significant ($p \leq 0.05$) effect of the period of first calving on

FLTMY and a non-significant ($p > 0.05$) effect on FLL in Nili-Ravi and Mehsana buffaloes, respectively. A non-significant ($p > 0.05$) effect of the period of first calving on FLSMY was reported by Pawar et al. (2012) in Murrah buffaloes, whereas a significant effect on FPY was found by Galsar et al. (2016) in Mehsana buffaloes, and by Kumar (2000); Chakraborty et al. (2010), and Patil (2016) in Murrah Buffalo.

Similar to our findings, Godara (2003) reported that the effect of AFC was non-significant ($p > 0.05$) on FDP, FSP, and FCI. Non-significant ($p > 0.05$) effects of AFC on FDP (Roychaudhary et al., 1971; Kanaujia et al., 1974; El-Arian, 1986; Chhikara, 1993; and Gajbhiye and Tripathi, 1999), on FSP (Kanaujia et al., 1974 and Thiruvenkadan et al., 2010), and on FCI (Roychaudhary et al., 1971; El-Arian, 1986; Chhikara, 1993; Gajbhiye and Tripathi, 1999; Chakraborty et al., 2010; and Thiruvenkadan, 2011) have also been reported in buffaloes. However, the findings of Kanaujia et al. (1975) and Eastham et al. (2018) differed; they found a significant ($p \leq 0.05$) effect of AFC on FCI. Moreover, the lowest FDP, FSP, and FCI for the animals first calved in rainy season could be attributed to a favorable climate and an abundant availability of high-quality fodder. Similar to our findings, Chaudhari (2015) reported that effects of season of first calving on FDP, FSP, and FCI in Nili-Ravi buffaloes were highly significant ($p \leq 0.01$); the effects were highest in winter and lowest in the rainy season. Chhikara (1993); Sharma (1996); Nath (1998); Gajbhiye and Tripathi (1999), Dass and Sadana (2000), and Kumar (2000) also reported significant ($p \leq 0.05$) effects of season of first calving on FDP. Significant ($p \leq 0.05$) effects of the season of first calving on FSP were reported by Sharma (1982); Kumar (1984); Chhikara (1993); Nath (1998), and Kumar (2000), and significant ($p \leq 0.05$) effects on FCI were reported by Kumar et al. (2003); Barman (2009); Thiruvenkadan (2011); Patil (2016), and Dev et al. (2016). However, Galsar et al. (2016) observed a non-significant ($p > 0.05$) effect on FDP, FSP, and FCI in Mehsana buffaloes. Similarly, Dhara (1994), Nath (1996), and Wakchaure et al. (2008) reported non-significant ($p > 0.05$) effects of season of first calving on FSP. Saha and Sadana (2000); Hussain et al. (2006), and Gupta et al. (2012) reported non-significant ($p > 0.05$) effects of season of first calving on FCI. Furthermore, the studies that related to the effect of period of first calving on first lactation reproduction traits were inconsistent with the earlier studies of Chaudhari (2015) in Nili-Ravi buffaloes and of Galsar et al. (2016) in Mehsana buffaloes, who reported non-significant ($p > 0.05$) effects of period of first calving on FDP. Significant ($p \leq 0.05$) effects of period of first calving on FSP were observed by Sharma (1996); Jain and Sadana (1998), Wakchaure et al. (2008), Barman (2009); Thiruvenkadan et al. (2014), and Chaudhari et al. (2016). Dhara (1994) and Thiruvenkadan et al. (2010) in Murrah buffaloes and Galsar et al. (2016) in Mehsana buffaloes noted that the effect of period of first calving on FCI was highly significant ($p \leq 0.01$). By contrast to our findings, Chaudhari (2015) in Murrah buffaloes and Galsar et al. (2016) in Mehsana buffaloes reported non-significant ($p > 0.05$) effects of the period of first calving on FSP, whereas Chaudhari (2015) reported a non-significant ($p > 0.05$) effect on FCI in Nili-Ravi buffaloes. This may be because of similar management practices across different periods. The low HL observed for buffaloes with an AFC of less than 36 months could be attributed to the fact that, because HL is the time between births and disposal, animals with a lower AFC are generally culled sooner than others because of their poor performance in terms of milk yield in the first lactation as well as subsequent lactations, something which can be attributed insufficient udder development. The animals with an AFC of 42–48 months had better reproduction and higher milk production owing to adequate growth at that age, although this depended on the farm conditions are resources available to rear the animals. Lower lifetime performance of early calvers may be attributed to the fact that energy was diverted from milk production to growth and development, resulting in low milk production in the first lactation and, eventually, subsequent lactations, as well as a reduction in lifetime milk yield.

