



Determination of critical heat stress zone for fertility traits using temperature humidity index in Murrah buffaloes

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Received: 29 January 2014; Accepted: 18 July 2014

ABSTRACT

The objective of the present study was to determine critical heat stress zone (CHSZ) in a year for fertility traits of Murrah buffaloes like service period (SP), pregnancy rate (PR) and conception rate (CR). Fertility data on 1,379 lactations and climatic parameters, viz. dry bulb temperature (T_{db}) and relative humidity (RH) spanned over 20 years (1993–2012) were collected from NDRI and CSSRI, Karnal. The regression analysis indicated that the maximum increase in SP and maximum decline in PR and CR with per unit increase in THI value. Two zones in a year were classified as non-heat stress zone (NHSZ) with $THI < 75$ for months October to March and heat stress zone (HSZ) with $THI \geq 75$ during April to September. SP increased by 8 and 19 days under NHSZ (56.71 - 73.21) and HSZ (75.39 - 81.60), while there was maximum increase in 28 days service period in May and June with per unit rise in monthly average THI value. A negative association between THI and PR, CR were also observed under NHSZ and HSZ. However, maximum decline in PR (7%) was found for May and June while June, July and August showed the highest depression in CR at 9 % with per unit increase in THI. Therefore, May and June were determined as CHSZ for SP and PR, whereas June, July and August as CHSZ for CR in Murrah buffaloes with THI 80.27 - 81.60.

Key words: Buffalo, Critical heat stress zone, Fertility traits, Temperature humidity index

Buffaloes contribute the highest share (56.64 %) to the milk production of India (BAHS 2012) and play an important role to the livestock production in terms of milk, meat and draught power. Buffaloes are considered as seasonal breeder as they have a distinct seasonal reproductive cycle and exhibit silent oestrus during summer (Qureshi *et al.* 2000). Heat stress is a major contributing factor for low fertility in Murrah buffaloes and its effect is aggravated when heat stress is accompanied with high relative humidity (Marai *et al.* 2007). It is possible to measure the level of heat stress in animals by formulating a temperature humidity index which takes into account both of air temperature and relative humidity. Buffaloes showed less physiological adaptation to extremes of heat. The skin of buffalo is a good absorbent for trapping ultraviolet rays (Shafie 1985) and it also shows poor heat dissipation ability due to less density of sweat glands present on the skin. Reddy *et al.* (1999) observed lowest conception rate (29.45 %) of Murrah buffaloes in April and highest conception rate in September (44.84 %). Till today, no study has been

conducted to define the favourable and critical period in a year in relation to the fertility traits such as service period, pregnancy rate and conception rate of Murrah buffaloes by using temperature humidity index. Therefore, the present study has been envisaged to determine critical heat stress zone in a year affecting fertility traits of Murrah buffaloes.

MATERIALS AND METHODS

Source of data: In the present study, the fertility records of Murrah buffaloes (581) spread over first, second, third and fourth lactation during a period of 20 years from 1993 to 2012 were collected from the Institute. The abnormal records of buffaloes showing abortion, dystocia, retained placenta and other reproductive disorders were not included in the study. Traits, viz. service period (SP), pregnancy rate (PR) and conception rate (CR) were generated in Murrah buffaloes. Pregnancy rate was estimated with the formula $PR = 21 / (DO - VWP + 11)$ as suggested by Van Raden *et al.* (2004). Voluntary waiting period (VWP) is the initial phase of lactation during which buffaloes were not inseminated. VWP of Murrah buffaloes had been standardized as 63 days at NDRI herd (Patil *et al.* 2014) for optimum daughter pregnancy performance. The conception rate was computed with the formula $CR = 1/N \times 100$ where, N, total number of inseminations required for pregnancy. A summary of the data set is presented in Table 1.

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Table 1. Edited and normalized data structure of fertility traits of Murrah buffalo

Parity	Initial observations	Observations under SP	observations under PR	observations under CR
first	581	477	417	464
second	409	355	273	350
third	244	222	157	216
4 th	145	138	108	135
Overall	1379	1192	955	1165

SP, Service period; PR, pregnancy rate; CR, conception rate.

