PRODUCTIVE PERFORMANCE OF CROSSBRED COWS IN HOT HUMID ENVIRONMENT

BY

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D E C L A R A T I O N

I hereby declare that this thesis entitled **PRODUCTIVE PERFORMANCE OF CROSSBRED COWS IN HOT HUMID ENVIRONMENT** 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,

Dated 31st May 1990

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CERTIFICATE

Certified that this thesis entitled **PRODUCTIVE PERFORMANCE OF CROSSBRED COWS IN HOT HUMID ENVIRONMENT"** is a record of rese arch work done independently by Mr D Noble 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

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INTRODUCTION

1 INTRODUCTION

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 essentially tropical, though large part of India is located north of the tropic of cancer and therefore subtropical Typical tropical climate is experienced in most parts of Kerala marked by high ambient temperature and relative humidity throughout the year It is not uncommon to experience temperatures as high as 40 deg C and relative humidity of 97 per cent Seasonal rhythm in climate is not pronounced and only little variation in day length is noticed There are two rainy seasons viz , south-west (June-July) and north-east (October-November) monsoons and the average monthly rainfall ranges from 150 to 700 mm The total annual receipt of rain is around 3000 mm The prevailing ambient temperature and humidity in Kerala impose much stress on farm animals

The Indian Zebu cattle are well adapted to the existing ecosystem Over the years, they developed this survival capacity to the harsh environmental conditions to which the animals are exposed in a greater part of the year But the cows are poor milk producers On the contrary, temperate breeds have high potential for milk production, but they lack the ability to withstand the tropical climate prevailing in most parts of India

In our country, large scale crossbreeding programmes of different exotic breeds with local cattle have been taken up in order to augment milk production The crossbreds are markedly superior to their indigenous parent stock with respect to productivity Experience has shown that upgradation by temperate breeds can be resorted to only if management is adequate in terms of feed, health care and protection from climatic stress

Cattle production in the tropics faces peculiar problems There is need for new Synthetic breeds to be developed, specially suited for production under the conditions actually encountered in tropics Afrikander and Santa Gertrudis have been developed with this aim In India, several synthetics are in the process of being developed, among which Karan Swiss and Karan Fries are well known Sunandini is very popular in Kerala, which is a crossbred originated from local cattle with Brown Swiss breed One serious handicap experienced in the development of these breeds is the deterioration of productivity when these crossbreds are inter-se to stabilize their exotic inheritance

Search is on for better breeding plans to prevent most of the deterioration in heterosis observed in continued grading up plans It may be possible to have a dairy crossbred from three or four different breeds of desirable genetic background Whatever be the future breeding policy adopted, there is need for critically assessing the suitability of climate for a particular genotype as well as the breed s adaptability to a given environ mental setting The main problem that confronts us is how to make an objective assessment of the intensity of strain experienced by crossbreds and to determine the exact stress factors which are responsible

Productivity is a consequence of two genetically determined sets of factors resistance to environmental stresses and potential for productivity Environmental stress factors are related to climate, nutritional fluctuations and managerial variables Each of these factors at certain levels acts as constraints on productivity But all genotypes are not affected to the same extent and same level of exposure to the environmental stress Because the productivity of a genotype changes with the environment, it is most useful when comparing different genotypes to distinguish between potential productivity, (productivity in the absence of stress) and realized productivity (productivity in the presence of known environmental stresses)

The extent to which the potential productivity is realized in a given environment is a measure of the adaptation of the genotype to that environment Whilst it is difficult to quantify potential productivity in absolute units, relative estimates can be made by comparing the productivity of two or more genotypes in a low stress environment Likewise, estimates of relative susceptibility to an environmental stress can be made by measuring the decrease in productivity of different genotypes when stress is imposed

Since adaptation involves at least both pituitary-adrenal axis and sympathetic-medullary system, the best way to recognize this process is by assessing the functional activity of these neurohormonal systems either directly or indirectly by monitoring the physiological consequence of hormonal and nervous activation This may consist of measuring the concentrations of certain chemicals in body fluids and using this information to assist in the determination of physiological and mental state of animals under stress For this approach to be meaningful, we have to pick out the appropriate parameter or biochemical constituent which reflect the resultant manifestations due to stress Since growth, milk secretion, immunity and reproduction are tied closely to endocrine functions, estimation of the levels of certain constituents in serum, urine, milk and other body fluids will have an ever increasing importance in the measurement of stress in livestock

Most of the work on stress assessment have been carried out in climatic chambers Some of the results obtained from chamber experiments are at variance with results obtained under field conditions and it is possible that the close confinement consequent on climatic chamber experiments might have had psychosomatic effects on the animals Also that, in experiments carried out under laboratory conditions, animals were sometimes subjected to temperature changes more abrupt or greater than those experienced naturally Cattle under natural conditions are exposed to constantly changing circadian temperature fluctuations This has marked effect on thermoregulatory behaviour

Thus exposure of the animal to a constant temperature in an environmental chamber over 24 hours may not provide information as to how cattle handle excess heat loads Cooler night time temperature does allow the animals to compensate than if they were exposed to high temperature humidity in a climatic chamber Very little information from the field has been published on this problem either to support or refute laboratory findings But this is understandable Scientists are usually reluctant to carry out research in which the variables cannot be strictly controlled and field work with large animals like cattle is especially difficult in this regard

At a time when technology could make rapid changes in nutritional, parasitic and disease components of environment, it is important to attempt to develop breeds of cattle which can capitalize these changes In the foreseeable future, the resistance to high ambient temperature and humidity are likely to remain necessary for efficient cattle production in the tropics The breeding programmes in tropics must incorporate these attributes for selection Thus attempts to combine high level of production potential with high level of resistance to environmental heat stress is a desirable goal for future research In simple terms we seek to achieve the right breed in the right place

In order to fulfill this objective, the primary requirement is the identification of suitable criteria to pick out the desirable animals There is none at present fully suitable for this purpose Most of the indices, now in vogue, have been developed based on physiological changes in dry or male stock under laboratory conditions It may not hold good for lactating dairy cows in field conditions This is especially true in case of crossbred cattle, since even the normal level of several physiological constituents in body fluids have not been established so far So there is need to monitor the changes of a wide range of constituents in low stress and high stress environments in order to choose the most reliable parameter which reflects the intensity of strain experienced

By understanding the principles of physiological reactions to stresses, scientists and animal breeders are able to alter housing, feeding and management conditions accordingly or to select different breeds and crosses in order to be able to keep under economically feasible production conditions in areas, which are considered unsuitable for this purpose

Ideally, measure of an animal s adaptability (adaptability index) to an environment should have high correlation with performance Though present evidence supports primary emphasis on performance, most of the available indices are based on physiological changes and no effort has been made so far to combine both physiological changes and performance, in an index The paucity of information on these lines has prompted to take up the present work of screening some of the physiological and production parameters reported to be associated with stress conditions inorder to identify biological markers of adaptation

The parameters studied include physiological responses like, rectal temperature, cardiac and respiration rates, productive parameters like milk yield, total solids, fat, mineral constituents of milk and biochemical constituents in blood like enzimes and hormones Effort had also made to evaluate simple management strategies, like supplementation of buffer salt and feeding of undegradable protien, that may help in mitigating the sufferings of heat stressed cows

REVIEW OF LITERATURE

2 REVIEW OF LITERATURE

2 1 Animal Stress

Exposure to a variety of environmental events elicits a wide range of physiological changes The two basic concepts of response mechanisms to stress are (1) the emergency reaction described by Cannon (1935) and related to activation of the sympathetic nervous system and the adrenal medulla The emergency reaction is a short latency response involving hormonal factors (catecholamines) that enables the subject to mobilize its resources quickly for metabolic requirements of flight or fight (2) The general adaptation syndrome described by Selye (19~6) is characterized by release of adrenocorticotropic hormone (ACTH) from the anterior pituitary gland This reaction in turn activates release of corticosteroides from the adrenal cortex Corticosteroids amplify and extend the metabolic effects of catecholamines The general adaptation syndrome of Selye occurs when there is a gradual or prolonged exposure to some of the extremes of physical environment or to other environmental stresses

The significance of an animal s ability to maintain constant internal environment while performing all its functions has long been recognized This constancy or steady state of physiological process in the face of disruptive external environmental influences is maintained by homeostatic mechanisms The homeostasis or ground state, as referred by Lee (1965) is being chal lenged by changes in environment Readjustment from subcellular level to whole organism are occurring constantly as part of the living process in an ever changing internal and external environment for survival These processes are referred to as adaptations and may be favorable or unfavorable to the economic interest of humans Stress may be climatic, such as extensive cold or heat, nutritional due to feed or water deprivation, social or internal due to physiological changes, pathogens or toxins (Hafez, 1968)

2 1 1 Climatic Factors

The climate of a location is made up of the variables of temperature, humidity, air movement, solar radiation and atmospheric pressure

2 1 1 1 Temperature

Ambient temperature has the most decisive effect of all climatic factors on dairy cows The optimum range of environmental temperature for European breeds of cattle is approximately 10-20 deg C Brahman cows, which have relatively low milk yield at neutral temperatures, are not similarly affected until temperatures are higher (Worstell and Brody, 1957) Air humidity, air movement, radiation etc have indirect effect, by increasing or lessening the temperature effect

2 1 1 2 Air Humidity

A relative humidity between 20/ and 90/ does not affect dairy cows if they are kept within the optimum temperature range Above 24 deg C the body functions are affected by air humidity because evaporation is inhibited by reduction in vapour pressure gradients between skin, lungs and the air In cattle, therefore, a rise of 1 deg C wet bulb thermometer corresponds to a rise of 20 deg C dry bulb thermometer (Sainsbury, 1965) Heat stress is generally a combined temperature-humidity effect

2 1 1 3 Air Movement

The effect of air movement varies depending on the prevail ing ambient temperature and humidity If ambient temperature rises above body temperature, the wind increases heat stress on animals thorough convective heat input If the animals are ex posed to sun out doors, radiation can raise their skin tempera- ture well above the ambient temperature with the result that the wind has a cooling effect It can be generally stated that wind brings relief to the animals which are exposed to sun out doors, raises their skin temperature due to solar radiation, well above the ambient temperature (Kibler and Brody, 1954)

2 1 1 4 Radiation

The total radiation to which an animal exposed outdoors is composed mainly of direct solar radiation and heat radiation from ground and surrounding structures The animals lose heat by radiation to other objects which are cooler The physiological properties of the pelage affect the degree of reflection of solar radiation and accordingly heat input Fifteen per cent of visible radiation is reflected by cream coloured coats of Africander cattle, where as only 4/ is reflected by the hides of dark Jersey cows Besides animal s pelage, solar radiation contributes to heat input in accordance with latitude, cloud cover and available shade (Bonsma and Pretorius, 194") Increase in solar radiation levels from 15 to 570 Watt/m² decreased voluntary consumption in Holstein cows by 24/ at ambient temperature of 27 deg C, 20/ at 20 deg C and by 9/ at 10 deg C The milk yield during e posure to sun was reduced approximately 9/ (Badica and Draghici, 198") High levels of radiation may affect cattle deleteriously Lack of shade during very hot days has been shown to reduce voluntary feed consumption Pattern of gra ing may be affected with grazing decreased in hot weather and shifting to cooler conditions of the night

2 1 1 5 Atmospheric Pressure

The direct effects on physiology of dairy cows at normal atmospheric pressure variations at any given site have yet to establish clearly

2 1 2 Nutritional Stress

Nutrition and stress interact in different ways (a) Stress can produce or aggravate nutritional deficiencies (b) Nutritional deficiencies can prevent the animal s ability to respond to stress (National Dairy Council, 1980) Nutrition, Stress and environment interrelate and all must be considered in selecting the best combination of management practices for optimum animal performance (Hutcheson and Cole, 1986)

2 1 ‾ Diseases

There is also a variety of environmental effects on lactating dairy cattle that can influence animal health Aflatoxin poisoning and ergotism are related to environmental conditions which favour growth of organisms producing these toxins (Head *et al* , 1980)

Two major examples of environmental effects on health of lactating cows are mastitis and metabolic adaptations of environ mental stress that may predispose cows to health problems Collier, *et al* , 1982) Increased milk somatic cell counts and a high incidence of clinical mastitis in dairy cattle occur during hot summer months

The susceptibility to diseases in the dairy cows and its relationship with occurrences of other diseases in current or preceding lactation were studied by Rowlands *et al* , (1986) Cows with ketosis or hypocalcaemia in one lactation were twice as likely to have hypocalcaemia in the next lactation and the occurrence of ketosis in consecutive lactations was also related hypocalcaemia In contrast, cows with retained placenta dystocia or endometritis in one lactation showed no increased likelihood of having the same disease in the next Within lactations, the occurrence of endometritis was strongly associated with dystocia and retained placenta Endometritis also linked with two fold increase in the incidence of ketosis and susceptibility to interdigital cleft lesions

The stress in periparturient period can be assessed by estimating glucocorticoid concentration in blood plasma (Heuwieser et al , 1987) During the last 7 days antepartum, a significant rise of the glucocorticoid concentration in blood plasma occurred and it continued upto 24 hours after parturition Glucocorticoid concentrations in plasma of animals with retained placenta were, during the first 48 hours post partum, almost identical with those of animals with undisturbed expulsion of placenta Animals on which a caesarian section had been carried out showed significantly higher glucocorticoid concentrations immediately after parturition and 3 hours postpartum than animals whose calves were extracted by traction

2 1 4 Social and Other Stress Factors

Isolation of animals from the flock causes emotional stress in animals resulting in changes in circulating levels of cortisol, glucose and T3 levels (Bobek et al , 1986)

A new approach utilizing a nonstressful technique of saliva collection and determination of salivary cortisol by radioimmunoassay to monitor the adrenocortical response of calves to repeated transport stress was reported by Fell and Shutt (1986)

2.2 Physiological Responses to Heat Stress

The principal manifestations of thermal stress on dairy cattle are increase in body temperature, increase in respiratory frequency and increase in heart rate. The thermal exchange between the animal and environment are through radiative, convective and evaporative heat exchanges, the rate of exchange depending on the ability of environment to accept heat and water vapour. Any impedance to these exchanges prevents heat loss, raising body temperature. During the day, heat gain from solar radiation and metabolism usually exceeds heat loss from radiation, convection and evaporation, so that some heat is stored and body temperature rises. At night, the heat flow reverses and stored heat is dissipated back to the environment and body temperature falls. The rate at which these heat exchange occur is dependent on their individual resistance. The resistance to heat exchange that affect the ability of an animal to regulate body temperature are tissue, coat and air resistance and evaporative resistance (Bianca, 1965).

The inevitable energy transformations which occur within animal tissues produce heat, in cattle under high heat loads, about 15 per cent is lost directly from the body core via the respiratory tract. The remainder must be transferred to the skin where it is then dissipated either non-evaporatively by convection and conduction or evaporatively by sweating (Hafez, 1968). While metabolism contributes about one third of the total load on beef cattle standing in a hot radiant environment (Finch, 1976), the ability of animals to remove metabolic heat efficiently is extremely important for maintenance of a steady body temperature

2 2 1 Body Temperature

Brody (1956) have established the critical high environmental temperature roughly as 30 deg C for temperate stock and 5 deg C air temperature for tropical stock Determination of critical temperatures under constant conditions of an environmental chamber can be misleading As pointed out by Berman and Metzer (1973), cattle under natural conditions are exposed to constantly changing circadian temperature fluctuations Compensatory feeding under cooler night time temperatures does allow cows to achieve higher milk production than if they are exposed to high environmental temperatures for 24 hours Thus, exposure of animals to constant temperature in environmental chamber may not provide accurate information on how cattle handle excess heat loads

Ansell (1974) observed that the cows were able to tolerate high rectal temperatures for long periods with little effect on performance, but sustained rectal temperature of 40 deg C were approaching the limits of tolerance in Friesian cows brought to Arabian Gulf from U K

Upper and lower critical temperatures of dairy cattle change with age, degree of insulation and milk production Critical temperature is defined as the lowest or highest temperature at which an animal can maintain normal body temperature without altering basal metabolic rate (Folk, 1974)

Keener *et al*, (1977) Studied the dynamics of thermal control in a Holstein non lactating dairy cow Bladder, tympanic and skin temperatures, CO_2 production and total water loss were measured It was concluded that there was feed forward and feed back control for regulation of body core temperature

The normal rectal temperature range for adult dairy cows lies between 38 deg C and 39 3 deg C Daily variations are known to exist, with the ma imum temperature occurring in the early afternoon and the minimum in the early hours of the morning A difference of 1 5 deg C is measured between these two extremes The thermoregulatory mechanism come into operation in a certain order Under conditions of moderate heat, vasodilatation enables direct heat output At hotter temperatures perspiration comes into effect, which is later on accompanied to an increasing extent by greater respiratory activity Only when all these mechanisms no longer suffice, does the body temperature rises This affects appetite and thyroid gland activity, which leads to a drop in heat production There is, however, a little beyond which these reactions are no longer adequate and the body temperature rises and the animal dies, at 4 4 deg C above normal body temperature, in case of cattle (Herz and Ste nhauf, 1978)

Cattle which control body temperature within a very small daily cycle are more productive than with a wide daily cycle Even small upward shifts in core temperature have profound ef fects on tissues and neuroendocrine functions, which in turn reduce fertility, growth, lactation and ability to work Importantly, there are genetic differences as well as phenotypic variations within breeds in body temperature (Turner, 1972) This genetic diversity indicates the usefulness of applying selection pressure to traits which act to defend body temperature, thereby lifting realized productivity The value of rectal temperature as an index of susceptibility of productive function have been studied by Turner (1984) The evidences for favorable responses to selection of cattle for low rectal temperatures in warm environments outweigh that of possible unfavorable responses

2 2 2 Cardiac Rate

The normal pulse rate of cows ranges from 60 to 70 beats a minute An increased pulse rate is physiologically more significant than an elevated respiration rate (Thomas et al , 1973) Some tests show a rise in pulse rate upto an ambient temperature of 24 deg C and a decrease as the temperature rises above this level These findings can be partially explained by the fact that there is positive correlation between cardiac rate and metabolic rate and that high heat levels consequently cause a rise in pulse rate, while moderate heat levels over a long period cause a drop It appears, therefore, to be questionable whether cardiac rate can be regarded as a good indicator of heat stress in cattle (Herz and Steinhauf, 1978)

Furukawa et al, (1979) observed that respiration rate and body temperature always increased with high ambient temperature and humidity, but heart rate raised markedly only above 30 deg C

2 2 7 Respiratory System

The reaction of respiratory system to heat stress fall into two phases In first phase, respiratory rate increases, while the breathing become shallower In the second phase the opposite occurs, the air turnover increases (Findlay, 1957) Zebu cattle rely less on respiratory cooling than Bos taurus breeds, which reach a rate of upto 200 times per minute at air temperature of 38 deg C Similarly 12% water evaporates through the respiratory passage of Brahman cattle compared with 24% given off by Shorthorns under the same conditions (Kibler and Yeck, 1959) In cows, whose heat output mechanisms are primarily vasodialatation and perspiration, panting seems to require a greater energy expenditure and is therefore less efficient (Herz and Steinhauf, 1978)

The rate and depth of breathing are controlled by hypothalamus, as long as the body temperature remains within normal range Panting occurs even at ambient temperatures of 26 deg C, when it is not possible to determine any increase in body temperature At body temperatures of over 40 deg C or there about, central heat receptors which are stimulated by blood temperature are mainly responsible for triggering off panting (Hensel, 1981)

The effect of panting, which accounts for only about 20 %0% of total evaporation, is somewhat uncertain In cattle, panting is not the main factor in the control of body temperature and heat stress There is notable preference for sweating rather than panting in *Bos indicus* rather than *Bos taurus* In panting, the animal provides its own airflow over the upper respiratory tract, facilitating evaporation from this surface and heat is drawn almost entirely from the core There is a 3 5 fold in crease in blood supply to the respiratory muscles, where work is increased during vigorous panting and to the nasal passages where evaporation takes place The efficiency of respiratory cooling to maintain homeothermy compared to sweating is very low because of the fact that heat is produced in the respiratory muscles with the act of panting Still the energy cost of panting, as measured in sheep is very small (Finch, 1984)

2 2 4 Perspiration

Cattle differ in their ability to sweat A relatively con stant amount of water evaporates continuously through the skin and respiratory passages, and it contributes relatively little to total cooling by evaporation

Zebu cattle have more sweat glands than *Bos taurus* breeds The fact that zebu type have bigger sweat glands appears to be far more important It is estimated that the storage capacity of sweat glands is about 40 ml per m^2 in European cattle compared with 480 ml per m2 in Zebu cattle It was also found that high sweat gland volume is related to high heat tolerance (Herz and Steinhauf 1978)

There is a close anatomical association of capillary beds with sweat glands (Jenkinson *et al.*, 1978) and the amount of blood directed to these capillary beds has an effect on rate of sweat production.

Heat adapted cattle are able to increase sweating rapidly, as soon as body temperature, either skin or core, commences to rise. In Bos indicus cattle, sweating rates increase exponentially in response to increases in body temperature, while in *Bos taurus* sweating rates tend to plateau after an initial increase (Finch *et al.*, 1982).

Cattle under heat loads increase blood flow to the sweat gland in the skin and facilitates both heat transfer and sweat production (Johnson and Hales, 1987).

Finch (1985) after his studies on resistance to evaporative heat transfer in *Bos taurus* and *Bos indicus* types, concluded that the degree of impedance varies with coat type. The *Bos taurus* type trapped water vapour in the air spaces between the hairs more than *Bos indicus* type resulting in compensatory sweating and in turn raise the overall mean values of body temperature in *Bos taurus*.

Klein and Weniger (1986) observed higher sweating rates in higher yielding groups in warm environment. Results of their investigation showed that it was difficult to make valid statements on adaptability because of considerable individual differences in reaction patterns between animals.

2 ~ Lactational Responses to Heat stress

2 ~ 1 Milk Production

Heat stress generally causes low milk production There are several studies on the effect of high temperatures on milk production and composition Ragsdale et al , (1949) reported drop in feed intake and milk production at temperatures above 25 deg C in Jersey and Holstein cows from climatic chamber experiments But under natural condition Rousoff et al , (1955) did not observe any close relationship between milk production of the cows and environmental temperature in similar temperature conditions It is possible that close confinement in e perimental chambers could itself produce depressant effects

The effect of high temperature on milk yield under controlled temperature conditions depend on the degree of heat tolerance of the cow and on the level of milk production (Johnson et al ,1963) This was based on the observation that milk yield decreased in all the cows during the first 2 weeks at 29 deg C and recovered during the following 7 weeks in heat tolerant cows but not in heat intolerant cows

The inevitable problem facing a worker has been the assessment of the depressant effect of the heat stress without proper experimental conditions Four main methods are in vogue (Clark ,1981)

1 Use of identical twins

2 Reversal or double reversal

3 Animals paired on the basis of age, previous lactation etc

4 Standard lactation curve method, whereby expected yield is calculated from the lactation curve compiled by various authors

All these methods have varying degrees of disadvantages Whatever method is used to determine the effects of experimental conditions on expected milk yields, results can only indicate trends when dealing with such inherently variable quantity and these results should be viewed in this light

There are fairly convincing proof that pure bred Friesians can thrive and produce remarkably well in the harsh climatic conditions characterized by high humidity temperature combination of the Arabian Gulf, which is once considered unfit for any kind of farming Even on those occasions when the stress does exceed tolerable limits, the provision of simple showering mechanism has been shown to control adverse effects The cows were able to tolerate high rectal temperatures for long periods with little effect on performance But sustained rectal temperatures of 40 deg C were approaching the limits of tolerance Based on the observations of the reaction of Friesian cattle to the high ambient temperatures of the United Arab Emirates, Ansell (1974) suggested that 1 very high temperatures and humidities need not be inimical to dairy performance if appropriate management techniques are used and if a suitable diet is provided and 2 the upper limit of tolerance of heat stress are higher than climatic chamber studies have indicated

Folman *et al* (1979) concluded after studying the effect of season on milk yield and milk composition in high yielding Israeli Friesian cows housed in open shed that hyperthermy decreased milk yield to a very small extent, in spite of high yields, but fertility was severely affected The difference in milk composition was also very small

Ingraham *et al* (1979) reported an estimated decrease in milk production for unit increase in Temperature-Humidity Index as 0 72 kg for non-shaded cows at daily ambient temperatures range from 22 to 29 deg C and THI values between 70 and 76 produced less milk and milk fat and had greater incidence of mastitis compared to shaded counterparts As reported by Shibata and Mukai (1979) with heat stress, body temperatures rose and milk production fell by about 20% A high plane of nutrition is necessary for high production Reduction in feed intake has been identified as a major cause of reduced milk production in dairy cows One of the greatest challenges to researchers and those associated with animal management is to find out ways and means for maintaining adequate nutrient intake to support desired production level with both economic and thermogenic efficiency (Fuquay, 1981)

A review of the literature indicates that heat stress generally causes lower milk production Breed and diet affects the degree of adverse response Heat stress is caused primarily by high temperature, but can be intensified by high humidity thermal radiation and low air movement (Morrison, 1983)

Kundu and Bhatnagar (1980) studied the milking potential amongst Karan Swiss in relation to the temperature-humidity index Highly significant negative correlation and regression from average milk yield on THI (-0 4845 and 3 0569 resp) confirm that production of Karan Swiss is reduced due to climatic stress Overall daily milk yield averaged 9 8 kg and THI 71 7

2 3 2 Milk Composition

Cobble and Ragsdale (1949) reported an increase in total solids and chloride as well as fat percentage in milk from Holstein and Jersey cows with an increase in temperature from 80 to 90 deg F Solids not-fat, lactose and nitrogen particularly in Holstein milk, tended to be lower at the same temperatures When cows were subjected to a rapid increase in temperature upto 100 deg F during a 14 day period, high increases in total solids, solids-not fat, fat percentage, chlorides and nitrogen were obtained, while lactose value showed a decrease Individual and breed differences in ability to withstand high environmental temperatures were observed

The composition of cow s milk changes during heat stress The secretion of milk fat decreases The yield of milk fat of cows exposed to thermal stress declines with decreasing milk yield (Richardson, 1961)

The fatty acid content of milk fat charges, short-chain fatty acids becoming less and long-chain fatty acids more prevalent The proportion of long chain saturated becomes greater and un saturated become smaller (Moody et al , 1971)

Lal and Mudgal (1972) reported for Tharparkar cows in hot-humid season highest values for SNF and lowest values (below the legal standard of 8 5% set for normal milk) during winter This trend may be related to the high adaptability of zebu cattle to the climate

Bandaranayaka and Holmes (1976) reported a reduction of 1% milk fat at 30 deg C Milk protein content was also reduced by the high temperature but lactose and osmolarity were unaffected Milk fat from cows at 30 deg C contained less C6 to C14 acids and more C18 The elevated temperature caused changes in metabolism which affected milk composition independently of feed intake and milk yield The authors suggests that some of the effects may occur through a decrease in saliva production leading to raised rumen pH, a lower proportion of acetate and lower milk fat content

