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Investigating non-genetic factors impacting calving interval of Mehsana buffaloes

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Abstract
Buffaloes are known as the backbone of the dairy industry in India contributing about half of milk production. Milk production is a complex trait, hence influenced by various non-genetic factors. This study investigates the impact of non-genetic factors on the reproductive performance of Mehsana buffaloes, focusing on their calving interval (CI). The dataset, comprising 43,074 records, was obtained from the National Dairy Development Board (NDDB), Anand, and recorded through the Indian Network for Animal Productivity and Health (INAPH). AI workers, union (milk co-operative society), tehsil Age at first calving, year of calving, month of calving, and lactation were considered as non-genetic factors. Statistical analysis, including Least Squares Analysis, revealed that all factors had a highly significant (p<0.01) influence on the calving interval except union and tehsil. These findings contribute valuable insights into dairy herd management strategies, aiding dairy farmers, policymakers, and researchers to optimize fertility and improve the overall productivity of Mehsana buffaloes.

Keywords: Least square means, Mehsana buffalo, calving interval, non-genetic factors, reproduction

Introduction
In recent decades, India has emerged as a global leader in milk production, with an annual output of approximately 221.06 million metric tons in 2021-22 (DAHD, 2023) [4]. Contributing significantly to this achievement are Indian buffaloes, particularly Mehsana buffaloes, prevalent in regions such as Mehsana, Banaskantha, Patan, Sabarkantha, and Gandhinagar in Gujarat. Accounting for about 4% of India's buffalo population (DAHD, 2022) [3], Mehsana buffaloes are renowned for their robust milk production potential, persistent breeding, and adaptability to semi-arid conditions (Prajapati *et al*., 2018) [10].

As majority of the economic important traits of dairy livestock's are influenced by the number of genes with minor effects and highly influenced by the environmental factors especially associated with management practices. Non-genetic factors, such as the environment and management techniques, are just as important as genetic factors in determining female fertility. The effect of these factors on dairy animal's reproductive attributes is particularly significant. (Ramadan SI. 2018) [12].

Reproductive performance has decreased as a result of indiscriminate breeding methods that only aim to maximize milk output. Reduced female fertility beside from affecting the calving interval and increases generation interval but it also hampers genetic progress in production traits, drives up insemination costs, increases involuntary culling rates, and diminishes overall milk yield per animal. Continuous selection for milk production traits often leads to a negative correlation with fertility traits (Windig *et al*, 2006) [13]. Many works have been conducted to find the impact of the various non-genetic factors on fertility traits (Purohit *et al*., 2021, Parmar *et al*., 2017, Galsar *et al*, 2016) [11, 7, 5], However, there hasn't been any studies undertaken regarding non-genetic aspects like the AI worker or union with such a huge data collection. The one of the key elements to take into account when analyzing fertility characteristics is the AI worker's skill, since it has a significant effect on the number of days open, which changes the calving interval.

This study aims to explore the impact of non-genetic factors on fertility traits, specifically focusing on the calving interval of Mehsana buffaloes. Understanding these factors is crucial for developing effective fertility management strategies, enhancing milk production efficiency, and ensuring the sustainability of the Indian dairy sector. By uncovering insights into the relationship between non-genetic factors and fertility traits, we aim to optimize reproductive performance.

Materials and Methods

A dataset comprising 43,074 fertility records of Mehsana buffaloes was obtained from the National Dairy Development Board (NDDB), Anand. The Calving interval (CI) was generated from the date of calving to successive dates of calving from the data, which is recorded through the Indian Network for Animal Productivity and Health (INAPH). The records span across 19-year period from 2004 to 2022. To ensure data quality, the dataset was subjected to pre-processing steps. Buffaloes that had abortions or improper records were removed before analysis. Outliers and duplicate records were removed, and the data were standardized and normalized for further analysis.

