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Association Between Meteorological Variables and Milk Yield Traits in Crossbred Dairy Cattle under Subtropical Climate

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ABSTRACT

The study was conducted on crossbred cattle maintained at Directorate Livestock Farms (DLF) of Guru Angad Dev Veterinary and Animal Sciences University (GADVASU) in Ludhiana, Punjab, India to assess the influences of meteorological variables on milk yield traits of crossbred cattle. Data on milk yield traits and the meteorological variables were collected for a period from 1991–2018. General Linear Model was applied to assess the influences of meteorological variables and other fixed factors on daily milk yield. Simple linear regression models were fitted to analyze the effect of meteorological variables on other milk yield traits. The results showed that the effects of Tem, THI and ATHI on DMY were found to be significant ($p<0.01$). The effects of Tem, THI and ATHI on TLMY, 305_DMY, LL and DPY were negative and non-significant, while negative and significant ($p<0.01$) on PY. The average 305_DMY decreased by 8.68, 5.72 and 5.59 kg per a unit increase in Tem, THI, and ATHI values, respectively. The average LL also showed a decline by 0.11, 0.11, and 0.13 days for per unit rise Tem, THI, and ATI correspondingly. From April-October, climate variables increased beyond the thermal thresholds (21°C for Tem, 75% for Hum, 68 units for THI, 316 W/m^2 for SR and 71 units for ATHI) for daily milk production in crossbred dairy cattle. The animals experienced heat stress for seven months (April-October) leads to reduction of milk production and may be controlled by heat stress management at the farm.

KEYWORDS: Crossbred dairy cattle, milk yield traits, meteorological variables

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1. INTRODUCTION

The effects of heat stress (HS) are devastating in the dairy industry unless managed well. It is considered to be one of the primary factors which reduce growth, milk production and fertility in dairy cows, which ultimately culminates in severe economic loss to livestock farmers around the world (Verwoerd et al., 2006; Hansen, 2007). It is more adverse in warmer and humid climatic areas. Reduced milk yield under heat stress is caused by associated effects on thermal regulation, energy balance and endocrine changes (Ominski et al., 2002). It is also reported that for every degree above Temperature Humidity Index (THI) of 69 in dairy cattle, a 0.4 kg decrease of milk production (Bouraoui et al., 2002). Milk yield reductions of up to 50% have also been reported for Holstein cows due to heat stress during the summer as compared to the winter (Baumgard and Rhoads, 2013). High yielding breeds are more susceptible to heat stress than the low yielding breeds (Pragna et al., 2017). Trnka et al., 2011 suggested that, by 2050, air temperature may rise by as much as 2°C. Bearing in mind the significant influence of heat waves on the well-being and productivity of dairy cows (Cook et al., 2005; De Palo et al., 2006; Herbut et al., 2018a), it is to be expected that in the course of the next few decades, climate conditions for raising cattle will deteriorate.

Air temperature, relative humidity, wind speed and solar radiation are meteorological variables that affect livestock. They all can be applied for measuring status of the heat stress. However, the common predictor of heat stress is Temperature Humidity Index (THI) which combines air temperature and relative humidity Other meteorological variables such as wind speed and solar radiation are also important measures of level of heat stress (Silva et al., 2010). Armstrong (1994) used THI <72 as a thermal comfort zone, 72–78 as mild heat stress, 79-88 as moderate heat stress, 89-98 as severe heat stress and >98 as danger heat stress. The livestock weather safety index (LWSI) classifications for heat stress are as follows: Normal (< 74), Alert (74<THI<79), Danger (79<THI<84), and Emergency (THI > 84).

Changes in wind speed influence the convection cooling whereas solar radiation greatly influences heat load and in combination, has a very significant impact on the regulation of thermal balance in dairy cows (Davis and Mader, 2003). The effective wind speed recommended for dairy cattle in the USA during heat stress is from 1.8 to 2.8 m s^{-1} (Bailey et al., 2016). Wind speed and solar radiation would also greatly improve the applicability of LWSI under varying environmental conditions (Herbut et al., 2018b). Basic THI does not take account for the effects of wind speed and solar radiation. Mader et al. (2006) studied on adjustment of basic THI for wind speed (WS) and solar radiation (SR) on the basis of daily average and reported that THI would be reduced by 3.14 units for each 1 m/s increase in WS and 1.49 units for each 100 W/m^2 decrease in SR. Adjusted THI (ATHI) assumes a lower limit for the occurrence of heat stress as 74, while values from 75 to 78 indicate the alert stage, from 79 to 83 danger conditions and >84 emergency conditions (Arias and Mader, 2010).

