Adoption of panting score as a heat stress assessment tool in Indian smallholder dairy system

A. Joshi, *K. Bhave, S. Joshi, V. Potdar, S. Shinde, Y. Gaundare, N. Punde, T. Shirsath, V. Dhanikachalam, S. Jadhav and B.J Hayes*

BAIF Development Research Foundation, Uruli Kanchan, Pune, Maharashtra, India, 412202
Corresponding author: akshay.joshi@baif.org.in

Abstract

Climate change is a critical global concern, significantly impacting livestock production and animal welfare. Rising temperatures expose animals to heat stress, which can be assessed through physiological indicators such as panting scores. This study incorporates the visual assessment of heat stress by measuring panting scores in Indian cattle and buffaloes. The severity of heat stress is categorized into five levels, ranging from mild to severe panting. Along with panting scores, we also collect weather data from each location, providing actual environmental conditions that influence heat stress levels. Trained enumerators across BAIF implementation areas record panting scores between 10 AM and 3 PM, the peak period for heat stress, throughout the year. The initiative recording spread over 13 states in India, with 236,874 records collected from 37,540 animals since May 2023, and data collection is still going on. The inclusion of this trait in the recording system provides a structured approach to monitoring panting score-based heat stress across different seasons, regions and breeds within the Indian smallholder dairy production system.

The results concluded that panting score is an effective tool for assessing heat stress in Indian smallholder dairy cattle. A highly significant variation in panting scores was observed across states, emphasizing the influence of environmental conditions. Temperature and THI were identified as the primary determinants of heat stress. The findings highlight the importance of panting score as a valuable indicator for evaluating heat stress and guiding targeted strategies to enhance heat tolerance in livestock.

Key words: Panting score, heat stress, smallholder dairy system

Introduction

Heat stress poses a significant challenge to livestock production, particularly in tropical and subtropical regions. Rising global temperatures due to climate change exacerbate the issue, leading to increased heat load on animals and compromising their welfare and productivity (Silanikove, 2000). Livestock, especially dairy cattle, experience physiological and behavioral changes in response to heat stress, which can result in reduced feed intake, altered metabolic processes, and lower milk yield (Bernabucci*et al.*, 2010). Economic implications are substantial; under a high greenhouse-gas emission scenario, annual global losses in cattle production due to heat stress could reach approximately $39.94 billion by the end of the century (Thornton*et al.*, 2022). In a subtropical country like India, with the highest cattle population and a significant proportion of crossbred cattle, heat stress creates a major impact on the national dairy industry, making efficient heat stress management essential.

Physiological responses to heat stress include increased respiration rate, elevated body temperature, and excessive sweating, which serve as mechanisms to dissipate heat (Kadzere*et al.*, 2002). However, prolonged exposure can lead to oxidative stress, immune suppression, and reproductive inefficiencies (Polsky and von Keyserlingk, 2017). Additionally, heat stress negatively impacts rumen function and nutrient absorption, further contributing to production losses in dairy cattle (West, 2003). Given these consequences, reliable and scalable methodologies for assessing heat stress are essential for implementing timely interventions.

Current methodologies for measuring heat stress include temperature-humidity indices (THI), rectal temperature monitoring, and infrared thermography (Mader*et al.*, 2006). While these approaches provide valuable insights, they often require specialized equipment or trained personnel, making them less feasible for large-scale field applications, particularly in developing countries like India. The Panting Score, a simple and non-invasive measure of heat stress, offers a practical alternative for monitoring cattle responses in real-time. By assessing panting behaviour, farmers and researchers can rapidly evaluate the severity of heat stress and take necessary management actions.

In Indian conditions, where climatic variability and resource constraints pose additional challenges, developing a robust yet easy-to-use methodology for heat stress assessment is crucial. An efficient system should enable large-scale data collection while minimizing animal handling and measurement errors. This study aims to evaluate the feasibility and reliability of simplified heat stress assessment techniques for crossbreed and indigenous breeds in Indian climatic conditions. The findings will contribute to improving livestock management strategies and enhancing the resilience of dairy and beef production systems against climate change-induced heat stress.

Methodology

Locations

The phenotype data collection program spread across 13 states in India, covering diverse agro-climatic zones and production systems. The selected states include Punjab, Haryana, Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Jharkhand, Gujarat, Maharashtra, Odisha, Karnataka, Andhra Pradesh, and Telangana. The study design ensures comprehensive representation from distinct environmental conditions and management practices. The distribution of study locations across these states is illustrated in Figure 1.

Trait definition and climate information

The present study focused on collecting phenotype data to assess heat stress using Panting Score, a reliable, non-invasive and simple indicator for evaluating thermal strain in cattle. The methodology for scoring was adapted from Mader*et al.* (2006) with slight modifications to suit Indian cattle and field conditions. The same scoring criteria were also applied to assess heat stress in buffaloes, considering their physiological differences in thermoregulation. To ensure consistency in assessment, trained field recorders followed standardized guidelines, and the classification of Panting Scores is detailed in Table 1.