Pan et al (1978) reported decrease in milk protein yield in Jersey and Sahiwal Jersey cows kept at 40 deg C for 2 weeks They also observed decreases in casein, beta-lactoglobulin and alpha-lactalbumin were found unaffected The concentrations of citric acid, calcium and potassium in cows milk decreased

2 4 Hormonal, Reproductive and Other Responses to Heat Stress

2 4 1 Endocrine Status

Animals exposed to acute heat have increased concentrations of plasma corticosteroids (Alwarez and Johnson, 1973) But there is a reversal of changes in plasma corticosteroids exposed to chronic heat stress Other parameters such as environmental humidity and milk production level may influence the magnitude of the neuroendocrine changes (Vanjonack and Johnson, 1975) It seems, the pituitary-adrenal response is more related to emotional reactions as indicated by restlessness, anxiety and escape attempts than to the physical quality of thermic stress (Johnson and Vanjonack, 1976)

Slebodzinski and Wallace (1977) assessed the responses of pituitary and thyroid to synthetic thyrotropin releasing hormone (TRH) in two breeds of cattle Levels of triiodothyronine (T3) and thyro in (T4) were lower in Shorthorn calves (SH) adapted to temperate conditions than in Africander cross (AX) calves selected for tropics The percentage increase in T3 was lower in AX than in SH calves T3 values before injection were negatively correlated with maximum T3 response and T4 T3 molar ratio was reduced between 2 5 and 4 5 h after TRH injection The initial increase in prolactin concentration was the same in both the breeds, but in AX, the concentration then declined to values well below preinjection values, where as in SH, prolactin returned only to preinjection levels When TRH was injected each hour for 4 h in increasing amounts, TSH and prolactin increased, the highest values being reached after 2 and 1 h respectively In

AX, T3 and T4 concentrations continued to increase for 8 h after the first TRH injection, where as in SH no further increase occurred It is concluded that measurement of resting serum T3 and T4 concentrations, combined with changes in T3 and prolactin after TRH injection may aid in early selection of cattle adapted to tropical conditions

Variables other than hormone concentrations have been suggested such as intensity of adrenocortical response to adrenocorticotropic hormone (ACTH) stimulation (Friend et al , 1979) for study of stress responses Similarly enzyme levels in adrenal medulla are controlled by neuronal influences and by adrenal cortical hormones, hence they too offer great potential for assessment of the amount of stress experienced by the organism over long periods of time (Kvetnansky, 1980)

Schams et al (1980) reported that serum prolactin increased significantly when ambient temperature was increased and decreased after reduction of temperature But no change was observed for somatotropin, thyrotropin, luteotropin and follitropin

Wetteman et al (1982) after studying the influence of ambient temperature on prolactin concentrations in serum of Holstein and Brahman Hereford heifers concluded that the concentrations of prolactin in serum of heifers is positively associated with ambient temperature and that the effects on temperature on basal and TRH stimulated concentrations of prolactin do not differ significantly between HF and Brahman x Hereford heifers Thus differences in tolerance to heat were not related to differences in prolactin concentration

Srikandakumar et al (1986) studied the effect of temperature and humidity stress on reproductive hormones in lactating Holstein cows The cows were subjected to either a high environmental temperature and relative humidity (HS) or a low environmental temperature and humidity (LS) regime The plasma progesterone profiles were similar in both treatments The plasma cortisol was significantly reduced during high stress

2 4 2 Reproduction

Effect of thermal stress on reproduction in dairy cattle occurs through several physiological mechanisms Vaught et al (1977) evaluated the effect of seasonally high environmental temperature on reproductive, endocrine and physiological function of cows The lactating cows were found particularly susceptible to the high temperature, which may adversely affect fertility influencing the synthesis, secretion or metabolism of ovarian hormones, particularly progesterone

A measurable decrease in uterine blood flow which is associated with decreased conception, reduced foetal growth and altered placental function, is attributed to thermal stress (Lewis et al , 1980 Thatcher and Roman-Ponce, 1980) Stress due to hot weather had no effect on the occurrence of preovulatory increase of LH or on the interval between the preovulatory increase and ovulation in lactating or nonlactating cows In comparison with lactating cows in cool weather, progesterone values were significantly increased in lactating cows in hot weather In-creased serum progesterone values and decreased fertility were associated with increased environmental temperature

Thermal stress for the first 10 days postpartum decreased the number of days for involution of uterus The postpartum reproductive period appears to be sensitive to environmental ef-fects both directly and via the conceptus during late gestation (Fuquay, 1981)

The uterus immediately after parturition undergoes a major decrease in size by vasoconstriction and peristaltic contractions (Kiracofe, 1981) Uterine production of PGF2 may contribute to this early process The postpartum uterus is the major site of prostaglandin production and both PGF2 and PGFM are major products of metabolism in caruncular tissue The process of uterine involution causes movement of uterus to its normal non pregnant position in pelvic canal Cows in no shade group had greater percentage of their uteri with the pelvic canal at ear-lier stages of postpartum

Collier <u>et al</u> (1982) investigated effects of heatstress of Holstein cows during the last trimester of pregnancy They have observed reduced birth weights of calves associated with lower concentrations of estrone sulfate in plasma of animals without shade during the experimental period Because estrone sulfate is produced by the pregnant uterus and conceptus, its reduction in-dicates reduced conceptus function during thermal stress

2 4 7 Electrolyte and Acid base Balance Complex

Perhaps the most intriguing of all physiological ramifications of heat stress are the changes in electrolyte and acid-base balance complex Dale and Brody (1954) first proposed possible alterations in acid-base balance during thermal stress in dairy cattle The ability of blood to take up CO_2 decreased with thermal stress The decrease was greater in larger, lactating cows than in small lactating cows The decline in CO_2 combining capacity was associated with rise in blood pH resulting in blood alkalosis

The resulting loss of carbon both through increased ventilation and alkaline reserve via urine reduces the substrate pool available for salivary buffering of rumen Daily salivary secretions (upto 180 litres) contain about 2 7 kg of bicarbonate which is the major buffering agent for the acid generating ruminal ecosystem (Swenson, 1977)

El-Nouty et al (1980) reported a significant drop in concentrations of serum and urinary potassium Concomitant with decrease in aldosterone, these investigators also detected an increase in urinary sodium loss Thus under heat stress, cattle increases sodium excretion while decreasing potassium excretion

Niles et al (1980) observed lower concentrations of aldosterone for unshaded cows and the levels went on reducing at every sampling hour During the same period plasma potassium concentration were found unaffected by shaded or unshaded environ ment This decrease in plasma aldosterone concentrations could not be explained by decrease in potassium Concentrations of prolactin were reduced markedly in both shade and unshaded animals when dietary potassium reached 1 64% (Collier et al , 1981) Collectively these results suggests that elevated prolactin and decreased aldosterone concentrations in heat stressed cattle may be involved in meeting water and electrolyte requirements during thermal stress

Concentrations of prolactin in plasma are increased during thermal stress in dairy cows (Roman-Ponce et al , 1981) This may be associated with altered metabolic state of heat stressed animals One possibility is that prolactin is involved in meeting increased water and electrolyte demands of heatstressed cows (Collier et al , 1982)

Blood acid base balance in response to chronic exposure to thermal stress in cattle is not well defined and may be involved in reduced reproductive and productive performance of dairy cows (Collier et al , 1982)

Sodium and potassium requirements of heat stressed cows need be assessed in greater detail to maximize productivity of animals during hot weather suplementation of K and Na during heat stress resulted in 3 to 11% increase in milk yield (Schneider et al , 1984b)

2 4 4 Body Water

Thomas and Razdan (1974) measured plasma, blood and extracellular fluid (ECF) volumes in Sahiwal x Brown Swiss and Sahiwal cattle during different seasons and shelter conditions The crossbreds equaled Sahiwals in respect of distribution of plasma and blood volume but the Sahiwals possessed a significantly higher percentage of ECF Shelter provided did not affect the attributes significantly Plasma volume per unit body weight was significantly more during the cold season than during other seasons ECF value expanded significantly during hot compared with mild season

Heat stress can cause changes in blood volume A significantly higher plasma volume and osmolarity at 35 deg vs 20 deg C was reported by El-Nouty <u>et al</u> (1980)

Saxena and Joshi (1980) studied the shifts in body water and its distribution in various physiological compartments in response to ambient temperatures of 17 deg to 37 deg C at 5 deg C intervals in F1 crosses of Holstein Friesian, Brown Swiss and Jersey with Hariana They have not observed any discernible change in total body water at lower temperatures But there was a marked rise in its extracellular compartment of water, with a corresponding decrease in intracellular compartment, when cattle underwent a 21 day stress at 37 deg C Such increase in extracellular water at 37 deg C were mainly due to increases in serum volume There was no breed difference, though the increase in serum was a little greater in crossbreds particularly of

Holstein Friesian crosses than in purebred Hariana

2 4 5 Blood Constituents

The blood plasma profiles are being increasingly used for determining the physiological changes of dairy cows during thermal stress

Gutierrez De La et al (1971) studied the effect of continuous environmental stress on some hematological values of beef cattle They have observed that the erythrocyte number and packed cell volume were not affected, but Brahman cattle had a higher count than Herefords and a higher packed cell volume The white blood corpuscle count was not significantly related to breed, se or treatment There was wide range of haemoglobin values with a nonsignificant tendency for hyperthermic cattle to have lower values than normal cattle Mean corpuscular volume (MCV) and hemoglobin (MCH) were related to breed and treatment, i e , lower in Brahman cattle and in hyperthermic conditions MCV was also related to se MCV and MCH might prove useful in gauging heat stress in cattle since they would indicate reduction of hemoglobin synthesis, possibly due to depressed thyroid activity O kelly, (197?) studied the plasma lipid changes in genetically different types of cattle during chronic hyperthermic induced by heat e posure and pyrogen Plasma cholesterol and phospholipids were higher in Bos indicus crossbred than in Bos taurus steers Hyperthermia with a pyrogen in all animals lowered the concentrations of total cholesterol and phospholipids and also the alkaline phosphatase activity, and increased the free to total cholesterol ratio Non-esterified fatty acid, glucose and total protein levels were unaffected Diurnal temperature cycles (8 hours at 35 deg C and 16 hours at 24 deg C) affected plasma composition similarly as hyperthermic with a pyrogen Increased rectal temperature raised circulating lymphocytes and eosinophiles

The effect of thermal stress on circulating erythrocytes and leukocytes was studied by Pappe et al (1977) There were no significant changes in either circulating erythrocytes or leukocytes for cows exposed to constant 2 deg C However, when cows were held under fluctuating temperature conditions significant depressions did occur for both erythrocytes and leukocytes

With the low and high protein feeds in lactating Holstein cows under thermal stress Hemoglobin (Hb) differed significantly, 10 70 and 11 72 g/100 ml and blood albumin and NPN also were higher with the high protein feed, as was glucose, but not statistically significant There were significant negative correlations between Hb or blood glucose and respiration rate or rectal temperature The high protein diet helped the cows to withstand thermal stress by preventing a decline in blood Hb and glucose (Hassan and Roussel, 1975)

Hyperthermia at 32 deg C lowered the concentrations of cholesterol ester, free cholesterol, lecithin, isolecithin and sphingomylin and the concentrations of unsaturated fatty acids contained in these fractions (O Kelly and Reich 1975)

Ross and Halliday (1976) conducted a survey of seasonal variations in constituents of bovine sera Higher cholesterol and lower serum albumin levels were observed during summer

Joshi et al (1980) studied the effect of acute heat exposure on the serum gamma-globulin content in zebu and zebu cross cattle Highest values were found in Hariana Holstein Friesian followed by Hariana Brown Swiss and the difference resulting from the three environmental temperature were more pronounced in Hariana Jersey and Hariana x Holstein Friesian Lowered gamma globulin may affect general resistance to infection The crossbreds were more susceptible to changes in their resistance after heat stress, amongst these Hariana x Brown swiss were most resistant One of the important reasons for reduction in gamma globulin level may be reduced voluntary food intake at high temperatures Serum 5- hydroxytryptamine (5 HT) values of crossbred heifers were estimated during exposure to heat stress (37 deg C) The 5-HT values fell on day of exposure, then rose sharply above original levels, even under continued heat stress (Joshi et al , 1980)

Denbow et al (1986) studied the effect of season and stage of lactation on plasma insulin and glucose following glucose injection in Holstein cattle Insulin was lowest in summer The results also indicates changes in glucose metabolism and insulin sensitivity to glucose during different seasons and stages

2.5 Nutritional and Metabolic Responses

Reducing dry matter intake and consequent reduction in heat generated during ruminal fermentation and body metabolism aid in maintaining heat balance. Reduced gut motility and rumination along with increased water intake lead to gut-fill. Rates of ruminal contractions are reduced at high environmental temperatures (Attebery and Johnson, 1969). The rate of passage of ingesta also reduced.

Experiments by McDowell et al. (1969) showed that part of the energy available for milk production at temperatures of 17-21 deg C was used for thermoregulation at a heat stress of 32 deg C in a controlled environment. The maintenance requirements rise considerably under heat stress conditions and hence, in many tropical areas the energy required for performance would be higher than temperate regions in order to maintain energy balance.

Gale (1973) reported reduced thyroid activity associated with thermal stress. Because the endocrine system is involved heavily in coordination of metabolism, alterations in hormone concentration in blood is likely to occur. Westhuysen (1973) found that the ability of an animal to accommodate to heat stress was inversely related to its thyroid activity.

Under heat stress cows choose, of their own accord, to take in large quantities of energy in the form of concentrates. For the same reason, very high yielding Holstein Friesian cows imported into the subtropical climate of Israel were fed on rations containing 70-75/ concentrates (Herz et al , 1973)

Reduced ruminal contractions and gut motility coupled with increased water intake resulted in increased gut fill exerting a depressing effect on appetite (Warran et al , 1974) Besides this a direct negative effect of elevated temperatures on the appetite centre of the hypothalamus may exist (Baile and Fobes, 1974)

Metabolism studies indicated that acutely heat-stressed cattle were in negative balance Hassan and Roussel (1975) evaluated the effects of dietary protein percent on lactational performance of Holstein cows during natural thermal stress Dry matter feed intake was 11 per cent greater with higher crude protein and actual fat corrected milk yields were 6 5 and 4 3 per cent greater Milk protein percentage and yield also were greater with higher dietary protein Additional evaluation of the efficiency of dietary protein utilization to meet maintenance and production requirements are warranted because high quality protein is often scarce and expensive and more efficient utilization is paramount

Kellaway and Colditz (1975) studied the effect of heatstress on growth and nitrogen metabolism in Friesian and F1 Brahman x Friesian heifers kept in controlled environment rooms and given a high quality diet Feed intake, growth and nitrogen metabolism were assessed during 7 periods of 21 days when the animals were maintained at 20 deg C or 38 deg C (68, 52 and 46 per cent RH, respectively) The F1 animals were found superior under heat stress conditions only Feed intakes and growth rates of Friesians and F1 animals were similar at 20 deg C With each successive increase in temperature, the feed intake and live weight gain of Friesians were significantly reduced With F1 animals, the reduction were much smaller Respiration rates and rectal temperature of Friesians were higher than those for F1 animals at 30 deg and 38 deg C Although the water intake of Friesians were much higher than those of F1 animals under heat stress, the calculated evaporative water losses were similar The efficiency of digestion in the two genotypes was similar at all temperatures

Bhandaranayaka and Holmes (1976) reported that the pH of the rumen contents was lower in cows kept at 30 deg C and the proportion of acetic acid was lower The elevated temperature caused changes in metabolism which affected milk composition independently of feed intake and milk yield The authors suggest that some of the effects occur through a decrease in saliva production, leading to raised rumen pH, a lower proportion of acetate and lower milk fat content

Milk production and efficiency have been enhanced by feeding protected lipids at 20 to 30 per cent of metabolizable energy intake (Wrenn <u>et al</u> , 1976 , Bines <u>et al</u> , 1978) Protected fat feeding has not been tested in lactating cows under thermal stress

Shibata and Mukai (1979) studied the effects of combination of different temperatures 30 deg and 10 deg C and different hay concentrate rations on milk production and general metabolic ef ficiency On lower hay diets cows maintained lower body tempera tures and higher milk yields at high ambient temperatures The results suggested a decrease in energy utilization for milk production under high temperatures as a result of heat stress

Niles <u>et al</u> (1980) observed low ruminal pH in heat stressed cows This may be important if energy density of diets for heat stressed cattle is increased by adding higher proportion of con centrates which may lower ruminal pH further

The hormones associated with adaptation and thermal stress are prolactin, growth hormone, thyroxin, glucocorticoid, an tidiuretic hormone and aldosterone Some of these hormones are implicated in nutrient partitioning (Bauman and Currie, 1980)

The effects of heat stress and dietary fiber content upon circulating thyro in (T4) and Triiodothyronine (T3) and upon excretion of T4 and T3 in faeces, milk and urine of lactating cows were studied by Magdub <u>et al</u> (1982) During heat (31 2 deg C) there were significant reductions in concentrations of T4 and T3 in plasma and in excretion of T4 and T3 in milk Excretion of T4 and T3 increased in urine during heat stress, whereas con centration and e cretion of T4 and T3 in faeces decreased Dietary fiber content had little effect upon T4 and T3 concentra tions in plasma or excretion in milk faeces and urine Excretion of T3 in milk was negatively correlated with rectal temperature and positively with content in plamsa The reduction in T4 and T3 of plasma and its derline in excretion suggests that environmental heat reduced synthesis of both hormones

Reduction in food intake in cattle is followed by a reduction in metabolic rate (Turner and Taylor, 1987) This physiological response to thermal stress is a strategy for maintaining normal body core temperature

In dairy cattle dry matter intake begins to decline at mean daily environmental temperatures of 25 or 27 deg C Other climatic factors such as wind velocity humidity and radiation also directly affect homeothermy under natural conditions and thus are interrelated with ambient temperature in affecting food consumption (Beede et al , 1985)

A model of temperature effects on cattle s daily feed intake has been developed by Senft and Rittenhouse (1985) taking account of time course of thermal acclimation and behavioral responses to thermal stress This model may have value in interpretation of laboratory studies as well as field studies, because the time frame of experiment will influence the results obtained, depend ing upon the acclimation state of the animal

The effect of environmental temperature on major mineral me tabolism of cows during feeding and fasting was studied by Kume et al (1986) For the experiments they used 4 dry, non-pregnant Holstein cows, housed in two independently controlled climatic rooms each housing two open-circuit respiration chambers Two of the cows were exposed to temperatures in the order 18, 27 and 36 deg C and 60 per cent RH The other two were exposed to the tem peratures in reverse order The cow s major mineral metabolism during fasting was measured 68-116 h after food There were no significant differences in body weight during feeding and fasting between treatment Hay intake during feeding and fasting increased with temperature Major mineral intake, except for K, was marginally inadequate Ca, P and Mg concentrations were affected by heat stress and increased rapidly at 27 deg C during fasting, although those excretions during feeding decreased with temperature Urinary P excretion during fasting was significantly higher than that during feeding, although urinary excretion of Ca and Mg was very low Sodium excretion during fasting was affected by heat stress, but K excretion was not The results suggest that major mineral requirements for maintenance may be affected by heat stress and increase with increasing temperature above 27 deg C

The digestion, absorption, and metabolism of nutrients are also altered in both acute and chronic thermal stress conditions With the combined effect of slower rate of passage of ingesta and greater ruminal volume, the retention time of potentially digestible feed is greater resulting in improved digestiblity These alterations in digestive function would be helpful, particularly for animals which can consume comparatively higher forage diets, to digest more completely However, this advantage is offset largely by lower feed intake resulting in less total nutrients being available to thermal stressed animal (Beede and Collier, 1986)

Clearly nutrient partitioning has been altered in heat stressed lactating cows in a manner to support increased water, electrolyte turnover and maintenance requirements, while reducing net energy flow to productive functions The most efficient method of reversing this process would appear to be removing thermal stress via physical protection (Beede and Collier, 1986)

2 6 Climatic and Adaptive Indices

The approaches to measuring stress may take into consideration component parts of the entire environment and as it affects all or component functions of the animals Obviously both environment and adaptive process involved need to be measured in order to make an objective assessment of stress and how it may be modified to lessen the effect

2 6 1 Climatic Indices

The objective is to achieve some readily comprehensive inde for comparing environments and to present in a single variable factor that characterize or imply both the thermal environment and the stress it imposes on an animal Eventhough the environ ment may be identified by the heat demand or heat stress it imposes, the fact remains that there is no simple single measure ment with standard meteorological equipment which will summarize or integrate the effects of environment (Mc Dowell, 1972)

One of the most important sources of heat stress for livestock and man can be solar radiation An index of this stress is devised by Minard et al (1957) based on the measurement of a standard black globe (Tg), the wet bulb (Tw) and shaded dry bulb temperature (Ta) such that

$$WBGT - 0 7 Tw + 0 2 Tg + 0 1 Ta$$

If a shaded, adequately ventilated wet bulb temperature Tw is substituted, then WBGT - 0 7 Tw + 0 3 Tg No direct measure ment of air temperature is required In the absence of a radiant heat load, air movement would not affect the inde value at all WBGT is unlikely to be applicable to all types of hot environment and direct application to animals with coat absorbability differing greatly from the characteristic blackglobe value must be questionable Furthermore, the size of the globe will determine the sensitivity to wind speed Further work might be justified in adapting the WBGT index as standard for comparing livestock environments where heat stress is a primary consideration

An understanding of the physical process in animal s heat balance leads to the suggestions that an environmental demand in dex should include measurements of the meteorogical elements and weightage should be given to various elements to reflect the relative importance to the animal (Bianca, 1961) There are over thirty such indices that have been found useful over specific range of environments It is not yet possible to compare differ ing climates in terms of their stressing effect on cattle Each combination of wind speed, temperature, humidity and time varies the effect

One of the most commonly used indices to distinguish geographical areas on the basis of the physical environment is the climograph It is based on the average monthly ambient temperature and humidity Perhaps the most promising one for cattle is that of Bianca (1962) in which the dry bulb temperature multiplied by 0 65 to give a stress factor The climograph does not give any single numerical value and therefore comparison on the basis of climographs are difficult to interpret

The temperature-humidity index (THI) was developed by the US weather Bureau as a warm weather discomfort index for the evaluation of livestock stress Johnson et al (1967) found a relationship with milk production for lactating cows The THI has units of temperature and is given deg C by (THI 0 72 (Tdb + Twb) + 40 6) where Tdb is the air temperature and Twb is the wet bulb temperature in deg C Monthly THI values can be used to compare the stress of areas which might display diverse temperature and humidity ranges The cows seemed to have little discomfort while the index was 70 or below but they become uncomfortable and milk yield and feed intake were depressed at 75 Cattle of all ages showed measurable degrees of discomfort at an index of 78 or above

Effective temperature (ET) (McDowell, 1972) is an index incorporating solar radiation in addition to ambient temperature and humidity

ET - Ka (db) + Kb (rh) + Ki (sr)

Where db - dry bulb temperature

rh relative humidity

sr solar radiation

ka, k, k1 are constants depending on the units employed

The measurement of solar radiation equires sophisticated equipments and not routinely collected from most of the meterogical stations in the country In tropics and subtropics the intensity of solar radiation under clear skies is fairly uniform from place to place and the duration of sunshine is a useful indicator of radiation load, besides, this is routinely collected at all meteorological stations If properly used, this can give a reasonable good indication of stress due to solar radiation as well as the effect of diurnal variation in thermal stress

An index incorporating hours of bright sunshine has been proposed by Thomas and Acharya (1981) The inde temperature-humidity-sunshine index (THSI) assumes that out of the total hours of bright sunshine, about 75 per cent would be stressful and the average conditions prevalent during this period will be presented by THI values based on dry and wet bulb temperature re corded at 3 PM and that during the rest of the period by THI values based on same temperature recorded at 9 AM

$$THSI - \frac{0\ 75(THI\ at\ 3\ P) + 24-0\ 75\ S\ (THI\ at\ 9\ AM)}{24}$$

where, S is the hours of bright sunshine

THI 0 72 (dbt deg C + Wbt deg C + 40 6)

dbt = dry bulb temperature deg C

wbt - wet bulb temperature deg C

Thomas and Acharya (1981) using the new temperature-humidity sunshine index (THSI) described the climatic environment at 6 stations of All India Coordinated Research Project on Cattle located at Bareilly, Jabalpur, Calcutta, Guntur, Hissar and Puna The average milk yield per day of lactation during the period from 1973 76 of Holstein Friesian and Jersey halfbreds were calculated and simple and partial regressions of these milk yields on daily maximum temperature, vapour pressure, temperature humidity-index and THSI worked out The THSI exceeding 75 accounted for more variation in milk yield between stations than did the other climatic indices considered All regression coefficients were consistently larger in HF than in Jersey half breds, indicating that the Jersey crossbreds were less affected by climate than the HF crossbreds The R^2 value for regression of milk yield on maximum temperature and vapour pressure was 0 757 and 0 144 for HF and Jersey halfbreds respectively

Buffington et al (1981) found that no correction factors are required for black globe temperature measured at a height of 2 1 m instead of the preferred height of about 1m (the centre of mass of dairy cows) It was concluded that the black globe humidity index (BGHI) is a more accurate indicator of animal comfort and production when animals are exposed to incident solar radiation Under conditions of little or moderate thermal radiation levels, BGHI and THI are equally effective

2 6 2 Adaptive Indices

Ideally, measures of an animal s adaptability to particular environment should have high correlation with performance (Mc Dowell, 1972) For the most part, this assessment has fallen into two categories Physiological adaptability which describes the animal s tolerance to hot environment determined principaly by shifts in heat balance and performance adaptability which describes changes in animal s performance in hot environment

The most prominent inde developed from field data is identified as Iberia Heat Tolerance Test (Rhoad, 1944) In this index, a coefficient of tolerance to heat stress (CFHT) is calculated from the cow s recorded body temperature after a period of exposure to summer conditions and the body temperature considered normal at thermally neutral environment for the cattle using the formula

CFHT 100 10 (BT−101 0)

where, CFHT − Coefficient of heat tolerance

BT − Average body temperature obtained under conditions of Iberia test

101 0 Normal body temperature of cattle in (deg F)

10 A constant to convert degrees deviation in body temperature from the normal to unit basis

100 Perfect efficiency in maintaining body temperature at 101 0 deg F

Benezra (1954) developed coefficient of adaptability based on equally weighted values for temperature and respiration rate

$$\text{Benezra's Coefficient of Adaptability (BCA)} = \frac{Tr}{nTr} + \frac{Rr}{nRr}$$

where Tr observed temperature

nTr - normal temperature

Rr - respiratory rate

nRr - normal respiration rate

The BCA is an improved index over Rhod s CFHT (Iberia Heat Tolerance Index) in that CFHT is based only on rectal temperature and BCA takes due weightage for both temperature and respiration rate

