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Influence of Season and Pregnancy on Thermoregulation and Haematological Profile in Crossbred Dairy Cows in Tropical Environment

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Abstract: The objective of this study was to evaluate the effects of season (summer vs winter) and stage of pregnancy on thermoregulation and haematological responses of crossbred dairy cows (Holstein-Friesian X Zebu) under tropical conditions. The rectal temperature (T_r) and respiration rate (RR) were significantly higher during summer at all stages of pregnancy. There was significant increase in T_r and RR with the advance of pregnancy in summer. Summer was associated with significantly lower packed cell volume (PCV) and haemoglobin (Hb) concentration in non pregnant cows. The PCV and Hb concentration tended to increase with the advance in pregnancy course in both seasons. The total leukocyte count (TLC) was significantly higher only in early pregnancy in winter. Environmental and nutritional measures should be adopted for alleviation of environmental stress in dairy farms.

Key words: Dairy cows · Season · Pregnancy · Thermoregulation · Blood parameters

INTRODUCTION

Dairy cattle are exposed to stressful climatic conditions in tropical regions, which influence their productivity and welfare. The indigenous Zebu (*Bos indicus*) breeds are adapted and tolerant to the hot environments because of low metabolic rate and great sweating capacity [1,2], but generally they exhibit low productive and reproductive performance [3]. Crossbreeding of cattle has been adopted for blending the adaptability of tropical cattle with the high milking potential of exotic breeds. However, the local environment can sustain only composite genotypes of a moderate level of *Bos taurus* blood [4]. Friesian crossbreds were noted to be the most suitable for their adaptability in addition to their high milking capacity. Adaptation to tropical environment has been reduced when the local Butana and Kenana cattle were crossbred with high producing, non-adapted Holstein-Friesian breed. Furthermore, selection for high milk yield was reported to reduce the heat tolerance of cows which magnifies the seasonal depression in productivity caused by climatic stress [5,6]; accordingly, high yielding cows are more sensitive to hot environment compared to low yielding cows [7,8].

Exposure of dairy cows to hot environment during summer could stimulates thermoregulatory mechanisms and produces reduction in the rates of metabolism, feed intake and productivity [9]. Heat stress influences reproduction and represents a major factor for lower fertility during summer in tropical environments. It reduces the length and intensity of oestrus [10, 11]. The competence of oocyte for fertilization and subsequent development is reduced during times of the year associated with heat stress [12, 13] and depression in conception rate in hot environment has been documented [14-16].

The blood constituents may reflect the influences of thermal stress and the physiological state of dairy cows. Assessment of PCV and Hb concentration was included in metabolic profile test amongst other biochemical constituents of blood [17-19]. Haemoconcentration may occur during hot weather. Toharmat *et al*. [20] reported an increase in PCV value and haemoglobin concentrations during summer, that could be associated with dehydration. Stressors including high ambient temperature which increase the level of glucocorticoids are linked to lower cellular immunity in animals [21]. A higher susceptibility to infections has been observed in cows suffering from heat stress [22]. However, reports on the effects of heat stress on the cell-mediated immunity of bovines are conflicting [23]. Additionally, stress-induced immunosuppression may be inhibited by pregnancy [24].

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Research is needed to evaluate the physiological performance of dairy cows under tropical conditions, so that the patterns of responses to climatic stress and physiological state can be established. Although the changes in indices as rectal temperature and respiration rate are ultimate indicators of heat stress, such data are not available for cattle in the tropics. The information obtained can be utilized in adopting environmental control and nutritional strategies that can alleviate stress and improve reproductive performance and milk yield. The findings could also be used to monitor the health status of cows. Therefore, the present study was undertaken to assess the effects of seasonal change in thermal environment and stage of pregnancy on thermoregulation and some haematological variables of crossbred dairy cows under local tropical conditions.

