DISCUSSIONS AND CONCLUSIONS

ENVIRONMENTAL PHYSIOLOGY

Overall observations on the physiological reactions of the straightbred and crossbred animals showed highly significant positive correlations with the climatic elements, particularly for the respiration rates.

1. Respiration rate

Respiration rates tended to alter rapidly with the change in the atmospheric temperature. Wide diurnal and seasonal variations observed in both the types of animals, irrespective of the treatments given, showed the sensitivity of respiratory rate as the foremost physiological index.
Diurnal variations in the respiration rate were found uniform in both the types of animals during the entire period of observations. The reactions were high with increasing atmospheric temperature.

Increase in the respiratory rate with the rise of the ambient temperature has been reported by many workers in India and abroad (Coronel, 1932; Manresa and Gomez, 1937; Regan and Richardson, 1938; Manresa and Erce, 1940; Seath and Miller, 1946; Lee and Riek, 1947; Kibler and Brody, 1950; Badreldin and Ghany, 1952; Johnston and Branton, 1952; Mullick and Kehar, 1952; Villegas et al., 1953; Kibler and Brody, 1954; Brody, 1956; Mullick, 1960 and Johnston and Frye, 1967).

Respiratory behaviour is one of the physiological mechanisms tangibly observed on cattle during heat stress. It can be rated as the primary mechanism followed by other complex mechanisms in combating stress during hot and/or humid climate.

The skin thermoreceptor may play an active role in stimulating the heat controlling centre through the hypothalamus and in turn the hypothalamus dictates the respiratory centres during heat stress (Johansson and Rendel, 1968 and Campbell and Lasley, 1969).

Increased respiratory rates might help the animals in dissipating more heat through evaporative cooling. Adolph (1947) concluded from his experiments that some animals achieved homeothermy of evaporative cooling through panting.
It was reported (Campbell and Lasley, 1969) that birds accomplish evaporative cooling by panting (begins at temperatures between 80 to 90°F) and so also with dogs.

In cattle, Kibler and Brody (1950), Bianca (1959) and Kibler and Yeek (1959) reported increased respiratory and skin vaporization at higher ambient temperature. Kleiber and Regan (1938), Brody (1945) and Campbell and Lasley (1969) studied that high respiratory rate can be attributed to the need for greater respiratory cooling at high temperature.

During heat stress, the temperature gradient between the body and the surrounding atmosphere becomes less and consequently the heat loss by convection and radiation becomes less. Evaporative cooling mechanism takes up a prominent role in such circumstances in maintaining homeothermy. Hence, the ability to withstand heat stress depends upon the ability to dissipate heat through evaporative cooling. Since cooling mechanism by skin vaporization is not very effective in cattle, evaporative cooling through increased respiratory rates becomes prominent during heat stress. In man, it was reported that sweating increase 80-fold from the normal rate by immersing the body in water at 108°F (Campbell and Lasley, 1969).

Between the types of cattle, crossbreds showed greater rise in respiratory rates than straightbreds during hot and dry humid climate. This was expected considering the genetic make-up of the cattle. Cold adapted breeds will definitely
manifest disturbed homeothermy under hot climatic conditions. This might also hold true to acclimatized cold breeds compared in the tropics to tropical breeds. Similar observations on breed differences have been reported by Villegas et al., (1953) and Kibler and Brody (1954).

In general, it has been stated that the rate of breathing is increased when the animal has burden or activity, that is, the blood has to get rid of greater amounts of waste carbon dioxide and to take in more oxygen to support the extra work of the body. This condition clearly prevails when the animals are under climatic stress (Park, 1970).

The difference in the degree of response to heat stress may give an indication regarding heat tolerance of the animals. Stress is expressed by the physiological ability to maintain its body temperature constant in extreme environmental temperature (Brody, 1945). All the animals in both the breeds under different feeding regimes (factorial, ad lib and group feeding, ad lib and standard feeding) showed uniform rise in respiratory rate. This shows that ad lib or standard feeding had no significant effect on the reactions of animals during any given climatic conditions including during heat stress. However, ad lib fed animals had significantly greater increase in the respiratory rate than the standard fed (P < .01). This shows that feeding activities had additive physical exertion, hence, increased respiration rate. The decrease in the respiratory rate in the ad lib fed crossbreds may be attributed to the cooling effect of forage containing greater...
volume of water. The thermostatic property of water probably induced normal physiological body mechanisms.

