Research Article:

EFFECT OF NON-GENETIC FACTORS AND TEMPERATURE-HUMIDITY INDEX (THI) ON DAILY MILK YIELD OF CROSSBRED JERSEY AND HOLSTEIN FRIESIAN COWS IN CHITWAN, NEPAL

Sagar Paudel[a, b*], Nirajan Bhattarai[a], Hom Bahadur Basnet[a], Neena Amatya Gorkhali[b], Saroj Sapkota[b] and Pratik Hamal[b]

[a]Faculty of Animal Science, Veterinary Science and Fisheries, Agriculture and Forestry University, Rampur, Chitwan, Nepal

[b]Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal

*Corresponding author: sagarnarc@gmail.com

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ABSTRACT

The effect of non-genetic factors on daily milk yield helps optimize production, improve economic efficiency, make informed management decisions, advance breeding programs, and adapt to changing climatic impacts. The present study had the main objective to assess the effect of temperature-humidity index (THI) and other non-genetic factors including year, season of calving, parity, season of milking, and stage of lactation on daily milk yield (DMY) of Jersey and Holstein-Friesian dairy herd reared under sub-tropical region at National Cattle Research Center (NCRP), Chitwan, Nepal. A total number of 88,268 individual daily milk records maintained under the pedigree performance recording scheme (PPRS) during the year 2016 to 2022 involving 50 to 75 lactating cows (depending upon the factors studied) were used for this study. Data were analyzed using General Linear Model procedure (GLM) using R Program version 4.4.1. Least Squares and Maximum Likelihood Estimation methods with unbalanced subclass numbers were used for the analysis of data. The overall mean daily milk yield (DMY) was 8.09 kg with 7.79 kg for Jersey breed and 8.40 kg for Holstein Friesian (HF) cattle breeds at National Cattle Research Program (NCRP), Chitwan. Primiparous (first parity) cows have highest DMY of 8.55 kg with significantly lower production (7.49 kg/day) for secundiparous (second parity) cows. An overall improvement in DMY was observed across breeds in recent years, likely due to breed improvement programs, although a slight decline was noted during the COVID-19 years (2019 and 2020). Highest DMY was observed during early stage of lactation (10.23 kg) and the month of December to May. Milk yield decreases with increasing THI levels (i.e., as heat stress increases), in both Jersey and Holstein Friesian (HF) breeds. This study revealed that milk yield in Chitwan dairy cows at NCRP farm is significantly influenced by non-genetic factors and thermal stress, with Holstein crosses producing more but being more heat-sensitive, while optimal parity, lactation stage, and cooler seasons enhanced productivity.

Key words: daily milk yield, environment, heat stress, seasonal effect, stage of lactation.

INTRODUCTION

Nepalese dairy sector is contributing about 0.25 percent to the total milk production in the world (FAOSTAT, 2019). Nepal is producing about 2.6 million metric tons of milk (MOALD, 2023) of which only 37 percent goes to the formal milk market. Dairy sector is creating significant numbers of employment opportunities with a major contribution on food, nutrition and economic security in Nepal (Neopane et al., 2018). According to DLS (2023), there are about 4.7 million heads of cattle of which only 22 percent are lactating. Dairy cows contribute about 30 percent to the total milk production in the country (MOALD, 2023). Jersey and Holstein-Friesian breeds of dairy cows are introduced in Nepal since decades for enhancing the productivity of Nepalese indigenous non-descript breeds of cattle. Because of this intervention, Nepal's milk production increased by 65 % since last 10 years i.e. from 1700073 to 2613843MT (MOALD, 2023). However, the daily milk yield (DMY) greatly depends upon various non-genetic factors including year, season of calving, breed, parity/lactation number, season of milking, stage of lactation. Besides these non-genetic factors, temperature-humidity index (THI) has also a significant influence on DMY. Extreme weather conditions, whether excessively hot or cold, negatively impact dairy cattle productivity by disrupting the normal physiological functions of animals across all categories (Paudel & Perrera, 2009).THI is considered as one of the major factors to be associated with heat stress which is one of the major concerns that severely affect the production potential of dairy animals. According to studies, milk production can decrease by 15–25% during the hottest summer months if appropriate mitigation measures (like shade, ventilation, and cooling systems) are not implemented (Giri et al., 2021).

