**Factors Affecting Conception Rates in Holstein Friesian Crossbreed Cattle in Uttarakhand, India**

**ABSTRACT**

The objective of the study was to identify the factors affecting variation in conception rate of Holstein Friesian crossbreed dairy cattle inseminated using frozen semen under field conditions. Total of 24,629 insemination records pertaining to 19,323 animals that were inseminated artificially at BAIF’s field Livestock Development Centers during the period of January 2022 to September 2024 in 11 districts. Logistic regression analysis was used to compute the odds ratio and probability of conception rate. Records were classified according to districts, lactation order, year of insemination & season of insemination. Districts, lactation order, year of insemination and season of insemination showed significant variation. The overall conception rate was 40.16%. Conception rate of Pauri Garhwal district showed highest conception rate 48.27% than other districts under study. Conception rate of heifers was lowest than other parities with the probability of 0.42. Highest conception rate was found in animals with fifth and above parity with probability 0.50. There was marginal difference between second to fifth parity. In season of insemination highest conception rate was observed in winter season 42.06% while lowest was in rainy season 40.45%. Highest conception rate (42.85%) was observed during year 2023while lowest (38.06 %) was in year 2024. It could be inferred that the factors like districts, lactation order, season of insemination and year of insemination should be considered while evaluating the conception rate.

**Key words**: Artificial insemination, Conception rate, Logistic regression, Odds ratio

**INTRODUCTION**

“The fertility of farm animals is primarily influenced by a combination of genetic potential and environmental factors, including nutrition, health, and overall management practices employed by farmers. The percentage of pregnancy rate is widely recognized as a key indicator for evaluating fertility performance. A low conception rate can lead to undesirable outcomes such as delayed age at first calving, prolonged service periods, and extended calving intervals, ultimately reducing the animal's overall lifetime productivity. These issues often stem from factors like failure to exhibit heat, reproductive disorders, or the need for multiple services per conception. The low heritability of fertility traits indicates a significant impact of environmental and management factors, highlighting the potential for improvement through better on-farm management practices” (Bhagat and Gokhale, 2013). Existing research on the relationship between factors such as animal breed, season of artificial insemination (AI), sire selection, lactation order, age at the time of AI, and AI sequence with pregnancy outcomes is limited in its ability to fully explain their influence on fertility strategies at the village level. This study aims to explore these factors and their impact on conception rates as a measure of fertility in dairy animals under field conditions in Uttarakhand, providing insights that could help in developing more effective fertility management practices at the grassroots level

**MATERIAL AND METHODS**

The data consisted of 24,629 insemination records pertaining to 19,323 Holstein Friesian crossbreed dairy cattle that were inseminated artificially at BAIF’s field Livestock Development Centers which provide doorstep AI service at villages. Artificial insemination requests were received via mobile phones, and the inseminations were carried out at the farmers' doorsteps using frozen semen. Cows that did not return to estrus within 60 to 70 days post-insemination were examined for pregnancy through rectal palpation. The pregnancy rate was determined using the formula recommended by Qureshi et al. (2008). The period covered was from January 2022 to September 2024. The available data were classified on the basis of districts, lactation order, year of insemination and season of insemination. The lactation sequence ranged from heifers, first to fifth and above. Conception rate: Conception rates (CR) were estimated from the proportion of pregnancies confirmed by the rectal palpation of the genital tract between 90 to 120 days of post-insemination among the total number of cattle inseminated artificially with frozen semen in a specified period of time. The conception rate was estimated by using the following formula:

Conception rate (CR) = No. of cattle pregnant/No. of cattle inseminated \*100

“Insemination dates were recorded using the mobile device and stored in server. For each cattle the conception rate (CR) was defined as pregnant or not. Statistical analysis: Conception is a binary trait having only one of the two possibilities namely, success or failure. The most commonly used multiple analysis technique poses difficulty when the dependent variable has only two outcomes viz. event occurring or not occurring. In such a data-set the assumption of normal distribution and equality of variances are violated. However, logistic regression model is found to be a better choice” (Dyke and Patterson 1952, Ron et al. 1984, Hosmer and Lemeshow 1989) and hence adopted in the present studies. Thirunavukkarasu and Kathiravan(2006), Shamsuddin et al. (2013), Suresh Kumar and Pasupathy (2015) have used a “binary logistic regression model for predicting the probability of conception rate in artificially inseminated bovines through fitted using various animal and management factors. To investigate if differences in conception rate existed between different sub classes of independent variables, a binary logistic regression model was constructed with conception rate as the dependent variable and the independent variables of interest were category of district, year of insemination, season of insemination and lactation order of cattle. The logistic regression model transforms the odds using the natural logarithm and relates it to explanatory variables through a linear equation”. In the case of multiple logistic regression, multiple continuous or categorical independent variables can be integrated into the model, allowing for the simultaneous assessment of their effects on the binary outcome. To evaluate the model’s goodness-of-fit, the Akaike Information Criterion (AIC) is commonly employed (Manoj et al., 2015). The analysis was conducted using R statistical software, version 4.2.2.