As regards the shelter conditions, the modified shelter group of animals showed significant decrease in respiratory rate than the standard shelter group. This shows that the shelter conditions studied had much difference in effect in aiding the animals to maintain homeothermy. The additional shade provided by the modified shelter during the course of the investigations had much favourable effects on the animals in both breeds. Although the difference in the respiratory rate of the modified shelter groups was narrow, it was found highly significant, statistically (P < .01).

Air humidity with high air temperature (hot humid season) increased the respiration rate. During hot humid months the capacity of the air to take-up moisture is reduced and hence surface evaporation rate decreases. The decrease in surface evaporation inhibits efficacy of surface evaporative cooling mechanism. Hence, evaporation from the skin is only of secondary importance. The respiratory rates increase to keep-up the rate of heat loss from the body.

The changes in the respiratory rates in hot dry and hot humid seasons reflect the physiological mechanism which could be brought into play to combat heat stress. But this type of physiological mechanism taxes the animal if it is not provided with suitable shade.
From the present investigations, it can be seen that animals under the modified shelter showed less variation in respiratory rates, than those under the standard shelter. The modified shelter provided extra safeguard against direct solar radiation and radiational stresses. Hence, it appears essential that animals should be protected from direct solar radiation, apart from shielding the animals from direct exposure to hot weather.

11. Pulse rate

Pulse rate showed changes with changing atmospheric temperatures in all the animals under the different treatment combinations and factors studied.

Diurnal as well as seasonal variations in pulse rate were shown to be significantly influenced by atmospheric conditions. Cold comfort season was characterized by the highest pulse rate.

Several scientific investigations have been reported on this subject. Many of the reports were contradictory.

Some scientists maintained that pulse rate is positively affected by increase in atmospheric temperature (Blaxter and Price, 1945; Seath and Miller, 1946-a; Mullick and Kehar, 1952; Beakley and Findlay, 1955 and Bianca, 1959).

On the other hand, Regan and Richardson (1938) observed no change in pulse rate with increased air temperature while Bonsma and Pretorius (1943) reported that in shade the pulse rate tended to vary little.
Beath and Miller (1946–a); Badreldin and Ghany (1952) and Mallick (1960) observed low level of pulse rate with the increase of temperature. However, Asker et al. (1952) observed slight decrease when buffaloes were exposed to sun.

Graf and Peterson (1952) on the other hand reported increased pulse rate at low temperature (-16 to 16 °F). Brody (1956) stated that there is virtually no call on homeothermic mechanisms for physiological adjustments between freezing and 60°F.

Increased rate of circulation through pulse rate would help increased peripheral circulation and this type of increase would help in dissipation of heat through more sweat formation. Increased respiration rates probably may lead to imperfect oxygenation of blood in the lungs and create a sort of anoxia, and as a compensatory mechanism circulatory rate may increase.

Increased circulation rate provides increased fluid matrix for transporting the heat generated at cellular level. In fact, blood volume was reported to have increased with increase in air temperature (Rao, unpublished Ph.D. thesis, 1970 and Tripathi, Rao and Sadhu, 1969).

111. Rectal temperature

The rectal temperature was shown to vary from morning to afternoon reading and also from season to season.

Diurnal and seasonal variations were both statistically
Both the *breeds* showed highly significant increase during the dry months. The change in ambient temperature significantly affected the rectal temperature.

Several workers reported that the rectal temperature of dairy animals rose with increased air temperature. But specific response or the degree of rise in rectal temperature might depend upon the *breed* and the ambient temperature at which the animals were reared and maintained. It is possible that the cumulative effect of continuous exposure to changing temperature has milder effect on homeothermy.

Positive correlations of rectal temperature to air temperature were observed by Manresa and Erce (1940); Gaalaas (1945); Seath and Miller (1946a); Kiek and Lee (1948); Branton *et al.* (1953); Quazi and Shrode (1954) and Harris *et al.* (1960).