Meteorological data pertaining to monthly average dry bulb temperature (T_{db}) and relative humidity (RH) for the period of study (1993 - 2012) were obtained from Central Soil and Salinity Research Institute (CSSRI), Karnal. Temperature humidity index (THI) values were estimated on month wise from January to December for each of 20 years (1993 - 2012) by using the formula developed by Yousef (1985).

$$THI = T_{db} + (0.36 \times T_{dp}) + 41.2$$

The monthly average dew-point temperature (T_{dp}) was estimated as per Jensen *et al.* (1990). $T_{dp} = 116.9 + 237.3 \times \ln(e) / 16.78 - \ln(e)$ where, e (Kpa), ambient vapour pressure and it was estimated as follows:

$$e \text{ (kpa)} = \frac{17.27 \times T_{db}}{T_{db} + 237.3} \times \frac{rh \times 0.611 \times e}{100}$$

Statistical analysis: The data were adjusted for significant non-genetic factors for parity (1–4), buffaloes calved in different periods (1–13) and age group at first calving (1–3) using a mixed least-squares model (Harvey 1990). The model considered was

$$Y_{ijkl} = \mu + S_i + pa_j + p_k + (AG)_l + e_{ijklm}$$

where, Y_{ijklm} is the observation on m^{th} Murrah buffalo belonging to l^{th} age group at first calving calved in k^{th} period of calving in j^{th} parity belonging to i^{th} sire and e_{ijkl} is random error $\sim NID(0, \sigma_e^2)$. The traits were adjusted with significant non-genetic factors. Monthly average THI values were classified into 2 zones in a year like non-heat stress zone (NHSZ) and heat stress zone (HSZ). The critical heat stress zone (CHSZ) within the heat stress zone of the year was identified by assessing the change in fertility traits in relation to unit change of monthly average THI values. The regression model used was

$$Y_{ij} = a + b x_i + e_{ij}$$

where, a is intercept, b is regression coefficient and e_{ij} is random residual $\sim NID(0, \sigma_e^2)$. The zone within the heat stress zone where maximum increase in service period and decline in pregnancy rate and conception rate were observed with per unit rise in monthly average THI, was determined as the critical heat stress zone affecting fertility traits of Murrah buffaloes.

RESULTS AND DISCUSSION

The lowest monthly average THI (56.71) was found in January and the highest mean THI (81.60) was in June over 20 years period (Fig. 1). Upadhyay *et al.* (2012) earlier reported THI as 75 in February and it was increased to 85 in May and 95 in July and August in Karnal (NRC 1971).

The overall least-squares means for service period, pregnancy rate and conception rate of Murrah buffaloes were estimated as 141.65 days, 0.38 and 70.62 %, respectively. Parity had significant effect ($P < 0.01$) on service period and also period of calving had significant effect ($P < 0.05$) on service period of Murrah buffaloes. The present study showed that buffalo in the first parity had a long service period as compared to second, third and fourth parities. This may be due to increased interval from calving to first oestrus. Buffaloes are more neglected by poor detection of oestrus in their first parity. The peculiar breeding behaviour is due to the frequent silent estrous of buffaloes. The appearance of symptoms of estrus in buffaloes is maximum during winter with shorter day length period and the reproductive performance of buffaloes is lower due to high air temperature and humidity in summer. Most of the buffaloes commence calving just after the rainy season i.e. their calving pattern starts in July and continued till October. The breeding season begins about 2–3 months after commencement of calving and this period of low environmental temperature and humidity may be favourable for optimum fertility of buffaloes. Patil *et al.* (2011) reported that the least-squares mean for first parity service period 161.65 ± 4.60 days in Murrah buffaloes. Nawale (2010) obtained least-squares mean for conception rate of Murrah buffaloes as 69.28 ± 03.54 %. Jamuna (2012) estimated the average pregnancy rate irrespective of parity as 0.36 ± 0.01 in Murrah buffaloes.

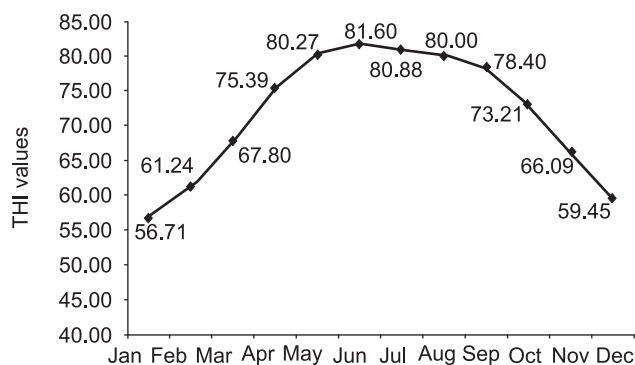


Fig. 1. Month wise average temperature humidity index (THI) values from 1993 to 2012.

