HEAT STRESS ALLEVIATING MEASURES FOR CROSSBRED COWS

By

P. THIRUMURUGAN

THESIS

Submitted in partial fulfilment of the requirement for the degree

MASTER OF VETERINARY SCIENCE

Faculty of Veterinary and Animal Sciences

Kerala Agricultural University

DEPARTMENT OF LIVESTOCK PRODUCTION MANAGEMENT

COLLEGE OF VETERINARY AND ANIMAL SCIENCES

MANNUTHY, THRISSUR, KERALA

1999

DECLARATION

I hereby declare that the thesis entitled "**HEAT STRESS ALLEVIATING MEASURES FOR CROSSBRED COWS**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Mannuthy

P. THIRUMURUGAN

CERTIFICATE

Certified that the thesis entitled **"HEAT STRESS ALLEVIATING MEASURES FOR CROSSBRED COWS"** is a record of research work done independently by **Sri. P. Thirumurugan** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Mannuthy

Dr. P.C. Saseendran
(Chairman, Advisory Committee)
Associate Professor
Department of Livestock
Production Manangement
College of Veterinary &
Animal Sciences, Mannuthy

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Sri. P. Thirumurugan**, a candidate for the degree of Master of Veterinary Science in Livestock Production Management, agree that the thesis entitled "**HEAT STRESS ALLEVIATING MEASURES FOR CROSSBRED COWS**" may be submitted by Sri. P. Thirumurugan, in partial fulfilment of the requirement for the degree.

Dr. P.C. Saseendran
(Chairman, Advisory Committee)
Associate Professor
Department of Livestock Production Management
College of Veterinary and Animal Sciences
Mannuthy

Dr. K.S. Sebastian
Associate Professor
Department of Livestock
Production Management
(Member)

Dr. C.K. Thomas
Professor and Head
Department of Livestock
Production Management
(Member)

Dr. C.A. Rajagopala Raja
Professor and Head
University Livestock Farm
(Member)

External Examiner

ACKNOWLEGEMENT

I wish to record my deep gratitude and indebtedness to Dr. P.C. Saseendran, Associate Professor and Chairman of the Advisory Committee, Department of Livestock Production Management, College of Veterinary and Animal Sciences, Mannuthy under whose valuable guidance and constant encouragement this study was successfully carried out. It is a matter of great pride to get an opportunity to work under the dynamic guidance of an able and affectionate academician of his calibre.

I wish to express my deep sense of gratitude to Dr. C.K. Thomas, Profesor and Head, Department of Livestock Production Management, Dr. K.S. Sebastian, Associate Professor, Department of Livestock Production Management and Dr. C.A. Raja Gopala Raja, Professor and Head, University Livestock Farm, Mannuthy, Members of the Advisory Committee for their valuable suggestions and help.

I am extremely grateful to Dr. S. Sulochana, The Dean, College of Veterinary and Animal Sciences, Mannuthy for the facilities provided for this work.

I express my heartful thanks to Dr. K.S. Anil and Dr. Leena Anil, Assistant Professors, Department of Livestock Production Management and Dr. A. Kannan and Dr. K. Ally, Assistant Professors, University Livestock Farm and Dr. Joseph Mathew, Assistant Professor, Pig Breeding Farm for their support and help during the study period.

I offer my heartful thanks to Dr. R. ThirupathyVenkatachalpathy, Assistant Professor, Department of Animal Breeding and Genetics for his unhesitating response, priceless help and friendliness which enabled a fairly strenuous task to remain throughout.

The whole hearted co-operation, help and motivation offered to me by my colleagues Dr. S. Ramakrishnan, Dr. V. Ramesh, Dr. S. Mohan, Dr. Jeethendra Shetty, Dr. P. Kanagaraju, Dr. A. Varadharajan, Dr. K. Latha, Dr. A. Arulmozhi, Dr. Liz Simon, Dr. Namsui Thou, Dr. Kanagasabai, Dr. M.T. Dinesh, Dr. P.T. Suraj, Dr. A. Prasad, Dr. D. Sukumar, Dr. Jayasree and all the members of the P.G. Hostel are thankfully acknowledged.

I gratefully acknowledge the help offered by staffs of Department of Statistics in analysis of the data.

I am thankful to Dr. Veeramani and Dr. Richard, Assistant Professors, AICRP, Mannuthy for their valuable helps rendered to write this thesis and Dr. S. Sagathevan, Assistant Professor, SBRS, Sandynellah, Nilgris for motivating me to undergo postgraduation.

I am thankful to staff and labourers of the University Livestock Farm and Department of Livestock Production Management for their help and co-operation.

I am thankful to Kerala Agricultural University for awarding me the fellowship for the post graduate study.

My heartful thanks to Shri. O.K. Ravindran, Peagles, Mannuthy for the perfect and well timed assistance in the preparation of this thesis.

I am forever fondly beholded to Prabha Das for her boon and benevolence.

I am short of words to express my deep gratitude to my beloved adopted parents and wife for their esteemed encouragement and heartful blessings showed on me in fulfilling this endeavour.

Above all, I bow my head in front of the God Nadukaniappan for the blessings showered on me.

P. THIRUMURUGAN

Dedicated to my Beloved Adopted Parents

and Wife

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

1. INTRODUCTION

Livestock plays an important role in our country. Livestock output value of GDP has increased from 8.65 to 9 per cent. The national commission on agriculture observed that next to agriculture, dairying is the most important subsidiary occupation. India is the first largest milk producer (73.4 million tonnes) in the world with cattle and buffalo population of around 206 and 80 million, respectively. By 2000 A.D., the milk production target of 78.0 million tonnes has been projected by planning commission. This progress in milk production can be achieved by intensive crossbreeding programme. But it has been seen that an improvement in genetic make up can contribute to a limited extent and the remaining is dependent on proper managemental practices which resulted in increased milk production.

Climate is one of the limiting factor in dairy production. Hot, humid environmental conditions occur seasonally or sporadically in many parts of the earth, but they persist for considerable length of time in an year, only in tropics. The climate of the Indian subcontinent is extremely tropical though large part of India is located north of the tropic of cancer. Since climatic conditions vary considerably from place to place within the country, defining animal needs of housing become extremely difficult.

Investigations on animal housing have also been limited, mainly due to high expenditure involved. Many types of traditional animal housing systems have been evolved in course of time. They need to be evaluated in the light of changing genetic structure of cattle population due to cross-breeding.

The population of crossbred cattle, in the country, has increased which resulted in a boost of milk production. But the farmers are finding it difficult to take advantage of the full production potential of crossbred cattle, due to acute shortage of the feeds and fodders and climatic stress on the animals due to poor adaptability, combined with the traditional and inadequate husbandry practices.

Climate in Kerala is unique and distinct from the other regions of the peninsula lying in the same latitude. Air temperature and relative humidity are always above the comfort zone, in this state. Daily temperature is above 27.0°C even during the coolest period of the year and lowest humidity is 65 per cent. The prevailing ambient temperature impose much stress on dairy animals.

Housing and environmental modifications are important tools to alleviate climatic stress during summer season. Housing practices necessarily involves modification of one or more modes of energy transfer between the animals and their surroundings. The important physical parameters governing heat transfer are surface of the animal, temperature of the surface (skin), temperature of the surroundings, ambient temperature, velocity of air, atmospheric humidity, emissivity of animal surface and conductivity of surroundings. To alter effectively the microclimate of an animal through housing and environmental modifications, one or more of the above factors must be altered.

The most effective shade source is the tree, cattle remain more comfortable under tree shade in the open than inside cattle houses (Gangwar, 1988). Water is an effective cooling agent, either through wetting of the animal surface which provides cooling as the water evaporates or through indirect evaporative cooling of air. Thus, during summer shutting off incidence of solar radiation by providing shade and sprinkling of water on animals helps to maintain their production level. So the present study aims to find out the effect of providing sprinkling of water in conventional tie-barn and open house with tree shade on physiological, behavioural and production performance of crossbred dairy cattle, during summer season of Kerala State.

Review of Literature

2. REVIEW OF LITERATURE

Environmental heat stress factors resulted in sizable economic loss to the producers of intensively managed livestock through the reduction of growth, production and low reproduction. The optimum productivity of cattle and buffaloes was occurred at an air temperature of 13-18°C, a relative humidity of 60-70 per cent, a wind velocity of 5-8 kmph and a medium level of solar radiation. The ideal climate occur in a subtropical latitudes in spring and fall seasons (Mc Dowell, 1972).

In the warm climatic regions, hot weather prevailed for 7-9 months or more in a year and environmental temperature exceeded the upper critical temperature of animals during major part of the day. Under such conditions, by understanding the principles of the physiological and other reactions of domestic animals, the managemental practices can be altered in order to maintain economically feasible production condition. Manipulation of the physical environment such as ambient temperature, relative humidity, wind velocity, solar radiation and day length were found to be the potentially important factors which influenced animal productivity. Report on the effect of these factors on the milk yield and its composition on crossbred dairy cattle in hot, humid climate are scanty and scattered. The works that were carried out in these aspects are reviewed here.

2.1 Heat stress factors

The principal climatic factors which resulted stress were air temperature, humidity and solar radiation. Wind was found to be partial heat stress factor when environmental temperature exceeded body temperature.

2.1.1. Atmospheric temperature

The ambient temperature or the air surrounding an animal's body were found to be extremely important to its comfort and normal physiological process. Normally, the heat is released from the warm skin of the livestock to the cooler air around it by conduction, when the temeprature rose above the comfort range (13-18°C), the heat loss diminished and when air temperature exceeded the skin temperature heat flowed in a reverse direction and the animals were subjected to heat stress (McDowell, 1972).

Sethi *et al.* (1975) reported that during protected (30.5°C) and unprotected ambient temperature (exposed to the environment at 38.4°C) dry matter intake of cow were 1.739 and 1.588 kg and water intake were 14.8 and 18.9 litres per 100 kg body weight, respectively.

Garcia and Rodriguez (1977) did not find significant difference, in rectal temperature, between Holstein Fresian and (H.F x Zebu) crossbred cows during hot summer climate.

Goel *et al.* (1979) reported that Haryana x Holstein, Haryana x Brown Swiss and Haryana x Jersey crossbreds were not differed in their heat tolerance ability to tropical climate of India.

Bunger *et al.* (1982) reported that respiration rate, body temperature, skin temperature, drinking frequency and water intake increased and feed intake, milk yield and fat content decreased in lactating dairy cows, when they were kept in a climatic chamber at 30°C and 70 per cent relative humidity during the day and 23°C and 80 per cent relative humidity at night.

The cows when exposed to temperatures of 20°C, 32°C and 20°C for successive 7 days periods, the respiration rate were 46, 106 and 53 per min and rectal temperature were 38.7°C, 39.7°C and 38.3°C respectively (Mohamed, 1984).

A reduction in milk yield (21-34%), heart rate (7-17%) and energy intake (31-45%) were found in a climatic chamber study at ambient temperature of 30°C and relative humidity of 70 per cent (Sorensen, 1985).

Mc Guire *et al.* (1985) found that mean mammary blood flow of cows were 2.66 and 2.75 litres per min under heat stress and thermoneutral conditions respectively.

According to Sorensen and Weniger (1987) ambient temperature of 30°C increased rectal temperature (39.5-40.5°C) and respiration rate, but significantly reduced milk yield (21-34%), heart rate (7-17%) and energy intake (31-35%).

Kabuga (1992) observed diurnal pattern of 38.6°C and 39.0°C of rectal temperature, 52.2 and 60.7 respiration rate and 58.1 and 64.1 pulse rate in the morning and afternoon respectively. It was also observed that mean ambient temperature of the previous day was more important to influence the physiological responses than the thermal factors of the same day.

According to Guerrero *et al.* (1993a) sprinkling water was useful in reducing heat stress of cows, kept in well ventilated and shaded area after sprinkling.

Mena *et al.* (1993) reported that cooling by combination of sprinkling for 30 second followed by controlled aeration for 6 min reduced both rectal temperature and respiratory frequency. But both the variable increased after 20-30 minutes when the cows were exposed to enviromental temperatures after treatments.

Montoya *et al.* (1995) reported that 2.7 litres of water per cow per hour evaporated from the cow's hair coat, when cooled by fan and sprinklers. They also stated that the evaporation rate was mainly depended on dry bulb temperature and relative humidity, wind speed and wind direction.

Barrington (1997) stated that milk yield was adversely affected by ambient temperatures of above 20°C in Friesian cows.

2.1.2. Relative humidity

Bianca (1965) reported that below 24°C air temperature, humidity had no effect on heat stress as the direct heat output mechanisms were adequate at these temperatures and evaporation played only an insignificant part.

Above 24°C, the body functions of various cattle breeds were significantly affected by air humidity because evaporation is inhibited by the reduction in water vapour pressure gradients between skin, lungs and the air. This effect is purely a physical one. The relationship established for the rate of heat loss from the bovine respiratory tract indicated that at 29°C and 60 per cent relative humidity, a cow was able to loose 3.4 Wm^2 of heat while at 90 per cent relative humidity, this was reduced by 25 per cent (Mc Dowell, 1972).

Ghosal and Guha, (1974) stated that under hot humid conditions, the respiratory volume was more than double that of a hot dry environment and the evaporative heat loss was lower under hot humid conditions.

According to Sainsbury (1975) a relative humidity of 20 to 90 per cent did not affect domestic animals if they were kept within their optimum temperature range.

Somanathan (1980) after an analysis of five years data of meteorological unit at Mannuthy, Kerala observed a mean relative humidity of 73.74 per cent with a minimum of 65.84 per cent during the month of July.

Starr (1981) had stated that heat balance could become a problem at 20°C and above when relative humidity exceeds 60 per cent.

Thiagarajan (1989) reported a mean relative humidity of 75.75 per cent in unshaded location of Livestock Farm, Mannuthy, Kerala.

2.1.3. Air movement

In assessing the suitability of an animal house, the effect of air flow on the animal's comfort found to be as important as temperature and humidity. The rate at which air moves over the skin of an animal affected the rate of heat loss from the body surface. In hot, humid environment, air movement was low (below 5 kmph) and evaporation is reduced (Mc Dowell, 1972).

A wind speed of 2.25 m per sec was quoted by Mc Dowell (1972) as ideal in hot dry day time environment and the restoration of heat balance is encouraged by wind speeds of the order 2.25 to 4.50 m per sec after sunset. In the real humid regions the congregation of animals reduced air circulation and restricted heat loss so that net effect of shade was minimum.

Ludri and Singh (1979) found that increased air movement by fans in a hot and humid climate, decreased the rectal temperature, respiration and pulse rates and increased the milk yield by 1.22 kg per cow per day.

Bruce (1981) stated that air velocity inside animal house is affected by the ventilation rate, and the position, shape and size of air inlets.

Smith (1981) stated that evaporative cooling could be used until the indoor relative humidity reached 70 to 75 per cent. Increased air velocity was observed to be of effect in that state.

An increase in air velocity increased heat loss when the body temperature was higher than the ambient temperature. In tropical zones, the advection of hot air over the animal has increased heat stress and in cold locations, air motion enhanced cold stress. In climatic zones between these two extremes air movement generally mitigated climatic stress (Starr, 1981).

Macfarlane (1981) stated that sparsely haired pigs and buffaloes lost heat more easily by convection in which buffaloes benefited more from air movement because of sweating.

Thiagarajan (1989) reported that under the hot, humid conditions the higher wind velocity in the open paddock favoured the cows considerably than the cows in the shelter. He also opined that under hot, humid conditions ventilation is most important and animals do not need much elaborate housing in order to utilise beneficial effects of free ventilation.

Calamari *et al.* (1995) reported that during the hot day at indoor air temperature of above 25°C mechanical ventilation reduced the rectal temperature ($P<0.001$) and respiratory rate ($P<0.05$) and increased the milk yield ($P<0.05$) of the cow.

Barrington (1997) suggested that mechanical ventilation systems for dairy cow housing offers several advantages, including a more consistent milk yield, more effective feed conversion, more constant level of total solids in milk and a better environment for milkers.

2.2. Effect of heat stress, shade and sprinkling

2.2.1. physiological norms

There is a relatively narrow zone of effective environmental temperature (13-18°C) in which heat production of an animal is minimal or thermoneutral which is offset by net heat loss or gain from the environment without the aid of special heat conserving or dissipating mechanisms

2.2.1.1 Rectal temperature

Rectal temperature was found to increase with increase in ambient temperature and there was a high positive correlation between rectal temperature and ambient temperature (Bianca, 1965; Thomas and Razdan, 1973). Warm blood animals kept their body temperature within a narrow range even when the ambient temperature fluctuated widely. The normal fluctuation range in body temperature was between 38.0 and 39.3°C in adult dairy cows with a difference of 2.5°C (Herz and Steinhauf, 1978). Diurnal variations in body temperature were occurred with the maximum in the early afternoon and minimum in the early morning (Amakiri and Funsho, 1979; Flamenbaum *et al.*, 1986).

However the diurnal difference measured was only 0.5°C between these two extremes (Wolfenson *et al.*, 1988).

Lactating cows had a higher rectal temperature than non-lactating cows (Wolft and Monty 1974) with the higher value in early lactation than in late lactation (Nauheimer - Thoneick *et al.*, 1988).

Bracelos *et al.*, (1989) found that higher air temperature had a significant effect on rectal temperature in both Holstein and Holstein x Zebu. Crossbred had significantly lower rectal temperature (38.9°C) than Holstein (39.3°C).

Under Egyptian climatic conditions, the rectal temperature of Friesian cattle were 38.8°C, 38.7°C and 38.5°C for summer, autumn and winter seasons respectively. In summer when these cows were exposed to direct sunlight, the rectal temperature increased to 39.8°C against 38.9°C of the cows kept in shade (Shafie and El-Sheikaly, 1970). Contrary to this report, studies carried out at the Kerala Agricultural University Farm (Somanathan and Rajagoplan, 1983) revealed that the rectal temperature of crossbred calves remained constant throughout the year inspite of wide variation in the ambient temperature and humidity.

Under conditions of moderate heat, vasodilatation enabled direct heat output in cattle (Thatcher and Collier, 1972). At hotter temperature, perspiration on accompanied increased heat dissipation by greater respiratory activity. Only when all these mechanisms failed the body temperature rose (Herz and Steinhauf, 1978). This affected appetite and thyroid gland activity and lead to a drop in heat production. When the body temperature risen 4.4°C, above normal body temperature it was found to be lethal in the case of cattle (Terui *et al.*, 1979).

When the ambient temperature was above 27°C, sprinkling with water significantly ($P<0.01$) reduced the body temperature of cattle (Morrison *et al.*, 1973); Zook *et al.*, 1975) and buffaloes (Gill *et al.*, 1976; Radadia *et al.*, 1980; Sharma *et al.*, 1982; Sethi *et al.*, 1994). During climate stress the rectal temperature were 39°C for buffalo and 38.8°C for cattle. Sprinkling of water helped to maintain body temperature in normal range for both cattle (38.5°C) and buffaloes (38.2°C). The effect was more for buffaloes than cattle (Hamid *et al.*, 1977).

Cooling by inspired air significantly reduced body temperature of cattle (Zook *et al.*, 1975). During summer Holstein Friesian cows maintained in an air conditioned tie-stall barn had significantly lower rectal temperature than the cows maintained in outdoor corrals with access only to shade (Wise *et al.*, 1988). Davison *et al.* (1988) found that rectal temperature was significantly ($P<0.01$) higher (40°C) when the Holstein Friesian cows were exposed to direct solar radiation compared with cows tethered under tree shade.

Thiagarajan *et al.* (1978) studied the effect of spraying water on crossbred dairy cows during hot summer having average ambient temperature of 37°C and relative humidity of 78 per cent. They found that the average rectal temperature of cows with and without spraying were 38.31°C and 38.64°C and skin temperature were 32.13°C and 33.90°C, respectively. Abdel and Ibrahim (1994) found that sprinkling of tap water on lactating Holstein Friesian cows significantly reduced the diurnal rise in rectal temperature. (38.6 Vs 39.7°C).

Overhead insulation and roof sprinkling reduced the ambient air temperature (Fuguay *et al.*, 1979). According to Igono (1986) provision of shade reduced air temperature during hot weather. Further, provision of a water spray or a fan did not alter the ambient temperature, but reduced rectal and skin temperature, compared with cows kept under shade without spray or fan. Her *et al.*, (1988) reported that sprinkling of water in hot summer season, decreased the typical diurnal rise in body temperature by 0.5-0.9.°C and maintained body temperature at 38.6°C, in Israeli Holstein cows under shaded location. Guerrero *et al.* (1993b) found that fine mist spraying did not reduce cow's body temperature instead reduced the animal's ability to lose heat because of reduced respiratory rate and increased humidity.

Flamenbaum *et al.* (1986) devised a method for cooling dairy cattle based on repeated wetting to attain maximal water trapping in the coat followed by its rapid evaporation by using forced ventilation. When cows were cooled five times a day for 30 min the rectal temperature were maintained within 38.2 to 38.9°C which were significantly lower than those not cooled. The spraying of water for a period of 0.5 min followed by 4.5 min of blowing air at an average speed of about 3 m per sec for 2 hours gradually decreased the body temperature of Israeli Holstein dairy cow from 39.2°C to 38°C (Kimmel *et al.*, 1992).

Sprinkler and fan cooling reduced heat stress and rectal temperature of dairy cattle upto 0.8°C during hot climate (Huang *et al.*, 1986; Wolfenson *et al.*, 1988; Turner *et al.*, 1989; Means *et al.*, 1992; Mena *et al.*, 1993; Marai *et al.*, 1995; Flamenbaum *et al.*, 1995; Omer et al., 1996; Frazzi *et al.*, 1997; Rossi *et al.*, 1998).

2.2.1.2. Respiration and cardiac rate

2.2.1.2.1. Effect of heat stress

Heat is well known to augment the respiratory activity of cattle. Friesian cows maintained under the climatic conditions in Egypt had exhibited seasonal differences in the respiration rates, the respective value for summer, autumn and winter were 45.2, 53.9 and 30.1 per min respectively (Shafie and El-Sheikaly, 1970). Thomas and Razdan (1973) reported that crossbred cattle had a significantly higher (P<0.01) average respiration rate (23.6 min vs 19.8 per min) and lower pulse rate 53.5 per min vs 55.8 per min) than the Sahiwal.

In Hariana, Tharparkar and Sahiwal breeds, Ghosal and Guha (1974) found that the respiratory volume and evaporative heat loss through the pulmonary tract under cool conditions (18.5°C) were appreciably lower than under hot, humid (39.5°C) or hot dry conditions (42.5°C).

Wolft and Monty (1974) observed a significant rise in respiration rate in response to hot weather in Friesian cows, but the response was much more significant in lactating cows than in non-lactating cows. When lactating cows were subjected to an ambient air temperature of 30°C, the respiratory rate increased by 130 per cent of the normal (Nauheimer-Thoneick *et al.*, 1988).

Herz and Steinhauf (1978) stated that at low ambient temperatures, skin evaporation corresponds roughly to that of respiratory passages. At high temperatures, evaporation through the skin was greater and accounted to about 70 to 80 per cent of total water loss through evaporation. Hence zebu cattle rely less on respiratory cooling than *Bos taurus* breeds, which breath at a rate of upto 200 per min at air temperature of 38°C. Similarly, 12 per cent of water evaporates through the respiratory passages of Brahman cows compared with 24 per cent given off by shorthorns under the same conditions.

Zia-ur-rehman *et al.* (1982) reported that the highest cardiac rate in Sahiwal cattle was recorded when the relative humidity and ambient temperatures were high. They also found that respiration rate in crossbred cattle was maximum in the month of August when the relative humidity was highest. Gangwar, (1988) found that pulse rate of cattle in thermoneutral zone (13 to 18°C) and hot environment (40°C) were 64.1 and 57.8 per min, respectively.

