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Genotype Environment Interaction on Milk Production Traits of Crossbred Dairy Cows under Tropical Climatic Condition of India

Rajalaxmi Behera, Ajoy Mandal, Saroj Rai[1], M. Karunakaran[2], Mohan Mondal[3], M.K. Ghosh[3]

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Abstract

Background: Genotype environment interaction plays vital role in animal productivity. Heat stress is one of the major environmental stressor affecting milk production and measured in terms of temperature humidity index (THI). Indian milk industry largely depends on crossbred cows bearing different degree of exotic inheritance. Thus, the role of genotype (genetic group) of the crossbred cows and environment (THI) interaction plays vital role in Indian climate which is mostly tropical in nature. Therefore, study was undertaken to examine the existence of genetic group × THI in crossbred dairy cows reared at institute herd of ICAR-National Dairy Research Institute, Eastern Regional Station, Kalyani, West Bengal.

Methods: A total of 12364 records each of monthly milk yield (MMY) and average daily milk yield in a month (AMY) of crossbred cows spanned over twenty two years (1994-2015) and weather parameters(temperature and relative humidity) for the corresponding years were collected from institute records. The data were classified into 8 genetic groups according to the genetic composition and 3 THI groups (THI <72, THI 72-78 and THI above 78). The interaction model was used to study the G×E interaction study using least squares analysis.

Result: Effect of non-genetic factors (parity, period of calving and stage of lactation) was found to be highly significant (P<0.01) and genetic group × THI was significant (P<0.05) of on both MMY and AMY. Genetic group bearing 50% Jersey and 50% Red Sindhi or Tharparkar were the most heat tolerant breeds. Jersey crossbred cows were more heat tolerant than Holstein crossbred cows. Crossbred cows with 50% Jersey inheritance performed better than higher Jersey inheritance during periods of THI above 72.

Key words: Crossbred cows, Genotype × environment, Heat stress, THI.

Introduction

Genotype × Environment interaction (G × E) is detected when performances of different genotypes differ in different environments (Falconer, 1952). When the differences amongst genotypes observed across environments without any alteration in their respective ranking, it is known as scaling effect while G × E causes re-ranking of genotypes or individuals in different environments (Lynch and Walsh 1998). Tropical and developing countries often rely on exotic animals for breeding purposes and therefore exposing the animals to altered climatic conditions and farming systems that can shrink the efficacy of the genetic improvement programs. In Indian context, crossbred cows with different degrees of exotic inheritance play crucial role in dairy sector and among the environmental factors influencing the dairy production system, heat stress is one of the chief factors. Temperature and humidity are the major components of thermal load on animals. Temperature humidity index (THI) since combines both temperature and humidity, is one of the most effective ways to assess thermal load on animals. Therefore, present study was designed to investigate the existence of genotype (genetic groups with different degrees of exotic inheritance) × environment (THI) interaction on milk production traits in crossbred dairy cows reared at institutional herd of Eastern Regional Station, ICAR-National Dairy Research Institute, Kalyani, West Bengal, India.

Animal Genetics and Breeding, Eastern Regional Station, ICAR-National Dairy Research Institute, Kalyani-741 235, West Bengal, India.

[1]Livestock Production Management, Eastern Regional Station, ICAR-National Dairy Research Institute, Kalyani-741 235, West Bengal, India.

[2]Animal Reproduction Gynaecology and Obstretics, Eastern Regional Station, ICAR-National Dairy Research Institute, Kalyani-741 235, West Bengal, India.

[3]Animal Physiology, Eastern Regional Station, ICAR-National Dairy Research Institute, Kalyani-741 235, West Bengal, India.

Corresponding Author: Rajalaxmi Behera, Animal Genetics and Breeding, Eastern Regional Station, ICAR-National Dairy Research Institute, Kalyani-741 235, West Bengal, India.
Email: drrajlaxmi.10@gmail.com

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Materials and Methods

The present study was conducted to assess genetic group × THI interaction on crossbred cows of different genetic compositions reared at institute herd of ICAR-National Dairy Research Institute, Eastern Regional Station, Kalyani, West Bengal. Data on monthly milk yield (MMY) and average daily milk yield in a month (AMY) of crossbred cows spanned over twenty two years (1994-2015) were collected. Climatological data *viz*; maximum temperature (^{0}C), minimum temperature (^{o}C), relative humidity (%) for the corresponding periods were also collected from institute records. The data on MMY and AMY were further standardised and 12364 records each of MMY and AMY were included for the present study.