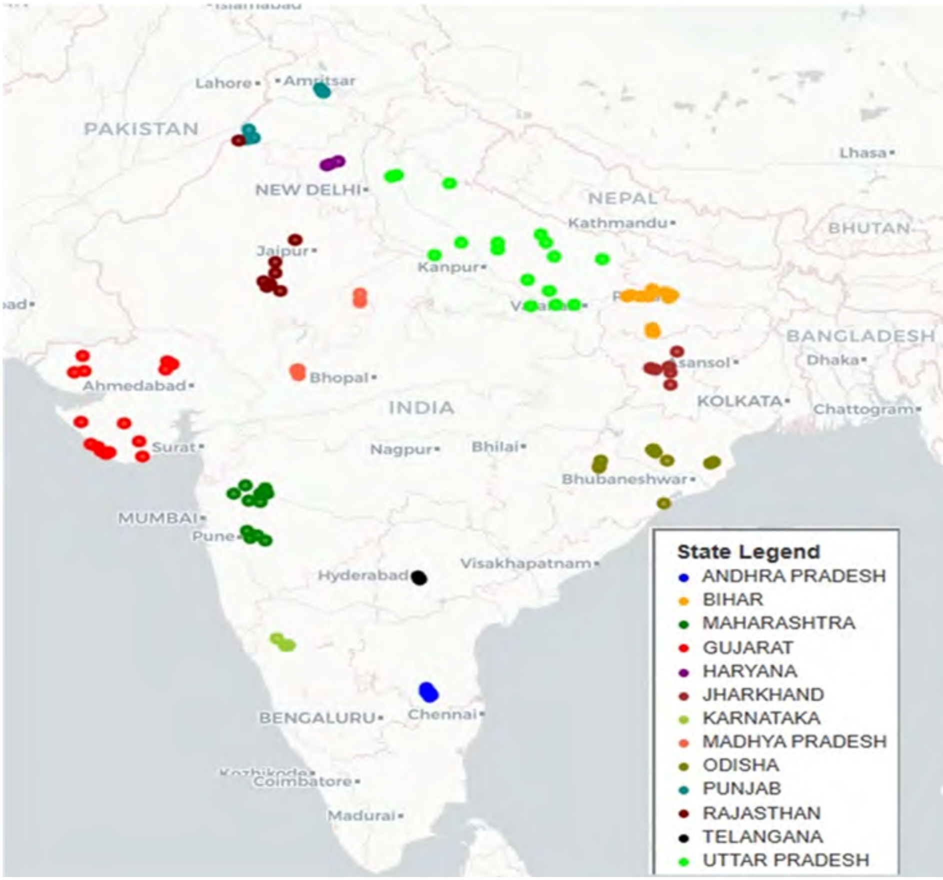


Figure 1. Phenotype data collection coverage across 13 states of India

Table 1. Panting score in cattle.

Score	Conditions
1	No panting
2	Slightly panting, mouth closed, no drools, easy to see chest movements
3	Fast panting, drools present, no open mouth. Tongue not extended
4	Open mouth, tongue slightly out excessive drooling, neck extended, head held up
5	Open mouth with tongue fully extended for prolonged period with excessive drooling, neck extended and head held down

To determine the environmental factors influencing heat stress, climate variables such as temperature, humidity, rainfall, and wind speed were recorded simultaneously with panting scores. Additionally, Temperature-Humidity Index (THI), as described by NOAA (1976), and Heat Load Index (HLI), proposed by Gaughan*et al.* (2008), were derived from weather parameters to quantify the thermal stress conditions.

Data recording system

BAIF initiated a multi-trait performance recording program under the Enhanced Genetics Project, which includes a structured performance data recording system in India. Since performance recording by farmers posed challenges, BAIF adopted an innovative approach by deploying trained and educated field performance recorders who visit farmers' doorsteps to collect data. The data was collected using BAIF's platform-independent software solution, ensuring accurate data flow. To enhance reliability, the recorded data was validated and checked using timestamps and GPS coordinates.

To understand the effect of heat stress on animals and optimize data collection efficiency, recording was scheduled between 10 AM and 3 PM, aligning with peak ambient temperatures when heat load is highest. Since panting score recording was integrated into a multi-trait performance evaluation, additional parameters such as production, reproduction, health status, linear type traits, body weight, and disease incidences were recorded simultaneously. Considering logistical constraints in large-scale field data collection, the frequency of panting score assessment was set at once every two months.

Training of performance recorders played a crucial role in ensuring accurate data collection, as panting score assessment relies on categorical observations linked to behavioral responses to heat stress. To standardize scoring, instructional videos demonstrating each panting score category were developed and integrated into the performance recording software for easy reference. To maintain consistency and minimize observer bias, refresher training sessions were conducted periodically.