The 6 hour room test (McDowell _et al_, 1955) was used extensively in attempts to estimate the comparative response of Jerseys and various combinations of crosses between Red Sindhi and Jerseys in a subtropical area (Southern Louisiana) and a temperate area (Maryland) In these tests large number of animals at both locations were subjected to 6 hours of 40 deg C ambient temperature and 60% relative humidity The objective was to ascertain the degree of rise in respiration rate and rectal temperature The very high temperature was chosen to assure some degree of response in all animals

Many indices based on assigning weightages to one or more of the parameters like rectal temperature, pulse and respiration rates have been devised in India The Izatnagar Index (Mullick, 1961) is based on respiration rate

The stress strain inde proposed by Lee (1965) for use with animals stems from studies with humans It will be difficult to estimate the maximum evaporative cooling possible for animals, because variations in pelage and other factors have more in fluence on evaporation rate from animals than for man

Statistical probability technique is used to predict animal performance resulting from weather (Hahn and Osurn, 1969) In milk production decline model they used a simple linear regres sion for summer time milk production decline as a function of THI

In other indices like water loss coefficient of adaptability , walking and water deprivation and E ercise and cooling efficiency , the regression rates of certain reactions on air temperature or humidity were used for comparison amorg groups and individuals (McDowell, 1972), Results have given some indica tion of breed group differences in cattle, but additional data on several environments is needed before decision can be made on their usefulness as indicators of superior adapted animals Ranking from these indices have not been related to animal per-formance sufficiently to be enlightening The Felling test and Hair coat score have shown reasonably good correlations between score and general performance in hot climates Although they are not direct measurements of response to heat stress, they provide valuable information on the animal s general capacity to thrive in hot environments But its usefulness in selection for adapt ability is questionable

Laboratory tests have utilized standard combinations of temperature and humidity to derive data for determining the regression rates of such reaction as rectal temperature, respiratory rate and sweating at various levels of temperature and humidity These tests require fewer animals and permiting repetition of the temperature humidity regimes, which gives more precise estimates of the stress strain relation than is ordinarily possible with field data (McDowell, 1972) As a result of the work carried out in Australia a combination of perspiration rate food consumption, rectal temperature and respiratory rate is suggested as a useful indication of heat tolerance, the first two factors being set into the equation with positive signs and the last two with negative signs (Turner, 1972) Another index the Dairysearch Index of Heat Tolerance (DIHT) proposed by Thomas et al 1977 incorporates due weightage for rectal temperature, pulse and respiration

$$\text{DIHT} = 0.5\,\frac{(x1)}{x} + 0.2\,\frac{(y1)}{y} + 0.3\,\frac{(z1)}{z}$$

Where, x, y and z are the normal values of rectal temperature, respiration and pulse rates and x1, y1 and z1 are the observed mean values of the afore-mentioned attributes respectively, after exposure An index based on all three physiological reactions, with appropriate weightages is likely to give more balanced information than an index based on only one or two of the physiological parameters

Three heat tolerance indices (Iberia Benezra and Dairysearch) were measured for 12 Holstein Friesian × Hariana, 12 Brown Swiss Hariana and 12 Jersey × Hariana heifers Dif ferences between breed groups were not significant (Goe et al , 1979) Kundu and Bhatnagar (1980) observed significant dif ference in heat tolerance coefficients when estimated by 4 methods, in animals within genetic groups They have not found any specific trend of correlation between heat tolerance coeffi cients and dai milk yield They were of the view that selec- tion of crossbred cows for heat tolerance may not necessarily result in selection for higher milk production The genetic groups used for their studies were 1st generation crossbred cows of Brownswiss Sahiwal, Holstein Friesian Sahiwal, Holstein Friesian × Tharparkar, Brown Swiss × Tharparkar and Jersey x Tharparkar cows in 2nd and 3rd lactation while at rest in loose housing for 32 days in peak lactation period The Iberia heat tolerance test scores averaged 80 71, 80 18, 78 61, 77 57 and 77 57 respectively Ranking of genetic groups was same for coefficients calculated by other heat tolerance indices and differences between groups were not significant

Heat tolerance of various crossbred genetic groups of cattle at Indian Veterinary Research Institute, Izatnagar in Uttar Pradesh of India (Srivastava and Sidhu, 1979) were worked out for 6 Hariana, 6 Hariana Jersey, 6 Hariana Brown Swiss, 6 Hariana Holstein Friesian females The Iberia heat tolerance coefficients averaged 88, 8‾, 79 and 76 respectively, all differences being significant except the difference between the last 2 groups The correlation between skin thickness and heat tolerance value was - 0 864, 0 955, 0 984 and 0 906 (P 0 05 or P < 0 01)

E pected losses for high producing cows and estimated year to year variability based on a model provided a measure of dispersion about the mean for risk assessment Other response functions for dairy cows like hay intake decline rectal temperature and conception rate responses also gave promise of predictive capability for reproduction and production efficiency (Hahn, 1981)

To the dairy farmer, stress is of importance as far as it influences the comfort of his animals and their ability to reproduce and produce on economic basis Production and eproduction are the ultimate indices of the effect of stress If a composite of optimal conditions are not maintained, the loss in production and reproduction will be more (Stott, 1981)

Nagarcenkar and Govindaiah (1988) estimated the sweat secretory area coefficients (SSAC) by taking into account sweat gland number per unit area and sweat gland area Similarly sweat secretory volume coefficients (SSVC) were computed on the basis of sweat gland number per unit area and sweat gland volume coefficient The SSAC and SSVC indices were inturn evaluated as measures of adaptability They have concluded that estimation of adaptability inde based on SSAC or SSVC values is much easier when compared to other physiological, anatomical traits and does not suffer in accuracy and applicability under field conditions Further they have claimed that on the basis of this inde suitable parental breeds could be selected successfully for better adaptability and productivity under hot climate at an early age of life This would minimize unnecessary waiting for a longer period of initiation of production and reproduction traits and to enhance productivity

2 7 Stress Amelioration

Dairy cattle management, in reality, is the manipulation of the animal environment to promote the most efficient production of milk A better understanding of environmental stress and adaptations will greatly help in deciding the potential management strategies that might be taken to alleviate or reduce partially the extent and severity of the effects of thermal stress

Three basic management strategies have been suggested for attenuating effects of thermal stress

1 Physical modification of environment, such as reducing the heat load of the animal (Buffington et al , 1983)

2 Genetic development of heat resistant breeds (Firch, 1984)

3 Improved nutritional management schemes (Mallonee et al 1985)

2 7 1 Physical Modification of Environment

Hot weather causes the milk production to decrease markedly Benefit-cost analyses have indicated that modification to the animals environment in addition to the use of shades to reduce heat stress are good for improved production and conception rates Summer facilities for animals should be planned to give maximum protection from direct solar radiation during the day, yet to permit maximum cooling by radiation at night At high ambient temperatures during the day, most heat loss occurs through evaporative cooling (Yeck and Stewart, 1959)

The use of water as cooling agent, through direct sprinkling on animal s skin or through indirect evaporative cooling of animal s skin, is an excellent technique for reducing heat stress Sastry et al (1973) reported that provision of shelter and water sprinkling in buffaloes gave significantly less heat stress and maintained high metabolic rate than in partially exposed to the sun and not sprinkled animals

The use of evaporative coolers has improved production in lactating dairy cows and has been economically feasible in Arizona (Stott and Wiersma, 1974)

In their studies with lactating dairy cow Thatcher et al (1974) reported that daytime air conditioning was more beneficial than 24 hour air conditioning A positive response to night time cooling was also seen

The night temperature, the coolest in the diurnal temperature cycle, may affect productivity and this would seem to be a particular problem when high humidity reduces heat loss, by radiation and evaporation (Fuquay, 1981) Higher rectal temperatures have been reported for dairy cows in midnight than on mid day (Scott *et al*, 1975)

Gomila *et al* (1977) studied the effect of zone cooling on milk yield, thyroid activity and stress indicators Cows were cooled approximately 14 hours a day by locking their heads in a plywood enclosure with air supply of 23 5 deg C Control cows were on the opposite side of the same open shed without one cooling Mean milk yields of the two groups were 20 97 kg zone cooled and 19 68 kg control Milk fat percentage and thyroid activity were not altered by zone cooling Respiration rate and rectal temperature decreased in zone cooled animals

Natural cross ventilation in a free stall shelter as compared to no cross ventilation resulted in significantly lower rectal temperatures and respiration rates Fans offer potentially practical method for increasing animal cooling during the night by increasing heat loss at the animal surface through evaporative and convective means (Fuquay, 1981)

Modifications of management and housing should be selected rationally, not all are profitable or acceptable For housing, the optimum environments for maximum production or efficiency may not be optimum from the standpoint of economics or of energy utilization The point cannot be emphasized too strongly that rational management be based on valid information about the biological and production systems (Hahn, 1981)

Adverse climates can be imposed by livestock structures designed and used for purposes unrelated to the animal needs In some instances, these structures can cause greater detrimental effects to animals than the natural environment (Hahn, 1981)

A broad spectrum of livestock structures and management is used to temper the adverse effects of climates (Buffigton et al , 1983) Shade, sprinklers, fans, evaporative cooling and air conditioning have been tried with varying degrees of success

However, Bempong et al (1985) concluded from their studies with Holstein Friesian / Hariana milch cows under shelter and water sprinkling conditions in summer that, loose house is adequate enough to maintain productivity Production efficiency in terms of dry matter intake per kg and milk produced was of similar order in loose house and loose house + sprinkling and sprinkling have potential advantages in providing comfortable micro environment resulting from stemming the high temperature mediated decrement in feed intake

Spray cooled animals produced on an average, 0 7 kg more milk per day than control (Igono et al , 1985) Direct sprinkling of water on cows conducts away surface heat and enables animals to vaporize more moisture from the skin, thereby allowing the cow to utilize the resultant latent heat of vaporiztion for body cooling They also suggested the use of milk temperature similar to rectal temperature as an indicator of climatic stress and spray cooling for improving cow comfort to lessen summer decline of milk production

2 7 2 Genetic Development of Heat Resistant Breeds

There is large exploitable genetic diversity within breeds in regulation of body temperatures and this could be used for selection to improve heat tolerance in cattle (Frish and Vercoe, 1977) It may be difficult through selection to achieve both thermoregulation and high inherent productivity Some potential productivity appears to be lost in the process of gaining improved thermoregulatory activities

Rindel (1979) elucidated the known physiological requisites for adaptability in hot humid tropical condition- low maintenance requirements, low metabolic rate, low appetite, low production, late sexual maturity and long calving intervals It is also essential for these breeds to have well developed mechanism for active cooling A low throughput of energy is part of their strategy for heat tolerance Resistance to diseases and a protein reserve to withstand nutritional stresses are other essential qualities for adaptability

Selection criteria are needed for combing traits that are physiologically antagonistic to each other The physiology of active cooling should be developed in high produces beyond the level expressed in adapted cattle in order to dissipate the extra heat generated by high metabolic rate associated with high level of production It is not known whether artificial selection using modern breeding techniques in indigenous breeds can elevate adaptability above the levels attainable by natural selection (Rindel, 1979)

In case of dairy cattle selection for higher yielding cattle which are also less sensitive to thermal stress under existing natural conditions would not seem plausible physiologically. Higher production necessitates higher metabolic heat production, contributing to perturbation of heat balance especially in warm climates. Genetic selection for major physiological defense mechanisms against rising body temperatures such as reduced feed intake and metabolic rate offers little potential advantage where increased productivity is desired (McDowell 1982).

Additional studies are needed to examine variability in heat tolerance of high producing animals and what possibilities may exist for intensive selection programmes with these animals. Possibly improved herds could be developed when selected for milk yield and heat tolerance under local conditions. Proper selection and management of high producing dairy animals and their offsprings are keys to maximizing profitability of a dairy enterprise regardless of physical location and degree of potential climatic stress (Collier et al., 1982).

According to Turton (1985), the development of new breeds of dairy cattle in the tropics may be aimed at producing a breed which possess a mosaic of desirable traits, having superior additive genetic merit of the temperate breed dairy cow for milk yield and the tropical adaptability of the zebu to climate and coexistence with ectoparasites. Though Holstein Freiesian is the best known temperate breed, the Jersey may have a better place as the temperate crossing breed in harsher environments

2 7 7 Nutritional Strategies

Thermal stress affects animals by directly altering the absolute requirement for specific nutrients, by affecting physiological processes and metabolism or by reducing total diet consumption There is scope for evolving potential nutritional management strategies that might offer promise for attenuating the effects of thermal stress and improving animal performance (Beede and Collier, 1986)

2 7 7 1 Diet

There is evidence for increased protein demand during heat stress Joshi et al (1968) observed an increased loss of nitrogen compounds through skin secretion in cattle The apparent need for additional dietary protein is further indicated by reduction in milk protein Kamal and Johnson (1970) reported that acute heat stress for 3 days cause catabolism of body protein in mature Holstein cows as indicated by decreases in body weight, nitrogen retention and whole body potassium

Leighton and Rupel (1956) reported that cows on a low fiber diet produced more milk and had lower rectal temperatures, respiration and pulse rates during mid-summer than did cows on high fiber diet Reduced milk fat percentage and increased digestive disturbance (Branding, 1963) may result from feeding of lower fiber Hassan et al (1972) observed increased feed intake when comparing Holstein cows in hot environment on a 21% crude protein diet with others on a 14% diet. They observed no significant difference in milk production between cows fed high and low protein diets, but they noted a trend in favour of the cows on the high protein diet, during summer study. Additional research is needed on the protein and amino acid requirements of dairy cows during heat stress.

Dairy cows have responded with increased milk production to increments of dietary crude protein ranging from 10.7 to 15.5% (Gardner and Park, 1973).

Hassan and Roussel (1975) reported that milk production was correlated with energy rather than with protein intake. The results suggests that high protein diet helped the cows to withstand thermal stress and maintain milk yields by increasing feed intakes.

With lactating dairy cows NRC (1981) suggests that the higher the proportion of the roughage in the diet, the greater and more rapid the reduction in dry matter consumption as environmental temperature rises. In general, the less digestible the diet fed to thermal stressed animals, the greater will be the rate and extent of reduction of consumption.

Protected fat feeding has not been tested with ruminants under thermal stress. In production systems where considerable forage is incorporated into diets, utilization of protected lipids might be particularly efficacious. Increasing digestible energy density of ruminant diets during thermal stress is an effective management strategy for enhancing productivity (Beede and Collier, 1986)

Influence of protein level and degradablity on milk yields of cows under heat stress was studied by Higginbotham and Huber (1986) Pooled milk yields and feed intakes were lowest on the high protein medium degradability ration and the highest dry matter intake was for medium protein high degradability ration Evaluation of the efficiency of protein of low degradability to meet production requirements of lactating heat stressed animals is needed since this may prove to be an effective strategy for improving productivity

2 7 3 2 Water

The provision of cooled water has improved milk production in dairy cows Cold water in the rumen has increased intake by 24% as well as lowered both rectal and tympanic membrane temperatures (Bhattacharya and Warner, 1968) The effect of rumen temperature on the appetite of ruminants may be indirect through its influence on the entire organism It is likely that the cold water in the rumen reduced the temperature of the blood passing through the hypothalamus, since it reduces both rectal and tympanic membrane temperatures

Milam et al (1986) also observed in lactating Holstein cows significant differences in tympanic membrane temperature after drinking water of 10 deg C There was a transient decrease in body temperature and dry matter intake/kg body weight Body weight was higher for cows drinking water of 10 deg C than for cows drinking water of 28 deg C and least square mean for milk yield was also higher (at 24 5 vs 22 1 kg/day)

2 7 7 3 Minerals

During thermal stress, lactating dairy cows were extensively resilient to changes to acid-base balance by dietary or environmental stresses (Dale and Brody, 1954)

Because animals reduce their voluntary intake during thermal stress, it is logical that mineral intake may be less than optimal in relation to potential productivity Jenkinson and Mabon (1973) noted marked increase in rates of loss of Na, Mg, Ca and Cl, but not P and significant correlations of these losses with sweating rate For lactating cows fed complete mixed diets, suplementation of K and Na during heat stress resulted in 3 to 11% increase in milk yield

El-Nouty <u>et al</u> (1980) reported relationships among thermal stress, plasma aldosterone concentrations and urine electrolyte exrection With prolonged exposure to 35 deg C in climate rooms plasma aldosterone concentrations of nonlactating Holstein cows were 40% lower at 20 deg C Under heat stress, cattle increase Na excretion while decreasing K losses Urinary Na excretion also increased

The acid-base balance during thermal stress in cattle is altered Ramifications of this may include blood acid base imbalance plus a decrease in the salivary bicarbonate pool avail able for rumen buffering Ruminal pH is lowered during thermal stress (Niles et al , 1980)

Effect of dietary potassium (0 66, 1 08, 1 64%) on physiological responses and feed intake were examined by Beede et al (1981) Although dietary potassium did not affect rectal temperature or respiration rate, milk yield responses to added potassium was greater in unshade (12% increase) than shade cows (6% decrease)

Schneider et al (1984 b, 1986) showed enhanced lactational performance of heat-stressed lactating cows fed high concentrate (60-70%) diets by providing 0 85 to 1% dietary sodium bicarbonate presumably buffering the rumen and maintaining a higher ruminal pH

Seybt and Roussel (1986) expressed the possibility of influencing aldosterone secretion by means of salts and thereby increasing milk yield on the basis of their studies with 72 Holstein Friesian cows The results indicate that the fall in milk production which occurs in cows during summer is mediated by the action of aldosterone, which increases in blood during hot periods in order to conserve water

Increasing calcium in the diet provided more buffering capacity in the GI tract True absorption of calcium did not differ from linearity due to source when fecal calcium was regressed on ingested calcium but did vary as a function of diet percentage Thus, calcium retention was increased when cows were fed 0 9 vs 0 6 % calcium These data suggests that a slow reacting inorganic calcium source should be fed at a higher amount to optimize feed intake and milk production (Wohlt et al , 1986)

2 7 3 5 Vitamins

Short term thermal stress caused a 30% decline in hepatic vitamin stores of steers (Page et al , 1959) Potential impact of this on reproductive performance, epithelial cell function and general health of animals in warm climates has not been studied Direct effects of heat stress on requirements of other vitamins and related potential changes in intermediary metabolism have not been characterized Further assessment will be required to ascertain whether thermal stress increases requirements for various vitamins and dictates additional suplementation above normal recommendations (Beede and Collier, 1986)

2 7 4 Management

Buffington et al (1983) suggested relatively simple nutritional strategies which may help in mitigating the sufferings of the heat stressed animals Placement of feed and water are important It may be arranged in such a way that the animals are always in the shade If feed and water is provided in unshaded area, it is likely that they go without nourishment until cooler period of the day Increasing number of feedings per day may make the animals to consume more feed Additionally, it would appear likely that total daily feed intake could be increased if more number of feedings are made in the night

MATERIALS AND METHODS

3 MATERIALS AND METHODS

The experiment was carried out in the crossbred dairy cows of the University Livestock Farm, Mannuthy, Trichur Eight cows each from three genetic groups (crossbreds of Brown Swiss, Holstein Friesian and Jersey with local cattle), the exotic inheritance of which ranged from 50 to 75 per cent were selected for the study Care had been taken to see that the breed groups were as homogeneous as possible in age, body weight, stage of lactation and parity

3 1 Plan of Work

The experimental schedule comprised of 3 trial periods The trial I (18th March to 10th April, 1986) was particularly designed to study the macrolevel responses due to added Climatic stress, while trial II (14th April to 6th May 1986) was to evaluate the effects of stress Trial III (10th April to 4th May, 1987) was mainly aimed at understanding the more intrinsic and subtle microlevel changes of the adaptive process

3 1 1 Trial I

Each genetic group selected was randomly divided into two equal halves of four animals each One half from each genetic group was given added stress by exposing them to direct solar radiation in an open paddock daily from 9 AM to 3 PM continuously for a period of 24 days starting from 18th March 1986 March to May is known to be the most stressful months as far as heat is concerned and generally devoid of clouds and rainfall and hence selected for this experiment The other half of 4 animals each of 3 genetic groups were provided protection from direct solar radiation by keeping them within sheds Feeding and other management conditions remained same for both the exposed and Sheltered groups

The study of animal responses at macro-level included recording of physiological parameters viz rectal temperature, cardiac and respiratory frequency, estimating major and certain minor constituents of milk and selected serum constituents The milk constituents analysed were total solids, fat, whey protien, nonprotien nitrogen, calcium, magnesium, sodium and potassium. Blood serum was analysed for alkaline phosphatase, cholesterol, creatinine, total protien, calcium, magnesium, sodium and potassium

3 1 2 Trial II

The effect of stress ameliorative measures viz , 1 suplementation of buffer salt at 0 85 per cent of the concentrate ration with sodium bicarbonate and 2 partial substitution of dietary protein with protein of low degradability (25 per cent of the concentrate ration replaced with coconut cake of 26 per cent crude protein and 19 per cent degradability) was studied in the same animals in continuation of Trial I Six animals of sheltered and exposed groups were randomly allotted for buffer salt (BS) and undegradable protein (UDP), while the other half remained as control The genetic grouping was ignored for the Trial II though two animals from each group randomly allotted the treatment BS and UDP The BS was supplemented in the daily rations and fed in the morning and evening in two equal quantities Similarly, the same concentrate feed in which 25 per cent of the ration substituted with solvent extracted coconut cake was fed to the other half of animals

The parameters studied were same as that of Trial I

3 1 3 Trial III

The overall frame work of trial III was essentially same as trial I, but utilized only half the number (four) of animals than that of trial I in each genetic group The trial was conducted in the same period of next year with different set of animals More sophisticated and precise analytical techniques like radioimmunoassay and enzyme analysis were carried out with the idea to study the micro-level responses to stress

The blood constituents estimated were lactate dehydrogenase (LDH), glutamic oxalacetic transaminase (GOT), glutamic pyruvic transaminase (GPT), triiodothyronine (T3) and thyroxine (T4) Milk samples were not analysed during Trial III, as in the previous trials, apart from recording of daily milk yield The climatic variables and physiological responses of animals were taken as in Trial I and Trial II

3 2 Meteorological Observations

Weather data within the shed and outside was collected with approved equipments and standard methods thrice daily IST 7 25, 14 25 and 17 30 hours The dry bulb, wet bulb and maximum minimum thermometers within Stevenson screen were employed for collection of meteorological data

Apart from direct recording of maximum temperature (MxT) and minimum temperature (Mnt),the other weather parameters were computed as follows

Daily Mean Temperature (DMT) (MxT + MnT)/2

Mean Day Temperature (MDT) -(Morning T + Afternoon T + Evening T)/3

Daily Mean Relative Humidity

(DMRH) (Morning H + Afternoon H + Evening H)/3

3 3 Physiological Parameters

Rectal temperature was taken using a clinical thermometer (deg C), cardiac rate (CR) by feeling pulse in the coccegeal artery and respiration rate by counting the flank movements, twice daily at the beginning and end of the exposure period The exposure to direct solar radiation was done from 9 AM to 3 PM daily continuously, for the trial period

3 4 Collection of Sample

Milk and blood samples were collected once in 4 days starting from day-4, immediately after the end of daily exposure time Six sample collections were made from both control and exposed animals during each trial period Daily milk yield was noted as the summation of two times milking Blood was collected in Trial III The samples were processed on the same day of collection for selected biocehemical parameters or stored at 4 deg C in refrigerator, for a day or two for estimation of rest of the constituents

3 5 Analysis of Sample

3 5 1 Milk Constituents

3 5 1 1 Total Solids and Solids-not-Fat (SNF)

Total solids estimated by gravimetric method as per procedure I S-1479 (ISI,1961) The solids not fat was calculated as total solids minus milk fat

3 5 1 2 Milk Fat

Milk fat per cent was determined as outlined in I S -1224 (ISI, 1958)

3 5 1 3 Non-protein Nitrogen

Non-protein nitrogen estimated in milk after precipitating all the protein using 15/ trichloroacetic acid, filtrate digested, distilled in micro-Kjeldahl apparatus and titrated against sodium hydroxide The per cent nitrogen value was multiplied by 6 38 to get its equivalent value as protein per cent (ISI, 1961)

3 5 1 4 Total Whey Protein

Estimation of total whey proteins, was done by dye binding method of Dolby (1961) for milk proteins with suitable modifications 10 ml milk was weighed, casein precipitated by adjusting the pH to 4 6 using 1 N HCl and filtered through Whatman No 40 filterpaper and 5 ml filtrate was diluted to 50 ml To 5 ml of this solution 5ml dye solution (made by dissolving 0 6165 g of amido black in 1 litre of 0 3 M citric acid) was added in a 15 ml centrifuge tube The tubes were centrifuged for 5 minutes at 2500 revolutions per minute One ml of the supernatant liquid diluted to 50 ml and transmittance measured at 615 nm Blanks were made with 5 ml water to 5 ml dye solution and dilutions made in the same manner

The spectrophotometer was set to zero optical density on water and readings were then made on blanks and samples The difference in optical density(D) between control (Do) and sample (Dx) were recorded Standards corresponding to total whey protein contents in milk of 2 g/L, 4g/L, 6g/L, 8g/L, and 16g/L were prepared using pure crystalline bovine albumen (Sigma) and processed similar to samples and optical density recorded A standard curve was constructed to read values directly against optical density

3 5 1 5 Milk Minerals

Mineral constituents estimated by digesting 1 ml milk in a 50 ml digestion flask by adding 3 ml Con HNO_3 on an electric heater The clear material was diluted to 50 ml with glass distilled water in a volumetric flask An aliquot was used for estimation of sodium and potassium in a flame photometer using appropriate filters (Hald and Mason, 1958) Calcium and magnesium were estimated in atomic absorption Spectrophotometer (Sunderman and Carrol,1965)

3 5 2 Blood Constituents

3 5 2 1 Alkaline Phosphatase

Alkaline phosphatase activity was determined with P-nitrophenyl phosphate as substrate using carbonate bicarbonate buffer of pH 10 (Bessey et al , 1946) Phosphatase catalyses the hydrolysis of the substrate to phosphate and p-nitrophenol serves as an indicator and in alkaline solution exhibits an intense yellow colour Standards were prepared containing 0 2, 0 4, 0 6, 0 8, 1, 2 and 4 M/L and optical density at 420 um in spectronic 21 plotted against the P-nitrophenol concentrations The concentration expressed in mM Units (IU/L) of plasma at pH 10 in carbonate bicarbonate buffer A millimole Unit is defined as the phosphatase activity which will liberate 1mM of nitrophenol per litre of serum per hour