MATERIALS AND METHODS

Animals and Management: Clinically healthy, multiparous crossbred (Butana X Friesian) dairy cows, aged 5-8 years were used in the study. The cows were selected from the herd of the governmental dairy farm at Khartoum North (15° 36' N; 32° 35' E). The animals were generally maintained on the normal grazing programme under natural summer and winter conditions. Animals were kept in shaded pens located close to the milking parlor, with appropriate facilities for feeding and watering. The non-grazing nutritional regimen comprised two types of feeds: roughages and concentrates. There were two types of roughages: alfalfa (*Medicao sativa*) and Abu 70 (*Sorghum bicolor*). The lactating cows were fed supplemental concentrate mixture twice daily, before milking at 8.00 a.m. and at 11.00 p.m. The roughages were offered twice daily at 10.00 a.m. and 5.00 p.m. Tables 1 shows the nutrient composition of the two types of roughage and the concentrate consumed by cows during the experimental period. All animals had free access to tap water during the course of the study.

Experimental Plan: The effect of season (summer vs winter) and physiological status of dairy cows on thermoregulation and blood constituents were assessed. In each season, 24 cows were assigned to 4 groups of 6 each: a group of non pregnant cows served as control and 3 groups represented, early, mid-and late pregnancy. The baseline data were obtained for all experimental groups of animals. Then the rectal temperature (Tr) and respiration rate (RR) were measured and blood samples were collected weekly at 9.00 to 11.00 a.m. for 9 weeks in each season. The haematological parameters were determined immediately after blood sampling.

Table 1: The nutrient composition of roughages and concentrate (g/kg)

Ingredients	Alfalfa (*Medicago sativa*)	Abu 70 (*Sorghum bicolor*)	Concentrate
Dry matter	230	280	952
Crude protein	46.1	19.2	29.25
Crude fibre	70.0	108.0	35.3
Ether extract	3.3	8.4	3.99
Ash	28.2	23.9	7.88

Climatic Conditions: The climatic data were obtained from the Meteorological Department of the Ministry of Science and Technology; the mean values of ambient temperature (Ta) and relative humidity (RH) recorded during the experimental period were calculated. The temperature-humidity index (THI) was computed using the equation described by Ravagnolo *et al.* [25]:

$$THI= (1.8 \times T + 32)-[(0.0055 \times RH) X (1.8 \times T-26)]$$

Where: T = Air temperature (°C)
RH = Relative humidity (%)

Rectal Temperature (Tr) and Respiration Rate (RR): The measurements of Tr of cows were made to the nearest ± 0.1°C using a certified digital thermometer. The thermometer was inserted into the rectum to a depth of approximately 8 cm for one minute before the reading was obtained. RR was measured visually by counting the flank movement with the aid of a stopwatch. The value was taken for one minute of regular breathing with the animal standing quietly.

Blood Collection and Analysis: Blood samples were collected aseptically by venipuncture from the jugular vein using disposable syringes and were immediately transferred to test tubes containing Na_2-EDTA as anticoagulant. The samples were used for haematological measurements using standard methods [26]. The packed cell volume (PCV) was measured in plain capillary tube using a microhaematocrit centrifuge (Hettich-Germany). The haemoglobin concentration (Hb) was determined by cyanmethaemoglobin technique using Drabkin's solution. The total leukocyte count (TLC) was performed in an imporoved Neubauer haemocytometer using Turk's solution dilution fluid.

Statistical Analysis: The experimental data obtained for 18 weeks covering two seasons (summer and winter) at different stages of pregnancy in dairy cows have been subjected to standard methods of statistical analysis. The mean values and standard deviations (Mean ±SD) were calculated and the analysis was performed using General

Linear Methods (GLM) procedure of Statistical Analysis System [27]. Analysis of variance (ANOVA) test was used to evaluate the effects of season and stage of pregnancy on thermoregulation and haematological parameters. The differences are considered statistically significant at *P* value < 0.05.