Estimation of Temperature Humidity Index (THI)

The monthly average temperature and relative humidity for the corresponding periods (1994-2015) were estimated from the climatological data and were used to estimate the monthly average Temperature Humidity Index (THI) for each of the 22 years using the following formula:

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

Where,

Ta – ambient air temperature (°C)

RH – relative humidity (%) NOAA (1976)

Further the 22 year's monthly average THI were estimated from each year's monthly average THI values.

The crossbred cows were classified into eight genetic groups based on their genetic composition as presented in Table 1. As per available literature, THI value of <72 is considered as comfortable, THI of 72-78 as mild heat stress zone, 79-88 is moderate heat stress zone, 89-98 imparts severe stress and more than 98 is very severe stress zone (Armstong 1994; Atrian and Shahryar, 2012). The present data set were classified into three THI zones: THI ≤ 72, THI = 72 to 78 and THI above 78 for studying genotype environment interaction. The effects of non-genetic factors like parity, stage of lactation, period of calving were estimated using least squares analysis for non-orthogonal data as suggested by Harvey, 1990. The model was used with the assumption that different components being fitted into the model were linear, independent and additive.

Study on genotype environment interactions

The interaction model was used for examining the existence of genotype environment interactions in the present study.The interaction model is an extension of the traditional genetic model by an adding random interaction of genotype and environment as an component and making P = G + E + G × E. The model used in present study was as follows:

$$Y_{ijklmn} = \mu + POC_i + SL_j + PA_k + GG_l + THI_m + (GGXTHI)_{lm} + e_{ijklmn}$$

Where,

Y_{ijklmn} = Observation of nth animal of mthTHI group, lth genetic group, Kth parity and jth stage of lactation and ith period of calving.

μ = Overall mean.

POC_i = Fixed effects of ith period of calving (1 to 6).

SL_j = Fixed effects of Jth stage of lactation (1 to 3).

PA_k = Fixed effects of kth parity (1 to 7).

GG_l = Fixed effects of lth genetic group (1 to 8).

THI_m = Fixed effects of mth THI zone (1 to 3).

$(GGXTHI)_{lm}$ = Fixed effects of genetic group THI interaction (1 to 24).

e_{ijklmn} = Random error ~ NID (0, σ^2e).

RESULTS AND DISCUSSION

The overall least-squares means for MMY and AMY of crossbred cows were 229.27±11.01 Kg and 8.30±0.38 Kg, respectively. Similar results have also been reported by several workers (Report, 2016). The reported AMY value is higher than the national average for AMY of crossbred dairy cows (GOI, 2016). The effect of parity was highly significant on both MMY and AMY. Maximum MMY and AMY were observed during 3rd and 4th parity and gradually a declined trend was observed (Fig 1 and 2). Similar significant effect of parity on milk production traits was reported by Basak and Das, (2018), Kumar *et al.,* (2003), Dangar (2015) and Kakati *et al.* (2017).

The effect of stage of lactation was found highly significant (P<0.01) on both the milk production traits. Maximum milk yield (MMY and AMY) was observed during the first stage of lactation and exhibited a declining trend (Table 2). Talukder *et al*. (2013) reported a similar trend of milk yield during the three lactation stages and a significant effect (P<0.01) of stage of lactation on milk yield in Sahiwal-Holstein Frisian crossbred cows. Effect of period of calving was highly significant (P<0.01) on both MMY and AMY. Maximum MMY and AMY were observed during the period 2005-2008, followed by 2013-2015 (Table 3). The differences in the milk production traits across different periods may be attributed to the managemental practices, feeds and fodders and sires used during different periods. The result is in agreement with Basak *et al.* (2018) and Kakati *et al.* (2017).

Table 1: Classification of genetic groups (genotypes) based on different level of exotic inheritance.