Somanathan and Rajagopalan (1983) recorded monthly variations in the respiratory rates of 10 to 24 months old crossbred cattle at Mannuthy. The maximum respiratory rate of 49.23 per min in April and minimum respiratory rate of 30.97 in July at the temperatures of 35.33 and 28.45°C were observed. Schebaita and Pfau (1984) reported that respiration of Brown Swiss and Friesian female calves were 65.0 and 70.6 per min and 99.0 and 107.8 per min under sheltered and unsheltered conditions, respectively during summer season.

2.2.1.2.2 Effect of shade and sprinklers

Zook *et al.* (1975) reported that insulation plus roof sprinkling or inspired air cooling significantly reduced the respiration rate of cows in loose house cowshed during hot summer climate. Gill *et al.* (1976) reported that respiration rate significantly (P<0.01) decreased in buffaloes with increased frequency of water sprinkling, and had no effect on pulse rate.

Hamid *et al.* (1977) stated that sprinkling with water reduced the rise in respiration rate for both cattle and buffaloes. But the effect was more to buffaloes than cattle. In unsprinkled buffaloes the respiration rate rose from 23 to 24 per min, in cattle it was from 37 to 47 per min. Hassan *et al.* (1979) found a higher respiration rate in crossbred cows (39 per min) than in buffaloes (27 per min). Showering of water on lactating buffaloes significantly (P<0.01) reduced respiration and pulse rates.

Radadia *et al.* (1980) and Kishonti and Adam (1985) found that cooling of cows by water sprinkling, when ambient temperature exceeded 25°C significantly reduced both cardiac and respiration rates than the uncooled cows.

Huang *et al*. (1986) found that in Holstein Friesian cows kept in a cowshed with electric fans and sprinklers in the hot season had lower average respiration rate (60.0 per min) than the cows kept without fans and sprinklers (78.5 per min). Sprinkler and fan cooling reduced both respiration and pulse rates of dairy cattle in hot, humid climate (Turner *et al*., 1989).

According to Igono (1986) provision of shade reduced the air temperature. Further provision of a sprinkler and a fan under the shade did not alter the ambient temperature, but reduced the climatic stress and respiration rate.

Sprinkling with water on dairy cattle significantly reduced the respiration rate (Means *et al*., 1992; Mena *et al*., 1993; Abdel and Ibrahim, 1994; Sethi *et al*., 1994; Marai *et al*., 1995; Omer *et al*., 1996; Frazzi *et al*., 1997; Rossi *et al*., 1998; Lin *et al*., 1998).

Omer *et al*. (1996) found that cooling of cows by sprinkling with water reduced the diurnal rise of respiration rate by 18.7 breaths per min and heart rate by 8.3 beats per min. Frazzi *et al*. (1997) found that sprinkling water on dairy cows during summer significantly reduced the pulse rate.

2.2.2. Milk production

2.2.2.1. Effect of heat stress

Christensen *et al.* (1975) found that milk yield of Friesian cows started falling when ambient temperature and relative humidity exceeded to 21°C and 60 per cent respectively. Renner (1976) suggested 13 to 16°C temperature and 70 to 85 per cent relative humidity as optimal for milk production. Beslin and Anjocic (1979) found that in Friesian cows, fat corrected milk yield was 4007 kg at 62 per cent relative humidity and ambient temperature of 23°C whereas it was 6483 kg at 83 per cent relative humidity and 5°C ambient temperature.

Hassan *et al.* (1979) reported that average daily milk yield of crossbred cows were 7.8, 7.6, 5.6 and 5.1 kg during winter, spring, summer and autumn, respectively.

Rodriguez *et al.* (1985) reported that relative humidity and air temperature were associated with 1.6 to 5.6 per cent of variability in milk production. Berman *et al.* (1985) reported the upper critical temperature for milk production as 26°C in Israeli Friesian cows. In the experiment by Nauheimer-Thoneick *et al.* (1988), switching over of lactating cows from an environment of 15°C and 70 per cent RH to 30°C and 50 per cent RH conditions reduced milk yield by 30.6 per cent in early lactation and 25.9 per cent in late lactation.

2.2.2.2. Effect of shade and sprinkler

Ingraham *et al.* (1979) found that providing shade increased the daily average milk yield to 18.5 kg where as it was only 14.5 kg in unshaded cows. Sastry *et al.* (1981); Bempong and Gupta, (1986); Johnson *et al.*, (1987); Davision *et al.* (1988) also reported similar results. In contrary to this, Thiagarajan (1989) found that crossbred cows under unshaded condition produced significantly ($P<0.05$) higher milk yield (mean weekly yield 36.47 kg) than under shaded condition (35.66 kg per week) during early lactation period. But he did not find any significant effect during late lactation period.

Hernandez and Castellanos (1983) found that cooling sprinkling with water increased milk yield by 7 per cent in Holstein Friesian and Brown Swiss cows and by 19 per cent in crossbred cows. Holstein cows cooled by water sprinkling even when ambient temperature exceeded 25°C produced more milk (6950 kg) than that of non cooled cows (6042 kg) (Kishonti and Adam, 1985). Igono *et al.* (1986) reported that provision of water spray and fan under the shade reduced the climatic stress and increased daily milk yield by 2 kg in Israeli Holstein cows. Johnson *et al.* (1987) found that in hot humid environment, cooling of Holstein cows by sprinklers increased the milk yield. The reduction in daily milk yield for uncooled cows was 2.9 kg at 32°C and 50 per cent RH, 9.5 kg at 32°C and 80 per cent RH, and 8.5 kg at 36°C and 65 per cent RH respectively. Her *et al.* (1988) found that cooling of cows by water sprinkling increased the milk yield by 2.6 kg per day (+ 8 per cent) above the control cows. Wolfenson *et al.* (1988) reported that cooling the high producing dairy cows by water sprinkler increased mean 150 - day milk production by 3.6 kg per day.

In Iraq, Juma *et al.* (1987) reported that cows sprinkled twice daily produced higher daily milk yield (9.0 ± 0.3 kg) than for those sprinkled once (7.9 ± 0.3 kg) and not sprinkled (7.5 ± 0.2 kg) cows.

Aboulnaga *et al.* (1989) reported that sprinkling of water on heat stressed cows increased greatly their plasma thyroxine and oxytocin concentration and milk yield by 13.3 per cent.

Her *et al.* (1988) reported that sprinkling of high producing Friesian cows when-ever dry bulb temperature exceeded 26 °C, increased mean daily milk yield by 4.8 kg. Turner *et al* (1989) found that cows cooled by sprinkling with water and fans whenever ambient temperature was above 26.7°C increased daily mean milk production by 3.59 kg. Bucklin *et al.* (1991) reported that cooling of Holstein Friesian cows by sprinkling with water during the summer increased daily average milk yield by 2.2 kg. Flamenbaum *et al.* (1995) reported that cooling of cows by sprinkling and forced ventilation increased daily average milk yield by 1.9 kg. Omer *et al.* (1996) and Hall *et al.* (1997) reported that cooling of cows by sequential sprinkling and forced ventilation, during summer increased daily mean milk production by 2 kg per day (15 per cent) as compared with uncooled cows. Rossi *et al.* (1998) found that during summer cooling of cows by sprinkling with water and powered ventilation increased milk yield from 1.5 to 2.5 per cent compared with uncooled cows.

2.2.3. Milk composition

2.2.3.1 Fat percentage

Average milk fat percentage of Brown Swiss x Ongole, HF x Ongole were 4.19 and 3.66 (Babu Rao and Jayaramakrishna, 1983). Naikare *et al.* (1992) reported that milk fat percentage of Friesian x Gir, Jersey x Gir, Friesian x JG, Jersey x FG and Brown Swiss x FG cows were 3.93, 4.36, 3.94, 3.99 and 3.94, respectively. The milk fat per percentages in the fortnights of 3,6,9,12 and 15 were 3.28, 3.73, 3.99, 4.35 and 4.60 in morning samples, and 3.81, 4.30, 4.64, 4.93 and

5.23 in evening samples for crossbred cows of Kerala (Iype *et al.* 1994).

Eley *et al.* (1978) did not find any difference in milk fat content between cows kept at 38.78 or 30.05°C ambient temperature. Similarly, Nauheimer-Thoneick *et al.* (1988) also did not observe any statistically significant difference in fat percentage of German Holstein Friesian cows subjected to 30°C constant temperature in the climatic chamber eventhough their milk yield declined by 26 to 30 per cent.

On the other hand Fuquay *et al.* (1980) found that milk fat percentage of cows subjected to 22 to 31°C air temperature was significantly lower than the cows subjected to 17 to 20°C.

Provision of shade, cooling by sprinkling with water and forced ventilation reduced the heat stress of diary cows, but had no effect on milk fat percentage (Zook *et al.*, 1975; Gill *et al.*, 1976; Bempong and Gupta, 1986; Means *et al.*, 1992; Omer *et al.*, 1996; Frazzi *et al.*, 1997). Cooling of buffaloes during summer by sprinkling with water and providing cooled drinking water increased the milk fat content (Radadia *et al.*, 1980; Varma *et al.*, 1990).

Berman *et al.* (1986) reported that Israeli Holstein cows cooled by sprinkling with water and forced ventilation during summer markedly increased milk fat secretion of cows in good condition than cows in poor condition. Buffaloes cooled for 30 min yielded more milk fat than those cooled for 15 min (Varma *et al.*, 1990). However Means *et al.* (1992) did not find any statistically significant difference for milk fat content of high yielding dairy cows when cooled by fan and sprinkler with three water application rates of 313.4, 492.9 and 704.1 litres per hour per nozzle.

2.2.3.2 Protein, SNF and Total solid percentage

Average total solids, solids not fat and protein percentage of milk of some important milk breeds of cattle

Author(s)	Breeds of cattle	Total solids percentage	Solids not fat percentage	Protein percentage
Babu Rao and Jayaramakrishna (1983)	Ongole	14.51	9.30	
	Ongole x Brown Swiss	13.29	9.09	-
	Ongole x HF	12.26	8.68	-
Bhalerao (1990)	Red sindhi	13.66	8.76	3.42
	Gir	13.30	8.67	3.32
	Tharparkar	13.25	8.70	3.36
	Sahiwal	13.37	8.82	3.33
	Jersey	14.91	9.54	3.73
	Friesian	12.26	8.86	3.13
	Crossbred	13.13	8.63	3.37
Johnson(1995)	Crossbred	12.99	-	-

Bianca (1965) reported that SNF and protein content of the milk decreased in the heat stressed cows. Sahiwal x Jersey heifers showed decrease in milk protein yield, casein, *lactoglobulin* and lactalbumin when subjected to 40°C ambient temperature (Pan *et al.*, 1978). However, Nauheimer-Thoneick, *et al.* (1988) did not see any significant reduction in milk protein per cent of cows maintained at 30°C.

Cooling of heat stressed cows by sprinkling with water had no effect on SNF, protein and total solids percentage of milk (Zook *et al.*, 1975; Gill *et al.*, 1976; Bempong and Gupta,1986; Means *et al.*, 1992; Omer *et al.*, 1996).

Radadia *et al.* (1980) found that during summer, SNF yield of buffaloes when cooled by showering, providing cooled drinking water and showering + cooled drinking water was 9.61, 9.57 and 9.81 per cent respectively whereas it was only 9.40 per cent in control. The difference was statistically significant.

Davison *et al.* (1988) reported that provision of tree shade increased ($p < 0.05$) SNF yield in multiparous cows, but had no effect in heifers.

2.2.4 Feed Consumption

2.2.4.1 Effect of heat stress factors

Thomas *et al.* (1969) in crossbred cattle found that dry matter intake was significantly less in summer by 0.59 kg DM per day per 100 kg body weight compared to winter. Mohamad, (1984) reported the daily dry matter intake of cows as 10.5, 6.6 and 9.8 kg, when they were exposed to successive 7 days periods at 20, 32 and 20°C ambient temperature. Nauheimer-Thoneick *et al.* (1988) reported that in lactating cows, at 30°C ambient temperature, the DM intake was reduced by 30.7 per cent in early lactation and 24.6 per cent in late lactation compared to 15°C. Marai *et al.* (1995) found that feed consumption rate of dairy cows significantly reduced during summer.

2.2.4.2 Effect of shade and sprinkling

Cooling of dairy cows by sprinkling with water during summer significantly increased feed consumption (Morrison *et al.*, 1973). Bempong *et al.* (1985) reported that daily dry matter intake of crossbred dairy cows in summer was 10.66 ± 0.11, 9.24 ± 0.11 and 10.08 ± 0.11 kg under tree shade, loose house and loose house plus sprinkling, respectively.

Huang *et al.* (1986) reported that high yielding Holstein Friesian cows kept in a cowshed with electric fans and water sprinklers during the hot season consumed more forage and concentrate (17.1 and 17.4 kg per day) than the cows kept without fans and sprinklers (15.0 and 14.6 kg per day).

Bharadwaj *et al.* (1992) found that mean daily dry matter intake of buffaloes kept under covered shed, covered shed plus showers, tree shade and exposed to direct sun rays were 14.14, 15.16, 15.54 and 14.96 kg, respectively.

Flamenbaum *et al.* (1995) reported that cooling of cows by sprinkling and forced ventilation increased mean daily feed intake by 1.6 kg.

Srivastava *et al.* (1998) reported that dry matter intake of lactating crossbred cows under 30 min sprinkling, 15 min sprinkling and no sprinkling treatments were 9.22 ± o.21, 8.90 ± 0.14 and 8.49 ± 0.14 kg, respectively.

Artificial cooling of dairy cows by sprinkling with water during summer non significantly increased feed intake (Thiagarajan *et al.* 1978 and Frazzi *et al.* 1997). Sorensen (1985) reported that cows did not reduce their roughage feed intake under warm condition when they were fed *ad libitum*.

2.2.5 Water consumption

2.2.5.1 Effect of heat stress

Water intake increased upto 38 to 40 per cent in buffaloes and 75 per cent in cattle from winter to summer. The water consumption was 25.9 and 49.6 litres in winter and summer respectively for cattle whereas the corresponding values were 31.8 and 46.5 litres in buffaloes. (Mullick, 1964).

The amount of water drunk was positively and significantly related to milk yield, dry matter content of the feed and air temperature (Castle and Watson, 1973; Castle and Thomas, 1975; Murphy *et al* 1983; Kirchessner *et al*. 1983; Ludri, 1983; Mohamed, 1984; Kume *et al*., 1986; Benedetti *et al*. 1990).

Castle and Thomas (1975) reported that average daily intake of water was 49.9 for British Friesian cows giving 16.8 kg milk daily at mean temperature of 8.2°C and relative humidity of 85 per cent. Average water intake was 3.7 kg per kg DM eaten.

Murphy *et al*. (1983) recorded the daily water intake of 89.24 kg, DM intake of 18.98 kg and milk production of

33.09 kg and observed an additional 0.90 kg of water consumption per kg milk.

Kirchessner *et al.* (1983) found that water restriction decreased mean basal dry matter intake from 14.07 to 13.13 kg and milk yield from 17.95 to 16.49 kg per day. But milk fat and protein content were not affected.

Daily mean water intake of cow were 27.2, 38.0 and 28.9 litres, when they were exposed to successive 7 day periods at 20, 32 and 20°C (Mohamed, 1984).

Benedetti *et al.* (1990) found that the voluntary water intake was 13.14 ± 0.45 litres in dry cows and 29.45 ± 0.49 litres in lactating cows respectively.

2.2.5.2. Effect of shade and sprinklers

Thiagarajan *et al.* (1978) found that cooling of crossbred cows with water sprinkling, during summer significantly reduced mean daily intake of water (40.78 lb) than uncooled cows (47.32 lb).

Bempong *et al.* (1985) reported that daily water intake of crossbred milch cows, during summer was 50.12 ± 1.11, 51.51 ± 1.13 and 46.86 ± 1,09 liters per head under tree shade, loose house and loose house + sprinkling, respectively. The corresponding values of water intake per kg DM intake and per kg milk produced were 4.75 ± 0.13 and 5.40 ± 0.14 5.65 ± 0.16 and 5. 39 ± 0.21, and 4.70 ± 0.13 and 4.55 ± 0.10 liters.

Bharadwaj *et al.* (1992) found that daily mean voluntary water intake of buffaloes housed in conventional barn without showers, barn with showers, under tree shade and exposed to direct solar radiation + showers were 83.6, 83.4, 85.8 and 89.5 liters, respectively.

Flamenbaum *et al.* (1995) reported that cooling of dairy cows by sprinkling and forced ventilation lowered mean daily water intake by 9 liters compared with uncooled cows.

Srivastava *et al.* (1998) reported that water through feed and drinking water intake of lactating crossbred cows under 15 min sprinkling, 30 min sprinkling and no sprinkling were 2.64± 0.02 and 19.45 ± 0.19, 2.60 ± 0.02 and 21.97 ± 0.61 liters, respectively.

2.2.6 Body weight change

Bodisco *et al.* (1973) found that the average body weight of lactating Holstein, Guernsey and Brown Swiss cows were 448, 483 and 423 kg respectively.

Youdan and King (1977) reported that both cows and heifers lost weight during early lactation period and subsequently showed a weight gain during late lactation period.

Mortinez *et al.* (1980) observed the first 10 months of lactation of Holstein Friesian cows as 17.45, 17.85, 16.80, 15.47, 14.30, 13.40, 12.32, 17.35, 10.25 and 8.47 kg, respectively and the body weight as 544.6, 488.4, 477.7, 487.1, 493.3, 506.2, 517.4, 525.9, 534.2 and 545.4 kg respectively.

Bhaskaran *et al.* (1981) observed a body weight gain from 294.83 ± 11.19 at parturition to 307.42 ± 11.01 kg at 6th fortnight in one group of crossbred cows. In another group body weight loss from 317.92 ± 14.96 kg at parturition to 209.75 ± 12.73 kg at 6th fortnight was also observed. Patil and Deshpande (1981) also observed gaining in body weight in seven cows at the rate of 2.375 kg per week and loosing body weight in nine cows at the rate of 1.546 kg per week.

At Mannuthy, Alexander (1983) reported the post partum body weight of crossbred cows at 15,30, 45,60 and 75 days as 317.30 ± 15.16, 314.50± 15.55, 315.70 ± 15.42, 317.20 ± 15.50 and 322.75 ± 38.02 kg. respectively.

Berman *et al.* (1986) reported that non cooled Israeli Holstein dairy cows tended to lose body weight and condition faster than those cows cooled by sprinkling with water and forced ventilation, in hot climate summer.

Huang *et al.* (1986) found that Holstein Friesian cows kept in a cow-shed with electric fans and sprinklers, in the hot season, had lower body weight loss than that those cows kept without fans and sprinklers.

Thiagarajan (1989) observed a uniform body weight change of crossbred cows, during the course of the lactation period at shaded and unshaded locations at Mannuthy.

Lu *et al.* (1992) reported that during the hot season in Taiwan, daily body weight loss to 120 days after calving was 0.3 and 1.6 kg for the cows housed in an air-conditioned barn and loose boxes, respectively.

2.2.7 Blood parameters

2.2.7.1 Haemoglobin

The average normal value of haemoglobin was found to be 11 g per cent (range 8-15 g per cent) in cattle (Schalm *et al.*, 1975).

Most research has shown that haemoglobin concentration decreased during heat stress (El-Masry, 1987; Daarder *et al.*, 1989; Yousef, 1990) due to the depression of haematopoiesis (Shebaita and Kamal, 1973) and haemodilution (Shebaita and Kamal, 1979).

Talvelkar *et al.* (1980) found that haemoglobin value (10.79 ± 0.24 g per cent) was slightly higher in crossbred cows than those in Gir cows (10.58 ± 0.33 g per cent).

Bahga *et al.* (1980) reported that haemoglobin value was higher in lactating buffaloes which were not cooled by showers or wallowing and exposed to normal environment. Radadia *et al.* (1980) reported that mean haemoglobin value of lactating murrah buffaloes under shower, cooled drinking water, cooled drinking water + shower and no treatment, were 10.25, 12.28, 12.58 and 10.48 g per cent, respectively. Aboulnaga *et al.* (1989) reported that cooling heat stressed cows by sprinkling with water and providing cooled drinking water increased their blood haemoglobin value.

Under Egyptian condition, both providing cooled drinking water and sprinkling with tap water increased haemoglobin value of high yielding Friesian cows (Habeeb *et al.*, 1989).

According to Bioucek *et al.* (1990) exposing dairy cows to high temperature during day time had no effect in haemoglobin percentage.

Abdel and Ibrahim (1994) found that cooling of heat stressed cows significantly increased haemoglobin value.

Marai *et al.* (1995) reported that under Egyptian subtropical condition, Haemoglobin value of Friesian cows decreased significantly in summer as compared with winter. But sprinkling with water significantly ameliorated this response to heat stress.

Gupta *et al.* (1996) reported that haemoglobin concentration of cows in mid-pregnancy, cows in late-pregnancy, cows after parturition and milking were 12.46 ± 0.45, 10.31 ± 0.40, 10.34 ± 0.58 and 9.97 ± 0.53 g per cent, respectively.

Das *et al.* (1997) reported that mean haemoglobin value of crossbred cattle in the New Alluvial and Red Laterite zones of west Bengal were 10.790 ± 0.246 and 12.406 ± 0.291 g per cent.

2.2.7.2 Packed Cell volume (PCV)

The average normal haematocrit percentage for cattle was reported to be 35 (range 24 to 48%) (Schalm *et al.*, 1975).

Most investigators reported that haematocrit percentage decreased in the heat stressed animals (Rowlands *et al.*, 1974; Bond *et al.*, 1991) due to red cell destruction and/or to haemodilution (Shebaita and Kamal, 1979) and to reduction in cellular oxygen requirements to minimize the metabolic heat load (Lee, 1965).

Talvelkar *et al.* (1980) reported that haematocrit percentage (37.61 ± 1) was non significantly higher in crossbred cows than those in Gir cows (36.59 ± 1.66).

Haematocrit value was higher in buffaloes which were not cooled by showers or wallowing and exposed to normal environment (Bahga *et al.*, 1980).

Radadia *et al.* (1980) reported that haematocrit percentage of lactating murrah buffaloes under shower, cooled drinking water, cooled drinking water + shower and no treatment, were 34.6, 33.05, 35.55 and 33.8, respectively.

Mohamed (1984) stated that haematocrit value did not differ, when pregnant cows were exposed to successive 7 day periods at 20, 32 and 20°C.

Seven mediterranean buffaloes were placed alternatively under natural ambient condition (21.5°C, 76.5% RH) and under heat stress (38.05°C, 55% RH). The haematocrit value under optimal and heat stressed conditions were 29.07 and 31.68 per cent (Neto *et al.*, 1989).

Bioucek *et al* (1990) reported that exposing dairy cows to high temperature, during day time had no effect in haematocrit percentage.

Abdel and Ibrahim (1994) found that cooling of heat stressed cows by sprinkling with tap water significantly increased haematocrit percentage.

Marai *et al.* (1995) reported that under Egyptian subtropical condition, haematocrit value of Friesian cows decreased significantly in summer as compared with winter. But sprinkling with water significantly ameliorated this response to heat stress.

Omer *et al.* (1996) reported that cooling of lactating Friesian cows by sequential sprinkling and forced ventilation reduced the blood haematocrit value.

Gupta *et al.* (1996) reported that haematocrit percentage of cows in mid-pregnancy, in late pregnancy, after parturition and milking cows were 31.7 ± 0.60, 29.8 ± 0.59, 32.1 ± 0.98 and 30.7 ± 0.71, respectively.

2.2.7.3 Erythrocyte Sedimentation Rate (ESR)

Normal erythrocyte sedimentation rate in cattle was reported to be zero mm per hr (Sharma and Jhanwar, 1973; Schalm, *et al.* 1975; Talvelkar *et al.*,1980; Benjamin, 1985). It was 1-8 mm per 24 hr (Ferguson, 1970), 3 mm per 24 hr (Bunce, 1974).

