Indian J Dairy Sci 76(1): 78-83
https://doi.org/10.33785/IJDS.2023.v76i01.011

RESEARCH ARTICLE

Effect of sprinkler with fan on growth, physiology and behaviour of Murrah buffalo calves

Roshan Kumar Bhuradia[1], Navav Singh[1] (✉), Sanjita Sharma[1], Sanjay Choudhary[2], Nischay Singh[1], Gireesh Joshi[1] and Anita Kavia[1]

Received: 27 June 2022 / Accepted: 17 October 2022 / Published online: 20 February 2023

Abstract: The aim of the present study was to investigate the effect of sprinkler with ceiling fans on the growth performance, physiological responses and behaviour of Murrah buffalo calves. For this study, a total of twelve Murrah buffalo female calves were selected based on the age and body weight and allocated to two treatments (n=6 each). In the first treatment (T1), the calves were provided with sprinkler with fan. While, in second treatment called control (T0), the calves were not provided with any cooling system. The average daily gain was greater in T1 than T0 calves on week (w) 3 (P=0.01), w 4 (P=0.03), w 5 (P=0.04), w 6 (P=0.02), w 7 (P=0.01) and w 8 (P=0.05). While it was similar between the calves of two groups on the w 1 (P= 0.32), w 2 (P=0.31), w 9 (P=0.16), w 10 (P=0.19), w 11 (P=0.12), w 12 (P=0.1).The overall eye temperature was significantly (P<0.05) higher in control group (37.42±0.04 ºC) than treatment group (36.42±0.13 ºC) calves. The overall muzzle (P=0.01) and skin temperature (P=0.001) was also significantly higher in control calves as compared to treatment calves. The average respiration rate was lower (P<0.05) in T1 (22.83±0.18 breaths/min) than in T0 (30.83±0.12 breaths/min) calves. Similarly, overall pulse rate was also lower (P<0.05) in T1 (38.36±0.11 No./min) as compared to T0 (60.19±0.13 No./min) calves. The average time spent on eating, ruminating and resting was significantly greater in T1 than in T0 calves. In conclusion, the provision of sprinkler with fan reduces physiological response along with body temperatures. Consequently, it improved the growth performance and helped in normal behavioural expression of the buffalo calves.

[1]Department of Livestock Production Management, Post- Graduate Institute of Veterinary Education & Research (PGIVER), Jaipur-302031, Rajasthan, India
[2]Department of Livestock Production Management, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Navav Singh (✉)
Department of Livestock Production Management, Post- Graduate Institute of Veterinary Education & Research (PGIVER), Jaipur-302031, Rajasthan, India
E-mail:drnavavsinghdhaker@gmail.com

Keywords: Buffaloes, Cooling systems, Growth, Heat stress

Introduction

The domestic riverine buffaloes (*Bubalus bubalis*) are the main dairy animals in India. Where, the performance of these animals is a great challenge due to high ambient temperature especially in summer months (Bah et al. 2021). Further,buffaloes are relatively more sensitive to solar radiation due to dark coat colour, comparatively lesser density of sweat gland and dense epidermis (Marai and Habeeb 2010).The exposure of buffaloes to the hot conditions strongly affects their bioenergetics, with adverse effects on the dry matter intake (9–13%), growth rate, metabolism of water, protein, energy and mineral balances (Kumar et al. 2018). These series of changes cause impairment of reproduction and productive performances (21% reduction in milk production) in buffaloes (Das et al. 2014). Further, young calves of buffaloes are reported to be more vulnerable leading to lower feed intake, decreased feed utilization efficiency which results in poor growth rate and lower life time productivity (Adin et al. 2009). Therefore, in order to combat thermal stress, for survivability and to abate heat load, these animals wallow in water ponds (Napolitano et al. 2013). Since, traditions at small buffalo farms in India and Pakistan, farmers splash the water on the buffalo body during late morning, afternoon and in early evening hours in order to reduce the effect of thermal stress (Bah et al. 2022). Moreover, buffaloes wallow in the community ponds at village level after grazing but over time, reduction in wallowing ponds in villages have led to limited or no access to water for wallowing (Bah et al. 2021). Further, traditional buffalo production system is shifting to intensive buffalo production system where water splashing to individual animal is not possible. Moreover, there has been an emphasis on reducing water use on cooling dairy animals with nominal effect on productivity and welfare (Tresoldi et al. 2018; Bah et al. 2021). So, in order to ameliorate thermal stress in buffaloes and to reduce water consumption for cooling various managemental methods *viz.,* sprinkling (Khongdee et al. 2011), showering, fanning, forced ventilation, foggers and misters have been tried with varied success. Similarly, Anderson et al. (2013) and Tresoldi et al. (2018) had reported that the most common method of cooling in dairy cows during summer is sprinklers/soakers or misters. Earlier various studies on the buffaloes also shown that the provision

