BIO-CLIMATOLOGICAL STUDIES ON DRY MATTER INTAKE AND WATER CONSUMPTION OF GROWING LIVESTOCK

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "BIO-CLIMATOLOGICAL STUDIES ON DRY MATTER INTAKE AND WATER CONSUMPTION OF GROWING LIVESTOCK" is a bona fide 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, or fellowship, or other similar title, of any other University or Society.

Mannuthy,
9-1-1980.

V.L. SOMANATHAN

CERTIFICATE

Certified that this thesis entitled "BIO-CLIMATOLOGICAL STUDIES ON DRY MATTER INTAKE AND WATER CONSUMPTION OF GROWING LIVESTOCK" is a record of research work done independently by Sri. V.L. Somanathan under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

Mannuthy,
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Dr. T.G. Rajagopalan,
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INTRODUCTION

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Crossbreeding with superior exotic breeds of cattle is the accepted policy of the Government of India to improve the milk production potential of our cattle.

Bulls of temperate origin with better genetic potential for milk are being utilised for this purpose. Considerable progress has been made in this field during the past few decades. The population of crossbred cattle, in the country, has increased tremendously which resulted in a boost of the milk production. But the farmers are finding it difficult to take advantage of the full production potential of the crossbred cattle, due to obvious reasons. Acute shortage of the feeds and fodders and climatic stress on the animals due to poor adaptability, combined with the traditional and inadequate husbandry practices are the important lacunae.

The climate of the Indian subcontinent is essentially tropical, characterised by the occurence of three distinct seasons - winter (October to February), Summer (March to June) and Rainy (July to September) (ICAR, 1977). Such a classification of the climate is applicable only to the northern parts of the country. In South India, especially in Kerala, no distinct winter season prevails and there are two wet periods and a distinct dry season (Nair, 1973). The rainy season, known as South-west and North-east Monsoons, spread from June to October, the bulk of the precipitation being received during the former season. The rainfall ranges from 150-700 cm in the year. There is absence of seasonal rhythm and little variation in day length (Nair, 1973). Mean ambient temperature is 27°C and temperature as high as 40°C used to be experienced during the months of March and April. The relative humidity is high throughout the year.

The prevailing ambient temperature and humidity impose stress on animals. This results in a low input - output efficiency of feed energy for productive processes as compared to that of cooler climates. (McDowell, 1972).

Since climate is one of the limitting factors in livestock production, the present study was undertaken to find out the distribution of climate in this locality and to study its effect on certain physiological reactions as well as growth, dry matter intake and water consumption of crossbred cattle.

REVIEW OF LITERATURE

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Bioclimatology, as the name implies, is the study of the direct and indirect inter-relationships between the geophysical and geochemical environments of the atmosphere and the living organisms i.e. plant and animals (McDowell, 1972). Though this branch of science is of recent origin, considerable amount of work has been carried out in this field, especially, with regard to the influence of climatic elements on livestock production. A good number of publications dealing with this subject are available from the western countries where the existing climatic conditions are not so hazardous to livestock production. In a tropical country like India, where the climatic elements pose serious problems for livestock production, comparatively very little work has been undertaken in this field so far.

Since ambient temperature and relative humidity are the two important bioclimatic factors which impose stress on animals in the tropics, through their effects on rectal temperature, respiration, dry matter intake, water consumption and growth, the previous reports on these topics are reviewed under different heads.

Rectal temperature

Homoeothermic animals maintain a constant body temperature with only very narrow fluctuations. The body temperature of mammals is seen affected by the age, the foetus having a higher temperature which gradually declines after birth and through advancing age to attain the level characteristic of the species. The fall in temperature according to advancing age amounted to 39.1° to 38.3°C in cattle (Hafez, 1968). Rectal temperature is usually taken as an index of the body temperature because, at this location a thermometer can be deeply inserted into the body of a conscious animal without exciting the animal. Quoting Bligh,Findlay (1961) has reported that for all practical purposes, the rectal temperature appeared a very good measure of the temperature of the animal which was within 0.2 to 0.3°C of the mean circulating blood temperature provided the heat content of the animal remained constant or changed only very slowly. The normal rectal temperature for adult dairy cattle ranged between 38.0°C and 39.3°C (Herz and Steinhauf, 1978). Body temperature was seen elevated during feeding, exercise, oestrous and at the terminal periods of pregnancy and was seen depressed during starvation and after the ingestion of large quantities of cold water. Citing MacDonald, Findlay (1962) has reported that the rectal temperature of sheep fell by 1-2°C and took two hours to return to normal after ingestion of cold water. Rectal temperature also showed diurnal fluctuation, having a minimum in the early morning and a maximum in the late afternoon (Hafez, 1968). Wrenn et al. (1961) reported elevations in the rectal temperature of animals in the mid morning and afternoon, which declined during early morning and evening. They have reported further that calves had the highest temperatures followed by pregnant cows, normal cows and ovariectomized cows in the declining order.