3 5 2 2 Cholesterol

The method of Zak (1957) based on the principle of Liebermann Buchard reaction was used The acetic acid solution of certain sterols produce a red colour when treated with ferric sulphate and sulphuric acid Standards were prepared by using solutions containing 0 05 - 4 0 mg cholesterol The total cholesterol from unknown sample was interpolated from the standard curve

3 5 2 3 Creatinine

Serum creatinine is determined by reactions in a protein free filtrate with alkaline picrate to form a yellow red colour known as Jaffe reaction The yellow red colour thus formed is compared photometrically to a series of standards prepared from pure solutions of creatinine, by the method of Folin and Wu (1919

3 5 2 4 Total Serum Proteins

The total serum proteins were estimated by the method of Inchiosa (1964) The protein react with cupric ions in alkaline medium to produce a violet colour The density of colour is proportional to the protein concentration The optical density was measured against blank at 555 nM

3 5 2 5 Lactate Dehydrogenase (LDH)

Estimated using UV method in a Photometer by the test kit supplied by Boehringer Mannheim GmbH Diagnostica This is an optimized standard method conforming to the recommendations of the Deutsche Gesellschaft fur klinische chemie, based on the principle

$$\text{pyruvate} + \text{NADH} + \text{H} \rightleftharpoons \text{L - lactate} + \text{NAD}$$

The reagents and sample were processed as per the assay procedure supplied along with the test kit

3 5 2 6 Glutamic Pyruvic Transaminase (GPT)

Photometric determination of the concentration of the pyruvate hydrazine formed with 2,4 - dinitrophenylhydrazine by the reaction,

$$\alpha\text{ oglutarate} + \text{L-alanine} \xrightleftharpoons{\text{GPT}} \text{L-glutamate} + \text{pyruvate}$$

is the test principle of the GPT estimation The assay protocol was supplied along with the test kit manufactured by Boehringer Mannheim GmbH Diagnostica and was followed

3 5 2 7 Glutamic Oxalacetic Transaminase (GOT)

The test principle is that GOT catalyses the reaction between

α oxoglutarate and L-aspartate resulting in L-glutamate and oxaloacetate

$$Oxalocetate + NADH + H \xleftarrow{MDH} L\text{-malate} + NAD$$

The estimation is in UV range at ~40 nm The assay procedure was supplied along with the kit was used

3 5 2 8 Thyroid Hormones

Thyroxine (T4) and triiodothyronine (T3) were estimated by radioimmunoassay technique (Abraham, 1977) in blood serum with commercially available T4 and T3 antisera The assay kits were produced and supplied by ISOPHARM, Radiopharmaceutical Division, Bhabha, Atomic Reserch Centre, Bombay The assay was performed as per the protocol supplied along with the assay kit at the Radiotracer Laboratory of Kerala Agricultural University, Vellanikkara Campus

3 5 2 8 1 Triiodothyronine

The radioimmuno assay method of T3 is based on the competition of unlabelled T3 for the limited binding sites of the specific antibody The antibody bound and free T3 are separated by the addition of charcoal suspension T3 concentration of the sample are quantitated by measuring the radioactivity associated with the bound fraction of sample and standards

The T3 assay kit (RIAK 4) offers a reliable, rapid and sensitive means of estimation of total serum T3 8-anilino-1-naphthalene sulphonic acid is used for blocking T3 binding to thyroxine binding globulin i The reagents for the assay

1 Triiodothyronine standard

2 Anti-triiodothyronine serum

3 Triiodothyronine free serum

4 I-125 triiodothyronine solution

5 Dextran coated charcoal

6 5,5, Diethylbarbituric acid, sodium salt

7 Hydrochloric acid

8 Sodium azide

9 Bovine serum albumin (cohn Fraction V)

ii Equipments and materials used

1 Precision microlitre pipettes 100 l and 50 l with disposable tips

2 Biopipette adjustable to deliver 0 1 ml to 1 ml with disposable tips

3 Glass pipettes and other glassware

4 Polysterene disposable tubes 12 x 17 mm

5 Vortex mixer, magnetic stirrer and centrifuge

6 Well type gamma scintillation counter

7 Logit-log graph sheet

iii Buffers used

Buffer 1 Barbitone containing 0 02/ sodium azide (0 08 M), pH 8 6

Buffer 2 Barbitone buffer containing 0 2/ bovine serum albumin iv Assay procedure

Standards and samples were set up in duplicate Added buffer, T3 free serum to tubes followed by antiserum in appropriate tubes I-125 T3 was added to all tubes, vortexed and kept at room temperature for 3 hours Then cold dextran coated charcoal was added with continuous stirring, mixed and incubated again at room temperature for 10 minutes Centrifuged the tubes at 1500 x g for 4 minutes Decanted the supernatant into numbered empty tubes The count was taken for the tubes containing the supernatant in a gamma scintillation counter

v calculations

The background counts were substracted from all the counts to get actual counts The averages of duplicates calculated and zero standard binding (Bo), / Blank (/ Bo) and / B/Bo of all standards and samples

For calculation of assays, standard curves were constructed by plotting the percent binding of standard concentrations and the percent binding of zero concentrations / B/Bo by the logit log transformation Read the sample values from the standard curve and divided the sample value i e , pg/tube by 50 to convert it to ng/ml

3 5 2 8 2 Thyroxine (T4)

In T4 radioimmunoassay, fixed amounts of 125 I T4 and T4 antibody are added to the serum sample and to a series of T4 stand ards in barbitone buffer T4 from the sample or standard compete with added 125 I - T4 to bind to antibody After incubation, separation of bound and free fraction is achieved by addition of polyethylene glycol (PEG) which precipitates the bound antigen After centrifugation and decantation, precipitate containing antibody bound T4 is counted in a gamma counter The protocol followed was similar to that of T3 The standard curve is plotted and T4 concentration of sample obtained from the curve The expected sensitivity (lower limit of detection) is 0 5 ug/per cent

3 6 Computation of Climatic and Adaptive Indices

3 6 1 Climatic Indices

3 6 1 1 Temperature Humidity Index

Temperature Humidity Index (THI) Johnson et al (1963)

$$THI = 0.72(Ta+Tdp)+40.6$$

Ta - air temperature

Tdp - dew point temperature

3 6 1 2 Temperature - Humidity - Sunshine Index

Temperature humidity sunshine index (THSI) developed by Thomas and Acharya (1981)

$$THSI = \frac{0.75\ S\ (THIe) + (24 - 0.75\ S) \times THI\ m}{24}$$

S hours of bright sunshine (Data obtained from Agrometerology Division of College of Horticulture, Vellanikkara)

THIe - temperature humidity Index at (2 00 PM)

THIm - Temperature humidity index, (9 00 AM)

3 6 2 Adaptive Indices

3 6 2 1 Benezra s Coefficient of Adaptability (BCA) (Benezra, 1954)

$$BCA = \frac{Tr}{Ntr} + \frac{Rp}{Nrp}$$

where, Tr = Observed temperature

Ntr Normal temperature

Rp Observed respiration rate

Nrp Normal respiration rate

3 6 2 2 Rhoad s Iberia Heat Tolerance Index (IHTI)

IHTI (100 - (10 (Tr - N)) (Rhoad, 1944)

where, Tr Observed temperature

N Normal temperature

~ 6 2 ~ Dairysearch Index of Heat Tolerance (DIHT)

(Thomas et al , 1973)

$$\text{DIHT} = \frac{0\ 5\ (x\ 1)}{x} + \frac{0\ 2\ (y1)}{y} + \frac{0\ 3\ (z1)}{z}$$

Where x, y, z are the normal values of rectal temperature, respiration rate and pulse rate, and 1, y1 and z1 are the ob served mean values of the afore mentioned parameters

3 7 Experimental Design and Statistical Analysis

The experimental design used was Factorial incomplete randomized block design Analysis of variances were used to test the significance of difference of means Correlations and multipple regressions techniques were used to test whether the variables were related using F and t tests, as per the methods suggested by Snedecor and Cochran (1967)

RESULTS

4 RESULTS

The results are presented in a series of tables and figures in three parts pertaining to Trials I to III Means with standard error ($\bar{x} \pm$ SE) and correlation coefficients are given in Tables 1 32 The results of the test of significance are indicated by asterick marks at appropriate places in the analysis of variance Tables numbered 33 to 50 To bring out the effect of various climatic stress factors, the data was rearranged in certain cases in ascending/descending temperature gradients, as the situation demanded, for the sake of depicting the results graphically and presented in Figures 1 to 10

The usage shed and open corresponds to that group of cows provided protection from direct solar radiation within the shed and those exposed to direct sun for six hours daily from 9 00 AM to 3 00 PM, to impose additional stress for the experiment The three genetic groups of animals used in the experiment were Brown Swiss Crosses (BSC), Holstein Friesian Crosses (HFC) and Jersey Crosses (JSC) All the results are tabulated almost uniformly under various genetic groups and two treatments viz , shed and open

4 1 Trial I (18th March to 10th April, 1986)

The climatic environment on 6 sample collection days (every

4th day from 21/7/1986) during Trial 1 period is presented in Table 1 The maximum temperature (MxT) of the period ranged from 77 to 78 deg C with mean day humidity (MDH) of 72 to 82 per cent The minimum temperature (MnT) ranged from 25 to 28 deg C The mean MxT for shed was 34 deg C while mean MnT was 27 and 26 deg C respectively for shed and open The mean humidity per cent within shed was 77 in the open 75 The temperature-humidity index at 2 30 PM (THIe) and temperature humidity-sunshine index (THSI) also computed and incorporated in Table 1 The average THIe during the period within shed was 85 and open 68, while the THSI in open was 84

The mean values of rectal temperature (RT) recorded at forenoon (FN) afternoon (AN) and its average values (AV) for shed and open groups of different crossbred genotypes are given in Table 2 The FN means of different genetic groups had highly significant (P 0 01) differences (Table 33) But in the case of AV values the significant differences (P <0 01) were observed in treatments, shed and open (Table 74 and 35) The average rectal temperature means (Table 35) between genetic groups also differed significantly (P<0 05) The effect of THI on RT is depicted in Figure 1

The effect of climatic environment on cardiac rate (CR) is presented in Table 7 The breed differences for CR of FN, AN and AV values were also highly significant (Table 76,77 and 78) The cardiac rate showed highly significant differences (P<0 01) between treatments in the afternoon and average values (Table 77

TABLE 1

Climatic environment during trial I period (every 4th day from 21 ¯ 1986)

Days	Max Temp deg C shed	Max Temp deg C open	Min Temp deg C shed	Min Temp deg C open	Mean day Hum per cent shed	Mean day Hum per cent open	Temp -Hum Index (¯pm) shed	Temp -Hum Index (¯pm) open	Temp Hum Sun Index open
1	¯3 0	¯5 5	27 0	25 0	71 7	70 3	83 1	92 7	81 7
2	¯4 0	¯7 0	26 5	26 0	78 ¯	75 0	87 4	86 2	80 1
¯	¯6 0	¯8 0	26 0	25 0	76 7	81 7	84 5	84 2	78 1
4	¯3 0	35 0	28 0	27 0	75 0	73 ¯	84 9	86 0	79 4
5	¯4 0	35 0	27 0	25 5	71 7	7¯ 3	86 0	9 9	8¯ 5
6	¯5 0	¯6 0	28 0	26 0	66 7	66 7	84 5	86 0	81 7

TABLE 2

Effect of environmental conditions on Rectal Temperature in deg C in different crossbred genetic groups during Trial 1 period (Mean ± SE)

Genetic groups	Fore noon shed	Fore noon open	After noon shed	After noon open	Average shed	Average open
Brown Swiss-Cross	38 5 ±0 081	38 5 ±0 056	39 5 ±0 079	40 2 +0 147	38 9 ±0 059	39 4 ±0 436
Holstein-Friesian Cross	38 4 ±0 069	38 2 ±0 050	39 2 ±0 086	40 2 ±0 111	38 8 ±0 07[illegible]	9 2 ±0 030
Jersey Cross	38 1 ±0 048	38 2 ±0 057	38 9 ±0 070	40 3 ±0 [illegible]93	38 5 ±0 060	39 1 ±0 072

TABLE 3

Effect of climatic environmental on Cardiac Rate/minute in different crossbred genetic groups during Trial 1 period (Mean ± SE)

Genetic groups	Fore-noon shed	Fore-noon open	After noon shed	After noon open	Average shed	Average open
Brown Swiss Cross	64 5 ±0 985	67 6 ±0 979	68 4 ±0 782	78 4 ±1 1[illegible]6	66 4 ±0 7[illegible]4	72 9 +1 05[illegible]
Holstein-Friesian Cross	6[illegible] 8 ±0 049	62 5 ±0 749	68 0 ±0 87[illegible]	7[illegible] 8 ±1 21[illegible]	65 7 ±1 301	68 4 ±0 951
Jersey Cross	59 6 ±0 855	58 6 ±0 766	64 0 ±1 100	71 7 ±1 097	61 9 ±0 874	65 0 +0 766

and 38) The breed differences for CR of FN, AN and AV values were also highly significant (Table 3) The Figure 2 gives the THI effect on CR

Figure 3 and Table 4 shows the effects on respiration rate (RR) of the environmental conditions for different genetic groups There was highly significant (P<0 01) differences for afternoon and average respiration rates of shed and open (Table 40 and 41) The forenoon and average values of breed groups were highly significant (P < 0 01)(Table 39 and 41)

On the basis of the changes in physiological responses of cows in shed and open, adaptability indices using Dairysearch Index of Heat Tolerance (DIHT), Rhoad s Iberia Heat Tolerance Index (IHTI) and Benezra s Coefficient of Adaptability (BCA) have been worked out and presented in Table 5 There were highly significant differences between different genetic groups (P<0 01) DIHT values were 1 74, 1 62 and 1 82 respectively for BSC, HFC and JSC The corresponding IHTI values were 67 76, 66 58 and 71 1 and for BCA 3 79, 3 97 and 4 64

The correlations among weather parameters (MxT, MDH and THI and adaptive indices (DIHT and IHTI) have been presented in Table 6 The correlations among weather parameters and physiological responses of different genetic groups in low stress and high stress conditions have been summarized in Table 7 The Table 8 gives the correlation coefficients between adaptive indices and physiological responses Figure 4 and 5 depicts the effect of temperature humidity index (THI) on Dairysearch index and Iberia

TABLE 4

Effect of environmental conditions on Respiration Rate/minute in different crossbred genetic groups during Trial 1 Period (Mean + SE)

	Fore noon		After noon		Average	
Genetic groups	shed	open	shed	open	shed	open
Brown Swiss-Cross	¯8 7 +1 224	¯9 7 +1 72¯	71 9 ±2 332	108 5 ±5 058	54 9 +1 564	81 4 ±1 859
Holstein-Friesian Cross	6 4 ±1 215	35 4 +1 40[illegible]	58 4 +2 017	102 6 ±4 22¯	47 +1 444	70 9 ±2 220
Jersey Cross	31 5 ±0 928	¯1 4 ±1 ¯68	51 8 ±1 969	109 6 ±5 5	41 8 ±1 ¯04	70 9 ±¯ 051

TABLE 5

Adaptability indices of different crossbred groups during Trial 1 Period (Mean ± SE)

Genetic groups	Dairy search Index of Heat Tolerance	Rhoad s Iberia Heat Test Inde	Benezra s Coefficient of Adaptability
Brown Swiss-Cross	1 74 ± 0 018	67 76 ±1 921	3 79 ±0 062
Holstein-Friesian Cross	1 62 ±0 018	66 58 ±1 784	97 ±0 045
Jo sey Cross	1 82 ±0 026	71 01 ±2 178	4 64 ±0 127

TABLE 6
Correlation coefficients between weather parameters and adaptive indices

Parameter	Brown Swiss Cross	Holstein-Friesian Cross	Jersey Cross
M T DIHT	0 150	- 175	0 162
MDH DIHT	- 420	- 805	466
THI x DIHT	0 224	0 058	0 1¯8
M T IHTI	0 089	0 169	179
MDH x IHTI	0 000	0 307	01¯
THI IHTI	0 051	- 241	0 218

Note M T - Maximum temperature MDH - Mean day humidty
THI - Temperature-humidty index DIHT Dairysearch inde
IHTI - Iberia heat tolerance index

TABLE 7
Correlation coefficients between weather parameters and Physiological responses in different crossbred genotypes

Parameter	Brown Swiss Cross shed	Brown Swiss Cross open	Holstein Friesian Cross shed	Holstein Friesian Cross open	Jersey Cross shed	Jersey Cross open
MxT x RT	0 8¯1	- 086	029	185	0 858	ᴗ 0
MDH x RT	087	00¯	0 5¯5	0 268	0 3¯0	146
THI RT	0 2¯4	051	0 855	0 514	276	0 554
MxT x CR	0 5¯1	0 626	0 844	0 24¯	0 415	0 111
MDH x CR	0 7¯6	- 080	281	116	776	- 377
THI CR	0 572	174	2¯0	- 569	¯94	391
MxT RR	0 293	0 1¯0	0 770	24¯	0 44¯	0 ¯¯0
MDH RR	402	398	493	860	- 569	327
THI RR	0 417	0 222	018	110	0 311	- 008

Note RT Rectal temperature deg C CR Cardic rate/minute
RR - Respiration rate/minute

TABLE 8.

Correlation coefficients between adaptive indices and physiological parameters

Parameter		Brown Swiss Cross shed	Brown Swiss Cross open	Holstein Friesian Cross shed	Holstein Friesian Cross open	Jersey Cross shed	Jersey Cross open
DIHT	RT	0 300	224	0 628	0 ¯95	0 468	0 414
IHTI x	RT	210	1 00	18¯	- 78¯	467	609
DIHT x	CR	0 086	0 782	0 212	0 020	0 25?	0 ¯14
IHTI x	CR	0 508	0 ¯4¯	- 570	- 270	- 687	579
DIHT x	RR	0 6¯¯	0 997	0 568	0 503	0 875	0 762
IHTI	RR	- 00	0 277	¯46	¯88	0 084	- 141

Note DIHT Dairysearch index CR - Cardic rate RT -Rectal temperature
IHTI Iberia heat toleeance index RR Respiration rate

TABLE 9

Effect of environmental conditions on yield of milk and some major milk constituents in different crossbred genetic groups during Trial 1 period

Parameter	Brown Swiss Cross shed	Brown Swiss Cross open	Holstein Friesian Cross shed	Holstein Friesian Cross open	Jersey Cross shed	Jersey Cross open
Milk Yield kg/day	5 41 ±0 15=	4 01 +0 122	5 57 +0 158	4 ¯1 ±0 157	6 46 +0 227	4 52 ±0 168
Total solids yields g/day	717 4 ±17 09	594 8 ±22 08	748 0 ±28 40	642 9 ±26 6	908 0 ± 2 ¯2	687 6 ±26 10
Fat yield g/day	¯61 2 +09 47	227 7 ±09 16	265 4 ±13 13	208,¯ ±11 47	350 ±10 74	230 7 ±08 15

heat tolerance inde of various crossbred genotypes during Trial I period

The effect of environmental conditions on milk yield, kg per day (MY) total solids yield g/day (TSY) and Fat yield g/day (FY) are presented in Table 9 Various treatment (shed and open) means for MY and TS were statistically significant (P < 0 05)

The correlations among physiological parameters, adaptive indices and weather parameters with milk yield are presented in Table 10 The effect of environmental condition on various milk constituents in different crossbred genetic groups are summarized in Table 11 and Figures 6 and 7 Only the total solids had any significant change (P < 0 05) while fat (FT) solids-not-fat (SNF), whey protein (WP), non-protein nitrogen (NPN) Calcium (Ca) Magnesium (Mg) Sodium (Na) and Potassium (k) showed statistically nonsignificant changes

Multiple regression coefficients (R^2) of milk yield, total solids and fat on climatic variables MxT, MnT and MDH of shed and open for different genetic groups are given in Table 11(a) Only the R^2 value for Jersey crosses in shed is highly significant (p 0 01) R^2 values of adaptive indices on climatic variables is presented in Table 11(b) The R^2 values of DIHT for HFC and JSC are highly significant while that of BCA for all genetic groups have significant values (p < 0 05) and none of the values of IHTI has significant R^2 values

The environmental effects on blood serum constituents are presented in Table 12 The parameters studied were alkaline

TABLE 10

Correlation coefficients among physiological parameters/ adaptive indices/weather parameters and milk yield

Parameters	Brown Swiss Cross shed	Brown Swiss Cross open	Holstein-Friesian Cross shed	Holstein-Friesian Cross open	Jersey Cross shed	Jersey Cross open
RT x MY	0 177	- 159	-.435	0 353	0 384	-.813
CR x MY	0 [illegible]77	0 101	0 150	[illegible]87	0 156	- 144
RR x MY	0 012	- 544	041	0 090	0 293	0 200
DIHT x MY	472	- 511	- 240	0 707	0 492	119
IHTI x MY	0 099	0 156	239	0 006	- 364	0 311
MxT MY	0[illegible]2	0 414	0 [illegible]37	- 216	0 070	0 6[illegible]9
MDH x MY	0 262	0 [illegible]90	0 349	0 01[illegible]	610	0 012
THI x MY	- 253	- 399	396	- 148	- 488	- 802

Note RT Rectal temperature
CR - Cardic rate
DIHT - Dairysearch index
RR - Respiration rate
MY - Milk yietd
IHTI - Iberia heat tolerance index

TABLE 11

Effect of envirormental conditions on Milk constituents in different crossbred genetic group during Trial I period (Mean ± SE)

Parameter	Brown Swiss Cross shed	Brown Swiss Cross open	Holstein-Friesian Cross shed	Holstein-Friesian Cross open	Jersey Cross shed	Jersey Cross open
Total solids percent	1[illegible] 41 ±0 327	14 78 ±0 296	13 [illegible]1 ±0 395	14 79 ±0 286	14 5[illegible] ±0 414	15 10 ±0 350
Fat percent	4 70 ±0 145	5 7[illegible] ±0 157	4 95 ±0 166	5 01 ±0 184	5 58 ±0 182	5 12 ±0 136
Solids-not-fat percent	8 497 ±0 216	9 029 ±0 199	8 615 ±0 221	9 819 ±0 160	9 042 ±0 263	9 976 ±0 258
Whey protein (g/L)	7 6[illegible] ±0 262	7 42 ±0 256	7 27 ±0 342	8 20 ±0 239	7 10 ±0 337	7 77 ±0 225
Nonprotein N as / protein	0 [illegible]8 ±0 012	0 44 ±0 016	0 45 ±0 026	0 47 ±0 021	0 42 ±0 019	0 48 ±0 019
Calcium m mol/L	83 90 ±2 718	86 88 ±3 536	8[illegible] 45 ±4 596	9[illegible] 95 ±4 886	82 47 ±1 868	91 1[illegible]5 ±2 812
Magnesium m mol/L	10 80 ±0 825	8 0[illegible] ±0 080	13 62 ±0 097	8 96 ±0 073	7 52 ±0 054	10 8[illegible] ±0 101
Sodium m mol/L	[illegible]1 66 ±1 300	30 8[illegible] ±1 191	32 67 ±1 241	30 8[illegible] ±1 58	31 25 ±1 628	33 [illegible]3 ±1 15[illegible]
Potassium m mol/L	57 58 ±1 902	51 88 ±1 234	74 58 ±2 185	56 54 ±1 585	51 75 +1 289	52 54 ±1 [illegible]79

TABLE 11 (a)

Mutipple regression coefficients of milk yield, total solids and fats in various genetic groups on climatic variables (M T, MnT and MDH) of shed and open

Parameter	Brown Swiss Cross shed	Brown Swiss Cross open	Holstein-Friesian Cross shed	Holstein-Friesian Cross open	Jersey Cross shed	Jersey Cross open
Milk yield	0 81[illegible]	0 329	0 4[illegible]3	0 117	0 99[illegible]**	0 775
Total solids	0 [illegible]87	0 405	0 [illegible]57	0 197	0 178	0 415
Fat	0 410	0 720	0 589	0 721	0 671	0 527

TABLE 11 (b)

Multipple regression coefficients of adaptability indices on climatic variables (M/T, MnT and MDH)

Parameter	Brown Swiss Cross	Holstein Friesian Cross	Jersey Cross
DIHT	0 7[illegible]6	0 944**	0 999**
IHTI	0 103	0 575	0 169
BCA	0 8[illegible]7*	0 8[illegible]1*	0 9[illegible]*

Note DIHT - Dairysearch Inde IHTI Iberia Heat Tolerance Index
BCA - Benezra s Coefficient of Adaptability

TABLE 12

Effect of environmental conditions on blood serum constituents in different crossbred genetic group during Trial I period (Mean ± SE)

Parameter	Brown Swiss Cross		Holstein-Friesian Cross		Jersey Cross	
	shed	open	shed	open	shed	open
Alkaline phosphatase I U/L	2 28 ±0 197	2 16 ±0 178	2 09 ±0 015	2 20 ±0 097	2 72 ±0 178	2 18 ±0 137
Cholesterol mg/100ml	105 08 ±3 093	97 04 ±3 208	120 39 ±3 151	106 92 ±3 989	117 00 ±1 705	121 88 ±4 545
Creatinine mg/100ml	2 57 ±0 214	2 88 ±0 215	2.84 ±0 226	2 49 ±0 218	2 70 ±0 254	2 61 ±0 227
Total serum protein g/L	100 08 ±2 134	94 79 ±2 255	94 88 ±2 529	103 66 ±1 578	97 54 ±2 378	102 63 ±1 414
Calcium m mol/L	5 36 ±0 286	5 29 ±0 238	6 02 ±0 209	5 076 ±0 029	4 81 ±0 314	5 472 ±0 317
Magnesium m mol/L	1 77 ±0 111	1 72 ±0 126	1 68 ±0 122	1 854 ±0 155	1 538 ±0 077	1 954 ±0 105
Sodium m mol/L	122 08 ±2 079	126 65 ±1 925	127 50 ±2 213	137 29 ±3 185	126 04 ±2 920	129 79 ±2 580
Potassium m mol/L	4 06 ±0 081	4 21 ±0 067	4 33 ±0 115	4 02 ±0 212	3 85 ±0 077	4 54 ±0 195

phosphatase (AP), cholesterol (CL), creatinine (CN), total serum proteins (TSP), calcium (SCa), magnesium (SMg), sodium (SNa), and potassium (SK) The differences were not significant

4 2 Trial II (14th April to 6th May, 1986)

In Trial II cows had not been categorized into genetic groups, as in Trial I, instead there were two groups of crossbred cows, one received buffer salt (BS) and other, undegradable protein (UDP) in their ration But for this change, the general presentation of the results are in the same pattern as Trial I

The climatic environment within the shed and outside on 6 sample collection days (every 4th day from 17/4/1986) during Trial II period is given in Table 13 The maximum temperature ranges from 74 to 38 deg C and mean day humidity (MDH) from 65 to 78 deg C and mean day humidity(MDH) from 65 to 75 per cent The weather indices temperature humidity index (THI) and temperature-humidity-sunshine index (THSI) are also incorporated in Table 13