Production potential of dairy animals based on test day milk yield has many implications that need to be considered while evaluating the dairy animals effectively selecting cows and in making management decisions with regard to genetic improvement in the herd. Thus, present study aimed to: 1) study the effect various non-genetic factors on daily milk yield of Jersey and Holstein-Friesian cows; and 2) determine the association between THI and daily milk yield in dairy herd reared at National Cattle Research Farm, Rampur, Chitwan, Nepal.

MATERIALS AND METHODS

Study site and climatic parameters

The present study was conducted at the National Cattle Research Program (NCRP), Rampur, Chitwan, Nepal. We used daily milk production data of about 50 to 75 cows maintained at NCRP from 2018 to 2023 to estimate the effect of different non-genetic factors on average daily milk yield (DMY). Climatological data viz; maximum temperature (^{0}C), minimum temperature (^{0}C), relative humidity (%) for the corresponding days throughout the research were collected from the Department of Hydrology and Meteorology (DHM), Kathmandu.

Number of records and Categorization of non-genetic factors

The analysis was conducted on 88,268 observations to evaluate the effects of breed and parity on daily milk yield in dairy cattle. Altogether 6 non-genetic factors including year, breed, parity, season of milking, stage of lactation, and temperature-humidity index (THI) were taken into account to observe their effect on daily milk yield. The breed had two levels: Jersey and Holstein-Friesian, year of calving had 6 levels (2016, 2017, 2018, 2019. 2020, 2021 and 2022). Similarly season of milking had 4 levels including spring (March-May), summer (June-August), autumn (September-November), and winter (December-February). Parity, on the other hand, had 3 levels viz: primiparous, secundiparous, and multiparous (Hansson & Woudstra 2023). On the basis of stage of lactation, the animals were grouped three categories i.e. early (5-105 days), mid (106-200 days) and late (≥201days).

Estimation of temperature-humidity index (THI)

Based on the climatological data, daily temperature-humidity index (THI) was determined using the following formula proposed by NOAA (1976).

$$THI = 0.8\ Ta + (RH/100) \times (Ta - 14.3) + 46.4$$

Where, Ta represents Ambient air temperature (°C) and RH represent Relative humidity (%).
Thus, THI values were grouped into three categories i.e. low THI (<72), moderate (72-78) and high (>78). Low THI value of <72 was considered as comfortable zone, moderate THI of

72-78 as mid heat stress zone, and high THI value of >78 was considered as high stress zone (Armstong, 1994).

Data analysis

Data were analyzed using General Linear Model procedure (GLM) using R Program version 4.4.1. Fixed effect model was used to estimate LS means and standard error of means. Level of significance (p values) for each factors was checked. Multiple comparisons (Tukey's test) was performed to identify significant differences between factor levels. The fixed effect model used for breed and parity with different level of factor for DMY is given below. Similar model was used for other factors and their interactions.

$$Y_{ijk} = \mu + B_i + P_j + BP_{i*j} + e_{ijk}$$

Where Yij is DMY for each observation, μ is overall mean, Bi is the effect of the ith breed, Pj is the effect of jth parity, BP_{ij} is the interaction effect, and e*ijk* is the random error assumed to be normally distributed with mean 0 and variance σ^2.

RESULTS AND DISCUSSION

The analysis was conducted on 88,268 observations to evaluate the effects of breed, parity, year of calving, season of calving, season of milking, stage of lactation and Temperature Humidity Index (THI) and their interaction on daily milk yield in dairy cattle of NCRP, Chitwan.

