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Original Research Article

Evaluation and Comparison of Heat Stress Indices for Cattle and Buffaloes

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A B S T R A C T

Cattle and buffaloes experience different level of stress during summer and hot humid conditions. However, the assessment of the heat stress and the translation of the heat stress in terms of physiological and psychological strain is complex. For over a century attempts have been made to construct an index, which will describe heat stress satisfactorily. The many indices that have been suggested can be categorized into two groups: "*physiological indices*" and "*environmental*", or "*direct indices*". The first groups are sophisticated indices, which are based on physiological variables; they are difficult to calculate and are not feasible for daily use. The latter group comprises of simple indices, which are based on the measurement of basic environmental variables. In this group many indices are in use for over four decades: the "temperature humidity index" (THI) and the "*TGWB Index*". The following research on heat stress indices and their comparison and evaluation to animal production and their performance. With the present knowledge it is suggested to adopt the TGWB Index under tropical conditions is recommended because globe temperature takes into accounts Tdb and solar radiant heat exchange and can help in finding stress level.

Keywords

Heat stress, Environmental variables, Heat stress indices, TGWB Index, THI

Introduction

In India during summer cattle and buffaloes are exposed to severe environmental heat stress, which may deteriorate productivity and performance of animals may even threaten to their survival. Thus, it is expected that the physiological heat strain experienced by an animal will be related to the total heat stress to which they are exposed, serving the need to maintain body-ore temperature within a relatively narrow range of temperatures. Many attempts have been made to estimate the stress inflicted by a wide range of climate, or to estimate the corresponding physiological strain and to combine them into a single index—a heat stress index. The difficulties in creating a universal heat stress index are outlined in the present research and a simple way to indicate the level of the environmental heat stress in tropical condition.

Major Effects of Heat Stress in Dairy Cattle

Heat stress affects on dairy cattle in several ways and finally causes to decrease animal milk production and performance.

Some of most important results of heat stress in dairy cattle include:

Some behavioural signs such as seek shade refuse to lie down, incoordination, inability to move,

Increased respiration rate and laboured breathing, or panting,

An increase in heart rate,

Excessive salivation,

Increased sweating,

Crowding around water sources, and increased water intake,

Decreased blood flow to internal organs,

Some changes in digestion of food, such as reduced or absent rumination (chewing of cud) and slower feed passage rate through digestive tract,

Decreased dry matter intake and feed intake,

Decreased milk production, and milk quality,

Change in body hormones level,

Poor reproductive performance,

Lower calves birth weight,

Increase the maintenance energy requirements. (Cunningham, 2002)

Materials and Methods

In order to evaluate a stress Index for cattle and buffaloes investigations were made from February to May 2008 at the cattle yard of the NDRI, Karnal.

It is situated at elevation of 250 meters above mean sea level at 29^{0} 42**'** *N* latitude and 79^{0} 59**'** *E* longitude. There are extremes of climatic conditions in this region.

In summer, the highest temperature goes up to 45 ^{0}C and in winter it reaches a minimum of around 3.5 to 4^{0}C with temperatures as low as -0.5^{0}C.

Environmental Parameters

Microenvironment- Black globe (Tg), Dry bulb (Tdb) and wet bulb (Twb) temperature were recorded with standard black globe, dry bulb and wet bulb thermometer. The mean and Tg, Tdb and Twb values observed from Feb to April.

Results and Discussion

The present study was undertaken to observed level of stress in animals during different months in relation to environment changes that occur from winter to summer, Since no suitable indices are available for tropical condition quantification of environmental stress an Index based on Globe temperature, wet bulb temperature has been evaluated, and the results on TGWB Index (Pramod, 2008) have been presented in Table 2.

The interrelationships of TGWB Index with THI and other indices have been presented in Table 3, Table 4. and Figure 1.