Ludhiana district is one of the hotter and humid sub-tropical climate areas, where it is characterized by extreme hotter summer and extreme colder winter seasons. Because of seasonal differences, the crossbred cattle have often experienced both heat and cold stresses; thereby their milk yields might highly be impaired. However, both the individual and combined influences of meteorological variables on milk yield traits of crossbred cattle population are not yet adequately studied and documented. Thus, the present study was carried out to establish the relationships between meteorological variables with milk yield traits in crossbred dairy cattle.

2. MATERIALS AND METHODS

2.1. Location and herd management practices

The study was conducted on crossbred cattle maintained at Directorate Livestock Farm (DLF) of Guru Angad Dev Veterinary and Animal Sciences University (GADVASU) in Ludhiana, Punjab, India covering a period of twenty-eight years (1991–2018) data of milk yield traits and meteorological variables. Ludhiana is located at 30.9°N 75.85°E. It has an average elevation of 244 meters (798 ft) above mean sea level. It features a humid sub-tropical climate under the Koppen climate classification, with three defined seasons; summer (from mid–April to the end of June), monsoon (Early July to end of September) and winter (early December to the end of February). The average high and low temperatures of the area are 29.8 and 16.7, respectively whereas the average maximum and minimum relative humidity are 82% and 46%, respectively. The district received annual average precipitation of 890 mm (Prabhiyot et al., 2013). The animals were housed under loose housing system and followed complete weaning practices. The animals had free access to roughage feed and water. Feeding of the animals depended on the age and physiological status.

2.3. Data sets and sources

Milk production data consisted of daily milk yield (DMY), total lactation milk yield (TLMY), 305 days milk yield (305_DMY), lactation length (LL), 1735 dry period (DP), peak daily milk yield (PY) and days to attend peak yield (DPY) records of 750 crossbred cows. Meteorological records pertaining to temperature (Tem), humidity (Hum), solar radiation (SR) and wind speed (WS) distributed over the twenty-eight years of periods (1991–2018) were used for the study. The milk production data were collected from Directorate of Livestock Farms, GADVASU, Ludhiana whereas the meteorological data were obtained from Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University (PAU), Ludhiana. Data from sick, sold, culled and incomplete was excluded from the study.

The daily THI values were estimated using daily average ambient temperature and humidity by equation of Mader et al. (2006) as THI = (0.8×Tdb)+[(RH/100)×(Tdb – 14.4)]+46.4, whilst the daily adjusted THI was calculated by modified formula of Mader et al. (2006): ATHI=4.51+THI-(1.922×WS)+(0.0068×SR). Where, Tdb: dry bulb temperature, RH: relative humidity, WS: wind speed and SR: solar radiation. The data of meteorological variables were classified into various groups using Sturges's Formula. Temperature was grouped as eight classes <7 (Tem1), 7–11 (Tem2), 12–16 (Tem3), 17–21 (Tem4), 22–26 (Tem5), 27–31 (Tem6), 32–36 (Tem7) and >36 (Tem). Humidity was made to have nine classes: <26 (Hum1), 26–35 (Hum2), 36–45 (Hum3), 46–55 (Hum4), 56–65 (Hum5), 66–75 (Hum6), 76–85 (Hum7), 86–95 (Hum8) and >95 (Hum9). Solar radiation had 8 classes: <112 (SR1), 112–152 (SR2), 153–193 (SR3), 194–234 (SR4), 235–275 (SR5), 276–316 (SR6), 317–357 (SR7) and >357 (SR8). THI was grouped as: <45 (TH1), 45–50 (THI2), 51–56 (THI3), 57–62 (THI4), 63–68 (THI5), 69–74 (THI6), 75–80 (THI7), 81–86 (THI8) and >86 (THI9). ATHI was also grouped into nine: <48 (ATH1), 48–53 (ATHI2), 54–59 (ATHI3), 60–65 (ATHI4), 66–71 (ATHI5), 72–77 (ATHI6), 78–83 (ATHI7), 84–89 (ATHI8) and >89 (ATHI9). Period of calving was classified into seven classes: 1991–1994 (POC1), 1995–1998 (POC2), 1999–2002 (POC3), 2003–2006 (POC4), 2007–2010 (POC5), 2011–2014 (POC6) and 2015–2018 (POC7).