**RESULTS AND DISCUSSION**

The results of analysis of conception rate using multivariate logistic regression model is presented in Table 1. In the present study, the overall conception rate in HF crossbreed cattle was observed to be 40.16% Potdar et.al.(2020) observed 47.33±0.32% conception rate in Holstein Friesian Crossbreed Cattle in Maharashtra State. Effect of district: The conception rates were significantly different between different districts. The probability of getting highest animals pregnant was noticed at Pauri Garhwal district 48.27% while lowest in Pithoragarh 30.05%. The reports of Bhagat et al.(2019) and Bansal et al. (2019) supported the present findings however, Pandey et al. (2016) reported non-significant effect of districts on pregnancy rate under Jharkhand state conditions. The individual farmers’ management and agro-climatic conditions of respective district might be attributed to the significant differences in pregnancy rate of animals. District wise detail conception rate is presented in Table 1.

**Table 1. Multivariate Logistic Regression Model for Conception Rate**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variables** | **Means** | **No. of observations** | **Odds ratio** | **Relative probability [1]** | **Estimated conception rate [2] percent** |
| **District\*\*\*** |
| Almora | 40.57% | 557 | 1 | 0.5 | 40.57% |
| Bageshwar | 43.48% | 253 | 1.09 | 0.52 | 42.28% |
| Chamoli | 49.40% | 332 | 1.34 | 0.57 | 46.44% |
| Champawat | 50.21% | 1948 | 1.43 | 0.59 | 47.77% |
| Dehradun | 45.67% | 4132 | 1.17 | 0.54 | 43.72% |
| Haridwar | 37.78% | 5019 | 0.99 | 0.50 | 40.46% |
| Nainital | 42.02% | 6778 | 1.07 | 0.52 | 41.97% |
| Pauri Garhwal | 49.49% | 120 | 1.47 | 0.59 | **48.27%** |
| Pithoragarh | 29.84% | 124 | 0.59 | 0.37 | 30.05% |
| Udham Singh Nagar | 31.58% | 5221 | 0.68 | 0.40 | 32.74% |
| Uttarkashi | 31.93% | 166 | 0.64 | 0.39 | 31.60% |
| **Parity/lactation Order \*\*\*** |
| Heifer | 36.56% | 6114 | 0.74 | 0.42 | 39.64% |
| One | 38.85% | 3318 | 0.81 | 0.45 | 41.68% |
| Two | 40.73% | 6283 | 0.87 | 0.47 | 43.50% |
| Three | 41.87% | 5747 | 0.90 | 0.47 | 44.16% |
| Four | 43.00% | 2242 | 0.92 | 0.48 | 44.74% |
| Above Five | 46.67% | 1005 | 1.00 | 0.50 | **46.67%** |
| **Year of Insemination\*\*\*** |
| 2022 | 41.57% | 6127 | 1.00 | 0.50 | 41.57% |
| 2023 | 41.86% | 13291 | 1.06 | 0.52 | **42.85%** |
| 2024 | 34.25% | 5291 | 0.84 | 0.46 | 38.06% |
| **Season of AI\*** |
| Rainy | 40.45% | 8762 | 1.00 | 0.50 | 40.45% |
| Summer | 38.62% | 7172 | 1.02 | 0.51 | 40.85% |
| Winter | 41.12% | 8775 | 1.08 | 0.52 | **42.06%** |

 Significance codes: 0 ‘\*\*\*’, 0.001 ‘\*\*’, 0.01, NS, nonsignificant (probability <0.05). 1 -The figure of 0.5 under relative probability indicates the reference figure for comparison with others as chosen by the Logit Regression Analysis method. The figures are odd ratio of Success (or Failure)/ Number of events, viz. Conceived (or Not Conceived)/ Number of AI. 2 - Estimated conception rates are computed after substituting actual figure (LS mean) in place of First reference values, converting the rest of the odds ratios accordingly and multiplying by 100.