Benjamin (1985) reported that the suitable time interval to read erythrocyte sedimentation rate (ESR) value in cattle was 8 or 24 hr.

Xavier (1981) observed that the climatic variable showed a non significant influence on ESR in buffaloes. Ambient temperature showed a non significant influence on ESR of both sheep and goats in Mannuthy (Gowri, 1998).

Sreekumar (1988) reported that exercise and environmental stress increased the erythrocyte sedimentation rate in cattle. The speed of setting is inversely related to the number of red cells (Schalm *et al*., 1975).

2.2.8 Feeding Behaviour

According to McDowell, (1972), in tropical summer climate, total daily feed intake could be increased if the number of nocturnal feedings were more frequent. Thomas and Razdan (1973) found that animals made a day-to-night shift in feeding regimen during summer. In winter, they ate 8.5 per cent more of dry matter during day than during night. In summer, they ate 12.4 per cent more of feed during night and cooler hóurs of the day, thus maintaining normal growth.

Winter *et al.* (1982) reported that irrespective of seasons, duration of feed intake varied between 4.8 and 6.7 hours per day and cows drank mainly at the time of feed intake and drank very little at night.

Mallonee *et al.* (1985) reported that increased environmental temperature reduced voluntary feed intake and rumination time and frequency. An associated effect was reduced gut motility along with increased water intake leads to gutfill.

Thiagarajan (1989) suggested that increasing the number of feedings per day may entice animals to take more and keep feed fresher. placement of feed and water in the shade minimises stress at feeding time.

In South Africa, Muller and Botha (1994) reported that shaded cows spent more time ($P<0.05$) for feeding during the day than no-shade cows. No-shade cows spent more time for feeding at night and cooler hours of the day. During hotter periods of the day, no-shade cows tended to crowd most of the time around water trough and shade cows spent more time to ruminate or to sleep under the shade.

2.2.9 Oestrus Behaviour

Sprinkling with water increased the intensity of oestrus and reduced the calving to conception period (Akmal *et al.*, 1975) and lowered oestrus cycle length from 28 to 25.2 days (Saidkhodzhaev, 1977). Harinatharao *et al.* (1979) reported similar results for buffalo.

Popov (1982) observed a pronounced oestrus and low interval (46 days vs 56 days) in exercised group than non exercised group.

Gwazdauskas *et al.* (1983) found that barn housed cows had 8.7 mounts per hr vs 6.1 and 5.5 for dry lot and pastured cows. Mounting activity increased with increasing maximum daily temperature up to 25°C.

Janeczek *et al.* (1986) observed a high intensity and duration of oestrus in the cows housed in 18.1 lux light intensity shed than those in 5.6 lux light intensity shed.

Her *et al.* (1988) stated that cows cooled by sequential sprinkling with water and forced ventilation for 30 min

9 times daily in summer, showed more standing oestrus behaviour than those cows cooled for 20 min twice daily.

Lu *et al.* (1992) reported that cows cooled by sprinkling with water and forced ventilation showed more pronounced standing oestrus behaviour than uncooled controls.

Rodthian *et al.* (1994) observed that the incidence of overt signs of oestrus was lower and the duration of oestrus was shorter during hot season than the cool season. Spray cooling ameliorated this response during hot season in Holstein cows housed in a free stall.

Rodthian *et al.* (1996) reported that silent oestrus occurred with greater frequency during the hotter season than in cooler season ($P<0.05$). They also found that type of floor influenced more on manifestation of sexual behaviour than season. The duration of oestrus and mean number of interactions were reduced ($P<0.05$) in cows confined to concrete flooring compared with mud floors.

Materials and Methods

3. MATERIALS AND METHODS

The Kerala Agricultural University Livestock Farm, Mannuthy, Thrissur District, Kerala State is the location of the present study. Mannuthy is geographically situated at 76, 16" E longitude, 10, 32" N latitude and 22.25 meters altitude.

Twelve early lactating crossbred cows belonging to University Livestock Farm of Kerala Agricultural University, were selected for the study. The animals were put into four groups of three each and were randomly allotted to four treatments

1. Treatment (T_1) : Open house with sprinkler
2. Treatment (T_2 : Open house without sprinkler
3. Treatment (T_3) : Conventional tie-barn with sprinkler
4. Treatment (T_4) : Conventional tie-barn without sprinkler

The whole experiment was carried out as a switch over trial with two weeks adjustment period and one month observation period in each switch over.

The experiment was conducted from 01-12-'98 to 25-05-'99 comprising of four switch over periods.

At the end of every switch over period the groups were transferred from one treatment to the other treatment as follows:

Group	Period-I	Period-II	Period-III	Period-IV
I	T_1	T_2	T_3	T_4
II	T_2	T_3	T_4	T_1
III	T_3	T_4	T_1	T_2
IV	T_4	T_1	T_2	T_3

The cow number, date of birth and date of calving details of the cows utilized in the experiment are furnished below:

Group	Cow number	Date of birth	Date of calving
I	883	17.01.96	29.11.98
	863	22.10.95	31.10.98
	943	07.08.95	05.10.98
II	885	02.02.96	11.11.98
	760	10.11.95	22.10.98
	1100	10.04.96	27.10.98
III	1113	09.06.93	28.11.98
	670	08.06.93	01.12.98
	757	03.07.95	24.10.98
IV	787	27.06.94	24.10.98
	800	27.10.94	07.12.98
	886	03.02.96	09.11.98

Management

Housing

The cows that were in T_1 and T_2, were kept loose in open house with tree shade. The cows that were in T_3 and T_4, were tied in a conventional type of cow shed with asbestos roof and side ventilation. The sprinkler in T_1 and T_3 were operated two times a day, once from 1300 to 1330 h and again from 1430 to 1500 h totalling one hour a day.

Feeding

The cows under all the treatments were provided with weighed quantity of pelleted commercial concentrate cattle feed in individual feed troughs twice daily as per the standards. The cows were given 1.0 kg of concentrate daily to meet maintenance requirements. In addition, for every 2.5 kg of milk produced, 1.0 kg of concentrate feed pellet was given. Daily concentrate requirement was worked out every ten days based on average milk production during that period.

For the cows in conventional tie-barn drinking water was provided thrice daily to the fill in individual water troughs and for the cows in open house, drinking water was kept accessible throughout the day from a common drinking water trough. Green grass obtained from the farm was fed *ad libitum* to all the cows thrice daily. The calves were weaned at the time of birth.

Recording climatic data

The climatic data were recorded daily, throughout the experimental period, once in the morning at 0800 h and again in the afternoon at 1400 h. These recordings were done at animal level to quantify the microenvironment prevalent around the animal, in all the treatment groups. The climatic variables recorded were the maximum and minimum temperatures, and dry bulb and wet bulb readings. The psychrometric tables were used to arrive the relative humidity in percentage using the wet and dry bulb readings.

Physiological variables

Physiological variables like cardiac rate, respiration rate and rectal temperature of the individual cows were measured and recorded twice in a day once at 0800 h and again at 1400 h on two consecutive days in a week.

The cardiac rate and respiration rate were directly determined by counting for a minute, using a stethoscope and a stop watch. Recordings were done for individual cows with minimum of disturbances.

The rectal temperature was measured with the help of a clinical thermometer inserted to standard depth and recorded in degree celcius for each of the cows.

Body weight

Body weights were recorded in kg by individually weighing the cows on a standard platform balance with 200 g accuracy. The body weight of the cows were taken during the start of experiment and subsequently on the day when they were switched over to the next treatment.

Milk yield

The milk yield of animals were recorded individually at each milking time and total yield was estimated by weighing the quantity in kg at each milking.

Milk composition

Milk samples were collected once in a week for laboratory analysis, separately for individual cows and at each milking, following standard procedures. The individual composite milk samples from morning and afternoon were analysed for total solids, solids not fat, fat, and protein contents as per the standard procedures.

Concentrate feed consumption

The concentrate feed consumption was calculated by individually weighing the feed given twice daily. There were no left overs.

Green grass consumption

The green grass consumption was assessed by providing weighed quantities of grass to individual cows and weighing the left overs.

Water consumption

The water consumption was measured by providing weighed quantities of water in individual buckets to each of the cows and weighing back of the left overs. Weighed quantities were repeatedly supplied till the cows refused water.

Concentrate, grass and water consumption were measured once in a fortnight. Moisture content of concentrate and grass were estimated according to standard methods (AOAC, 1965).

Blood parameters

The blood samples from the individual cows were collected, in early morning before feeding, from the jugular vein into a vial containing EDTA anticoagulant once in a fortnight. Haemoglobin, erythrocyte sedimentation rate and packed cell volume were estimated as per standard procedures.

Oestrus behaviour

During the experiment period cows in all the groups were closely watched for onset, duration and intensity of oestrus and changes in external genitalia and behavioural manifestation. The intensity of oestrus was graded as high, medium or low from the clinical and behavioural signs as described by Sharma *et al.* (1968).

Analysis of data

The statistical analysis of the experimental data was carried out as per the methods suggested by Snedecor and Cochran (1967).

Results

4. RESULTS

The results of an experiment conducted to find effect of providing sprinklers to alleviate heat stress in crossbred cows are summarised in Tables 1 to 25 and Figures 1 to 11.

4.1 Climatic variables

Mean of the climatic variables such as maximum and minimum temperatures, mean temperature, relative humidity at morning, relative humidity at afternoon, mean relative humidity, wind speed, rainfall, rainy days and sunshine hours for each of the switch over periods are presented in Table 1.

During the experimental period, the mean maximum temperature ranged from 34.5 to 36.9°C and the minimum temperature from 22.4 to 23.2°C. The per cent relative humidity in the morning varied from 77.7 to 85.0 while in the afternoon it ranged from 45.4 to 63.5. In general, the variation in the climatic profile was very small between periods.

4.2 Microclimatic changes

Mean and standard error of the microclimatic changes recorded during the experimental period in the T_1, T_2, T_3 and

T_4 locations and the results of analysis of variance are presented in Table 2 and depicted in Fig.1 and 2.

The mean maximum temperature recorded in the T_1, T_2, T_3 and T_4 were 32.03, 32.17, 33.27 and 33.40°C respectively. The corresponding values for the mean minimum temperature were 22.77, 22.80, 24.22 and 24.35°C.

The mean relative humidity recorded at morning in the T_1, T_2, T_3 and T_4 were 82.09, 82.08, 83.96 and 83.73 per cent respectively. The respective values for the mean relative humidity at afternoon were 56.83, 56.60, 60.53 and 59.95 per cent.

Both within the tie-barn and within the open house, the mean maximum and minimum temperatures, and mean relative humidity at morning and afternoon did not differ significantly due to sprinklers. But the difference between the tie-barn and open house were highly significant ($P<0.01$) for all the above said variables.

4.3 Physiological norms

4.3.1 Rectal temperature

The mean rectal temperatures of cows (Table 3) recorded during the morning in the T_1, T_2, T_3 and T_4 were 38.56, 38.53, 38.52 and 38.52°C respectively, the difference between treatments were non significant. The respective values at the afternoon were (Table 4) 38.48, 38.98, 38.97 and 40.02°C and the difference between treatments were found to be highly significant ($P<0.01$).

4.3.2 Respiration rate

The mean respiration rates of the cows recorded at the mornings were 29.37, 29.72, 29.20 and 29.91 per min respectively for the cows in T_1, T_2, T_3 and T_4 (Table 5). The corresponding values at the afternoon were 47.80, 57.02, 57.36 and 73.86 per min. The difference between treatments were highly significant (Table 6).

4.3.3 Cardiac rate

The means of the cardiac rates during the morning were 62.77, 62.57, 62.74 and 63.17 per min respectively for the cows in the T_1, T_2, T_3 and T_4, the difference between treatments were non significant (Table 7). The corresponding values at the afternoon were 74.05, 74.13, 74.64 and 84.59 per min, the difference between T_4 (open house without sprinkler) and other treatments were highly significant ($P<0.01$).

4.4 Milk production

The mean weekly total milk yield in kg of the individual cows during the experimental period with results of statistical analysis are presented in Table 9 and Figure 6.

The mean weekly total milk yields of the cows in the T_1, T_2, T_3 and T_4 were 58.53, 55.68, 56.17 and 54.46 kg respectively. The difference between treatments were found to be statistically non significant.

4.5 Milk composition

The mean values of total solids, solids not fat, fat and protein percentages of individual cows, along with statistical analysis results are presented in Tables from 10 to 13. For all the variables the differences between treatments were statistically non significant.

4.6 Feed consumption

The mean daily concentrate feed consumption of the cows in the T_1, T_2, T_3 and T_4 were 4.43, 4.25, 4.40 and 4.24 kg respectively (Table 14) and there were no difference between treatments. The corresponding values for green grass consumption were 26.16, 24.10, 23.25 and 21.25 kg per day which were statistically ($P<0.01$) significant (Table 15).

4.7 Water consumption

It can be seen from Tables 16 to 18 that the mean drinking water, feed water and total water consumption of the cows in the T_1, T_2, T_3 and T_4 were 23.72, 28.60, 26.43 and 31.72; 20.31, 19.72, 19.75 and 19.32; 43.44, 49.98, 46.18 and 52.65 kg per day respectively. Statistical analysis revealed highly significant differences ($P<0.01$) in the drinking and total water consumption. Drinking and total water consumption were higher in T_4 (tie-barn without sprinkler) and feed water consumption was higher in T_1 (open house with sprinkler).

4.8 Blood parameters

4.8.1 Haemoglobin

The mean haemoglobin values of the cows in the T_1, T_2, T_3 and T_4 were 11.05, 10.26, 10.51 and 9.31 g per cent respectively (Table 19). The difference between treatments were found to be highly significant ($P<0.01$).

4.8.2 Packed cell volume (PCV)

The mean packed cell volume, per cent of the cows in the T_1, T_2, T_3 and T_4 were 31.33, 30.20, 30.47 and 28.89 respectively (Table 20). The difference between treatments were significant ($P<0.01$).

4.8.3 Erythrocyte sedimentation rate (ESR)

The mean erythrocyte sedimentation rate of the cows in the T_1, T_2, T_3 and T_4 were 3.21, 3.68, 3.26 and 4.18 mm per 24 hours respectively (Table 21). Statistical analysis revealed that the difference between treatments were significant ($P<0.01$).

4.9 Body weight change

The body weights of the experimental cows taken at each of the switch over periods and tabulated and presented in Table 22. There was a uniform loss in body weights of all the experimental cows as lactation progressed upto the peak yield stage, thereafter the cows had shown tendency to regain body weights irrespective of the type of treatment given.

4.10 Feeding behaviour

Feeding behaviour of the cows observed during the course of the experiment in the T_1, T_2, T_3 and T_4 were tabulated and presented in Table 23.

4.11 Oestrus behaviour

Number of cows observed in oestrus during the experimental period, duration and intensity of oestrus, physical changes of external genitalia during oestrus, behavioural manifestation of oestrus and number of cows conceived are tabulated and presented in Tables 24 and 25.

Table 1. Mean environmental variables during the experimental periods

Sl. No.	Environmental variables	Period I	Period II	Period III	Period IV	Mean
1.	Maximum temperature (°C)	34.5	34.8	36.9	36.1	35.5
2.	Minimum temperature (°C)	22.4	23.2	22.5	23.1	22.8
3.	Mean temperature (°C)	27.5	28.8	29.7	29.6	28.65
4.	Relative humidity morning (%)	79.5	77.7	81.6	85.0	80.95
5.	Relative humidity afternoon (%)	57.0	60.1	45.4	63.5	56.50
6.	Mean relative humidity (%)	68.3	68.9	63.5	74.3	68.75
7.	Wind speed (kmph)	6.2	5.8	5.7	3.2	5.23
8.	Rainfall (mm)	10.5	-	18.6	112.5	35.4
9.	Rainy days	1	-	2	5	2.0
10.	Sunshine hours per day	9.0	9.2	9.5	8.9	9.15

Table 2. Mean and SE of microclimatic changes

Period	Treatment groups	Maximum temperature °C	Minimum temperature °C	Relative humidity (%) Morning	Relative humidity (%) Afternoon
I	T_1	29.99±0.10	21.50±0.68	80.83±0.34	59.13±0.83
	T_2	30.24±0.10	22.25±0.16	80.83±0.28	57.90±0.75
	T_3	31.09±0.10	24.10±0.10	83.57±0.37	64.20±0.59
	T_4	31.40±0.11	24.34±0.10	83.43±0.22	62.37±0.64
II	T_1	31.88±0.14	23.36±0.14	78.43±0.21	59.18±0.15
	T_2	32.04±0.13	23.24±0.14	78.80±0.22	59.20±0.18
	T_3	32.89±0.11	23.92±0.12	81.47±0.25	62.53±0.26
	T_4	32.99±0.11	24.08±0.09	81.37±0.20	61.13±0.18
III	T_1	34.38±0.11	22.80±0.16	82.60±0.37	44.90±0.51
	T_2	34.34±0.11	22.89.0.16	81.97±0.42	44.47±0.50
	T_3	35.53±0.15	24.39±0.16	83.56±0.44	47.83±0.62
	T_4	35.62±0.15	24.46±0.17	83.10±0.45	47.97±0.62
IV	T_1	31.82±0.63	22.73±0.34	86.50±0.80	64.10±1.84
	T_2	32.05±0.57	22.86±0.35	86.70±0.76	64.83±1.90
	T_3	33.57±0.56	24.48±0.40	87.23±0.58	67.57±1.76
	T_4	33.52±0.57	24.50±0.42	87.00±0.63	68.20±1.78
Mean values					
	T_1	32.03^{b}	22.77^{b}	82.09^{b}	56.83^{b}
	T_2	32.17^{b}	22.80^{b}	82.08^{b}	56.60^{b}
	T_3	33.27^{a}	24.22^{a}	83.96^{a}	60.53^{a}
	T_4	33.40^{a}	24.35^{a}	83.73^{a}	59.95^{a}
'F' values		11.85**	56.22**	10.12**	5.90**
C.D. Values		0.57	0.32	0.89	2.34

** Figures having different superscription in a column differ significantly ($P<0.01$)

MICROCLIMATIC CHANGES

Fig. 1 MAXIMUM AND MINIMUM TEMPERATURE

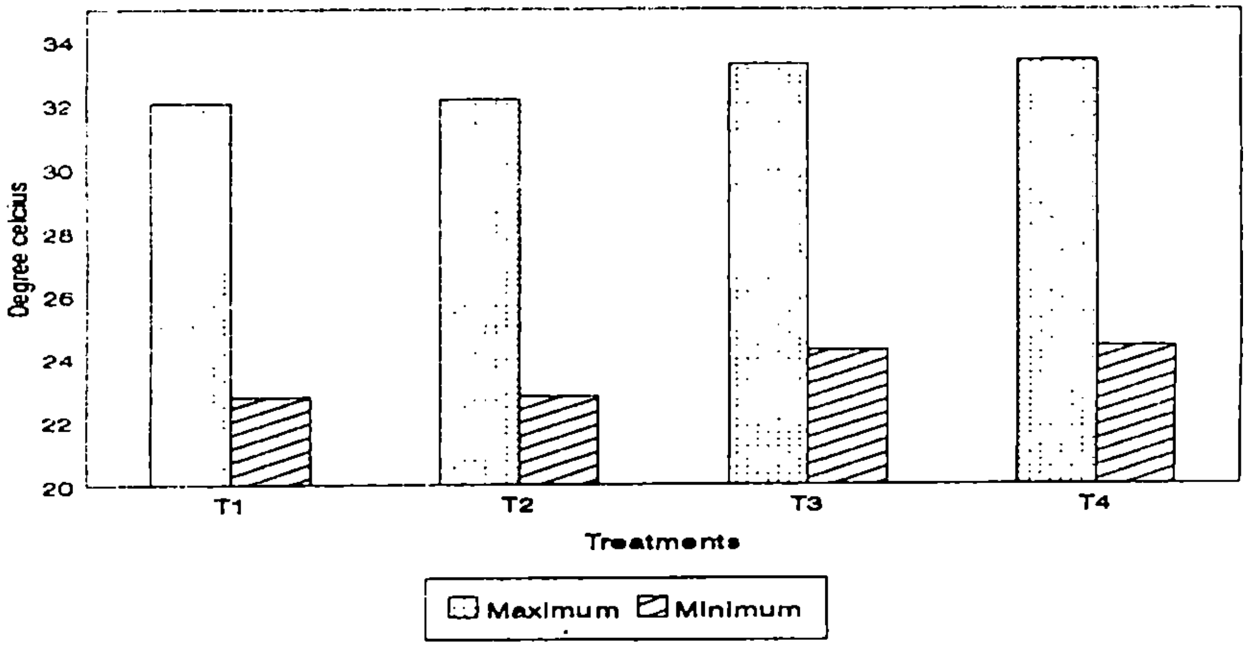

Fig. 2 RELATIVE HUMIDITY MORNING AND AFTERNOON

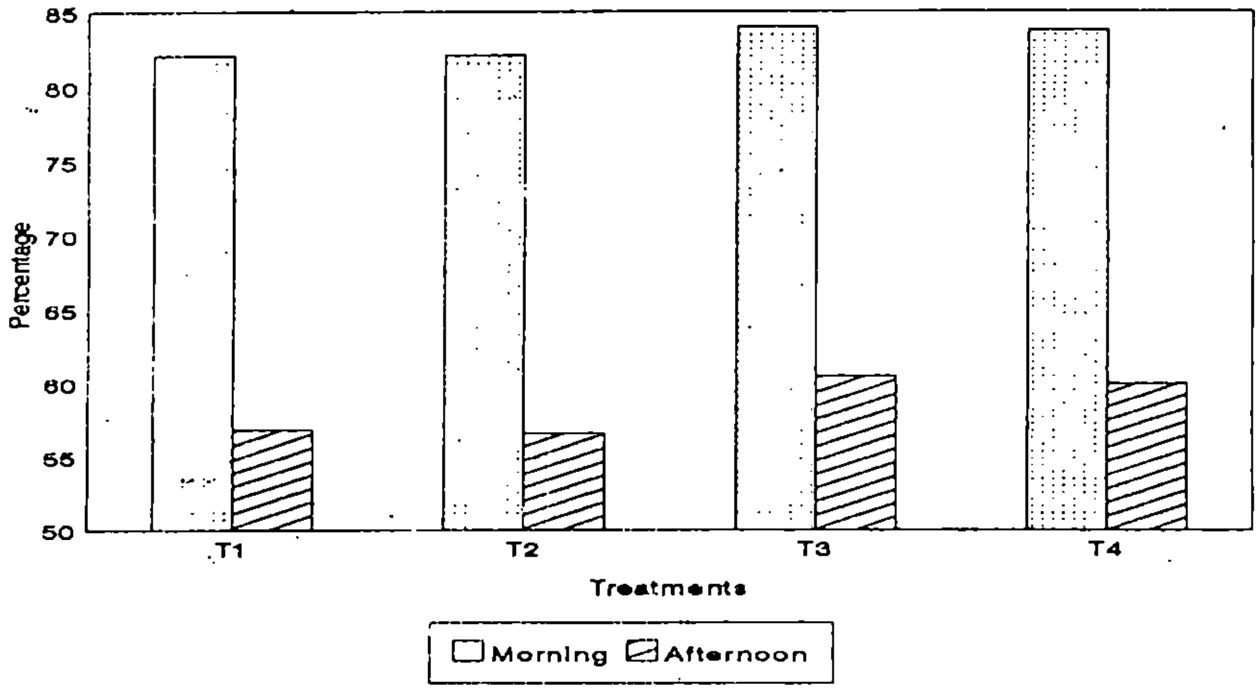

Table 3. Mean rectal temperature in degrees celsius at forenoon

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	38.57	38.33	38.46	38.56
I	863	38.53	38.46	38.57	38.59
	943	38.69	34.41	38.55	35.55
		T_2	T_3	T_4	T_1
	885	38.66	38.50	38.58	38.27
II	760	38.45	38.52	38.52	38.61
	1100	38.69	38.56	38.53	38.50
		T_3	T_4	T_1	T_2
	1113	38.41	38.52	38.41	38.42
III	670	38.50	38.46	38.73	38.48
	757	38.49	38.50	38.69	38.44
		T_4	T_1	T_2	T_3
	787	38.42	38.43	38.70	38.54
IV	800	38.46	38.44	38.65	38.57
	886	38.49	38.86	38.65	38.59