Table.1 List of temperature humidity indices

S. No.	Temperature Humidity Index	Author(s)
1	$THI\ 1 = (0.15 \times T_{db} + 0.85 \times Twb) \times 1.8 + 32$	Bianca, 1962
2	$THI\ 2 = (0.35 \times T_{db} + 0.65 \times Twb) \times 1.8 + 32$	Bianca, 1962
3	$THI\ 3 = [0.4 \times (T_{db} + Twb) \times 1.8 + 32 + 15$	Thom, 1959
4	$THI\ 4 = (0.55 \times T_{db} + 0.2 \times Tpo) \times 1.8 + 32 + 17.5$	National Research Council, 1971
5	$THI\ 5 = (1.8 \times T_{db} + 32) - (0.55 - 0.0055 \times RH) \times (1.8 \times T_{db} - 26) = 0.81 \times T_{db} + 0.143 \times RH) + 0.0099 \times RH \times T_{db} + 46.3$	National Research Council, 1971
6	$THI\ 6 = (T_{db} + Twb) \times 0.72 + 40.6$	National Research Council, 1971
7	$THI\ 7 = (T_{db} + 0.36 \times Tpo) + 41.2$	Yousef, 1985a
8	$BGHI = Tg + 0.36\ Tpo + 41.5$	Buffington *et al.*, 1981
9	$WBGT = 0.7\ Twb + 0.2\ Tg + 0.1\ Tdb$	WSRC, 1995
10	$ETI = 27.88 - 0.456\ Tdb + 0.010754\ Tdb^2 - 0.4905\ Ur + 0.00088 Ur^2 + 1.1507 V - 0.126447 V^2 + 0.019876 T_{db} Ur - 0.046313\ T_{db} V$	Baeta *et al.*, 1987
11	$ESI = 0.63\ T_{db} - 0.03\ Ur + 0.002 S + 0.0054 T_{db} Ur - 0.073(0.1 + S)^{-1}$	Moran *et al.*, 2001
12	$HLI = 33.2 + 0.2 Ur + 1.2\ T_g^* - (0.82\ V)^{0.1} - \log(0.4 V^2 + 0.0001)$	Gaughan *et al.*, 2002
13	$PRR = 5.4\ T_{db} + 0.58\ Ur - 0.63\ V + 0.024\ S - 110.9$	Eigenberg *et al.*, 2002, 2003

Where:

BGHI	Black Globe Humidity Index
WBGT	Wet Bulb-Glob Temperature
ETI	Equivalent Temperature Index
ESI	Environmental Stress Index
HLI	Heat Load Index
PRR	Respiratory Rate Predictor
T_{db}	Dry bulb temperature (°C)
T_g	Wet bulb temperature (°C)
T_{po}	Dew point temperature (°C)
V	Wind velocity (km/h)
Ur	Relative humidity (%)
S	Solar irradiance (Whm^{-2})
T_g^*	Predicted Black globe temperature (°C)
T_g^*	$= 1.33\ Tdb - 2.65\ Tdb^{1/2} + 3.21 \log(S+1) + 3.5$

Table.2 Value of observed (Tg.obs) and calculated (Tg.cal) globe temperature on 29th April 2008 (Karnal 29^0 42' *N* latit. and 79^0 59' *E* long.)

Time	Tg.cal (°C)	Tg.obs (°C)	Difference (%)
8.00AM	36.39	34.50	5.40
8.30AM	39.89	38.50	3.48
9.00AM	41.70	41.00	1.68
9.30AM	45.19	45.00	0.42
10.00AM	47.02	47.00	0.03
10.30AM	47.69	48.00	0.64
11.00AM	47.78	50.00	4.64
11.30AM	49.50	52.00	5.05
12.00PM	49.56	52.00	4.92
12.30PM	48.42	48.50	0.16
1.00PM	50.06	50.50	0.88
1.30PM	51.14	50.50	1.25
2.00PM	50.51	50.50	0.02
2.30PM	50.96	50.00	1.88
3.00PM	50.81	51.50	1.36
3.30PM	50.11	50.00	0.21
4.00PM	50.41	49.50	1.80
4.30PM	50.41	48.00	4.25
5.00PM	48.11	44.50	7.49
Total	905.6	901.5	0.45