**DISTRICT WISE AI**

District has highly significant effect over conception rate; highest conception rate was observed at Pauri Garhwal 48.27% followed byChampawat & Chamoli as 47.77% & 46.44% respectively. District wise detailed conception rate is given in Table -1. The conception rate of cattle in Pauri Garhwal district is performing better than in other districts due to several factors. Firstly, Pauri Garhwal has better access to veterinary services and artificial insemination (AI) facilities, ensuring timely breeding and improved conception outcomes. Secondly, the availability and quality of green fodder and balanced nutrition are relatively better in Pauri Garhwal, supporting the reproductive health of cattle. Thirdly, farmers in Pauri Garhwal are more aware and trained in heat detection and reproductive management practices, reducing missed estrus and improving conception efficiency. Fourth, climatic conditions in Pauri Garhwal are more favourable for cattle breeding, with less environmental stress compared to the harsher and colder climate of Pithoragarh, which can negatively impact fertility. Finally, Pauri Garhwal may have a higher proportion of genetically superior or crossbred cattle with better reproductive traits, leading to improved conception rates over indigenous breeds more commonly found in Pithoragarh.

**YEAR OF AI**

In present investigation conception rate noticed to be significantly reduced from 41.57 % in the year 2022 to 38.06 % in the year 2024. Seasonal variation of environment, nutrition, and management alters estrus activity and duration of estrus. Conception rates reduce under stress of heat and cold.

**SEASON OF AI**

Seasonal variations significantly impact reproductive efficiency in cattle, particularly conception rates following artificial insemination (AI). The findings indicate a higher percentage of inseminations performed during the winter (36%) and rainy seasons (35%), yet pregnancy rates were significantly higher in the winter season (42.06%), followed by summer (40.85%) and rainy (40.45%). Studies such as Shindey et al. (2014), Pandey et al. (2016), and Potdar et al. (2016) observed higher pregnancy rates in animals inseminated during the summer season. They attributed this trend to residual health benefits from the preceding winter, where animals typically experience better nutritional status and lower disease prevalence, enhancing their reproductive performance in the early summer months. In contrast, Bhagat and Gokhale (2013, 2016) and Bansal et al. (2019) found higher conception rates in winter, which is often associated with lower heat stress, improved feed intake, and enhanced hormonal balance, all contributing to better fertility outcomes.

Research shows that heat stress during summer and the humid rainy seasons can suppress fertility by disrupting endocrine function and reducing estrus intensity and ovulation rates. Wolfenson et al. (2000) and Rensis and Scaramuzzi (2003) reported that elevated temperatures impair follicular development, reduce estradiol secretion, and decrease luteinizing hormone (LH) surge, leading to poor estrus expression and reduced conception rates. Additionally, high temperatures and humidity contribute to early embryonic loss, as Putney et al. (1988) demonstrated that embryos exposed to maternal heat stress in early development stages have reduced survival rates.

Furthermore, heat stress induces negative energy balance, as reported by Lucy (2003), which impairs ovarian cyclicity and delays resumption of postpartum estrus cycles. This is especially problematic in crossbred dairy cattle, which are more susceptible to thermal stress due to their higher metabolic heat production (Garner et al., 2016). In contrast, cooler winter conditions alleviate heat stress, allowing for normal reproductive hormone secretion, improved oocyte quality, and enhanced uterine environment, thereby increasing conception rates.

In conclusion, while seasonal distribution of AI varies, fertility is often highest during cooler periods due to reduced heat stress and better physiological conditions. To further substantiate these findings, more research focused on climatic stress impacts, thermoregulation mechanisms, and seasonal fertility interventions is necessary, particularly under Indian subtropical field conditions.