Mean values: T_1 : 38.56
T_2 : 38.53
T_3 : 38.52
T_4 : 38.52

`F' value : 1.24 NS

NS- Statistically not significant

Table 4. Mean rectal temperature in degrees celsius at afternoon

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	38.56	38.86	38.93	39.98
I	863	38.53	39.03	39.00	39.01
	943	38.50	39.05	38.89	39.06
		T_2	T_3	T_4	T_1
	885	38.88	39.00	39.99	38.44
II	760	38.93	38.98	39.12	38.45
	1100	39.08	39.01	39.04	38.45
		T_3	T_4	T_1	T_2
	1113	38.96	39.88	38.47	38.97
III	670	39.05	39.22	38.44	38.96
	757	38.99	40.04	38.45	39.00
		T_4	T_1	T_2	T_3
	787	39.99	38.51	39.02	38.92
IV	800	39.95	38.44	39.04	38.91
	886	39.03	38.47	38.97	39.01

Mean values: T_1 : 38.48^{c}

T_2 : 38.98^{b}

T_3 : 38.97^{b}

T_4 : 40.02^{a}

\`F' value : 35.72**

CD value : 0.21

** Figures having different superscription differ significantly (P<0.01)

Fig. 3 RECTAL TEMPERATURE
MORNING AND AFTERNOON

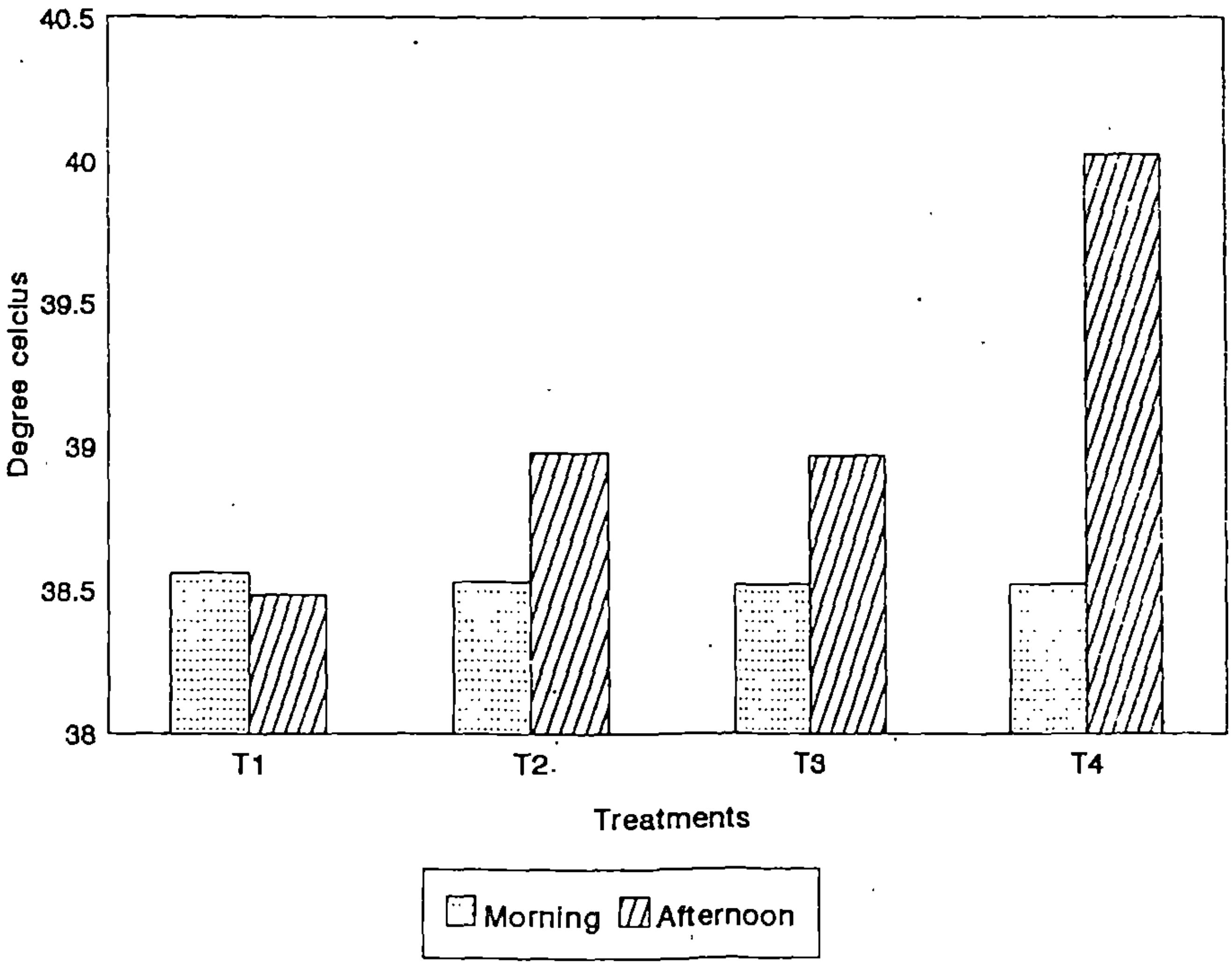

Table 5. Mean respiration rates per minute at forenoons

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	26.4	27.4	26.9	27.3
I	863	25.0	27.6	27.0	27.5
	943	24.2	27.4	26.7	26.6
		T_2	T_3	T_4	T_1
	885	29.8	30.2	29.3	30.3
II	760	28.4	31.2	30.7	30.7
	1100	31.2	29.6	32.2	29.4
		T_3	T_4	T_1	T_2
	1113	29.9	31.2	31.6	30.5
III	670	28.7	28.4	29.4	29.5
	757	30.7	30.5	30.7	28.0
		T_4	T_1	T_2	T_3
	787	33.2	32.4	32.7	31.1
IV	800	32.9	32.2	33.1	29.1
	886	29.1	30.1	31.0	29.3

Mean values: T_1 : 29.37
T_2 : 29.72
T_3 : 29.20
T_4 : 29.91

'F' value : 1.19 NS

NS - Statistically not significant

Table 6. Mean respiration rates per minute at afternoons

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	40.4	47.9	47.8	73.6
I	863	43.7	49.2	49.3	75.1
	943	42.6	51.5	52.9	77.7
		T_2	T_3	T_4	T_1
	885	54.0	56.3	72.0	46.0
II	760	60.8	64.9	75.4	45.3
	1100	66.2	66.1	74.2	48.6
		T_3	T_4	T_1	T_2
	1113	55.0	72.7	53.9	59.9
III	670	63.3	74.4	55.2	60.2
	757	59.9	70.3	52.1	60.0
		T_4	T_1	T_2	T_3
	787	70.2	49.6	57.5	56.1
IV	800	74.1	49.0	58.7	58.9
	886	76.6	47.2	58.3	57.8

Mean values: T_1 : 47.80^{c}

T_2 : 57.02^{b}

T_3 : 57.36^{b}

T_4 : 73.86^{a}

'F' value : 102.22**
CD value :3.10

** Figures having different superscription differ significantly (P<0.01)

Fig. 4 RESPIRATION RATE
MORNING AND AFTERNOON

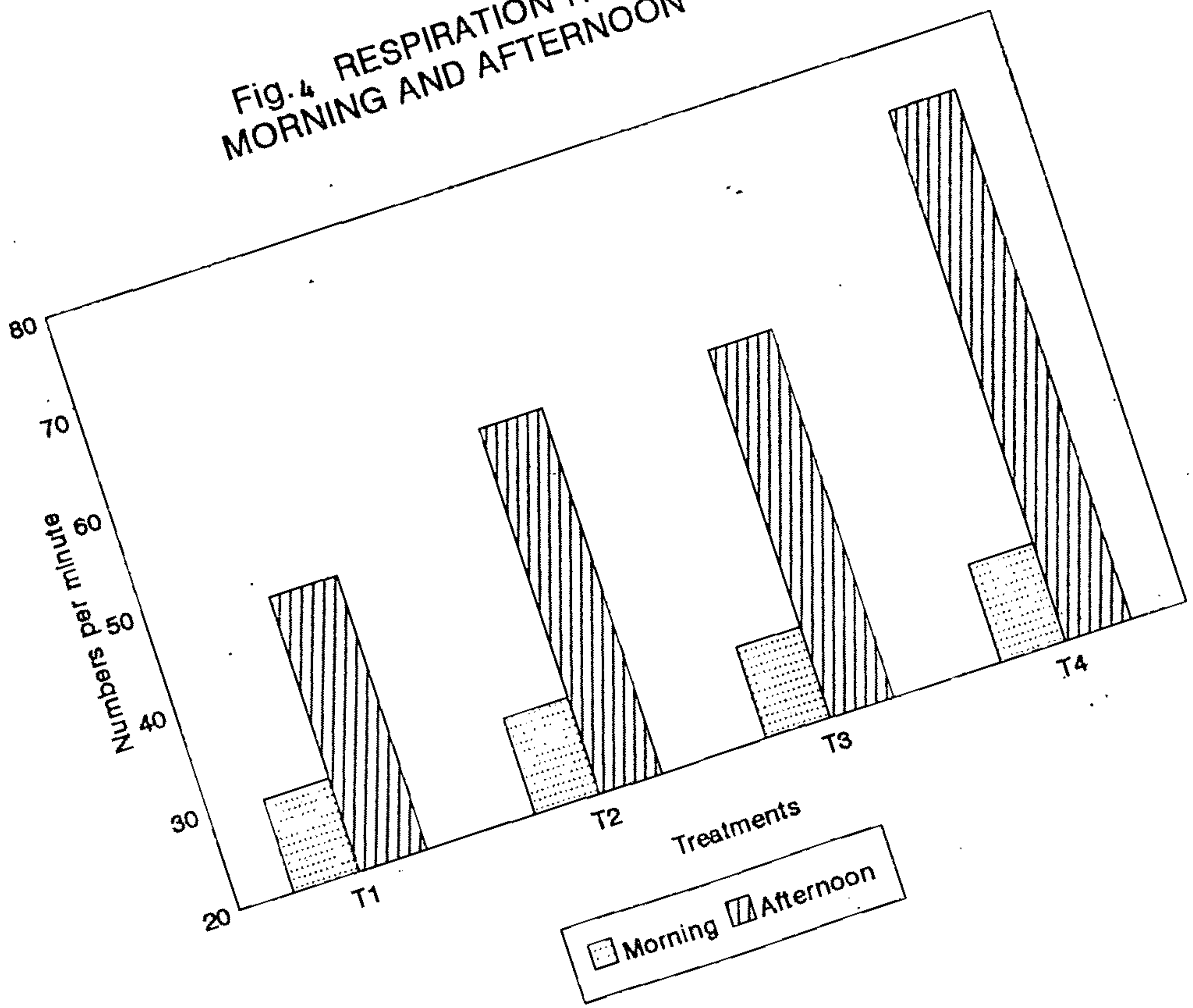

Table 7. Mean cardiac rates per minute at forenoons

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	58.7	59.3	60.8	61.6
I	863	59.2	57.7	59.4	60.9
	943	58.2	60.1	61.8	60.5
		T_2	T_3	T_4	T_1
	885	58.9	57.7	58.8	61.1
II	760	59.9	60.9	61.5	62.6
	1100	61.1	63.1	62.4	64.7
		T_3	T_4	T_1	T_2
	1113	63.9	63.7	64.7	65.6
III	670	62.0	66.4	63.3	66.6
	757	65.6	68.2	66.6	67.6
		T_4	T_1	T_2	T_3
	787	62.3	63.3	63.2	65.0
IV	800	65.2	63.8	64.4	65.8
	886	66.5	67.0	66.4	66.9

Mean values: T_1 : 62.77
T_2 : 62.57
T_3 : 62.74
T_4 : 63.17

`F' value : 0.841 NS

NS - Statistically not significant

Table 8. Mean cardiac rates per minute at afternoons

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	68.9	69.4	70.8	79.8
I	863	69.1	69.5	72.4	80.9
	943	70.1	69.8	70.5	75.6
		T_2	T_3	T_4	T_1
	885	79.2	78.5	89.6	79.4
II	760	81.6	80.9	88.5	80.4
	1100	72.4	73.5	90.6	72.2
		T_3	T_4	T_1	T_2
	1113	82.6	95.4	83.5	84.5
III	670	74.6	88.8	74.9	74.4
	757	70.8	82.5	70.7	70.5
		T_4	T_1	T_2	T_3
	787	79.5	71.1	72.3	71.5
IV	800	76.4	68.5	67.4	69.8
	886	87.5	79.8	78.5	79.8

Mean values: T_1 : 74.05^{a}

T_2 : 74.13^{a}

T_3 : 74.64^{a}

T_4 : 84.59^{b}

'F' value : 103.99**
CD value : 1.46

** Figures having different superscription differ significantly ($P<0.01$)

Fig.5 CARDIAC RATE
MORNING AND AFTERNOON

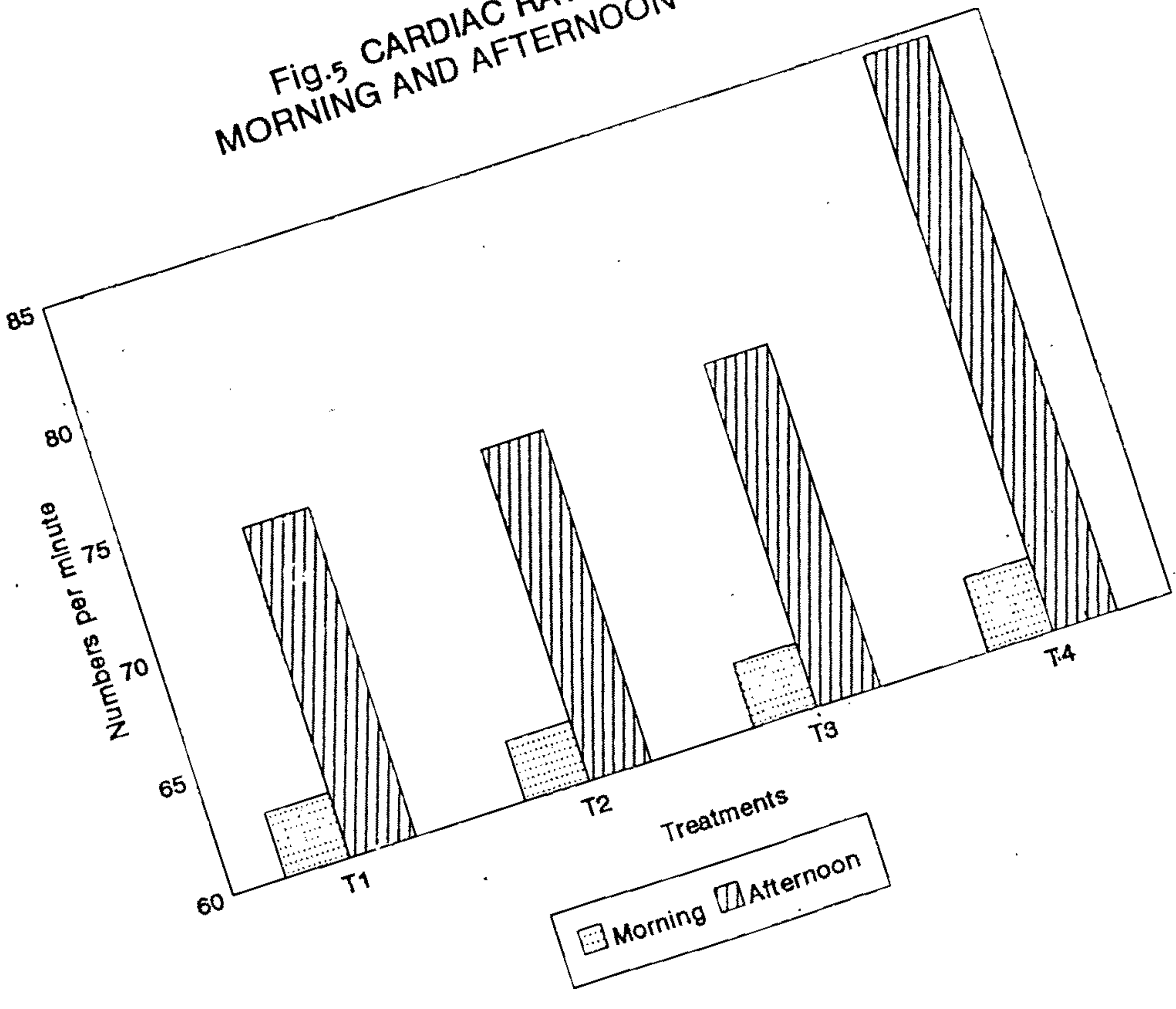

Table 9. Mean weekly milk yield of individual cows (kg)

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	87.52	85.12	70.58	70.70
I	863	65.51	62.76	38.94	32.59
	943	55.18	49.23	32.90	31.99
		T_2	T_3	T_4	T_1
	885	91.26	84.63	60.57	59.38
II	760	47.53	40.88	36.21	38.16
	1100	54.60	53.15	34.04	35.98
		T_3	T_4	T_1	T_2
	1113	60.06	72.61	62.96	49.14
III	670	62.67	39.85	43.59	41.49
	757	74.64	68.74	41.62	08.52
		T_4	T_1	T_2	T_3
	787	75.88	79.12	71.89	62.16
IV	800	81.92	87.63	81.45	78.52
	886	48.44	45.68	25.13	14.84

Mean values: T_1 : 58.53
T_2 : 55.68
T_3 : 56.16
T_4 : 54.46

`F' value : 1.12 NS

NS - Statistically not significant

Fig. 6 MEAN WEEKLY MILK PRODUCTION(Kg)

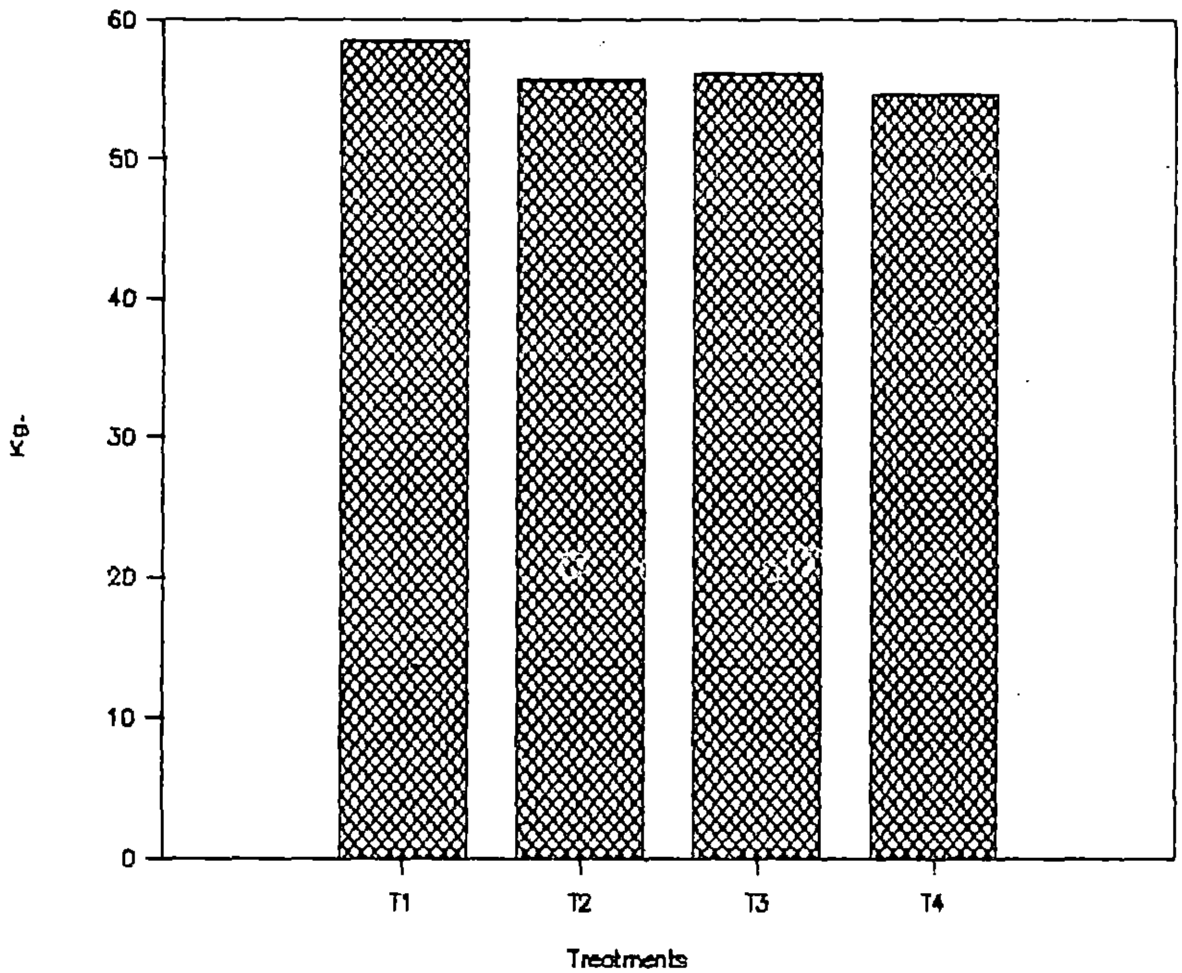

Table 10. Mean milk fat percentage of individual cows

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	4.04	4.06	4.10	4.38
I	863	3.74	4.50	4.70	4.80
	943	5.06	5.78	5.22	5.32
		T_2	T_3	T_4	T_1
	885	5.38	5.40	5.50	5.44
II	760	4.24	4.98	5.20	5.50
	1100	5.56	5.80	5.56	5.98
		T_3	T_4	T_1	T_2
	1113	4.36	4.22	4.64	4.44
III	670	4.90	5.16	5.12	4.98
	757	5.56	5.70	6.54	6.20
		T_4	T_1	T_2	T_3
	787	4.86	5.08	4.84	5.90
IV	800	5.10	6.28	5.84	6.08
	886	6.64	6.84	6.42	6.38

Mean values: T_1 : 5.36
T_2 : 5.19
T_3 : 5.28
T_4 : 5.20

'F' value : 0.86 NS
NS - Statistically not significant

Table 11. Mean milk protein percentage of individual cows

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	3.18	3.14	3.16	3.24
I	863	3.11	3.26	3.31	2.87
	943	3.30	3.29	3.22	3.51
		T_2	T_3	T_4	T_1
	885	3.20	3.05	3.12	3.15
II	760	2.97	2.94	2.99	3.10
	1100	3.36	3.35	3.34	3.35
		T_3	T_4	T_1	T_2
	1113	3.26	3.32	3.30	3.25
III	670	3.27	3.35	3.37	3.25
	757	3.17	3.23	3.20	3.19
		T_4	T_1	T_2	T_3
	787	3.10	3.25	3.18	3.19
IV	800	3.25	3.21	3.15	3.26
	886	3.22	3.20	3.19	3.19

Mean values: T_1 : 3.22
T_2 : 3.20
T_3 : 3.20
T_4 : 3.21

'F' value : 0.10 NS

NS - Statistically not significant

Table 12. Mean milk solids not fat percentage of individual cows

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	8.45	8.25	8.04	8.63
I	863	8.66	8.43	8.24	8.84
	943	8.47	8.26	8.02	8.62
		T_2	T_3	T_4	T_1
	885	8.60	8.41	8.25	8.86
II	760	8.50	8.30	8.03	8.67
	1100	8.72	8.53	8.42	8.94
		T_3	T_4	T_1	T_2
	1113	8.28	8.06	8.02	8.68
III	670	8.51	8.34	8.14	8.74
	757	8.36	8.14	8.01	8.65
		T_4	T_1	T_2	T_3
	787	8.72	8.53	8.32	8.92
IV	800	8.61	8.43	8.25	8.85
	886	8.70	8.52	8.32	8.92

