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Effect of Heat Stress on Adaptability and Physiological Responses in Cross-bred Cows

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ABSTRACT

Present study demonstrates the influence of heat stress on adaptability and physiological responses in cross-bred cattle. Eighteen cross bred cows were selected from three districts of central plane zone of Uttar Pradesh, on the basis of their body weight, body condition and parity and were divided into three groups, 6 cows were kept in each district. The experiments were carried out in spring and summer season at Lucknow, Unnao and Sitapur districts of Uttar Pradesh. Physiological responses *viz.* Rectal Temperature, Pulse rate and Respiration rate are recorded twice a day during both seasons. Temperature Humidity Index (THI) of all three districts was also calculated. There was found a significant ($P<0.01$) deference in THI values in spring and summer seasons in all three districts. There was no significant change in Physiological response like Rectal Temperature, Pulse Rate and Respiration Rate in both seasons in morning hours but there was found significant ($P<0.01$) increase in Rectal Temperature, Pulse Rate and Respiration Rate in summer season as compare to spring season at afternoon. Overall Mean±SEM of Iberia heat Tolerance coefficient and Gaalaa's heat Tolerance coefficient were significantly ($P<0.01$) more closure to 100 in spring season as compared to summer season. Overall Mean±SEM of Benezera coefficient of Adaptability and Dairy Search Index was significantly ($P<0.01$) more closure to 2.00 and 1.00 respectively in spring season. In conclusion Heat tolerance indices and physiological responses show more adaptability in spring season as compared to summer season in cross-bred cows.

HIGHLIGHTS

- No significant change in physiological parameters during morning hours.
- Better adaptation in spring season as compared to summer season.

Keywords: Temperature Humidity Index, Heat Tolerance, Season, Adaptability, Dairy Search Index

Agriculture sector is the backbone of India and livestock is one of the emerging driving forces in the growth and development of this field. Dairy farming has been an important part of the agricultural scenario for thousands of years as it provides high-quality foods to meet the nutritional demands of the population. Livestock has become an important source of income and employment for the small landholders as India accounts for a total of 37.28 per cent of cattle, 21.23 per cent of buffalo, 26.40 per cent of goats and 12.17 per cent of sheep of the world's population (Sonavale *et al.,* 2020). In India, there is a large percentage of cattle population which is mainly reared for milk and draught/draft purposes. India is the largest milk producer in the world with production recorded to 187.75 million tons in 2019 (20th livestock censuses in the country). There is a continuous need to sustain and amplify this production in order to meet the protein requirements in the present as well as in the future.

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As the fact about the changing weather conditions which are deteriorating the environment with global climatic changes, one of the greatest challenges to production facing dairy farmers in India is the heat stress and the strain that it causes to the lactating dairy cows. Lactating cows produces large amount of metabolic heat and accumulates extra heat from the energy transferred by radiation. When animals are unable to lose excess metabolic heat by the different heat loss mechanisms (conduction, convection, radiation and sweating) they develop heat stress syndrome (Collier *et al.,* 2019). Heat stress is one amongst the most stressful condition and has the crucial impacts on growth and development (Singh *et al.,* 2016). Extreme hot condition causes economic losses because it decreases milk yield and growth performance in dairy cattle. Developing optimal environmental factors can be used to prevent heat stress and reduce economic losses. Temperature humidity index (THI) is the simplest, effective and most commonly used technique, which predicts the severity of heat stress on livestock (Vitali *et al*., 2009; Rashamol *et al*., 2019). In this context, the adaptation of animals to the hot and cold climatic conditions is also a major field of interest as such animals shows the least variation in their physio-biochemical traits when raised under such stressful conditions. It has been commonly observed that the animals differ in their nature of being susceptible and tolerant when subjected to the thermal stress. Physiological parameters like respiration rate, heart rate, body temperature and skin temperature give an immediate response to climatic stress and thus to the level of comfort of the animal. These responses have been used as a measure of dairy cow comfort and adaptability to an adverse environment or as sensitive physiological measure of environmental modification (Roman-Ponce *et al*., 1978). The present study therefore gives an account on the effect of heat stress on the physiological parameters in the cattle reared under hot and arid conditions with an aim to assess their overall adaptability to heat stress.