Data

A total of 236,874 panting score records from 37,540 animals, maintained by 9,222 farmers, were collected since May 2023 across 13 states. This dataset includes 163,421 records from 26,601 cows and 73,424 records from 10,939 buffaloes. Data collection was carried out using an independent software platform developed by BAIF Development Research Foundation, Pune, ensuring real-time and structured recording under field conditions (Gaundare*et al.*, 2023). The software, accessible via an online platform, allowed efficient data entry, reducing errors and maintaining consistency (https://consoles.bisldonline.org/).

Statistical analysis

Given the varying degrees of admixture in crossbred cattle across different agro-climatic zones in India, the present study focuses exclusively on heat stress responses in crossbred cows. A subset of the available data, comprising only crossbred cows from 13 states, was used for analysis. The number of crossbred cows ranged from 53 in Gujarat to 3,938 in Maharashtra. Due to the limited sample size in Gujarat (53), Madhya Pradesh (75), and Telangana (55), these states were excluded from the analysis.

Various statistical approaches were employed to examine heat stress patterns in crossbred cows. To visualize and compare climate parameters such as temperature, humidity, and THI with panting scores, line graphs depicting means and standard deviations were generated for each state. These graphs provided insights into how crossbred cows responded to heat stress over different months, with trend lines incorporated for better interpretation. The normality of panting scores was assessed using the Kolmogorov-Smirnov test, which confirmed a non-normal distribution. Consequently, a Kruskal–Wallis test was used instead of ANOVA to compare panting scores across states. A Dunn's post-hoc test (with p-value adjustment) was performed to identify statistically significant differences between groups, and the Bonferroni correction was applied to account for multiple comparisons and minimize false positives. A box plot illustrating the distribution of panting scores by state, along with Kruskal–Wallis test results and mean values, was generated to enhance visualization.

Clustering analysis was conducted to classify states based on the response of crossbred cows to heat stress under different climatic conditions. The analysis incorporated temperature, humidity, HLI, THI, and panting scores. Since these variables were measured in different units, z-score normalization was applied to standardize them (mean = 0, standard deviation = 1). To determine the optimal number of clusters, Within-Cluster Sum of Squares (WSS) was plotted against different cluster numbers, and the elbow method was used to identify the point where WSS stopped decreasing significantly. Based on this criterion, a K-means clustering algorithm grouped the states into three clusters, with centroid-based clustering assigning each state to the nearest cluster center. Principal Component Analysis (PCA) was then employed to reduce dimensionality for visualization.

A separate PCA analysis was performed to identify the primary contributors to heat stress in crossbred cattle by analyzing the relationships between climate variables and panting scores. All climate parameters and panting scores were standardized before analysis. PCA biplots and loading plots were generated to visualize the contribution of each variable to heat stress.

All statistical analyses were performed in R software (Version 4.4.2) (R Core Team, 2024). The following R packages were used: lubridate, ggplot2, plyr, dplyr, ggrepel, tidyr, FactoMineR, factoextra, NbClust, cluster, ggpubr, ggfortify, PerformanceAnalytics, corrplot, and FSA.

Result and discussion

The mean and standard deviation for Temperature, Humidity, THI, and Panting Score across different states over the months are presented in Figure 2 and Annex 1. These figures illustrate seasonal variations in climatic conditions and heat stress responses. The general trend indicates that crossbred cattle exhibit higher panting scores during the summer months (March to June), particularly in alignment with elevated THI and temperature levels. Additionally, a slight increase in panting scores was observed in October, likely due to residual heat stress effects post-monsoon. The correlation between THI, temperature, and panting score was moderate (Figure 4), reinforcing the direct impact of environmental heat stress on physiological responses.

Crossbred cattle maintained by farmers across different states exhibit varying levels of exotic inheritance, ranging from low to high. To assess the variation in panting scores among crossbred cows with different genetic compositions, a Kruskal–Wallis test was performed across nine states, as the data was not normally distributed. The results indicated highly significant differences between states ($P<0.01$), with Figure 3 depicting the distribution of panting scores. The presence of outliers suggests that certain cows