RESULTS

Climatic Conditions: The ambient temperature (Ta), relative humidity (RH) and temperature-humidity index (THI) prevailing during the experimental period are shown in Table 2. The data indicate that the highest mean values of Ta (°C) were measured in June in dry summer while the minimum mean value was recorded during December in winter. The minimum mean value of RH (%) was measured in June, during dry summer, whereas higher mean value was recorded in March during winter. The THI value during summer (80.92) was markedly higher compared to the value obtained in winter (65.75).

Thermoregulation: Table 3 shows the effects of season and stage of pregnancy on rectal temperature (Tr) in dairy cows. Tr was significantly higher during summer for both non pregnant (P<0.05) and pregnant cows at different stages of pregnancy (P<0.001). During summer, cows in mid-and late pregnancy had significantly (P<0.001) higher Tr values compared to early pregnancy and non pregnant cows. However, during winter, there was no significant increase in Tr with the advance of pregnancy.

Table 2: The mean values of ambient temperature, Ta (°C), relative humidity, RH (%) and temperature-humidity index (THI) during the experimental period

	Ta (°C)			RH (%)	THI
	Max.	Min.	Mean	(Mean)	(Mean)
Summer	40.3±3.0	25.7±2.3	32.9±1.7	43.4±19.8	80.92
Winter	27.6±2.5	14.8±1.9	21.3±1.9	33.1±5.3	65.75

Table 3: Effects of season and stage of pregnancy on rectal temperature, T_r (ºC) in dairy cows

	Season		
Group	Summer	Winter	LS
A	$^{A}38.35±0.31^{a}$	$^{A}38.13±0.67^{b}$	*
B	$^{A}38.48±0.24^{a}$	$^{A}38.19±0.48^{b}$	***
C	$^{B}38.71±0.46^{a}$	$^{A}38.17±0.64^{b}$	***
D	$^{B}38.81±0.46^{a}$	$^{A}38.30±0.48^{b}$	***
LS	***	NS	

A: Empty cows; B: Early pregnancy; C: Mid pregnancy; D: Late pregnancy
^{A,B}: Mean values within the same column with different superscripts (capital) are significantly different.
^{a,b}: Mean values within the same row with different superscripts (small) are significantly different.
*: P<0.05 ***: P<0.001 NS: Not significant

Table 4: Effect of season and stage of pregnancy on respiratory rate, RR (breaths/min) in dairy cows

	Season		
Group	Summer	Winter	LS
A	$^{A}40.92±4.90^{a}$	$^{A}33.83±2.44^{b}$	***
B	$^{A}41.33±5.30^{a}$	$^{A}34.23±2.24^{b}$	***
C	$^{A}42.83±5.90^{a}$	$^{A}34.03±2.43^{b}$	***
D	$^{B}45.37±6.20^{a}$	$^{B}35.03±2.42^{b}$	***
LS	***	*	

A: Empty cows; B: Early pregnancy; C: Mid pregnancy; D: Late pregnancy

^{A,B}: Mean values within the same column with different superscripts (capital) are significantly different.
a,b: Mean values within the same row with different superscripts (small) are significantly different.
*: P<0.05 ***: P<0.001

Table 5: Effect of season and stage of pregnancy on PCV (%) in dairy cows.

	Season		
Group	Summer	Winter	LS
A	$^{A}28.54±3.79^{a}$	$^{A}30.96±4.13^{b}$	**
B	$^{B}32.27±3.45^{a}$	$^{B}31.87±3.08^{a}$	NS
C	$^{B}34.25±2.26^{a}$	$^{B}33.88±4.79^{a}$	NS
D	$^{C}35.56±2.89^{a}$	$^{C}36.08±4.33^{a}$	NS
LS	***	***	

A: Empty cows; B: Early pregnancy; C: Mid pregnancy; D: Late pregnancy

^{A,B,C}: Mean values within the same column with different superscripts (capital) are significantly different.
^{a,b}: Mean values within the same row with different superscripts (small) are significantly different.
**: P<0.01 ***: P<0.001 NS: Not significant

Table 6: Effect of season and stage of pregnancy on haemoglobin concentration, Hb (g/dL) in dairy cows