of sprinklers dropped respiration rate and body temperature, and improved dry matter intake and milk yield as compared to non-cooled buffaloes during summer (Aggarwal et al. 2008; Yadav et al. 2016; Ahmad et al. 2019). Furthermore, evaporative cooling through foggers, sprinklers and fans has turn out to be a common practice to improve milk production (Avendano-Reyes et al. 2006), feed utilization and to decrease rectal temperature, pulse rate and respiration rate (Rahangdale et al. 2012) in dairy animals as a tool to combat heat stress during hot environment. However, to our best knowledge there is no available information on the effect of cooling system on growth performance and physiological variable of the buffalo calves.

Further, Rajasthan state in India have different environmental condition with highest temperature may reaches to 49 ºC during summer months, however, humidity ranges 45% to 47%. The state is having very low rainfall (32.7 to 64.9 cm). In Jaipur, temperature may reaches to 35 ºC during September and October months. While, the thermoneutral zone and comfort zone for the buffaloes is 15º to 25ºC, leading to higher thermal stress, poor milk production and reproductive efficiency. Considering all this information, we hypothesized that use of sprinkler with fan may reduce the physiological responses and improve the growth rate of buffalo calves. Therefore, the aim of the present study was to investigate the effect of sprinkler with fan on the growth performance, physiological responses and behaviour of Murrah buffalo calves in hot summer in Rajasthan region of India.

Materials and Methods

The Institutional Animal Ethics Committee (IAEC, Registration No. PGIVER/IAEC/2022-16) approved this study, which was conducted following IAEC established standards as per Article Number 13 of the committee for the Control and Supervision of Experiments on Animals (CPCSEA) policies of the Government of India. The present study was conducted at the farm of Post Graduate Institute of Veterinary Education & Research (PGIVER), Jaipur, Rajasthan, India (longitude=75°522 15.062 2 E, latitude= 26°532 34.662 2 N and altitude= 431 m above the mean sea level). The summer in Jaipur, Rajasthan, India is very hot while winters are extremely cold. The maximum temperatures hover at 40 °C to 47 °C in May and June Months. Heat wave prevails for a few days in the season, when day temperature rises to 4-6 ° C above normal. The winter minimum temperatures remain about 4-9 °C and fall below zero degrees. The experiment began in 01 August 2021 and ended in 31 October 2021. During this period, temperature may reaches to 35 °C in Jaipur.

Experimental design

For this study, a total of twelve Murrah buffalo female calves were selected based on the age (4 to 12 month) and body weight (106.33±14.72) and allocated to two treatments (n=6 each). In the first treatment (T1), the calves were provided with sprinkler with fan. The six sprinklers and two ceiling fans (8 feet height at 7 feet distance) were fitted at the height of 2.10 m from the ground level. The sprinkler with fan cooling system was operated at 11 am to 4 pm with gap of 5 minutes. While, in second treatment called control (T0), the calves were not provided with any cooling system.

Housing and feeding of calves

The experimental calves of both treatments groups were allocated to a loose housing system with a covered shed and an adjoining open paddock with a total floor space of 3 m^2 per calf and a shared feeder through a fence line feed barrier, and a shared drinker. The allocation of floor space and feeding space was consistent with the standards of the Bureau of Indian Standards for buffaloes in loose housing systems (BIS: 1223-1987). The floors of the calves' enclosures were made of concrete, with grooves under the covered and open area. The roof was flat type with average height of 2.65m from the ground.

