



Effect of heat ameliorative measures on microclimate, physiological, blood biochemical parameters and milk production in lactating Surti buffaloes

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ABSTRACT

The present investigation was carried out to evaluate the effect of heat ameliorative measures (fans, foggers, green agro shadenet) on physiological, haematological, biochemical and milk production parameters in Surti buffaloes. Lactating Surti buffaloes (36) were equally divided into two groups and kept in two sheds. Group I animals were housed in a shed without any modification while Group II animals housed in a shed fitted with fans and foggers inside the shed and roof top white washed with microfine lime and open paddock was covered with green shade net and foggers were fitted. There were significant differences in the THI values of both inside and outside of the sheds at majority of periods during the hot-dry season. The floor and roof temperature of control shed at almost all-time intervals was significantly higher than the floor temperature of treatment shed. Significant difference in rectal temperature was observed at 14 and 28 days while respiration rate was significantly lower in animals of treatment shed. In treatment group, total erythrocyte count and haematocrit was significantly low at day 21 and mean platelet volume was significantly high at day 42. Significantly high levels of cholesterol, chloride and sodium at day 21 and glucose, protein, triglyceride, GSH, TAS and sodium at day 42 were observed in treatment group. Weekly milk yield (kg) during hot-dry season was significantly higher for treatment group than control group at 3rd, 4th and 5th weeks of the experiment. Evening milk yield of treatment group was significantly higher than the control and the cumulative milk yield (for 42 days) was also significantly higher for treatment group than control group (180.08 vs.150.80 kg). It can be concluded that microclimate modifications help in reducing heat stress and has beneficial effect on physiological responses, blood biochemical parameters and total milk production in lactating Surti buffaloes during hot dry season.

Key words: Foggers, Heat stress, milk yield, Surti buffalo, Temperature humidity index

High ambient temperature, relative humidity, solar radiation are responsible for heat stress which adversely affects the productive, reproductive performance as well as the welfare of buffaloes. Owing to their thermolytic properties, viz. black colour of skin, sparse hairs and less number of sweat glands, buffaloes are more prone to heat stress than other dairy animals. Buffaloes are said to be in heat stress when the ambient temperature is more than the body temperature and the animals are unable to dissipate heat from body. They can thrive in temperature as high as 40°C and as low as 4°C but their productive and reproductive performance is lowered as the ambient temperature increases above 32°C. Temperature humidity

index (THI) is one of the parameters used for assessment of heat stress in animals. Different scientists have used different formulae for calculation of THI. THI values of < 71 indicate thermal comfort zone, 72–79 mild heat stress, 80–90 indicate moderate heat stress while more than 90 indicate severe heat stress (Armstrong 1994) but it also varies with the species and breed of the animal. Further, Bohamanova *et al.* (2007) have suggested that indices with larger emphasis on humidity seem to be suitable for humid climate, while those that emphasize on ambient temperature are preferred for hot dry climate. Heat ameliorative measures to reduce the THI of the shed as well to enhance the ventilation and cool the body surface of buffaloes can reduce the heat stress in buffaloes and improve the productive performance of the animals. Use of fans alone as one of the heat ameliorative measures may help in evaporative heat loss but use of both fans and foggers reduces the body surface temperature and acts as a better heat ameliorative measure. Gaughan *et al.* (2010) reported that sprinklers and fans may be used to reduce the heat load in dairy animals. The present study was therefore carried

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out to compare the variations in ambient temperature, humidity and THI in the shed with/without heat ameliorative measures and to evaluate the effect of foggers, fans and green agro shadenet on physiological, haematological, biochemical parameters and milk production in lactating Surti buffaloes.

MATERIALS AND METHODS

The experiment was conducted on 36 lactating Surti buffaloes maintained at Livestock Research Station (LRS), of the university. The experiment was carried out during hot-dry (25 April–05 June, 2017) season. The animals were maintained under loose housing and group management system. The housing space for the animals was specified as per BIS standards. Considering their parity, stage of lactation and weekly milk yield, animals were divided into two groups, viz. Group I (animals were housed in a shed made up of cement concrete and without shed modification) and Group II (animals were housed in similar type of shed like control group but roof of the shed was painted white with commercially available micro fine lime powder and four heavy duty fans were fitted equidistantly along the long axis of the covered area). Further, 11 foggers were fitted at a height of 7 ft from the ground and the distance between two foggers were 6.9 ft. Open paddock area was covered with 75% green agro shade net at a height of about 10 ft and three lines of foggers were fitted under the green agro shadenet. The distance between two fogger lines was about 9.5 ft and distance between two foggers in a line was about 10 ft. Automatic electronic switches were used to switch on at 09:00 h and switch off at 17:00 h daily for these fans and foggers. Further, cyclic timer was used to switch on and off these foggers. Besides these housing modifications, all other management practices were similar to both group of animals. Automatic data loggers were fitted in the open paddock as well as inside the closed area of the

shed to record the meteorological variables, viz. temperature and humidity. THI was calculated as per the formula suggested by Tucker *et al.* (2008). Temperature of the floor as well as the roof of the experimental shed was recorded at 09:00, 14:00 and 17:00 h daily with the help of non contact infrared thermometer (Fluke 59 mini). The milk yield of the individual buffalo was recorded by electronic weighing balance. Rectal temperature and respiration rate were recorded at fortnight interval. Blood samples were collected in EDTA and clot activator tubes for separation of plasma and serum. Haematological parameters were analysed by the haematology analyser on the day of collection. Plasma and serum samples were separated and frozen at -20°C till analyzed for biochemical parameters like glucose, protein, albumin, creatinine, cholesterol, triglyceride, TAS, glutathione, chloride, lactate, sodium, potassium, bicarbonate, HDL cholesterol, LDL cholesterol and cortisol. Statistical analysis of parameters was carried out by using SAS 9.3.