The effects of environmental conditions on rectal temperature of crossbred cows during 2 ameliorative treatments of buffer salt supplementation and UDP feeding is presented in Table 14 The forenoon RT was significantly different in shed and open groups (P < 0 05) (Table 42) The afternoon and average values did not differ significantly (Table 43 and 44)

Table 15 depicts the effect of environmental conditions on CR during BS/UDP trial The FN and AV means had highly significant differences for both shed and open, as well as means of

TABLE 13

Climatic environment within shed and outside on 6 sample collection days during Trial II period (14th April to 6th May 1986)

Days	Max Temp deg C shed	Max Temp deg C open	Min Temp deg C shed	Min Temp deg C open	Mean day Humi per cent shed	Mean day Humi per cent open	Temp -Hum Index (3dm) shed	Temp -Hum Index (3dm) open	Temp Hum -Sun shed	Temp Hum -Sun open
I	35 0	36 0	28 0	26 0	70 0	71 7	84 9	85 6	82 2	81 4
II	35 0	38 0	28 0	27 0	71 7	65 0	86 0	87 4	81 8	81 5
III	34 0	35 5	26 0	24 5	7[illegible]	6[illegible]	84 9	78 4	78 1	79 1
IV	34 0	35 0	27 0	27 0	75 0	75 0	84 5	86 0	80 6	80 6
V	3[illegible] 0	34 0	27 5	25 0	73 [illegible]	75 0	8[illegible] 4	84 5	80 6	78 7
VI	34 0	34 0	28 0	26 5	7[illegible]	7[illegible]	84 5	84 9	81 6	80 9

TABLE 14

Effect of environmental conditions on Rectal Temperature in deg C in crossbred cattle during 2 stress ameliorative treatments

Treatment	Fore noon shed	Fore noon open	After noon shed	After noon open	Average shed	Average open
Buffer Salt	~8 6 ±0 086	~8 0 ±0 068	~9 7 ±0 293	39 7 ±0 288	~9 0 ±0 08~	~9 0 _0 061
Undegrable Protein	38 5 ±0 072	~8 1 ±0 050	~9 2 ±0 10~	40 2 +0 089	38 8 ±0 079	~9 2 ±0 059

TABLE 15

Effect of environmental conditions on Cardiac rate/minute on crossbred cattle during 2 stress ameliorative treatments

Treatment	Fore noon shed	Fore noon open	After noon shed	After noon open	Average shed	Average open
Buffer Salt	67 25 ±0 984	63 44 ±1 219	72 67 ±1 084	73 17 ±1 0?6	69 86 ±0 969	68 19 ±0 970
Undegrable Protein	70 ~9 ±1 222	65 67 ±1 097	75 56 ±0 899	71 25 ±1 159	72 92 ±0 912	69 5 +0 962

BS and UDP (P 0 01) (Table 45 and 47) However, the cardiac rate in the AN had not differed statistically (Table 46) The respiratory changes are given in Table 16 The AN and AV respiratory rate was statistically different between shade and open groups (P ≤ 0 01)(Table 49 and 50) The forenoon means also differed significantly (Table 48)

The adaptability indices for the group of animals receiving BS and UDP on the basis of changes in low and high stress environment are presented in Table 17 The Table 18 contains correlations coefficients among weather parameters and adaptive indices Very high correlation was observed for mean day humidity with DIHT (r - 717 to - 783) while IHTI had fairly high values for both MDH and MDT (r= 0 297 to 0 806 and - 326 to - 788) The effect of temperature humidity index (3PM) on DIHT is depicted in Figure 8

The correlations among weather parameters and physiological responses for BS and UDP feeding have been summarized in Table 19 Table 20 gives the effect of environmental conditions on MY, TSY and FY The treatments, shed and open had highly significant (P<0 01) differences for milk yield The total solids yield also showed significant differences (P ≤ 0 05) but not for fat yield

The correlation coefficients among various weather parameters and milk yield of crossbreds in different ameliorative treatments have been presented in Table 21 and Figure 9

Table 22 summarizes the effect of environmental conditions on milk constituents during ameliorative treatments The means

TABLE 16

Effect of environmental conditions on Respiration Rate on crossbred cattle during 2 stress ameliorative treatments

Treatments	Fore-noon shed	Fore-noon open	After noon shed	After noon open	Average shed	Average open
Buffer Salt	47 6 ±1 704	42 4 ±1 056	68 6 +2 127	100 2 ±2 000	58 3 ±1 678	71 0 ±1 537
Undegrable Protein	48 9 ±1 952	44 1 ±1 245	64 6 ±2 600	112 4 ±2 978	56 5 ±2 025	79 2 ±1 718

TABLE 17

Adaptability indices during 2 ameliorative treatments

Treatment	Dairysearch Index of Heat Tolerance	Iberia Heat Test Inde	Benzera s coefficient of Adaptab
Buffer Salt	1 76 +0 017	75 54 ±1 549	[illegible] 11 ±0 052
Undegrable Protein	1 46 ±0 018	67 10 ±1 904	[illegible] 45 ±0 059

TABLE 18

Correlation coefficients between weather parameters and adaptive indices during ameliorative treatments

Parameter		Buffer Salt shed	Buffer Salt open	Undegrebale Protein shed	Undegrebale Protein open
M T	DIHT	0 ~95	0 616	0 192	0 ~45
MDH	DIHT	78~	- 623	712	- 17
THI	DIHT	0 ~5~	086	0 044	0 217
MxT	x IHTI	522	788	~~6	704
MDH	x IHTI	0 5 5	0 54~	0 297	0 806
THI	IHTI	486	- 101	543	0 407

TABLE 19

Correlation coefficients between weather parameters and Physiological responses in crossbred cows

Parameter		Buffer Salt shed	Buffer Salt open	Undegrebale Frotein shed	Undegrebale Frotein open
M T	FT	0 527	0 8~0	0 4~0	0 844
MDH	x RT	- 084	- 597	- 054	- 010
THI	RT	0 494	0 1~5	0 590	151
MxT	CR	0 914	0 ~08	0 811	0 721
MDH	x CR	90~	279	8~1	456
THI	x CR	0 699	0 327	0 627	0 109
MxT	RR	0 803	0 622	0 7~~	0 249
MDH	RR	495	657	317	0~6
THI	RR	0 242	121	0 705	0 2 ~

TABLE 20.

Effect of environmental conditions on milk yield and yield of major milk constituents during two stress ameliorative treatments

Parameter	Buffer Salt shed	Buffer Salt open	Undegradable Protein shed	Undegradable Protein
Milk Yield Kg/day	5 10 [illegible]	[illegible] ±0 078	[illegible] 8 ±[illegible] 1 [illegible]	54 +0 1 1
Total solid yields g/day	745 9 ±44 6[illegible]	745 9 ±23 55	870 5 ±[illegible]7 99	6[illegible]6 1 +27 [illegible]7
Fat yield g day	27[illegible] ±17 89	229 [illegible] ±07 09	[illegible]25 2 ±14 11	250 5 ±11 09

TABLE 21

Correlations among weather parameters and milk yield of various crossbred in different ameliorative treatments

Parameter	Buffer Salt shed	Buffer Salt open	Undegrebale Protein shed	Undegrebale Protein open
MxT x MY	0 660	0 890	0 804	0 760
MDH x MY	- 652	- 692	698	- 650
THI x MY	0 571	0 222	0 582	- 025

TABLE 22

Effect of environmental conditions on Milk constituents of crossbred cows during two stress ameliorative treatments

Parameter	Buffer Salt		Undegradable Protein	
	shed	open	shed	open
Total solids percent	14 69 ±0 17	16 84 ±0 715	15 07 ±0 298	15 25 ±0 201
Fat percent	5 18 ±0 194	5 98 +0 127	5 65 +0 154	5 72 +0 199
Solids-not-fat percent	9 4 ±0 719	10 89 ±0 301	9 45 ±0 271	9 64 ±0 219
Whey protein (g/L)	8 49 ±0 216	8 22 ±0 184	8 [illegible]9 ±0 175	8 03 ±0 208
Nonprotein N as / protein	0 48 ±0 018	0 50 ±0 014	0 56 ±0 016	0 49 ±0 022
Calcium m mol/L	84 97 ±7 660	86 80 ±3 621	78 18 ±1 640	72 13 ±2 207
Magnesium m mol/L	17 01 ±0 557	19 04 ±0 845	20 96 ±0 817	27 92 ±1 218
Sodium m mol/L	36 39 ±2 208	27 50 ±1 177	32 78 ±1 245	27 22 ±0 369
Potassium m mol/L	52 50 ±1 070	51 49 ±0 5[illegible]7	49 56 ±0 519	57 80 ±0 857

TABLE 23

Effect of environmental conditions on blood serum constituents of crossbred cows during two stress ameliorative treatments

Parameter	Buffer Salt Cross shed	Buffer Salt Cross open	Undegradable Cross shed	Undegradable Cross open
Alkaline phosphatase I U/l	2 76 ±0 110	2 24 ±0 172	2 72 ±0 126	2 17 ±0 155
Cholestero l mg/100ml	82 88 ±3 994	84 97 ±3 122	79 00 ±7 321	90 78 ±4 130
Creatinine mg/100ml	4 29 ±0 274	4 7 ±0 265	4 28 ±0 227	4 37 ±0 210
Total serum protein g/L	99 71 ±7 016	104 89 ±1 721	102 77 ±1 892	105 20 ±1 812
Calcium m mol/L	4 54 ±0 700	4 15 ±0 287	5 469 ±0 374	7 021 ±0 636
Magnesium m mol/L	1 61 +0 610	1 21 ±0 174	1 79 ±0 077	1 27 ±0 069
Sodium m mol/L	108 06 ±2 488	123 33 +4 712	115 56 ±2 984	121 50 ±4 940
Potassium m mol/L	4 48 ±0 175	4 94 ±0 159	5 18 ±0 121	6 22 ±0 499

were not statistically significant, except of total solids for treatments shed and open and not for BS and UDP (P 0 05)

None of blood serum constituents showed any significant changes during stress ameliorative experimental period (Table 27) The mean values for AP, CL, CN, TSP, SCa, SMg, SNa and SK are presented for both BS and UDP groups in shed and open conditions

4 7 Trial III (10th April to 4th May, 1987)

The overall presentation of results are similar to that of Trial I The Tables 24 to 32 summarize the results of Trial III

The micro and macro climatic environment of the Trial III period is depicted in Table 24 The MxT ranged from 38 to 41, MnT from 25 to 29 and humidity per cent from 60 to 72 THI and THSI also given in the same Table

The changes in physiological parameters, are presented in Tables 25, 26 and 27 The average rectal temperatures in two treatments of shed and open differed significantly (P < 0 01) The cardiac rates in the FN and AN between shed and open also got highly significant differences (P < 0 01) The respiration rate (RR) between different breed groups were observed to be highly significant P < 0 01) The afternoon changes in respiration rate was also highly significant The AV values of RR showed breed difference which was highly significant statistically

The influence of environmental conditions and its reflection in Dairysearch Inde of heat tolerance and Iberia heat tolerance

TABLE 24

Climatic environment within shed and outside on 6 sample collection days during Trial III period (10th April to 4th May 1987)

Days	Max Temp deg C shed	Max Temp deg C open	Min Temp deg C shed	Min Temp deg C open	Mean day Hum per cent shed	Mean day Hum per cent open	Temp Hum Index (3dm) shed	Temp Hum Index (3dm) open	Temp Hum -Sun open
I	38	38	27	25 5	60 0	65 0	82 2	85 6	87 4
II	40	41	29	26 0	65 0	61 7	85 5	88 1	86 0
III	39	39	28	26 0	66 7	7[illegible] 3	8[illegible] 9	88 1	87 4
IV	40	41	27	26 0	71 7	73 [illegible]	81 9	84 5	86 0
V	38	39	27	25 0	60 0	61 7	81 6	8[illegible] 5	87 4
VI	38	39	26	25	65 0	61 7	82 9	86 0	86 0

TABLE 25

Effect of environmental conditions on Rectal Temperature in deg C in different crossbred genetic groups during Trial III Period

Genetic groups	Fore-noon shed	Fore-noon open	After noon shed	After noon open	Average shed	Average open
Brown Swiss Cross	38 4 +0 089	38 4 ±0 051	39 [illegible] ±0 127	40 [illegible] ±0 075	[illegible]8 85 ±0 091	39 4[illegible] ±0 055
Holstein Friesian Cross	38 [illegible] ±0 051	38 2 ±0 022	39 5 ±0 081	40 6 ±0 079	[illegible]8 8 ±0 073	38 9 ±0 179
Jersey Cross	38 [illegible] ±0 052	38 1 ±0 022	39 45 ±0 093	40 2 +0 092	39 0 ±0 079	39 1 ±0 055

TABLE 26.

Effect of environmental conditions on Cardiac Rate/minute in different crossbred genetic groups during Trial III Period

Genetic groups	Fore-noon		After-noon		Average	
	shed	open	shed	open	shed	open
Brown Swiss Cross	87 2 +1 268	77 0 ±1 635	80 7 +0 547	86 7 ±0 969	80 9 ±0 652	81 8 ±1 046
Holstein-Friesian Cross	81 5 ±1 192	77 7 ±2 011	83 0 ±0 903	89 7 ±1 6	82 7 ±0 997	87 5 ±1 576
Jersey Cross	85 7 ±1 547	70 3 ±0 547	86 2 ±1 945	88 7 ±1 801	84 9 ±2 057	79 5 ±1 024

TABLE 27

Effect of environmental conditions on Respiration Rate/minute in different crossbred genetic groups during Trial III Period

Genetic groups	Fore noon		After-noon		Average	
	shed	open	shed	open	shed	open
Brown Swiss Cross	49 7 ±0 776	45 7 ±0 163	83 7 ±2 496	105 0 ±1 407	66 7 ±1 795	75 7 ±0 665
Holstein-Friesian Cross	41 7 ±1 384	40 7 ±1 516	78 7 ±2 976	96 0 ±2 267	6 0 ±1 441	68 3 ±1 441
Jersey Cross	41 7 +0 787	45 7 ±1 231	71 7 ±2 576	105 0 ±2 56	56 7 ±1 557	74 2 ±1 588

inde is presented in Table 28

The effect of environmental conditions on milk yield of Brown Swiss, Holstein Friesian and Jersey crossbred cows are given in Table 29 The mean values differed for breed as well as for treatment ($P < 0.05$)

Table 30 is of the correlation coefficients between weather parameters and milk yield of different crossbred genotypes

The effect of environmental conditions on blood serum constituents are enlisted in Table 31 The parameters include lactate dehydrogenase (LDH), glutamic oxalacetic transaminase (GOT), glutamic pyruvic transaminase (GPT), Triiodothyronine (T_3) and Thyroxine (T_4) There were no statistically different changes except for T_3 between treatments shed and open ($P < 0.01$) The effect of temperature-humidity (THI) on T_3 is presented in Figure 10

Table 32 gives correlation coefficients between serum triiodothyronine (T_3) concentration and milk yield and physiological parameters The multiple regression coefficients (R^2) of T_3 levels in shed and open of various genetic groups on climatic variables are presented in Table 32(a) The R^2 value for HFC is significant ($p < 0.05$) while the same for JSC is highly significant ($p < 0.01$)

TABLE 28

Effect of environmental conditions on adaptive indices in different crossbred genetic groups during Trial III Period (Mean ± SE)

Genetic groups	Dairysearch Index of Heat Tolerance	Rhoad s Iberia Heat Test Inde	Benezra s Coefficient of Adaptability
Brown Swiss Cross	1 76 ±0 017	67 18 ±1 426	17 ±0 029
Holstein-Friesian Cross	1 36 ±0 014	58 92 ±1 418	7 10 ±0 050
Jersey Cross	1 48 ±0 025	67 59 ±1 569	7 59 ±0 056

TABLE 29.

Effect of environmental conditions on milk yield during Trial III Period (Mean ± SE)

Parameter	Brown Swiss Cross		Holstein Friesian Cross		Jersey Cross	
	shed	open	shed	open	shed	open
Milk Yield kg/day	7 70 ±0 099	6 20 ±0 096	8 00 ±0 101	6 00 ±0 16[illegible]	6 90 +0 167	5 64 ±0 153

TABLE 30

Correlation coefficients between weather parameters and milk yield of different crossbred genotypes

Parameters	Brown Swiss Cross		Holstein Friesian Cross		Jersey Cross	
	shed	open	shed	open	shed	open
MxT x MY	0 062	- 119	0 607	090	0 492	0 080
MDH x MY	198	0 793	0 746	0 261	0 058	0 267
THI MY	035	470	885	574	527	741

TABLE 31

Effect of environmental conditions on blood serum constituents Trial III period (Mean ± SE)

Parameter	Brown Swiss Cross shed	Brown Swiss Cross open	Holstein Friesian Cross shed	Holstein Friesian Cross open	Jersey Cross shed	Jersey Cross open
Lactate dehydrogenase IU/L	1248 ±82 115	1400 ±92 061	1379 ±51 291	1489 ±64 470	1171 ±96 382	1874 ±270 167
Glutamic Oxal-acetic T IU/L	87 45 ±4 578	78 00 ±5 780	88 80 ±6 216	73 0 ±6 494	91 10 ±9 317	105 50 ±20 548
Glutamic Pyr-uvic T IU/L	17 50 +1 990	24 00 ± 250	15 70 ±2 415	17 74 ±1 124	21 04 ±1 937	27 40 ±7 099
Triiodothyronine ng/ml	1 00 ±0 067	0 625 ±0 046	0 90 ±0 054	0 65 ±0 058	1 06 +0 070	0 717 ±0 068
Thyroxine ng/ml	32 50 ±3 615	18 37 ±1 796	20 87 +1 852	25 83 ±1 817	27 67 ±2 637	27 00 ±7 284

Note T Transaminase

TABLE 32

Correlation coefficient between serum triiodothyromine concentrations and milk yield, and physiological parameters

Parameter	Brown Swiss Cross shed	Brown Swiss Cross open	Holstein-Friesian Cross shed	Holstein-Friesian Cross open	Jersey Cross shed	Jersey Cross open
T3 Milk Yield	0 217	504	319	- 798	270	706
T3 x Rectal Temperature	0 250	146	728	271	0 299	424
T3 x Cardiac Rate	- 044	- 288	- 720	191	554	- 514
T3 x Respiration Rate	0 823	- 540	713	0 299	618	0 664

Note T3 - Triiodothyronine

TABLE 32 (a)

Multipple regression coefficients of triiodothyronine (T3) levels of various genetic groups in shed and open on climatic variables

Genetic groups	R^2 - values	
	Shed	Open
Brown Swiss Cross	0 717	0 710
Holstein Friesian Cross	0 719	0 974*
Jersey Cross	0 684	0 987**

TABLE ⁻⁻

Analysis of variance for Rectal Temperature (fore -noon) during exposure e periments
(Treatment - Within shed, e posure)
(Breed Brown Swiss, Holstein Friesian and Jersey Crosses)

CD FOR TREATMENT MEANS COMPARISON, 9 906366E-02
CD FOR BREEDMEANS COMPARISON, 0 1213277

SOURCE	DF	SS	MS	F
TREATMENT	1	0 00000	0 00000	0 0000
BREED	2	2 00000	1 00000	10 87⁻8 * *
INTR	2	0 29688	0 14844	1 6286
ERR	1⁻8	12 5781⁻	0 09115	

* * Highly Significant (P 0 01)

TABLE 34

Analysis of variance for Rectal Temperature (after- noon) during exposure experiments
(Treatment - Within shed, exposure)
(Breed Brown Swiss, Holstein Friesian and Jersey Crosses)

CD FOR TREATMENT MEANS COMPARISON, 0 2994268
CD FOR BREEDMEANS COMPARISON, 0 ⁻667214

SOURCE	DF	SS	MS	F
TREATMENT	1	41 6406⁻	41 6406⁻	49 5616 * *
BREED	2	1 75000	0 87500	1 0414
INTR	2	12500	1 56250	1 88⁻2
ERR	1⁻8	114 50000	0 82971	

* * Highly Significant (P < 0 01)

TABLE 35

Analysis of variance for Rectal Temperature (Average) during exposure experiments
(Treatment – Within shed, exposure)
(Breed – Brown Swiss, Holstein Friesian and Jersey Crosses)

CD FOR TREATMENT MEANS COMPARISON, 0 3016262
CD FOR BREEDMEANS COMPARISON, 0 ⁻694151

SOURCE	DF	SS	MS	F
TREATMENT	1	13 ⁻1250	1⁻ 31⁻50	15 6146 * *
BREED	2	7 18750	⁻ 59⁻75	4 215. *
INTR	2	0 609⁻8	0 ⁻0469	0 ⁻541
ERR	138	118 75000	0 86051	

* Significant (P 0 05)
* * Highly Significant (P < 0 01)

TABLE 36

Analysis of variance for Cardiac Rate (fore noon) during exposure experiments
(Treatment Within shed, exposure)
(Breed Brown Swiss, Holstein Friesian and Jersey Crosses)

CD FOR TREATMENT MEANS COMPARISON, 2 741009
CD FOR BREEDMEANS COMPARISON, 3 357036

SOURCE	DF	SS	MS	F
TREATMENT	1	3 06250	3 06250	0 04⁻5
BREED	2	1178 00000	589 00000	8 ⁻657 * *
INTR	2	140 81250	70 40625	⁻ 58⁻2 *
ERR	138	2711 56⁻00	19 64900	

* Significant (P < 0 05)
* * Highly Significant (P 0 01)

TABLE 37.

Analysis of variance for Cardiac Rate (After noon) during exposure experiments
(Treatment - Within shed, exposure)
(Breed - Brown Swiss, Holstein Friesian and Jersey Crosses)

CD FOR TREATMENT MEANS COMPARISON, 1 753267
CD FOR BREEDMEANS COMPARISON, 2 147305

SOURCE	DF	SS	MS	F
TREATMENT	1	2272 56700	2272 56700	70 5027 * *
BREED	2	744 75000	372 77500	12 9269 * *
INTR	2	106 60938	53 31250	1 8738
ERR	178	3926 25000	28 45109	

* * Highly Significant (P < 0 01)

TABLE 38

Analysis of variance for Cardiac Rate (Average) during exposure experiments
(Treatment - Within shed, exposure)
(Breed - Brown Swiss, Holstein Friesian and Jersey Crosses)

CD FOR TREATMENT MEANS COMPARISON, 1 551667
CD FOR BREEDMEANS COMPARISON, 1 900396

SOURCE	DF	SS	MS	F
TREATMENT	1	592 12500	592 12500	26 2478 * *
BREED	2	937 68750	466 84780	20 6911 * *
INTR	2	108 25000	54 12500	[illegible]
ERR	178	[illegible]050 [illegible]0000	[illegible]	

* * Highly Signif [illegible] 01)

TABLE 39

Analysi o v ri a ce for respirat on Rate (Fore noon) during e posure e per er ts
(Treatmen W thin shed, e pos re)
(Breed Brown Swiss, Hol tein Friesian and Jersey Crosses)

CD FOR TREATMENT MEANS COMPARISON, 2 120578
CD FOR BREEDMEANS COMPARISON, 2 597118

SOURCE	DF	SS	MS	F
TREATMENT	1	0 03125	0 03175	0 0007
BREED	2	1460 53100	730 26560	17 3 00 * *
INTR	2	22 10938	11 05469	0 2596
ERR	138	5877 72800	42 58973	

* * Highly Significant (P < 0 01)

TABLE 40.

Analysis of variance for Respiratior Rate (After noon) during exposure experiments
(Treatment - Within shed exposure)
(Breed - Brown Swiss, Holstein Friesian and Jersey Crosses)

CD FOR TREATMENT MEANS COMPARISON, 11 805
CD FOR BREEDMEANS COMPARISON, 14 45811

SOURCE	DF	SS	MS	F
TREATMENT	1	76268 00000	76268 00000	58 4010 * *
BREED	2	3075 62500	1517 81300	1 1622
INTR	2	2611 87500	1705 97800	3 8203
ERR	178	47174 50000	341 84420	

* * Highly Significant (P < 0 01)

TABLE 41

Analysis of variance for Respiration Rate(Average)during exposure experiments
(Treatment – Within shed, exposure)
(Breed – Brown Swiss, Holstein Friesian and Jersey Crosses)

CD FOR TREATMENT MEANS COMPARISON, 3 185127
CD FOR BREEDMEANS COMPARISON, 3 900968

SOURCE	DF	SS	MS	F
TREATMENT	1	24076 69000	24076 69000	253 2520 * *
BREED	2	4056 50000	2028 25000	21 3343 * *
INTR	2	99 43750	49 71875	0 5194
ERR	1¯8	13210 38000	95 72736	

* * Highly Significant (P < 0 01)

TABLE 42

Analysis of variance for Rectal Temperature(fore noon)during ameliorative experiments
(Treatment – Within shed, exposure)
(Breed – Buffer Salt and Undegradable protein feeding)

CD FOR TREATMENT MEANS COMPARISON, 0 1464213
CD FOR BREEDMEANS COMPARISON, 0 146421¯

SOURCE	DF	SS	MS	F
TREATMENT	1	9 98438	9 98438	49 6961 * *
BREED	1	0 06250	0 06250	0 3111
INTR	1	0 54688	0 54688	2 7559
ERR	140	27 78125	0 19844	

* * Highly Significant (P ≤ 0 01)

TABLE 43

Analysis of variance for Rectal Temperature (After noon) during ameliorative experiments
(Treatment - Within shed, exposure)
(Breed - Buffer Salt and Undegradable protein feeding)

CD FOR TREATMENT MEANS COMPARISON, 0 9765912
CD FOR BREEDMEANS COMPARISON, 0 9765912

SOURCE	DF	SS	MS	F
TREATMENT	1	9 68750	9 68750	1 08˜9
BREED	1	0 00000	0 00000	0 0000
INTR	1	8 93750	8 93750	5 3121
ERR	140	235 54690	1 68248	

TABLE 44

Analysis of variance for Rectal Temperature (Average) during ameliorative experiments
(Treatment - Within shed, exposure)
(Breed - Buffer Salt and Undegradable protein feeding)

CD FOR TREATMENT MEANS COMPARISON, 0 ˜629˜46
CD FOR BREEDMEANS COMPARISON, 0 ˜629˜46

SOURCE	DF	SS	MS	F
TREATMENT	1	1 0156˜	1 01563	0 8228
BREED	1	0 1406˜	0 14063	0 11˜9
INTR	1	1 234˜8	1 2˜4˜8	6 6506
ERR	140	25 984˜8	0 18560	

TABLE 45

Analysis of variance for Cardiac Rate(Fore noon)during ameliorative experiments
(Treatment - Within shed, exposure)
(Breed - Buffer Salt and Undegradable protein feeding)

CD FOR TREATMENT MEANS COMPARISON, 2 217567
CD FOR BREEDMEANS COMPARISON, 2 217567

SOURCE	DF	SS	MS	F
TREATMENT	1	654 50000	654 50000	14 2025 * *
BREED	1	258 68750	258 68750	5 61[illegible]5 *
INTR	1	7 56250	7 56250	0 1631
ERR	140	6490 18800	46 [illegible]5848	

* Significant (P < 0 05)
* * Highly Significant (P < 0 01)

TABLE 46

Analysis of variance for Cardiac Rate (After noon) during ameliorative experiments
(Treatment - Within shed, exposure)
(Breed - Buffer Salt and Undegradable protein feeding)

CD FOR TREATMENT MEANS COMPARISON, 4 710546
CD FOR BREEDMEANS COMPARISON, 4 710546

SOURCE	DF	SS	MS	F
TREATMENT	1	130 31250	130 [illegible]1250	0 6[illegible]67
BREED	1	8 43750	8 4[illegible]750	0 0406
INTR	1	207 93750	207 9[illegible]750	5 2751
ERR	140	5518 62500	39 41875	

TABLE 47

Analysis of variance for Cardiac Rate(Average)during ameliorative experiments
(Treatment Within shed, exposure)
(Breed - Buffer Salt and Undegradable protein feeding)

CD FOR TREATMENT MEANS COMPARISON, 1 867727
CD FOR BREEDMEANS COMPARISON, 1 867727

SOURCE	DF	SS	MS	F
TREATMENT	1	232 50000	2"2 50000	7 1122 * *
BREED	1	171 18750	171 18750	5 2367 * *
INTR	1	27 62500	27 62500	0 8441
ERR	140	4581 68800	32 726"4	

*   Significant (P < 0 05)
* * Highly Significant (P < 0 01)

TABLE 48.