Calves were offered concentrate at 1 % of their body weight, and *ad libitum* chopped green and dry fodders. Clean and fresh water with salt lick was offered *ad libitum*. Calf concentrate was composed of maize 35%, wheat bran 20%, gram 10%, Groundnut cake 32%, mineral mixture 2%, and common salt 1%.

Body weight and average daily gain

The body weight of the experimental calves was recorded on weekly (w) basis until the end of the experiment. Weights of all calves were recorded in the morning between 6:00 a.m. and 6:30 a.m., before feeding and watering, using an electronic weighing machine with a precision of 500g. The average daily gain (ADG) was calculated in grams as (Final body weight-Initial body weight)/ weekly intervals and expressed in gm/day.

Physiological parameters

Physiological parameters viz., rectal temperature (RT), muzzle temperature (MT), eye temperature (ET), skin temperature (ST), pulse rate (PR) and respiration rate (RR) were recorded on daily basis at 3:00 PM and the average of these recorded values are presented in weeks. The eye, muzzle and skin temperature were taken by using digital thermometer at the distance of one meter from the calves. The RT (°C) was measured from rectum with the help of digital thermometers. The PR (beats per min) was taken from the coccygeal artery. The RR (times per min) was recorded from the distance without disturbing the animals observing the flank movement. The RR was recorded first followed by PR and RT for getting actual observation.

Recording of behaviour of calves

Behaviors parameters of calves were observed by using CCTV (CP Plus) video cameras installed to record the activity of animals

for 24 hours per day. The CCTV cameras were installed in such a way as to have a complete view of animals inside the covered area as well as in open area. The camera had 8x digital zoom for closer viewing. The cameras were enabled with array infrared technology for best night vision. Cameras were installed at different places and different angles in the experimental shed so that whole shed can be covered in viewing angle. The images and video were stored in 16 channel digital video recorder (DVR) having hard disk of 4 TB space. All the parameters were recorded in hours: minutes format initially which were later changed to hours according to needs of parameters.

Statistical analysis

The Body weight, ADG and various physiological parameters, time spent on eating, rumination, resting and standing were compared using a mixed model (IBM SPSS Statistic 22.0 computer software). Treatment, time, and their interaction were included as fixed effects, and the individual calves were included as random effects. Differences were considered statistically significant when *P dH* 0.05. Results are presented as LS means ± SEM.

Results and Discussion

Growth performance

Body weight and average daily gain

There were non-significant effects of group and their interaction (P=0.822), while there was significant effect of time on the calves' body weight (P=0.001). The average body weight of the calves did not differ between the two groups on all the sampling weeks (P=0.979, 0.955, 0.933, 0.903, 0.884, 0.854, 0.882, 0.798, 0.782, 0.766, 0.749, 0.735, 0.719, respectively) (Fig 1 A). There was an effect of time (p <0.01), group (p <0.01), and an interaction between group and time (p <0.01) on the calves ADG. The average daily gain was greater in T1 than T0 calves on w 3 (P=0.01), w 4 (P=0.03), w 5 (P=0.04), w 6 (P=0.02), w 7 (P=0.01) and w 8 (P=0.05). While it was similar between the calves of two groups on the w 1 (P= 0.32), w 2 (P=0.31), w 9 (P=0.16), w 10 (P=0.19), w 11 (P=0.12), w 12 (P=0.1) (Fig 1 B). The results of this study support the initial hypothesis that provision of sprinkler along with ceiling fans was effective in reducing the thermal stress and in improving the growth performance of the buffalo calves. The core body temperature of animals rises primarily because of reduced heat loss due to the dropping of thermal gradient between the skin surface and environment. So, an ideal thermal gradient between the animal body and the surrounding environment is essential for the effective dissipation of heat energy. Once ambient temperature rises well beyond the upper critical limit, thermoregulation is incapable to avoid an elevation of core body temperature. However, in this study, animals remained under sprinkler with ceiling fans, therefore, probably had a lower body temperature. The results of the present study on ADG are reinforced by previous studies which revealed the positive impact of sprinkler with fan (Vijayakumar et al. 2009), four times washing (Das et al. 2011), fan-cum-mist cooling (Singh et al. 2014) and modified roofing (Khongdee, 2016), on weight gain in buffaloes. A higher ADG in T1 group of calves may be due to improved feed intake as a result of better cooling through provision of sprinkler along with ceiling fans. In Addition, efficient utilization of feed under calm micro-environments might have triggered in more weight gain in cooled calves. The lower average daily weight gain in control calves indicated higher tissue catabolism and reduced anabolic activity due to extra energy requirements to dissipate excess body heat (West, 2003) in order to sustain homeothermy in heat-stressed animals.