Effect of Breed on Daily milk yield

The overall least square mean of daily milk yield was 8.09 kg, with a standard error of 0.024. There was a highly significant difference (P < 0.001) in milk yield between Jersey and Holstein breeds Table 1). Holstein cows had a higher least square mean milk yield (8.40 kg) than Jersey cows (7.79 kg). The narrow confidence intervals indicate high precision in the estimates. This finding is expected since HF crosses are generally found to possess greater milk production potential than the Jersey crosses, line with earlier research. Timsina (2010) also reported a similar mean daily milk yield of 7.93 liters in Phulbari, Chitwan. Upadhyaya et al. (2018) also recorded the mean daily milk yield in Chitwan in cows at 9.24±0.21 liters. These are comparable to reports from Ethiopia, in which Jersey cattle produced a mean of 6.85 liters/day under similar dairy farming and economic conditions as in Nepal (Meena et al., 2015; Hunde et al., 2015). Ayalew et al. (2015) also reported greater average yields of 11.21 liters under Holstein crosses, slightly higher than the present results. Similar study was done by Amasaib et al. (2011) reported DMY in crossbred dairy cows of Sudan under tropical condition was 9.20-11.9 kg.

Effect of Parity on Daily Milk Yield

Parity also had a highly significant effect (P < 0.001) on milk production as presented in Table 1. Primiparous cows (1st lactation) had the highest yield (8.55 kg), indicating good performance in first-lactation animals. Secundiparous cows (second lactation) produced the lowest (7.49 kg), which may reflect physiological or management-related factors during the second lactation. Multiparous cows (third or higher lactation) showed intermediate performance (8.23 kg), suggesting better adaptation and maturity in later lactations.

The results clearly demonstrate that both breed and parity significantly influence daily milk yield. Holstein breed and primiparous cows are associated with higher productivity. These findings can guide breeding, selection, and management strategies to enhance milk production efficiency.

Table 1. Effect of breed and parity on mean daily milk yield (L/day)

Factor	n	Daily milk yield (LSM)	Standard Error of Mean (SEM)	Confidence Interval
Overall mean	88268	8.09	0.024	7.45-8.59
Breed				
Jersey cross	67654	7.79	0.018	7.75-7.82
HF cross	20629	8.40	0.027	8.35-8.45
Level of Significance			***	
Parity				
Primiparous (1st)	27054	8.55[a]	0.023	8.50-8.59
Secundiparous (2nd)	21613	7.49[b]	0.025	7.45-7.54
Multiparous (≥3rd)	39616	8.23[a]	0.027	8.18-8.28
Level of Significance			***	

Note: n – number of observations, LS – Least square mean, SEM – Standard Error of Mean, L/day – liter per day, HF – Holstein Friesian

The study evaluated the impact of breed and parity on daily milk yield with clear differences among groups. The overall mean milk yield was 8.09 L/day but there were differences by breed and parity type. Holstein cows yielded significantly (P <0.001) more milk (8.40 L/day) than Jersey cows (7.79 L/day) which is consistent with earlier published research which found that Holsteins, being a larger framed breed and genetically selected for high milk production, will yield more milk by volume than Jersey cows on average (Heins et al., 2012). On the other hand, Jersey cows are a breed that typically yields higher fat and protein percentages above Holsteins in milk and breeds which are more favorable for use in cheese and butter production in spite of lower milk yields (Pryce et al., 2016). The biological differences between breeds in factors like body size, metabolism, and feed efficiency can account for differences in yield (Cole & VanRaden, 2018). Cows primiparous had the highest yield (8.55 L/day), followed by multiparous (≥3rd lactation, 8.23 L/day), and secundiparous (7.49 L/day) cows. The lower yield of second parity cows is contrary to some studies that suggest and argument at or near the third lactation is peak milk production (Dürr et al., 2008). Differences in biological performance could relate specifically to metabolic stress associated with simultaneously managing both pregnancy and lactation (Krpálková et al., 2014). Multiparous cows may exhibit some resilience as a result of physiological adaptation, but declines in productivity due to age were evident for all cows past the threshold of their fifth lactation (Niozas et al., 2019). The established connections confirm that breeding (genetic) and physiological (parity) factors are important in dairy productivity. Holsteins have an advantage in volume, yet the parity effects (which are principally important for multifactorial evaluation) complicated the interactions between lactation, cow health, and udder condition. Future research would benefit by evaluating management in some way to promote yields in diverse parities, especially during moderate declines in productivity in the secundiparous group.