	Season		
Group	Summer	Winter	LS
A	$^{A}11.39±2.00^{a}$	$^{A}11.41±2.84^{b}$	*
B	$^{A}11.99±2.04^{a}$	$^{A}11.48±1.17^{a}$	NS
C	$^{B}12.99±1.56^{a}$	$^{B}12.61±1.90^{a}$	NS
D	$^{C}13.46±1.32^{a}$	$^{C}13.36±1.41^{a}$	NS
LS	***	***	

A: Empty cows; B: Early pregnancy; C: Mid pregnancy; D: Late pregnancy

^{A,B,C}: Mean values within the same column with different superscripts (capital) are significantly different.
^{a,b}: Mean values within the same row with different superscripts (small) are significantly different.
*: P<0.05 ***: P<0.001 NS: Not significant

Table 7: Effect of season and stage of pregnancy on total leukocyte count, TLC (X10^3/μL) in dairy cows.

	Season		
Group	Summer	Winter	LS
A	^{A}8.41±1.30^a	^{A}8.79±2.11^a	NS
B	^{A}8.42±1.27^a	^{B}9.69±2.17^b	***
C	^{A}8.66±1.37^a	^{A}8.63±2.38^a	NS
D	^{A}8.25±1.37^a	^{A}7.92±2.989^a	NS
LS	NS	**	

A: Empty cows; B: Early pregnancy; C: Mid pregnancy; D: Late pregnancy

^{A,B}: Mean values within the same column with different superscripts (capital) are significantly different.

^{a,b}: Mean values within the same row with different superscripts (small) are significantly different.

**: P<0.01 ***: P<0.001 ; NS: Not significant

Table 4 shows that the cows maintained significantly (P<0.001) higher respiration rate (RR) during summer for all physiological states investigated. The cows had significantly higher RR values during late pregnancy in summer (P<0.001) and winter (P<0.05).

Haematological Values: Tables 5 and 6 show that non pregnant cows had significantly lower PCV (< 0.01) and Hb concentration(< 0.05) values in summer. In both seasons, there was a significant (P<0.001) increase in PCV and Hb concentration with the advance of pregnancy. Table 7 shows that the cows had significantly (P<0.01) higher total leukocyte count (TLC) in winter only for early pregnancy state.

DISCUSSION

This study evaluated the effects of seasonal change in thermal environment and pregnancy on thermoregulation and some haematological parameters in crossbred dairy cows. The climatic data (Table 2) indicate that the cows were exposed to higher thermal load during tropical summer. The THI value during summer (80.92) induced high heat stress; the value during winter (65.75) is considered to be comfortable to dairy cows. The THI is usually used as an indicator of thermal stress in animals. Heat stress in dairy cows is considered to be cool when THI values are lower than 72. Index values higher than 72, 78, and 88 reflect the potential for mild, high and severe levels, respectively [6]. Kendall *et al*. [28] indicated that the THI threshold for lactating dairy cows indicating the first physiological response to thermal stress was THI: 67. Although THI is simplistic, it is currently the best heat stress indicator for attle, and can account for up to 78% of an animal's response to the climatic environment [29]. The high THI reported during summer in the current study may compromise the success of pregnancy in cows. The pregnancy rate of dairy cows declined from 55 to 10% when the THI increased from 70 to 84 [30]. Other studies [31, 32] reported that in dairy cows, the conception rates were lower during summer months compared to inter.

Seasonal change in thermal environment influenced thermoregulation in dairy cows. The effects of hot environment are associated with change in heat balance, and accordingly higher values of Tr and RR were measured under hot summer conditions (Tables 3 and 4). In line with the present results, other researchers have reported that the body temperature of cows in summer was higher than that in winter [13, 15, 33]. Berman *et al*. [34] suggested that the upper limit of ambient temperature at which Holstein cattle may maintain a stable body temperature is 24-26°C and that above 26°C, practices should be instituted to minimize the rise in body temperature. The thermal load on cows subjected to heat stress is the sum of heat gained from the environment and heat generated by metabolic processes. Previous studies indicate that respiratory rate (RR) is positively correlated with ambient temperature [35] and THI [36], so that RR may be used as an indicator of heat stress in cattle [37]. However, Kadzere *et al*. [38] noted that the body temperature of dairy cattle shows great susceptibility to thermal load and it is considered as a sensitive indicator of thermal stress.