Body temperature

The overall rectal temperature was slightly higher in control group of (101.94±0.13 ºF) calves as compared to treatment calves (101.19±0.11 ºF), although the difference was not statistically significant (P=0.19).The overall eye temperature was significantly (P<0.05) higher in control group (37.42±0.04 ºC) than treatment group (36.42±0.13 ºC) calves. Similarly, the overall muzzle (P=0.01) and skin temperature (P=0.001) (Table 1) was also significantly higher in control as compared to treatment calves.

Rectal temperature was lower in the calves of the treatment group than in the control group. Owning to dark skin color, sparse hair coat and very few sweat glands, buffaloes absorb a profound quantity of solar radiation and are considered more susceptible to heat stress (Kishore et al. 2016; Kapila et al. 2016; Lakhani et

Table 1 Mean± SEM of overall average body temperature and physiological parameters of two different groups of calvesData are presented as LS means ± SEM. a, b indicates differences between the mean values of different groups.

Parameter	Control (To)	Treatment (T1)
Body temperature		
Overall RT (ºF)	101.94±0.13	101.19±0.11
Overall ST (ºC)	36.75±0.06^{b}	33.64±0.10^{a}
Overall MT (ºC)	36.59±0.02^{b}	36.22±0.01^{a}
Overall ET (ºC)	37.42±0.04^{b}	36.42±0.13^{a}
Physiological parameters		
Respiration rate (breaths/min)	30.83±0.12^{b}	22.83±0.18^{a}
Pulse rate (beats/min)	60.19±0.13^{b}	38.36±0.11^{a}

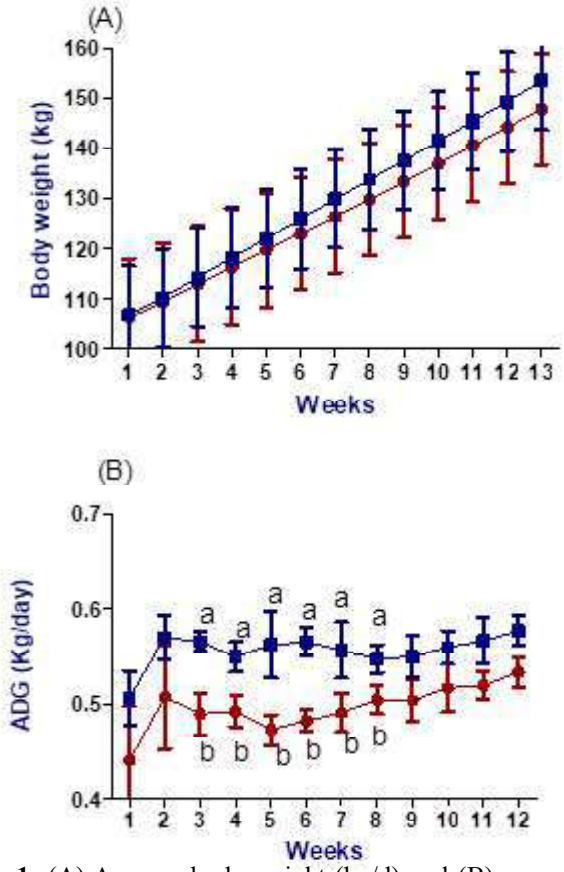

Fig 1: (A) Average body weight (kg/d) and (B) average daily gain (kg/day)of Murrah buffalo calves had provision of sprinkler with fan (▲ ; T1), no sprinkler with fan group (Ï% ; T0). Data are presented as LS means ± SEM. Different letters indicate differences between the mean values of the groups at that time point ($p<0.05$).

al. 2018; Prasad et al. 2020). The provision of sprinkler with fan results in evaporative cooling in the treatment calves of the present study, which results in lower environmental temperature and consequently body temperature of the calves (Avendaño-Reyes et al. 2006; Ambulkar et al. 2011). Further, higher eye temperature in control groups may be because of dilation of ocular blood vessels and increased visual alertness in response to stress (Stewart et al. 2007). It is probably because the eyes have rich capillary beds that are innervated with sympathetic and responsible for changes in the eye blood flow and further rhythmic changes in eye temperature (Uddin et al. 2019; Prasad et al. 2020).