Non-heat stress zone and heat stress zone for fertility traits: On analyzing the trends of month-wise average THI values during 20 years, the whole year was divided into 2 zones, viz. non-heat stress zone (NHSZ) and heat stress zone (HSZ). Monthly average THI < 75 were found for October to March while THI ≥ 75 was observed during

April to September. The months from October to March were included under NHSZ and the months from April to September were included under HSZ. The average THI in NHSZ was estimated as 64.08 with a range from 56.71 - 73.21 while, average THI 79.42 was obtained in HSZ with a range 75.39 - 81.60 (Fig. 1). The livestock weather safety index (LCI 1970) quantified heat stress zone into 4 categories like normal (≤ 74), alert ($74 < \text{THI} < 79$), danger stress ($79 \leq \text{THI} < 84$) and emergency stress ($\text{THI} \geq 84$) in Livestock. Moran (2005) described 5 categories by analyzing the effect of heat stress on cattle in terms of temperature humidity index as no stress (< 72), mild stress (72 - 78), severe stress (78 - 89), very severe stress (89 - 98) and dead cows (> 98).

Critical heat stress zone for fertility traits: The average service period of Murrah buffaloes found increased by 8 days in non-heat stress zone and 19 days in heat stress zone with per unit increase in THI value. However, there was maximum increase in 28 days service period for May and June with per unit increase in THI (Table 2). The pregnancy rate of Murrah buffaloes decreased by -1 % and -4 % with per unit increase in THI under non-heat stress zone and heat stress zone, respectively. However, maximum decline in -7 % pregnancy rate was found for May and June (Table 2). Similarly, the maximum depression in conception rate (-9 %) of Murrah buffaloes was in June, July and August as compared to heat stress zone with per unit increase in THI (Table 3). Therefore, May and June were identified as

Table 2. Association of temperature humidity index with service period and pregnancy rate of Murrah buffaloes in 3 zones

Zones	Service period			Pregnancy rate		
	a	b	R ² (%)	a	b	R ² (%)
NHSZ (October - March)	-389.72	8.05	7.69	1.20	-0.01	0.75
HSZ (April - September)	-1353.46	19.12	6.36	3.47	-0.04	2.68
CHSZ (May, June)	-2073.03	27.90	15.84	5.74	-0.07	7.55

a, Intercept; b, regression coefficient; R², coefficient of determination; NHSZ, non-heat stress zone; HSZ, heat stress zone; CHSZ, critical heat stress zone.

Table 3. Association of temperature humidity index with conception rate of Murrah buffaloes in three zones

Zones	Conception rate		
	a	b	R ² (%)
NHSZ (October - March)	-39.20	1.74	1.89
HSZ (April - September)	475.37	-5.13	5.50
CHSZ (June, July, August)	821.14	-9.37	16.94

a, Intercept; b, regression coefficient; R², coefficient of determination; NHSZ, non-heat stress zone; HSZ, heat stress zone; CHSZ, critical heat stress zone.

critical heat stress zone (CHSZ) for service period and pregnancy rate, whereas June, July and August were determined as CHSZ for conception rate in Murrah buffaloes with THI 80.27 - 81.60. This clearly signified the adverse impact of environment during hot months on reproductive performances of Murrah herd. The lower fertility in heat stress zone may be due to lower availability of energy in terms of high quality green fodder to maintain a good reserve of body energy. Absence of rain, high temperature and humidity in context with temperature humidity index aggravate the condition and the animals are under maximum heat stress after a long exposure to the day time temperature. The reproductive activity in cattle and buffaloes were favourable during non-heat stress zone when there is more green fodder availability and when the environment is cool with low temperature humidity index values. The reduction of fertility in cows with unit change in THI was reported by various workers. Ravagnolo and Mistral (2002) analyzed the effect of THI on non return rate (NR) of Holstein cows and they found that NR45 showed a decrease of 0.005 with per unit increase in THI on the day of insemination at THI more than 68. Amundson *et al.* (2006) observed the negative associations of THI with pregnancy rate of *Bos taurus* crossbred cows and there was -2.06% change in pregnancy rate for each unit of change in THI during the first 21 day of the breeding season.

The results revealed that the reproductive performance of Murrah buffaloes was adversely affected in the critical heat stress zone of a year. May and June were critical for service period and conception rate, while June, July and August were critical for conception rate in Murrah buffaloes. Such adverse effects on the fertility traits are due to high average daily persistence of THI above 75.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, National Dairy Research Institute (NDRI) for providing necessary infrastructure and facilities for the successful completion of research work. Special thanks to Indian Council of Agricultural Research (ICAR), Ministry of Agriculture, Government of India for providing Junior Research Fellowship to the first author for conducting the study.

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