It was, however, reported that exposure of homeothermic animals to outside climate conditions did not vary the body temperature (Howel, 1927 and Alcaide, 1950).

Thompson *et al.* (1954) showed that European *breeds* of cattle had higher rise in rectal temperature than the Zebu cows and heifers. Taneja (1960) pointed out that Zebu crosses exhibited more rise in temperature than their straight-bred parents, under heat stress. Kleiber (1961) reported that animals pre-conditioned to high environmental temperatures increased their heat tolerance and consequently exhibited
less variation in body temperatures during heat stress.

The little variation in rectal temperature recorded in these investigations during the different seasons in both breeds irrespective of the treatments might be due to the fact that they were constantly exposed to high ambient temperatures during their growth and continuous exposures to the prevailing climatic temperature at the same place. But even the small difference in the observations were highly significant, statistically.

The decreased rectal temperature observed in the animals under modified shelter indicates decreased thermal and radiational stresses.

Likewise, the decreased rectal temperature of animals under \textit{ad lib} feeding can be probably attributed to the thermostatic property of water. The increased ingestion of green fodder supplied additional water which might have lowered the rectal temperature.

**Conclusions**

Observations on the physiological reactions gauged by the respiration rate, pulse rate and rectal temperature showed high degree of correlation with the climatic environments. From this angle, it can be inferred that animals should be provided sufficient shelter for obtaining equational balance of thermogenesis and thermolysis. The modified shelter in this study was not sufficient to cut down the distressing effects of climate especially during hot/humid months including
direct solar ration as shown by the uniform diurnal and seasonal variations of the physiological indices.
Statistical analysis showed that none of the factors studied significantly influenced the number of inseminations for successful insemination (table 23). However, it was observed that crossbreds required less number of inseminations (1.4) on the average than straightbreds (3.0). Breed differences have been reported by Bhatnagar et al. (1969). Out of 232 inseminations in crossbreds (F₁), the average number of inseminations per conception was 1.34; Red Sindhi, 1.8 ± 0.4; Sahiwal, 2.3 ± 0.3 and Tharparkar, 2.4 ± 0.3. Banez (unpublished M.Sc. dissertation, 1964) observed 1.7 services for Sahiwal before successful conception and 2.2 for Tharparkar. However, Kavitkar et al. (1968) reported that Sahiwal being a slow breeder required more services. Erb et al. (1943) reported that some families have higher breeding efficiency, and breeding efficiency was hence considered to be inherited.

Zambian workers (Rakha, Igboeh and King, 1971) likewise found breed variations on the breeding efficiencies of indigenous Central African Cattle. Their calculations showed that Angoni, Mashona and Hereford (exotic and hence probably unadapted) required on the average, 1.41, 1.83 and 2.76 inseminations for successful conception.

As regards the types of shelter and systems of feeding, although no significant differences were observed, the crossbreds under standard shelter showed earlier signs of heat, requiring less number of inseminations, and earlier successful conception. However, under standard system of feeding cows
required less number of inseminations, and calved earlier, but required more number of days for the onset of first oestrus.

In this context, Seath and Staples (1941), Rigor et al. (1961); Villegas (1961) and Cole (1966) were all agreed that it was not only the climatic environment but also the availability of good fodders that resulted in better reproductive efficiency of the animals.

Johansson and Rendell (1968) stated that both the quantity and composition of feeds can influence the sexual behaviour of animals in a neuro-hormonal way.

Campbell and Lasley (1969) reported an increase in reproductive efficiency from 30% to 60% in the "cooled" group during summer months. High environmental temperature was found detrimental to the ova and sperm in the female reproductive tract, resulting to lower fertility and higher embryonic mortality.

In India, Bhattacharya (1968) reported poor fodder supply as an indirect effect of climate which lowered the efficiency of reproduction. However, Marshall (1922) recorded an opposite reproductive behaviour.

The findings that ad lib fed group required more number of days from calving to successful insemination might be attributed to arrested or disturbed oestrus and conception rates. Vishnu (1965) reported that fatness hindered the development of follicles, when the ovary is infiltrated with the production of fertile sperms and resulted too in hormonal
imbalance which were responsible for sterile conditions. Johansson and Rendel (1968) reported that many environmental factors resulting in endocrine imbalance affect sexual functions.