Basically, skin temperature rises with increase in solar radiation (Das et. al. 1999). In our study, lower skin temperature in T1 groups is due the fact of lower environmental temperature due to provision of time bound sprinklers with ceiling fans, which have cooled the animals through conduction process (Ahmad et al.2017). The present study results are in general agreement with the previous finding of Singh et al. (2005) on Nili-Ravi buffalo; Das et al. (2011) on Nili-Ravi calves and Singh et al. (2014) on Murrah buffalo, who had reported significant decrease in skin temperature when buffaloes were subjected to water splashing during hot summer.

Physiological parameter

The average respiration rate was lower (P<0.05) in T1 (22.83±0.18 breaths/min) than in T0 (30.83±0.12 breaths/min) calves (Table 1). Similarly, overall pulse rate was also lower (P<0.05) in T1 (38.36±0.11 beats/min) as compared to T0 (60.19±0.13 beats/min) calves (Table 2). All through hot and humid climatic conditions, the environmental temperature is generally higher than the body temperature of calves, and they cannot release additional body heat to the environment. Therefore, in order to release extra body heat, animals evaporate heat from the body through increased respiration rate. Therefore, the provision of sprinkler with fan in the treatment group of present study have prevented in rising of environmental temperature in surrounding of the calves. On the similar line, Seerapu et al. (2015) had reported lower respiration rate among the animals provided with foggers and foggers plus fans during the summer season than the animals of the control group. Moreover, Singh et al. (2014) in Murrah buffalo calves reported significant decreased in respiration rate when these animals were subjected to water splashing during hot summer season.

Further, provisions of sprinkler with ceiling fan have resulted in higher pulse rate in the control group. This is possibly because of higher environmental temperature, heat stress, stimulate hypothalamic-pituitary-adrenal axis to secrete adrenaline and cortisol. This higher adrenaline hormone constricts blood vessels resulting in higher blood flow within the blood vessels. Similarly, present study results are in support with the findings of Ganaie et al. (2013) and Das et al. (2014) who had reported lower pulse rate in the treatment group having provision of fogger with fans.

Behaviour of calves

Time spent on eating, rumination, resting

The data pertaining to average time spent on eating, rumination and resting by calves are graphically depicted in fig 2 A, B, C. The average time spent on eating (373.09±5.64min/d *vs* 338.48±4.22min/d), rumination (520.73±6.98 min/d *vs* 504.36±6.18min/d) and resting (778.62±5.58 min/d *vs* 683.83±6.19min/d) was significantly greater (P<0.05) in T1 than T0 calves, respectively. The time spent on eating and rumination was higher in calves which were having provision of sprinkler with fans (treatment group). It has been reported earlier that the season can be a critical factor in altering the feeding behaviour of calves (Grant and Albright 2001). Further, any temperature higher than their thermo-neutral zone reduces the voluntary feed intake of animals (Hooda et al. 2010). Likewise, Magrin et al. (2017) stated that young bulls exposed toeH74 temperature-