RESULTS AND DISCUSSION

Ambient temperature: Least squares' means of weekly mean ambient temperature ($^{\circ}\text{C}$) both inside and outside of the shed was significantly ($P \leq 0.05$) higher at almost all stages of the study for control group than treatment group (Table 1).

Further, weekly average ambient temperature during 09–17 h (hotter part of the day) was also significantly higher ($P \leq 0.05$) both inside and outside the shed in control group than treatment group at majority of periods (Table 1). Inside the shed, weekly average ambient temperature was about $2\text{--}3^{\circ}\text{C}$ lower while it was lower by around $3\text{--}5^{\circ}\text{C}$ in the open paddock area of the treatment than the control shed between 9–17 h. Use of white painting of roof top, fan and foggers inside the shed and use of green agro shadenet and foggers outside the shed might have played significant role

Table 1. Least squares' means (LSM $\pm$ SE) of weekly mean temperature ($^{\circ}\text{C}$) inside the shed and open paddock and inside the shed and open paddock during 09:00–17:00 h

Group	W1	W2	W3	W4	W5	W6
<i>Weekly mean temperature ($^{\circ}\text{C}$) inside the shed</i>						
Control	30.25 $\pm$ 0.27	30.81 $\pm$ 0.72	30.33 $\pm$ 0.22	30.17 $\pm$ 0.26	30.86 $\pm$ 0.08	30.67 $\pm$ 0.23
Treatment	28.35 $\pm$ 0.12	29.15 $\pm$ 0.72	28.75 $\pm$ 0.23	28.54 $\pm$ 0.27	29.04 $\pm$ 0.09	28.84 $\pm$ 0.23
Overall	29.30 $\pm$ 0.30	29.98 $\pm$ 0.54	29.54 $\pm$ 0.27	29.35 $\pm$ 0.29	29.95 $\pm$ 0.26	29.75 $\pm$ 0.30
<i>Weekly mean temperature ($^{\circ}\text{C}$) of open paddock</i>						
Control	31.34 $\pm$ 0.16	32.86 $\pm$ 0.35	33.66 $\pm$ 0.53	33.08 $\pm$ 0.14	34.30 $\pm$ 0.50	34.16 $\pm$ 0.32
Treatment	29.90 $\pm$ 0.12	31.70 $\pm$ 0.22	32.47 $\pm$ 0.36	32.35 $\pm$ 0.14	32.38 $\pm$ 0.37	32.13 $\pm$ 0.19
Overall	30.62 $\pm$ 0.22	32.28 $\pm$ 0.26	33.06 $\pm$ 0.35	32.72 $\pm$ 0.14	33.34 $\pm$ 0.40	33.14 $\pm$ 0.33
<i>Weekly average temperature ($^{\circ}\text{C}$) inside the shed during 09–17 h</i>						
Control	33.63 $\pm$ 0.25	33.50 $\pm$ 0.86	32.94 $\pm$ 0.38	33.01 $\pm$ 0.42	33.45 $\pm$ 0.13	33.19 $\pm$ 0.33
Treatment	30.38 $\pm$ 0.60	31.03 $\pm$ 0.87	30.39 $\pm$ 0.39	30.49 $\pm$ 0.43	30.70 $\pm$ 0.13	30.44 $\pm$ 0.34
Overall	32.00 $\pm$ 0.55	32.26 $\pm$ 0.68	31.66 $\pm$ 0.44	31.75 $\pm$ 0.45	32.07 $\pm$ 0.39	31.81 $\pm$ 0.45
<i>Weekly average temperature ($^{\circ}\text{C}$) of open paddock during 09–17 h</i>						
Control	37.60 $\pm$ 0.42	40.41 $\pm$ 0.63	40.60 $\pm$ 0.89	39.30 $\pm$ 0.25	40.53 $\pm$ 0.79	40.13 $\pm$ 0.45
Treatment	30.38 $\pm$ 0.60	31.03 $\pm$ 0.87	30.39 $\pm$ 0.39	30.49 $\pm$ 0.43	30.70 $\pm$ 0.13	30.44 $\pm$ 0.34
Overall	35.13 $\pm$ 0.72	38.61 $\pm$ 0.61	38.84 $\pm$ 0.70	37.95 $\pm$ 0.41	38.03 $\pm$ 0.84	37.70 $\pm$ 0.72

Means showing different superscripts in lower case letters in a column differ significantly ($P \leq 0.05$).

in lowering down the temperatures inside and outside the treatment shed, respectively.

