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REGULAR ARTICLES

Effect of ambient management interventions on the production and physiological performance of lactating Sahiwal cattle during hot dry summer

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Abstract

During summer season, increase in the environmental temperature in the subtropical regions of Pakistan is negatively affecting the performance of dairy animals. The study objective was to determine the effect of ambient management (90 days) on productive and physiological performance of lactating Sahiwal cows during hot dry summer season. Fifteen lactating cows during the early lactation stage, having similar parity (3), daily milk production (6.2 l), were randomly allocated to three treatments, 5 cows each, i.e., (1) kept under roof shade only, (2) provision of fans along with roof shade, and (3) provision of roof shade, fans, and sprinklers designated as S, SF, and SFS, respectively. The fans were of 360-rpm capacity and showers were on for 40 min after every 90-min interval from 9:00 to 21:00 h. THI values were 81.1 ± 0.7, 80.5 ± 0.7, and 77.7 ± 0.4 under S, SF, and SFS treatments, respectively. Cows were milked twice daily. Respiration rate (RR) and rectal temperature (RT) data were collected at 14:00 h on daily basis. The daily milk production was significantly higher in cows under SF (7.9 ± 1 kg) followed by SFS (6.9 ± 1.2 kg) and S (6.1 ± 0.9 kg) treatments. The mean RT (101.0 ± 0.04 °F) was significantly lower in cows under SFS than that on SF and S treatments and similarly mean RR was also lower (21.2 breaths/min) in cows under SFS followed by SF and S treatments. It is concluded that milk production and physiological performance in Sahiwal cows can be improved by fan-assisted ventilation during hot dry summer in subtropical regions.

Keywords Effect · Hot · Summer · Production · Physiology · Sahiwal · Cattle

Introduction

Many Asian countries are classified as hot dry subtropical regions and are subject to long duration of hot summer having high environmental temperature. Heat stress is the most limiting factor affecting animal's production and farmer income in the subtropical regions. Non-evaporative cooling is less in animals when environmental temperature rises above the thermo-neutral zone (Hansen 2007). Physiological responses to heat stress depend on the duration and intensity of the heat stress and on animal genetics (Kumar et al. 2010). Lactating cows are particularly sensitive to heat stress, which is associated with reduced milk production (Nardone et al. 2006).

Milk protein and milk fat levels showed significant variation among cows during hot environmental conditions. Scanty field conditions data is available on the performance of Sahiwal cows under sprinkling with water to reduce the heat load during hot dry summer, despite the fact that difficulties are being faced in managing the dairy animals in the field rather than controlled experimental conditions (Renna et al. 2010). Effect showering has not been studied earlier in lactating Sahiwal cows in field conditions; therefore, the present study was conducted to determine the effect of strategic ambient management on milk production and physiological performance of Sahiwal cows during hot dry summer season.

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Materials and methods

Location of study

The study was conducted during hot dry summer months (April to June) at the University of Veterinary and Animal Sciences, Ravi campus, Pattoki, Punjab, Pakistan, 31° 1′ N 73° 51′ E. The average rainfall during April, May, and June months was 14, 2.6, and 9.3 mm, and the average minimum and maximum temperature was 19.9 and 34.9 °C, 24.3 and 39.7 °C, and 27.9 and 41.2 °C, respectively.

Experimental animals

Experiment was conducted on 15 ($n = 15$) lactating Sahiwal cows of similar parity (3), daily milk production (6.2 l), and 35–45 days of lactation. Fifteen (15) Sahiwal cows were divided into three groups (5 cows each) according to completely randomized design and assigned to one of the three treatments including (1) kept under roof shade only, (2) roof shade along with fans, and (3) roof shade, fans, and sprinklers during hot day hours between 10:00 AM to 6:00 PM designated as S, SF, and SFS, respectively. Sahiwal cows were fed on oat silage and concentrate (allowance at 5 kg/cow) in twice a day feeding. Fresh drinking water was provided daily ad-lib in rubber tubs, and daily water intake was recorded on weekly interval.