Effect of Year of Calving on Daily Milk Yield

The analysis showed a highly significant effect (P < 0.001) of the year of calving on daily milk yield, indicating that milk production varied notably across years. The overall least square mean for daily milk yield across all years was 7.94 kg as presented in Table 2. The lowest milk yield was recorded in 2016 at 6.44 kg, suggesting possible management or environmental challenges during that period. A gradual increase in yield is observed from 2016 to 2018, with 2018 reaching a high of 8.51 kg. The highest yield was in 2021, with cows averaging 8.86 kg/day, indicating possibly improved genetics, nutrition, or management. The yield slightly decreased in 2022 (8.18 kg) but remained higher than earlier years. These year-wise variations may reflect changes in herd composition, environmental conditions, or management practices over time. Research by Gurses et al. (2014) and Teke and Akdag (2010) reported that calving year significantly influenced 305-day milk yield (305 DMY) in Jersey cows. Similarly, Missanjo et al. (2011) observed that calving year had a notable impact on milk, fat, and protein yields in Jersey cattle. Variations across different years could be attributed to differences in feeding practices, genetic selection, and herd management strategies as discussed by Cobanoglu and Kul (2019).

Effect of Season of Calving on Daily Milk Yield

The season of calving also showed a highly significant effect ($P < 0.001$) on milk production. December–February (winter season) calving resulted in the highest mean daily milk yield of 8.91 kg, likely due to cooler temperatures, higher fodder production and better feed intake. March–May and September–November seasons followed with 8.57 kg and 7.73 kg, respectively. June–August (monsoon season) had the lowest yield at 7.15 kg, possibly due to heat stress, higher humidity, forage quality issues and ultimately problem with feed intake. This indicates that cows calving during cooler months tend to perform better in terms of milk production, highlighting the importance of calving season planning in herd management.

Both year and season of calving significantly influence daily milk yield in dairy cattle herd at NCRP, Rampur. Optimal productivity was observed in 2021 and among cows calving in the winter months (December–February). These insights can be applied to adjust breeding and calving schedules for maximizing milk yield. The intermediate production during December–February (7.75 kg/day) concurs with Brouček et al. (2009)**,** who noted that while cold stress may slightly reduce efficiency, well-managed winter nutrition can maintain stable yields. However, Hahn (1999) cautioned that severe cold without proper shelter can negatively impact production

Table 2. Effect of year and season of calving on DMY (L/day) in dairy cattle of NCRP, Chitwan.

Factors	n	Daily milk yield (LS Mean)	Standard Error of Mean (SEM)	Confidence Interval
Overall mean	88268	7.94	0.045	6.09-8.97
Year of calving				
2016	396	6.44[c]	0.179	6.09-6.79
2017	10159	6.94[c]	0.039	6.86-7.01
2018	14063	8.51[a]	0.032	8.44-8.57
2019	18109	8.18[b]	0.030	8.12-8.24
2020	18602	7.91[b]	0.029	7.85-7.96
2021	17740	8.86[a]	0.030	8.80-8.92
2022	9214	8.18[b]	0.042	8.09-8.26
Level of significance			***	
Season of calving				
March-May	19746	8.57[a]	0.029	8.52-8.63
June-August	14781	7.15[b]	0.033	7.08-7.21
September-November	31308	7.73[b]	0.024	7.68-7.78
December-February	22448	8.91[a]	0.027	8.86-8.97
Level of significance			***	