Genetic group	Genetic composition	No. of observations
1	CB cattle - Holstein inheritance (≥ 50%)	186
2	50% Jersey and 50% Tharparkar	2374
3	50% Jersey and 50% Red Sindhi	1190
4	50% Jersey and 25% exotic inheritance from Holstein/ Brown swiss and 25% indigenous inheritance	2257
5	50% Jersey and 50% indigenous inheritance form more than two indigenous breeds	2720
6	25% Jersey and 25% Holstein with 50% indigenous inheritance	972
7	>50% to <75% Jersey inheritance	2442
8	≥75% Jersey	223

Estimation of Monthly average THI

In the present study, lowest monthly average THI value was observed during January and highest on June. Comfortable THI value (<72) were observed only for four months across the year (January, February, November and December). Mild thermal load (THI 72 to 78) was observed during March and October while moderate heat stress (THI 79-88) was observed for six months (April to September) which was above 80 (Fig 3). Mandal *et al.* (2017) classified heat stress on crossbred dairy cows of ERS, ICAR- NDRI herd into two groups slight to moderate heat stress (THI <80) and severe heat stress (THI ≥80) and reported that 66.6% of the days of the year were moderately stressful and 33.4% were severe stressful. When THI exceeded 80, the morning milk yield (kg) and overall herd average (kg/day) were decreased.

Table 2: Effect of stage of lactation on milk production traits.

SL (days)	MMY (Kg)		AMY (Kg)	
	Mean	SE	Mean	SE
<90	267.41[a]	11.10	10.69[a]	0.28
90-180	255.51[ab]	11.10	8.52[b]	0.28
181 and above	164.87[b]	11.03	5.69[c]	0.28

Similar superscripts indicate non-significant and dissimilar superscripts indicate significant difference among subclasses (P<0.01).

Table 3: Effect of period of calving on milk production traits.

POC	POC code	MMY (Kg)		AMY (Kg)	
		Mean	SE	Mean	SE
1994-1996	1	203.27[a]	12.16	7.38[a]	0.41
1997-2000	2	229.10[b]	11.59	8.34[b]	0.40
2001-2004	3	228.96[b]	11.28	8.33[b]	0.39
2005-2008	4	247.58[c]	11.28	8.93[c]	0.39
2009-2012	5	223.44[b]	11.57	8.03[b]	0.39
2013-2015	6	243.24[c]	12.11	8.78[c]	0.41

Similar superscripts indicate non-significant and dissimilar superscripts indicate significant difference among subclasses (P<0.01).

Effect of THI on MMY

Effect of THI was highly significant on both MMY and AMY. As presented in Fig 4 and 5, animals performed better during the thermal comfort period when THI was lower than72 (232.41± 11.15 kg and AMY = 8.81 kg) in comparison to moderate heat stress periods (THI 72-78 MMY = 229.34 ±11.40 kg and AMY = 8.1 kg) and severe heat stress periods (THI above 78; MMY = 226.04 ±11.05 and AMY = 7.98 kg). Declined trend in milk yield as heat stress (THI) arises has been reported by several workers. Mandal *et al.* (2017) studied on crossbred cows of ERS, ICAR-NDRI herd and reported that when THI exceeded 80, the morning milk yield (kg) and overall herd average (kg/day) were decreased. Heat stress negatively affects milk yield in cattle. Rejeb *et al.* (2012) studied heat stress in response to milk yield on 13 Holstein cows and recorded reduction in milk yield during summer compared to spring and they attributed this reduction to changes in metabolism, physiology and feed intake.

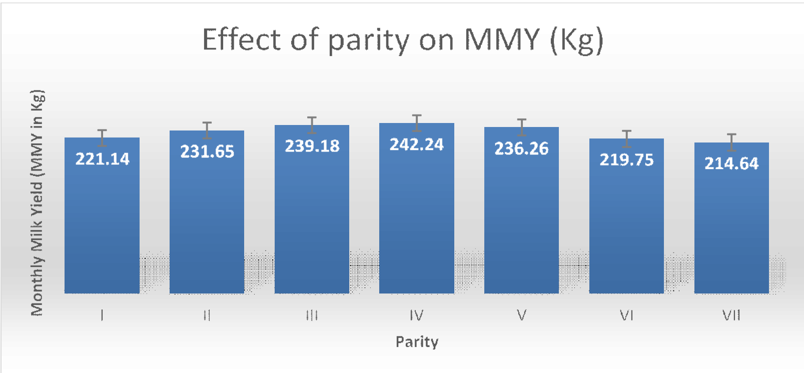

Fig 1: Effect of parity on monthly milk yield (kg).