Relative humidity: Slightly higher value of RH was observed inside the control shed than the treatment shed (Table 2). In the open paddock area, there was no definite trend in the RH values for both group of animals. Most of these values of RH were non-significant and use of fans might have reduced the RH inside the shed.

Temperature humidity index: There were significant differences ($P \leq 0.05$) in the weekly mean THI and THI values during 09–17 h (during hotter part of the day) of both inside and outside of the sheds at majority of the periods during the hot-dry season (Tables 3, 4). THI values were higher for control group than treatment group both inside and outside of the shed during entire study period. THI increases with increase in temperature and RH. Use of fans, foggers, green agro shade net as well as the white

washing of the roof top might have played some role in lowering the values of these two determinants of THI. Present findings of significantly lower THI by use of fans and foggers and green net corroborate with the findings of Seerapu *et al.* (2015) and Kamal *et al.* (2016).

Floor and roof temperature: The floor temperature of control shed at all time intervals during entire study period was significantly higher ($P \leq 0.05$) than the floor temperature of treatment shed (Table 5). Its highest value (55.7°C) was observed during 3rd week for open paddock of control shed. Temperature of the open paddock in the control shed was $10\text{--}15^\circ\text{C}$ higher than the treatment, indicating that the use of green shade in the open paddock reduced temperature of the floor as it cuts down the solar radiation. Kamal *et al.* (2014) reported that agro-net shade in open paddock provided favourable microclimate to crossbred calves in comparison to asbestos sheet shade. It was observed that

Table 2. Least squares' means (LSM $\pm$ SE) of weekly relative humidity (%) inside the shed and of open paddock

Group	W1	W2	W3	W4	W5	W6
<i>Weekly mean relative humidity (%) inside the shed</i>						
Control	66.20 $\pm$ 0.90	72.01 $\pm$ 1.26	72.70 ^a $\pm$ 0.94	68.10 $\pm$ 0.82	69.62 $\pm$ 1.32	70.94 ^a $\pm$ 1.76
Treatment	68.09 $\pm$ 1.50	69.20 $\pm$ 1.90	67.27 ^b $\pm$ 0.34	68.61 $\pm$ 1.25	66.87 $\pm$ 0.31	66.22 ^b $\pm$ 0.97
Overall	67.15 $\pm$ 0.88	70.61 $\pm$ 1.16	69.99 $\pm$ 0.89	68.36 $\pm$ 0.72	68.25 $\pm$ 0.75	68.58 $\pm$ 1.17
<i>Weekly mean relative humidity (%) for open paddock</i>						
Control	71.73 ^a $\pm$ 1.07	70.69 $\pm$ 1.59	68.96 $\pm$ 2.18	71.33 ^a $\pm$ 0.82	63.83 ^a $\pm$ 1.78	65.20 ^a $\pm$ 1.05
Treatment	66.89 ^b $\pm$ 1.34	67.20 $\pm$ 1.56	65.77 $\pm$ 2.00	67.36 ^b $\pm$ 0.96	71.37 ^b $\pm$ 2.78	74.25 ^b $\pm$ 0.82
Overall	69.31 $\pm$ 1.06	68.94 $\pm$ 1.17	67.36 $\pm$ 1.49	69.35 $\pm$ 0.82	67.60 $\pm$ 1.90	69.72 $\pm$ 1.41

Means showing different superscripts in lower case letters in a column differ significantly ($P \leq 0.05$).

Table 3. Least squares' means (LSM $\pm$ SE) of mean temperature humidity index (THI) inside the shed and of open paddock

Group	W1	W2	W3	W4	W5	W6
<i>Weekly mean THI inside the shed</i>						
Control	81.16 ^a $\pm$ 0.34	82.93 $\pm$ 1.12	82.30 ^a $\pm$ 0.36	81.35 ^a $\pm$ 0.49	82.61 ^a $\pm$ 0.21	82.54 ^a $\pm$ 0.53
Treatment	78.64 ^b $\pm$ 0.28	79.95 $\pm$ 1.00	79.11 ^b $\pm$ 0.36	78.98 ^b $\pm$ 0.41	79.49 ^b $\pm$ 0.13	79.10 ^b $\pm$ 0.40
Overall	79.90 $\pm$ 0.41	81.44 $\pm$ 0.83	80.71 $\pm$ 0.51	80.17 $\pm$ 0.5	81.05 $\pm$ 0.45	80.82 $\pm$ 0.57
<i>Weekly mean THI for open paddock</i>						
Control	83.68 ^a $\pm$ 0.19	85.77 ^a $\pm$ 0.32	86.61 ^a $\pm$ 0.37	86.26 ^a $\pm$ 0.18	86.58 ^a $\pm$ 0.42	86.67 ^a $\pm$ 0.33
Treatment	80.75 ^b $\pm$ 0.21	83.43 ^b $\pm$ 0.19	84.29 ^b $\pm$ 0.20	84.45 ^b $\pm$ 0.19	85.15 ^b $\pm$ 0.31	85.32 ^b $\pm$ 0.23
Overall	82.22 $\pm$ 0.43	84.60 $\pm$ 0.37	85.45 $\pm$ 0.38	85.35 $\pm$ 0.28	85.86 $\pm$ 0.32	85.99 $\pm$ 0.27

Means showing different superscripts in lower case letters in a column differ significantly ($P \leq 0.05$).