Note: n – number of observations, LS – Least square mean, SEM – Standard Error of Mean, L/day – liter per day

Effect of season of milking and stage of lactation on DMY (L/day)

The season of milking had a highly significant effect (P < 0.001) on the mean daily milk yield of dairy cows, indicating notable seasonal variation in productivity (Table 3). The highest daily milk yield was recorded during the March–May period (8.84 kg), suggesting favorable climatic conditions or feed availability in spring. This was followed by December–February with 7.75 kg, possibly due to cooler temperatures improving cow comfort and intake. June–August (monsoon season) saw a decline in milk yield (7.58 kg), likely due to heat stress, feed quality issues, and total feed intake. The lowest yield occurred in September–November (6.81 kg), which may reflect residual effects of monsoon or suboptimal forage conditions. Several studies support the observed spring (March–May) yield advantage. Kadzere et al. (2002) reported that moderate temperatures and high-quality spring forages enhance feed intake and metabolic efficiency, leading to increased milk synthesis. Similarly, West (2003) attributed spring yield peaks to improved pasture quality and optimal thermoregulation in dairy cows.

The intermediate production during December–February (7.75 kg/day) concurs with Brouček et al. (2009)**,** who noted that while cold stress may slightly reduce efficiency, well-managed winter nutrition can maintain stable yields. However, Hahn (1999) cautioned that severe cold without proper shelter can negatively impact production. The monsoon (June–August) decline (7.58 kg/day) matches observations by Upadhyay et al. (2009), who linked reduced summer yields to heat stress and altered rumen function. Das et al. (2016) further reported that high humidity during monsoons exacerbates heat stress effects while deteriorating forage quality. The lowest yields in September–November (6.81 kg/day) may reflect cumulative seasonal stressors, as noted by Collier et al. (2006)**,** who described prolonged heat stress effects on lactation persistency.

The stage of lactation also had a highly significant effect (P < 0.001) on daily milk yield. Early lactation (5–105 days) showed the highest yield at 10.23 kg, which is expected as this stage typically includes the cow's peak milk production period. Milk production declined in the mid-lactation stage (106–210 days) to 7.79 kg. The late lactation stage (>210 days) recorded the lowest yield, averaging 5.21 kg, reflecting the natural decline in production as lactation progresses. Both season of milking and stage of lactation significantly influence daily milk yield. Cows milked in the spring (March–May) and in their early lactation phase produce the most milk. The pattern aligns with the normal lactation curve of dairy cows and underlines the importance of stage-specific nutrition and management to optimize overall yield. Understanding these patterns can guide better feeding schedules, breeding programs, and herd planning to enhance productivity throughout the year. The observed patterns in milk yield where cows produce the most milk during the spring time frame of (March to May) and early lactation phase are consistent with lactation biology and the noted effects of the environment on lactation. The lactation curve will peak post calving and then begin to decrease as lactation progresses (Bruckmaier & Gross, 2020). In early lactation cows have increased metabolic needs as cows consume body reserves to generate milk and therefore nutritional management is critical to prevent excessive weight loss and metabolic diseases (Bell et al., 2021). Climate patterns can affect milk production as well which can add to the complexity; spring is ideal for milk production. In spring, pasture conditions improve, giving cows in lactation high quality, high energy forage, which increases dry matter intake (DMI) and thus increasing milk production (Baudracco et al., 2019). Cooler weather can reduce heat stress in dairy cows and heat stress can reduce milk production because of decreased appetite (West et al., 2023). In contrast, the summer heat stress would increase production losses due to decreased feed intake and altered rumen function (Tao et al., 2020).

The previous section has provided evidence of the interactions between stage of lactation and season, and the need for stage related management. Energy-dense diets with balanced protein to meet metabolic needs are critical for early-lactation cows (NRC, 2021).

Table 3. Effect of season of milking and stage of lactation (LSM and SEM) on DMY (L/day) in dairy cattle of NCRP, Chitwan.