MATERIALS AND METHODS

Design of experiment has been approved by the Institutional animal ethics committee. The study was conducted in spring and summer season in Department of Veterinary Physiology and Biochemistry, College of Veterinary Science and Animal Husbandary, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh. The experiments were carried out in both seasons at Lucknow, Unnao and Sitapur district of Central plane zone of Uttar Pradesh. All the climatic variable were recorded twice daily at 7:30 am to 2:30 pm in the experimental animal selected for the study. Eighteen lactating cross bred cows of age group 2-4 years were randomly selected for the study. The animals were divided into 3 groups as one group in each district containing six animals in each group. The cross bred cows were maintained under standard managemental condition at different private dairy farms/field conditions of Lucknow, Unnao and Sitapur district.

The animals were maintained in open area made up of brick floor and have asbestos roof. The provision were made inside the house that the animal were free to move to access the feed and water. The animals were given feed and water *ad libitum*. All the animals were fed on a ration consisting of concentrate mixture and roughages (berseem, maize or jowar fodder as per the availability in the farm) and fed as per the standard feeding practices followed at the farm. Concentrate mixture consisted of mustard cake, maize, wheat bran, rice bran, mineral mixture and salt. For summer season proper shade facility are available at the farm.

The physiological parameter including Rectal temperature, Pulse rate and Respiration rate were recorded twice a day (7:30 am and 2:30 pm) during the study period in spring and summer seasons. The Rectal temperature was recorded by digital electronic thermometer inserted 5 cm deep in rectum insuring to touch the rectal mucosa until it showed the stable temperature with a beep sound. Respiration rate of animals was recorded by observing the flank movement. One inward and out ward movement was counted as one respiration and total respirations per minute were recorded. To record the pulse rate, coccygeal artery was palpated beneath the root of tail and pulsations were recorded per minute. Meteorological parameters like maximum and minimum environmental temperature and relative humidity were recorded in both seasons during study period.

To evaluate the tolerance capacity of cows, following test was applied as Iberia heat tolerance test (HTC) evaluated as per Rhoad, (1944), Gaalaa's heat tolerance test evaluated as per Gaalass, (1947), Benezra's coefficient of adaptability (BCA) evaluated as per Benezra, (1954)

and Dairy search index (DSI) evaluate as per Thomas *et al*. (1973). Temperature Humidity Index (THI) was also calculated as per the formula given by National Research Council (1971).

Statistical analysis of data was carried out to find the Mean ± SE. Paired "t-test" were done to find significant difference between groups of experiment and their interaction by using Data were subjected to analysis by Computer software package.

RESULTS AND DISCUSSION

Mean values of Temperature humidity Index is presented in the Table 1. Overall Mean±SE of Temperature humidity Index was 79.52±1.11 Vs 87.93±0.91 in Lucknow, 79.25±1.17 Vs 85.78±1.83 in Sitapur and 79.20±1.11 Vs 87.94±0.91 in Unnao districts of Uttar Pradesh in spring (March) and summer (June) seasons respectively.

Table 1: Mean ± SE of Temperature Humidity Index (THI) in Spring and Summer season in Lucknow, Sitapur and Unnao district of Uttar Pradesh

THI	Lucknow	Sitapur	Unnao
Spring season	79.52^{a}±1.11	79.25^{a}±1.17	79.20^{a}±1.11
Summer season	87.93^{b}±0.91	85.78^{b}±1.83	87.94^{b}±0.91

Notes: Means bearing different superscripts differ significantly (P<0.01).

These values varies significantly (P<0.01) in both seasons. THI values in all three districts during spring season showed there was no or mild stress in cross-bred cows where as moderate to severe stress in summer season which affected physiological responses and also adaptability in the animals including hematological or biochemical changes and productive as well as reproductive performance in dairy animals (Hsu and Liu, 1996). According to Fuquay (1981), the THI is widely used method for determining the severity of heat stress in animals. As per Bligh, (1973) Temperature humidity index values of 70 or less do not impose any thermal stress are considered comfortable, 75–78 mild stressful, and more than 78 considered heat stress. As per Wiersma and Armstrong (1989) quantification of heat stress, there was no stress when THI below 72, mild stress 72-78 and moderate stress 78-88.