Conclusions

While there exist clear cut breed differences in the breeding efficiencies of the animals under study, some factors other than those discussed should be given attention. In case of the crossbred cows better housing and plane of nutrition had more favourable effects in comparison with the straightbreds.

The observations were only made on a small number of animals and perhaps pursuing this study on a large number will throw more light in this direction, in as much as large variations on the behaviours of the individual animals were observed in the different parameters studied.
Tables 29a, b, c, d, e, f, g and h show the individual and group average values of the production performances and corresponding percentages over a lactation period of 305 days under the different treatment combinations and factors studied.

Statistical analysis of the production performance showed significant differences ($P \leq 0.01$) between the straightbred and crossbred cows (table 26a). However, the systems of feeding (ad libitum vs. standard) and shelter conditions (modified vs. standard) including their interactions did not reveal any significant effect. Similar findings on ad libitum system of feeding fodder and in some instances, fall in production have been reported elsewhere (Bartlett et al., 1940; Kruger et al., 1955; Barber et al., 1956; Bush and Vetter, 1956; Holmes et al., 1956; Brown and Beal, 1960; Malatyan et al., 1960; Saran and Jackson, 1967; Huff et al., 1970 and Thomas et al., 1970).

Heinrich and Renk (1967) stated that maximum yield can be obtained only when the ration is qualitatively and quantitatively optimal and that additions to such optimum rations do not lead to increased milk yield.

It has been also reported that the level of concentrate feeding did not have much effect on milk production (Butterworth, 1961 and Miller, 1961) or butter fat production (Hotchisset et al., 1960; Skorobogatykh, 1961 and Zeremiski et al., 1964).
Conclusions

In general, it can be inferred that the prevailing shelter conditions and conventional feeding regimes followed at the National Dairy Research Institute cattle herd should be maintained until better results of research in this direction are known.

The fact that modified shelter and increased feeding of quality fodders did not significantly increase the production of the cows reject the general belief in the beneficial effect of overfeeding in the production performance of cattle.
LACTATION PRODUCTION EFFICIENCY

The milk production efficiencies for each animal was calculated by employing a formula (p.93). The individual efficiencies under group feeding and factorial experiment have been presented in tables 27a, 27b, and 29.

Statistical analysis of the data on group fed as well as in factorial experiment showed that none of the treatment combinations or factors studied was significant. However, the magnitude of the average difference of the gross efficiency of production of crossbreds as compared to straightbreds was higher, of the order of four percent (30.12 vs. 26.63, i.e. 13.3% more efficient) in group feeding and six percent (23.16 vs. 17.53, i.e. 24.5% more efficient) in the factorial experiment. This indicated the superiority of crossbred cows over the straightbreds in utilizing the feed nutrients for production performance.

The maximum possible gross efficiency of milk production was estimated to be 35% (Brody, 1945). But if the maintenance requirements are separated from the energy utilized, net efficiency for milk production alone may exceed even 60%. This was, however, shown to be influenced by the type of roughage utilized (Kleiber, 1961).

The fact that the animals used for the study showed gross energy efficiency near the theoretical value of Brody (1945), indicated that by feeding good quality roughages, it is possible to maintain the milk production efficiencies of the animals.
As regards the increased production efficiency brought about by additional shelter, this could be possibly due to the decreased thermal stress on the body mechanisms. The additional body heat due to high productivity was masked by the lowered climatic environment under modified shelter, hence, nutrient utilization was increased. Campbell and Lasley (1969) reported that a comfortable cow converts feeds in milk more efficiently than one exposed to high environmental temperature.