Non-genetic Factors Considered

a) **AI worker:** In female fertility, the person who did artificial insemination has a major role especially from the detection of heat, thawing of semen, and semen deposition accuracy. These factors change the period of the service period and ultimately lead to changes in the calving interval and productive life of the animals. AI persons have been taken as the factors and the person has a minimum of 10 AI data has been included in the final analysis. A total of 183 AI workers with a minimum of 12 records and a maximum of 852 records were recorded and taken as fixed factors.

b) **Unions:** In the study, two milk unions (Banas Milk Union and Mehsana Milk Union) operating within their respective areas, were considered as non-genetic factors. Union is called for milk co-operative societies, which runs progeny testing programs for this breed. Majorly within breeding tracts of Mehsana two major milk co-operatives are there, the Mehsana Union and Banas Union. Union having their policy for breeding and management as well as the between districts there are many socio-economic variations so that union is taken as a variance factor.

c) **Tehsil:** A total of 24 tehsils of the breeding tract of the Mehsana have been taken in which the progeny testing program of the two-milk union is going. Each tehsil has a similar socio-economic condition, environment, and pattern of the husbandry practices so the tehsil has been taken as the fixed factor to know its impact on the calving interval.

d) **Calving Months:** The month of calving was used as one of non-genetic factor and Buffaloes were grouped into 12 months from January to December based on the month of calving to account for seasonal variations.

e) **Year of Calving:** The year of calving is an essential non-genetic factor considered in this study. Buffaloes were grouped based on the calving year to assess the long-term trends and potential effects of changing environmental and management factors over the 19-year study period from 2004 to 2022. All the factors with levels are described in Table 1.

f) **Lactation:** Lactation of the animal has an important role in fertility traits. With the increase or change in lactation, the physiology and the behaviour and physiological pattern have been changed, which impacts the fertility of the animals (Zobel *et al*. 2015) [14]. Looking this into the consideration the lactation number of the animals has been taken into consideration. Up to 8 lactation the lactation has been coded from 1 to 8 and the 9 and above lactation has been coded as 9 for the downstream analysis.

g) **Age at First Calving (AFC):** AFC is an important parameter influencing the productivity of buffaloes. The AFC data were collected and grouped into six-month periods for analysis. The AFC class is divided into 14 subclasses AFC1 (>2 years), AFC2 (2 to 2.5 years), AFC3 (2.5 to 3 years), AFC4 (3 to 3.5 years), AFC5 (3.5 to 4 years), AFC6 (4 to 4.5 years), AFC7 (4.5 to 5 years), AFC8 (5 to 5.5 years), AFC9 (5.5 to 6 years), AFC10 (6 to 6.5 years), AFC11 (6.5 to 7 years), AFC12 (7 to 7. years), AFC13 (7.5 to 8 years) and AFC14 (>8 years).

Table 1: Various Non-Genetic Factors Included in Study

Sr No	Non-genetic factor	Level	Description
1	AI worker	183	The person who did artificial insemination
2	Union	2	Banas Milk Union & Mehsana milk Union
3	Tehsil	25	Tehsil in which animal is reared
4	Month of calving	12	January to December
5	Year of Calving	15	2009-2022(2-15) and before 2009 coded as 1
6	Lactation	9	Each lactation records
7	Age at first Calving (AFC)	14	Each of the 6 months

Statistical Analysis

The statistical analysis was conducted using R software (R Core Team and R Core Team, 2022). A Least Squares Analysis was performed to assess the effects of non-genetic factors (AI worker, unions, tehsil, calving months, AFC, lactation, and year of calving) on the fertility of Mehsana buffaloes. This analysis helps identify the relationships between the independent variables and the dependent variable (calving interval). The least squares analysis was conducted using the following statistical model:

$$Y_{ijklmnop} = \mu + A_i + B_j + C_k + D_l + E_m + F_n + G_0 + e_{ijklmnop}$$

Where,

Y_{ijklm} = mth calving interval record of animal which inseminated by ith AI worker, reared under jth union and kth tehsil calved in lth month and mth year, nth lactation and oth age at the first calving group

μ = Population mean

A_i = Fixed effect of ith AI worker, who did the insemination

B_j = Fixed effect of jth union in which animal reared

C_k = Fixed effect of kth tehsil in which animal reared

D_l = Fixed effect of lth month in which animal calved

E_m = Fixed effect of mth year in which animal calved

F_n = Fixed effect of nth lactation in which animal was

G_o = Fixed effect of oth age at first calving group

$e_{ijklmnop}$ = random error with zero mean and constant variance

Results and Discussion

The analysis of the calving interval (CI) in Mehsana buffaloes revealed that AI worker, month, year of calving, lactation of animal, and age at first calving are highly influencing the calving interval in the Mehsana buffaloes under the field conditions, whereas the Union and tehsil has a non-significant effect on the calving interval (Table 2). This suggests that these factors have a substantial impact on the reproductive performance of buffaloes. The least squares mean calving interval was observed as 458.83±3.43 days (Table 3). Similar findings of least squares mean for calving interval by Purohit *et al*. (2021) [11], Galsar *et al*. (2016) [5], and Patel *et al*. (2019) [15] in Mehsana buffaloes.