**LACTATION ORDER**

Animal lactation order significantly affected pregnancy rate (Table 1). Shindey et al. (2014), Bhagat and Gokhale (2016), Potdar et al. (2016) and Bansal et al. (2019) also recorded similar results, however, Bhagat and Gokhale (2013) and Pandey et al. (2016) recorded non-significant effect of parity on pregnancy rate.Highest conception rate was observed in animals with fifth and more parity 46.67% while lowest conception rate was observed in heifers 39.64%. Gunasekaran et al. (2008), Razi et al. (2010), Bhagat and Gokhale (2016), Pandey et al. (2016) and Bansal et al. (2019) also noticed lowest pregnancy rate in heifers. The lower conception rate in crossbred heifers, particularly under field conditions in India, can be attributed to several physiological factors, including delayed onset of ovarian cyclicity, hormonal imbalances, and suboptimal uterine environment. Crossbred heifers (such as Holstein Friesian and Jersey crosses with indigenous breeds) often exhibit delayed puberty and irregular estrous cycles, which contribute to reduced fertility. Crossbred heifers frequently experience delayed resumption of ovarian activity after puberty. This delayed cyclicity is associated with low levels of luteinizing hormone (LH) and irregular secretion of gonadotropin-releasing hormone (GnRH), which impairs follicular development and ovulation (Purohit, 2008). Without timely ovulation, conception rates are reduced even if insemination is properly timed. Crossbred heifers, particularly those with high Holstein Friesian inheritance, have higher metabolic rates. This can lead to negative energy balance (NEB) during growth and early lactation, which disrupts the hypothalamic-pituitary-gonadal axis and delays the return to cyclicity (Lucy, 2003).

**SOME IMPORTANT FACTORS**

**Environmental factors** like high temperatures and humidity cause heat stress, which suppresses estrus expression by reducing physical activity and altering hormone secretion (LH, estradiol). Heat stress impairs follicular development, leading to weak or silent heats and lower conception rates. In contrast, cold stress in low temperatures can also disrupt ovarian cyclicity by affecting metabolic and endocrine functions. Humidity combined with high temperatures worsens stress, impacting uterine health and embryo survival. Overall, extreme environmental conditions reduce fertility by compromising estrus behavior and reproductive **physiology** in cattle.

**Differences in AI technician skills** across districts can lead to variations in conception rates, as proper heat detection and correct insemination techniques are critical for success. In some districts, technicians are better trained in identifying the optimal time for insemination, improving conception outcomes. In contrast, poor timing of AI, either too early or too late, reduces fertilization chances. Handling and storage of semen may also vary, affecting sperm viability at insemination. Additionally, technician experience in following hygiene and precise deposition techniques greatly influences reproductive performance between districts.

**Variability in nutritional management** across districts affects cattle body condition and hormone balance, directly influencing estrus expression and conception rates. In areas with poor-quality feed and mineral deficiencies, reproductive performance declines due to delayed puberty and anestrus. Districts with better balanced ration programs and mineral supplementation show improved reproductive health and fertility outcomes. Access to timely reproductive health interventions, like deworming, vaccination, and treatment for uterine infections, also varies, impacting conception rates. Overall, differences in nutritional support and veterinary services create significant gaps in reproductive

 **CONCLUSION**

 The study indicated that conception rate significantly affected due to district, insemination year, season of insemination and lactation order of animal . These factors need to be emphasized for having better pregnancy in AI bred cattle under Uttarakhand field conditions. From a practical standpoint, these findings suggest that strategic reproductive management should be tailored to mitigate seasonal stressors. During high-temperature periods like summer and the rainy season, farmers and livestock managers should adopt heat stress alleviation practices, such as providing shade, fans, sprinklers, and cooling systems, along with ensuring adequate hydration and nutritional supplementation, especially minerals like zinc and selenium, known to support reproductive health. Additionally, timing artificial insemination during cooler parts of the day (early morning or late evening) can improve conception outcomes. Veterinary extension services should focus on educating AI technicians and farmers about seasonal fertility management, including timely detection of estrus, proper insemination timing, and monitoring body condition scores, especially in crossbred dairy cattle that are more vulnerable to climatic stress. Furthermore, record-keeping of AI timing, conception rates, and environmental conditions can help identify patterns and optimize breeding strategies for different districts.In conclusion, applying these practical interventions based on seasonal insights can lead to improved reproductive performance, better conception rates, and enhanced productivity in cattle herds, ultimately contributing to sustainable livestock management and profitability in varying climatic conditions. Future research should focus on evaluating the impact of targeted nutritional strategies and mineral supplementation on improving conception rates across seasons. Additionally, studies on AI technician skill levels and sire fertility traits can provide insights into optimizing reproductive efficiency in diverse environmental conditions.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

 ChatGPT-4, the latest version of OpenAI's conversational AI model as of 2024.

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