Table 4. Least squares' means (LSM $\pm$ SE) of average temperature humidity index (THI) inside the shed and of open paddock during 09:00–17:00 h

Group	W1	W2	W3	W4	W5	W6
<i>Weekly average THI inside the shed during 09–17 h</i>						
Control	83.43 ^a $\pm$ 0.31	84.69 $\pm$ 1.30	84.63 ^a $\pm$ 0.58	83.66 ^a $\pm$ 0.72	84.34 ^a $\pm$ 0.20	84.58 ^a $\pm$ 0.69
Treatment	79.91 ^b $\pm$ 0.94	81.13 $\pm$ 1.22	80.48 ^b $\pm$ 0.59	80.96 ^b $\pm$ 0.66	81.00 ^b $\pm$ 0.21	80.47 ^b $\pm$ 0.61
Overall	81.67 $\pm$ 0.68	82.91 $\pm$ 0.99	82.56 $\pm$ 0.70	82.31 $\pm$ 0.60	82.67 $\pm$ 0.48	82.53 $\pm$ 0.72
<i>Weekly average THI of open paddock during 09–17 h</i>						
Control	89.85 ^a $\pm$ 0.35	92.77 ^a $\pm$ 0.44	92.86 ^a $\pm$ 0.47	92.60 ^a $\pm$ 0.21	94.01 ^a $\pm$ 0.26	94.05 ^a $\pm$ 0.30
Treatment	83.20 ^b $\pm$ 0.26	86.78 ^b $\pm$ 0.27	86.96 ^b $\pm$ 0.26	87.10 ^b $\pm$ 0.23	87.39 ^b $\pm$ 0.63	87.91 ^b $\pm$ 0.32
Overall	86.52 $\pm$ 0.95	89.78 $\pm$ 0.87	89.91 $\pm$ 0.86	89.85 $\pm$ 0.78	90.70 $\pm$ 0.98	90.98 $\pm$ 0.88

Means showing different superscripts in lower case letters in a column differ significantly ($P \leq 0.05$).

Table 5. Least squares' means (LSM±SE) of weekly floor temperature (°C) inside and outside of shed and roof at 09:00, 14:00 and 17:00 h