Recording of parameters

Oat silage was analyzed for dry matter (DM), crude protein (CP), and ash contents according to a recommended method (AOAC 2000). Oat grass silage and concentrate DM, CP, and ash values were 41.0 and 91.1, 7.7 and 13.75, 14.2 and 7.1%, respectively. Silage pH and gross energy (kJ/kg) were 3.9 and 15,112, respectively. Sahiwal cows were offered weighed quantity of silage individually, and next morning, refusal was weighed to calculate daily DMI.

The shed temperature and relative humidity were measured by a LCD digital temperature humidity thermometer HTC-1 (power supply 1.5 V × 1, storage condition − 20 to 60 °C, 20–80% RH, Shenzhen DSC Tools Co., Ltd., China) at 12:00 PM and 6:00 PM daily to calculate THI. THI was calculated according to Mader et al. (2006),

$$\mathrm{THI} = (0.8 \times \mathrm{Tdb}) + [(\mathrm{RH}/100) \times (\mathrm{Tdb}{-}14.4)] + 46.4$$

whereas, Tdb = dry bulb temperature; RH = relative humidity.

Milk production was recorded twice daily at morning and evening milking (05:00 AM and 05:00 PM) during the experiment. Milk samples were analyzed on a weekly basis for milk composition using an automatic analyzer, Funke-Gerber Lacto Star.

Respiration rate (RR), pulse rate (PR), skin temperature (ST), and rectal temperature (RT) were recorded twice a week. The RR was measured by observing the flank movement after one complete inward and outward movement through the hand. The PR (beats per 10 s) was recorded from the coccygeal artery. The ST was recorded by a 1.2″ LCD non-contact digital infrared thermometer (laser temperature gun sensor − 50–380 °C) whereas the RT was observed with the help of a digital thermometer (CTA302 digital thermometer, Citizen Systems Japan Co. Ltd). The blood samples were collected from the jugular vein at 7 AM, every 2-week basis, and in sterile vials containing disodium salt of EDTA (2 mg/ml) as anticoagulant under aseptic condition for estimation of white blood cells (WBC), red blood cells (RBC), hemoglobin (Hb), hematocrit (HcT), and serum was collected by centrifuging at 5000 rpm for 5 min just after 2 h of blood collection. Hematological parameters were analyzed through an automated hematological analyzer (Stac Abacus Junior 5 Hematological Analyzer, STAC Medical Science & Technology Co., Ltd., China) on every 2-week basis, while the blood serum was frozen at − 20 °C until further analysis. The blood serum was analyzed by a kit method through spectrophotometer (IRMECO UV-VIS, Model U2020, Serial No. 20A1133, IRMECO GmbH, Geesthacht, Germany). The blood serum was analyzed for serum total protein, albumin, glucose, and cholesterol through commercially available kits (Mignarri et al. 2015) while globulin was calculated by subtracting albumin from total protein.

Statistical analysis

The collected data were subjected to one-way ANOVA test, and multiple comparisons among means were carried out through LSD test (Steel et al. 1997). All the statistical analysis was performed through the statistical software SAS 9.1.3.

Results

Meteorological parameters

During the hot dry period, the ambient temperature (°C) of shed S, SF, and SFS was 33.9, 33.56, and 31.08, respectively. Relative humidity of shed S, SF, and SFS was 39.3, 38.4, and 39.1%, respectively. Whereas, THI was calculated as 81.1, 80.5, and 77.7, in S, SF, and SFS, respectively (Table 1).

Dry matter intake, water intake, milk production, and composition

Daily DMI significantly decreased during hot dry season in Sahiwal cows maintained under S (8.60 kg/day) as compared to that under SF (10.14) and SFS (10.45 kg/day).