Mean values: T_1 : 8.48
T_2 : 8.48
T_3 : 8.45
T_4 : 8.45

`F' value : 1.88 NS

NS - Statistically not significant

Table 13. Mean milk total solids percentage of individual cows

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	12.49	12.31	12.41	13.01
I	863	12.40	12.93	12.94	13.64
	943	13.53	14.04	13.24	13.94
		T_2	T_3	T_4	T_1
	885	13.98	13.81	13.75	14.30
II	760	12.74	13.28	13.23	14.17
	1100	14.28	14.33	13.98	14.92
		T_3	T_4	T_1	T_2
	1113	12.64	12.28	12.66	13.12
III	670	13.41	13.50	13.26	13.72
	757	14.92	13.84	14.55	14.85
		T_4	T_1	T_2	T_3
	787	13.58	13.61	12.32	13.82
IV	800	13.71	14.62	14.09	14.93
	886	15.34	15.36	14.74	15.30

Mean values: T_1 : 13.82
T_2 : 13.59
T_3 : 13.73
T_4 : 13.65

'F' value : 1.12 NS

NS - Statistically not significant

Table 14. Mean concentrate feed consumption per day (kg)

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	5.50	6.00	5.17	5.00
I	863	4.83	4.50	3.50	2.83
	943	4.50	3.50	3.50	3.00
		T_2	T_3	T_4	T_1
	885	6.00	5.67	4.67	4.67
II	760	3.50	3.17	3.17	3.50
	1100	4.00	4.17	3.33	3.50
		T_3	T_4	T_1	T_2
	1113	5.50	5.50	4.00	3.83
III	670	4.33	3.00	3.50	3.33
	757	5.33	5.17	3.83	2.33
		T_4	T_1	T_2	T_3
	787	5.17	5.33	5.17	5.00
IV	800	5.33	6.00	5.83	5.50
	886	4.67	4.00	3.00	2.50

Mean values: T_1 : 4.43
T_2 : 4.25
T_3 : 4.40
T_4 : 4.24

'F' value : 0.724 NS

NS - Statistically not significant

Table 15. Mean green grass consumption of individual cows in kg

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	25.33	25.00	26.00	20.33
I	863	25.67	25.33	24.00	23.33
	943	24.67	23.00	22.67	21.53
		T_2	T_3	T_4	T_1
	885	24.00	26.33	25.00	27.00
II	760	25.67	27.67	25.33	29.13
	1100	17.67	20.00	20.00	26.00
		T_3	T_4	T_1	T_2
	1113	16.67	18.33	29.33	20.67
III	670	28.00	28.00	33.33	31.67
	757	18.00	20.00	26.33	22.00
		T_4	T_1	T_2	T_3
	787	20.33	26.33	26.00	27.00
IV	800	18.33	26.67	20.33	23.33
	886	25.33	27.33	27.33	19.33

Mean values: T_1 : 26.16^{a}

T_2 : 24.10^{b}

T_3 : 23.25^{b}

T_4 : 21.25^{c}

`F' value : 37.14**

CD value : 2.0

** Figures having different superscription differ significantly (P<0.01)

Fig.7 GREEN GRASS CONSUMPTION

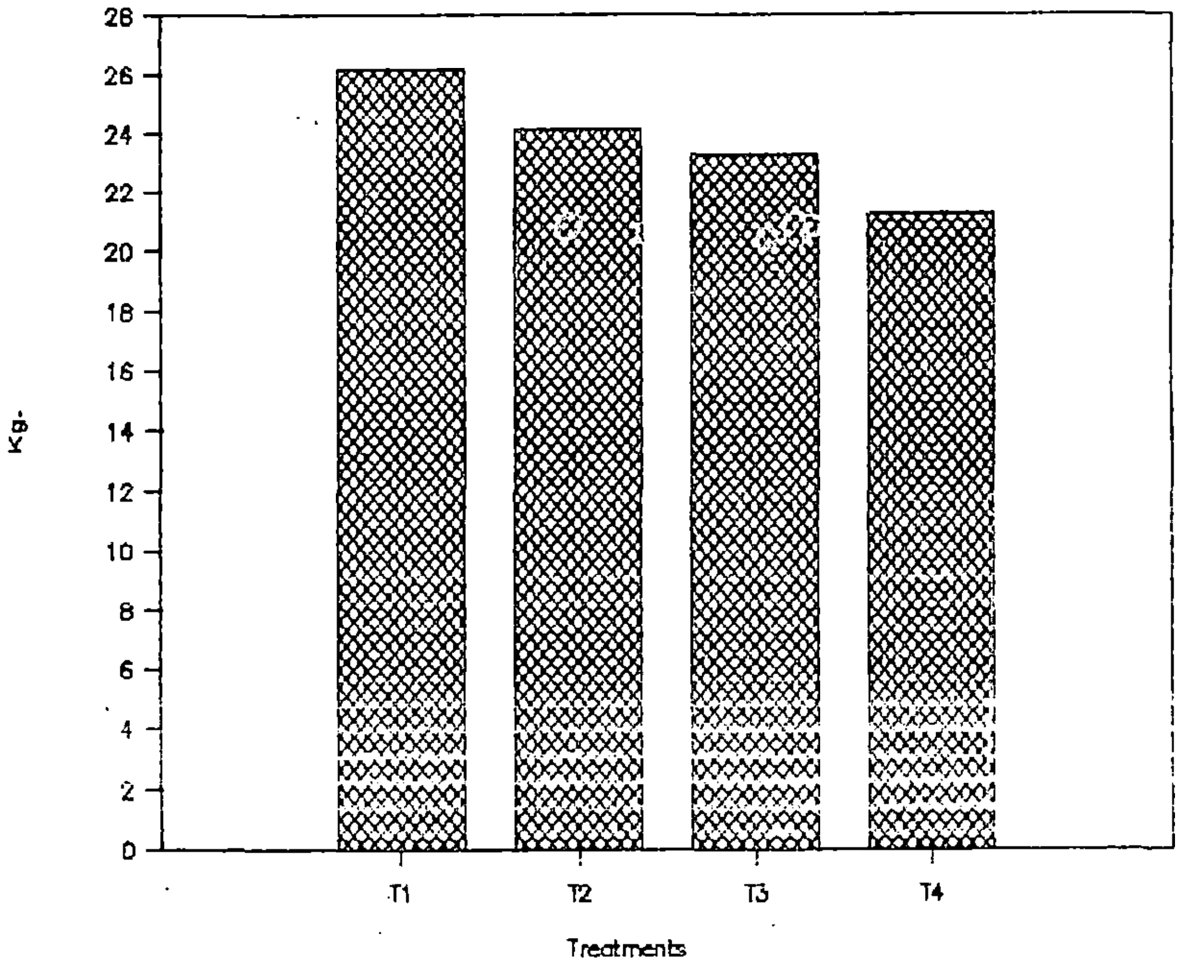

Table 16. Mean (drinking) water consumption of individual cows in kg

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	23.33	33.33	27.67	28.67
I	863	20.33	29.67	25.33	36.33
	943	25.33	30.00	22.33	22.67
		T_2	T_3	T_4	T_1
	885	30.67	26.33	28.00	24.33
II	760	24.33	25.00	22.67	19.33
	1100	27.00	26.00	25.00	14.00
		T_3	T_4	T_1	T_2
	1113	23.17	31.67	22.67	25.00
III	670	22.67	36.00	16.00	19.00
	757	30.33	36.33	19.67	20.33
		T_4	T_1	T_2	T_3
	787	41.67	36.67	35.00	33.33
IV	800	35.00	34.00	31.00	28.67
	886	37.00	29.00	28.00	26.33

Mean values: T_1 : 23.72^{d}

T_2 : 28.60^{b}

T_3 : 26.43^{c}

T_4 : 31.72^{a}

`F' value : 45.10**

CD value : 1.50

** Figures having different superscription differ significantly ($P<0.01$)

Table 17. Mean involuntary water (feed water) consumption of individual cows in kg

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	22.27	21.80	21.85	22.58
I	863	22.56	21.94	20.01	20.77
	943	18.83	19.87	18.87	19.97
		T_2	T_3	T_4	T_1
	885	20.95	22.90	20.94	22.44
II	760	22.14	23.81	23.53	24.88
	1100	15.39	17.38	16.72	20.13
		T_3	T_4	T_1	T_2
	1113	14.67	16.08	16.23	17.08
III	670	24.14	25.80	25.20	25.96
	757	15.78	17.48	17.03	18.02
		T_4	T_1	T_2	T_3
	787	18.45	20.87	21.81	22.32
IV	800	16.06	18.12	17.22	19.39
	886	13.46	15.10	14.50	15.88

Mean values: T_1 : 20.31^{a}

T_2 : 19.72^{ab}

T_3 : 19.75^{ab}

T_4 : 19.32^{b}

\`F' value : 3.56*

CD value : 0.62

* Figures having different superscription differ significantly (P<0.05)

Table 18. Mean total water (feed water + drinking water) consumption of individual cows in kg

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	43.60	55.13	49.52	51.25
I	863	40.89	51.31	45.34	51.10
	943	44.16	49.87	41.20	52.64
		T_2	T_3	T_4	T_1
	885	51.62	49.23	48.94	46.77
II	760	56.47	48.81	56.20	44.21
	1100	42.39	43.38	49.72	32.13
		T_3	T_4	T_1	T_2
	1113	37.84	47.75	38.90	42.08
III	670	46.81	55.80	41.20	44.96
	757	46.11	47.81	36.70	38.35
		T_4	T_1	T_2	T_3
	787	66.12	56.54	56.81	55.65
IV	800	54.06	52.12	58.22	48.04
	886	50.46	44.10	52.50	42.21

Mean values: T_1 : 43.44^{d}

T_2 : 49.98^{b}

T_3 : 46.18^{c}

T_4 : 52.65^{a}

`F' value : 23.06**
CD value : 2.45

** Figures having different superscription differ significantly (P<0.01)

Fig. 8 DRINKING, FEED AND TOTAL WATER CONSUMPTION

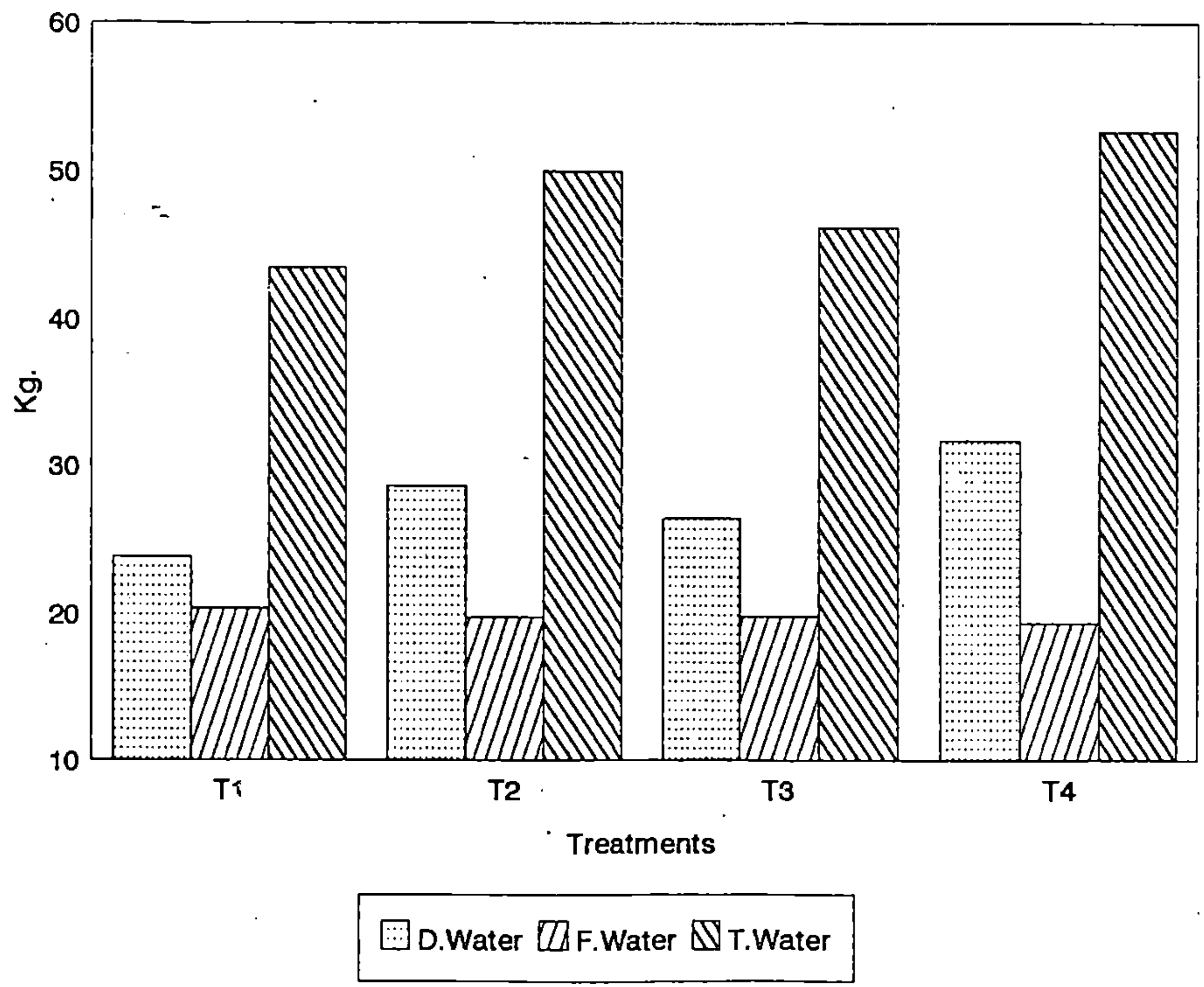

Table 19. Mean haemoglobin values of individual cows in g per cent

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	12.26	10.66	11.33	8.16
I	863	12.40	11.16	12.33	8.33
	943	11.83	09.83	10.16	8.00
		T_2	T_3	T_4	T_1
	885	11.00	10.00	8.66	9.00
II	760	12.16	10.50	8.66	8.16
	1100	09.16	11.33	9.00	9.00
		T_3	T_4	T_1	T_2
	1113	11.33	9.60	12.00	9.33
	670	11.33	9.66	11.83	9.00
III	757	10.50	9.00	10.66	8.00
		T_4	T_1	T_2	T_3
	787	11.66	12.00	11.33	9.33
IV	800	10.33	12.16	11.00	9.00
	886	10.66	11.33	10.50	8.50

Mean values: T_1 : 11.05^{a}

T_2 : 10.26^{c}

T_3 : 10.51^{b}

T_4 : 9.31^{d}

'F' value : 99.17**

CD value : 0.21

** Figures having different superscription differ significantly ($P<0.01$)

BLOOD PARAMETERS
Fig.9 HAEMOGLOBIN

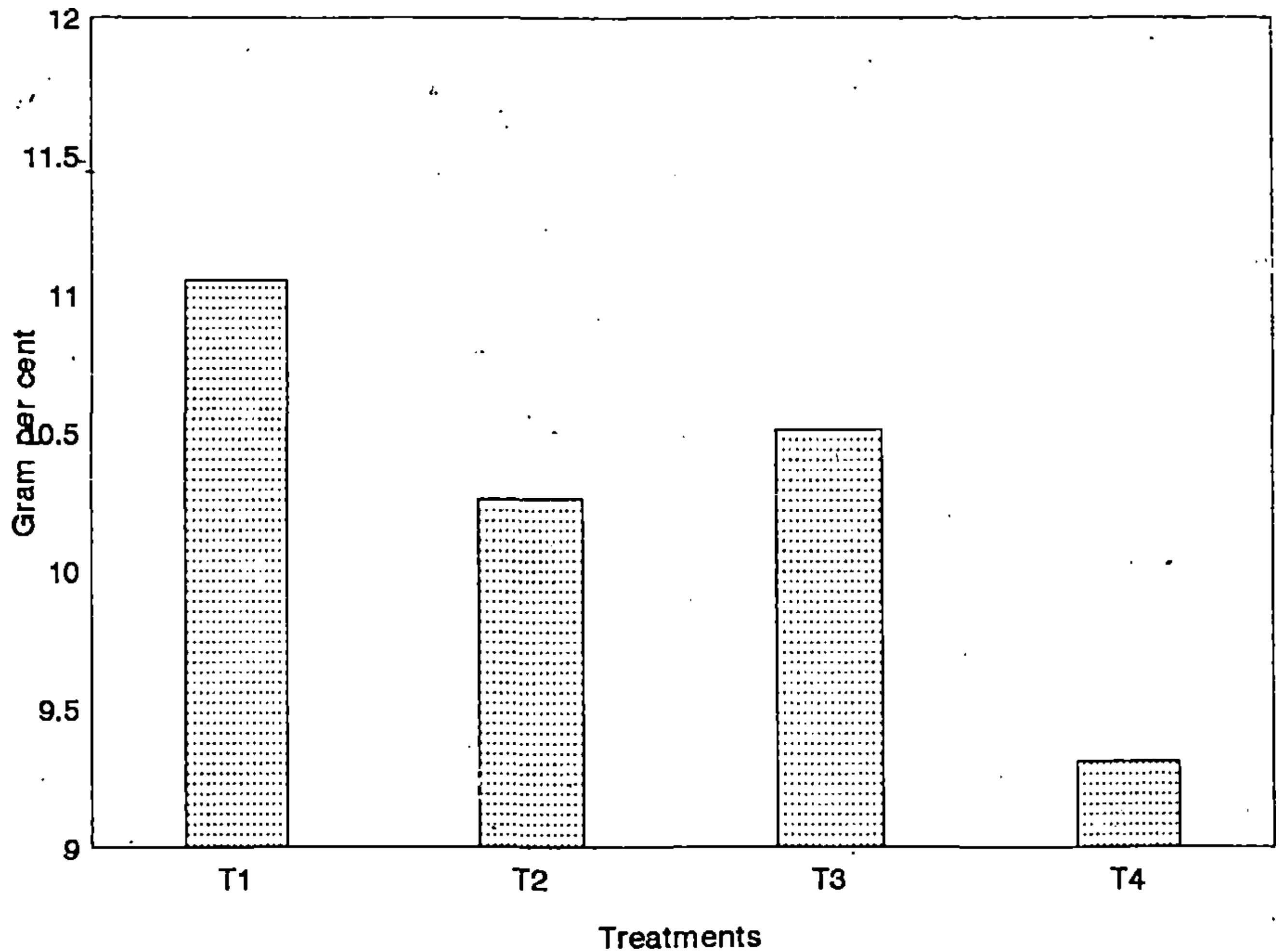

Table 20. Mean packed cell volume (PCV) percentage of individual cows

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	33.33	30.66	30.66	29.00
I	863	33.66	30.33	30.00	27.66
	943	34.66	30.33	30.33	27.00
		T_2	T_3	T_4	T_1
	885	31.66	30.00	28.00	30.00
II	760	34.33	32.33	30.66	32.33
	1100	31.00	29.00	27.33	29.33
		T_3	T_4	T_1	T_2
	1113	30.66	27.33	28.66	27.00
III	670	30.33	27.33	29.33	28.66
	757	30.33	27.00	29.66	28.33
		T_4	T_1	T_2	T_3
	787	29.66	30.00	29.00	30.33
IV	800	32.33	32.33	30.66	31.33
	886	33.33	32.66	30.33	30.33

Mean values: T_1 : 31.33^{a}

T_2 : 30.19^{b}

T_3 : 30.47^{ab}

T_4 : 28.89^{c}

'F' value : 8.799**
CD value : 0.99

** Figures having different superscription differ significantly (P<0.01)

Table 21. Mean erythrocyte sedimentation rate (ESR) of individual cows (mm per 24 hours)

Group	Cow No.	Period I	Period II	Period III	Period IV
		T_1	T_2	T_3	T_4
	883	3.00	3.33	3.66	4.16
I	863	2.83	3.50	3.50	4.16
	943	3.00	3.33	3.33	3.66
		T_2	T_3	T_4	T_1
	885	3.33	3.33	4.33	3.00
II	760	3.66	3.66	4.66	3.33
	1100	3.66	3.33	4.50	3.50
		T_3	T_4	T_1	T_2
	1113	2.83	4.16	3.66	4.00
III	670	2.66	4.00	3.33	3.50
	757	3.00	3.83	3.83	4.00
		T_4	T_1	T_2	T_3
	787	4.18	3.16	4.16	3.33
	800	4.33	2.83	4.00	3.50
	886	4.16	3.00	3.66	3.00

Mean values: T_1 : 3.21^{c}

T_2 : 3.68^{b}

T_3 : 3.26^{c}

T_4 : 4.18^{a}

'F' value : 44.11**

CD value : 0.20

** Figures having different superscription differ significantly (P<0.01)

Fig. 11 ERYTHROCYTE SEDIMENTATION RATE(mm per 24 hrs)

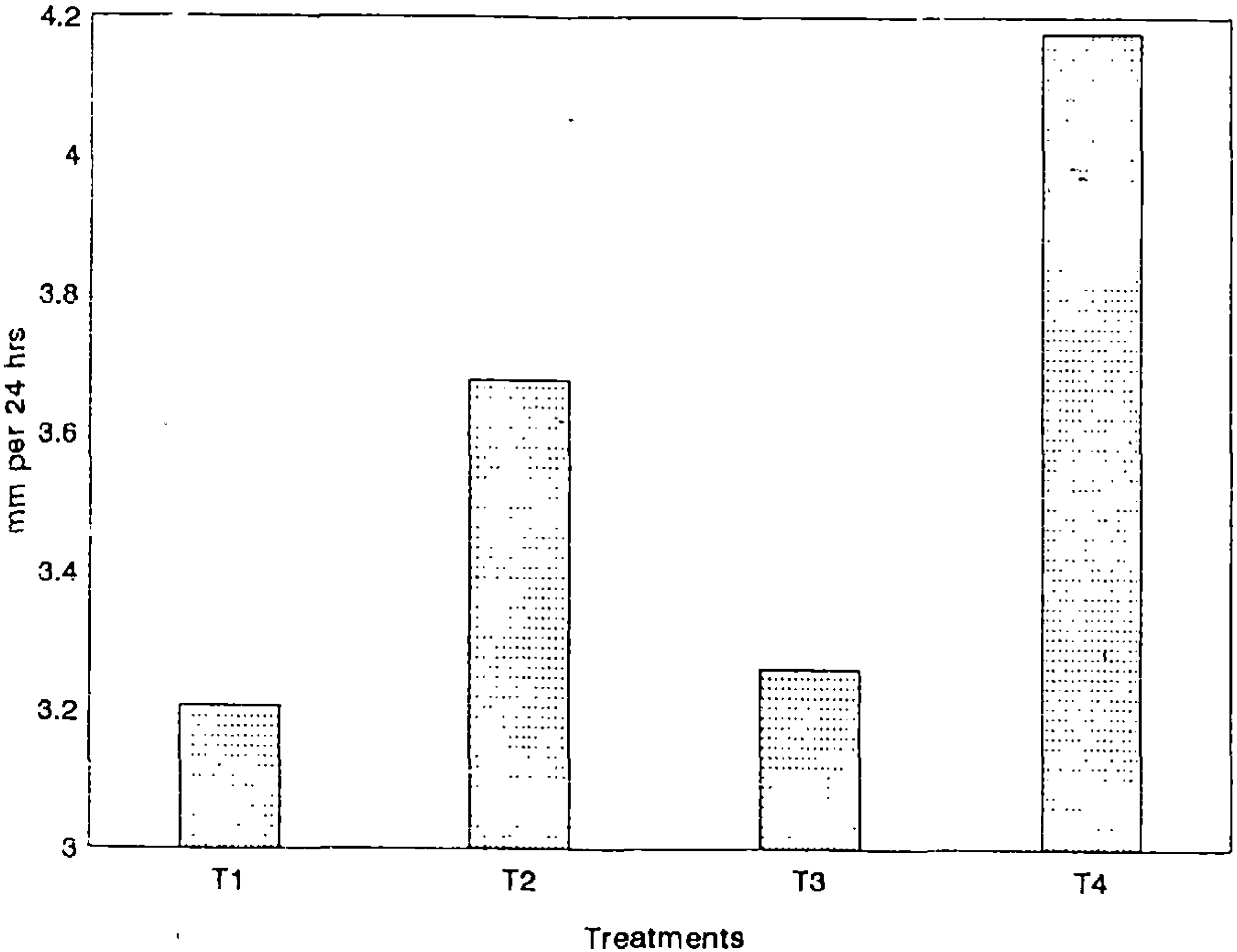

Table 22. Body weight change (kg)