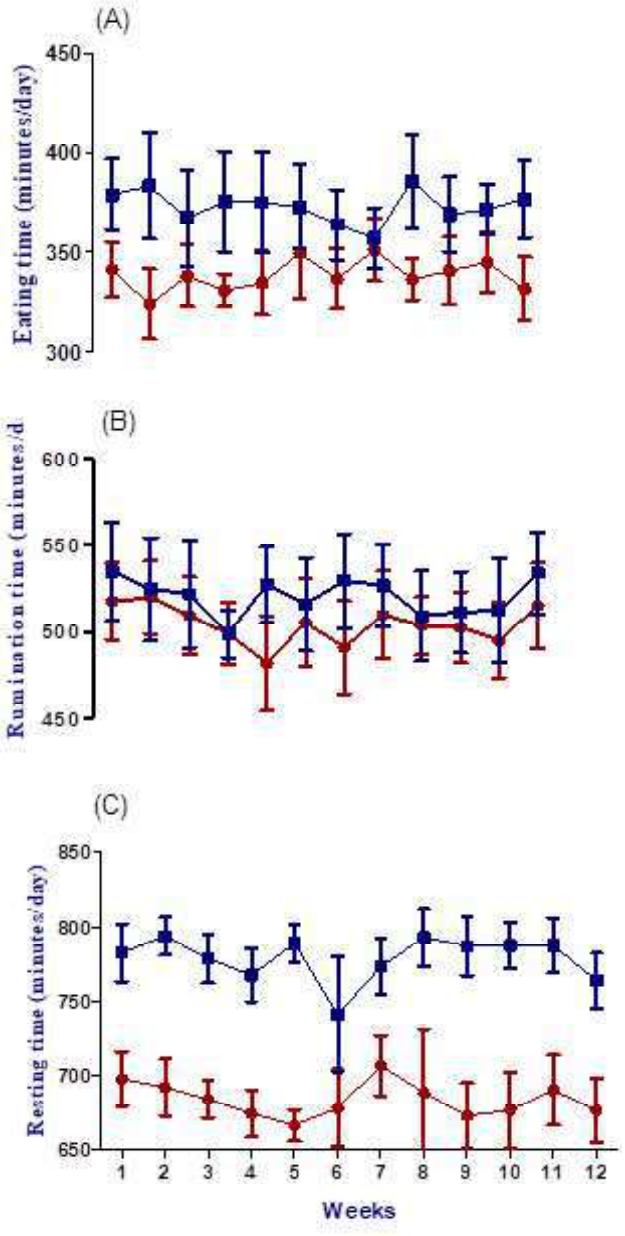

Fig 2: (A) Average time spent on eating (min/d) (B) average time spent on rumination (min/d) and (C) Average time spent on resting behaviour of Murrah buffalo calves had provision of sprinkler with fan (▲ ; T1), no sprinkler with fan group (Ï% ; T0).

humidity index (THI) decreases their time spent on eating and ruminating compared to their counter parts under optimum THI conditions, however the provision of ceiling fans augmented time spent on rumination and exploring activities in young calves. The calves in our study under control group spent less time for eating and ruminating, possibly in an effort to decline metabolic heat and to maintain their core body temperature (Nardone et al. 2010). The time spent on resting was significantly ($P<0.05$) lower in the calves of the control group compared to the treatment group. The lower time spent on resting among calves housed in the control shed might be due to concrete flooring and also the animals might have spent most of their time standing for heat dissipation as the body surface area exposed to air is more when they keep standing. The evaporation from the body surface increases by standing in calves or there may be a chance of sun-heated floor, which might have decreased the resting time in the present study (Kamal et al. 2018). Further, the increased standing time is the most common behavioural change observed in animals under heat stress (Widowski 2001). Tucker et al. (2008) observed 10% increase in standing time when heat load increased by 15% in dairy cattle, might be due to increased heat loss by exposing the more amount of skin to airflow.

Conclusions

The provision of sprinkler with fan reduces physiological response along with body temperatures. Consequently, it improved the growth performance and helped in normal behavioural expression of the buffalo calves.

Acknowledgements

The authors are grateful to the Vice-Chancellor-Rajasthan University of Veterinary and Animal Sciences (RAJUVAS), Bikaner, Rajasthan. India and the Dean, Post Graduate Institute Of Veterinary Education And Research (PGIVER), Jaipur, Rajasthan, India for providing funds and facilities to conduct this experiment.