Table 1 Ambient temperature and humidity data during hot dry summer

Parameters	S	SF	SFS
Ambient temperature (°C)	33.90 ± 0.85a	33.56 ± 0.75a	31.09 ± 0.55b
Humidity (%)	39.27 ± 2.84a	38.37 ± 3.28a	39.07 ± 3.71a
THI	81.10 ± 0.73a	80.52 ± 0.67a	77.69 ± 0.47b

Different letters within the same row indicate significantly different result ($p < 0.05$)

S shade only (control), *SF* shade and fan, *SFS* shade, fan, and shower

Higher quantity of water intake was observed in cows under S followed by SF and SFS (77.92, 71.05, 69.53 l/day) respectively. Mean daily water intake of different groups of lactating Sahiwal cows during hot dry summer is presented in Table 2.

Milk production (kg/day) was found highest in SF (7.93) followed by SFS (6.94) than that in S (6.06). Milk fat (%) in cows under S, SF, and SFS was found 3.99, 4.05, and 4.42, respectively. Milk protein (%) was 3.55, 3.86, and 3.93 in S, SF, and SFS, respectively. Milk SNF (%) was observed as 8.32, 8.35, and 8.68 in S, SF, and SFS treatment, respectively. Milk lactose (%) was observed 4.56, 4.57, and 4.77 in S, SF, and SFS, respectively.

Physiological parameters

Mean daily rectal temperature in cows under treatment S was 38.6 °C, SF was 38.5 °C, and the SFS was 38.3 °C. Skin temperature of S, SF, and SFS was 34.2, 33.6, and 32.4 °C, respectively. Pulse rate (beats/min) was 69.7, 62.8, and 61.7 in cows under S, SF, and SFS treatments, respectively. Respiration rate (breaths/min) in cows under S, SF, and SFS was 28.04, 24.40, and 21.23, respectively.

Hematology

White blood cells ($10^{-3}/\mu l$) of S, SF, and SFS were 7.1, 7.4, and 7.6, respectively. Red blood cells ($10^{-6}/\mu l$) in cows under S, SF, and SFS treatments were observed as 7.8, 8.2, and 8.3, respectively. The highest increase in RBC concentrations was found in SFS followed by SF than that in S. Hb (g/dl) levels in cows under S, SF, and SFS were 13.1, 13.5, and 13.9, respectively. HcT (%) levels of S, SF, and SFS were 34.4, 35.7, and 36.4, respectively.

Table 2 Productive performance of Sahiwal cows during hot dry summer

Parameters	S	SF	SFS
DMI (kg/day)	8.6 ± 0.71b	10.1 ± 0.38a	10.5 ± 0.39a
Water intake (l/day)	77.9 ± 2.26a	71.0 ± 3.83b	69.5 ± 3.94b
Milk yield (kg/day)	6.1 ± 0.94b	7.9 ± 1.04a	6.9 ± 1.15ab
Fat (%)	3.9 ± 0.06b	4.0 ± 0.05b	4.4 ± 0.07a
Protein (%)	3.6 ± 0.09b	3.8 ± 0.09ab	3.9 ± 0.13a
SNF (%)	8.3 ± 0.12a	8.4 ± 0.13a	8.7 ± 0.11a
Lactose (%)	4.6 ± 0.06a	4.6 ± 0.04a	4.8 ± 0.01a

Means of triplicate analysis. Different letters within the same row indicate significantly different result ($p < 0.05$), $n = 5$ per group

S shade only (control), *SF* shade and fan, *SFS* shade, fan, and shower

Blood serum biochemistry

Total protein (mg/dl) was 8.1, 9.4, and 10.2; albumin (mg/dl) levels were 47.9, 38.5, and 34.6; and blood serum globulin concentrations (mg/dl) were 39.8, 29.1, and 24.3 of in cows under S, SF, and SFS, respectively. Blood serum glucose (mg/dl) in cows under S, SF, and SFS treatment was 73.8, 82.0, and 87.2, respectively. Decreased blood serum glucose concentration (mg/dl) was observed in heat-stressed animals (S) followed by fan-grouped animals (SF) than that in sprinklers group (SFS). Similarly, decreased blood serum cholesterol concentration (mg/dl) was observed in S than that in SF and SFS animals. The cholesterol concentration (mg/dl) was 193.1, 207.4, and 228.2 in cows under S, SF, and SFS treatment, respectively.