The results indicate that pregnancy influenced the thermal responses of dairy cows. The increase in rectal temperature (Tr) and respiration rate (RR) with the advance of pregnancy, particularly during summer (Tables 3 and 4) is associated with increase in metabolic heat production and confirms findings reported by other researchers [39,40]. Furthermore, prior studies also indicated that extra heat production that occurs during pregnancy is primarily foetal in origin and the foetus loses its heat via foetal circulation and uterine wall [41,42]. Hormones play a major role in thermoregulation during pregnancy; secretion of adrenocortical hormones and sex hormones may increase basal metabolic rate (BMR) during mid-and late pregnancy, which influences thermoregulation of the mother [43]. Secretion of progesterone during pregnancy increases the sensitivity of respiratory centre to CO_2 which influences pulmonary ventilation. The increase in RR during pregnancy could also be related to the fact that pregnancy leads to limited excursion of the diaphragm; this is compensated by increase in respiratory frequency. The more pronounced pattern of thermal responses of cows with advance of pregnancy in summer indicates additive effects of gestation and environmental temperature.

The PCV and Hb concentration showed significantly higher values in winter for empty cows. However, no significant differences were observed between summer and winter in different stages of pregnancy (Tables 5 and 6). This finding is in general agreement with Toharmat and Kume [44]; they did not find significant difference in PCV and Hb between hot and cool environment. The current result, however, disagrees with the findings reported by Toharmat *et al*. [20] which demonstrated increases in PCV and Hb concentration in summer. The observed decrease in PCV and Hb concentration in non-pregnant cows during summer could be attributed to haemodilution and is in general agreement with the results of Lee *et al*. [45]. Heat stress influences energy and water metabolism [46] and it may induce increases in plasma and extracellular fluid volume in proportion to the thermoregulatory requirement [38]. The decline in PCV and Hb in heat-stressed animals could be attributed to haemolysis, haemadilution and /or to reduction in cellular O_2 requirements to minimize metabolic heat production [47]. The decrease in haematological indices of empty cows during summer could also partly be associated with a decline in food intake.

The haematological indices were influenced by pregnancy and thermal environment. Pregnancy influenced PCV and Hb concentration in dairy cows. In both seasons, the PCV and Hb concentration showed increase with the advance of pregnancy (Tables 5 and 6). In Holstein-Friesian cows, Hb decreased with ongoing lactation and pregnancy, but increased several weeks before parturition [18]. Our results for crossbred cows are in general agreement with other reports in cows in the tropics [48,49]. Similar results were also reported in sheep [50,51]. The increase in Hb concentration during pregnancy may be associated with erythrocyte release from the spleen due to the stress of pregnancy [52]. Also it could be related to changes in erythrocyte stimulating factor (ESF) release which is controlled by the relationship between oxygen demand of tissues and the amount of oxygen carried by blood [26].

The irregular pattern of total leukocyte count (TLC) observed in the current study (Table 7) could be attributed to the fact that the TLC is affected by many internal and external factors which may not induce similar effects under farm conditions. However, previous studies in sheep [51, 53] reported an increase in TLC at parturition associated with neutrophilia and lymphopenia. For early pregnancy data, the TLC was significantly higher in winter compared to respective summer value (Table 7). However, previous reports [45,54, 55] indicated that high ambient temperature evoked leukocytosis in cattle.

In conclusion, the results indicate that crossbred dairy cows are exposed to climatic stress during tropical summer conditions. Although cattle may have the ability to adapt physiologically and cope with environmental stress, necessary measures should be adopted to minimize the adverse effects during summer.