Mean±SE of Rectal Temperature (RT) was 100.16±0.05, 101.17±0.05 and 101.16±0.05°F in Lucknow, Sitapur and Unnao districts respectively in spring season in morning hours and 101.46±0.05, 101.46±0.05 and 101.48±0.05°F in Lucknow, Sitapur and Unnao districts respectively in spring season in afternoon hours (Table 2) and weekly variations in RT in all three districts were shown in Fig 1A, 2A and 3A. Mean±SE of Rectal Temperature (RT) was 101.18±0.04, 101.19±0.04 and 101.16±0.04 °F in Lucknow, Sitapur and Unnao districts respectively in summer season in morning hours and 101.65±0.04, 101.63±0.04 and 101.64±0.03°F in Lucknow, Sitapur and Unnao districts respectively in summer season in afternoon hours (Table 2) and weekly variations in RT in all three districts were shown in Fig 1A, 2A and 3A. In study it was found that there was no significant change in rectal temperature in both seasons in morning hours but there was found significant (P<0.01) increase in rectal temperature in summer season at afternoon as compare to spring season. Similar finding was also reported by Lal *et al.* (1987) in Haryana cattle. They were also reported

Table 2: Mean ± SEM of Rectal Temperature (°F), Pulse Rate (per minute) and Respiration Rate (per minute) in morning and afternoon during Spring and Summer season of Cattle in Lucknow, Sitapur and Unnao districts of Uttar Pradesh

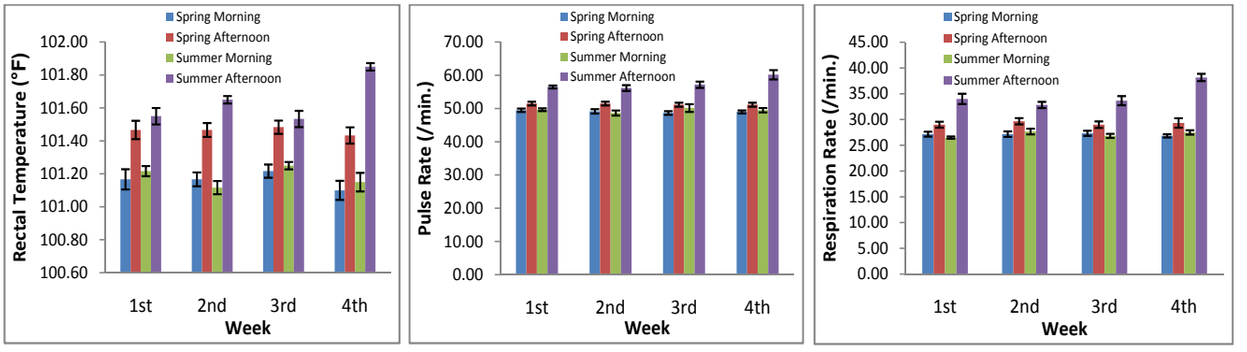
District	Parameters	Rectal Temperature (°F)		Pulse Rate (per minute)		Respiration Rate (per minute)	
	Season	Spring	Summer	Spring	Summer	Spring	Summer
Lucknow	Morning	101.16±0.05	101.18±0.04	49.08±0.54	49.50±0.75	27.13±0.46	27.13±0.40
	Afternoon	101.46±0.05	101.65±0.04	51.33^{a}±0.58	57.50^{b}±0.91	29.25^{a}±0.69	34.67^{b}±0.80
Sitapur	Morning	101.17±0.05	101.19±0.04	48.88±0.52	49.00±0.72	27.17±0.47	27.28±0.40
	Afternoon	101.46±0.05	101.63±0.04	51.39^{a}±0.56	57.08^{b}±1.07	29.54^{a}±0.62	34.27^{b}±0.78
Unnao	Morning	101.16±0.05	101.16±0.04	48.83±0.51	49.54±0.72	27.13±0.46	27.26±0.40
	Afternoon	101.48±0.05	101.64±0.03	50.83^{a}±0.48	56.67^{b}±1.41	29.25^{a}±0.69	34.75^{b}±0.82

Notes: Means bearing different superscripts differ significantly (P<0.01).

significant rise in rectal temperature and other responses when ambient temperature increased. Heat stress also caused several physiological as well as behavioural disturbances in the animals (West, 2003; Gaworski and Rocha, 2016) and due to the persistent heat stress core body temperature increased as the heat dissipation capacity in the animals was exhausted (Hansen, 2004; Collier and Gebremedhin, 2015; Collier *et al*., 2019). Animals exposed to extreme heat stress also had varied cardiovascular functions essential for thermoregulation.