Analysis of variance for Respiration Rate (Fore noon) during ameliorative experiments
(Treatment - Within shed, exposure)
(Breed - Buffer Salt and Undegradable protein feeding)

CD FOR TREATMENT MEANS COMPARISON, 2 990519
CD FOR BREEDMEANS COMPARISON, 2 990519

SOURCE	DF	SS	MS	F
TREATMENT	1	890 00000	890 00000	10 6196 *
BREED	1	84 00000	84 00000	1 002"
INTR	1	1 0"125	1 03125	0 0122
ERR	140	11815 84000	84 "9888	

*   Significant (P < 0 05)

TABLE 49

Analysis of variance for Respiration Rate (After noon) during ameliorative experiments
(Treatment - Within shed, exposure)
(Breed - Buffer Salt and Undegradable protein feeding)

CD FOR TREATMENT MEANS COMPARISON, 15 89796
CD FOR BREEDMEANS COMPARISON, 15 89796

SOURCE	DF	SS	MS	F
TREATMENT	1	56644 00000	56644 00000	23 9156 * *
BREED	1	600 25000	600 25000	0 2534
INTR	1	2368 50000	2368 50000	9 2481
ERR	140	35855 00000	256 10720	

* * Highly Significant (P < 0 01)

TABLE 50

Analysis of variance for Respiration Rate (Average) during ameliorative experiments
(Treatment Within shed, exposure)
(Breed - Buffer Salt and Undegradable protein feeding)

CD FOR TREATMENT MEANS COMPARISON, 9 691187
CD FOR BREEDMEANS COMPARISON, 9 691187

SOURCE	DF	SS	MS	F
TREATMENT	1	11306 75000	11306 75000	12 8468 * *
BREED	1	367 37500	367 37500	0 4174
INTR	1	880 12500	880 12500	7 9940
ERR	140	15413 75000	110 09820	

* * Highly Significant (P < 0 01)

DISCUSSION

5 DISCUSSION

5 1 Trial I

5 1 1 Climatic Environment

The ambient temperature and relative humidity within and outside shed had comparatively small difference of 1-2 deg C and 0 - 6 percent respectively (Table 1) The stress responses ob served in the exposure group of cows during the Trial period may be attributable to the effect of solar radiation

5 1 2 Physiological Parameters

The effect of environmental conditions on the 3 cardinal physiological attributes, viz , rectal temperature, cardiac rate and respiration rate are presented in Tables 2,3, and 4 respectively

5 1 2 1 Rectal Temperature

The rectal temperature (RT) showed the least fluctuations among the three parameters The forenoon RT between breed groups was statistically different (P <0 01) (Table 33) The BSC had maximum RT of 38 5 deg C while JSC had the minimum of 38 15 and HFC comes in between with 38 3 deg C (Table 2) The animals with low RT in the warm environments are more adaptable than the ones with high RT (Turner, 1984)

The afternoon mean RT values were highest for JSC but the mean values for forenoon and average were lowest for JSC While the animals that remained indoors recorded a rise of 1, 0 8, 0 8 deg C for BSC, HFC and JSC respectively, the exposed animals had the corresponding values as 1 7, 2, 2 1 deg C A difference of 1 5 deg C is well within the diurnal variation normally seen Variation over and above this can be attributed to the effect of stress The thermoregulatory mechanisms come into operation in a certain order First comes vasodilatation, followed by perspiration, accompanied by greater respiratory activity Only when all these mechanisms no longer suffice, the body temperature rises (Herz and Steinhauf, 1978) But the order in which these physiological reactions play dominant role and the relative magnitude of the activity of each of these thermoregulatory responses may vary with breeds or even with individuals (Finch et al , 1982) The preference for each of these activities as the major thermoregulatory activity under moderate, high and heavy thermal stress loads have to be studied, in order to understand more about the relative efficiency of each of the physiological activities in thermoregulation

The increase of rectal temperature on exposure was more for JSC, which was not a favorable response But to maintain high productive function higher metabolic rate is necessary which in turn will raise the rectal temperature further If the rise in temperature is commensurate with high production, it can be jus-

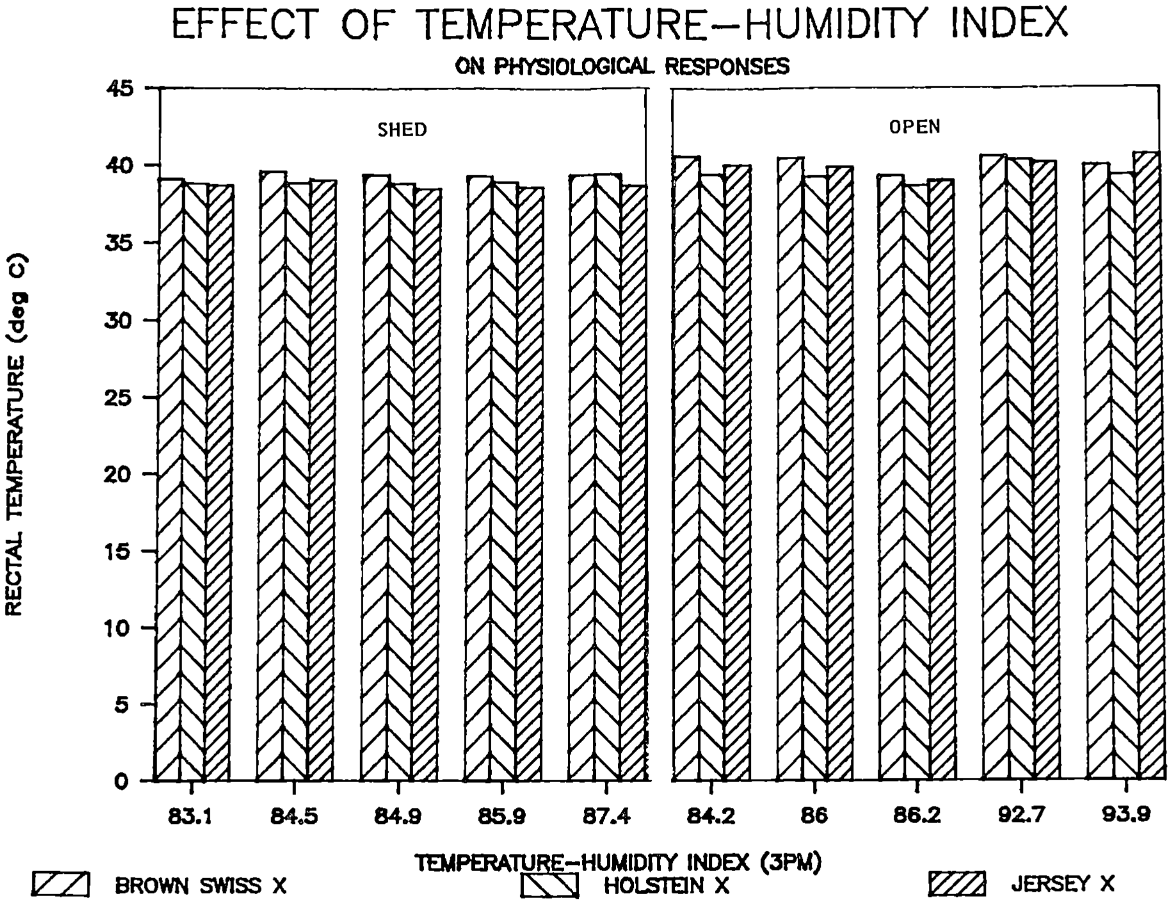

Figure 1

Effect of temperature-humidity index (3PM) on rectal temperature of various crossbred tified So, for lactating dairy cows, merely, a high RT cannot be considered as an indication of poor adaptation if linked with productive function A better assessment would be the rate of decline of milk production with unit increase in RT, at high thermal stress conditions The effect of THIe on RT is depicted in Figure 1

5 1 2 2 Cardiac Rate

The means of cardiac rate (CR) (Table 3) between genetic groups showed highly significant (P < 0 01) differences (Table 36,37 and 38) The JSC had the lowest CR of 59 6 beats/minute while HFC had 67 8 BSC had 64 5 inside the shed in forenoon The afternoon cardiac rate also show the same trend The effect of THIe on CR is presented in Figure 2 CR mean of both afternoon and average showed highly significant differences (P <0 01) between breeds and between treatments (Table 37 and 38) These findings are important because there is a positive correlation between cardiac and metabolic rates High levels of metabolism consequently cause a rise in pulse rate (Herz and Steinhauf, 1978) But the physiological requisites for adaptability in hot humid tropical conditions demand low metabolic rate (Rindel, 1979) On the other side, higher production necessitates higher metabolic heat production (McDowell, 1982) This shows the complexities of incorporating two antagonistic traits i e traits for high milk production potential coupled with high level of adaptability in an animal The animal having ability to maintain

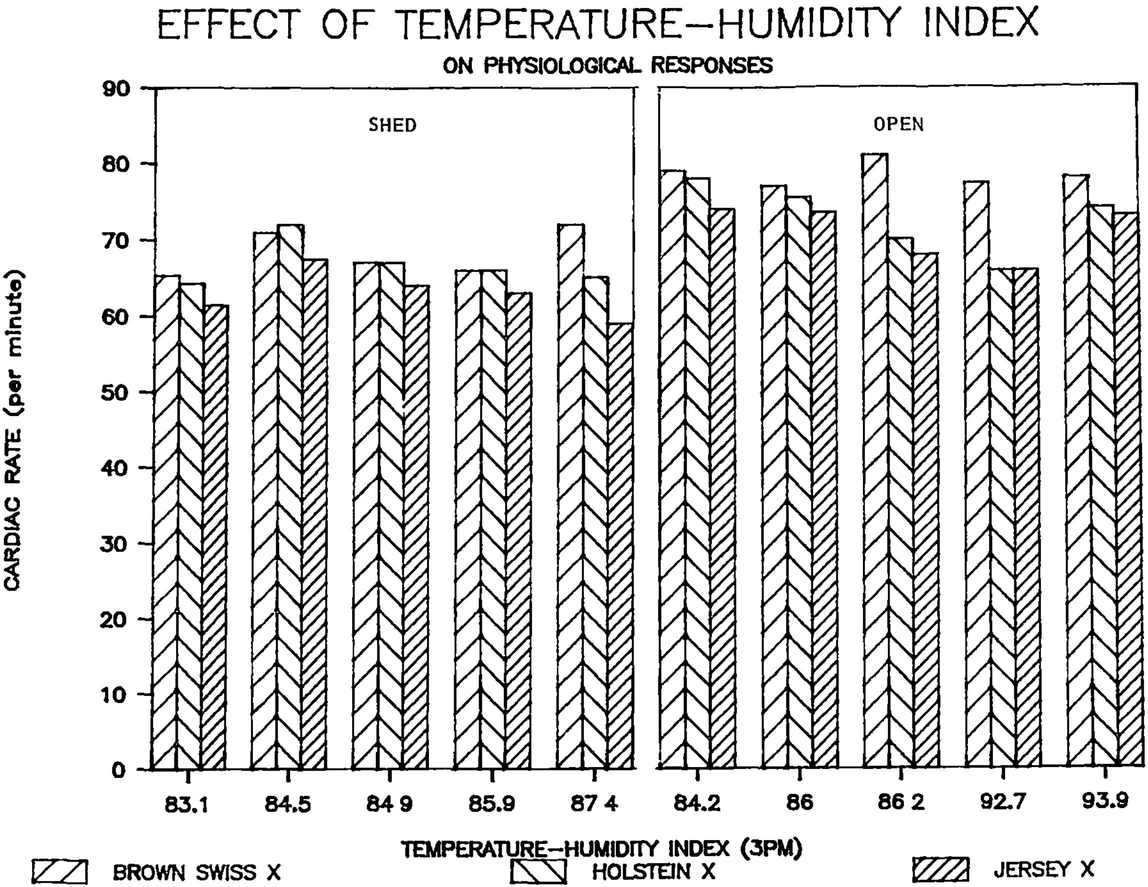

Figure 2

Effect of temperature humidity index (3PM) on cardiac rate of various crossbred a low cardiac rate at stressful conditions can be considered to a better adapted one than the animal having high CR in such conditions But animals which exhibit high CR should also produce more, otherwise no beneficial purpose being served

5 1 2 ~ Respiration Rate

The respiration rate (RR) in forenoon (Table 4), in shed as well as open for three different genetic groups had highly significant differences (F < 0 01) (Table 39) The Jersey crosses have the lowest and HFC and BSC had higher rates in that order Same trend prevailed in the forenoon for the exposed cows also In the afternoon the RR was significantly higher (P < 0 01) (Table 40) than forenoon in the cows kept open than those kept indoors, in all the three genetic groups The average RR was also statistically different (P <0 01) (Table 41) The effect of THIe on RR is highlighted in Figure ~

The increase in RR in JSC in the shed during the day time was 20 ~ per minute while the values for HFC was 22 per minute and BSC it was ~~ per minute The corresponding values of exposed cows were for JSC 78, HFC 67 and BSC 69 As in RT the RR also was highest for the JSC Unlike RT and CR, the RR had a wider range of fluctuations Not only the number changes but the depth and type also varied Especially in high temperature humidity ranges, the counts per minute will not alone convey the intensity of respiratory activity One of the interesting observations made during the course of the Trial was, when some

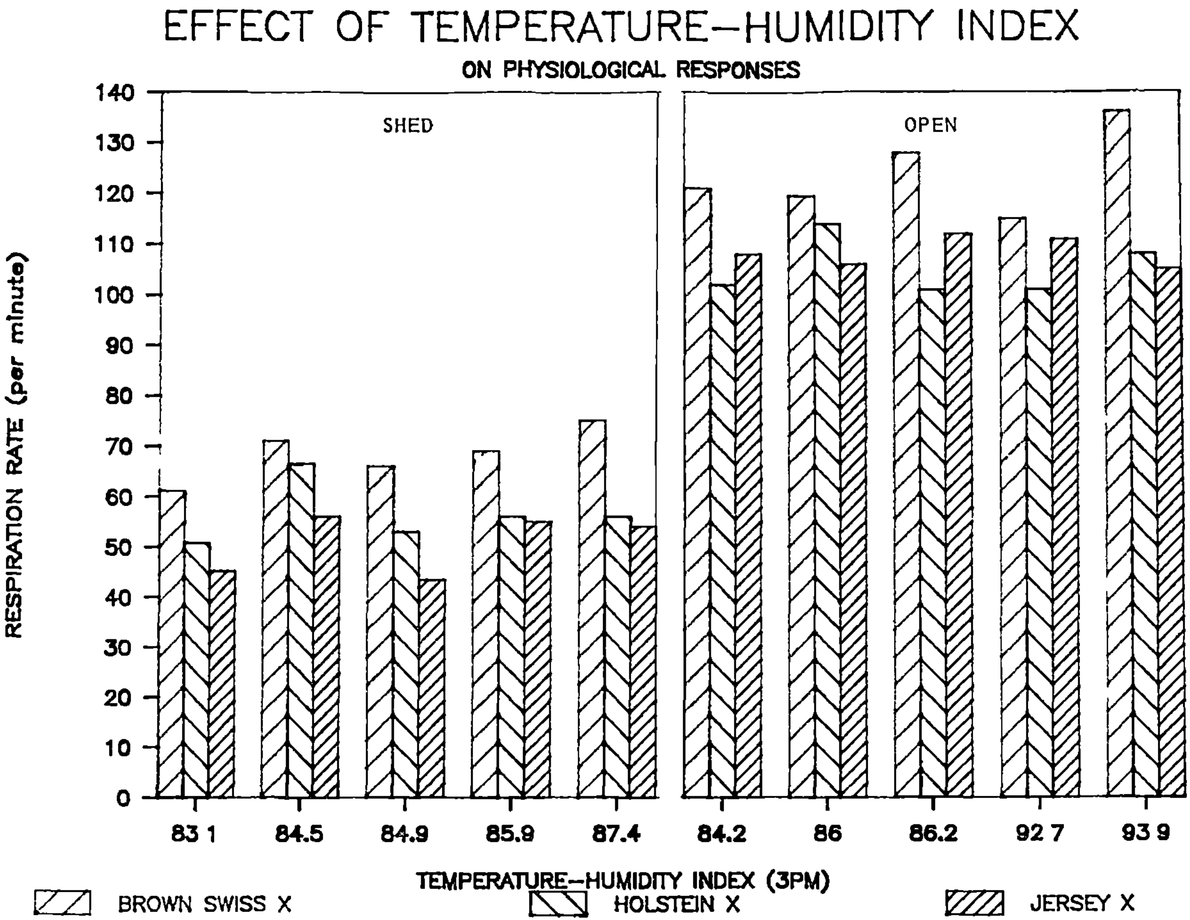

Figure 3

Effect of temperature humidity index (3PM) on respiration rate of various crossbred genotypes kept in shed and open during Trial I period animals were exhibiting uneasiness at low respiratory frequency, others were apparently normal, though their RR was high It was felt as though some animals were unable to accelerate RR beyond a certain level and they appeared to be more restless The question remains as to the desirability of having a narrow range of physiological responses as the criteria for best adaptability It may hold good for lower thermal stress loads, but definitely not for heavy stress conditions normally encountered in April - May months in most parts of Kerala The chances are there that the secondary respiratory activity with pumping type forceful exhalation of low frequency might have been compared against the normal, physiological respiration of high frequency and erroneously arriving at a wrong conclusion, if the consideration is based merely on the number The problem is that, the depth, volume and type of respiratory reaction cannot be easily judged Inclusion of such parameter in adaptability indices may be inconvenient at times and can only be used with caution

A low basal respiratory rate with ability to accelerate to high frequencies at times of demand, is a more desirable trait for adaptability, than the one unable to increase the rate in high thermal stress conditions The validity of keeping the desirability of close to normal approach as test criteria need to be reviewed

5 1 3 Adaptability Indices

On the basis of physiological reactions many indices have been evolved giving weightage to one or more of the attributes Three indices have been chosen to test the adaptability of different genetic groups studied The most widely used Rhoad s Iberia heat tolerance index (IHTI) is based only on rectal temperature, the Benezra s coefficient of adaptability (BCA) rely on equally weighted rectal temperature and respiration rate, while the Dairysearch inde of heat tolerance (DIHT) had given 0 5, 0 3 and 0 2 as relative weightages for rectal temperature, pulse and respiration rates respectively (Thomas et al , 1977) The values have been worked out for 3 crossbred genotypes using these 3 different indices (Table 5) The best adapted animal will have an index value of 1 for DIHT, 100 for IHTI and 2 for BCA and better the adaptability if closer to these values

The three indices ranked the relative adaptability of crossbred genetic groups studied in different ways The DIHT value for HFC was 1 62 followed by BSC with 1 74 and JSC with 1 82 The IHTI placed JSC in first position with an index value of 71 01, BSC 67 76 and HFC 66 58 The BCA put BSC as the best among the three groups with an inde value of 3 79, then HFC with 3 97 and JSC with 4 64 (Table 5) It is doubtful whether the in dices have correctly ranked the genetic groups in the order of their relative adaptive ability to the environmental conditions to which they were exposed

There are reasons to confirm this openion The most popular

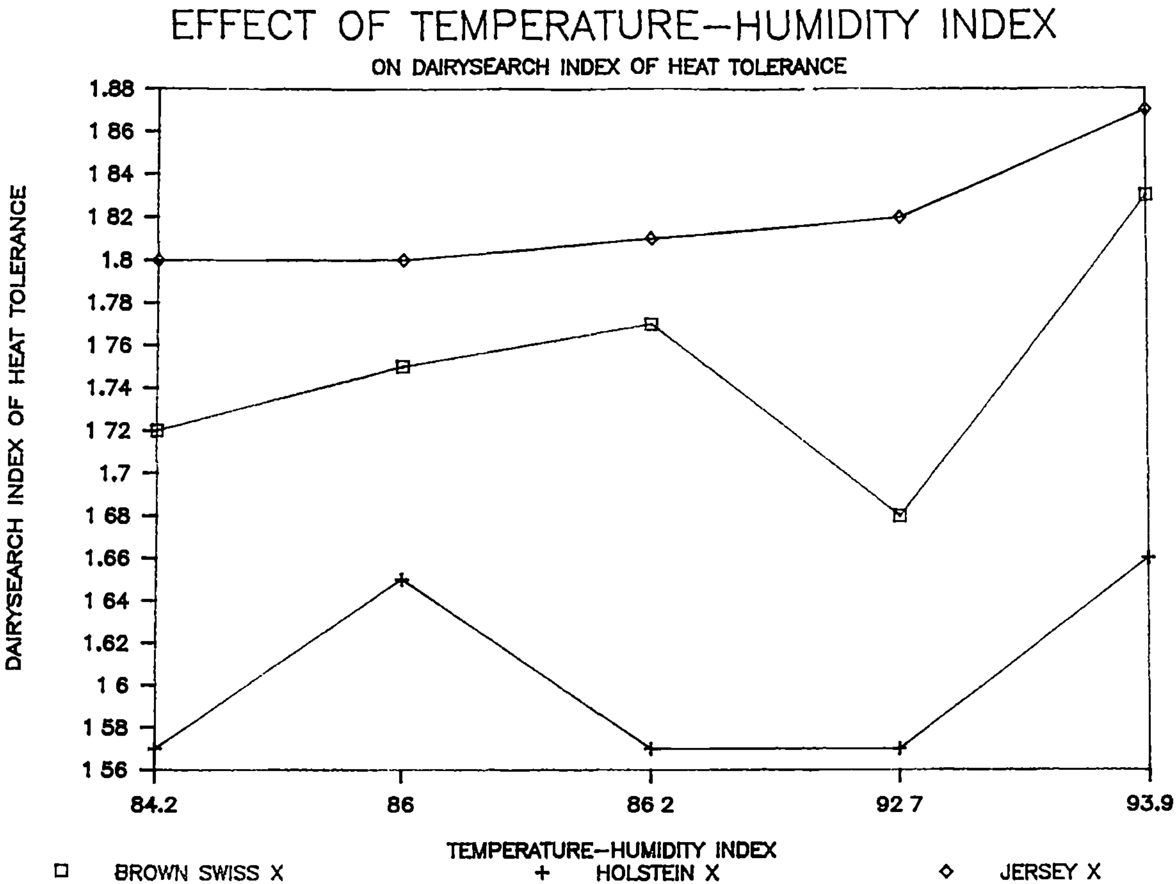

Figure 4

Effect of temperature humidity index (3PM) on Dairy search index of heat tolerance adaptive indices are based on physiological responses An index value close to the normal value (in thermally neutral environment) is considered as ideal one This may hold good for moderate thermal stress conditions But in heavy thermal stress condition coupled with lactational stress, the dairy cow may have to accelerate its physiological responses, in order to adapt with the situation A poor adapted animal may show second degree changes in respiration at lower stress loads, while better adapted animals continue to function normally, even at high stress conditions There are chances to construe a poor adapted animal to be a better one, if the assessment of adaptability is based on the desirability of narrow range of physiological reactions

For a high producing cow, besides the heat load from solar radiation, the animal has to eliminate relatively high load of metabolic heat generated within the body The physiological responses are bound to be in an elevated plane, compared to low producing animals To be able to produce more and simultaneously to remain better adapted, demand slightly higher plane of physiological responses in a high producer than in a low producer Hence, due allowance for the demands for production need to be made in the index, if judicious assessment is the goal Afterall, the ultimate criteria is the productive performance of the animal and not the physiological responses To be able to produce well in unfavorable climatic environment, whatever be the strategies an animal adopt to adapt to the condi