Group	09:00 h						14:00 h						17:00 h					
	W1	W2	W3	W4	W5	W6	W1	W2	W3	W4	W5	W6	W1	W2	W3	W4	W5	W6
<i>Weekly floor temperature inside the shed</i>																		
Control	28.3 ^a ±0.4	31.2 ^a ±0.5	32.3 ^a ±0.7	31.7 ^a ±0.4	31.7 ^a ±0.4	31.7 ^a ±0.4	32.0 ^a ±0.2	32.5 ^a ±0.4	34.4 ^a ±0.7	33.5 ^a ±0.2	33.3 ^a ±0.6	33.5 ^a ±0.7	32.5 ^a ±0.2	33.1 ^a ±0.6	33.2 ^a ±0.6	32.8 ^a ±0.3	32.8 ^a ±0.7	33.2 ^a ±0.6
Treatment	26.5 ^b ±0.5	30.0 ^b ±0.4	30.1 ^b ±0.4	29.7 ^b ±0.6	30.3 ^b ±0.1	30.6 ^b ±0.2	29.2 ^b ±0.1	30.0 ^b ±0.4	31.7 ^b ±0.7	31.4 ^b ±0.5	32.6 ^b ±0.3	32.6 ^b ±0.3	29.5 ^b ±0.1	30.5 ^b ±0.4	31.9 ^b ±0.7	30.8 ^b ±0.4	31.3 ^b ±0.2	31.9 ^b ±0.3
Overall	27.4 ^a ±0.4	30.6 ^a ±0.4	31.2 ^a ±0.5	30.7 ^a ±0.4	31.0 ^a ±0.3	31.2 ^a ±0.3	30.6 ^a ±0.4	31.3 ^a ±0.4	33.0 ^a ±0.6	32.4 ^a ±0.4	32.9 ^a ±0.3	33.1 ^a ±0.4	31.0 ^a ±0.4	31.8 ^a ±0.5	32.6 ^a ±0.5	31.8 ^a ±0.4	32.1 ^a ±0.4	32.5 ^a ±0.4
<i>Weekly floor temperature of open paddock</i>																		
Control	37.6 ^a ±1.3	44.3 ^a ±0.6	46.7 ^a ±1.2	43.1 ^a ±1.1	37.6 ^a ±0.3	35.7 ^a ±0.4	54.0 ^a ±0.6	53.1 ^a ±1.2	55.7 ^a ±0.8	54.4 ^a ±0.3	52.2 ^a ±1.3	48.2 ^a ±1.5	48.5 ^a ±1.4	51.5 ^a ±1.0	53.0 ^a ±1.7	49.8 ^a ±0.6	45.8 ^a ±1.8	43.1 ^a ±1.6
Treatment	30.8 ^b ±0.6	33.4 ^b ±0.2	35.1 ^b ±0.6	33.4 ^b ±0.6	33.3 ^b ±0.2	33.0 ^b ±0.2	36.2 ^b ±0.6	37.0 ^b ±0.5	38.8 ^b ±0.7	38.3 ^b ±0.3	38.8 ^b ±0.5	38.7 ^b ±0.5	34.6 ^b ±0.2	36.6 ^b ±0.5	36.2 ^b ±0.3	37.1 ^b ±0.5	36.6 ^b ±0.3	37.5 ^b ±0.7
Overall	34.2 ^a ±1.2	38.8 ^a ±1.5	40.9 ^a ±1.7	38.3 ^a ±1.5	35.5 ^a ±0.6	34.4 ^a ±0.4	45.1 ^a ±2.5	45.1 ^a ±2.3	47.2 ^a ±2.4	46.4 ^a ±2.3	45.5 ^a ±2.0	43.5 ^a ±1.5	41.6 ^a ±2.0	44.0 ^a ±2.1	44.6 ^a ±2.5	43.4 ^a ±1.8	41.2 ^a ±1.6	40.3 ^a ±1.1
<i>Weekly temperature of roof (°C)</i>																		
Control	28.3 ^a ±0.8	32.6 ^a ±0.8	36.6 ^a ±2.3	32.7 ^a ±0.6	32.9 ^a ±0.3	32.2 ^a ±0.2	40.1 ^a ±0.7	41.4 ^a ±0.5	41.7 ^a ±0.6	41.7 ^a ±0.2	41.1 ^a ±0.8	38.7 ^a ±0.9	40.4 ^a ±1.2	43.4 ^a ±0.7	44.0 ^a ±0.9	42.3 ^a ±0.2	41.7 ^a ±1.0	40.0 ^a ±0.7
Treatment	26.1 ^b ±0.7	30.1 ^b ±0.4	32.8 ^b ±1.2	29.7 ^b ±0.6	30.9 ^b ±0.1	31.1 ^b ±0.1	32.4 ^b ±0.3	34.3 ^b ±0.5	35.1 ^b ±0.8	34.7 ^b ±0.3	34.6 ^b ±0.3	34.0 ^b ±0.5	32.9 ^b ±0.4	34.2 ^b ±0.7	33.9 ^b ±0.4	34.6 ^b ±0.3	35.0 ^b ±0.4	34.9 ^b ±0.3
Overall	27.2 ^a ±0.6	31.3 ^a ±0.5	34.7 ^a ±1.4	31.2 ^a ±0.6	31.9 ^a ±0.3	31.6 ^a ±0.2	36.2 ^a ±1.1	37.8 ^a ±1.0	38.4 ^a ±1.0	38.2 ^a ±1.0	37.9 ^a ±1.0	36.4 ^a ±0.8	36.6 ^a ±1.2	38.8 ^a ±1.4	38.9 ^a ±1.5	38.5 ^a ±1.1	38.4 ^a ±1.1	37.4 ^a ±0.8

Means showing different superscripts in lower case letters in a column differ significantly (P≤0.05).

the roof temperature of control shed at all time intervals during entire study period was significantly higher ($P \leq 0.05$) than the roof temperature of treatment shed (Table 5). Its highest value (44°C) was observed during 3rd week for control shed. White washing of the roof top with the microfine lime powder was able to reduce the mean temperature of the treatment shed by $2\text{--}3^\circ\text{C}$ at 9.00, $4\text{--}8^\circ\text{C}$ at 14:00 and $5\text{--}11^\circ\text{C}$ at 17:00 h. White washing with the microfine lime helps in the reflection of the solar radiation and transfer of heat via convection from the roof top to the inside of roof does not take place and therefore the temperature of roof on the inner side is lower in treatment shed than the control. Alvarado *et al.* (2009) reported that a compound roof system in combination of radiation reflectors and thermal insulation could substantially lower the heat conducted through a concrete roof.

Rectal temperature and respiration rate: Rectal temperature (RT) and respiration rate are used as indicators of heat stress. In treatment group, rectal temperature was slightly lower than the control group (Table 6) and significant difference ($P \leq 0.05$) was observed at day 14 and 28 in the evening RT. Respiration rate (RR) was significantly lower ($P \leq 0.05$) in treatment group as compared to control at day 28 and 42 both in the morning as well as evening (Table 6). Respiration rate as well as rectal temperature increases with increase in ambient temperature, relative humidity and THI. Use of fans and foggers causes reduction in heat stress by allowing heat evaporation from the body. Respiration rate is one of the best markers of heat stress in pure bred Holstein cows (Vanessa *et al.* 2016). Rectal temperature and respiration rate increases as the THI increases (Kamal *et al.* 2016) and if animals are exposed to direct solar radiations (Gudev *et al.* 2007). Reduction in rectal temperature and RR occurs as a result of wallowing and misting during summer in lactating Murrah buffaloes (Yadav *et al.* 2016) and also in evaporative cooled and tunnel ventilated barns in cattle (Collier *et al.* 2006) and RR reduced by use of fans and foggers (Seerapu *et al.* 2015). Wallowing caused significant reduction in RT in lactating Murrah buffaloes (Aggarwal and Singh 2008).