2.4. Statistical analysis

Statistical Analysis Software (SAS 9.3) was used for data analysis. Descriptive statistical procedure (proc means) was employed to estimate descriptive statistics for both milk yield traits and meteorological variables. Least squares analysis of Harvey (Harvey 1990) under fixed model was applied to analyse the effects of month and year on meteorological variables. For assessing the trends of change in meteorological factors over time (year), linear regression analysis was used.

Y_{ijk}=μ+M_i+Y_j+e_{ijk}

Where, Y_{ijk}=the Y_{ij}^{th} Observations of meteorological variables, μ=Overall population mean, M_I=Fixed effects of ith month, Y_j=Fixed effects of the jth year and e_{ijk}=Random error- NID ~(0, $σ^2$e).

General Linear Model (GLM) was employed to assess the influences of meteorological variables on daily milk yield.

Model including THI: Y_{ijkl} =μ+MOC_i+POC_j+THI_k+e_{ijkl}

Model including ATHI: Y_{ijkl}=μ + MOC_i+POC_j+$ATHI_k$+e_{ijkl}

Where, Y_{ijkl}=the ijkth Observations of crossbred cows, μ=the overall population mean, MOC_i=the fixed effects of the ith month of calving, POC_j=the fixed effects of the jthperiod of calving, THI_k=the fixed effects of the kth THI sub-classes, $ATHI_k$=the fixed effect of the kth Adjusted THI sub-classes and e_{ijkl}=Random residual error, which is NID ~(0, $σ^2$e).

Model including Tem, Hum and SR was used as Y_{ijklmn}= μ+MOC_i+POC_j+Tem_k+Hum_l+SR_m+e_{ijklmn}, Where, Y_{ijklmn} =the ijklmnth Observations of crossbred cows, μ=the overall population mean, MOC_i=the fixed effects of the ith month of calving, YOC_j=the fixed effects of the jth period of calving, Tem_k=the fixed effects of the kth temperature sub classes, Hum_l =the fixed effects of the lth humidity sub classes, SR_m = the fixed effects of the kth Solar Radiation sub classes and e_{ijklmn}=Random residual error, which is NID ~(0, $σ^2$e).

Simple linear regression was applied to analyse the associations of meteorological factors with milk yield traits in order to explore the change in performances traits with a unit change in the meteorological variables.

Y_{ij}=a+∑bX_i+e_{ij}, where, Y_{ij}=Observations of the ith milk yield traits of jth cows, a=intercept; b=regression coefficients; X_i = the ith meteorological variables; e_{ij}=residual errors; NID ~(0, $σ^2$e).

3. RESULTS AND DISCUSSION

3.1. Description of data sets

The descriptive statistics for milk yield traits, meteorological variables during the period of twenty-eight years are presented in Tables 1 and 2. The overall means for DMY, PY, DPY, TLMY, 305_DMY, LL and DP were 12.57 kg, 21.72 kg, 47.48 days, 4478.64 kg, 3813.69 kg, 370.12 days and 91.36 days, respectively whereas the overall means for temperature, relative humidity, THI, WS, SR and ATHI were 23.57°C, 66.15%, 70.85 units, 1.17 m s^{-1}, 224.94 W m^{-2} and 74.64 units, respectively. The mean adjusted temperature and humidity index (ATHI) exceeded the basic temperature and humidity index (THI) by 3.79 units. This might due to the effect of heat load resulted from solar radiation, hence the incorporation of wind speed and solar radiation in the basic THI estimation can properly measure the level of heat stress.

3.2. Trends of meteorological variables

The least squares analysis (Table 3) clearly showed that the values of all the meteorological variables significantly

Table 1: Descriptive statistics of datasets of milk yield traits of crossbred cattle

Traits	N	Mean	SE	SD	Var	CV%	Min	Max
DMY	281698	12.57	0.01	5.80	33.67	46.16	2	75
PY	1730	21.72	0.20	8.31	69.03	38.25	7	75
DPY	1704	47.48	0.74	30.54	932.73	64.32	11	167
TLMY	1735	4478.64	47.99	1998.97	3995893.22	44.63	1004.7	17510.9
305_DMY	1735	3813.69	32.43	1350.91	1824944.49	35.42	1004.7	10493.1
LL	1735	370.12	2.91	121.18	14684.27	32.74	152	928
DP	1735	91.36	0.97	40.58	1646.63	44.42	19	264