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REFERENCES

1. Blackshaw, J.K. and A.W. Blackshaw, 1994. Heat stress in cattle and the effect of shade on production and behaviour. Austral. J. Exp. Agric., 34: 285-295.
2. Hansen, P.J., 2004. Physiological and cellular adaptation of Zebu cattle to thermal stress. Anim. Rep. Sci., 82-83: 349-360.
3. Ageeb, A.G. and J.K. Hiller, 1991. Effects of crossing local Sudanese cattle with British Friesians on performance traits. Bul. Anim. Health Prod., 39: 69-76.
4. Musa, L.M.A., R.C.D. Bett, M.K.A. Ahmed and K.J. Peters, 2008. Breeding options for dairy cattle improvement in the Sudan. Outlook on Agric., 37: 289-295.
5. Al-Katanani, Y.M., D.W. Webb and P.J. Hansen, 1998. Factors affecting seasonal variation in non-return rate of lactating dairy cows. J. Dairy Sci., 81(Suppl. 1): 217 (Abstract).
6. Chaiyabutr, N., S. Champongsang and S. Suadsong, 2008. Effect of evaporative cooling on the regulation of body water and milk production in crossbred Holstein cattle in a tropical environment. Int. J. Biometeorol., 52: 575-585.
7. Igono, M.O. and H.D. Johnson, 1990. Physiological stress index of lactating dairy cows based on diurnal pattern of rectal temperature. J. Interdiscipl. Cycl. Res., 21: 303-320.