Haematological parameters: In treatment group, total erythrocyte count and haematocrit was significantly

($P \leq 0.05$) low at day 21 and mean platelet volume was significantly ($P \leq 0.05$) high at day 42 (Table 7). Rest of the parameters did not differ significantly. Haque *et al.* (2013) reported that there was no effect of acute increase in temperature on TEC but packed cell volume and haemoglobin increased in Murrah buffaloes.

Heat ameliorative measures such as misting and wallowing also reduced the PCV in Murrah lactating buffaloes (Yadav *et al.* 2016), increased haemoglobin values in Murrah heifers provided with fans and sprinklers (Vijayakumar *et al.* 2011).

Blood biochemical parameters: In the treatment group, significantly ($P \leq 0.05$) high levels of cholesterol, chloride and sodium at day 21 and glucose, protein, triglyceride, GSH, TAS and sodium at day 42 of the experiment was observed (Table 8). Bicarbonate was significantly ($P \leq 0.05$) lower in treatment group at day 42. High levels of glucose indicate that the animals in the treatment group were not in negative energy balance and dry matter intake must have been sufficient to maintain the blood glucose level. Lower glucose, total protein and cholesterol levels in summer in Murrah lactating buffaloes were reported by Verma *et al.* (2000) and in Murrah heifers provided with fans and sprinklers by Vijayakumar *et al.* (2011). Gudev *et al.* (2007) reported that the values of total protein and cholesterol were lower in group of buffaloes exposed to solar radiation. Lower levels of cholesterol may be attributed to high glucocorticoids in summer and reduce feed intake.

High concentration of sodium and chloride at day 21 and 42 may be due less consumption of water by the animals and more evaporative loss of water. Increased water consumption results in more excretion of sodium in urine. High sodium levels in Murrah buffaloes during summer season by use of misting and wallowing were also reported by Yadav *et al.* (2016). Further, low concentration of GSH and TAS indicate that animals in control group were experiencing oxidative stress. Heat stress may even lead to oxidative stress that results in increased production of reactive oxygen species (ROS) which is scavenged by endogenous and exogenous antioxidants. GSH is one of the internal antioxidant. However, non-significant differences in total antioxidant power in animals provided

Table 6. Least squares' means (LSM $\pm$ SE) of rectal temperature ($^\circ\text{F}$) and respiration rate (no/min) at different intervals during hot-dry season

Group	14 th day		28 th day		42 nd day	
	Morning	Evening	Morning	Evening	Morning	Evening
Rectal temperature ($^\circ\text{F}$)						
Control	99.39 $\pm$ 0.18	102.17 ^a $\pm$ 0.20	100.47 $\pm$ 0.13	103.53 ^a $\pm$ 0.22	101.16 $\pm$ 0.14	103.33 $\pm$ 0.22
Treatment	99.23 $\pm$ 0.23	101.20 ^b $\pm$ 0.19	100.31 $\pm$ 0.14	102.38 ^b $\pm$ 0.23	101.14 $\pm$ 0.15	103.07 $\pm$ 0.28
Overall	99.31 $\pm$ 0.15	101.68 $\pm$ 0.16	100.39 $\pm$ 0.10	102.96 $\pm$ 0.19	101.15 $\pm$ 0.10	103.20 $\pm$ 0.18
Respiration rate (no/min)						
Control	27.11 $\pm$ 1.74	29.78 ^a $\pm$ 0.94	37.00 ^a $\pm$ 1.41	36.44 ^a $\pm$ 0.64	38.56 ^a $\pm$ 1.48	44.78 ^a $\pm$ 0.65
Treatment	26.89 $\pm$ 0.71	26.33 ^b $\pm$ 0.93	31.78 ^b $\pm$ 0.54	28.11 ^b $\pm$ 0.84	33.83 ^b $\pm$ 0.53	32.44 ^b $\pm$ 0.99
Overall	27.00 $\pm$ 0.93	28.06 $\pm$ 0.71	34.39 $\pm$ 0.87	32.28 $\pm$ 0.88	36.19 $\pm$ 0.87	38.61 $\pm$ 1.20

Means showing different superscripts in lower case letters in a column differ significantly ($P \leq 0.05$).