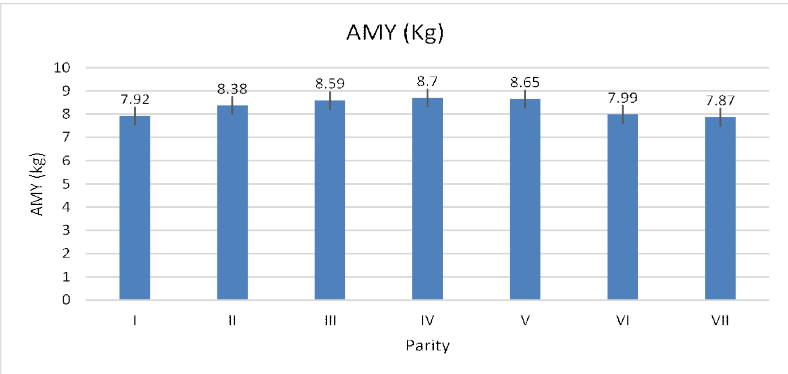

Fig 2: Effect of parity on AMY (Kg).

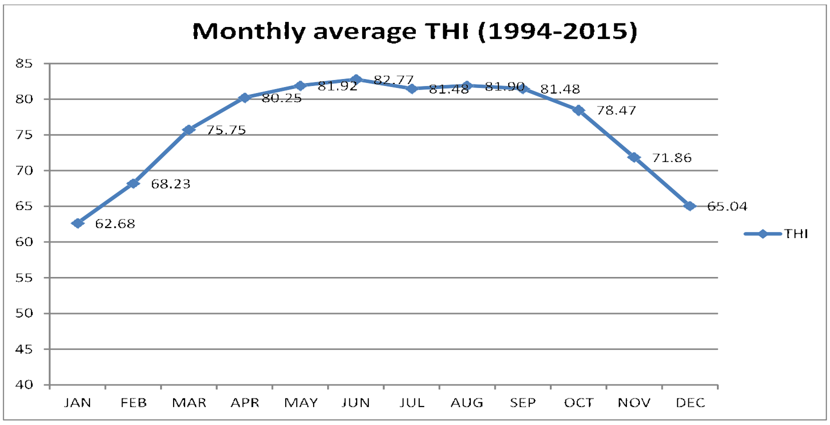

Fig 3: Trend of monthly average THI (1994-2015) at ERS, ICAR-NDRI, Kalyani herd.

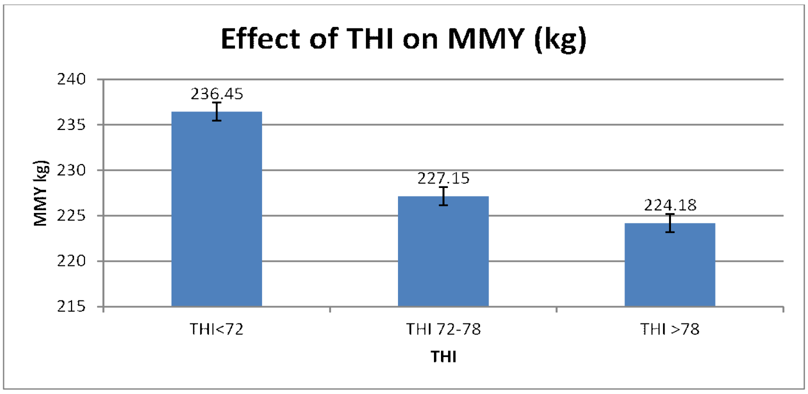

Fig 4: Effect of THI on monthly milk yield (MMY) during 1994-2015.