Factor	n	Daily milk yield (LS Mean)	Standard Error of Mean (SEM)	Confidence Interval
Overall Mean	88268	7.75	0.037	5.15-10.36
Season of milking				
March-May	22154	8.84[a]	0.036	8.77-8.91
June-August	23038	7.58[a]	0.043	7.49-7.66
September-November	21210	6.81[b]	0.041	6.73-6.89
December-February	21881	7.75[a]	0.045	7.66-7.84
Level of Significance			***	
Stage of lactation				
Early (5-105 days)	25030	10.23[a]	0.035	10.16-10.36
Mid (106- 210 days)	23803	7.79[b]	0.036	7.72-7.86
Late (> 210 days)	39450	5.21[c]	0.034	5.15-5.28
Level of Significance			***	

Note: n – number of observations, LS – Least square mean, SEM – Standard Error of Mean, L/day – liter per day

Interaction between breed and stage of lactation of DMY

The interaction between breed and lactation stage in dairy cattle at NCRP, Chitwan significantly influences ($P<0.05$) milk production as presented in Table 4. This study had shown that Holstein Friesian (HF) cows typically have higher milk yields compared to Jersey in all stages of lactation (early, mid and late). HF tends to have 5 to 7 % higher milk production than Jersey in different stages of lactation. This might be due to genetic potential, larger mammary gland capacity, higher feed consumption and metabolic efficiency of HF breed (Weigel, 2001; Kelsey et al., 2003) compared to Jersey, which are more specialized in higher concentrations of milk fat and protein content (Auldist, 1998). Additionally, HF cows exhibit a longer lactation curve, contributing to sustained milk production throughout different stages (Tekerli et al., 2000).

Table 4. Effect of Interaction between Breed and Stage of lactation on DMY in dairy cattle of NCRP, Chitwan.

Factors	Stage of lactation (LSM±SEM) (L/day)		
Breed	Early	Mid	Late
Jersey cross	9.93	7.48	4.91
SE	0.035	0.035	0.033
HF cross	10.54	8.09	5.52
SE	0.041	0.041	0.040
Level of Significance		***	

Note: n – number of observations, LSM – Least square mean, SEM – Standard Error of Mean, L/day – liter per day, HF – Holstein Friesian

Interaction between Breed and year of milking on DMY

The interaction between breed and year of milking significantly affects daily milk yield, particularly in dairy breeds such as Holstein Friesian (HF) and Jersey cows as presented in Table 5. The interaction stems from genetic potential, adaptability, environmental responses, and management aspects across different lactation years. Several studies by researchers highlight how this interaction influences daily milk yield. Genetic improvement tools like selective breeding (Lasley, 1972), assisted reproduction techniques like artificial insemination using semen from high genetic merit proven bulls, and embryo transfer lead to superior cows producing increased milk yield in successive years of milking (NABGRC, 2022; NABGRC, 2021; Dhami, 2021). In addition, good husbandry practices including balanced feeding (concentrate, forages, silage and straw), timely vaccination, deworming and drenching in the farm improved daily milk yield in both the breeds. However, pandemic conditions (such as COVID-19) and environmental catastrophe (such as floods, earthquakes etc.) also affect the daily milk production in that particular year. This can be clearly seen in the results in Table # during 2016 after the devastating earthquake effect and during 2019 and 2020 with COVID-19 effect.

Table 5. Effect of Interaction between Breed and year of milking on DMY in dairy cattle of NCRP, Chitwan.