Sl.No.	Cow No.	Date of weighment				
		1.12.98	14.1.99	27.2.99	12.4.99	25.5.99
1.	883	381.0	354.0	336.5	356.0	363.6
2.	863	358.0	3400	329.0	348.0	353.6
3.	943	344.4	320.0	317.0	321.6	340.0
4.	885	370.0	335.0	321.0	330.0	348.0
5.	760	299.4	281.4	272.0	290.0	292.0
6.	1100	288.0	271.0	263.4	267.0	275.8
7.	1113	313.6	283.0	284.0	282.0	302.0
8.	670	371.2	337.0	320.0	335.0	347.0
9.	757	339.0	307.8	292.0	298.0	309.0
10.	787	377.0	302.0	305.0	304.0	325.0
11.	800	335.0	299.0	292.0	288.0	298.0
12.	886	281.5	260.0	244.0	256.0	263.4

Table 23. Feeding behaviour

Sl.No.	Behaviour	T_1	T_2	T_3	T_4
1.	Feeding shortly after morning milking	++	++	++	++
2.	Feeding during hot hours of the day	++	++	++	+
3.	Feeding shortly after afternoon milking	++	++	++	++
4.	Night time feeding	+	++	+	+++
5.	Wastage of roughage feed (green grass)	++	++	++	++
6.	Wastage of concentrate feed	-	-	-	+
7.	Showing competition during feeding	++	++	+	+
8.	Exhibition of agonistic behaviour during feeding	++	++	+	+
9.	Placing foreleg into manger	+	+	+	+
10.	Rumination during hot hours of the day	++	++	+	+
11.	Rumination shortly after night fall	+++	+++	+++	+++
12.	Drooling of white frothy saliva from the mouth during hot hours of the day	-	-	+	++
13.	Rumination while standing	++	++	++	+
14.	Rumination while lying	++	++	++	++

+++ - Most commonly occur
++ - Commonly occur
+ - Rarely occur
'-' - Not seen

Table 24. Oestrus behaviour

1. Physical changes of external genitalia, intensity and duration of oestrus

Treatments		T_1	T_2	T_3	T_4
Number of animals observed		6	5	5	6
1. Vulval oedema					
	High	4	4	3	3
	Medium	1	1	2	2
	Low	-	-	-	1
2. Hyperaemia of vaginal mucosa	High	4	4	3	3
	Medium	2	1	2	2
	Low	-	-	-	1
3. Vulval discharge					
	Stringy	5	4	3	3
	Watery	-	1	1	-
	Scanty	1	-	1	3
4. Intensity of oestrus					
	High	5	4	3	2
	Medium	1	1	1	1
	Low	-	-	1	3
5. Duration of oestrus (hours)					
	Range	20-30	22-36	18-36	12-30
	Mean	30.00	28.86	31.00	26.75
6. Number of animals conceived		5	2	3	1

Table 25. Behavioural manifestation of oestrus

Sl.No.	Behaviour	T_1	T_2	T_3	T_4
1.	Restlessness	+++	+++	+	+
2.	Frequent urination	+++	+++	++	++
3.	Mounting on other animals	++	++	-	-
4.	Allow to mount other animals	++	++	-	-
5.	Bellowing	+	+	+	+
6.	Raised tail	++	++	+	+
7.	Chin pressing other animals	++	++	+	+
8.	Allowing chin pressing	++	++	+	+
9.	Sniffing other animals	+++	+++	+	+
10.	Allowing sniffing	+++	+++	+	+
11.	Licking other animals	++	++	+	+
12.	Allowing licking	++	++	+	+

+++ - Most commonly occur
++ - Commonly occur
\+ - Rarely occur
'-' - Not seen

Discussion

5. DISCUSSION

5.1 Micro climatic changes

5.1.1 Air temperature

During the study period the overall mean maximum temperatures recorded in the T_1, T_2, T_3 and T_4 locations were 32.03, 32.17, 33.27 and 33.40°C respectively (Table 2). These were lower than the maximum temperature recorded in outside the animal houses (35.45°C). This indicated that providing shade considerably reduced the ambient temperature. Similar findings were reported by Igono (1986); Gangwar (1988) and Thiagarajan (1989). In the present study the difference in maximum temperature between conventional tie-barn and open house being highly significant ($P<0.01$). The maximum temperature in the open house with tree shade was significantly ($P<0.01$) lower than the conventional tie-barn. This is in agreement with that of Gangwar (1988) who reported that the most effective shade source was tree, cattle remained more comfortable under the tree shade in the open than inside the cattle houses. Providing sprinkler in the tie-barn and in the open house were found to have no significant effect on ambient temperature. This observation is in accordance with that of Igono (1986) who reported that provision of shade reduced the air temperature during the hot weather. Further provision of a water spray or a fan did not alter the ambient temperature.

The overall mean minimum temperature recorded were 22.77, 22.80, 24.22 and 24.35°C in the T_1, T_2, T_3 and T_4 locations, respectively. The difference in minimum temperature between tie-barn and open house were found to be highly significant ($P<0.01$). The minimum temperature in T_1 and T_2 were similar to that of air temperature prevailed at the atmosphere (22.88°C) during the cooler hours of the day. However, the minimum temperature recorded in the T_3 and T_4 were higher than the minimum temperature recorded in outside the animal house. This is in agreement with that of Thomas and Razdan (1973) who found that provision of shelter had a heat preserving effect during the colder periods. Similarly, Thiagarajan (1989) also reported that the air temperature prevailed in the open house was lower than what was prevalent under housed conditions during the cooler hours of the day.

In general, the ambient temperature prevailed during the study period was higher than what was reported as comfortable or ideal temperature for better livestock production (McDowell, 1972; Berman *et al.*, 1985).

5.1.2 Relative humidity

The mean relative humidity recorded in the T_1, T_2, T_3 and T_4 locations were 82.09, 82.08, 83.96 and 83.73 per cent respectively for morning (Table 2). The corresponding relative humidity per cent for afternoon were 56.83, 56.60, 60.53 and 59.65. Highly significant ($P<0.01$) difference was found between the conventional tie-barn and open house locations in the relative humidity levels recorded both at morning and afternoon and the relative humidity in the conventional tie-barn was always found to be higher than what was recorded at open house. This is in agreement with that of Gangwar (1988) who suggested that the higher relative humidity per cent in the tie-barn locations might be due to accumulation of moisture in the atmosphere inside the animal house due to the interference with free exchange of air by housing arrangements. This is in accordance with Starr (1981) who stated that certain types of animal houses instead of giving comfort, found to be detrimental to animal performance by compounding effect of heat stress factors and questioned the wisdom of providing shelters in the areas that are hot and humid. Both in the tie-barn and in the open house providing sprinkler had no effect on relative humidity. This observation is in accordance with that of Igono (1986) who reported that provision of shade reduced the air temperature during the hot weather. Further provision of a sprinkler did not alter the relative humidity per cent and ambient temperature. But it is in contrast with reports of Thiagarajan *et al.* (1973) who reported that provision of sprinkler in the shelter reduced the ambient temperature and increased the relative humidity. Shade was desirable for animal comfort in hot humid environment, but the shade was in the form of tree shade and not the shade provided by the roof (Gangwar, 1988). In general, the relative humidity recorded in the present experiment was higher than 50 per cent and some times even crossing 90.0 per cent. Starr (1981) suggested that heat balance could become a problem at 20°C and above, when relative humidity was in excess of 60.0 per cent. The excess humidity levels recorded in the present study at Mannuthy could be classified as humid and hot.

5.1.3 Air movement

During the study period the mean wind speed recorded in outside environment was 5.23 kmph. It was lower than what had been suggested as ideal for tropical animal husbandry by McDowell (1972) who recommended a wind speed of 8 kmph as ideal. Thiagarajan (1989) reported that under the hot, humid conditions the higher wind velocity in the open paddock favoured the cows considerably than the cows in the shelters. He also opined that under hot humid conditions ventilation was most important and animals did not need elaborate housing in order to utilise beneficial effect of free ventilation.

5.2 Physiological reactions

5.2.1 Rectal temperature

It can be seen from table 3 that the experimental cows in the four treatment locations had not shown any significant difference in their rectal temperature during the 0800 h recording. The rectal temperature recorded at 1400 h (Table 4) was higher than the values obtained for 0800 h recording in T_2, T_3 and T_4. This observation is in accordance with that of Amakiri and Funsho (1979); Flamenbaum et *al*. (1986); Wolfenson et *al*. (1988) and Bracelos et *al*. (1989) who reported that the maximum diurnal rise in rectal temperatures were observed in the early afternoon and minimum rectal temperatures were observed in the early hours of the morning and the difference was highly significant.

In the present study, both in the T_1 (open house with sprinkler) and T_3 (Tie-barn with sprinkler) sprinkling water significantly (P<0.01) reduced diurnal rise in rectal temperature. Similar findings were reported by Morrison *et al*. (1973); Zook *et al*. (1975); Thiagarajan *et al*. (1978); Fuguay *et al*. (1979); Huang *et al*. (1986); Wolfenson et *al*. (1988); Turner *et al*. (1989); Means et al. (1992); Mena *et al*.

(1993); Marai *et al.* (1995); Omer *et al.* (1996); Frazzi *et al.* (1997) and Rossi *et al.* (1998).

In T_1 (open house with sprinkler) cooling of cows by sprinkling with water and free ventilation in the open area with tree shade prevented diurnal rise in rectal temperature and helped to maintain it within the normal (38.48°C). Similarly, Her *et al.* (1988) reported that sprinkling of water in hot summer seasons, decreased the typical diurnal rise in body temperature and maintained the body temperatures at 38.68°C. Flamenbaum *et al.* (1995) reported that body temperature of cows cooled by fans and sprinkler remained below 38.9°C during day hours versus peak body temperature of 39.7°C for uncooled cows

5.2.2 Respiration rate

The respiration rates were not significantly differed between treatments (Table 5) for morning recording. Whereas, for the afternoon recording, the differences between treatments were found to be highly significant ($P<0.01$). Highest respiratory rate (73.86 per min) was recorded in T_4 (Tie-barn without sprinkler), clearly indicated that high ambient temperature (33.4°C) increased the respiratory rate. The increase was more than double (Table 6) of the morning value. This is in agreement with that of Nauheimer-Thoneick *et al.* (1988) who reported that when lactating cows were subjected to an ambient air temperature of 30°C, the respiratory rate increased by 130 per cent of the normal.

In the present study, both in the T_1 (open house with sprinkler) and T_3 (tie-barn with sprinkler) sprinkling of water significantly ($P<0.01$) reduced the diurnal rise in respiratory rate as compared with T_4 by 26.06 breaths per min in T_1 and by 16.5 breaths per min in T_3. Similar findings were reported by Means *et al.* (1992); Mena *et al.* (1993); Abdel and Ibrahim (1994); Sethi *et al.* (1994); Marai *et al.* (1995); Omer *et al.* (1996); Frazzi *et al.* (1997) and Lu *et al.* (1998). Rossi *et al.* (1998) found that cooling of cows by sprinkling with water reduced the diurnal rise of respiratory rate by 18.7 breaths per min.

In the present experiment, the respiration rate for afternoon recording was not found to be differed between T_2 and T_3. This indicated that free ventilation prevailed in the open combined with the beneficial effect of tree shade (T_2) were equally effective to that of cooling of cows by sprinkling with water in the tie-barn (T_3) as heat stress reducing measures. This is in accordance with that of Gangwar (1988) who reported that the most effective shade source was the tree, cattle remained more comfortable under tree shade in the open than inside cattle houses.

5.2.3 Cardiac rate

It can be seen from Tables 7 and 8 that the cardiac rates were not significantly different between treatments for forenoon recording, whereas for the afternoon recording, the difference was highly significant ($P<0.01$). Highest cardiac rate (84.59 per min) was recorded in T_4 (Tie-barn without sprinkler). This indicated that combined effect of high ambient temperature (33.40°C) and relative humidity (59-95 per cent) acted as powerful heat stress factors and increased the cardiac rate. This is in agreement with that of Zia-ur-rehman *et al.* (1982) who reported that the highest cardiac rate in Sahiwal cattle was recorded when the relative humidity was high along with high ambient temperature; but in contrast to Gangwar (1988) who found that pulse rate of cattle in thermoneutral zone (13 to 18°C) and hot environment (40°C) were 64.1 and 57.8 per min respectively.

Sprinkling water significantly ($P<0.01$) reduced the cardiac rate by 10 beats per min in T_1 and T_3 compared with T_4. Similarly, Radadia *et al.* (1980) and Kishoniti and Adam (1985) found that cooling of cows by water sprinkling when ambient temperature exceeded 25°C significantly reduced the cardiac rate in dairy cattle. Turner *et al.* (1989) and Frazzi *et al.*(1997) found that sprinkling of water on dairy cattle significantly ($P<0.01$) reduced the pulse rate in hot humid climate.

In the present study, in T_2 (open house without sprinkler) cardiac rate was not found to be significantly different from that of T_1 and T_3. This indicated that free ventilation in the open combined with tree shade significantly reduced the effect of heat stress as reported by Gangwar (1988).

5.3 Milk production

During the study period the experimental cows had a weekly average milk yield of 58.53, 55.68, 56.16 and 54.46 kg when they were housed in T_1, T_2, T_3 and T_4 locations (Table 9). Though the mean weekly milk yield were increased in T_1 by 4.07 kg and in T_3 by 1.7 kg compared with T_4, statistical analysis revealed that the increase in milk yield was not significant. Similarly, Zook *et al.* (1975) reported that insulation, sprinkling with water and inspired air cooling had no significant effect on milk yield of Guernsey and Holstein Friesian cows. Radadia *et al.* (1980) also reported that showering, cooled drinking water and showering plus cooled drinking water increased the milk yield of Murrah buffaloes, but the increase was not statistically significant. Like this, Berman *et al.* (1986) reported that Israeli Friesian cows cooled by sprinkling with water and forced ventilation in hot climate summer did not significantly affect milk yield of cows in good condition, but had a marked effect on cows in poor condition. Frazzi *et al.* (1997) reported that both artificial aeration and sprinkling with water reduced the negative effect of heat stress on dairy cows, but had no effect on milk production. Rossi *et al.* (1998) reported that during summer, sprinkling with water and powered ventilation had no significant effect on milk yield of cow. However, milk yield was higher (1.5 to 2.5 per cent) in the cooled cows.

But significant increase in milk production due to sprinkling of water on dairy cows during summer were reported by Sastry *et al.* (1981); Hernandez and Eastellanos (1983);Kishonti and Adam (1985); Huang *et al.* (1986); Igono *et al.* (1986); Johnson *Et al.* (1987); Her *et al.* (1988); Turner *et al.* (1989), Bucklin *et al.* (1996), Flamenbaum *et al.* (1996); Hall *et al.*(1997) and Lin *et al.* (1998). Hernandez and Castellanos (1983) found that cooling sprinkling with water increased milk yield by 7 per cent in Holestin Friesian and Brown Swiss cows and by 19 per cent in crossbred cows. Igono *et al.* (1986) reported that provision of water spray and fan under the shade reduced the climatic stress and increased daily milk yield by 2 kg in Israeli Holstein cows. Turner *et al.* (1989) found that cows cooled by sprinkling with water and fans whenever ambient temperature was above 26.7°C increased daily mean milk production by 3.59 kg. Flamenbenum *et al.* (1995) reported that cooling of cows by sprinkling and forced ventilation increased the daily average milk yield by 1.9 kg. Omer *et al.* (1996) reported that cooling of cows by sequential sprinkling and forced ventilation, during summer increased daily milk production by 2 kg as compared with uncooled cows.

5.4 Milk Composition

5.4.1 Fat percentage

In the present study mean values of fat percentage in the composite milk of cows were 5.36, 5.19,5.28 and 5.20 when they were present in the T_1, T_2, T_3 and T_4 respectively. Statistical analysis did not reveal significant difference in fat percentages between the treatments (Table 10). Similar findings were reported by Zook et *al.* (1975); Gill *et al.* (1976); Eley *et al.* (1978); Bempong and Gupta, (1986); Nauheimer-Thoneick *et al.* (1988); Means *et al.* (1992); Omer *et al.* (1996) and Frazzi *et al.* (1997).

Nauheimer-Thoneick *et al.* (1988) did not find any statistically significant difference in fat percentage of German Holstein Friesian cows subjected to 30°C constant temperature in the climatic chamber eventhough their milk yield declined by 26 to 30 per cent. But, Radadia *et al.* (1980) and Varma *et al.* (1990) found significantly increased milk fat percentage in buffaloes during summer when they were cooled by sprinkling with water and providing cooled drinking water. Similarly, Berman *et al.* (1986) reported that Israeli Holstein cows cooled by sprinkling with water and forced ventilation during hot climate summer significantly increased milk fat percentage of cows in good condition than in poor condition.

5.4.2 Protein percentage

The mean values for milk protein content were 3.22, 3.20, 3.20 and 3.21 per cent for T_1, T_2, T_3 and T_4 treatment respectively. This is closely related with the observations obtained by Bhalerao (1990) for milk protein percentage of crossbred cows as 3.36. In the present study statistical analysis did not reveal difference in protein percentage between treatments (Table 11). Similar findings were reported by Zook *et al.* (1975); Gill *et al.* (1976); Bempong and Gupta (1986); Means et *al.* (1992) and Omer *et al.* (1994).

5.4.3 Solids Not Fat percentage

The mean values for milk solids not fat percentage were 8.48, 8.48, 8.45 and 8.45 for T_1, T_2, T_3 and T_4 respectively

(Table 12) Babu Rao and Jayaramakrisha (1983) reported that the average milk solids not fat percentage of Ongole x Brown Swiss and Ongole x Holstein Friesian cows were 9.09 and 8.68 respectively. The present observation is comparable with Bhalerao (1990) who found that average milk solids not fat percentage in cross-bred cows of India as 8.63.

In the present study, statistical analysis did not reveal significant difference in milk solids not fat percentage between treatments (Table 12). This is in accordance with the observations of Zook *et al.* (1975); Gill *et al.* (1976); Bempong and Gupta (1986); Means *et al.* (1992) and Omer *et al.* (1994) who have reported that cooling of heat stressed cows by sprinkling with water had no effect on milk solids not fat percentage. However, Davison *et al.* (1988) reported that provision of tree shade increased ($P<0.05$) SNF yield in multiparous cows, but had no effect in heifers.

5.4.4 Total Solids

During the study period, the average milk total solids content of experimental cows were 13.82, 13.59, 13.73 and 13.65 per cent in the T_1, T_2, T_3 and T_4 respectively (Table 13). This is comparable with that of Bhalerao (1990) who reported that average milk total solids percentage of crossbred cows of India as 13.13. But Johnson (1995) reported that milk total solids contents of crossbred cows was 12.99 per cent. Babu Rao and Jayaramakrishna (1983) reported that average milk total solids content of Ongole x Brown Swiss and Ongole x Holstein Friesian were 13.29 and 12.26 per cent respectively.

In the present study, statistical analysis did not reveal significant difference in milk total solids percentage between treatments (Table 13). This is in agreement with that of Zook *et al.* (1975); Gill *et al.* (1976); Bempong and Gupta (1986); Means *et al.* (1992) and Omer *et al.*(1994).

5.5 Feed consumption

The mean concentrate feed consumption per day per cow in the T_1, T_2,T_3 and T_4 treatments were 4.43, 4.25, 4.40 and 4,24 Kg respectively (Table 14). The cows were fed with concentrate feed pellete according to their milk yield. They invariably consumed the whole quantity of given feed. Statistical analysis did not reveal significant difference in concentrate feed intake between treatments (Table 14). This is in accordance with the reports obtained by Thiagarajan (1989).

The green grass consumption of cows when in the T_1, T_2, T_3 and T_4 were 26.16, 24.10, 23.25 and 21.25 kg respectively. Statistical analysis revealed highly significant ($P<0.01$)

difference in green grass consumption between treatments (Table 15). Grass consumption in the T_4 (Tie-barn without sprinkler) was significantly (P<0.01) lower than T_1, T_2 and T_3. It is clear that heat stress reduced the feed consumption as reported by Thomas *et al.* (1969); McDowell (1972); Johnson (1987); Gangwar (1988); Marai *et al.* (1995) and Srivastava *et al.* (1998). However, cows in T_2 and T_3 did not significantly differ in their grass consumption. This indicates that in the open house free ventilation and the tree shade significantly reduced the heat stress compared with tie-barn without sprinkler (T_4) as reported by Gangwar (1988). Sprinkling of water on cows (T_1 and T_3) significantly increased the feed consumption. Similar findings were observed by Morrison et al. (1973); Bempong *et al.* (1985); Huang *et al.* (1986); Bharadwaj *et al.* (1992); Means *et al.* (1992); Flamenbaum *et al.* (1995); Marai *et al.* (1995); Lin *et al.* (1998) and Srivastava *et al.* (1998).

Flamenbaum *et al.* (1995) reported that cooling of cows by sprinkling with water and forced ventilation increased mean daily feed intake by 1.6 kg. Srivastava et *al.* (1998) reported that dry matter intake of lactating crossbred cows were 9.22 ± 0.21, 8.90 ± 0.14 and 8.49 ± 0.14 kg under 30 min sprinkling, 15 min sprinkling and no sprinkling treatments respectively.

In contrary to the present findings, Sarensen (1985) reported that cows did not reduce their roughage feed intake under warm conditions when they were fed *ad libitum*.Thiagarajan *et al.* (1978) and Frazzi *et al.* (1997) reported that artificial cooling of dairy cows by sprinkling with water during summer slightly increased feed intake but that was not statistically significant.

5.6 Water consumption

The mean (drinking) water consumption of cows in the T_1, T_2, T_3 and T_4 were 23.72, 28.61, 26.43 and 31.72 kg respectively (Table 16). The corresponding values for involuntary water (feed water) consumption were 20.31, 19.72, 19.75 and 19.32 kg (Table 17). For total water (involuntary + drinking water) consumption were 43.44, 49.98, 46.18 and 52.65 kg respectively (Table 18). Statistically analysis revealed that the differences between treatments in drinking water and total water consumptions were significant at 1.00 per cent level, whereas involuntary water consumption was significant at 5.00 per cent level.

The overall mean per day total water consumption of cows in the non sprinkled locations (T_2 and T_4) were significantly ($P<0.01$) higher than in the sprinkled locations (T_1 and T_3). This clearly indicate that heat stress increased the water consumption and cooling of cows by sprinkling with water during heat stress significantly ($P<0.01$) reduced the water consumption. Similar findings were reported by Castle and Watson (1973); Castle and Thomas (1975); Murphy *et al.* (1983); Kirchgessner *et al.* (1983); Mohamed (1984); Kume *et al.* (1986) and Benedetti *et al.* (1990). Mohamed (1984) reported that daily mean water intake of cow was 27.2, 38.0 and 28.9 litres, when they were exposed to successive 7 day periods at 20, 32 and 20°C respectively.