Table 2: Least Square Analysis of Variance for Calving Interval

Factors	Degree of freedom	Sum Sq	Mean Sq	F value	p value
AI worker	182	63313494.41	347876.34	9.61	***
Union	1	11637.92	11637.92	0.32	NS
Tehsil	23	980266.14	42620.27	1.18	NS
Month of calving	11	41378663.58	3761696.69	103.95	***
Year of calving	14	39190569.37	2799326.38	77.36	***
Lactation	8	1767639.04	220954.88	6.11	***
Age at first calving	13	1640659.16	126204.55	3.49	***
Residuals	42821	1549527461	36186.16		
*** for p value < 0.001 NSNon-Significant					

The variation in calving interval due to changes in the AI workers was notable, and the range spanned from population mean by -170.85 days to 498.23 days (Table 3). It is observed that the range is found to be varying from worker to worker (Figure 3). The variation in the AI worker may be due to their experience and skill in detecting heat, timely insemination, semen deposition accuracy, identification of the health status of the animals, etc. It is inferred from the present study that skilled and experienced workers may help to reduce the service period and optimize the reproduction potential of the animals.

The significant differences in calving interval between Banas Milk Union (1) and Mehsana Milk Union (2) and between the different tehsils (Table 3 and Figure 2) depict the information of the various management practices and policies within different regions. The non-significant effect of these factors may be due to the known fact that fertility is influenced by many factors and the common reasons are observed throughout the breeding tract. However a significant effect of the cluster was observed by Patel *et al*. (2004) [16], Parmar *et al*. (2017) [7], and Purohit *et al.* (2021) [11] on the calving interval but they observed a non-significant effect of the cluster on the service period. These studies, include only one union and make clusters based on the socioeconomic condition of the farmers or based on the geographic locations.

It’s observed from the result that the calving interval increases from October onwards up to February and shows a declining trend from March to September (Table 3 and Figure 1). In concordance with this study, the highly significant ($P \leq 0.01$) effect of the season of calving Parmar *et al*. (2017) [7] and Galsar *et al*. (2016) [5] in Mehsana buffaloes. This fluctuation in calving interval may be accounted for due to differences in availability and quality of feed during these months. Furthermore, the influence of climatic factors, such as cold and hot months, affect the metabolism of buffaloes and the expression of the oestrus cycle (Petrocchi *et al*, 2023) [9]. Management strategies during these months, such as temperature regulation and feeding practices, may improve the fertility of the animals.

The year of calving exhibited considerable differences, with Calving intervals throughout the years. It is depicted in Figure 2 that the overall calving interval has shown declining trends in the last few years indicating that female fertility is also taken care of. Similar significant effects of the period of calving were also observed by Purohit *et al*. (2021) [11], Parmar *et al*. (2017) [7], and Galsar *et al*. (2016) [5] in the same breed. This variation may be attributed to the selection and breeding over the years, facilitated by progeny testing programs. Additionally, recent improvements in the fertility, are due to awareness of female fertility in the livestock keepers. The impact of the year of calving on calving interval indicates ongoing genetic improvement through selection and breeding practices. Over the study period, advancements in genetic technologies, including progeny testing, have likely contributed to the improved fertility observed in more recent years.

The lactation has a significant impact on the calving interval, it's revealed that as lactation increases the calving interval declines up to 5^{th} to 6^{th} lactation, and then it changes it may due to a smaller number of observations. As the increase in the lactation, the physiological status of the animal changes and its body is attending its weight properly so it lead to improving its reproductive potential. The range of calving interval varied significantly across different groups for each factor (Table 3 and Figure 3). In concordance with the present study, Parmar *et al*. (2017) [7] and Purohit *et al*. (2021) [11] reported a significant effect of the AFC group on the calving interval in Mehsana. The findings of this study underscore the importance of non-genetic factors in influencing the fertility of Mehsana buffaloes. AI worker, Age at first calving, year of calving, month of calving, and lactation were all found to significantly impact the calving interval, highlighting their potential as crucial determinants of reproduction performance in the breed for downstream analysis.