Mean±SE of Pulse Rate (PR) was 49.08±0.54, 48.88±0.52 and 48.83±0.51/min. in Lucknow, Sitapur and Unnao districts respectively in spring season in morning hours and 51.33±0.58, 51.39±0.56 and 50.83±0.48/ min in Lucknow, Sitapur and Unnao districts respectively in spring season in afternoon hours (Table 2) and weekly variations in PR in all three districts were shown in Fig 1B, 2B and 3B. Mean±SE of Pulse Rate (PR) was 49.50±0.75, 49.00±0.72 and 49.54±0.72/min in Lucknow, Sitapur and Unnao districts respectively in summer season during morning hours and 57.50±0.91, 57.08±1.07 and 56.67±1.41 in Lucknow, Sitapur and Unnao districts respectively in summer season in afternoon hours (Table 2) and weekly variations in PR in all three districts were shown in Fig 1B, 2B and 3B. In present study it was found that there was no significant change in Pulse Rate (PR) in both seasons in morning hours but there was found significant ($P<0.01$) increase in Pulse Rate in summer season at afternoon as compare to spring seasons. Similar finding was also reported by Lal *et al.* (1987) in Haryana cattle. They were also reported significant rise in Pulse Rate and other responses when ambient temperature increased. A positive correlation was found between environmental temperature and pulse rate in cross bred heifers (Mishra *et al.,* 1995).

Mean ± SE of Respiration Rate was 27.13±0.46, 27.17±0.47 and 27.13±0.46/min. in Lucknow, Sitapur and Unnao districts respectively in spring season in morning hours and 29.25±0.69, 29.54±0.62 and 29.25±0.69/min in Lucknow, Sitapur and Unnao districts respectively in spring season in afternoon hours (Table 2) and weekly variations in RR in all three districts were shown in Fig 1C, 2C and 3C. Mean±SE of Respiration Rate was 27.13±0.40, 27.28±0.40 and 27.26±0.40 in Lucknow, Sitapur and Unnao districts respectively in summer season in morning hours and 34.67±0.80, 34.27±0.78 and 34.75±0.82/min in Lucknow, Sitapur and Unnao districts respectively in summer season in afternoon hours (Table 2) and weekly variations in RR in all three districts were shown in Fig. 1C, 2C and 3C. In study it was found that there was no significant change in Respiration Rate **(**RR) in both seasons in morning hours but there was found significant ($P<0.01$) increase in Respiration Rate in summer season at afternoon as compare to spring session. Similar finding was also reported by Lal *et al.* (1987) in Haryana cattle, Razdan (1969) in Tharparkar heifer. There was found significant increase in respiration rate and other physiological responses in high ambient temperature (Mullick and Kehar 1952). It was found that if the animals were unable to dissipate heat by sensible heat loss mechanisms, adopted evaporative cooling method resulted panting and increased respiration frequency



A **B** **C**

Fig. 1: Rectal Temperature **(A)**, Pulse Rate **(B)** and Respiration Rate **(C)** during Spring and Summer season in Cattle in Lucknow

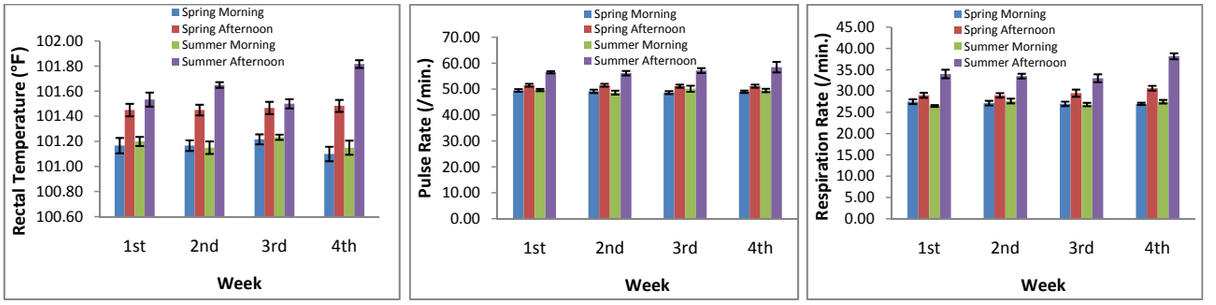


Fig. 2: Rectal Temperature **(A)**, Pulse Rate **(B)** and Respiration Rate **(C)** during Spring and Summer season in Cattle in Sitapur