N: Number; S.E: Standard error; SD: Standard deviation; Var: Variance; Min: Minimum; Max: Maximum

Table 2: Descriptive statistics of datasets of meteorological variables

Variable	N	Mean	S.E.	SD	Var	CV (%)	Min	Max
Tem (°C)	10248	23.57	0.07	7.43	55.25	31.54	4.80	38.60
Hum (%)	10248	66.15	0.15	15.47	239.19	23.38	15.50	100.00
THI (unit)	10248	70.85	0.10	10.61	112.53	14.97	41.84	89.80
WS (m/s)	10248	1.17	0.01	0.71	0.51	61.06	0.00	6.61
Sunshine (Hr)	10248	7.67	0.04	3.62	13.09	47.16	0.00	20.00
SR (W/m^2)	10248	224.94	0.72	72.89	5312.62	32.40	72.96	459.18
ATHI (unit)	10248	74.64	0.10	10.57	111.63	14.16	43.41	92.31

($p<0.01$) varied across the different months and years for the period of twenty-eight years from 1991–2018 (supplementary file). This might therefore demonstrate that daily milk yield with 3 days prior of milking and other milk yield traits (TLMY, 305_DMY, LL, DP, PY and DPY) with month of calving/year of calving directly or indirectly related. The minimum least square means (11.84°C for Tem, 53.82 units for THI and 57.35 units for ATHI) were observed in January; however, their maximum least squares mean were observed in different months [Tem (31.98°C) in June; THI (82.79 units) in July and ATHI (86.06 units) in August]. The least square means of Hum ranged from 40.44% in month of May to 78.11% in the month of August, whilst the minimum (0.65 m s^{-1}) and maximum (1.80 m s^{-1}) least square means of wind speed were found in November and June, respectively. The variations of meteorological variables over different years were also explained by linear regression analysis (Tables 4). The linear regression analysis

Table 3: Analysis of variance for meteorological variables

Source of variance	Mean sum of square values						
	DF	Tem	Hum	THI	WS	SR	ATHI
Month	11	45775.61**	134621.85**	94153.92**	137.28**	2791477.82**	92217.08**
Year	27	81.36**	1826.55**	161.24**	2.29**	35282.37**	190.47**
RE	10209	5.92	103.02	11.08	0.36	2231.32	12.18

**: $p<0.01$; DF: Degree of freedom

showed that the value of temperature increased by 0.034°C for every one-year increase whereas the Hum, THI and ATH increased by 0.033%, 0.048 unit and 0.049 unit, respectively for every one-year increment but SR showed a decreasing trend (-1.041 W m^{-2} per a year) during the period of twenty-eight years. The fluctuations in meteorological variables over month and year observed in the present study were as a result of seasonal changes in weather patterns showing a direct relationship between environmental variables and heat production in dairy crossbred cattle. The highest humidity occurred when the temperature was lowest. The highest and lowest temperatures were recorded in July and May, respectively whereas the highest and lowest humidity were observed in August and May, in that order. In line with the present findings, previous findings were reported by Tibor et al. (2017) and Kaiser (2017).

Table 4: Linear regression of various meteorological variables on year

Model variable	Estimates of regression parameters		
	a	b	r^2
Tem	-43.761±18.257	0.034±0.009**	0.343
Hum	-0.713±105.954	0.033±0.053**	0.015
WS	10.250±3.335	-0.005±0.002**	0.222
SR	2311.657±229.533	-1.041±0.115**	0.761
THI	-24.710±25.591	0.048±0.013**	0.349
ATHI	-24.182±28.512	0.049±0.014**	0.316