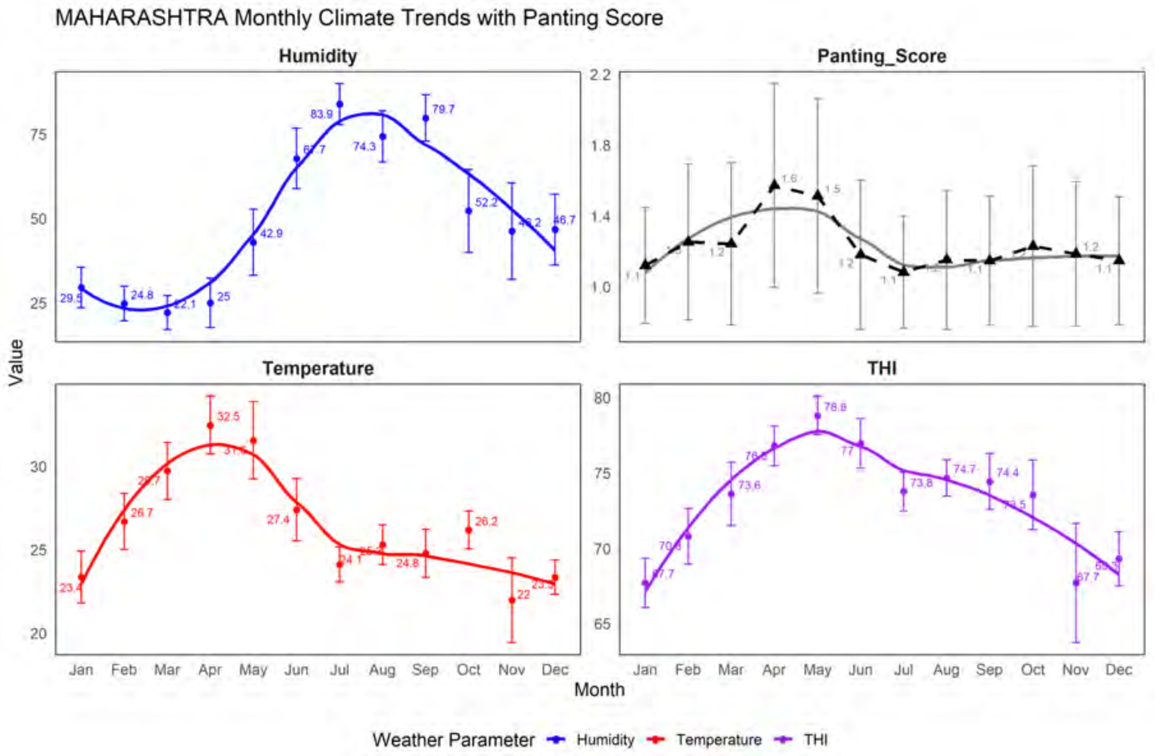


Figure 2. Climate trends in Maharashtra states and their comparison with panting score.

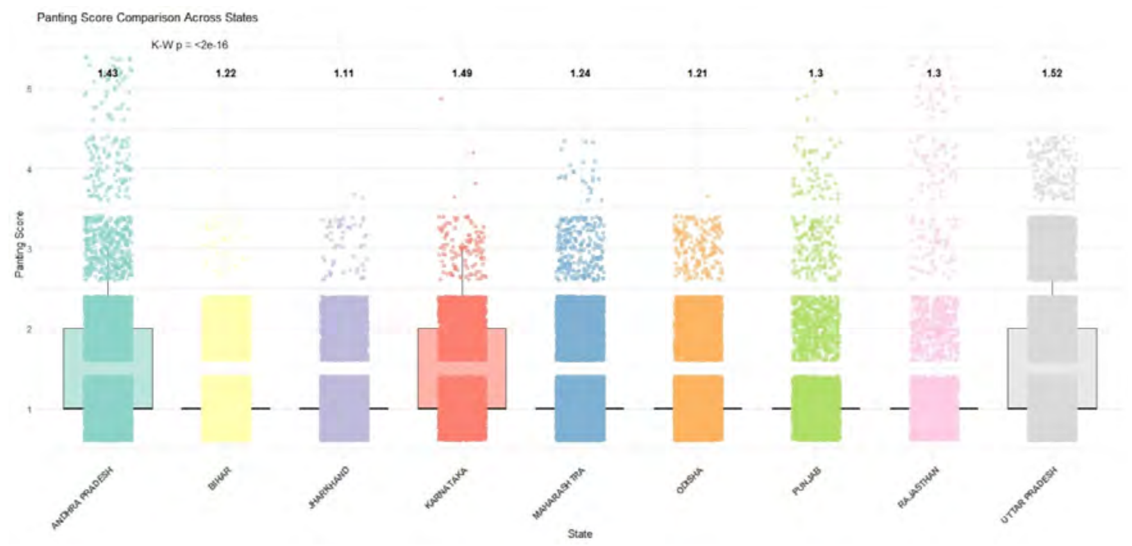


Figure 3. Distribution of panting scores within a state.