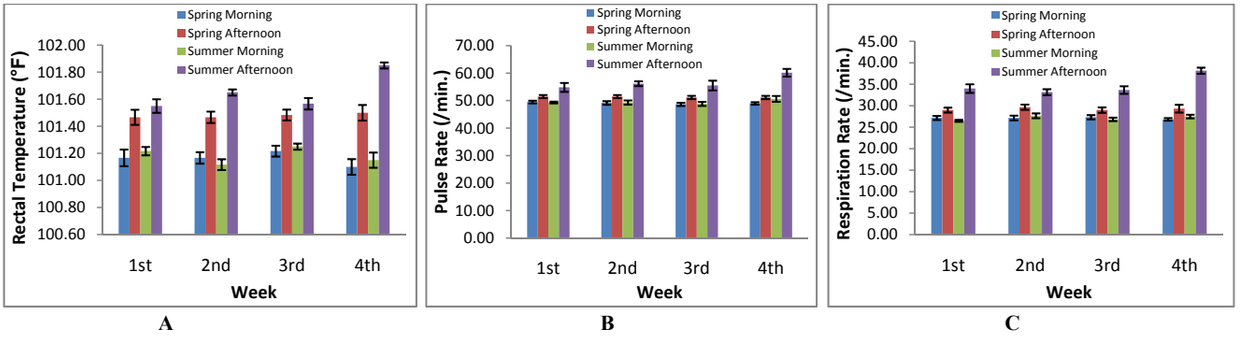


Fig. 3: Rectal Temperature **(A)**, Pulse Rate **(B)** and Respiration Rate **(C)** during Spring and Summer season in Cattle in Unnao

(Brown-Brandl *et al.,* 2005; Wankar *et al.,* 2019). Marai and Haeeb (2010**)** also reported that the exposure of high temperature lead to high consumption of oxygen and increased Respiration rate.

Mean values of Iberia heat tolerance coefficient (IHTC) during different seasons in cross-bred cows in Lucknow, Sitapur and Unnao districts are represented in Table 3. The Mean±SE of Iberia Heat Tolerance coefficient was 95.333±0.452 Vs 93.542±0.360 in Lucknow, 95.375±0.475 Vs 93.750±0.363 in Sitapur and 95.208±0.490 Vs 93.458±0.342 in Unnao districts in spring and summer season respectively. Overall Mean±SEM of Iberia heat Tolerance coefficient was 95.305±0.472 and 93.583±0.355 and varies significantly (P<0.01) in spring season and summer season respectively. These values of Iberia heat Tolerance coefficient were more closure to 100.00 in spring session showed more adaptability in spring season as compared to summer session. Our observations are in agreement with Mandal and Tyagi (2008) where they found significantly (P<0.01) higher deviation in Iberia heat tolerance coefficient from their respective values of perfect thermal adaptability during monsoon and summer seasons as compared to winter season. Abdel-Samee, (1991) also used Iberia heat tolerance coefficient for detection of heat adaptability of growing lamb in subtropics.

Mean values of Gaalaa's heat tolerance coefficient (GHTC) during different sessions in cross-bred cows in Lucknow, Sitapur and Unnao districts are represented in Table 3. The Mean±SE of Gaalaa's Heat tolerance coefficient was 93.629±0.612 Vs 90.958±0.505 in Lucknow, 93.525±0.665 Vs 91.250±0.509 in Sitapur and 93.292±0.685 Vs 90.842±0.479 in Unnao districts in spring and summer season respectively. Overall Mean±SEM of Gaalaa's heat tolerance coefficient was 93.482±0.654 and 91.017±0.498 and varies significantly (P<0.01) in spring season and summer season respectively. These values of Gaalaa's heat tolerance coefficient were more closure

Table 3: Mean ± SEM of Iberia Heat Tolerance Coefficient, Gaalaa's Heat Tolerance Coefficient, Benezra Coefficient of Adaptability and Dairy Search Index during Spring and Summer season of Cattle in Lucknow, Sitapur and Unnao districts of Uttar Pradesh