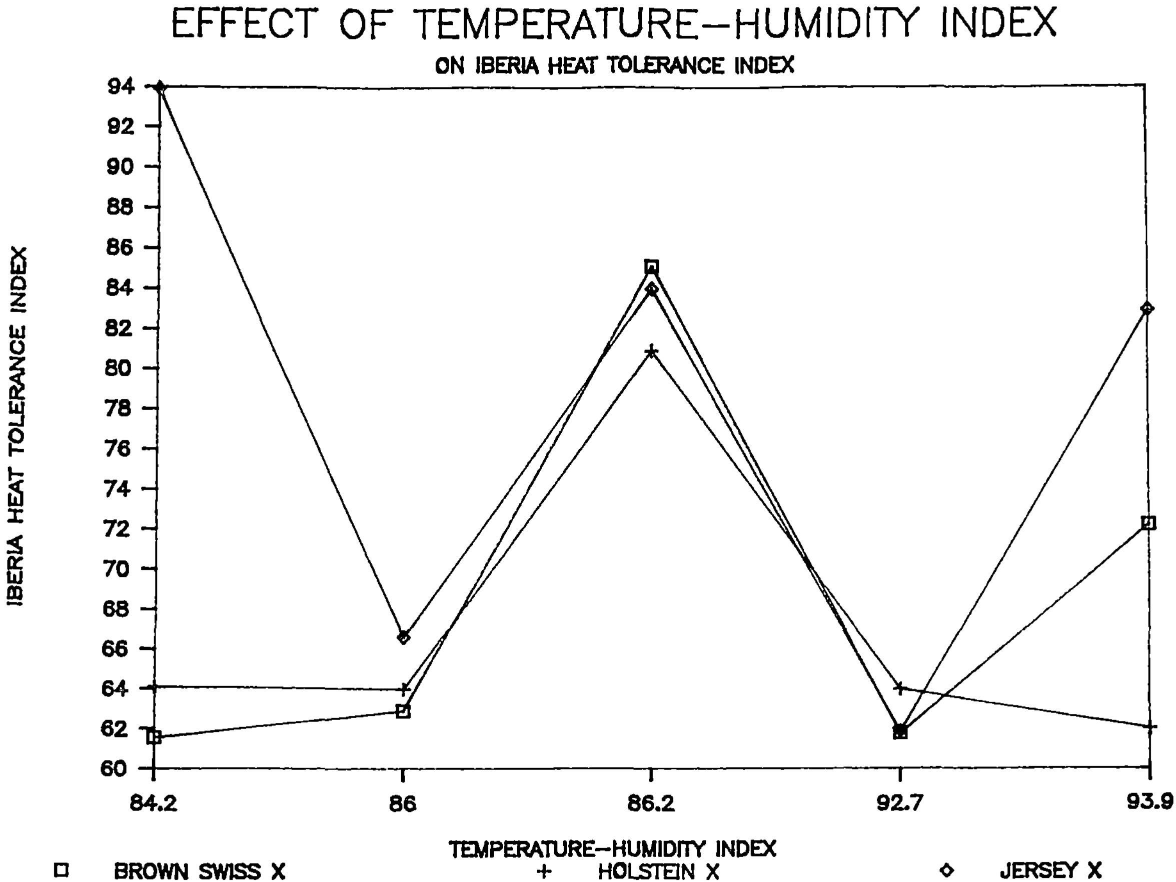

Figure 5

Effect of temperature-humidity index (3PM) on Iberia heat tolerance index of
cro sbred genot pes d r ng Tr al 1 period

tions, due recognition need to be given If high respiratory frequency is a necessary strategy to maintain homeothermy in hot humid environments, the ability to step up respiratory rate should be taken as a positive attribute, not the otherway around

As a compensatory adaptive mechanism, animals continuously exposed to high thermal stress conditions, will have a relatively low basal physiological responses than other animals On the other hand better adapted animals raise physiological responses to a higher plane in heavy stress conditions than poorly adapted animals This phenomenon put the better adapted animals in a disadvantageous position To avoid this, weightage need to be given for the attribute of having low level of physiological responses at basal conditions

The correlation coefficients between the weather parameters and adaptive indices (Table 6 and Figures 4 and 5) amply illustrates some of the views expressed above The coefficients for maximum temperature (MxT) as well as temperature humidity index (THI) between both Dairysearch (DIHT) and Iberia (IHTI) index were within range of - 241 to 0 224 indicating the poor relationship There was a strong negative correlation for HFC (- 805) between mean day humidity (MDH) and DIHT showing that high humidity adversely affected the HFC more than BSC and JSC (420 and - 466 respectively)

High correlation exists between M T and RT at low stress conditions (shed) for BSC and JSC (r 0 871 and 0 858 respectively) But HFC had slightly negative relationship (r

- 029) at similar conditions At high stress conditions (open) all genetic groups showed negative relationship Evidently the rectal temperature was raised when the MxT went higher till a certain point, thereafter the RT decreased The coefficients of exposed animals are - 086, - 185 and - 330 for BSC, HFC and JSC respectively The Jersey crosses showed better ability to step up as well as to cut down the increase in RT and therefore, exercised better control than other groups

For MDH when BSC and JSC exhibited feeble relationship, the HFC showed a strong relationship (0 535 and 0 265) for shed and open The same trend was reflected in THI also The HFC appeared to be particularly vulnerable to high humid conditions even at low temperature ranges (r 0 855 and 0 514 for shed and open) but for JSC, only when the stress was high in the open (r = 0 554)

Strong positive correlation existed for maximum temperature and cardiac rate for all genetic group studied in shed and open conditions (Table 7) Highest relationship was for HFC shed (r= 0 844) followed by BSC (r = 0 531) and JSC (r 0 415) and the corresponding values in the open were 0 626 for BSC 0 243 for HFC and 0 111 for JSC At high stress conditions the increase in CR was controlled better by JSC compared to HFC and BSC

For respiration rate also, the strongest relationship (r=0 770) was noted for HFC in shed as indicated by the correlation coefficient between MxT and RR The corresponding values for BSC and JSC are 0 297 and 0 370 respectively In the open

HFC showed a negative relationship (r= - 247) while BSC and JSC had positive values (r = 0 130 and 0 370 respectively) The correlation coefficient between physiological responses and the adaptive indices (DIHT and IHTI) are presented in Table 8 While a high IHTI value close to 100 is desirable a low value around 3 indicates better adaptability as regards to DIHT is concerned, meaning thereby negative correlation with IHTI is equivalent to a positive correlation DIHT and *vice versa* An index based on physiological responses should have high correlation with all three physiological responses But DIHT showed maximum relationship with RR Though IHTI is based only on RT, its relationship with RT as well as CR and RR were better than DIHT

It is evident from the study of correlated responses of different physiological responses to climatic conditions, the increase in respiration rate and cardiac frequency were strategies to maintain low rectal temperature So the three attributes may not be treated in similar lines The hypotheses that inclusion of all three responses with deferring weightages will give more accuracy to an inde may prove to be wrong The RR is the most elastic attribute among the three cardinal physiological responses and hence incorporation of such an attribute may also distort the index value more if not properly used It appears that the inde based on RT alone (IHTI) is more reliable than the one based on equal weightage to RT and CR (BCA) or deferring weightages to RT, CR, and RR (DIHT) Therefore the ranking of IHTI can be taken as the most authentic and accordingly JSC is

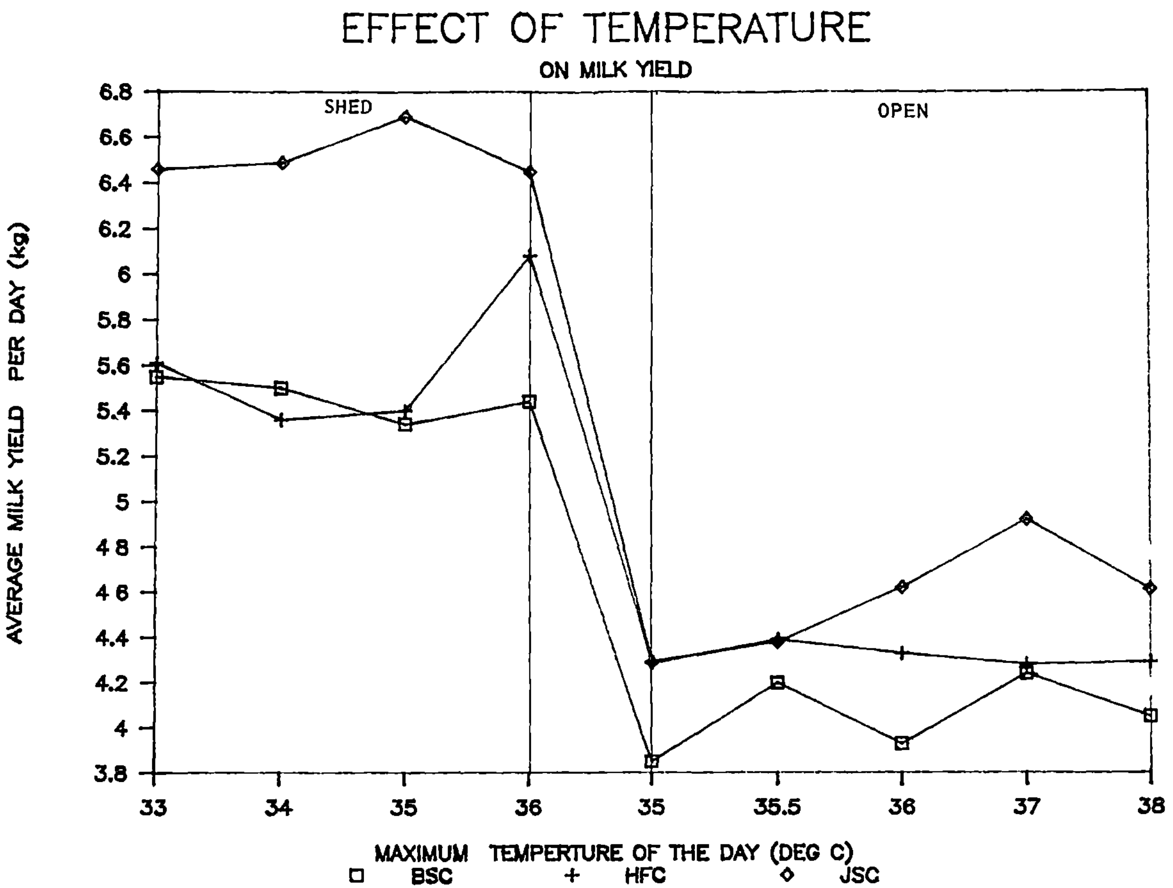

Figure 6

Effect of maximum day temperature on milk yield of regarded as the most adapted among the three genetic groups followed by BSC and HFC

5 1 4 Milk and Milk Constituents

5 1 4 1 Milk Yield

The effect of environmental conditions on daily yield of milk total solids and fat is presented in Table 9 The milk yield of shed and open differ statistically ($P < 0\ 05$) but not the breed means for milk yield The difference in production in shed and open was 1 4, 1 26 and 1 94 kg/day for BSC, HFC and JSC respectively The reduction in production was observed to be more in case of JSC compared to BSC and HFC This cannot be attributable to the environmental effect on the animal alone While BSC and HFC genetic groups selected for the experiments have almost comparable levels of milk production around 5 5 kg, the JSC had 6 5 kg It is natural that the higher producing animals suffer more than the low producing ones resulting in a more pronounced reduction for JSC The effect of MxT and THIe on milk yield are presented in Figures 6 and 7

The total solids yield (TSY) also followed a similar trend to that of milk yield The treatment means differed significantly ($P < 0\ 05$) The reduction in TSY is almost proportional to the reduction in milk yield of different genetic groups The changes in fat yield were statistically not significant

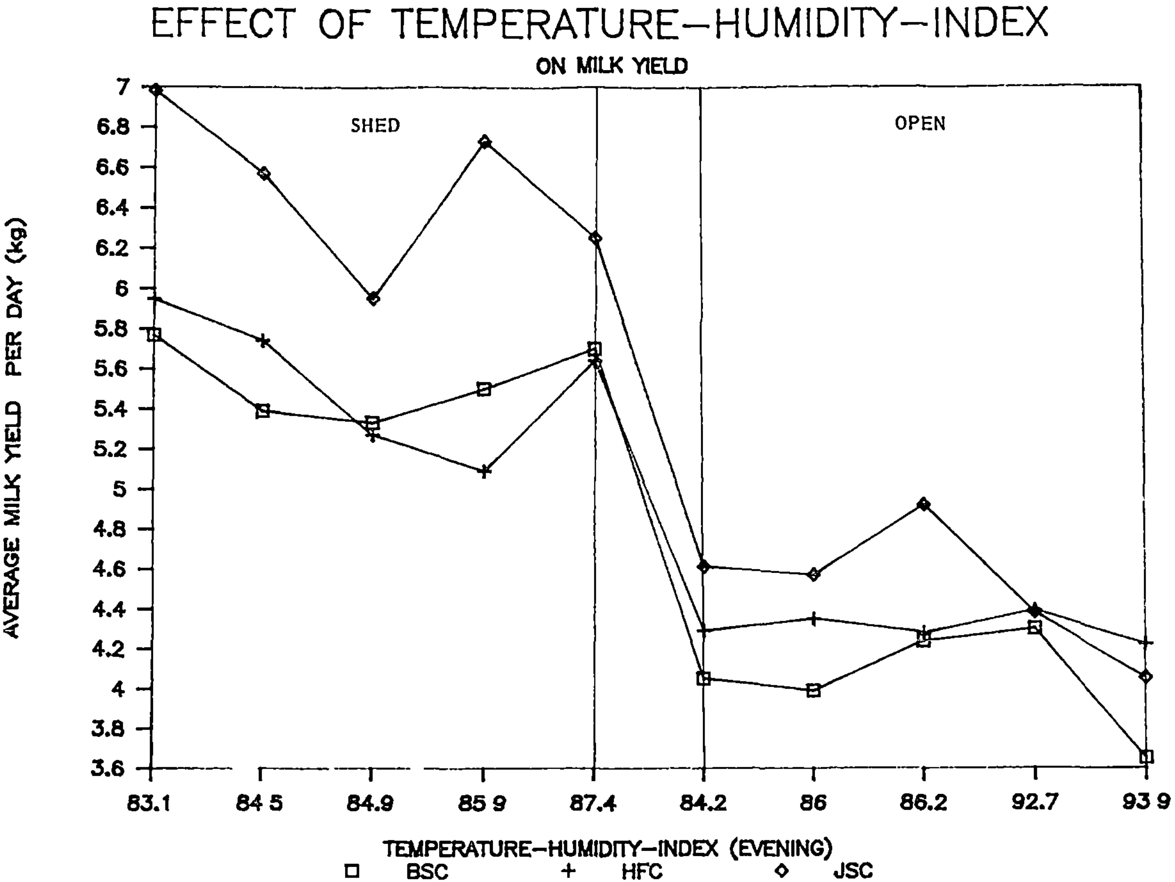

Figure 7

Effect of temperature humidity index (3PM) on milk yield of various crossbred genotypes kept in shed & open during Trial I period

The correlation coefficients of milk yield with physiological parameters, adaptive indices and weather parameters are presented in Table 10 No uniformity in the pattern of correlated responses were discernible either with genetic groups or with treatments, shed and open Among physiological parameters a high correlation coefficient (r = 813) for RT was observed for JSC in the open while HFC had with CR (r = ¯87) and BSC for RR (r - - 544) Evidently when JSC s production get affected only with high rectal temperature in the exposed condition, but the HFC with high CR and BSC with high RR Again a reflection of better adaptability of JSC since a rise in RT comes as a last resort to maintain homeothermy The correlated responses of adaptive indices with milk yields of various genetic groups in shed and open was very erratic An adapted animal is also expected to produce well Chances are that the adaptive indices failed to identify the adapted genetic groups or the adapted genotypes have not produced well as expected or a combination of both these factors have contributed to this erratic correlationship A low DIHT value indicates better adaptability, but the reverse is true for IHTI For high stress conditions of the open for BSC and JSC had correlation coefficients of 511 and 119, the HFC had 0 707 which appears to be very abnormal but the correlation for milk yield with IHTI is more convincing The coefficients in the shed are for BSC - 099, HFC, 2¯9 and for JSC, 119 The corresponding values in the open are 156, 006 and 0 ¯11 This is again probably due to the failure of the adaptive indices to rank the genotypes in terms of real adaptive ability based on physiological responses The IHTI appears to be better than DIHT in this regard

Though it is illogiccal to separate the the components of the climate to study the individual effects, an effort had been made to understand the impact of MxT and MDH on MY The correlation coefficients obtained were erratic and no conclusion could be drawn However, THI s relationship with MY was more explicit and when the THI value increased the MY decreased The JSC suffered more compared to BSC and HFC in high temperature-humidity conditions.

5 1 4 2 Milk Constituents

The effect of environmental conditions on various milk constituents are presented in Table 11 Only the means of total solids differed statistically ($P < 0.05$) The changes in levels of fat, solids-not-fat, whey protein, non protein nitrogen, calcium, magnesium, sodium and potassium were not significant

High stress conditions (open) caused increase in total solids (TS) Cobble and Ragsdale, (1949) reported an increas [illegible] TS with increase in ambient temperature Lal and Mudja [illegible] also observed the same trend in hot humid se[illegible] [illegible] the view that, this trend was relate[illegible] t[illegible] [illegible] [illegible] cattle to the climate

There are contradictory reports regarding the changes of fat content of [illegible] [illegible]ated with high environmental temperature While [illegible] [illegible]ge was reported by Cobble and

Ragsdale (1949), Richardson (1961), observed a decrease in secretion of milk fat Bandaranayaka and Holmes (1976) also reported a reduction of milk fat at 30 deg C But in the present study a slight increase in fat percent was observed in BSC and HFC while it decreased in JSC The fat yield decreased in all genetic groups, though the changes were statistically not significant Richardson (1961), also observed the yield of fat of cows exposed to thermal stress declines with decreasing milk yield

Pan et al , (1978) observed a decrease in concentrations of calcium and potassium in Jersey and Sahiwal x Jersey cows kept at 40 deg C for 2 weeks The same trend was observed in the present study also in case of BSC and HFC but slightly more levels were seen for JSC The changes were not statistically significant Breed to breed deferences are known to exist in Ca and Mg content of milk, the Red Dane and Hostein Friesian crossbred milk contained higher amounts of Ca and Mg than Jersey crossbred milk But in the present study the changes in different genetic groups were not statistically significant A slight increase in Ca and Mg levels of Jersey crossbred cows in the exposure group were noticed but not in BSC and HFC

The most desirable attribute for the dairy cow of the tropics will be high level of production coupled with high level of adaptability Combining these two genetically antagonistic characters seems to be not possible (McDowell, 1982) Probably, it is possible to identify a genetic group or individuals which possess a mosaic of desirable traits (Turton,1985) He had elucidated the requirements of cattle in the humid tropics as to have superior genetic merit of the temperate breed of dairy cow for milk yield, tropical adaptability of Zebu to climate and ability to coexist with ectoparasites and disease conditions Some amount of potential productivity have to be sacrificed for achieving better adaptability Considering the correlated responses of milk production and adaptability to climatic stress, the Jersey crossbred had an edge over other crossbred groups studied

5 1 5 Blood Serum Constituents

The effect of environmental conditions on the blood serum constituents have been presented in Table 12 The parameters studied were alkaline phosphatase, cholesterol, creatinine, total serum proteins, calcium, magnesium, sodium and potassium None of the parameters had showed any statistically significant changes between breed groups or between treatments

5 2 Trial II

5 2 1 Climatic Environment

The climatic environment during Trial II period had not fluctuated significantly from Trial I in terms of MxT, MnT, MDH, THI or THSI (Table 13). The Trial II period was immediately after the first Trial and the experimental animal s overall management conditions etc , remained same except that one half of the animals within shed and exposed received buffer salt (@ 0 85 percent of the concentrate feed supplemented with sodium bicarbonate) in their ration while other half received a concentrate ration 25 persent of which replaced with solvent extracted coconut cake containing 26 percent crude protein of low degradability (19 per cent)

5 2 2 Physiological Parameters

5 2 2 1 Rectal Temperature

The rectal temperature (RT) (Table 14) of forenoon was significantly different (P < 0 05) between the treatments, shed and exposure (Table 42), which may be due to an adaptive strategy to accommodate high stress levels, developed due to continued exposure to solar radiation

The afternoon and average rectal temperature of animals indoors and outside did not differ unlike Trial I period (Table 43 and 44), indicating that both buffer salt (BS) supplementation and undegradable protein feeding (UDP) had beneficial effects Since lower RT rates though not statistcally signifcant, were noticed for BS group, it can be presumed that sodium bicarbonate supplementation was superior to undegradable protein feeding

5 2 2 2 Cardiac Rate

The forenoon cardiac rate (CR) (Table 15) was significantly lower (P 0 01) in the exposed group compared to the group remained within shed (Table 45) The means of BS and UDP feeding group also different significantly (P < 0 01) The changes in the CR in the afternoon was not significant (Table 46), again indicating that both the ameliorative treatments tried (BS supplementation and UDP feeding) had helped to maintain CR without much fluctuation The average CR values also reflect the significant changes observed both for treatments, shade and exposure well as for BS and UDP feeding (Table 47)

5 2 2 3 Respiration Rate

Compared to the respiratory rate (RR) in Trial I period (31-39 per minute) the average values observed in Trial II period (Table 16) was higher (47-49 per minute), probably due to higher productive activity in a better homeostatic condition facilitated by the two ameliorative treatments

The means of afternoon RR of both treatments and feeding regimes varied significantly (P < 0 01) (Table 49 and 50) The group received BS supplementation had maintained RR with minimum fluctuations

By judging the merits of the two ameliorative treatments on the basis of the three physiological responses RT, CR and RR, supplementation of BS and UDP feeding had helped in mitigating the heatstress effects in cattle and the BS supplementation in a better way

5 2 3 Adaptability Indices

The favorable effects of the two ameliorative treatments are reflected in the adaptive indices computed using three methods vi , Dairysearch, Iberia and Benezra s indices While the average DIHT values during the Trial II period (Table 17) had a lower range of 1 36 and 1 46 compared to values presented in Table 5, indicating the beneficial role played by the two ameliorative treatments The supplementation of BS showed the most favorable response to lower the DIHT to 1 36, closer to the ideal index of 1 The same effect was noticed in IHTI and BCA also The effect of THIe on DIHT during ameliorative treatments shown in Figure 8

The THI was positively correlated for animals in shed for both ameliorative treatments BS and UDP (r 0 53 and 0 044) with DIHT and is negatively correlated (r - 086 and 219) for exposed animals during ameliorative treatment (Table 18), indicating that during higher stress conditions when THI values increases, the adaptive indices values reduced slightly, showing the beneficial role of the ameliorative treatments studied

5 2 4 Milk and Milk Constituents

5 2 4 1 Milk Yield

The average milk yield (MY) of cows irrespective of breed groups within the shed during Trial period 1 was 5 8 kg/day and of those exposed was 4 3 kg/day During ameliorative experiments

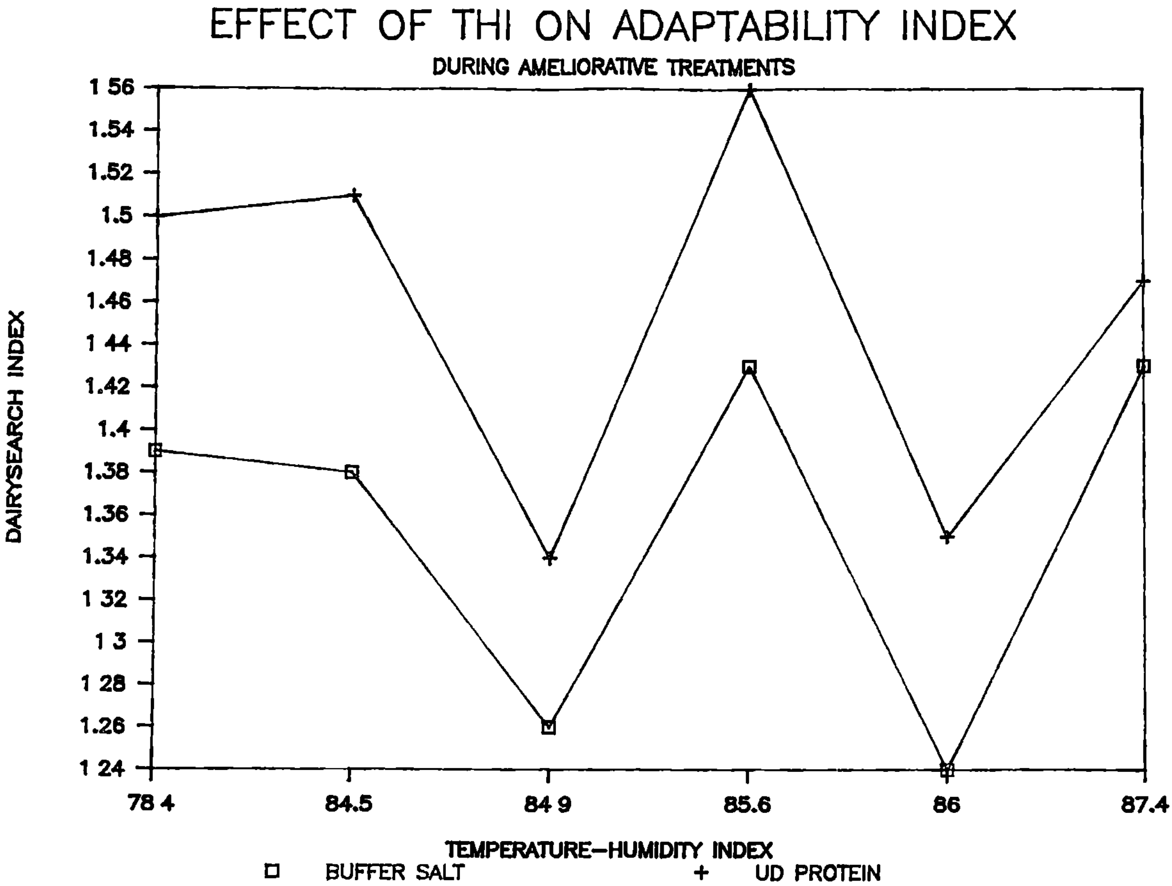

Figure 8

Effect of temperature humidity index (3PM) on Dairy search index of various crossbred genotypes during ameliorative treatments the corresponding valles were 5 5 and 4 _ kg/day respectively (Tables 9 and 20)

The differences in yield were orly marginal between two Trial periods If due allowance was given for the stage of lactation of animals, it would have been an increase in yield rather than a marginal reduction As the ameliorative e periment was conducted after the 1st Trial and most of the animals were in their declin ing phase of lactation, the drop in production would have been more than actually registered if the treatments had not helped to sustain the production The effect of THIe on MY is presented in Figure 9

5 7 4 2 Milk Constituents

The average total solids yields (TSY) had risen from 791 to 800 g/day for the animals within shed and f om 642 to 701 g/day during the ameliorative experiments indicating that the benefi cial effects of the treatments are more for thermally high stressed animals than for low stressed ones The fat yield g/day also showed the same trend The average fat yield improved from 292 to 299 g/day for animals kept within the shed and 222 to 240 g/day for e posed animals

The differences in means of milk yield and yield of total solids between BS and UDP groups are not statistically sig nificant but the treatments shed and open are significant (P 0 05) The yield of fat is not significantly different between ameliorative treatments or between shed and open (Table 20)