Sprinkling water on cows during summer significantly reduced mean daily intake of water (Thiagarajan *et al.*, 1978; Bempong *et al.*,1992; Flamenbaum *et al.*, 1995 and Srivastava *et al.*, 1998). Thiagarajan *et al.* (1978) found that cooling of crossbred cows with water sprinkler during summer significantly reduced mean daily intake of water (40.78kg) than uncooled cows (47.32 kg). Bempong *et al.* (1985) reported that daily water intake of crossbred milk cows, during summer was 50.12 ± 1.11, 51.51 ± 1.13 and 46.86 ± 1.09 litres per head under tree shade, loose house and loose house + sprinkling, respectively.

Flamenbaum *et al.* (1995) reported that cooling of dairy cows by sprinkling and forced ventilation lowered mean daily water consumption by 9 litres compared with uncooled cows. Srivastava *et al.* (1998) reported that feed water and drinking water consumption of lactating crossbred cows under 15 min sprinkling,30 min sprinkling and non sprinkling locations were 2.64 ± 0.02 and 19.45 ± 0.19, 2.60 ± 0.02 and 21.97± 0.61 litres respectively. It is concluded that cooling of cows by sprinkling with water might have reduced the heat stress which inturn caused reduction in the water consumption.

5.7 Blood parameters

5.7.1 Haemoglobin

It can be seen from Table 19 that the average haemoglobin values of cows in the T_1, T_2, T_3 and T_4 treatments were 11.5, 10.26, 10.51 and 9.31 g per cent respectively. Statistical analysis revealed that the differences in haemoglobin percentages between treatments were highly significant ($P<0.01$).

In the present study, haemoglobin content of sprinkling treatments (T_1 and T_3) were found to be significantly ($P<0.01$) higher than the non sprinkling treatments (T_2 and T_4). This indicates that heat stress lowered the haemoglobin content and sprinkling of water on cows significantly increased the haemoglobin value. This observation is in agreement with those of Shebaita and Kamal (1973); Shebaita and Kamal (1979); El-Masry (1987); Daarder *et al.* (1989) and Yousef (1990) who reported that haemoglobin concentration decreased during heat stress, but in contrast with the finding of Bioucek *et al.* (1990) who reported that exposing dairy cows to high temperature during day time had no effect in haemoglobin percentage. In the present study, sprinkling of water on cows significantly increased the haemoglobin content. Similar findings were reported by Habeeb *et al.* (1989); Abdel and Ibrahim (1994) and Marai *et al.* (1995).

5.7.2 Packed cell volume

The overall mean packed cell volume of cows in the T_1, T_2, T_3 and T_4 treatments were 31.33, 30.19, 30.47 and 28.89 per cent (Table 20). Statistical analysis revealed that the difference in PCV per cent between treatments were highly significant (P<0.01). Packed cell volume percentage in T_1,T_2, and T_3 treatments were significantly higher than in T_4 treatment. This clearly indicates that heat stress reduced the PCV in T_4 and that sprinkling of water in T_1 and T_3, and free ventilation in T_2 significantly reduced the heat stress and increased the PCV content. Similar findings were observed by Rowlands *et al.* (1974); Shebaita and Kamal (1975);

Lee (1965); Radadia *et al.* (1980); Abdel and Ibrahim (1994); Marai *et al.* (1995) and Omer *et al.* (1996).

The present observation in PCV percentage is in contrast with the observation of Mohamed (1984) who reported that PCV value did not differ when the cows were exposed to successive seven day periods at 20, 32 and 20°C and also Biocek *et al.* (1996) reported that exposing dairy cows to high temperature during day time had no effect in haematocrit percentage.

5.7.3 Erythrocyte Sedimentation Rate (ESR)

It can be seen from Table 21 that the mean erythrocyte sedimentation rate was significantly (P<0.01) lower in T_1 and T_3 (3.21 and 3.20 mm per 24 hours) than in T_2 and T_4 (3.68 and 4.18 mm per 24 hours). This observation in the present study indicates that heat stress increased the ESR value and sprinkling water decreased the ESR value. Similarly, Sreekumar (1988) reported that exercise and environmental heat stress increased the ESR in cattle. But, Xavier (1981) reported that climatic variables had no effect on ESR in buffaloes. Gowri (1998) reported that ambient temperature had no effect on ESR of both sheep and goats at Mannuthy, Kerala.

5.8 Body weight change

It can be seen from Table 22, there was a uniform loss in body weights of all the cows as lactation progressed upto the peak yield stage, thereafter the cows had shown a tendency to regain body weight irrespective of the type of treatment given. Similarly, Youdan and King (1977) reported that both cows and heifers lost weight during early lactation period and subsequently showed a weight gain during late lactation period. The average body weight loss was 113 lb (9.6 per cent). Bhaskaran *et al.* (1981) and Patil and Deshpande (1981) observed the positive as well as negative body weight changes in crossbred cows during early lactation period. Mortinez *et al.* (1980) found that there was a uniform reduction in body weights of Holstein Friesian cows upto the peak yield period and thereafter the cows had shown a tendency to regain body weights in the later lactation period. Lu *et al.* (1992) reported that during the hot season, daily body weight loss to 120 days after calving was 0.3 and 1.6 kg for the cows housed in an air-conditioned barn and loose boxes respectively.

5.9 Feeding behaviour

During the hot hours of the day in T_4 (Tie-barn without sprinkler) feed intake and rumination were less compared to night hours. This observation is in agreement with Muller *et al.* (1994) who have reported that during summer the unshaded cows spent more time for feeding at night and cooler hours of the day than the shaded cows. Thomas and Razdan (1973) found that crossbred cattle made a day-to-night shift in their feeding regimen during summer.

In the present study mean voluntary feed intake was lower for cows in T_4 (21.25 kg per day per cow) compared with cows in T_1, T_2 and T_3 (26.16, 24.10 and 23.25 kg per day per cow). This indicates that heat stress in T_4 significantly reduced the voluntary feed intake (Table 15). This observation is in agreement with Muller *et al.* (1995) who have reported that increased ambient temperature significantly reduced voluntary feed intake, rumination time and frequency.

5.10 Oestrus behaviour

Sprinkling water increased the intensity of oestrus in T_1 and T_3 (Table 24). This is agreement with Akmal *et al.* (1975) and Saidkhodshaev et *al.* (1977). In the present study sprinkling of water increased the oestrus length of cows present in T_1 and T_3 (30.00 and 31.00 hours) when compared to the cows in T_2 and T_4 (28.86 and 26.75 hours) This is in accordance with the findings of Harinadharao *et al.* (1979); Rodthian *et al.* (1994) and Rodthian *et al.* (1996) who have reported that cooling of animals during hot summer season increased the intensity and length of oestrus.

Behavioural manifestations of oestrus (Table 25) such as mounting on other animals, allowing mounting by other animals and restlessness were more pronounced in the open house (T_1 and T_2) when compared in the tie-barn (T_3 and T_4). Similar findings were observed by Popov *et al.* (1982) and Gwazdauskas *et al.* (1983). Her *et al.* (1988) and Lu *et al.* (1992) who have reported that cows cooled by sprinkling with water and forced ventilation showed more pronounced standing oestrus behaviour than uncooled controls.

Summary

6. SUMMARY

An experiment was conducted to find the effect of sprinkling water on crossbred cows in conventional type of cattle shed and open house with tree shade during summer season of Kerala.

Twelve early lactating crossbred cows were selected and put into four groups of three each and were randomly allotted to four treatments such as open house with sprinkler (T_1), open house without sprinkler (T_2), conventional tie-barn with sprinkler (T_3) and conventional tie-barn without sprinkler (T_4). The whole experiment was carried out as a switch over trial with two weeks adjustment period and one month observation period in each switch over. The cows in T_1 and T_2 were kept loose in open house with tree shade and T_3 and T_4 were tied in a conventional type of cow shed with cement asbestos roof and side ventilation. The sprinklers in T_1 and T_3 were operated two times a day, once from 1300 to 1330 h and again from 1430 to 1500 h totalling one hour a day.

During the experimental period microclimatic changes, physiological reactions of the cows, milk yield and composition, feed and water consumption, blood parameters, body weight change, feeding and oestrus behaviour were measured. Analysis of variance were carried out to differentiate responses between treatments.

The overall mean maximum temperature recorded in the T_1, T_2, T_3 and T_4 locations were 32.03, 32.17, 33.27 and 33.40°C respectively. These were lower than the maximum temperature recorded in outside the animal houses (35.45°C). Both within the tie-barn and within the open house, the mean maximum and minimum temperatures and mean relative humidity at morning and afternoon did not differ significantly due to sprinkling water. But the differences between the tie-barn and open house were highly significant ($P<0.01$) and higher in the tie-barn for all these variables. In general, the microclimate prevailed in all the treatment locations during the study period was higher than what was recommended as comfortable or ideal for better dairy production.

Physiological reactions such as rectal temperature, respiratory and cardiac rates did not vary significantly between treatments for morning recording. Sprinkling water, tree shade and free ventilation prevailing in the open in T_1 has reduced the heat stress of cows and prevented diurnal rise in rectal temperature and helped to maintain it within the normal (38.50°C) even at afternoon. Highest rectal temperature (40.20°C) was recorded in T_4. In all the groups respiratory rate recorded at 1400 h were higher than the

0800 h recording. Highest respiratory rate was recorded in T_4 (73.86 per min). Sprinkling water significantly (P<0.01) reduced the respiratory rate in T_1 and T_3 (47.80 and 57.36 per min). For all the treatment groups cardiac rate recorded at afternoon were higher than the morning recording. Highest cardiac rate was recorded in T_4 (84.59 per min). Sprinkling water significantly reduced the cardiac rate in T_1 and T_3 (62.77 and 62.74 per min).

Mean weekly milk yield of cows in T_1, T_2 and T_3 increased by 4.70, 1.22 and 1.71 kg per head respectively compared with T_4. Milk composition such as total solids, solids not fat, fat and protein percentages did not vary significantly between treatments.

Concentrate feed intake did not vary significantly between treatment groups. Average daily green grass consumption was higher in T_1 (26.16 kg per cow). Heat stress reduced the average daily green grass consumption of cows in T_4 (21.25 kg per cow). Statistical analysis revealed a highly significant (P<0.01) difference in water consumption between treatments. Daily water consumption was highest in T_4 (31.72 kg). This might be due to the need for increased evaporative loss of water, makes an increased water intake necessary, sprinkling water decreased the necessity for loss of water from body to effect evaporative cooling and reduced water requirement in T_1 and T_3 (23.72 and 26.43 kg).

Statistical analysis revealed that there were highly significant ($P<0.01$) difference in haemoglobin, packed cell volume and erythrocyte sedimentation rate between treatments.

There was a uniform loss in body weights during early lactation in all the experimental cows, thereafter as lactation progressed, the cows had shown tendency to regain body weights irrespective of type of treatment given.

Sprinkling water in T_1 and T_3 encouraged the feeding and rumination during hot hours of the day and consumed significantly more feed. In T_4, feed intake and rumination were not much pronounced during hot hours of the day and feed intake was more common during night hours. However, the quantity of feed consumed was significantly lower than the T_1 and T_3.

Sprinkling water in T_1 and T_3 increased the intensity and duration of oestrus and successful insemination rate.

Due to the beneficial effect of open air, cows under the tree shade in the open were more comfortable. The milk production and successful insemination rate of cows in the open house were more than the cows kept inside the conventional type of cattle shed. Sprinkling water reduced the heat stress and increased the milk production and successful insemination rate both in the tie-barn and open house, but the effect was more in the open house. While interpreting these results in terms of actual management practices under existing dairy farming system in Kerala, it is difficult and not economic to keep the cow under loose housing system. Instead the cows may be tethered under the tree shade or simple shade areas with roof supported on pillors affording maximum ventilation. Sprinkling or splashing of water during hot hours of the day may be practiced to reduce drop in milk production and fertility rate during summer.

References

REFERENCES

Abdel, S.A.M. and Ibrahim, H.(1994). Tri-iodothyronine and blood metabolites in relation to milk yield and spray cooling of heat stressed lactating Friesian and Holsteins in Egypt. *Egypt J. Anim. Prod.* **29**(2): 215- 227.

Aboulnaga, A.I., Kamal, T.H., El-Masry, K.A. and Marai, I.F. (1989). Short term response of spray cooling and drinking cold water for improving milk production of heat stressed Friesian cows. *Alexandria, Egypt*. 2(10): 607-612.

Akmal, Khanov, S.H., Prokof, E.X.M. and Saidkhodehaev, A.(1975). Control of the reproductive functions of cows in a hot climate. *Monochoe Myashoe Skotovodstve*. 5:40-41.

Alexander, T.J. (1983). Effect of different dietary levels on the postpartum reproductive performance of crossbred cows. M.V.Sc. thesis, Department of Animal Reproduction, Kerala Agricultural University, Mannuthy.

Amakiri, S.F. and Funsho, O.N. (1979). Studies on rectal temperature, respiration rate and heat tolerance in cattle in the humid tropics. *Anim. Prod.* **28**: 329-334.

AOAC (1965). Official Methods of Analysis. Association of Official Analytical chemists. Washington, D.C., 10th Ed.

Babu Rao, T. and Jayaramakrishna, V.(1983). Milk Constituents of three genetic groups of Cows. *Indian J. Dairy Sci.* 36(3): 286-293.

Bahga, G.S., Gangwar, .P.C., Srivastava, R.K. and Dhingra, D.P. (1980). Effect of spray cooling and wallowing on blood composition in buffaloes during summer. *Indian J. Dairy Sci.* 33(3) : 294-298.

Barrington, S. (1997). Summer ventilation. Temperature regulation in the dairy cow. *Producteur - de - Lait Quebecois.* 17(5): 26-29.

Bempong, I.A. and Gupta, L.R. (1986). Effect of shelter and sprinkling on the production of lactating crossbred cows during summer. *Indian J. Anim. prod. Mgmt.* 2(1): 16-19.

Bempong, I.A., Gupta, L.R. and Georgie, G.C. (1985). Voluntary feed and water intakes of Holstein Friesian x Hariana milch cows under shelter and water sprinkling condition in summer. *Indian J. Anim. prod. Mgmt.* 1(2): 53-58.

Benedetti, E., Silva, H.M. and priego, R.R. (1990). Effect of dry matter intake and milk production on voluntary intake of water in dairy cows. Arquivo *Brasileiro - de - Medicina Veterinaria Zootechnia.* 42(1) : 25-38.

Benjamin, M.M. (1985). Outline of Veterinary Clinical Pathology. 3rd edition. Iowa State University Press. Indian edition. Kalyani Publishers, New Delhi.

Berman, A., Flamenbaum, I. and Wolfenson, D. (1985). Alleviation of heat stress and its impact on reproduction in dairy cattle. The reproductive potential of cattle and sheep. *Joint Isracel - French symposium, Rehovot, Israel*. (2) : 21-23.

Berman, A., Schindier, H., Flamenbaum, I. and Wolfenson, D. (1986). Interaction of body condition and cooling for increasing dairy cattle production in hot climate summer. Proceedings, sixth international conference on production disease in farm animals, Belfast, UK.

Beslin, R. and Anojcic, B. (1979). The effect of temperature and humidity in the byre on milk production and milk fat percentage of cows. *Dairy Sci. Abstr.* **43**:1150.

Bhalerao. (1990). Dairying. In Handbook of Animal Husbandary. 2nd Ed., ICAR Publication, New Delhi. P : 667.

Bharadwaj, A., Sethi, R.K. and Chopra, S.C. (1992). Influence of environmental stress on voluntary intake in lactating Murrah buffaloes. *Indian Dairyman*. **44**(10): 489-492.

Bhaskaran, K.V., Iyer, N. and Madhavan, E. (1981). Effect of body weight changes during post partum period on the reproductive performance of crossbred cows. *Kerala J. Vet. Sci.* 13(2): 337-340.

Bianca, W. (1965). Reviews of the progress of dairy science section. A. Physiology - cattle in a hot environment. *J. Dairy Res.* 32:291 -306.

Bioucek, J., kovalcikova, M., Kovalcik, K. and Letkovicova., M. (1990). Effect of the daytime exposure to high temperatures on the blood picture of dairy cows. *Pollnohospodarstvo*. 36(5) : 464-469.

Bodisco, V., Manrique , U., Valle, A. and Cevallos, E. (1973). Tolerance of heat and atmospheric humidity in Holstein, Brown swiss and Guernsey cows. *Agronomia Tropical*. 23(3): 241-261.

Bond, E.R. Cris, W.L., Davis, D.R., Brum, E.W. and Ludwick., T.M. (1991). Forage composition and growth and physiological characteristics of cattle grazing serveral varieties of tall fescues during summer conditions. *J. Anim. Sci*. 59: 584-593.

Bracelos, A.F., Garcia, J.A., Cardoso, R.M. Torres, C.A.A., Ferreira, B.A., Garcia, A.J., Maciel, C.R. and Torres, A.C.A. (1989). Effect of climate and diet on the physiological reactions of buffaloes, zebu cattle, *Bos taurus* and their crosses. 1. Rectal temperature and respiration rate. *Revista de Sociedade Brasileira de Zootechnia*. 18(1): 32-41.

Bruce, J.M. (1981). Ventilation and temperature control criteria of pigs : In Environmental aspects of housing for animal production. Ed. Clark, J.A., Butterworths, London. pp. 197-216.

Bucklin, R.A., Turner, L.W. Beede, D.K., Bray D.R. and Hemken, R.W. (1991). Methods to relieve heat stress for dairy cows in hot, humid climates. *Appl. Engy. Agric.* 7(2): 241-247.

Bunce, S.A. (1974). Observation on the blood sedimentation rate and the packed cell volume of some domestic farm animals. *Brit. Vet. J.* **110**: 322-328.

Bunger, G., Moreau, D.and Weniger, J.H. (1982). Influence of fluctuating temperature and relative humidity on thermoregulation in lactating German Friesian cows in a climatic chamber. *Zeitschrift fur Tierzüchtung und Zuchtungsbiologie.* **99**(2): 111-122.

Calamari, L., Maianti, M.G., Cappa, V. and Frazzi, E. (1995). The influence of air speed on yield and milk characteristics in dairy cows during summer. *Annali della Facoltà di Agraria Universita cattolica del sacro cuore Milano.* 35(1-2): 95-107.

Castle, M.E. and Thomas, T.p. (1975). The water intake of British Friesian cows on ration containing various forages. *Anim. Prod.* 20(2): 181-189.

Castle., M.E. and Watson, J.N. (1973). The intake of drinking water by grazing cows. The effect of water availability. *J. Brit. Grasl. Assoc.* 28(4): 203-207.

Christensen, E., Stone, E.J., Tanner, S.C. and Aguiler, A. (1975). Effect of variations in feeding and climatic factors on production and composition of milk of Holstein cows. *Indian Vet. J.* 52(1): 55-58.

Daarder. A.H., Marai, I.F.M., Habeeb,A.A. and Yousef., H.M. (1989). Improvement of growth performance of Friesian calves under Egyptian Sub-tropical conditions. 1. Internal cooling technique using diuritics and drinking cool water. *Alaxandria* 2: 595-605.

Das, U., Roy, S., Roy, B.N., Gosh, S.P. and DeSarkar, M.K. (1997). Some blood constitutents of crossbred cattle in two agro-climatic zones of West Bengal. *Indian J. Anim. Sci.* 36(1): 11-13.

Davison, T.M., Silver, B.A., Lisle, A.T. and Orr, W.W. (1988). The influence of shade on milk production of Holstein Friesian cows in a tropical upland environment. *Australian J. Experi. Agric.* 28(2): 149-154.

Eley, R.M., Collier, R.J., Bruss, M.L., van H.H. and Wilcox. C.J. (1978). Inter-relationship between heat stress parameters and milk composition and yield in dairy cattle. *J. Dairy Sci.* **61** (suppl.1) : 147-156.

El-Masry, K.A. (1987). The role of thyroxine in improving productivity of heat stressed animals with different techniques. Ph.D. Thesis, Faculty of Agriculture, Zagazig University, Zagazig, Egypt.

Ferguson, W. (1970). Poultry housing in the tropics: applying the principle of thermal exchange. *Trop. Anim. Hlth. Prod.* 2: 44-48.

Flamenbaum, I., Wolfenson, D., Mamen, M. and Berman, A. (1986). Cooling dairy cattle by a combination of sprinkling and forced ventilation and its implementation in the shelter system. *J. Dairy Sci.* **69**(12): 3140-3147.

Flamenbaum, I., Wolfenson, D., Kunz, P.L., Maman, M. and Berman, A. (1995). Interactions between body condition at calving and cooling of dairy cows during lactation in summer. *J. Dairy Sci.* **78**(10): 2221-2229.

Frazzi, F., Calamari, L., Calegari, F., Mianti, M.G., Cappa, V., Bottcher, R.W. and Hoff, S.J. (1997). The aeration, with and without misting: effects on heat stress in dairy cows. Livestock symposium, Bloomington, Minnesota, USSA. 907-914.

Fuguay, J.W., Zook, A.B., Daniel, J.W., Brown, W.H. and poe, W.E. (1980). Modifications in freestall housing for dairy cows during the summer. *J. Dairy Sci.* **62**(4): 577-583.

Gangwar, P.C. (1988). Environmental control as a means of improving animal productivity in the tropics. *Indian J. Anim. Sci.* **58**(4):487-497.

Garcia, L. and Rodriguez, S. (1977). Genetic aspect of tolerance to humid heat in Holstein females. II. Genetic parameters. *Indian Vet. J.* **54**(1): 72-75.

Ghosal, A.K. and Guha, S. (1974). Heat loss by respiration in Holstein, Tharparkar and Sahiwal breed under hot dry and hot humid conditions. *Indian J. Anim. Hlth.* **13**:111-115.

Gill, R.A., Rizwan, I., Muqtadi, M., Ahmad, Z. and Ahmad, M. (1976). Effect of water sprinkling on production performance and physiological functions of lactating buffaloes. *Pakistan J. Agric. Sci.* **13**(1): 53-58.

Goel, V.K., Joshi, B,C, and Kaushik, S.N. (1979). Heat tolerance of Hariana x Holstein, Hariana x Brown Swiss and Hariana x Jersey. *Indian J. Anim. Sci.* **49**(7): 507-510.

Gowri, M. (1998). Bio-climatological influence on physiological norms of sheeps and goats. M.V.Sc. Thesis. Department of Livestock Production Management, Kerala Agricultural University, Mannuthy.

Guerrero, M., Gomez, C.A., Serradilla, M.J.M., Guerro, Y.M. Cabrera, A. and Manrique, J.M.S. (1993a). Alleviation of heat stress in dairy cows: Sprinkling plus aeration. *Archivos Zootecnia.* **42**(156): 89-92.

Guerrero, M., Gomez, C.A.,Sorradilla, M.J.M., Guerrero, Y.M., Cabrera, A. and Mangrique, J.M.S. (1993 b). The use of mist spraying to relieve heat stress in dairy cows. *Archivos Zootecnia.* **42**(157): 179-182.

Gupta, N., Chauhan, H.V.S. and Khan, J.R. (1996). Comparative study of certain haematological parameters in various physiological status in Sahiwal cows. *Intl. J. Anim. Sci.* **11**: 115-116.

Gwazdauskas, F.C., Lineweaver, J.A. and McGilliard, M. L. (1983). Environmental and management factors affecting oestrus activity in dairy cattle. *J. Dairy Sci.* **66**(7): 1510-1514.

Habeeb, A.A., Samee, A.M. and Kamal, T.H. (1989). Effect of heat stress, feed supplementation and cooling technique on milk yield, milk composition and some blood contituents in Friesian cows under Egyptian conditions. *Alexandria, Egypt.* 2 (October) : 629-635.