Table 7. Least squares' means (LSM±SE) of haematological parameters at different intervals during hot-dry season

Parameter	Day 21			Day 42		
	Control	Treatment	Overall	Control	Treatment	Overall
RBC (10 ⁶ /mm ³)	7.10±0.13 ^b	6.73±0.09 ^a	6.91±0.09	6.29±0.11	6.17±0.13	6.23±0.08
MCV (µm ³)	47.22±0.63	46.46±0.56	46.84±0.42	46.64±0.75	45.82±0.59	46.23±0.47
HCT (%)	31.06±0.79 ^b	26.84±0.65 ^a	28.95±0.63	29.03±0.76	27.69±0.66	28.36±0.51
PLT (10 ³ /mm ³)	214.94±9.10	210.94±13.81	212.94± 8.14	200.72±7.42	191.22±12.51	195.97±7.21
MPV (µm ³)	7.24±0.10	7.38±0.08	7.31±0.07	7.18±0.09 ^b	7.48±0.11 ^a	7.33±0.07
WBC (10 ³ /mm ³)	10.31±0.46	11.79±0.59	11.05±0.39	10.94±0.65	11.76±0.65	11.35±0.46
Hb (gm/dl)	10.31±0.24	9.82±0.14	10.07±0.14	9.47±0.24	9.31±0.21	9.39±0.16
MCH (pg)	15.68±0.20	15.51±0.19	15.59±0.13	15.25±0.27	15.41±0.20	15.33±0.17
MCHC (gm/dl)	33.11±0.16	33.39±0.16	33.25±0.11	32.78±0.38	33.64±0.20	33.21±0.22
RDW (%)	18.74±0.38	18.62±0.48	18.68±0.30	26.22±8.52	17.93±0.31	22.08±4.26
LYM (%)	52.64±1.63	55.52±1.34	54.08±1.07	55.88±1.38	53.04±1.24	54.46±0.95
MID (%)	8.10±0.28	7.89±0.26	7.10±0.20	8.16±0.33	8.017±0.26	8.09±0.21
GRAN (%)	39.26±1.54	36.59±1.26	37.93±1.01	35.96±1.21	38.94±1.20	37.45±0.88

Means showing different superscripts in lower case letters in a column differ significantly ($P \leq 0.05$). RBC, Red Blood cell; MCV, Mean corpuscular volume; HCT, Hematocrit; PLT, Platelet count; MPV, Mean platelet volume; WBC, White blood cells; Hb, Haemoglobin; MCH, Mean corpuscular haemoglobin; MCHC, Mean corpuscular haemoglobin concentration; RDW, Red cell distribution width; LYM, Lymphocyte; MID, Midsized cells; GRAN, Granulocytes.

Table 8. Least squares' means (LSM±SE) of blood biochemical parameters at different intervals during hot-dry season

Parameter	Day 21			Day 42		
	Control	Treatment	Overall	Control	Treatment	Overall
Glucose (mg/dl)	54.35±1.36	52.94±1.90	53.67±1.15	57.29 ^a ±1.70	63.06 ^b ±1.11	60.18±1.12
Protein (gm/dl)	6.71±0.11	7.00±0.13	6.85±0.09	7.39 ^a ±0.18	7.94 ^b ±0.15	7.67±0.13
Albumin (gm/dl)	3.36±0.03	3.50±0.13	3.43±0.06	3.50±0.12	3.72±0.14	3.61±0.09
Creatinine (mg/dl)	2.38±0.17	2.57±0.20	2.47±0.13	1.06±0.10	1.33±0.14	1.19±0.09
Cholesterol (mg/dl)	104.41 ^a ±5.31	146.13 ^b ±7.86	124.64±5.91	129.83±4.65	140.00±3.63	134.92±3.03
Triglyceride (mg/dl)	22.40±3.12	31.44±5.16	26.68±3.05	14.75 ^a ±1.61	19.25 ^b ±0.97	17.00±1.01
Reduced glutathione - GSH (mg/dl)	6.86±0.12	7.05±0.19	6.95±0.11	10.86 ^a ±0.37	12.15 ^b ±0.39	11.51±0.29
Total antioxidant status - TAS (µM)	556.00±25.57	555.50±28.59	555.75±18.82	466.29 ^a ±11.69	541.36 ^b ±18.08	503.83±12.45
Chloride (meq/l)	102.06 ^a ±1.56	107.86 ^b ±2.20	104.68±1.39	102.67 ^a ±0.91	108.50 ^b ±0.94	105.58±0.84
Lactate (mg/dl)	23.71±1.11	27.06±1.38	25.33±0.91	28.33±1.22	28.00±1.13	28.17±0.82
Sodium (meq/l)	137.76 ^a ±1.65	145.31 ^b ±2.18	141.42±1.49	129.17 ^a ±1.97	143.06 ^b ±2.42	136.11±1.93
Potassium (meq/l)	5.59±0.17	5.43±0.23	5.52±0.14	6.11±0.25	6.78±0.26	6.45±0.19
Bicarbonate (mmol/l)	27.29±2.02	27.44±1.73	27.36±1.31	19.69 ^a ±0.89	16.94 ^b ±0.68	18.31±0.60
HDL cholesterol (mg/dl)	72.65±4.46	75.33±6.02	73.92±3.60	62.82±3.26	66.30±2.65	64.56±2.08
LDL cholesterol (mg/dl)	88.20±7.85	95.00±10.72	91.42±6.41	72.80±4.21	70.44±4.50	71.62±3.01
Cortisol (µg/dl)	0.80±0.25	1.20±0.25	1.00±0.18	1.00±0.26	0.80±0.29	0.90±0.19

Means showing different superscripts in lower case letters in a column differ significantly ($P \leq 0.05$).

with and without natural and artificial shade has been observed in summer season in beef cattle (Aengwanich *et al.* 2010). Oxidative stress is also measured by measuring the total antioxidant status (TAS) that uses the conversion of ferric ions to ferrous ion. In present study, TAS was significantly higher in the treatment group, however non-significant differences in the biological antioxidant potential (BAP) in HF cows in different seasons were reported (Mirzad *et al.* 2017). Non-significant differences in cortisol were observed in present study and similar results were

reported in Nilli Ravi buffaloes provided with niacin supplementation, curtains, fans and foggers (Das *et al.* 2014).