Discussion

Increase in environmental temperature and relative humidity together, above a certain limit, forms the index known as THI which when exceeds 72, heat stress condition for dairy animals prevails. During the experimental period, mean THI were well above the normal THI units. THI used to measure when dairy animals suffered from the heat stress (Broucek et al. 2009). In present study, strategic management interventions were taken to decrease heat load and increase animal comfort to get better production as fan increases air flow which in turn, remove heat from the body to make animal's skin temperature within normal range while shower combined with fan cools animals through conduction effect.

Result of dry matter intake, water intake, and milk production SFS animals did not perform better than those in SF because Sahiwal cattle did not like the shower directly on their body. Animals in S treatment had lowered milk production due to decreased DMI. In thermal stress, lower milk production was

Table 3 Physiological parameters of Sahiwal cows during hot dry summer

Parameters	S	SF	SFS
Rectal temperature (°C)	38.6 ± 0.07a	38.5 ± 0.09a	38.3 ± 0.04b
Skin temperature (°C)	34.2 ± 0.25a	33.6 ± 0.27a	32.4 ± 2.01b
Pulse rate (beats per min)	69.7 ± 0.55a	62.8 ± 1.25b	61.7 ± 2.14b
Respiration rate (breaths/min)	28.1 ± 0.75a	24.4 ± 0.79b	21.2 ± 1.7c

Means of triplicate analysis. Different letters within the same row indicate significantly different result ($p < 0.05$), $n = 5$ per group

S shade only (control), *SF* shade and fan, *SFS* shade, fan, and shower

the basic result of decreased energy balance or lowered nutrient intake. Our results are in line with those of the study by Karimi et al. (2015) who observed increased milk production in cooled animals in heat stress conditions. Cardot et al. (2008) reported heat-stressed dairy cow-ingested feed intake (20.5 kg/day) that were similar to the present study. The significant reduction in environmental temperature in the evening enhances the cows to dissipate maximum heat load accumulated during the daytime.

Significantly, increased quantity of water intake was observed in the controlled group, while, non-significant difference was observed in SF and SFS. Increased water intake and decreased DMI might be used as strategy by the animals to ameliorate heat load during hot dry period. Water intake was increased in heat-stressed cows to dissipate heat load through respiratory tract and evaporation means. So, water intake increased in S as compared to that in other groups. The result of the present study is in line with that of the study by O'Brien et al. (2010) who reported increased quantity of water intake in cows during heat stress period.

Cow milk composition during hot dry summer is presented in Table 2. Decrease in milk fat and milk protein (%) might be associated with increase in environmental temperature. When environmental temperature increased, it decreases the fatty acid synthesis which in turns reduces the milk fat (Yasmin et al. 2012). Decreased milk protein contents could be due to the decreased dry matter intake as well as might be due to decreased energy intakes. Decreased level of DMI during the lactation is associated with depression in protein content. Results of our study are in harmony with those of the study by Yasmin et al. (2012) who reported decreased milk fat and protein contents during hot summer months (Tables 3 and 4).

Body temperature and RR of dairy animals indicate great susceptibility to hot environment; therefore, it is a sensitive indication of heat stress (Das et al. 2016). Changes in ST and RR might be related with the changes in the ambient temperature and higher value of ambient temperature was found in S so the animals kept in S showed increased ST and RR than those in the SF and SFS. Increase in the RR is the first reaction when dairy animals experience increased environmental temperature. Vaidya et al. (2014) reported increased ST in cattle during the summer season. Increased in respiration rate may be used as an index of discomfort in dairy animals.