Factors	Year of milking (LSM±SEM) L/day						
Breed	2016	2017	2018	2019	2020	2021	2022
Jersey cross	5.89	6.60	8.09	7.74	7.43	8.39	7.90
SEM	0.175	0.037	0.032	0.030	0.029	0.030	0.042
HF cross	6.51	7.21	8.71	8.36	8.05	9.01	8.52
SEM	0.178	0.045	0.038	0.035	0.034	0.035	0.045
Level of Significance				***			

Note: n – number of observations, LSM – Least square mean, SEM – Standard Error of Mean, L/day – liter per day, HF – Holstein Friesian

Interaction between breed and parity on Daily Milk Yield

The table 6 shows the interaction effect of breed and parity on daily milk yield in dairy cattle. The results indicated Holstein Friesian (HF) consistently outperformed Jersey cattle in all parity groups. Milk yield increased with parity in both breeds, with multiparous cows producing the highest milk yield of 7.88 and 8.50 liters per day for Jersey and HF respectively. Primiparous cows (first-time calvers) had the lowest milk yield, as expected due to incomplete physiological development of the udder system. The difference in performance across parities is statistically significant ($p < 0.001$), indicating a strong interaction between breed and parity. These findings suggest that both breed selection and parity stage are crucial considerations in optimizing milk production. Stage of lactation plays a similar role in both the milk protein and fat percentages, as suggested by Van Arendonk et al. (2009) that lactation stage and energy balance affect milk fat composition by impacting the multiple pathways associated with fatty acids. Supporting their assertion, Gurmessa et al. (2012) noticed that the contents of fat in milk, on average, tended to be higher ($p < 0.05$) during early and late lactation compared to mid-lactation. In the study, Gurmessa et al. (2012) concluded that fat content in milk was stable regardless of age, parity or pregnancy, while values of milk components like lactose, solids-not-fat (SNF) and protein were impacted, and shown to change ($p < 0.05$) with age and pregnancy stage. It is also well established that fat and protein are likely to decline as cows age. In our study, daily milk yields (DMY) across parities were significant ($p < 0.05$). In second-parity cows, DMY was highest at 8.00 ± 3.23 liters, with third-parity cows at 6.89 ± 4.00 liters, and first-parity cows producing the least amount at 5.06 ± 2.33 liters. Previous research by Baul et al. (2015) found numerous differences in milk production was found between first and third lactations. Therefore, lactation stage and parity need to considered when assessing milk yield and composition in dairy cattle

Table 6. Effect of Interaction between breed and parity on DMY in Dairy cattle of NCRP, Chitwan.

Factors	Parity (LSM ±SEM) L/day		
Breed	Primiparous	Secundiparous	Multiparous
Jersey cross	6.84	7.59	7.88
SE	0.034	0.037	0.033
HF cross	7.45	8.21	8.50
SE	0.039	0.042	0.041
Significance Level		***	

Note: LSM – Least square mean, SEM – Standard Error of Mean, L/day – liter per day, HF – Holstein Friesian

Interaction between Breed and Milking Season on Daily Milk Yield

The table # presents the interaction effect between breed (Jersey and Holstein Friesian - HF) and milking season (spring, summer, autumn, and winter) on daily milk yield, along with standard errors (SE). The interaction was found to be highly significant ($P < 0.001$), indicating that the effect of milking season on milk yield differs notably between the two breeds. Both breeds showed the highest milk yield in spring and the lowest in autumn, but the extent of yield fluctuation across seasons differed between breeds. Jersey and Holstein Friesian (HF) in spring season has highest yield at 8.53 and 9.15 kg, suggesting favorable production and breed's high genetic potential of both breeds during this season. But yield dropped in summer to 7.27 and 7.88 kg for Jersey and HF, likely due to heat stress or reduced feed intake. In autumn yield was recorded lowest at 6.50 and 7.12 kg, indicating unfavorable conditions. In every season, HF outperformed Jersey in daily milk yield, with the largest difference observed in spring (0.62 kg more) and the smallest in autumn (0.62 kg more). The difference in yield between breeds was more pronounced during spring and winter, when environmental conditions were likely more favorable and breed potential could be better expressed. The interaction analysis confirms that Holstein Friesians are more productive than Jerseys across all seasons, but both breeds experience significant seasonal variation. Spring is the most productive season for both breeds, while autumn is the least. This interaction emphasizes the need for season-specific management and breed selection strategies to optimize milk production throughout the year.