Lower concentrations of cortisol in lactating buffaloes that were provided cooling had been reported by El-Khashab (2010), while Marai and Haebe (2010) concluded that plasma cortisol level increases during acute heat stress and decreases during chronic phase.

Milk yield (in kg): Least squares' means (LSM±SE) of weekly milk yield (kg) during hot-dry season was higher

Table 9. Least squares' means (LSM±SE) of weekly, cumulative (42 day) and morning and evening milk yield (in kg)

Group	Week						42-day cumulative milk yield
	1	2	3	4	5	6	
Control	28.09±1.12	27.60±1.51	24.94 ^b ±1.34	23.37 ^b ±1.87	24.35 ^b ±1.72	22.45±2.44	150.80 ^b ±9.08
Treatment	31.03±1.41	31.25±1.61	30.33 ^a ±1.69	29.82 ^a ±1.59	32.28 ^a ±1.97	28.74±2.70	180.08 ^a ±10.96
Overall	29.56±0.92	29.43±1.13	27.64±1.16	26.59±1.32	28.20±1.45	25.51±1.87	165.44±7.44
<i>Weekly morning milk yield (kg)</i>							
Control	20.10±1.55	21.63±1.46	19.08±1.07	17.77±1.31	18.35±1.28	18.20±1.54	83.27±7.34
Treatment	19.96±1.05	20.40±1.32	19.38±1.04	18.77±1.12	19.44±1.14	18.04±1.67	88.77±7.51
Overall	20.03±0.94	21.03±0.98	19.22±0.74	18.25±0.85	18.91±0.84	18.11±1.13	85.94±5.19
<i>Weekly evening milk yield (kg)</i>							
Control	13.65 ^b ±1.25	13.70 ^b ±1.21	13.83±1.01	13.62±1.07	14.47±0.97	13.58 ^b ±1.13	48.30 ^b ±9.11
Treatment	17.27 ^a ±1.12	18.32 ^a ±0.85	15.95±0.87	15.94±0.87	15.59±1.12	16.53 ^a ±0.83	79.23 ^a ±7.45
Overall	15.66±0.89	16.29±0.84	15.18±0.68	15.05±0.70	15.12±0.76	15.05±0.75	63.7±6.36

Means showing different superscripts in lower case letters in a column differ significantly ($P \leq 0.05$).

for treatment group than control group during entire study period. It was significantly higher ($P \leq 0.05$) for treatment group than control at 3rd, 4th, and 5th weeks. Further, cumulative milk yield (for 42 days) was also significantly higher ($P \leq 0.05$) for treatment group than control group (180.08 vs. 150.80 kg) (Table 9). Lesser milk yields in the control group of animals may be attributed to their exposure to higher level of heat stress in comparison to treatment group of animals which is evident from the difference in THI values for both groups of animals (Table 3 and 4) during entire study period.

Similar findings were reported by Das *et al.* (2014) who reported that microclimate modifications, nutrient supplementations and management alterations help in reducing heat stress and has beneficial effect on total milk yield. Bouraoui *et al.* (2002) observed that milk yield in Holstein cows decreased by 0.41 kg/cow/day for each point increase in THI above 69 in Mediterranean climate. Yadav *et al.* (2016) reported that increase in milk yield was more due to wallowing in hot humid season than misting in Murrah lactating buffaloes. Ambulkar *et al.* (2011) also reported significant increase in milk yield under high pressure fogger system in Murrah buffaloes.

There was non-significant difference in morning milk yield between control and treatment groups during entire study period. Also, there was significant difference in evening milk yield between control and treatment group during 1st, 2nd and 6th week. Further, cumulative evening milk yield also differed significantly between these two groups. The difference in total weekly cumulative milk yield during entire study period was solely due to the difference in the evening milk yield between these two groups (Table 9). It indicates that the heat ameliorative measures provided to the treatment group of animals during hotter part of the day (09:00 to 17:00 h) had considerably lowered the heat stress and animals were more comfortable and subsequently produced more milk than control group of animals.

From the findings of this study, it may be concluded that a combination of whitewashing of roof top, fans inside the shed and green agros shade net (75%) in open paddock

and foggers both inside and outside the shed could efficiently act as heat ameliorative measures during hot-dry season as it lowers mean temperature, relative humidity and THI during 09:00 to 17:00 h. It also reduces roof and floor temperatures which ultimately results in lower THI, rectal temperature, respiration rate, higher antioxidant status and subsequently milk yield.

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