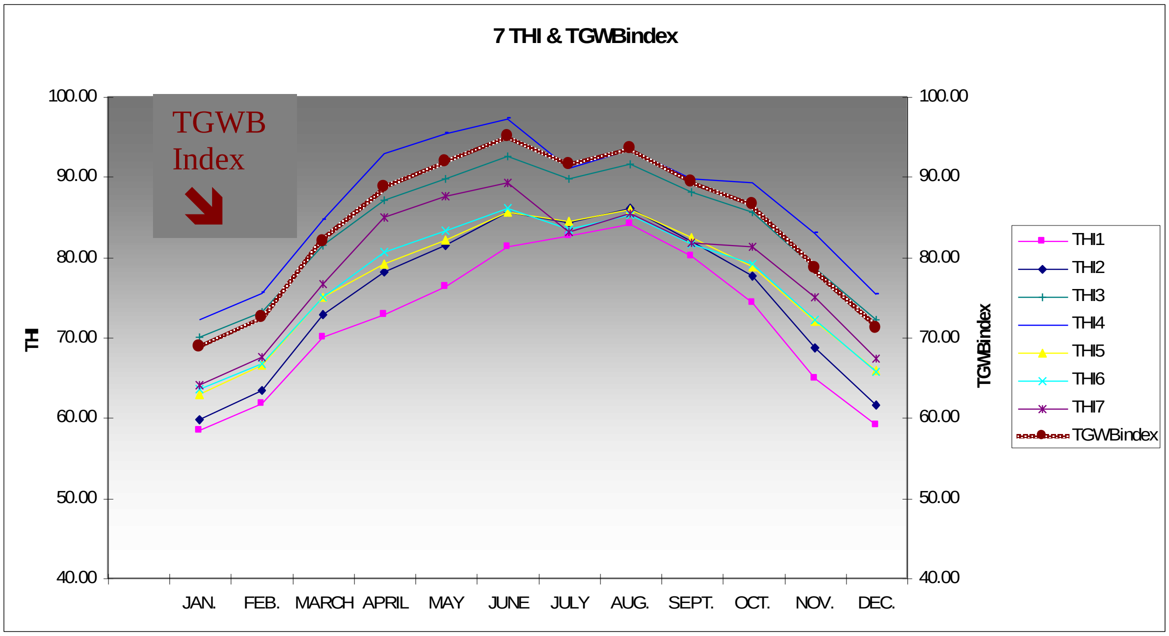
Table.3 Interrelationship between TGWB Index and different Temperature Humidity Indices for the year 2005 at Karnal, Haryana, India

S. No.	Indices	R^2
1.	THI*1* (Bianca, 1962)	0.688
2.	THI*2* (Bianca, 1962)	0.920
3.	THI*3* (Thom, 1959)	0.999
4.	THI*4* (NRC,1971)	0.898
5.	THI*5* (NRC,1971)	0.949
6.	THI*6* (NRC,1971)	0.999
7.	THI*7* (Yousef, 1985)	0.896

Table.4 R^2 of all 5 other indices for 2005 of KARNAL with TGWB Index

S. No.	Indices	R^2
1.	Environmental Stress Index (ESI)	0.9765
2.	Equivalent Temperature Index (ETI)	0.8045
3.	Heat Load Index (HLI)	0.9787
4.	Black Globe Humidity Index (BGHI)	0.9716
5.	Wet Bulb – Globe Temperature (WBGT)	0.9812

Fig.1 Interrelationships of TGWB Index with Temperature humidity indices during different months at Karnal, Haryana



Interrelationships of TGWB Index with different Temperature humidity indices

Different Temperature humidity indices with variable weightings to humidity and temperature have been suggested. We calculated Temperature humidity indices for different months of year 2005 for Karnal, Haryana (Lat. 29°43' N, Long 76° 58' E) and compared with TGWB Index and have been presented Figure 1.

The minimum values calculated for the Index are near 60 when Tg was 16 and Twb was 12, in the absence of solar radiation, Tg and Tdb was equal. At this label of solar radiation, the values obtained by TGWB Index are equal to THI. Therefore, this index will have a better representation of thermal stress on animals as it incorporates solar radiation exchange with black globe both in visible and infrared region of energy.

TGWB index was related with Temperature humidity indices and results have been presented in Table 3. and Fig. 2. THI1 with a weighing of 0.15 to Tdb and 0.85 to Wet bulb [THI1 = (0.15 X T_{db} + 0.85 x Twb) x 1.8 + 32] (Bianca, 1962), the relationship (R^2) was 0.68, and THI with different Tdb and Twb weighing improved relationship to a level of 0.92. The THI indices with an equal weightage to Tdb and Twb were observed to have a maximum interrelationship with TGWB index. This primarily because of the fact that in TGWB Index equal weightage has been awarded to Tg and Twb. Other indices have also been correlated and interrelationship presented in Table 4.

Lactating dairy cattle and buffaloes create a large quantity of metabolic heat and accumulate additional heat from radiant energy. Cattle and buffaloes experience different level of stress during summer and hot humid conditions. Heat stress is caused by a combination of climatic factors like air temperature, humidity, solar radiation, wind velocity etc. Different indices based on climatic elements have found limited utility in livestock production system in tropical countries. TGWB index for cattle and buffaloes will help to generate more proactive responses to avoid excessive thermal stress effects on livestock productivity.

Index based on Tg and Twb has been suggested for use in place of THI for adoption because globe temperature takes into account Tdb and solar radiant heat exchange The use of these indices at farm level is recommended, as they are capable of indicating heat stress. The use of these indices under field conditions will require a black globe, dry bulb, wet bulb themameter. However, further investigation is required for tropical countries animals.

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