**: p<0.01

3.3. Influences of meteorological and other fixed factors on daily milk yield

The least square means along with standard error for daily milk yield of crossbred cattle across environmental factors are estimated month wise. (Supplementary file). The effects of month of calving, period of calving, THI, ATHI, Tem, Hum and SR on DMY were found to be significant (p<0.01). Cows calved in February and March had better (p<0.01) milk yield per day than cows calved in other months of the study period. However crossbred dairy cows calved in August had the lowest daily milk yield. Higher daily milk yield was observed for cows calved in POC5 followed by POC4 and POC7; but dairy cows calved within POC1 and POC2 had significantly (p>0.05) lower daily milk yield. Lower daily milk yield was found for cows in THI9 followed by THI8 and THI7; but the daily milk yield of cows under THI4 was higher (p<0.01) next to cows under THI5. Similarly, dairy cows in ATHI5 had significantly higher (p<0.01) daily milk yield; but the cows under ATHI1 produced lesser daily milk yield. Tem4 followed by Tem5 was comfortable temperature range as better daily milk production was observed under them. However lower daily milk yield was recorded for cows under Tem1. Dairy cows under Hum7, and SR7 produced significantly higher daily milk yield; but milk yield of dairy cows in Hum2 and SR1 were lower. The influences of month of calving and THI on daily milk yield observed in the present study was similar with the report of Kaiser (2017) who found higher daily milk yield in the month of February and March. He also found higher daily milk yield in the THI range of 63–68 units which is in agreement with the present finding. However, on the same study, lower daily milk yield was observed in the month of October and under THI range of 74.00–79.00 units. However, cows in THI range of 30 to 40 had the greatest amounts of milk and the cows in THI range of 81 to 90 had lower milk (Ghavi et al., 2012).

According to the results of the study (supplementary file) clearly revealed that sudden decrease in the daily milk yield of crossbred dairy cattle was observed when an increase in Tem ≥21°C, Hum ≥75%, THI ≥68 Units, SR ≥ 316 W m^{-2} and ATHI ≥71 units. The threshold THI value (68 units) for DMY was observed in the present study was comparable with previous findings reported by various workers. Collier et al. (2009) reported that the DMY decreased around 2.2 kg/day when the THI values >65 to 73. Bouraoui et al. (2002) observed a decrease DMY when the THI index exceeded from 68 to 78 for Tunisian dairy cattle whereas Kaiser (2017) found a sudden reduction in DMY when THI rose from 63–68 units. However, the present finding was higher as compared to reports of Bohmanova et al. (2017) who indicated a THI of >65 as an upper critical THI for lactating cows and Brugemann et al. (2012) showed a THI of 60 as an upper critical THI for lactating HF cows; but it was lower as compared to Tibor et al. (2017) who reported >25°C for temperature and >72 for THI as threshold of heat stress. In the present study, daily milk production was found to be decreasing in short range of THI (>63–68) as compared as ATHI (>66–71). The reduction in DMY in our study (0.054 kg per a THI unit rise from 68) was lower than reported by various workers as milk yield decrease per a unit of THI rise was 0.2 kg (Ravagnolo and Misztal, 2000); 0.18 to 0.36 kg (Herbut and Angrecka, 2012); 3.98 kg per a unit rise THI>68–78 (Bouraoui et al., 2002); 4 kg per a unit THI>72 (Falta et al., 2008). In line with our finding, Brügemann et al. (2012) found milk yield decline by 0.08 kg per a THI unit and by 0.046 kg per a unit THI (Tibor et al., 2017).

The influences of meteorological factors (Tem, THI and ATHI) on milk yield traits obtained in the current study were in line with the results of Kaiser (2017) who found lower and higher 305 days milk yield in the month of July and January, in that order for Sahiwal cows. In contrast to the present finding, the same author reported highest and lowest average LL in the month of February and August, respectively. However, the effects of THI on 305 days milk yield and lactation length under various linear regression models in this study were found to be lower as compared to the report of Kaiser (2017) who also obtained higher lactation length (2 days) due to per a unit increase in THI as compared as the present finding for the same trait. However, significant effect of THI on LMY was observed by Kohli et al. (2014) in high yielding cattle.