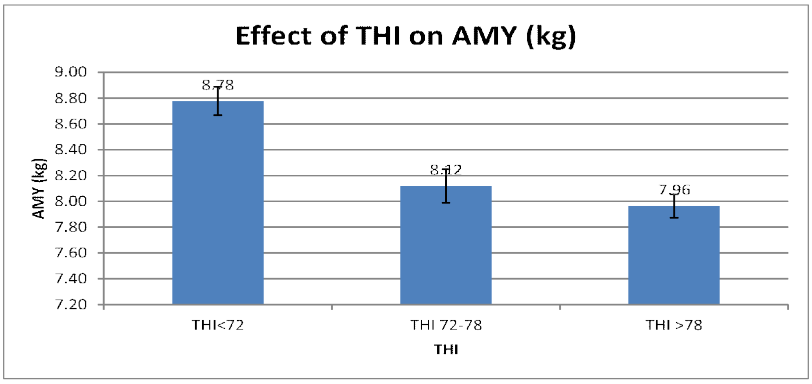

Fig 5: Effect of THI on average daily milk yield in a month (AMY) during 1994-2015.

The effect of THI and genetic group were significant (P<0.01) on both MMY and AMY (Table 4). The cows exhibited maximum MMY and AMY at thermal comfort period (THI <72) and gradually a declined trend was observed at THI zone 72-78 and lowest MMY and AMY at THI above 78. The result is in agreement with Behera *et al.,* (2018) who recorded maximum daily milk yield at thermal comfort period zone and gradual declined trend at heat stress zone and critical heat stress zone in Murrah buffalo. The interaction model revealed that the effect of genetic group X THI was significant (P<0.05) on both MMY and AMY. The literature is scanty on genotype and THI interaction on animal productivity. However, Behera *et al*. (2018) reported a decline in monthly test day fat yield and SNF yield in Murrah buffaloes with rise in THI. Hammami *et al*. (2009) advocated that breeders should select animals (genotypes) for production traits in environmental conditions similar to the environmental conditions where the animal is intended to perform as genotype X environment plays a vital role in expression of the phenotype. Perusal of Table 5 and 6 reveal that genetic group bearing 50% Jersey + 50% Tharparkar, 50% Jersey + 50% Red Sindhi and 50% Jersey + 50% indigenous cattle were the most heat tolerant breeds as they exhibited least decline in MMY (-1.24%, -1.95% and -2.08%, respectively) and AMY (-6.31%, 7.39 and -6.84%, respectively)) at THI above 78 zone as compared to thermal

Table 4: Effect of genetic group on monthly milk yield (MMY) and average daily milk yield in a month (AMY).

GG	Genetic group	LSM ± SE (MMY in Kg)	LSM ± SE (AMY in Kg)
1	CB cattle - Holstein inheritance (≥ 50%)	190.17**a ± 16.01	7.03**a ± 0.51
2	50% Jersey and 50%Tharparkar	243.10**c ± 11.57	8.85**c ± 0.39
3	50% Jersey and 50% Red Sindhi	244.94**c±11.45	8.86**c±0.39
4	50% Jersey and 25% exotic inheritance from Holstein/ Brown Swiss and 25% indigenous inheritance	217.55**b±11.29	7.82**b±0.39
5	50% Jersey and 50% indigenous inheritance form more than two indigenous breeds	234.70**bc ± 11.31	8.48**bc ± 0.39
6	25% Jersey and 25% Holstein with 50% indigenous inheritance	224.59**bc ± 11.87	8.16**bc ± 0.40
7	>50% to <75% Jersey inheritance	227.37**b± 11.25	8.18**b± 0.39
8	≥75% Jersey	251.65**c ± 14.59	9.01**c ± 0.47

Similar superscripts indicate non-significant and dissimilar superscripts indicate significant difference among subclasses (P<0.01)

Table 5: Monthly milk yield (MMY) of crossbred cows under different THI zones.