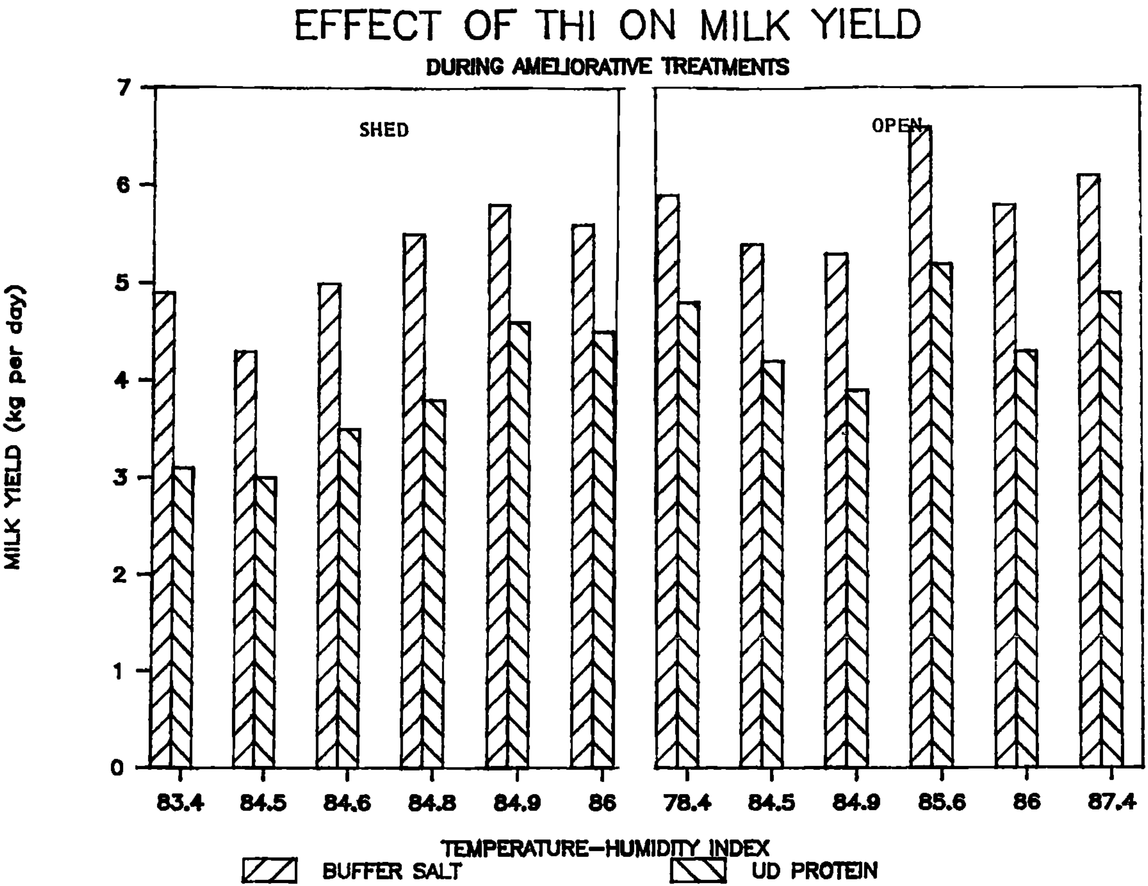

Figure 9

Effect of temperature humidity index (3PM) on milk yield of various crossbred genotypes during ameliorative treatments

Correlations among weather parameters and milk yield of crossbred cows during the ameliorative treatments had been presented in Table 21 High positive correlation for both BS and UDP groups in shed and open for MxT and similar negative relationship with MDH suggests that it was not the high temperature prevailed in the environment, but the high humidity was detrimental to milk production The combined effect of temperature and humidity ie THIe on milk yield had a strong positive relationship for BS and UDP groups kept within the shed (r=0 571 and 0 582) and the corresponding coefficients for animals exposed in the open was 0 222 and - 025 thereby proving the superiority of BS in ameliorating the stress and restoring production

The effect of environmental conditions on various milk constituents are presented in Table 22 The means of total solids, fat, solids not-fat, whey protein, nonprotein nitrogen, calcium, magnesium, sodium, and potassium on buffer salt supplementation or feeding of undegradable protein feeding in shed or open did not differ significantly All the constituents were within the normal ranges reported

5 2 5 Blood Serum Constituents

The effect of environmental conditions on blood serum constituents of crossbred cows during the stress ameliorative treatments have been summarized in Table 27 The values for alkaline phosphatase, cholesterol creatinine, total serum protein, calcium, magnesium, sodium and potassium were presented None of the constituents differed significantly between shed or open or between ameliorative treatments, supplementation of buffer salt and feeding of undegradable protein

5 7 Trial III

5 7 1 Climatic Environment

The maximum temperature within the shed during the Trial period had fluctuated only 2 deg C from 38 to 40 At the same time, outside temperature had fluctuated 3 deg C from 38 to 41 The minimum temperature within the shed ranged from 25 to 26 deg C and outside 26 to 29 deg C (Table 24) Mean day humidity also had not fluctuated much (60 to 74 percent) indicating that climatic conditions were almost uniform throughout the Trial III period and devoid of any abrupt changes A comparison with Trial I period indicates that the environment of Trial III period was one of high temperature and low humidity while the first one was of low temperature and high humidity But the combined effect of temperature and humidity as indicated by THI values, the 1st Trial had an average index of 85 to 88 while Trial III had 86 to 87 The corresponding values for THSI were 82 and 81 The stressful effects appeared to have almost remained same during the two Trial periods

5 3 2 Physiological Parameters

5 3 2 1 Rectal Temperature

The rectal temperature (RT) in the afternoon between treatments are highly significant (P 0 01) Between FN and AN rectal temperature, there was a difference of 1 9 2 4, and 2 1 deg C in case of BSC, HFC and JSC respectively (Table 25)

5 3 2 2 Cardiac Rate

One salient observation on cardiac rate (CR) was the highly significant difference (P 0 01) in the forenoon cardiac rate (Table 26) Though both the groups remained indoors in the same environmental conditions, other than the exposure period the exposed group had relatively low cardiac rate This may be taken as one of the strategies for coping up with the increased demands at times of stress The Jersey crosses had relatively high FN cardiac rate in exposed group, the exposed group showed remarkable ability to reduce CR to the minimum compared to other groups The results on CR shows that though all genetic groups exhibited adaptive changes to added stress, the magnitude was more to the Jersey crossbreds The afternoon CR also had significant changes between treatments (P 0 01)

5 3 2 3 Respiration Rate

The FN respiration rate (RR) of different genetic groups had highly significant differences (P 0 01) (Table 27) Similar to the observations of Trial I, BSC had the highest rates while JSC had the least The afternoon treatment means were higly significant and the average had differences between genetic groups All changes were highly significant (P <0 01) The HFC stepped up the rate by 17 the BSC 21 and JSC 34 per minute compared to their sheltered counter parts, when stress was imposed

The panting or polypnoea is the chief defence mechanism against heat stress which cattle posses and is equivalent to sweating in man (Findlay, 1957) Panting differs from other processes of heat loss in that, it is a controlled thermoregulatory mechanism The mechanism conform largely to the concepts of negative feed back control shifts in body temperature increasing evaporative heat loss which in turn stabilize body temperature (Hensel, 1981) Thus the panting is an efficient mechanism of heat loss

The Jersey crosses showed better ability to raise the respiration rate and keep the body temperature to the lowest rates compared to other crosses studied On the contrary HFC could accelerate to a much lesser magnitude resulting in higher RT and CR compared to JSC The temperate cattle rely more on increased respiration as their principal means of dissipating heat (Finch, 1986)

The JSC have used this attribute efficiently for thermoregulation than other crosses A heat tolerant dairy cow besides capable of eliminating large amounts of excess heat, should allow productive process to proceed at high level at high air temperatures and humidity The physiological measurement of reaction to heat stress should be related to heat tolerance only if it is related to productivity

5 3 3 Adaptability Indices

Adaptability indices using Dairysearch index of heat tolerance (DIHT), Iberia heat tolerance inde (IHTI) and Benezra s coefficient of adaptability have been worked out Table 28) The BSC and HFC had not differed significantly between their indices, but the JSC had significantly different higher values (P 0 01) The DIHT and BCA placed the JSC in the il ladapted genotype The IHTI on the contrary put JSC in the best adapted position It is again because of the inherent, dis crepancies of the indices described earlier under heading 5 1 3 Adaptability Indices

5 3 4 Milk Yield

While Jersey crosses were more efficient in controlling various physiological reactions near to proffered levels under varying stress conditions than other crosses studied, the milk productive performance followed reverse trend The Holstein crosses exhibited the least reduction in milk yield per day around 1 5 kg, the Brown Swiss crosses had 2 and Jersey crosses had 2 25 kg reduction from their sheltered counter parts Probably reduced milk production itself is part of the adaptive strategy for better thermoregulation

Unfavourable correlates of thermoregulation with production may exist. Better adapted animals might have also inherently low food intake and heat production regardless of the level of environmental heatstress (Frisch and Vercoe 1977). For instance, _Bos indicus_ cattle regulated body temperature efficiently and are deemed heat tolerant because their productivity is not greatly depressed in hot environments. However, in the absence of heatstress these genotypes have lower maintenance metabolic rates, lower food intake and lower growth rates than Bos taurus breeds. Thermoregulation requires increasing blood flow to the skin surfaces where evaporation occurs. This means a concomitant decrease in blood flow to the visceral organs and hence water and nutrients to and from organs of high metabolic rate such as digestive tract and reproductive organs get reduces. Such adjustments in the partitioning of water and blood flow away from energy metabolism to thermoregulation would act to dampen the metabolism of production (Finch, 1986). It may be difficult to combine attributes of a controlled body temperature to achieve both efficient thermoregulation and inherent productivity. So, for a compromise, we may have to sacrifice some potential productivity in the process of gaining improved thermoregulatory abilities. Therefore, Jersey crosses is the preferred genotype for a heatstressed environment. Before arriving at conclusive decision, the life long productivity of different genotypes should be taken into consideration. The detrimental effects of improper thermoregulation may be reflected on life long produc tivity, since it affect fertility, growth and resistance to diseases The genotypes sustained higher yield under same stress condition over short periods of time may prove to be less productive in the long run

Table 30 gives the correlationship between milk yield (MY) and climatic parameters The effect of maximum day temperature (MxT) on MY do not follow a definite direction as indicated by the correlation coefficients The correlation between THIe and MY was more predictable indicating that THIe can represent the climate better than either MxT or MDH Similar observation was made in Trial I also (Table 10)

5 3 5 Blood Constituents

The effect of environmental conditions on 2 enzymes, lactate dehydrogenase (LDH), glutamic oxalacetic transaminase (GOT) and two thyroid hormones, triiodothyronine (T3) and thyroxine (T4) are presented in Table 31

The serum T3 levels were lower in exposed cows (P < 0 01) The means of other constituents studied do not differ significantly The T3 levels in exposed animals ranged from 0 625 to 0 717 ng/ml, showing that all genetic groups were equally capable of regulating T3 levels, in order to adapt to high stress conditions The trend is same in low stressed animals also Only the range was higher from 0 90 to 1 00 ng/ml The effect of THIe on T3 is depicted in Figure 10

The thyroxine (T4) levels in different breed groups and

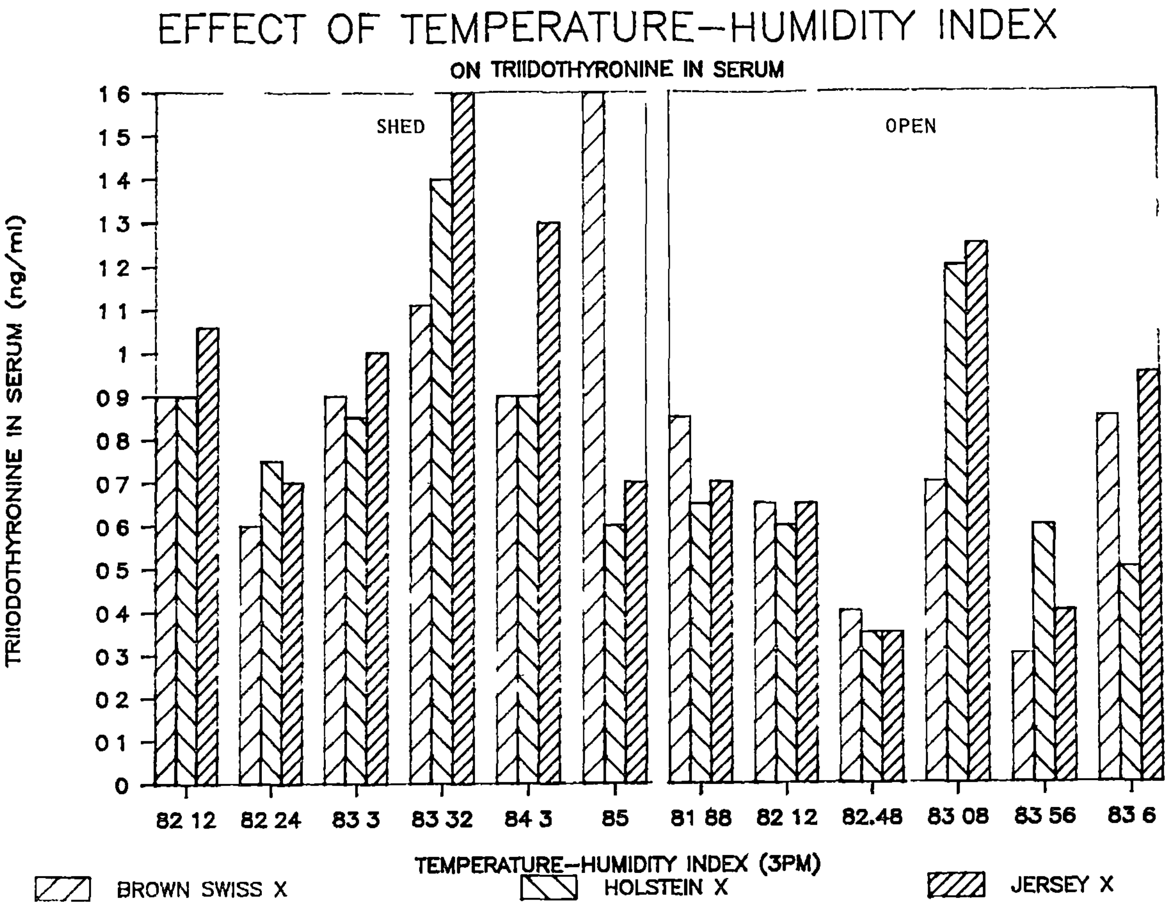

Figure 10

Effect of temperature humidity index (3PM) on triiodo thyronine in serum of various crossbred genotypes during Trial III period stress conditions do not follow a definite pattern as in the case of T3 While elevated levels (32 5 ng/ml) are observed in sheltered B8C lower levels (25 87 ng/ml) were found in exposed HFC The JSC have maintained almost equal levels on both sheltered and exposed conditions E posure to direct solar radiation was correlated with decreased thyroid activity The mechanism by which environmental heat depressed thyroid functions are unclear, because of the limited information on thyroid stimulating hormone (TSH) in blood of cattle under heatstress (Hart et al , 1978) Many other nutritional and hormonal interactions are possible The low levels f thyroid activity reported in the present study can be partially attributed to reduced synthesis of T3 and T4 by the thyroid gland This view is supported by the findings of Magdub et al , 1981 They have also suggested that the relationships among milk T4 and T3, plasma T3 and rectal temperature offer opportunity to use milk T4 or T3 to assess thyroid status (plasma T4 and T3) and heatstress

The high level of plasma (66 07 ng/ml) T4 reported by Magdub et al , 1981 is also because of necessity for higher metabolic activities required for sustaining comparatively higher yields (11 92 kg/day) compared to the requirement for lower yields (7 0 kg/day) reported in the present study Their cows were also subjected to much lower environmental temperature (31 2 deg C compared to higher mean maximum temperature of 39 deg C with relative humidity of 65 percent) and to direct solar radiation to which the cows were exposed to, in Trial III However, the T3 concentrations were almost same in both experiments (0 65 ng/ml) indicating that the T3 concentration in the circulation has more biologically active use of to assess the environmental stress

The correlation coefficients between serum triiodothyronine (T3) concentrations and milk yield, as well as, with physiological parameters are presented in Table 32 Stronger negative relationship was observed in cows exposed in the open than in the group maintained inside the shed Apparently, a feeble negative relationship is advantageous for better adaptability For the exposed group when BSC had the correlation coefficient of - 504, the HFC had - 398 and JSC had only - 306 The high T3 activity is associated with high metabolic rate and in turn with high productive activity, on the contrary related to low adaptive ability From the correlation coefficients it is difficult to arrive at a conclusion as to which genetic group struck a balance to maintain better adaptability without sacrificing production Jersey appears to be better in this regard

There was no definite direction to the physiological activities in relation to the T3 levels in high and low stressed animals as indicated by the correlation coefficients between T3 and physiological parameters Among the physiological parameters, cardiac rate appeared to be more related to T3 activity than rectal temperature and respiration rate It appears that the JSC can regulate the T3 levels in heat stress conditions more effectively than the other crosses as evident from the significant R^2 values (Table 32(a))

SUMMARY AND CONCLUSION

6 SUMMARY AND CONCLUSION

Experiments were conducted to assess the relative performance of three crossbred genetic groups viz Brown Swiss, Holstein Friesian and Jersey crosses in terms of physiological and productive adaptability in hot humid environmental conditions of Kerala Simple management strategies to ameliorate the effects of stress, like, supplementation of buffer salt (sodium bicarbonate 0 85 percent of the concentrate ration) and feeding of ration with solvent extracted coconut cake containing high proportion of undegradable protein) were also tried Effort had been made to assess adaptation using the neuroendocrine approach consisted of measuring the concentration of certain biochemicals in body fluids (blood and milk), apart from the conventional physiological approach by Studying rectal temperature, cardiac and respiratory rates

Adaptability indices based on the aforesaid physiological parameters independently or in combinations of two or more had been worked out for different genetic groups Climatic variables were recorded The combined effect of temperature humidity and temperature humidity hours of bright sunshine by standard climatic indices had been computed Its effects on milk yield, physiological and biochemical parameters were studied

The e perimental programme consisted of three Trial periods each e tending fo ?4 days during the summer months of April and May Eight animals each from three genetic groups were e posed to direct solar radiation from 9 AM to ? PM, while same umber of animals were kept within the shed throughout the day during the experimental period E cept for e posure feeding and other managemental conditions remained same for both the groups Blood and milk samples were collected at the end of the e posure period (PM) from e posed animals and from those remained indoors once in 4 days Milk and blood constituents were estimated, means and standard error worked out, statistical significance tested cor relation coefficients among climatic variables, physiological responses, adaptive indices and milk yield were comp ted and presented in Tables 1 to 50 and Figure 1 to 10

A comparison among climatic environments of the Trial periods indicate that the Trial I period was comparatively one of low temperature high humidity, while Trial III was of high temperature low humidity The stress levels almost remained same during both the periods as indicated by temperature humidity in de values The trial II was an e tension of Trial I and no marked fluctuations were noticed between Trial I and Trial II periods

6.1 Trial I

The three cardinal physiological responses viz. rectal temperature, cardiac and respiratory rates had marked fluctuations. The forenoon physiological responses between different genetic groups were statistically significant. But in the afternoon, the significant differences were between the animals kept within the shed and those exposed to direct solar radiation and not between genetic groups except for cardiac rate. The Jersey crosses had significantly lower physiological responses in the forenoon and lower cardiac rate in the afternoon. At the same time the Jersey crosses recorded highest rectal temperature and respiratory rates in the afternoon among the three crossbred groups studied.

The reduction in milk yield was more marked in Jersey crossdbreds exposed to direct solar radiation while they fared better in the low stress conditions within shed. A low basal physiological response and ability to maintain low cardiac rate are positive attributes for better adaptability, the adaptive indices based on physiological responses appeared to have failed in raking the genotypes in terms of their relative adaptive ability to hot humid conditions. The inbuilt drawbacks of the adaptive indices based on physiological responses were discussed. The dangers of assessment of adaptability based on the desirability of a narrow range of physiological reactions are highlighted.

To be able to produce well in unfavourable climatic environment, whatever be the strategies an animal adopt to adapt to the conditions, due recognition need be given. If high espiratory frequency is a necessary strategy to maintain homeothermy in hot humid environments, the ability to step up respiratory frequency should be taken as a positive attribute not otherwise Besides this, due weightage is needed to be given for having a low level of physiological responses at basal conditions

The respiration rate is the most elastic attribute among the three physiological responses and hence incorporation of such a parameter also distort the index value more if not properly used It appears that the index based on rectal temperature alone is more reliable than the one based on equal weightage to rectal temperature and cardiac rate or differing weightages to all three responses Considering the correlated responses of milk production and adaptive ability to hot humid conditions, the Jersey crossbred had an edge over other crossbreds studied Since lack of adaptation affects reproduction and resistances to diseases, besides production, lifelong productivity should be taken into consideration before arriving at a final conclusion

6 2 Trial II

Unlike in Trial I, the means of afternoon rectal temperature and cardiac rate didn t differ significantly, indicating that both buffer salt supplementation and feeding of undegradable protein had helped in mitigating the heatstress effects in cattle and the buffer salt supplementation did so in a better way though not statistically significant The beneficial effects of the ameliorative treatments were more for high stressed animals in the open than the low stressed group in the shed None of the milk or blood constituents showed significant changes compared to Trial I period

6.3 Trial III

The Trial III was intended to verify observations made during the Trial I period Since non of the milk and blood constituents studied showed remarkable changes to be used as biological markers of adaptability, an effort had also been made to study more intrinsic microlevel manifestations of adaptive neurohormonal changes by studying blood enzymes and hormones reported to be associated with stress conditions, using more sophisticated laboratory methods The levels of lactate dehydrogenase (LDH), glutamic oxalacetic transaminase (GOT) and glutamic pyruvic transaminase (GPT) did not differ significantly between environmental conditions or between genetic groups Among thyroid hormones, thyroxine (T4) and triiodothyronine (T3), the T3 levels differed significantly between the exposed and sheltered animals The exposed animals had low levels compared to sheltered counter parts

The Jersey crosses had maintained almost equal levels in both low stress and high stress conditions Since T3 levels are closely associated with adaptive and productive functions, the ability to control the levels in different stress conditions assumes greater relevance A breed which can achieve effective thermoregulatory function and sustain high yields are desirable qualities for the adapted animals of the Tropics

The results of the Trial III, regarding the physiological parameters and adaptive indices were almost similar to the values obtained during Trial I

6 4 Reflections

As the generation intervel in dairy cow is very long compared to other farm animals, environmental studies must be long term and they must be performed in practical conditions comprising of large number of animals Laboratory scale experiments with few animals may only serve as indicative studies

If a comparison between low stress and high stress conditions was the need of the experiment, the environment selected should have significant differences, so that the effects could be clearly discernible

6 5 Future Research

Stress response is complex and involves great deal of alterations in the neurohormonal system vis a vis the environment The knowledge of these subtle changes are undoubtedly of great value for identifying biological markers of adaptation We are still in the first phase of appraisal and that much effort will be required before practical evaluation is possible

There is need to develop better adaptive indices, suitable for high stress conditions prevailing in the Tropics The possibility of incorporating blood levels of triiodothyronine with productive parameters need to be explored. There is also scope for improving the efficiency of adaptive indices based on physiological responses by providing due weightage for the attribute of having low basal response levels coupled with rate of decline in milk production on exposure to high stress conditions.

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Note * Original article not referred

PRODUCTIVE PERFORMANCE OF CROSSBRED COWS IN HOT HUMID ENVIRONMENT

BY

NOBLE, D.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirements for the degree

DOCTOR OF PHILOSOPHY

FACULTY OF VETERINARY & ANIMAL SCIENCES
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ABSTRACT

The physiological and productive adaptability of Brown Swiss Holstein Friesian and Jersey crossbreds in hot humid environmental conditions of Kerala was evaluated Effect of dietary supplementation of buffer salt and feeding of high proportion of undegradable protein to ameliorate the effect of stress also studied Various biochemical parameters in blood and milk were screened for identifying biological markers of adaptation

The relevant literature had been reviewed The major stress factors for cattle had been enumerated The heat stress in particular was dealt with exhaustively and its impact on crossbred dairy cattle organized under physiological lactational hormonal reproductive nutritional and metabolic responses The role of physiological modification of the environment genetic development of heat resistant breeds and various nutritional strategies which had been adapted for amelioration of heat stress also reviewed

The experimental schedule comprised of three trial periods The Trial I was designed to study the macrolevel responses due to added climatic stress while Trial II was to evaluate two stress

ameliorative treatments viz dietary supplementation of buffer salt (sodium bicarbonate at 0 85 percent of concentrate ration) and partial substitution of dietary protein with protein of low degradability Trial III was mainly aimed at understanding the more intrinsic and subtle microlevel changes of the adaptive process

The protocol for the experiment followed was essentially the same for all the three trials For Trial I eight crossbred cows from three genetic groups were exposed to direct solar radiation from 9 AM to 3 PM while equal number of animals were kept within the shed throughout the day Except for the exposure feeding and other managemental conditions remained same Milk and blood samples were collected immediately after the exposure period (3 PM) from exposed and sheltered animals once in four days A total number of six samples were collected during the trial period Physiological responses were measured daily before and after the exposure period Recording of climatic variables were done using approved instruments and methods Milk samples were analysed for total solids fat solids not fats whey protein calcium magnesium sodium and potassium

During Trial II period half the number of animals of each genetic group was fed supplementary buffer salt and undegradable protein The parameters studied were same as that of Trial I In Trial III a fresh set of animals were used and the parameters studied were different The blood constituents estimated were lactate dehydrogenase (LDH) glutamic oxalacetic transaminase

(GOT) glutamic pyruvic transaminase (GPT) triiodothyronine (T3) and thyroxine (T4) Milk samples were not analysed during Trial III as in the previous two trials

Climatic indices and adaptive indices were computed means and standard error of milk and blood constituents as well as physiological responses were worked out statistical significance tested correlation and multiple regression coefficients worked out and presented in Tables 1 to 50 and the results illustrated using Figures 1 to 10 Sophisticated analytical procedures like atomic absorption spectrophotometry automatic enzyme analysis and radioimmuno assay techniques were employed apart from the other standard methods used

From the results obtained the adaptive indices based on physiological responses appeared to have failed in ranking the genotypes in terms of their relative adaptive ability to hot humid conditions The inbuilt drawbacks of the adaptive indices based on physiological responses were discussed as well as questioned the desirability of having a narrow range of physiological responses in an adaptive index

Dietary supplementation of buffer salt and feeding of un degradable protein had helped in ameliorating the effects of heat stress in cattle The beneficial effects of the treatments were more for high stressed than in low stressed cows

The results of Trial III regarding the physiological parameters and adaptive indices showed similar trends as that of Trial I One important observation was that the levels of triiodothyronine (T3) levels differed significantly between exposed and sheltered animals the exposed had low levels compared to sheltered counterparts

To be able to produce well in hot humid environments whatever be the strategies an animal adopt with minimum effect on productive processes due recognition need be given If high respiratory frequency is a necessary strategy it should be taken as a positive attribute

Supplementation of buffer salt at Ø 85 percent of the concentrate ration can be advocated for stress amelioration The possibility of incorporating blood levels of triiodothyronine in adaptive indices with productive parameters need to be explored There is also scope for improving the efficiency of adaptive indices now in vogue by providing due weightage for the attribute of having low basal physiological response levels combined with the rate of decline in milk production under high heat stress conditions