References

Adin G, Solomon R, Nikbachat M, Zenou A, Yosef E, Brosh A, Shabtay A, Mabjeesh SJ, Halachmi I, Miron J (2009) Effect of feeding cows in early lactation with diets differing in roughage-neutral detergent fiber content on intake behavior, rumination, and milk production. J. Dairy Sci 92:3364-73

Aggarwal A, Singh M (2008) Skin and rectal temperature changes in lactating buffaloes provided with showers and wallowing during hot-dry season. Trop Anim Health Prod 40:223–228

Ahmad M, Bhatti JA, Abdullah M, Ullah R, Hasni MS, Ali M, Rashid A, Qaisar I, Rashid G, Uddin R (2019) Different ambient management intervention techniques and their effect on milk production and physiological parameters of lactating Nili-Ravi buffaloes during hot dry summer of subtropical region. Trop Anim Health Prod 51:911-918

Ahmad M, Bhatti JA, Abdullah M, Javed K, Din R, Ali M, Rashid G, Ahmed N, Jehan M (2017) Effect of different ambient management interventions on milk production and physiological performance of lactating Nili-Ravi buffaloes during hot humid summer. Livest Res Rural Dev 29:230

Ambulkar DR, Nikam SD, Barmase BS, Ali SZ, Jirapure SG (2011) Effect of a high-pressure fogger system on body comfort and milk yield in Murrah buffaloes during the summer. Buffalo Bull 30:130–138

Anderson SD, Bradford BJ, Harner JP, Tucker CB, Choi CY, Allen JD, Hall LW, Rungruang S, Collier RJ, Smith JF (2013) Effects of adjustable and stationary fans with misters on core body

temperature and lying behavior of lactating dairy cows in a semiarid climate. J Dairy Sci 96:4738-4750

Avendaño-Reyes L, Alvarez-Valenzuela FD, Correa-Calderón A, Saucedo-Quintero JS, Robinson PH, Fadel JG (2006) Effect of cooling Holstein cows during the dry period on postpartum performance under heat stress conditions. Livest Sci 105:198-206

Bah M, Rashid MA, Javed K, Pasha TN, Shahid MQ (2021) Effects of sprinkler flow rate on physiological, behavioral and production responses of Nili Ravi buffaloes during subtropical summer. Animals 11:339

Bah M, Shahid MQ, Pasha TN, Javed K (2022) Performance and welfare of dairy buffaloes subjected to different cooling strategies during subtropical summer. Trop Anim Health Prod 54:1-8

Das KS, Singh J, Singh G, Upadhyay R, Malik R, Oberoi P (2014) Heat stress alleviation in lactating buffaloes: Effect on physiological response, metabolic hormone, milk production and composition. Indian J Anim Sci 84:275-80

Das KS, Singh G, Paul SS, Malik R, Oberoi PS, Deb SM (2011) Physiological responses and performance of Nili-Ravi buffalo calves under different washing frequency during hot summer months in tropics. Trop Anim Health Prod 43:35–39

Das SK, Upadhyay RC, Madan ML (1999) Heat stress in Murrah buffalo calves. Livest Prod Sci 61:71–78

Ganaie AH, Shanker G, Nazir A, Bumla NA, Ghasura RS, Mir NA, Wani SA, Dudhatra GB (2013) Biochemical and physiological changes during thermal stress in Bovines. J Vet Sci Technol 4:126–132

Grant RJ, Albright JL (2001) Effect of animal grouping on feeding behavior and intake of dairy cattle. J Dairy Sci 84:156–163

Hooda OK, Singh S (2010) Effect of thermal stress on feed intake, plasma enzymes and blood bio-chemicals in buffalo heifers. Indian J Anim Nutr 27: 122-127.

Kamal R, Dutt T, Patel M, Dey A, Bharti PK, Chandran PC (2018) Heat stress and effect of shade materials on hormonal and behaviour response of dairy cattle: a review. Trop Anim Health Prod 50:701–706

Kapila N, Sharma A, Kishore A, Sodhi M, Tripathi PK, Mohanty AK, Mukesh M (2016) Impact of heat stress on cellular and transcriptional adaptation of mammary epithelial cells in riverine bufalo (Bubalusbubalis). PloS One 11:e0157237.