8. West, J.W., 2003. Effects of heat stress on production in dairy cattle. J. Dairy Sci., 86: 2131-2144.
9. Armstrong, D.V., 1994. Heat stress interaction with shade and cooling. J. Dairy Sci., 77: 2044-2050.
10. Abilay, T.A., H.D. Johnson and M. Madan, 1975. Influence of environmental heat on peripheral plasma progesterone and cortisol during the bovine estrous cycle. J. Dairy Sci., 58: 1836-1840.
11. Jordan, E.R., 2003. Effects of heat stress on reproduction. J. Dairy Sci., 86 (E Suppl.): E 104-E 114.
12. Zeron, Y., A. Ocheretny, O. Kedar, A. Borochov, D. Sklan and A. Arav, 2001. Seasonal changes in bovine fertility: relation to developmental competence of oocytes, membrane properties and fatty acid composition of follicles. Reproduction, 121: 447-454.
13. Al-Katanani, Y.M., F.F. Paula-Lopez and P.J. Hansen, 2002. Effect of season and exposure to heat stress on oocyte competence in Holstein cows. J. Dairy Sci., 85: 390-396.
14. Du Preez, J.H., S.J. Terblanche, W.H. Gieseke, C. Maree and M.C. Welding, 1991. Effect of heat stress on conception in a dairy herd model under South African conditions. Theriogenology, 35: 1039-1049.
15. Ryan, D.P., J.F. Prichard, E. Kopel and R.A. Godke, 1993. Comparing early embryo mortality in dairy cows during hot and cool season of the year. Theriogenology, 39: 719-737.
16. De Rensis, F. and R.J. Scaramuzzi, 2003. Heat stress and seasonal effect on reproduction in the dairy cow. Theriogenology, 60: 1139-1151.
17. Payne, J.M., S.M. Dew, R.I. Manston and F. Margaret, 1970. The use of metabolic profile test in dairy herds. Vet. Rec., 87: 150-158.
18. Steinhardt, M., H.H. Thielscher, T. von Horn, R. von Horn, K. Ermgassen, J. Ladewig and D. Smidt, 1994. The haemoglobin concentration in the blood of dairy cattle of different breeds and their offspring during the peripartum period. Tierarztl Prax, 22: 129-135.
19. Kida, K., 2002. The metabolic profile test: Its practicability in assessing feeding management and periparturient diseases in high yielding commercial dairy herds. J. Vet. Med. Sci., 64: 557-563.
20. Toharmat, T., I. Nonaka, M. Shimizu, K.K. Batajoo and S. Kume, 1998. Effects of prepartum energy intake and calving season on blood composition of periparturient cows. Asian-Austral. J. Anim. Sci., 11: 739-745.
21. Sunil Kumar, B.V., K. Ajeet and K. Meena, 2010. Effect of heat stress in tropical livestock and different strategies for its ameliorations. J. Stress Physiol. Biochem., 7: 45-54.
22. Webster, A.J.F., 1983. Environmental stress and the physiology, performance and health of ruminants. J. Anim. Sci., 57: 1584-1593.
23. Lacetera, N., U. Bernabucci, D. Scalia, B. Ronchi, G. Kuzminsky and A. Nardone, 2005. Lymphocyte functions in dairy cows in hot environment. Int. J. Biometeorol., 50: 105-110.
24. Nakamura, H., T. Seto, H. Nagase, M. Yoshida, S. Dan and K. Ogino, 1997. Inhibitory effect of pregnancy on stress-induced immunosuppression through corticotropin hormone (CRH) and dopaminergic systems. J. Neuroimmunol., 75: 1-8.
25. Ravagnolo, O., I. Misztal and G. Hoogenboom, 2000. Genetic component of heat stress in dairy cattle, development of heat index function. J. Dairy Sci., 83: 2120-2125.
26. Jain, C.N., 1996. Schalm's Veterinary Haematology. 5th edn. Lee and Febiger, Philadelphia.
27. SAS Users Guide, 1996. Statistics, Version 6.11 Edition: SAS Inst., Inc., Cary, NC, USA.
28. Kendall, P.E., G.A. Verkerk, J.R. Webster and C.B. Tucker, 2007. Sprinklers and shade cool cows and reduce insect-avoidance behavior in pasture-based dairy systems. J. Dairy Sci., 90: 3671-3680.
29. Gaughan, J.B., T.L. Mader, S.M. Holt, G.L. Hahn and B.A. Young, 2002. Review of current assessment of cattle and microclimate during periods of high heat load. Anim. Prod. Austr., 24: 77-80.
30. Ingraham, R.H., D.D. Gillette and W.C. Wagner, 1974. Relationship of temperature and humidity to conception rate in Holstein cows in a subtropical climate. J. Dairy Sci., 57: 476-481.
31. Villa-Mancera, A., M. Mendez-Mendoza, R. Huerta-Crispin, F. Vazquez-Flores and A. Cordova-Izguierdo, 2011. Effect of climatic factors on conception rate of lactating dairy cows in Mexico. Trop. Anim. Health Prod., 43: 597-601.
32. Nabenishi, H., H. Ohta, T. Nishimoto, T. Morita, K. Ashizawa and Y. Tsuzuki, 2011. Effect of temperature-humidity index on body temperature and conception rate of lactating dairy cows in southwestern Japan. J. Reprod. Dev., 57: 450-456.