Hall, A. B., Young, B.A., Goodwin, P.J., Gaughan, J.M., Davison, T., Bottcher, R.W. and Hoff, S.J. (1997). Alleviation of excess heat load in the high producing dairy cows. *Livestock Environ.* 5 (2) 29-31.

Hamid,K., Richards, S.A. and Sykes, A.A. (1977). Field observations on temperature regulation in the Swamp buffalo. *Malasian Appl. Bio.* 6 (1) : 91-92.

Harinatharao, C., Rao, C.V. and Naidu, K.N. (1979). Effect of improved management on oestrus behaviour in buffaloes. *Indian J. Dairy Sci.* 32(4): 489-491.

Hassan, A., El-Komy, A. and Badawy, A. (1979). Seasonal variations in body reactions, daily milk yield and milk composition of crossbred cows and buffaloes. *Indian J. Dairy Sci.* 32 (4): 264-270.

Her, E., Wolfenson, D., Flamenbaum, I., Folman, V., Kaim, M. and Berman, A. (1988). Thermal, productive and reproductive responses of high yielding cows exposed to short term cooling in summer. *J. Dairy Sci.* 71(4): 1085-1092.

Hernandez, G.J.F. and Castellanos, R.A. (1983). Effect of water sprinkling on production and reproductive performance of purebred and crossbred cows in the subhumid tropics. *Veterinaria, Mexico.* **14**(1): 6-11.

Herz, A. and Steinhauf, D. (1978). The reaction of domestic animal to heat stress-Animal research and development. Vol.7. Institute for Scientific cooperation, Landhausstr.

Huang, C.S., Li, R.Z. and Cao, G. X. (1986). Effect of increasing air speed and of sprinkling on the performance of dairy cows in the hot season. *J. Dairy Sci.* **69**(2): 1002-1009.

Igono, M.O. (1986). Effect of a humid temperature climate and environmental modifications with shade, spray and fan on milk production, thermal balance and hormone function of dairy cows. *Intr. Biol. Sci. Engg.* **46**(11): 3645-3651.

Ingraham, R.H., Stanley, R.W. and Wangner, W.C. (1979). Seasonal effects of tropical climate on shaded and nonshaded cows as measured by rectal temperature, adrenal cortex hormones, thyroid hormones and milk production. *American J. Vet. Res.* **40**: 1792-1799.

Iype, S., Raghavan, K.C., Girija, C.R., Aravindakshan, T.V., Radhakrishnan, J. and Mukundan, G. (1994). Milk fat percentage of various stages of lactation of the crossbred cattle in Kerala. *Indian J. Anim. Sci*. 64(3): 312-313.

Janeczek, W., Hibner, A. and Lukaszewski, Z. (1986). The effect of natural light on some reproductive indices in cows housed in a tie-barn, *Mehycyna Weterynasyjna*. 13 :42-45.

Johnson, H.D., Li, R., Meador, N., Spencer, K.J. and Manalu, W. (1987). Influence of temperature, humidity, wind and water sprays above the thermoneutral zone on milk yields for lactating Holstein cattle *J. Dairy Sci*. 70 (Supp.1): 122.

Johnson, G.S. (1995). Preparation of mozzarella cheese using skin milk filled with cocount milk. M.V.Sc. Thesis submitted to Kerala Agricultural University.

Juma, M.K., Al-Jassim, A.F. and Jassim, A.F. (1987). Effect of clipping of coat and sprinkling on daily summer milk yield in Holstein cows in central Iraq. *J. Agric. Res*. 6(1): 29-40.

Kabuga, J.D. (1992). The influence of thermal conditions on rectal temperature, respiration rate and pulse rate of lactating Holstein Friesian cows in the humid tropics. *Intl. J. Biotech*. 36(3): 146-150.

Kimmel. E., Arkin, H. and Berman, A. (1992). Evaporative cooling of cattle: transport phenomena and thermovision. *American Soc. Agric. Engr.* 40: 14-18.

Kirchessner, M., Schwarz, F.J. and Zinner, P.(1983). The effect of a restricted water supply on the feed intake and milk production of dairy cows. *Zuchtungskunde*. 55(1): 40-47.

Kishonti, L. and Adam, T. (1985). Effect of heat on dairy cows and use of water sprinkling to compensate for heat stress. *Allattenyesztes Takarmanyozas*. 34(6): 521-529.

Kume. S., Kurihara, M., Takahashi, S.,Shibata, M. and Aii, T. (1986). Effect of hot environmental temperature on major mineral balance in dry cows. *Japanese J.Zootech. Sci.* 57(11) : 940-945.

Lee, D.H.K. (1965). Climatic stress indices for domestic animals. *Intl. J. Biometeor.* 9(1): 29.35.

Lin, J.C., Moss, B.R., Koon, H. Flood, C.A., Smith, R.C., Cummins, K.A. and Coleman, D.A. (1998). Comparison of various fan, sprinkler, and mister systems in reducing heat stress, in dairy cows. *Appl. Engg. Agric.* 14(2): 177-182.

Lu, G., Hwang, S.Y., Yang, S.P., Chang, G.M. and Hsu, T.T. (1992). Studies on housing of lactating Holstein cows after calving in air conditioned barns during the hot season in Taiwan. *J. Taivan Liv. Res.* 25(1) : 1-10.

Ludri, K.S. (1983). Effect of hot humid and cold climatic conditions on milk production, nutrient conversion and water requirement of crossbred cows. *Indian J. Anim. Sci*, 53(8): 812-817.

Ludri, R.S. and Singh, M. (1979). Milk production, dry matter and water consumption of crossbred cows milked with or without oxytocin. *Inidan J. Anim. Sci*. 57(7): 778-780.

Macfarlane, W.V. (1981). The housing of large animals in hot climates : In Environmental aspects of housing for animal production. Ed. Clark, J. A., Butterworths, London, pp: 259-284.

Mallonee, P.G., Beede, D.K., Collier, R.J. and Wilcox, C.J. (1985). Production and physiological responses of dairy cows to varying dietary potassium during heat stress. *J. Dairy Sci*. 68: 1479-1483.

Marai, I.F.M., Habeeb, A.A., Daader, A.H. and Yousef, H.M. (1995). Effects of Egyptian subtropical summer conditions and the heat stress alleviation technique of water spray and a diaphoretic on the growth and physiological functions of Friesian cows. *J. Environ*. 30(2): 219-225.

Mc Dowell, R.E. (1972). Improvement of livestock production in warm climates. Free man, W.H. and Co., SanFrancisco, USA.

Mc Guire, M.A., Collier, R.J. , Beede, D.K. and DeLorenzo, M.A. (1985). Effect of acute thermal stress on mammary blood in early lactation. *J. Dairy Sci.* 68 (suppl.1) : 166-167.

Means, S.I., Bucklin, R.A., Mordstedt, R.A., Beede, D.K., Bray, D.R. and Wilcox, C.J. (1992). Water application rates for a sprinkler and fan dairy cooling system in hot humid climates. *Appl. Engy. Agric.* 8(3): 375-379.

Mena, G., Guerrero, Y., Gomee, C., Serradialia, M.J.M., Guerrero, Y.M., Cabera., A.G., Manrique, J.M.S. (1993). Alleviation of heat stress in dairy cows: Sprinkling plus aeration. *Archivos de zootechnia.* 42(5) : 89-92.

Mohamed, A.A. (1984). Some physiological responses of pregnant cows exposed to heat stress. *Indian J. Anim. Sci.* 54(11): 1072 - 1073.

Montoya, R.F., Bucklin, R.A., Nordstedt, R.A., Horn, J.V., Bray, D.R. and Horn, V.J. (1995). Factors affecting water usage in fan and sprinkler cooling systems for dairy cattle. *Appl. Engr. Agric.* 11(1): 125-130.

Morrison, S.R., Givens, R.L. and Lofgreen, G.P. (1973). Sprinkling cattle for relief from heat stress. *J. Anim. Sci.* 36 (3) : 428 - 431.

Mortinez, N., Combellas, J., Verde, O. and Lopez, S. (1980). Changes in milk yield and body weight in Holstein Friesian cows during lactation. *Instituto de Prod Anim.* 10: 39.

Muller, C.J.C. and Botha, J.A. (1994). Effect of summer climatic conditions on different heat tolerance indicators in primiparous Friesian and Jersey cows. *South African J. Anim Sci.* 23(3-4) : 98-103.

Mullick, D.N. (1964). A study on the metabolism of food nutrients in cattle and buffaloes under climatic stress. *J. Arid Zone Res.* 14:137-145.

Murphy, M.R., Davis, C.L. and McCoy, G.C. (1983) Factors affecting water consumption by Holstein cows in early lactation. *J. Dairy Sci.* 66(1): 35-38.

Naikare, B.D., Kale, K.M.,Jagtap, D.Z. and Narawade, v.s. (1992). Factors affecting fat percentage and total fat in Gir crosses. *Indian J. Anim. Sci.* 62(12): 1209-1211.

Nauheimer-Thoneick, H., Thomas, C.K. and Weniger, J.H. (1988). Investigations on energy metabolism of loctating cows. III. Effect of long term high environmental temperature on parameters of thermoregulation, food intake and milk yield. *"Ziichtungskunde"*: 60-76.

Neto, C.O., Kohayagawa., A., Brisighelho, R.C.S. and Lobo, M.A.M. (1989). Effect of heat stress on some blood biochemical parameters and feed intake of buffaloes. *Pesquisa Agropeeuaria Brasileira.* **24**(1): 43-49.

Omer, E.A., Kirrella, A.K., Fawzy, S.A. and El-Keraby, F. (1996). Effect of water spray followed by forced ventilation on some physiological status and milk production of post calving Friesian cows. *AlexandriaJ. Agric. Res.* **41**(2): 71-81.

Pan, Y.S., Mclean, D.M. Graham, E.R.B. and Ellis, N.J.S. (1978). Effect of heat stress on the protein composition and manufacture properties of milk from two diverse breeds of dairy cattle. 20th International Dairy congress. Vol. E:28-29. New Sowth Wales, Australia.

Patel, B.M., Avaidya, M.B., Thakore, V.R. and Shukla, P.C. (1971). Seasonal variation in certain biochemical and haematological constiutents in the blood of Surti buffaloes. *Indian. J. Anim. Sci. 41*(7): 537-541.

Patil, J.S. and Deshpande, B.R. (1981). The study of body weight changes during antepartum, parturition and post partum periods in Gir cows with special reference to exhibition of postpartum oestrus. *Indian Vet. J.* **58**: 376-379.

Popov, N.F. (1982). Exercise and sexual functions in cows. *Veterinarya Moscow*, USSR. (9) : 52-55.

Radadia, N.S., Sastry, N.S.R., Pal, R.N. and Juneja, I.J. (1980). Studies on the effect of certain summer managemental practices on lactating Murrah buffaloes. 3. physiological reactions and some attributes of blood. *Haryana Agric. Univ. J. Res.* **10**(3): 442-447.

Renner, E. (1976). Effect of climatic factors on performance of dairy cows. *Dairy Sci. Abstr.* **40**: 1159.

Rodriguez, L.A., Mekonnen, G., Milcox, C.J., Martin, F.G. and Krienke, W.A. (1985). Effect of relative humidity maximum, minimum temperature, pregnancy and stage of lactation on milk composition and yield. *J. Dairy Sci.* **68**: 973-981.

Rodthian, P., King, G., Subrod, S. and Pongpiachan. P. (1996). Oestrous behaviour of Holstein cows during cooler and hotter tropical seasons. *Anim. Reprod. Sci.* **45**(1-2): 47-58.

Rodthian, P., Subrod, S., Pongpiachan, P., Simasatikul, N., Adrichem, V., King, G. and Adrichem, V.P. (1994) Oestrus and related behaviour demonstrated by Holstein cows in northern Thailand during cool and hot seasons. Sustainable animal production and the environment. Proc. 7th Anim. Sci. Cong., Bali, Indonesia. (July) : 11-16.

Rossi, P., Ferrari, P., Liberati, P. and Zappavigna, P. (1998). Reduction of heat stress in dairy cattle in summer. *Informatore Agrario*. **54**(19) : 53-59.

Rowlands, G.J., Manstor, R., Pocock, R.M. and Dew, S.M. (1974). Relationship between stage of lactation and pregnancy and blood composition in a herd of dairy cows and the influence of seasonal changes in management on these relationships. *J. Dairy Res.* **42**: 540-562.

Saidkhodzhaev, A.B. (1977). The effect of sprinkling on reproduction of cows in the hot season. *Trudy Uzbekshogo Nauchno Issledovated skogo Instituta Zhivotnovodstva*. **27**: 91-101.

Sainsbury, D.W.B. (1975). The housing of large animal livestock. *Vet. Rec.* 77:945.

Sastry, N.S.R., Juneja, I.J.Yadav, R.S., Gupta, L.R., Thomas, C.K. and Tripathi, V.N. (1981). Effect of provision during summer of extra shelter and sprinkling water on young buffalo heifers on their later productive and reproductive functions. *Indian Vet. J.* **58**(9): 753-754.

Schalm, O.W., Jain, N.C. and Carrol, J.E. (1975). Veterinary Haematology. 3rd ed. Library of Congress Cataloging in publication data. Lea and Febiger, Philadelphia. 144-156.

Schebaita, M.K. and Kamal, T.H. (1973). Invivo body composition in ruminants. 1. Blood volume in Friesian and water buffaloes. *Alexandria J. Agric. Res*. 21: 339-350.

Schebaita, M.K. and Kamal, T.H. (1979). Changes in the electrolytes of serum and urine with heat exposure in the bovine. Proc. 6th Intl. conf. Anim. Prod. Vol.1. Zagozig University, Zagazig, Egypt, pp. 261-271.

Schebaita, M.K. and Pfau, a. (1984). Lean body mass and body fat changes in lactating animals under Sahara climate. *World Rev. Anim. Prod.* **11**: 50-57.

Sethi, R.K., Bharadwaj, A. and Chopra, S.C. (1994). Effect of heat stress on buffaloes under different shelter strategies. *Indian J. Anim. Sci.* **64**(11); 1282-1285.

Sethi, O.N., Rai, G.S., Yadav, P.C., Pandey, M.D. and Rawat, J.S. (1975). Effect of high environmental temperature on the rate of secretion and chemical composition of parotid saliva. *Indian J. Anim. Sci.* **45**(1): 10-14.

Shafie, M.M. and El-sheikhaly, L.M. (1970). Heat tolerance of Friesian cattle under Egyptian climatic conditions. *VAR. J. Anim. Prod.* 10: 99-103.

Sharma, A.K., Gangwar, P.C., Srivastava, R.K. and Dhingra, D.P. (1982). Aritificial cooling of buffaloes (*Bubalus bubalis*) in a hot environment, and plasma oxytocin concentration. *J. Agric. Sci. UK.* **198**(2): 421-423.

Sharma, U.V. and Jhanwar, B.M. (1973). Effect of supplementation of wheat straw with concentrate on voluntary intake, digestibility and growth in cattle. *Indian J. Anim. Sci.* **43**(4): 688-691.

Sharma, O.P., Singh, B.P. and Tomar, N.S. (1968). Studies on oestrous cycle in Hariana cows. *Indian Vet. J.* **45**(12): 1014-1021.

Smith, W.K. (1981). Poultry housing problems in the tropics and subtropcis. In Environmental aspects of housing for animal production. Ed. Clark, J.A., Butterworths, London. pp. 235-258.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical analysis. Oxford and IBH Publishing Co, New Delhi. pp. 299-338.

Somanathan, V.L. (1980). Bio-climatological studies on dry matter intake and water consumption of growing livestock. M.V.Sc. Thesis. Department of Animal Management, Kerala Agricultural University, Mannuthy.

Somanathan, V.L. and Rajagopalan, T.G. (1983). Bioclimatological studies on growing livestock. II. Effect of ambient temperature and relative humidity on rectal temperature and respiration rate of crossbred cattle. *Kerala J. Vet. Sci.* **14**: 137-140.

Sorensen, B. (1985). Oxygen consumption, rectal temperature, milk yield and feed consumption in German Black pied cows subjected to heat stress during their first lactation. *Berlin Fachbereich Veterinarmedizin der Freien.* **35**: 125-130.

Sorensen, B. and Weniger, J.H. (1987). Investigations on energy metabolism of lactating cows under heat stress. 2. Results on energy metabolism during different part of lactation and its relation to some parameters of thermoregulatory relevance. *Zuchtungskunde* **59**(5): 307-315.

Sreekumar, D. (1988). Draught potentialities of indigenous and crossbred cattle. M.V.Sc. Thesis. Department of Livestock Production Management, Kerala Agricultural University, Mannuthy.

Srivastava, D.K., Verma, D.N. and Singh, S.P. (1998). Effect of shower on feed consumption, physiological response and water metabolism in crossbred cow. *Indian Vet. Med. J.* **22** (June):101 -104.

Starr, J.R. (1981). Climate and the need for housing. In Environmental aspects of housing for animal production. Ed. Clark, J.A., Butterworths, London, pp: 19-36.

Talvelkar, B.A., Kulkarni, B.A. and Raikar, R.K. (1980). Haematological studies in Gir and crossbred cows. *Indian Vet. J.* 57(8): 640-643.

Terui, S., Ishino, S., Matsuda, K., Shoji, Y., Ambo, K. and Tsuda, T. (1979). Effect of experimental high environmental temperature and humidity on steers. *Tohoka J. Agric. Res.* **30**: 95-101.

Thatcher, W.W. and Collier, R.J. (1972). Effect of season, climate and temperature on reproduction and lactation. *J. Dairy Sci.* **57**: 360-370.

Thiagarajan, M. (1989). Effect of environmental heat stress on performance of crossbred dairy cattle. Ph.D. Thesis, Department of Livestock Production Management, Kerala Agricultural University, Mannuthy.

Thiagarajan, M., Michael, R.D. and Prabhakaran, R. (1978). Effect of sprinkling water on crossbred cows during summer. *Kerala J. Vet. Sci.* 9(2): 215-220.

Thomas, C.K., George, G.C. and Razdan, M.N. (1969). Studies on the performance of crossbred cattle. Part II. Effect of shelter and different environmental conditions on nutrient utilization by Sahiwal x Brown Swiss (F1) and purebred Sahiwal cattle. *Indian J. Dairy Sci*. **22**: 173-175.

Thomas, C.K. and Razdan, M.N. (1973). Adaptability of 1/2 Sahiwal, 1/2 Brown Swiss cattle to subtropical conditions. 1. Feeding behaviour. *Indian J. Anim. Sci*. 43(1): 5-9.

Turner, L.W., Chastain, J.P., Hemken, R.W., Gates, R.S. and Crist, W.L. (1989). Reducing heat stress in dairy cows through sprinkler and fan cooling. *Am. Soc. Agric. Engr*. **89**: 17-20.

Varma, D.N., Husain, K.Q., Acharya, R.M., Lokeshawar, R.R. and Kumar, A.T. (1990). Effect of shower on physiological parameters, nutrient utilization and milk production in buffaloes. *Proc. Sec. World buffalo cong*. India. **4**: 323-327.

Winter, P., Weniger, J.H., Huhn, J.F. and Tawfik, F.S. (1982). Comparison of taurine and zebu cattle and their crossbreds at pasture and in housing in Bangladesh. II. Influence of climate on use of shower and water intake at pasture. *Zeitschrift Tieresuchtung Und Zuchtungs biologie*. **97**(4): 268-275.

Wise, M.E., Armstrong, D.V., Huber, J.T., Hunter, R. and Wiersma, F. (1988). Hormonal alterations in the lactating dairy cow in response to thermal stress. *J. Dairy Sci.* 71(9): 2480-2485.

Wolfenson, D., Flamenbaum, I. and Berman, A. (1988). Dry period heat stress relief effects on prepartum progesterone, calf birth weight and milk production. *J. Dairy Sci.* 71(3): 809-818.

Wolft, L.K. and Monty, D.E. (1974). Physiological responses to intense summer heat and its effect on the oestrus cycle of non-lactating and lactaing Holstein Friesian cows in Arizona. *Am. J. Vet. Res.* 35: 187-192.

Xavier, F. (1981). Effect of season on certainphysiological norms of female buffaloes. M.V.Sc. Thesis, Department of Animal Management, Kerala Agricultural University, Mannuthy.

Youdan, B.P. and King, J.O. (1977). The effect of body weight changes on fertility during the post partum period in dairy cows. *Br. Vet. J.* 133(6): 635-641.

Yousef, M.K. (1990). Studies on adaptation of Friesian cattle in Egypt. Ph.D. Thesis, Faculty of Agriculture. Zagazig University, Zagazig, Egypt.

Zia-ur-Rehman, Gillani, A.H., Ahmed, M. and Ali, C.S. (1982). Adaptability of crossbred dairy heifers to summer season measured by rectal temperature, pulse rate and respiration rate. *Indian Vet. J.* **59**(2): 170-175.

Zook, A.B., Fuquay, J.W., Poe, W.E., Brown, W.H. and Chapin, L.E. (1975). Effect of summer modifications in a free stall shelter on milk and plasma constituents in dairy cattle. *J. Dairy Sci.* **58**(5): 739-745.

HEAT STRESS ALLEVIATING MEASURES FOR CROSSBRED COWS

By

P. THIRUMURUGAN

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

MASTER OF VETERINARY SCIENCE

Faculty of Veterinary and Animal Sciences

Kerala Agricultural University

DEPARTMENT OF LIVESTOCK PRODUCTION MANAGEMENT

COLLEGE OF VETERINARY AND ANIMAL SCIENCES

MANNUTHY, THRISSUR, KERALA

1999

ABSTRACT

An experiment was conducted to find the effect of sprinkling water on crossbred cows during summer season of Kerala. Twelve early lactating crossbred cows were selected and put into four groups of three each and were randomly allotted to four treatments as open house with sprinkler (T_1), open house without sprinkler (T_2), tie-barn with sprinkler (T_3) and tie-barn without sprinkler (T_4).

The mean maximum temperature recorded in the T_1, T_2, T_3 and T_4 locations were 32.03, 32.17, 33.27 and 33.40°C respectively and these were lower than the maximum temperature recorded outside the animal houses (35.45°C). Both within the tie-barn and within the open house, the mean maximum and minimum temperatures and mean relative humidity morning and afternoon did not differ significantly due to sprinkling of water. But the differences between the tie-barn and open house were highly significant ($P<0.01$) and higher in the tie-barn for all these variables.

Physiological reaction such as rectal temperature, respiratory rate, and cardiac rate did not vary significantly between treatments for morning recording. For afternoon recording the differences were highly significant. Sprinkling of water in T_1 and T_3 markedly reduced the diurnal rise in physiological norms compared to T_4. The difference between T_2

171478

and T_3 was comparable. Mean weekly milk yield of cows in T_1, T_2 and T_3 increased by 4.70, 1.22 and 1.71 kg per head respectively compared with T_4. Milk composition such as total solids, solids not fat, protein and fat percentages did not vary significantly between treatments. Green grass consumption differed significantly between treatments and highest in the T_1 (26.16 kg per cow). Daily water consumption differed significantly between treatments and highest in the T_4 (31.72 kg).

Haemoglobin, packed cell volume and erythrocyte sedimentation rate differed significantly ($P<0.01$) between treatments. There was a uniform loss in body weights of all the experimental cows as lactation progressed upto the peak yield stage, thereafter the cows had shown tendency to regain body weights irrespective of the type of treatment given. Sprinkling water in T_1 and T_3 encouraged the feeding and rumination of cows during hot hours of the day and consumed significantly more feed. Sprinkling of water in T_1 and T_3 increased the intensity and duration of oestrus and successful insemination rate.

The results suggest that during the summer season of kerala tree shade or simple shade areas with roof supported on pillors affording maximum ventilation and sprinkling or splashing of water during hot hours of the day may be practiced to alleviate heat stress and reduce drop in milk production and fertility rate during summer.