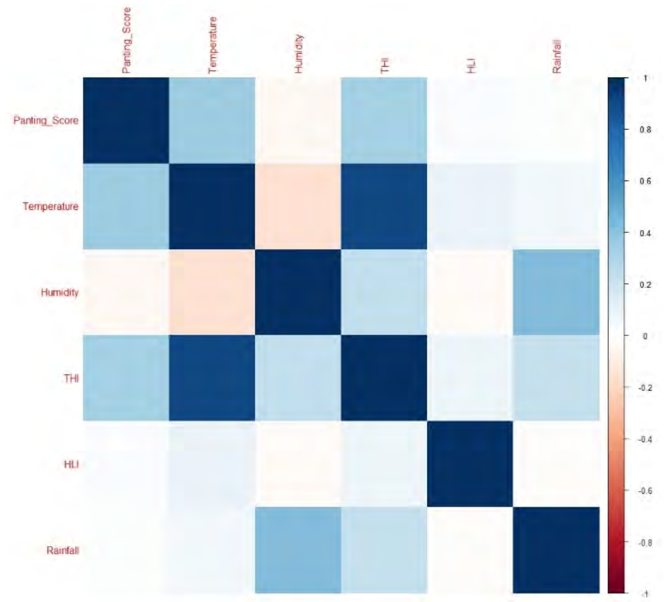


Figure 4. Correlation plot between climate parameters and panting score.

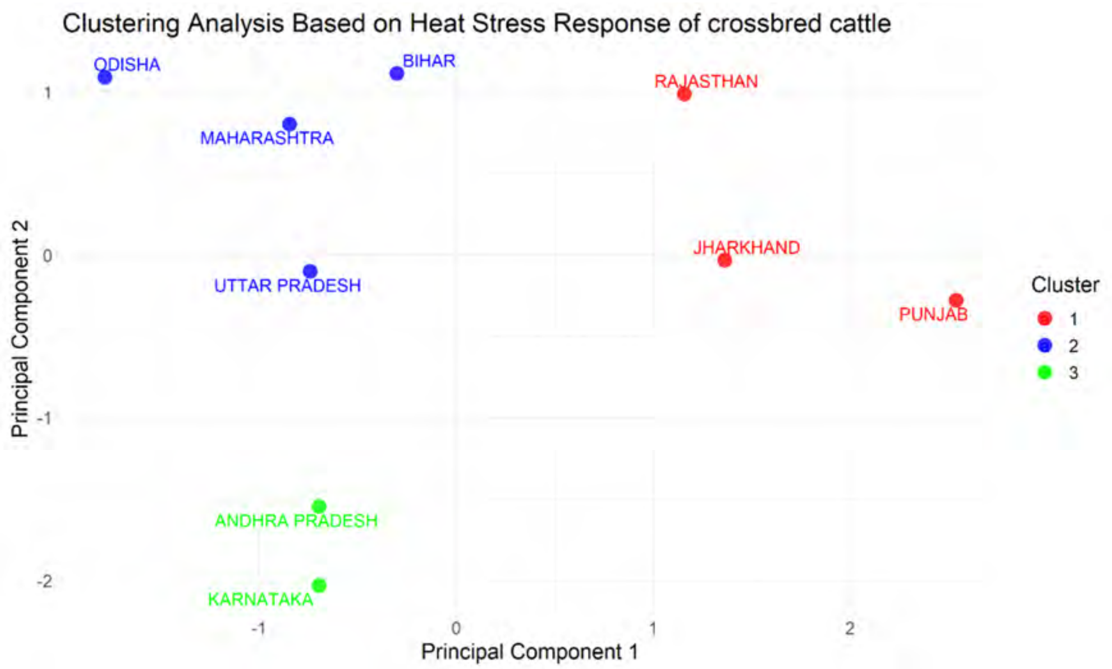


Figure 5. Cluster analysis based on climate parameters and panting score recorded on admixed crossbred cattle maintained in various states.