Khongdee T, Sripoon S, Vajrabukka C (2011) The effects of high temperature and wallow on physiological responses of swamp buffaloes (Bubalus bubalis) during winter season in Thailand. J Therm Biol 36:417-421

Khongdee T (2016) Effects of roof modifications on growth performance and physiological changes of crossbred beef heifers (Bos indicus). Songklanakarin J Sci Techno l38:183-188

Kishore A, Sodhi M, Sharma A, Shandilya UK, Mohanty AK, Verma P, Mann S, Manishi M (2016) Transcriptional stability of heat shock protein genes and cell proliferation rate provides an evidence of superior cellular tolerance of Sahiwal (*Bos indicus*) cow PBMCs to summer stress. Res Rev J Vet Sci 2:34–40

Kumar VS, Kumar RP, Harikrishna CH, Rani MS (2018) Effect of heat stress on production and reproduction performance of buffaloes-A review. Pharma Innov 7(4):629-33

Lakhani P, Mohanned NA, Lakhani N, Jindal R, Nayyar S (2018) Seasonal variation in physiological responses, stress and metabolic related hormones, and oxidative status of Murrah buffaloes. Biol Rhythm Res 49:844–852

Marai IF, Haeeb AA (2010) Buffalo's biological functions as affected by heat stress—A review. Livest Sci 127:89-109

Magrin L, Brscic M, Lora I, Rumor C, Tondello L, Cozzi G, Gottardo F (2017) Effect of a ceiling fan ventilation system on finishing young bulls' health, behaviour and growth performance. Animal 11:1084–1092

Napolitano F, Pacelli C, Grasso F, Braghieri A, De Rosa G (2013) The behaviour and welfare of buffaloes (Bubalus bubalis) in modern dairy enterprises. Animal 7:1704-1713

Nardone A, Ronchi B, Lacetera N, Ranieri MS, Bernabucci U (2010) Effects of climate changes on animal production and sustainability of livestock systems. Livest Sci 130:57–69

Prasad CK, Singh P, Barman D, Potshangbam C, Bhatt N, Singh SV, Lathwal SS (2020) Eye temperature, an indicator for stress levels in young buffalo bulls- a case study of micro-environment modifcation. J Agrometeorol 22:266–273

Rahangdale PB, Ambulkar DR, Somnathe RD (2012) Influence of summer managemental practices on physiological responses and temperament in Murrah buffaloes. Buffalo Bull 30:139-147.

Seerapu SR, Kancharana AR, Chappidi VS, Bandi ER (2015) Effect of microclimate alteration on milk production and composition in Murrah buffaloes. Vet World 8:1444–1452

Singh SV, Hooda OK, Narwade B, Baliyan B, Upadhyay RC (2014) Effect of cooling system on feed and water intake, body weight gain and physiological responses of Murrah buffaloes during summer conditions. Indian j dairy sci 67:426-31

Singh G, Kamboj ML, Patil NV (2005) Effect of thermal protective measures during hot humid season on productive and reproductive performance of Nili-Ravi bufaloes. Indian Bufalo J 3:101–104

Stewart M, Webster JR, Verkerk GA, Schaefer AL, Colyn JJ, Stafford KJ (2007) Non-invasive measurement of stress in dairy cows using infrared thermography. Physiol Behav 92:520–525

Tresoldi G, Schütz KE, Tucker CB (2018) Cooling cows with sprinklers: Spray duration affects physiological responses to heat load. J Dairy Sci 101(5):4412-23

Tucker CB, Rogers RA, Schütz KE (2008) Effect of solar radiation on dairy cattle behaviour, use of shade and body temperature in a pasture-based system. Appl Anim Behav Sci 109:141–154

Uddin J, Phillips CJ, Goma AA, McNeill DM (2019) Relationships between infrared temperature and laterality. Appl Anim Behav Sci 220:104855

West J W (2003) Effects of heat-stress on production in dairy cattle. J dairy sci 86:2131-2144

Vijayakumar P, Pandey HN, Singh M, Dutt T, Tomar AK (2009) Behavioural response to heat ameliorative measures on buffalo heifers. Indian J Anim Sci 79:433-436

Widowski T (2001) Shade seeking behaviour of rotationally grazedcows and calves in a moderate climate. In: Livestock environment VI Proceeding of the 6th International Symposium.

Yadav B, Pandey V, Yadav S, Singh Y, Kumar V, Sirohi R (2016) Effect of misting and wallowing cooling systems on milk yield, blood and physiological variables during heat stress in lactating Murrah buffalo. J Anim Sci Technol 58:1-10