On the other hand, production efficiency decreased under ad lib feeding. This is possible in the sense that when more nutrients are available in the body of the animal utilization of the same tends to diminish. McCullough (1953) reported that by "Increasing the protein content of the total ration from an average of 16% in the fescue to 25% in the temporary forage increased the wastage from 42 to 96% of the total digestible nutrients". McDonald and Bell (1958) also observed that increased feed consumption resulted in decreased feed conversion efficiency of milk production. It was, however, reported by Campbell and Lasley (1969) that limited feeding, if not too drastic often results in increased efficiency of grains. This condition was found to be true in different species and may possibly result from an increased rate of digestibility or to a less feed wastage.
Conclusions

One of the reasons why crossbreds are superior to straightbreds in total milk production may be the apparently greater feed conversion ability shown by the former. This, however, needs to be further investigated using fodders of different nutritive values and also taking economic factors into consideration, over whole lactation periods.
SURFACE AREA STUDIES AND BODY MEASUREMENTS

1. Factorial experiment

Statistical analysis of surface area measurements showed non-significant differences (table 35). However, the animals kept under modified shelter had smaller surface area compared to the animals under standard shelter. This was possibly because animals under modified shelter had benefitted from the decreased solar intensity and other thermal stresses or environmental hazards that might have affected the surface area. Brody (1945) and Saini et al. (1967-a) have also shown that environmental variations could bring about changes in the surface area of the animals, especially during heat stress. However, Johnson et al. (1967) failed to notice such changes in cattle. It was further concluded that skin surface rolls-up during winter and spreads out during summer (Brody, 1945 and Saini et al., 1967-a).

11. Formulae for prediction of surface area

Exponential formulae for calculating surface area from body weight measurements have been worked out for the straightbred and crossbred cattle. It was found that the exponential values were in the order of 0.4060 in straightbreds and 0.4640 in crossbreds. However, the "constant" in the former was higher than in the latter. Brody (1945) stated that surface area of animals varied from species to species and even due to age.

These observations on the value of the exponential
"b" in the formula $Y = (x_1)^b$ were less in the case of both the breeds compared to the value in the formula suggested by Brody (1945) in which "b" was of the order of 0.7. This can not be applied rigidly in the case of straightbred and crossbred cattle. The present findings are similar to those of Rao and Mullick (1963) who reported value of "b" as 0.4379 for buffaloes.

The smaller surface area as indicated by the lower exponential values, may be of great advantage in keeping down heat production during heat stress.

The low surface area, as explained earlier, may be a characteristic of thermogenic types compared to the temperate animals which obey the surface law and hence belong to the thermolytic type (Sadhu, 1963).

Surface area formulae connecting body measurements, viz., body length, height and heart girth have been calculated for both the breeds.

Correlation analyses of these allied characters and regression equations have substantial information in calculating the surface area in both the breeds. However, it was observed that height contributed very negligible information in the case of straightbreds. There seems to be no literature to explain this situation. Findlay (personal communication, 1971) explained that "The longer and more slender legs of the Sahiwal will represent less surface area than the fatter, shorter legs of the crossbreds". This holds true when limbs
are treated as cylinders. In totality, the regression equations \( R^2 \) explained the total variation in the difference of the surface area of crossbreds which was 25.1% higher than that of the straightbreds.

A perusal of the data on surface area per unit body weight shows that it decreases with increase in body weight. This finding is in agreement with those of Brody (1945), Kleiber (1961), Rao and Mullick (1961) and Blaxter (1962). Blaxter (1962) pointed out that it is an added advantage from the view point of the dynamics of circulatory physiology and transportation of oxygen for a larger animal to have smaller surface per unit body weight.

The surface area per unit body weight in both the classes of animals showed no greater variation. This may reflect on the acclimatizing capacity of the crossbreds to tropical atmosphere as the straightbreds.

111. Correlations of the allied (SA, BW, H and HG) characters to production performance.

Correlation analyses for the individual allied characters showed varied relationship in both the classes of the animals studied (crossbred and straightbred).

Tests of statistical significance showed that none of the allied characters was correlated significantly with the production performance (liquid milk and FCM), except body length in straightbreds, which was significant and negative \( (P < .05) \) in its correlation with liquid milk production. This indicates that the longer the body of the animals the
lower was the milk production.

The generalization of these findings is in agreement with Johansson (1967), Berruecos and Bolanos (1968) and Breitentain and Fiedler (1968). Wilson et al. (1969) reported the non significant effect of body size to milk yield and composition.

The statistically significant and negative correlation of body length in straightbreds needs critical examination. However, Buben (1969-a) recorded lower milk yield for cows with relatively longer legs, smaller bones shorter bodies and larger heads than cattle with higher milk and fat yields.