33. Bewley, J.M., M.E. Einstein, M.W. Grott and M.M. Schutz, 2008. Comparison of reticular and rectal core temperatures in lactating dairy cows. J. Dairy Sci., 91: 4661-4672.
34. Berman, A., Y.M. Folman, M. Kaim, Z. Mamen, D. Herz, A. Wolfenson and Y. Graber, 1985. Upper critical temperatures and forced ventilation effects for high yielding dairy cows in a tropical climate. J. Dairy Sci., 68: 1488-1495.
35. Eigenberg, R.A., G.L. Hahn, J.A. Nienaber, T.M. Brown-Brandl and D.E. Spiers, 1999. Development of a new respiration rate monitor for cattle. Trans. ASAE, 43: 723-728.
36. Bouraoui, R., M. Lahmar, A. Majdoub, M. Djemali and R. Belyea, 2002. The relationship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate. Anim. Res., 51: 479-491.
37. Gaughan, J.B., S.M. Holt, G.L. Hahn, T.L. Mader and R. Eigenberg, 2000. Respiration rate-is it a good measure of heat stress in cattle. Asian-Austral. J. Anim. Sci., 13(Suppl.): 329-332.
38. Kadzere, C.T., M.R. Murphy, N. Silanikove and E. Maltz, 2002. Heat stress in lactating dairy cows: a review. Livest. Prod. Sci., 77: 59-91.
39. Metcalfe, J., M.K. Stock and D.H. Barron, 1988. Maternal physiology during gestation. In: The Physiology of Reproduction, (Editors: E. Knobil and J.D. Neil). pp: 121-130. Raven Press, New York..
40. Freetly, H.C. and C.L. Ferrell, 1997. Oxygen consumption and blood flow across the portal drained viscera and liver of pregnant ewes. J. Anim. Sci., 75: 1950-1955.
41. Rattray, P.V., W.N. Garrett, N.E. East and N. Hinman, 1974. Efficiency of utilization of metabolizable energy during pregnancy and energy requirement for pregnancy in sheep. J. Anim. Sci., 38: 383-393.
42. Schroder, H., R.D. Gilbert and G.G. Power, 1988. Computer model of foetal-maternal heat exchange in sheep. J. Appl. Physiol., 65: 460-468.
43. Guyton, A.C. and J.E. Hall, 1996. Overview of the circulation; Medical physics of pressure, flow and resistance. In: Textbook of Medical Physiology. 9th Edn. pp: 161-164. W.B. Saunders, Philadelphia, P.A.
44. Toharmat, T. and S. Kume, 1997. Effect of heat stress on minerals concentration in blood and colostrum of heifers around parturition. Asian-Austral. J. Anim. Sci., 10: 298-303.
45. Lee, J.A., J.D. Roussel and J.F. Beatty, 1976. Effect of temperature-season on bovine adrenal cortical function, blood cell profile and milk production. J. Dairy Sci., 59: 104-108.
46. Silanikove, N., 1994. The struggle to maintain hydration and osmoregulation in animals experiencing dehydration and rapid rehydration: the story of ruminants. Exp. Physiol., 79: 281-300.
47. Habeeb, A.A., I.F.M. Marai and T.H. Kamal, 1992. Heat stress. In: Farm Animals and the Environment (Editors: C. Phillips and D. Piggins) pp: 27-47. CAB International, Wallingford, U.K.
48. Baqi, M.A. and M.M. Rahman, 1987. Study on some haematological values at different stages of pregnancy of Pabna milking cows. Indian J. Dairy Sci., 40: 368-370.
49. Rajora, V.S. and S.P. Pachauri, 1994. Blood profiles in pre-parturient and post-parturient cows and in milk fever cases. Indian J. Anim. Sci., 64: 31-34.
50. Anosa, V.O. and D.A. Ogbogu, 1979. The effect of parturition on the blood picture of sheep. Res. Vet. Sci., 26: 380-382.
51. Hassan, G.A., M.H. Salem, F.D. El-Nouty, A.B. Okab and M.G. Latif, 1987. Haematological changes during summer and winter pregnancies in Barki and Rahmani sheep (*Ovis aries*). World Rev. of Anim. Prod., 23: 89-95.
52. Kumar, B. and S.P. Pachauri, 2000. Haematological profile of crossbred dairy cattle to monitor herd health status at medium elevation in central Himalayas. Res. Vet. Sci., 69: 141-145.
53. Roy, A., K.L. Sahni and I.C. Datta, 1965. Studies on certain aspects of sheep and goat husbandry. VII-Variations in blood corpuscles of sheep and goat during different seasons, pregnancy, parturition and post-parturition period. Indian J. Vet. Sci., 35: 24-32.
54. Wegner, T.N., J.D. Schuh, F.E. Nelson and G.H. Stott, 1976. Effect of stress on blood leukocyte and milk somatic cell counts in dairy cows. J. Dairy Sci., 59: 949-956.
55. Elvinger, F., P.J. Hansen and R.P. Natzke, 1991. Modulation of function of bovine polymorphonuclear leukocytes and lymphocytes by high temperature *in vitro* and *in vivo*. Am. J. Vet. Res., 52: 1692-1698.