In agreement with our results, a non-significant ($p > 0.05$) effect of AFC on PL was also reported by Godara (2003) and by Ilieva and Peeva (2007) in Murrah buffaloes. However, Nilforooshan and Edriss (2004) and Teke and Murat (2013) observed a significant ($p \leq 0.05$) effect of AFC on total LTMY. By contrast, a non-significant ($p > 0.05$) effect of AFC on total LTMY was reported by Dev (2015). In addition, a non-significant ($p > 0.05$) effect of AFC on PDs was recorded by Balaine (1971); Gaur and Raheja (1996), and Bhutkar et al. (2014) on MY/PL, on MY/PDs by Dev (2015), and on MY/HL by Thiruvenkadan et al. (2015). Furthermore, in accordance with our results, Khalil et al. (1992) reported a significant ($p \leq 0.05$) effect of the season of first calving on PDs. Chaudhari (2015) found that the effect of season on UDs and total LTMY was non-significant ($p > 0.05$) in Nili-Ravi buffaloes. A non-significant ($p > 0.05$) effect of season of first calving on MY/HL was also reported by Dutt et al. (2001). A significant ($p \leq 0.05$) effect of season of first calving on PL was reported by Godara (2003) in Murrah buffaloes. Our results differ from the findings of Chaudhari (2015), who reported a non-significant ($p > 0.05$) effect of season of first calving on HL and PL in Nili-Ravi buffaloesand from those of Dev (2015), who found the same in Murrah buffaloes. A significant ($p \leq 0.05$) effect of season of first calving on total LTMY was reported by Tailor et al. (1998) in Surti buffaloes. A significant ($p \leq 0.05$) effect of season on UDs was observed by Singh et al. (2005), and a significant effect ($p \leq 0.05$) of season on MY/PL and MY/PDs was reported by Khalil et al. (1992). The high HL noticed in 1983–87 may be because of the lower number of auctions of animals during 1983–87; hence, animals remained in the herd for a longer time until disposal. Moreover, an increasing trend in lifetime milk yield found across the periods (1998–2012) may be due to the adoption of better management practices over the period of time. Likewise, a continuous increasing shift was also found for the MY/PDs with the passage of time. In conformity with our results, Chaudhari (2015) reported a highly significant ($p \leq 0.01$) effect of the period of first calving on HL and total LTMY in Nili-Ravi buffaloes. A significant ($p \leq 0.05$) effect of period of first calving on PDs was noticed by Khalil et al. (1992), and a significant ($p \leq 0.05$) effect of period of first calving on MY/PL and MY/PDs was reported by Dev (2015). However, in contrast to our results, Dev (2015) reported a non-significant ($p > 0.05$) effect of the period of first calving on HL, total LTMY, and MY/HL. A non-significant ($p > 0.05$) effect of period of calving on PDs was also reported by Malhotra and Singh (1980) and by Gupta and Tripathi (1994) in Red Sindhi cattle. Chaudhari (2015) reported a significant ($p \leq 0.05$) effect of the period of first calving on PL and UDs in Nili-Ravi buffaloes. Furthermore, the increasing trend observed for all the lifetime traits with a greater number of parities may be appointed to the fact that the animals completed a greater number of lactations owing to their continuous better performance and remained in the herd for a longer time. Similar to our results, Ambhore et al. (2017) reported a highly significant ($p \leq 0.01$) effect of LC on HL and PL.

5 Conclusions

The Nili-Ravi buffaloes that first calved at an age between 42 and 48 months had better production and reproduction potential than those that did not. The first lactation production *viz.* FLTMY, FLSMY, FPY, and FLL, and lifetime traits such as PDs, total LTMY, and standard LTMY were best in this category of animals. Additionally, this group had significantly ($p \leq 0.05$) lower FDP and UDs. Hence, attempts should be made to attain an AFC of approximately 42 months, and strategies such as feeding, health, reproduction, housing, and breeding management of young heifers in the dairy farm should be targeted in an organized manner. First lactation production traits such as FLTMY and FLSMY were significantly ($p \leq 0.05$) higher among the animals that first calved in the autumn. On the other hand, reproduction potential was better in the group of buffaloes in which first calving occurred in the rainy season: parameters such as FDP, FSP, and FCI were significantly ($p \leq 0.05$) lower. A breeding plan should be customized and coordinated considering the seasonal and environmental conditions of the year with the goal of achieving a high success rate in conception, which could further lead to an overall improvement of the reproductive cycle and production performance of the livestock in a herd.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding authors.

Ethics statement

Ethics review and approval were not required for the animal study because the work was based on livestock data recorded for a period of 35 years.

Author contributions

PT collected and compiled data, and drafted the manuscript. AB designed the experiment. AC collected data, and was involved in classification and statistical analysis. MJ and SKu interpretated the results. SKh revised the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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