Correlations of surface area to production performances in both classes of the animals were positive. The magnitudes of correlation were higher in crossbreds than those in straightbreds. At the time of this writing, there seems to be no literature on this aspect.

Regarding body weights, the crossbreds exhibited negative correlations to production performance. This seems to be closely in agreement with Singh and Desai (1965-a) and Singh and Singh (1967) that milk yield was not dependent on body weight. Likewise, Garjkeviči (1968) and Dohy and Kelemeti (1968) found negative correlation with FCM and relative milk yield, respectively. Non linear relationship between body weight and yield was found by Rønningen (1967).

In case of the straightbreds, positive correlations
were observed. This is similar to the findings of Gaines (1941) and Tibor (1969).

Other parameters showed slight correlations to production performances. These indicate that these parameters need no considerable impact on the productive capacities of the breeds studied.

Conclusions

The initial difference the surface area brought about by the two shelter conditions, although not significant, leads to the conclusion that the crossbred cows as well as the straightbreds need better shelter conditions during hot days. The modified shelter decreased the surface area as a result of decreased intensity of thermal and radiational stresses.

Regarding the prediction of the surface area formula under field conditions, it can be inferred that inclusion of the allied characters (BW, BL, H and HG) are indispensable in obtaining reliability of surface area. In this regards, formulae for different species should be calculated to take care of the difference in measurements of allied characters, as shown in this investigation.

In the correlation of body measurements to production performance although no significant differences were found among the parameters studied, the small magnitude of correlations, positive or negative, should be taken care of. This study was only conducted with small number of animals.
Probably, increasing the population size in a future study will throw more light on this aspect.

In general, better shelter conditions and appropriate nutrition are good indices in attaining normal biological and thermoregulatory adaptation of cattle. Without these provisions the skin surface areas are affected, as a result of physiological disturbances especially during heat stress.
1. Behavioural patterns

The activities which inhibit the free behaviour of the cows can be attributed to hot climatic conditions. The cows, in order to overcome the situation moved rapidly towards the comfort frame. High ambient temperature depressed the appetite and shifted the feeding habits to night time when the sensible temperature was pleasant in regulating body mechanisms.

Lying on the concrete floor and beside the drinking troughs seem to be a normal activity in escaping the intensity of thermal and radiational stresses. The cooling effect of the floor gave relief from the heat stress. Such activity helped the animal in attaining the equational balance of thermogenesis and thermolysis.

Frequency in drinking was attributed in counteracting the effect of environmental temperature stress whereby reducing internal heat load. Cows, being homeothermic, regulate body temperature by consuming large volumes of water when the outside temperature exceeds the comfort zones. The tissue fluids by their thermostatic properties, served as heat regulating media. The high specific heat of water enables it to absorb the heat. These reactions result also in minimum rise of temperature in the body of the animals.

11. Health of the animals

The frequent occurrence of diseases during summer months
can be attributed to the unfavourable effects of thermal and radiational stresses. Periods of high temperatures depressed the health conditions of the animals. This normally occurred when the animals were in a state of unequal balance of thermogenesis and thermolysis.

Comparative evaluations of ad libitum group feeding and factorial experiment adjusting duration of observation showed the latter to have satisfactory health conditions of the animals. The shelter conditions as well as the individual stanchions might have contributed in attaining better health under the factorial experiment. Under loose confinement chances of infections of diseases of healthy animals are more than under individual feeding system.

However, under group feeding, the ad lib fed crossbreds had more cases of diseases than the standard fed within the general herd. This situation was reverse in case of the straightbreds. One possible explanation of this might be that crossbreds, which are believed to be more sensitive to diseases, got infected with even least contact. In the ad lib fed paddock, the space was comparatively smaller than the general herd and so the chances of spreading infection was more. On the other hand, constant associations of animals among themselves resulted in more cases of disease infection, considering the number of the straightbred animals within the general herd to be large.
Conclusions

Observations on the behavioural patterns and health of the animals under *ad lib* group feeding suggested need for better shelter conditions. However, more detailed studies are indicated for forming clear conclusions.