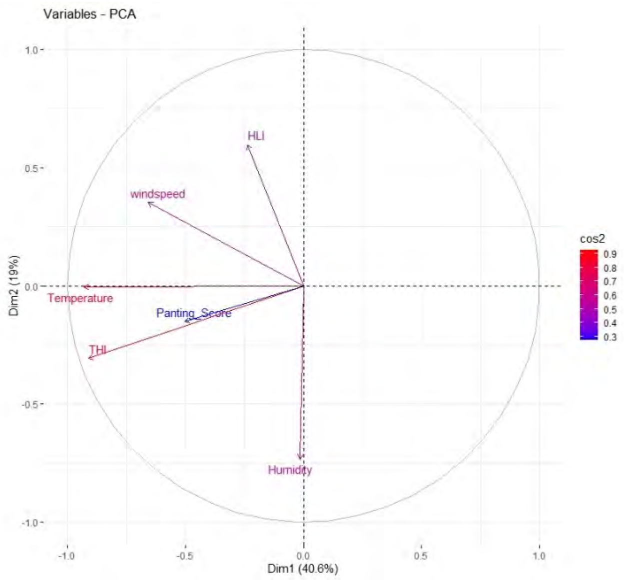
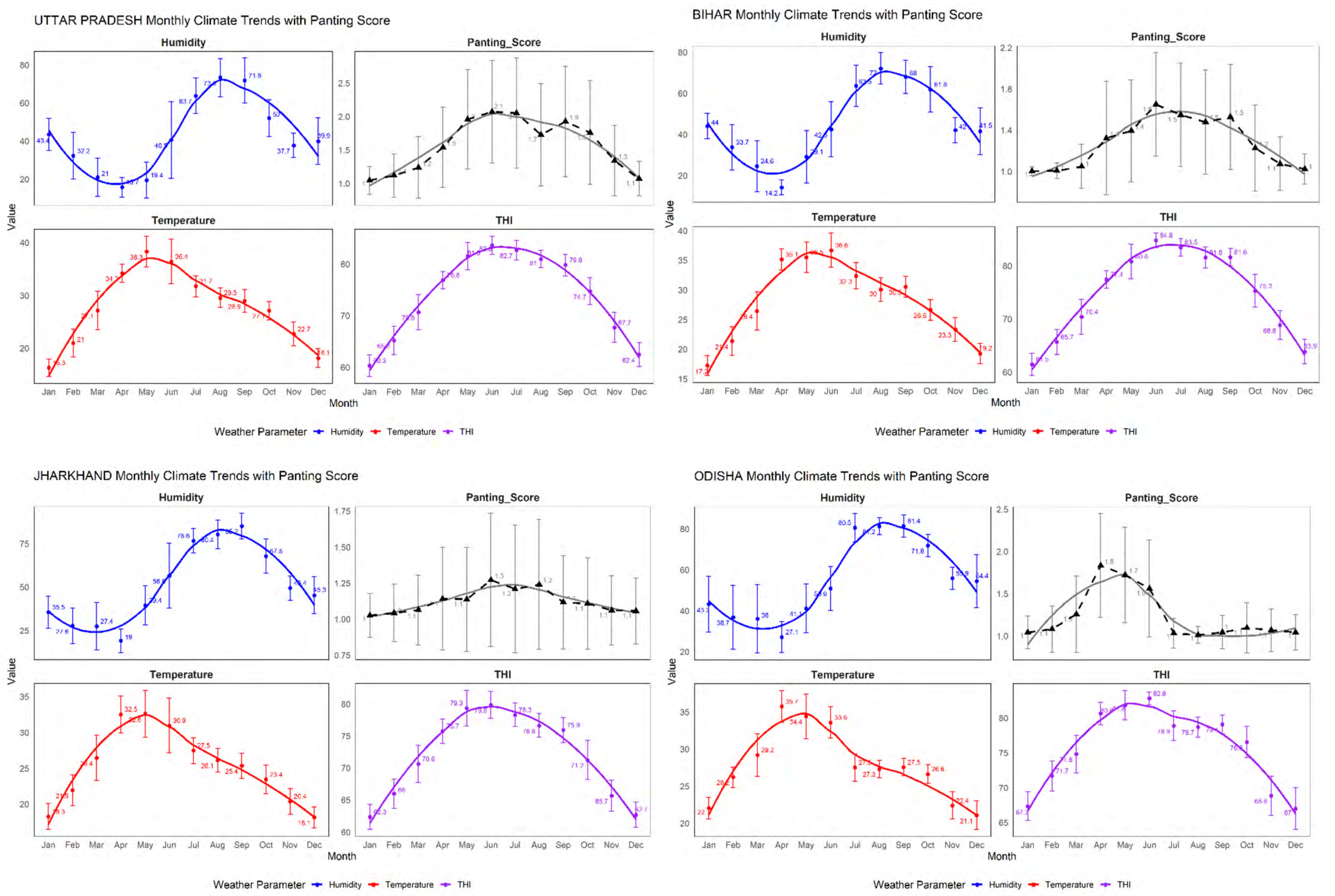


Figure 6. Principal component analysis: biplot to see relationship between the variables and their contribution to the principal components