3.4. Association of meteorological variables on milk yield traits

The monthly least square means for TLMY, 305_DMY, LL, DP, and DPY and meteorological variables were estimated (supplementary file). The parameter estimates for the effects of meteorological variables on milk yield traits under various linear regression models are presented table 5 to 8. The highest and lowest monthly least square means for TLMY, 305_DMY and PY were 4775.20, 4278.90; 4051.46, 3586.93 and 24.21, 20.07 kg, respectively. The highest means for these traits were observed in the month of February whereas the lowest values were found in July. In the month of February, the Tem, Hum, THI, SR and ATHI averaged 15.03°C, 73.90%, 58.87 units, 138.32 w/m^2 and 60.91 unit, respectively whereas the corresponding values in the month of July were 30.54°C, 74.97%, 82.79 units, 252.20 w/m^2 and 85.98 unit, respectively. High average LL (399.66) was found in the month of April but the average lowest LL was observed in the month of May. In April, the average Tem, Hum, THI, SR and ATHI were estimated as 26.44°C, 46.77%, 72.95 units, 289.09 W/m^2 and 76.76 unit, respectively; but for month of May the corresponding values were 31.19°C, 40.44%, 78.02 units, 300.87 w/m^2 and 81.19 unit, in that order. The highest average dry period of crossbred cattle was found as 96.06 days in the month of June. In the month of June, the average Tem, Hum, THI, SR and ATHI were 31.98°C, 55.01%, 81.39 units, 288.34 w/m^2 and 84.41 units, in that order; however, the average lowest dry period (87.75 days) was observed in the month of November. The average Tem, Hum, THI, SR and ATHI in the month of November were 19.02°C, 64.84%, 64.60 units, 167.44 w/m^2 and 68.98 units, correspondingly.

Table 5: Linear regression of daily milk yield (DMY) and Peak Yield (PY) on different meteorological variables in crossbred dairy cattle

Model variables	DMY			PY		
	a	b	r^2 (%)	a	b	r^2 (%)
Tem	14.07	-0.07±0.03**	33	24.64	-0.13±0.03**	60
THI	16.29	-0.054±0.02**	42	27.73	-0.10±0.024**	56.52
ATHI	16.59	-0.06±0.02**	43	28.16	-0.10±0.02**	57.27

**: $p<0.01$

Table 6: Regression of 305 days lactation milk yield (305_DMY) and total lactation milk yield (TLMY) on different meteorological variables in crossbred dairy cattle

Model variables	305_DMY			TLMY		
	a	b	r^2 (%)	a	b	r^2 (%)
Tem	4013.11	-8.68±5.05ns	23	4679.56	-8.47±6.97ns	13
THI	4213.62	-5.72±3.58ns	20	4909.72	-6.06±4.84ns	14
ATHI	4226.23	-5.59±3.64ns	19	4929.60	-6.023±4.91ns	13

NS: Non significant

Table 7: Regression of lactation length (LL) and dry period (DP) on different meteorological variables in crossbred dairy cattle

Model variables	LL			DP		
	a	b	r^2 (%)	a	b	r^2 (%)
Tem	373.48	-0.11±0.52ns	0.4	87.71	0.16±0.11ns	18
THI	378.79	-0.11±0.37ns	0.9	84.33	0.102±0.08ns	15
ATHI	380.47	-0.13±0.30ns	1	88.84	0.10±0.09ns	15

NS: Non significant

Table 8: Regression of days to attend peak yield (DPY) along with standard errors on different meteorological variables in crossbred dairy cattle

Model variables	a	b	r^2 (%)
Tem	49.06	-0.10±0.20	2
THI	47.81	-0.011±0.14	0.06
ATHI	57.27	-0.01±0.14	0.02

NS: Non significant

The average highest (54.51 days) and lowest (39.40 days) DPY were observed in the months of October and June, respectively. In the month of October, the Tem, Hum, THI, SR and ATHI averaged 24.64°C, 64.83%, 72.77 units, 210.15 w/m^2 and 77.43 unit, respectively whereas the corresponding values in the month of June were 31.98°C, 55.01%, 81.39 units, 288.34 w/m^2 and 84.41 units, in that order. The study indicated that crossbred cows calved in the months with lower average Tem, THI, SR and ATHI and relatively high humidity values had consistently higher 305_DMY and PY until a certain threshold (Figure 1 and 3). However, the LL was found to be continuously higher for crossbred cows which calved in the month with moderate average Tem, THI, SR and ATHI and low Hum values (Figure 2) and average DP was observed as continuously higher for crossbred cows calved in the month with high average Tem, THI SR and ATHI and low Hum values.