District	Iberia Heat Tolerance Coefficient (IHTC)		Gaalaa's Heat Tolerance Coefficient (GHTC)		Benezra Coefficient of Adaptability (BCA)		Dairy Search Index (DSI)	
	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
Lucknow	95.333±0.452	93.542±0.360	93.629±0.612	90.958±0.505	2.279±0.030	2.517±0.035	1.031±0.007	1.107±0.012
Sitapur	95.375±0.475	93.750±0.363	93.525±0.665	91.250±0.509	2.291±0.027	2.512±0.036	1.033±0.005	1.104±0.008
Unnao	95.208±0.490	93.458±0.342	93.292±0.685	90.842±0.479	2.279±0.030	2.520±0.036	1.031±0.007	1.102±0.014
Mean ± SEM	**95.305^{a} ± 0.472**	**93.583^{b} ± 0.355**	**93.482^{a} ± 0.654**	**91.017^{b} ± 0.498**	**2.283^{a} ± 0.029**	**2.516^{b} ± 0.036**	**1.032^{a} ± 0.006**	**1.104^{b} ± 0.011**

Notes: Means bearing different superscripts differ significantly (P<0.01).

to 100.00 in spring season showed more adaptability in spring season as compared to summer season.

Mean values of Benezera coefficient of adaptability (BCA) during different seasons in cross-bred cows in Lucknow, Sitapur and Unnao districts are represented in Table 3. Mean±SE of Benezera coefficient of Adaptability was 2.279±0.030 Vs 2.517±0.035 in Lucknow, 2.291±0.027 Vs 2.512±0.036 in Sitapur and 2.279±0.030 Vs 2.520±0.036 in Unnao districts in spring and summer season respectively. Overall Mean±SEM of Benezera coefficient of Adaptability was 2.283±0.029 and 2.516±0.036 and varies significantly (P<0.01) in spring season and summer season respectively. These values of Benezera coefficient of Adaptability were more closure to 2.000 in spring season showed more adaptability in spring season as compared to summer season. Our observations are in agreement with Mandal and Tyagi (2008). They found significant (P<0.01) variation in thermoadaptability of Frieswal bulls during different seasons.

Mean values of Dairy Search Index (DSI) during different seasons in cross-bred cows in Lucknow, Sitapur and Unnao districts are represented in Table 3. Mean±SE of Dairy Search Index was 1.031±0.007 Vs 1.107±0.012 in Lucknow, 1.033±0.005 Vs 1.104±0.008 in Sitapur and 1.031±0.007 Vs 1.102±0.014 in Unnao districts in spring and summer season respectively. Overall Mean±SEM of Dairy Search Index (DSI) was 1.032±0.006 and 1.104±0.011 and varies significantly (P<0.01) in spring season and summer season respectively. These values of Dairy Search Index were more closure to 1.000 in spring season showed more adaptability in spring season as compared to summer season. Mandal and Tyagi (2008) used Dairy Search Index for studying thermoadaptability in Frieswal calves during different seasons of the year also found significant (P<0.01) variation in thermal adaptability during different season. As per physiological response and thermal tolerance in monsoon and summer season were found very stressful and winter was more comfortable for Frieswal calves.

Normally in natural conditions acclimatory responses (i.e., response to a single stressor) are seen rarely. Acclimatization response is seen when animals are subjected to multiple stressors (Collier *et al.,* 2019). However, persistent stressful conditions for several years might lead to permanent metabolic adaptations to be incorporated genetically for supporting the ongoing physiological state (Bernabucci *et al.,* 2010).

CONCLUSION

There was a significant (P<0.01) deference in Temperature humidity Index (THI) values in spring and summer seasons which showed no or mild stress in spring season where as moderate to severe stress in summer season. There was no significant change in Physiological response like Rectal Temperature, Pulse Rate and Respiration Rate in both seasons in morning hours but found significant (P<0.01) increase in summer season at afternoon hours. Overall mean values of Iberia HTC, Gaalaa's HTC, Dairy Search Index and Benezra Coefficient of Adaptability showed more thermal adaptability in spring season as compare to summer season in the cross-bred cattle. Increased respiration rate and pulse rate in animals is the most important physiological indicator to poor thermal

adaptability in summer season and extreme hot conditions influences cardinal physiological responses and thermal adaptability in crossbred cows.

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