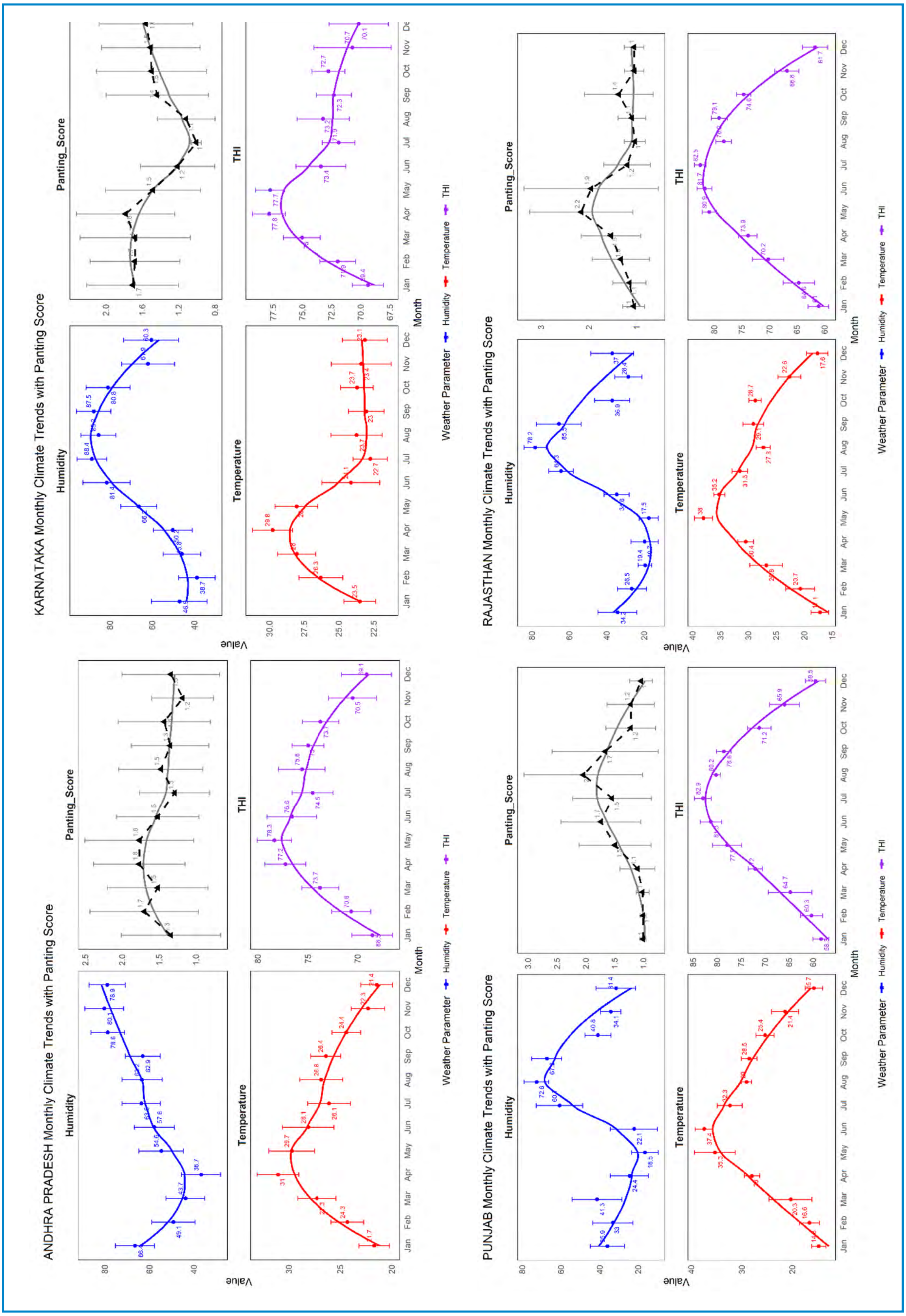
in specific regions experience disproportionately higher heat stress, possibly due to localized environmental conditions or differences in genetic adaptability.

A key objective of this study was to classify states based on Panting Score, Temperature, Humidity, and THI to identify regional heat stress patterns in crossbred cattle. Clustering analysis effectively grouped states with similar climatic conditions and heat stress responses (Figure 5). THI, Humidity, and Panting Score played a crucial role in cluster formation, with PCA visualization further confirming distinct separation based on heat stress indicators. The K-means clustering categorized states into three distinct groups. The red cluster, including Rajasthan, Punjab, and Jharkhand, exhibited the highest panting scores, indicating poor heat adaptability. In contrast, the green cluster, comprising Andhra Pradesh and Karnataka, demonstrated better adaptation to hot and humid conditions. This pattern aligns with breed composition, as Jersey crossbreds in Andhra Pradesh are known for their heat tolerance, while HF crossbreds with high exotic inheritance in Punjab, along with harsh climatic conditions in Rajasthan, make adaptation more challenging. Understanding the genetic makeup of crossbred populations in these regions provides valuable insights into heat stress resilience.

Principal Component Analysis (PCA) further elucidated the primary drivers of heat stress. The first two principal components explained 59.6% of the total variance, with PC1 accounting for 40.6% and PC2 for 19%. Temperature, Humidity, and Panting Score were closely aligned, indicating that higher temperature and humidity strongly influence panting responses. Additionally, THI and HLI demonstrated a strong association as key heat stress indicators. Wind speed, in contrast, exhibited a different directional influence, suggesting its unique role in mitigating heat stress effects. These findings confirm that temperature and THI are the predominant factors influencing heat stress in crossbred cattle, with humidity and wind speed playing secondary yet significant roles.



Annex 1. Climate trends in various other states and their comparison with panting score.