The fact that tying the animals (factorial experiment) with metal chains did not result in any physical injury and moreover maintained satisfactory level of health suggests that this procedure can be a guarantee for better management.
GENERAL CONCLUSIONS

In general, the results embodied in the thesis brought out interesting matters which need critical examination.

1. From the standpoint of production (including efficiency of feed conversion) and reproduction, of the classes of the animals studied, the provision made for the modified shelter did not give considerable help in either class of the animals fed in excess of the standard rations or standard rations prescribed by Sen and Ray (1964).

2. On the other hand, the physiological studies on the respiration rate, pulse rate, rectal temperature, body measurements and surface area under the same factors and treatment combinations gave opposite responses as compared to the production performances. Observations showed that respiration rate was the most sensitive index affecting homeothermy of cattle. It had a very highly positive correlation with increasing climatic elements particularly during hot humid atmospheric conditions.

3. In the final evaluation, although the homeothermy of both the classes of animals was taxed during heat stress under the different shelter conditions, this did not cause wide difference in the productive performances. It was assumed also that some factors other than those studied may be able to maintain the normal physiological body mechanisms of the animals at the existing sheds of the National Dairy Research Institute's cattle herd, Karnal.
4. It can, therefore, be inferred that in as much as the success of livestock production is best expressed in terms of cost per unit of measurement, the prevailing shelter condition at the said Institute, which is itself minimal for dairy cattle anywhere in India, can be recommended for the plains of Northern India and Pakistan where the climatic conditions are similar to those at Karnal.

5. Similarly, the standard rations prescribed by Sen and Ray (1964), instead of the common practice of overfeeding the milch animals (by feeding concentrates assuming standard intake of forage and then offering forage in excess of the assumed intake), could be recommended for adoption on the basis of carefully controlled experiments reported in this thesis.
FIG. 18 (A & B) FORTNIGHTLY AVERAGES AND DIURNAL VARIATIONS OF ANIMALS IN RECTAL TEMPERATURES, PULSE AND RESPIRATION RATES UNDER GROUP FEEDING.
FIG. 19. FORTNIGHTLY (MORNING AND AFTERNOON) AVERAGES OF ZEBU AND CROSS-BRED COWS IN RECTAL TEMPERATURES, PULSE AND RESPIRATION RATES UNDER GROUP FEEDING
FIG 20A. FORTNIGHTLY AVERAGES AND DIURNAL VARIATIONS OF RESPIRATION RATES.
FIG. 20B. FORTNIGHTLY AVERAGES AND DIURNAL VARIATIONS OF RESPIRATION RATES
RESPIRATION RATES PER MINUTE

FIG20C: FORTNIGHTLY (MORNING AND AFTERNOON) AVERAGES OF RESPIRATION RATES
FIG20D: FORTNIGHTLY (MORNING AND AFTERNOON) AVERAGES OF RESPIRATION RATES

GROUP AVERAGES
RESPIRATION RATES PER MINUTE

JULY 1969
AUG
SEP
OCT
NOV
DEC
JAN 1970
FEB
MAR
APR
MAY
JUN
FIG. 2IA. FORTNIGHTLY AVERAGES AND DIURNAL VARIATIONS OF PULSE RATES
FIG. 2IB. FORTNIGHTLY AVERAGES AND DIURNAL VARIATIONS OF PULSE RATES
FIG. 2IC. FORTNIGHTLY (MORNING AND AFTERNOON) AVERAGES OF PULSE RATES
FIG. 2I0. FORTNIGHTLY (MORNING AND AFTERNOON) AVERAGES OF PULSE RATES.
<table>
<thead>
<tr>
<th>Month</th>
<th>Morning</th>
<th>Afternoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>JUN.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JULY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEP.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCT.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOV.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEC.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JAN.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEB.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAR.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>APR.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JUN.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIG. 22A. FORTNIGHTLY AVERAGES AND DIURNAL VARIATIONS OF RECTAL TEMPERATURES**
FIG 22B. FORTNIGHTLY AVERAGES AND DIURNAL VARIATIONS OF RECTAL TEMPERATURES
FIG 22C. FORTNIGHTLY (MORNING AND AFTERNOON) AVERAGES OF RECTAL TEMPERATURES