Overall, the results of this study emphasize the importance of considering non-genetic factors in dairy herd management for optimizing reproductive performance in Mehsana buffaloes. The identification of factors that significantly influence calving interval can aid dairy farmers and policymakers in implementing targeted strategies for enhancing fertility performance and improving the overall productivity of the breed.

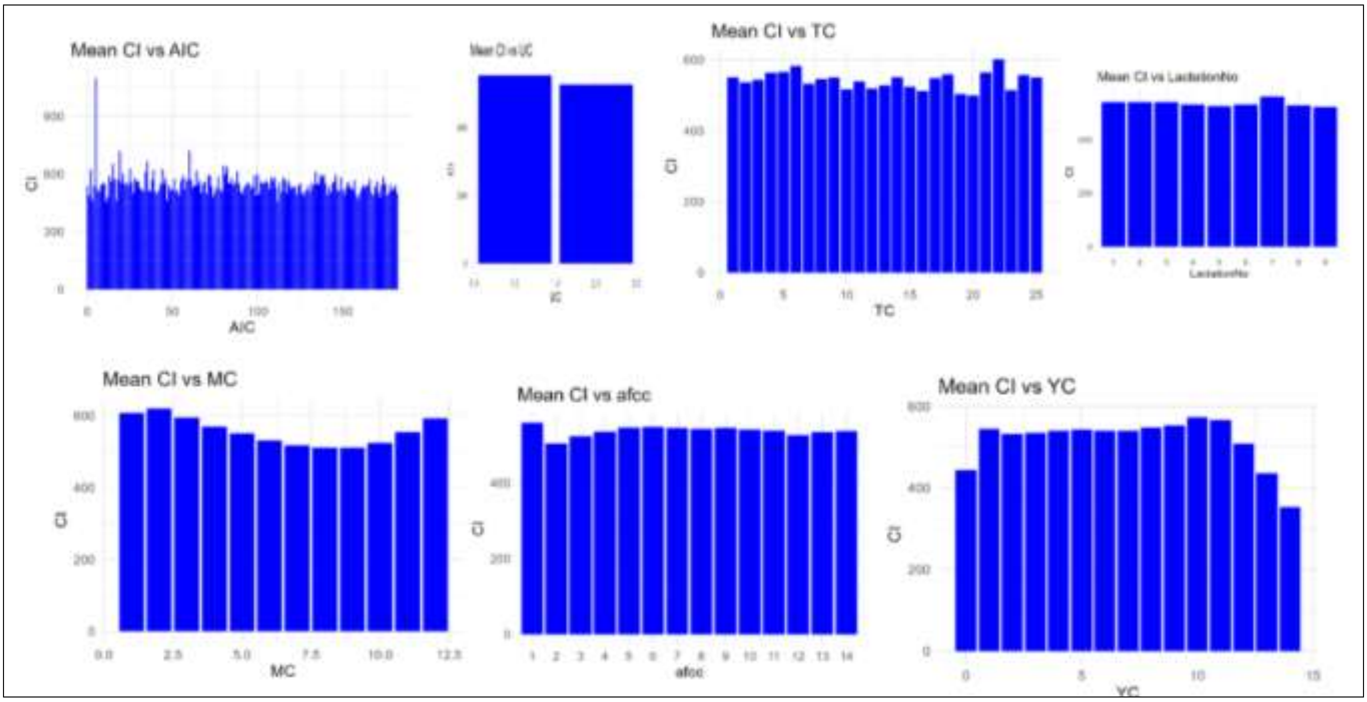


Fig 1: Phenotypic mean of each level of non-genetic factors

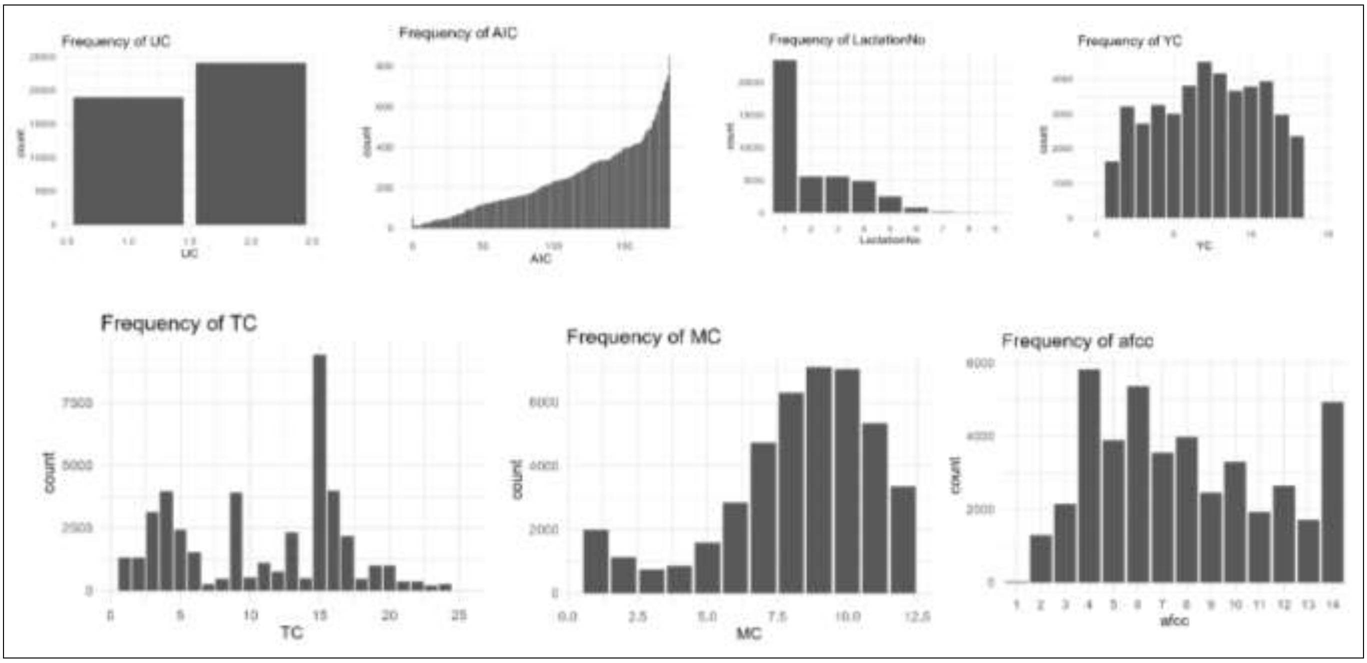
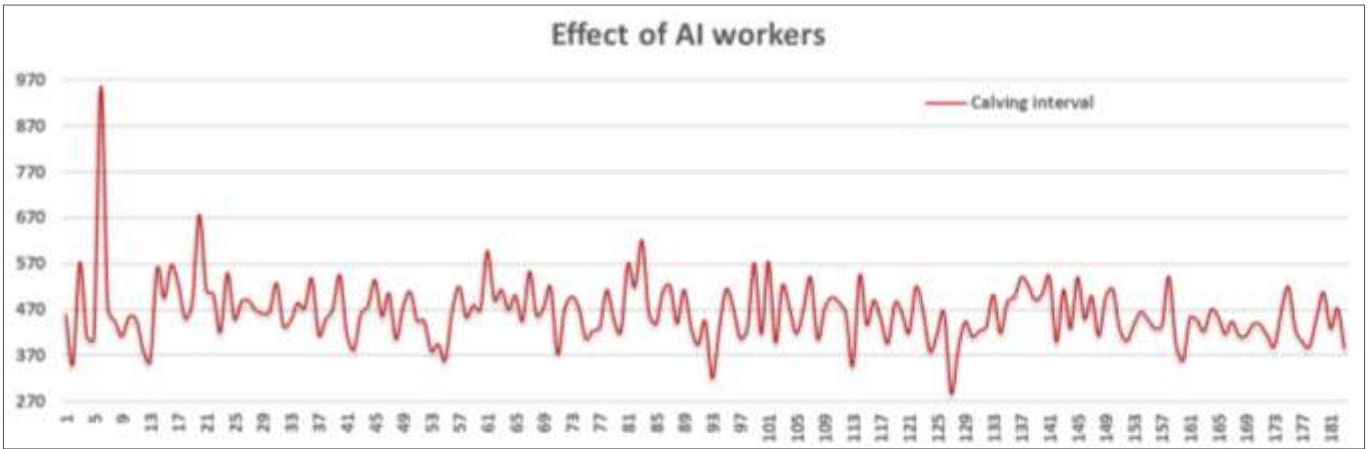