GG	Composition	MMY	THI <72	THI 72-78	THI >78 %	change at THI 72-78% compared to breed average MMY	change at THI 72-78% compared MMY at THI<72	change at THI>78 compared to breed average MMY	change at THI>78 compared MMY at THI<72
1	50% or More Holstein	190.17	213.65	185.32	171.53	-2.58	-13.26	-8.73	-19.71
2	50% J 50% T	243.10	244.85	242.64	241.81	-0.19	-0.90	-0.53	-1.24
3	50% J 50% RS	244.94	247.75	244.17	242.91	-0.32	-1.45	-0.70	-1.95
4	50% J + 25% Exotic + 25% Indigenous	217.55	221.74	215.34	215.57	-1.01	-2.89	-1.05	-2.78
5	50% J + 50% more than two Indigenous Breeds	234.70	237.3	234.42	232.37	-0.12	-1.21	-1.97	-2.08
6	25% J+ 25% Holstein	224.59	227.32	224.11	222.34	-0.21	-1.41	-1.40	-2.19
7	>50% to <75% Jersey inheritance	227.37	233.53	226.09	222.49	-0.56	-3.19	-2.17	-4.73
8	≥75% Jersey	251.65	265.44	245.08	244.42	-2.62	-7.67	-2.49	-7.92

Table 6: Average Daily Milk Yield in a month (AMY) of crossbred cows under different THI zones.

GG	Composition	MMY	THI <72	THI 72-78	THI >78 %	Change at THI 72-78% compared to breed average MMY	Change at THI 72-78% compared MMY at THI<72	Change at THI>78 compared to breed average MMY	Change at THI>78 compared MMY at THI<72
1	50% or more Holstein	7.03	7.76	6.99	6.35	-8.76	-9.16	-8.76	-20.17
2	50% J 50% T	8.85	9.22	8.71	8.67	-1.95	-0.46	-1.95	-6.31
3	50% J 50% RS	8.86	9.31	8.52	8.68	-1.93	-1.88	-1.93	-7.39
4	50% J + 25% exotic + 25% indigenous	7.82	8.26	7.71	7.49	-4.00	-2.85	-4.00	-9.99
5	50% J + 50% more than two indigenous Breeds	8.48	8.84	8.33	8.27	-2.38	-0.72	-2.38	-6.84
6	25% J+ 25% Holstein	8.16	8.67	7.92	7.88	-3.23	-0.51	-3.23	-9.97
7	>50% to <75% Jersey inheritance	8.18	8.56	7.92	7.78	-4.67	-1.77	-4.67	-9.85
8	≥75% Jersey	9.01	9.60	8.85	8.59	-4.38	-2.94	-4.38	-11.41

comfort zone (THI<72). Jersey crossbred cows were more heat tolerant than Holstein crossbred cows in relation to the effect of heat stress (THI) on the milk production traits. Cows with 50% or more Holstein inheritance exhibited maximum decline in MMY (-19.71%) and AMY (-20.177%). Crossbred cows with 50% Jersey inheritance performed better than higher Jersey inheritance during periods of THI above 72. Cows bearing more than 50% Jersey inheritance exhibited more decline in MMY and AMY at severe heat stress zone (THI >78) as compared to cows with 50% Jersey inheritance. Among the Jersey crossbred cows, the cows bearing >75% Jersey inheritance exhibited maximum decline in MMY (-7.92%) and AMY (-11.41%). Similar result was found by Kashyap (2016) who recorded a maximum decline in daily milk yield in Karanfries cows bearing above 62.5% Holstein inheritance, followed by 50 to 62.5% Holstein inheritance and least decline in cows with ≤ 50% Holstein inheritance during critical heat stress periods per unit rise in THI.

CONCLUSION

Crossbred cows with different degrees of exotic inheritance play crucial role in dairy sector and among the environmental factors influencing the dairy production system, heat stress is one of the chief factors. Thermal load negatively affects animal's milk yielding capacity. Measurement of thermal load is proficiently done by constructing temperature humidity index (THI). Genetic group × THI plays a key role in Indian dairy sector which largely depend on crossbred cows with different exotic inheritance. The present study revealed crucial role of genetic group × THI on milk production traits. Genetic Group bearing 50% Jersey and 50% Red Sindhi or Tharparkar were the most heat tolerant breeds. Jersey crossbred cows were more heat tolerant than Holstein crossbred cows. Crossbred cows with 50% Jersey inheritance performed better than higher Jersey inheritance during heat stress periods.

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