Blood hematology results were in harmony with that of the study by Parmar et al. (2013) in Sahiwal cows, and who reported non-significant difference in WBC and Hb concentration in cow during the hot summer season. Significant increase in RBC and HcT was observed during the hotter months of summer in thermal-stressed group of animals. In the hot summer season, increased RBC and HcT concentration may be due to the hemo-concentration, which may be developed due to dehydration or excitement, resulting in the erythrocytes concentrated in the spleen which may have resulted in abnormal increased HcT (Reece 2005). These results are in agreement with those of the studies by Chaudhary et al. (2015), who reported increased RBC in cattle during hot dry season.

Results of the present study revealed that hot dry summer exerted serious effect on some biochemical parameters of lactating Sahiwal cattle. Serum total protein concentration decreased and their fraction; albumin and globulin levels increased in controlled treatment (S), and vice versa in the sprinkling with water Sahiwal cows, with significant difference ($p < 0.05$) for total protein, albumin, and globulin in heat-stressed animals (S) than that in cooled animals (SFS). Saleh and El-Sokkary (2003) reported decreased production of total protein, albumin, and globulin in camel during heat stress period. Decrease in serum glucose might be due to lowered energy intake as consequences of decreased dry matter intake

Table 4 Hematological values of Sahiwal cattle during hot dry summer

Parameters	S	SF	SFS
WBC (10^{-3}/μl)	7.19 ± 0.10	7.40 ± 0.07	7.62 ± 0.14
RBC (10^{-6}/μl)	7.87 ± 0.2b	8.23 ± 0.12ab	8.34 ± 0.15a
Hb (g/dl)	13.1 ± 0.52	13.5 ± 0.17	13.9 ± 0.89
HcT (%)	34.44 ± 0.6c	35.73 ± 0.29b	36.42 ± 0.67a

$n = 5$. Different letters within the same row indicate significantly different result ($p < 0.05$)

S shade only (control), *SF* shade and fan, *SFS* shade, fan, and shower, *WBC* white blood cells, *RBC* red blood cells, *Hb* hemoglobin, *HcT* hematocrit

Table 5 Blood biochemical parameters of Sahiwal cattle during hot dry summer

Parameters	S	SF	SFS
Total protein (mg/dl)	8.09 ± 0.25c	9.38 ± 0.16b	10.26 ± 0.66a
Albumin (mg/dl)	47.89 ± 1.75a	38.51 ± 1.95b	34.60 ± 2.71b
Globulin (mg/dl)	39.81 ± 1.44a	29.08 ± 2.01b	24.34 ± 2.98b
Glucose (mg/dl)	73.83 ± 2.66b	82.03 ± 2.01ab	87.23 ± 1.97a
Cholesterol (mg/dl)	193.10 ± 2.97c	207.45 ± 4.43b	228.23 ± 6.99a

$n = 5$. Different letters within the same row indicate significantly different result ($p < 0.05$)

S shade only (control), *SF* shade and fan, *SFS* shade, fan, and shower

and the negative effect of thermal stress on gluconeogenesis of heat-stressed animals in hot environment. Decreased values of glucose during hot summer were observed by Shwartz et al. (2009), who reported lower level of glucose in heat-stressed animals due to muscular catabolism for energy supply. Abeni et al. (2007) reported lower value of glucose explained by the negative effect due to reduction in gluconeogenesis. Results of serum cholesterol are presented in the Table 5. Reduced DMI could play an important role in decreased cholesterol concentration of heat-stressed animals. This decreased DMI might have additional stress to cholesterol synthesis in thermal-stressed animals. Results of the present study are in line with those of Rasooli et al. (2004) in cattle and Sejian et al. (2010) in ewes, who reported decreased cholesterol in thermally stressed animals during hot summer.

Conclusion

It is concluded that productive and physiological performance of lactating Sahiwal cows can be improved by providing facility of fan-assisted ventilation during hot dry summer in subtropical regions.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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