Fig 2: Observation of each level of non-genetic factors



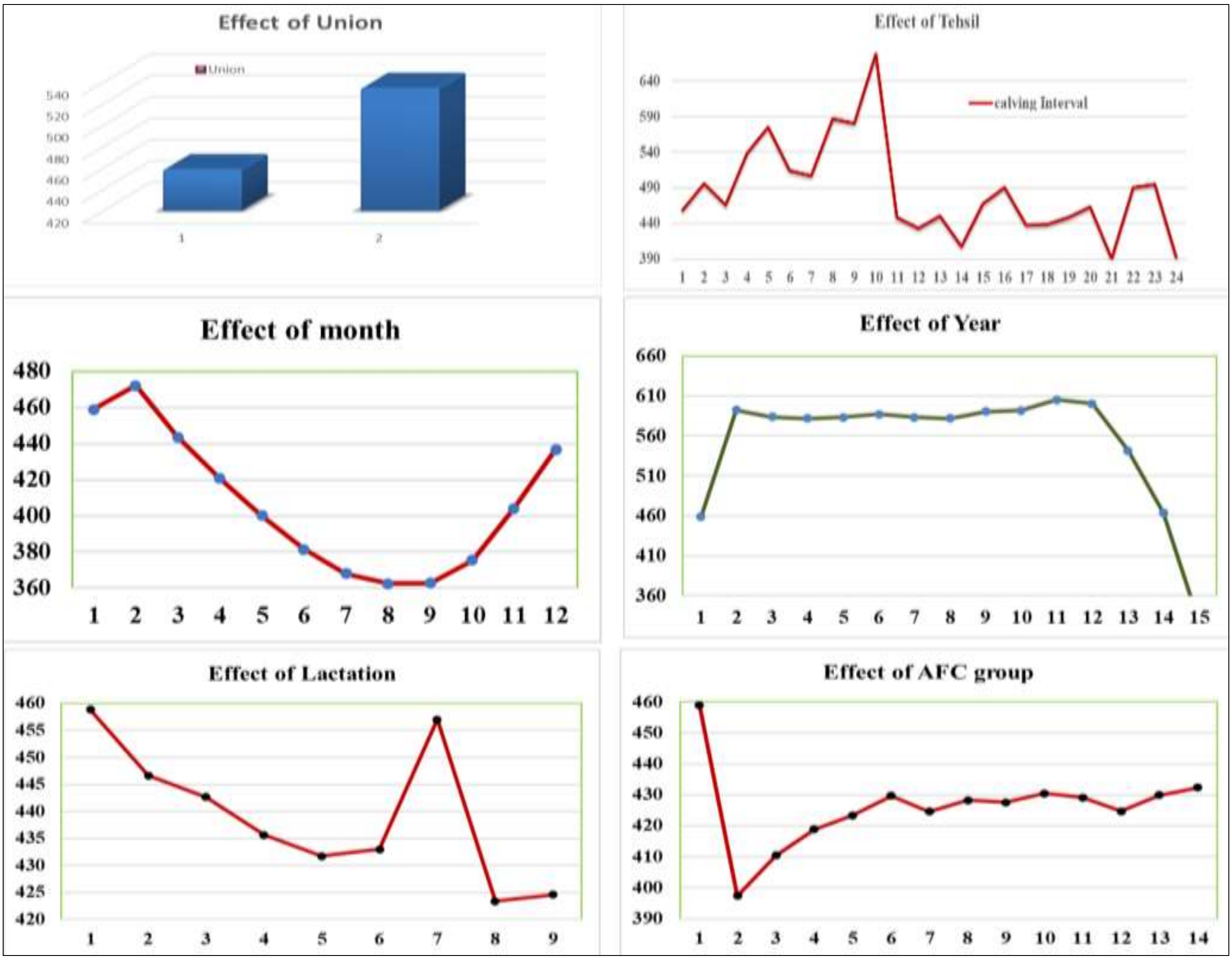


Fig 3: Effect of the various level of non-genetic factors on calving interval

Table 3: Effect of various levels of non-genetic factors on the calving interval (deviation from the population mean, μ = 458.83 days