The effect of Tem, THI and ATHI on DMY were found to be significant ($p<0.01$). DMY declined by 0.07 kg for every 1°C increase in average air Tem from threshold (21°C), by 0.054 kg for a unit increase in THI from threshold (68 units) and 0.06 kg for a unit rise in ATHI from threshold (71 units); however, the effects of Tem, THI and ATHI

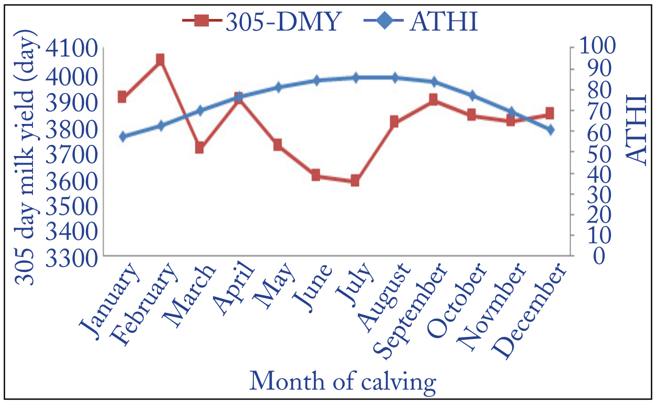

Figure 1: Influence of monthly adjusted temperature and humidity index (ATHI) on 305 days lactation milk yield over months of calving in crossbred dairy cattle

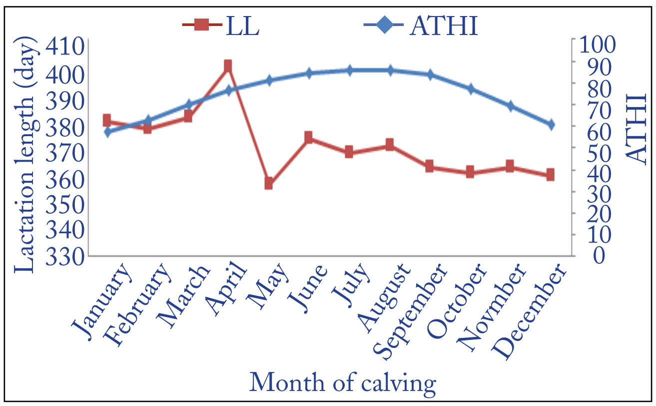

Figure 2: Influence of monthly adjusted temperature and humidity index (ATHI) on lactation length over months of calving in crossbred dairy cattle

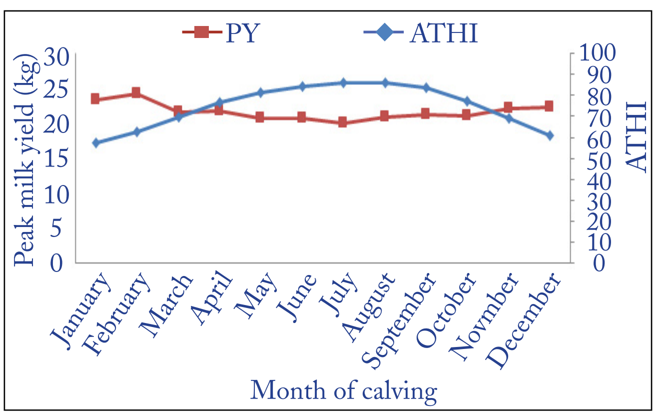

Figure 3: Influence of monthly adjusted temperature and humidity index (ATHI) on peak yield over months of calving in crossbred dairy cattle

on TLMY, 305_DMY, LL and DPY was found to be negative and non-significant (p>0.05); but negative and significant (p<0.01) on PY. DP were insignificantly (p<0.05) and positively influenced by Tem, THI and ATHI. The underlined reasons for insignificant influences of different meteorological variables on all milk yield traits except DMY and PY observed in our study might be the animals were maintained under the loose sheds and proper feeding and watering management. The average TLMY decreased by 8.47, 6.06 and 6.023 kg due to per a unit increase in Tem, THI and ATHI values, respectively, while average 305_DMY decreased by 8.68, 5.72 and 5.59 kg per a unit increase in Tem, THI and ATHI values, in that order. The average LL also showed a decline by 0.11, 0.11, and 0.13 days for every 1 unit rise Tem, THI and ATI, correspondingly. A unit rise in Tem, THI and ATHI resulted in a decrease in PY by 0.13, 0.10 and 0.10 kg, respectively. The average DPY decreased by 0.10 days, 0.01 days, and 0.011 days due to per a unit increase in the Tem, THI and ATHI, respectively.

4. CONCLUSION

The effects of meteorological and other fixed factors on daily milk yield were found to be highly significant. During the month of April to October, climate variables increased beyond the thermal thresholds (68 units for THI, 316 W/m^2 for SR and 71 units for ATHI) for daily milk production of crossbred dairy cattle. The dairy farmers and enterprises should take integrated management interventions to mitigate the impacts of heat stress on dairy cattle whenever an increases beyond the threshold.

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