ANDHRA PRADESH Monthly Climate Trends with Panting Score
KARNATAKA Monthly Climate Trends with Panting Score
PUNJAB Monthly Climate Trends with Panting Score
RAJASTHAN Monthly Climate Trends with Panting Score
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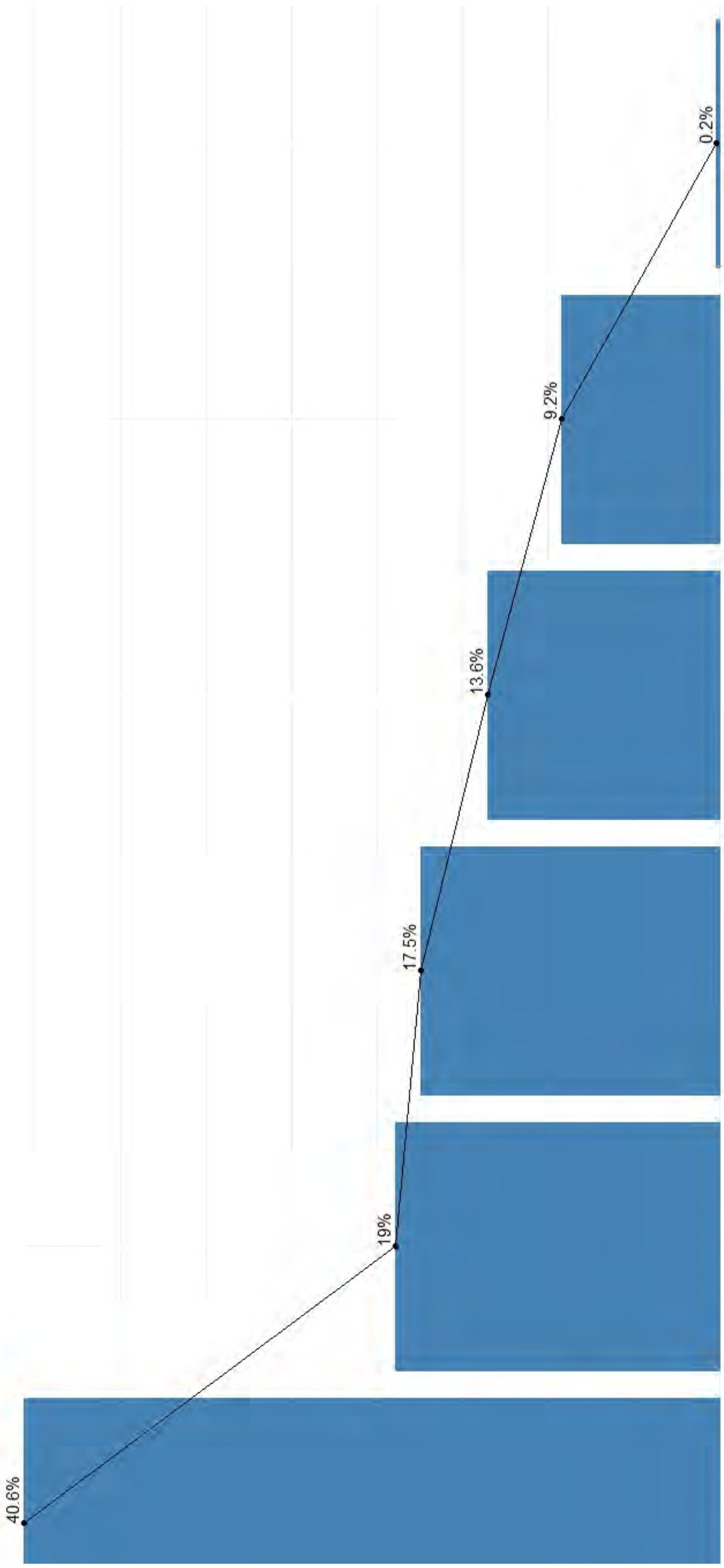

Annex 2. Principal component analysis: The proportion of variance explained by each principal component.

Conclusion

The study demonstrated that crossbred cattle experienced peak heat stress during summer (March–June), with a secondary increase observed in October, primarily influenced by Temperature and THI. Significant variation ($P<0.01$) in Panting Scores across states emphasized the role of environmental conditions in heat stress responses. Clustering analysis identified distinct regional patterns, with Rajasthan, Punjab, and Jharkhand exhibiting higher Panting Scores, while Andhra Pradesh and Karnataka showed better adaptability to heat stress. PCA confirmed that Temperature and THI were the primary determinants of heat stress, with Humidity and Wind Speed contributing as secondary factors.

In addition to Panting Scores, data on body weight, feeding patterns, and genotypes of animals are also being recorded. Future studies should focus on comparing the environmental impact across different breed compositions and analysing how factors such as body condition score (BCS), feeding, and body weight influence heat stress responses. This approach will provide deeper insights into adaptive mechanisms and aid in developing targeted strategies for improving heat tolerance in Indian livestock.

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