Table 7. Effect of Interaction effect of Milking seasons and breed on DMY of dairy animals at NCRP, Rampur.

Factors	Milking season(L/day) (LSM±SEM)			
Breed	Spring	Summer	Autumn	Winter
Jersey cross	8.53	7.27	6.50	7.44
SE	0.036	0.043	0.040	0.044
HF cross	9.15	7.88	7.12	8.06
SE	0.041	0.048	0.045	0.049
Level of Significance		***		

Note: LS – Least square mean, SEM – Standard Error of Mean, L/day – liter per day, HF – Holstein Friesian

Interaction effect of Temperature-Humidity Index (THI) and breed on daily milk yield

The table 8 presents the interaction effect of Temperature-Humidity Index (THI) and cattle breed on daily milk yield in dairy cows of NCRP, Chitwan. Milk yield decreases with increasing THI levels (i.e., as heat stress increases), in both Jersey and Holstein Friesian (HF) breeds. Across all THI conditions, HF cows produce more milk than Jersey cows, under low THI, HF yielded 8.29 kg/day vs. 7.67 kg/day for Jersey, and under high THI, HF yielded 7.85 kg/day vs. 7.23 kg/day for Jersey.

The relationship between Temperature Humidity Index (THI) and breed plays an important role in the dairy cows daily milk production. Various environmental elements such as wind speed, relative humidity (RH), solar radiation, air temperature (AT), and their interactions frequently result in decreased performance in dairy cattle (Habeeb et al., 2018). The degree and duration of heat stress affect their physiological and productive reactions. According to research, high AT has a detrimental effect on milk fat content and yield (Binsiya et al., 2017; Habeeb et al., 2018). According to research, heat stress can cause a 3–10% fluctuation in milk production during the lactation period (Aggarwal & Upadhyay, 2013). Lactating cows prefer temperatures between 5°C and 25°C for the best milk production (Kadzere et al., 2002).

The decline in milk production due to heat stress is evident, indicating both breeds are negatively affected by higher THI, although HF still maintains higher productivity overall (Liu et al., 2019). The interaction is statistically significant ($p < 0.001$), demonstrating a meaningful difference in how breeds respond to varying levels of heat stress. These results highlight the importance of heat stress management and breed choice in sustaining milk production under tropical and subtropical conditions.

Table 8. Interaction effect of Temperature-Humidity Index (THI) and breed on daily milk yield of dairy cows at NCRP, Rampur

Interaction	THI (LSM±SEM) L/day		
Breed	Low	Moderate	High
Jersey cross	7.67	7.40	7.23
SE	0.044	0.046	0.032
HF cross	8.29	8.02	7.85
SE	0.048	0.050	0.039
Significance		***	

Note: LS – Least square mean, SEM – Standard Error of Mean, L/day – liter per day, HF – Holstein Friesian

CONCLUSION

This study showed that dairy cows in Chitwan, Nepal, are affected directly by non-genetic factors in addition to thermal stress, which has a great impact on milk production. Holstein Friesian crosses were prolific milk producers, but also more susceptible to heat stress compared to Jersey crosses, particularly in summer when a high Temperature-Humidity Index (THI) decreased productive capacity. Milking early and mid to late parity cows and cows being milked in the early- to mid-lactation stages gave the best yield; cooler seasons and optimal calving seasons increased production as well. The interaction of breed with year, parity, season, stage of lactation, and THI significantly influenced milk output, which indicates that targeted management strategies may be required when developing heat stress management strategies. Providing priority to the implementation of heat stress mitigating practices, increasing the match between the calving and feed seasons, and breed-based feeding and nutritional programs, would greatly increase milk production for farmers managing crossbred cows in Nepal. Overall, these findings provide important insight into improving milk production for dairy farms in Nepal under changing climate conditions, as well as indicating the need for further research on genetic-environment interactions to increase sustainable dairy husbandry.

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