AI workers (p<0.001)					
Level	**Calving interval**	**Level**	**Calving interval**	**Level**	**Calving interval**
2	-108.07	62	32.90	123	9.36
3	114.30	63	54.80	124	-79.71
4	-49.58	64	11.08	125	-41.29
5	-55.00	65	42.32	126	4.62
6	498.43	66	-13.14	127	-170.86
7	11.15	67	94.57	128	-75.84
8	-13.59	68	-0.89	129	-14.71
9	-46.94	69	15.91	130	-47.89
10	-4.18	70	60.19	131	-35.56
11	-8.94	71	-84.94	132	-25.94
12	-76.52	72	13.28	133	43.60
13	-102.31	73	39.88	134	-39.80
14	100.93	74	16.71	135	28.13
15	36.78	75	-50.90	136	38.61
16	108.51	76	-35.39	137	81.79
17	67.92	77	-27.46	138	63.31
18	-9.02	78	54.43	139	31.83
19	25.33	79	-9.28	140	46.67
20	218.36	80	-37.24	141	83.20
21	53.34	81	110.85	142	-59.31
22	45.38	82	60.94	143	55.33
23	-38.14	83	162.20	144	-29.96
24	91.27	84	2.43	145	82.09
25	-9.00	85	-20.71	146	-9.53
26	28.39	86	51.83	147	41.31

27	31.20	87	64.04	148	-46.06
28	10.79	88	-18.55	149	38.87
29	2.65	89	54.51	150	55.99
30	5.58	90	-27.51	151	-31.84
31	68.98	91	-65.44	152	-57.17
32	-24.78	92	-13.34	153	-22.42
33	-12.80	93	-138.08	154	6.12
34	25.51	94	-31.04	155	-9.87
35	14.30	95	56.09	156	-29.80
36	79.59	96	14.42	157	-24.10
37	-42.94	97	-52.01	158	83.57
38	-9.21	98	-31.88	159	-64.00
39	11.82	99	113.35	160	-100.28
40	86.86	100	-41.82	161	-5.91
41	-41.68	101	116.57	162	-11.96
42	-76.10	102	-60.37	163	-36.20
43	2.18	103	63.71	164	11.58
44	18.01	104	15.75	165	-3.92
45	76.42	105	-40.69	166	-41.61
46	-3.00	106	12.79	167	-14.53
47	46.76	107	82.21	168	-45.72
48	-52.73	108	-52.79	169	-45.16
49	16.90	109	14.29	170	-20.12
50	50.45	110	38.04	171	-21.65
51	-12.60	111	27.93	172	-45.40
52	-13.03	112	4.64	173	-68.72
53	-78.59	113	-111.13	174	9.37
54	-64.03	114	87.28	175	61.33
55	-98.70	115	-21.36	176	-32.81
56	8.16	116	31.95	177	-59.32
57	61.73	117	-8.83	178	-69.32
58	-4.62	118	-62.00	179	-7.13
59	21.40	119	25.79	180	49.28
60	10.36	120	4.80	181	-29.40
61	139.31	121	-39.52	182	13.89
		122	61.33	183	-74.26
Union (p>0.05)					
2	75.99				
Tehsil (p>0.05)					
2	36.76	10	219.83	18	-20.23
3	7.22	11	-9.97	19	-10.39
4	80.06	12	-25.59	20	3.85
5	116.58	13	-8.20	21	-68.69
6	55.11	14	-51.30	22	31.23
7	47.52	15	8.66	23	36.15
8	128.45	16	31.38	24	-67.25
9	121.41	17	-21.63		
Month of Calving (*p*<0.001)					
2	13.24	6	-77.30	10	-83.47
3	-15.16	7	-90.73	11	-54.81
4	-38.19	8	-96.38	12	-21.99
5	-58.81	9	-96.03		
Year of calving (*p*<0.001)					
2	133.41	7	124.65	12	141.64
3	124.76	8	122.94	13	82.74
4	123.08	9	131.68	14	5.02
5	124.59	10	132.88	15	-131.77
6	128.23	11	146.23		
Lactation (*p*<0.001)					
2	-12.24	5	-27.12	8	-35.48
3	-16.23	6	-25.86	9	-34.30
4	-23.25	7	-1.83		
Age at first calving group (*p*<0.001)					
2	-61.43	6	-29.22	10	-28.45
3	-48.43	7	-34.31	11	-29.71
4	-39.96	8	-30.56	12	-34.10
5	-35.53	9	-31.23	13	-28.97
				14	-26.57

Conclusion

This comprehensive study emphasizes the significant influence of non-genetic factors on the fertility performance of Mehsana buffaloes, particularly the calving interval. Age at first calving, year of calving, month of calving, and lactation showed a highly significant impact on reproductive performance. The findings underscore the importance of optimizing management practices and breeding strategies to optimize reproductive performance and improve the overall productivity of Mehsana buffaloes.

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