Many observations were made on the reaction of the rectal temperature of cattle according to varying conditions of ambient temperature and relative humidity by previous workers. Kibler et al. (1950) observed that when Holstein and Jersey cows were subjected to temperatures ranging from 50° to 105°F (10° to 40.5°C) in a climatic chamber, the rectal temperature began to rise at a chamber temperature of 70° to 80°F (21.1° to 26.6°C) and at 105°F (40.5°C) the rectal temperature of Holsteins reached 108°F (42.2°C) and that of Jerseys 106°F (41.1°C). In a similar study Regan (1951) reported a rise in the body temperature when animals were exposed to temperatures above 80°F (26.6°C) in the case of Holsteins and 85°F (29.4°C) in the case of Jerseys and Guernseys. By exposing Brown Swiss and Brahman cows and heifers to increasing temperature from 40°F (4.5°C) to 105°F (40.5°C), Kibler and Brody (1952) observed a rise in the rectal temperature, the rise starting at 80°F (26.7°C) in lactating Brown swiss cows, at 90°F (32.2°C) in both the heifers and at 100°F (37.7°C) in dry Brahman cows.

Alcaide (1953) reported the highest body temperature for Philippine native cattle in May (38.65°C) and the lowest in February (38.37°C). But when the body temperature was compared between the dry and the wet seasons (January-May Vs. June-December) the difference was not significant. There was a significant sex difference in the mean body temperature, as that of males was found to be 38.46±0.021° C and that of females 38.56±0.027°C. Asker <u>et al</u>.(1953) reported that when buffaloes, Egyptian, Jersey, Shorthorn and grade Shorthorn cows were exposed to sun for two hours, the rectal temperature was found increased and the effect was of the highest magnitude in buffaloes and the lowest in Egyptian cows. They have also reported a significant positive correlation between air temperature and rectal temperature.

Findlay (1953) has reported the combined effect of temperature and humidity on rectal temperature of Ayreshire calves. Upto 30°C at low or high humidity no significant effect was noticed on rectal temperature. Above 30°C the rectal temperature commenced to rise. The discomfort noticed was more at high ambient temperature in high relativ humidity than that in low relative humidity. When Jersey and Jersey x Sindhi (F1) crossbred cows were exposed to ambient temperature of 105°F (40.5°C) and 34 mm Hg vapour pressure, McDowell *et al.*(1953) observed an increase in the rectal temperature of all the animals, the increase being more pronounced in the Jersey than the crossbreds. In a similar study with Australian Illaware Shorthorn (A.I.S) and Jersey cows, Robinson and Klemm (1953) reported a noticeable rise in rectal temperature with an ambient temperature above 95°F (34.9°C) and the rise in the rectal temperature parallelled rise in humidity. Johnston and Branton (1954) reported a significant seasonal difference in the rectal temperature of Holstein, Guernsey and Jersey bulls in the Gulf coast area. Comparing the effects of weather conditions on buffaloes, Friesian cows and calves, Alim and Ahmed (1956) reported a significant relation between body temperature and air temperature in the case of Friesians where as in the case of buffaloes, they observed no significant relation between those two parameters.

The rectal temperatures of Holstein, Jersey and Indian cows of the same weight as the Jerseys, rose to 108°F (42.2°C), 106°F(41.1°C) and 105°F (40.5°C) respectively, when exposed to an ambient temperature of 105°F(40.5°C) (Brody, 1956). Among them the Indian cows were found to be the most heat tolerant. Johnston (1958) reported an increase in rectal temperature of animals exposed to high ambient temperature, without prior adaptation. In a study conducted with exotic crossbreds and Indian breeds of cattle, Mullick and Kehar (1958) have reported a positive correlation between air temperature and rectal temperature.

Many workers have reported increase in the rectal temperature of animals exposed to high environmental temperatures both in climatic chambers and outside (Bianca, 1959 a and b, Harris et al. 1960; Williams et al. 1960; Bond et al. 1961).

With regards to the combined effects of ambient temperature and relative humidity, Bhatnagar and Choudhury (1960) reported that the rectal temperature was affected by the ambient temperature. Comparing air conditioning of barns with hot weather conditions, Johnston et al.(1960) observed increased rectal temperature for cows maintained under hot weather conditions (ambient temperature of 70-97°F (21.1-36°C) as against 62-72°F (16.6-22.2°C) in the air conditioned barn). Mullick (1960) reported a decrease in the rectal temperature of cows during summer months when the humidity was high.

Based on a study of the influence of the roughage ration on dairy cows at high climatic temperatures, Scott and Moody (1960) reported a significantly low body temperature for animals maintained on low roughage ration.

When the effects of air temperature, wind velocity, solar radiation and vapour pressure on the responses of cattle were compared, Shrode et al. (1960) reported that air temperature was the most important environmental variable producing summer stress in cattle. Johnson et al. (1961) reported 2.55°C rise in the rectal temperature of animals exposed to ambient temperature of 88°F (31.1°C) as against an exposure to 65°F (18.3°C). Raghavan and Mullick (1961) reported higher rectal temperature in buffalo bulls with the rise in the air temperature. Thompson et al. (1962) reported an adverse effect of high ambient temperature on rectal temperature. Van Arsdel and Bogart (1962) have also reported an association between ambient temperature and rectal temperature.

Bianca (1963) reported that the rectal temperature response of animals can be used as an indicator of the heat tolerance of animals since that gave the clearest and most consistent reaction of animals to heat stress. Thompson et a (1963) reported a rise in the rectal temperature of Holstein heifers following initial exposure to a hot environment, (75-95°F) (23.9-34.9°C) and thereafter a decline on continuous exposure. According to the report of Rao and Mullick (1965) changes in the ambient temperature is a major cause in bringing out changes in the body temperature of kids, humidity having the least influence. But Riggs (1966) has reported that atmospheric temperature is significantly correlated with body temperature of animals maintained at warm, humid areas. In a study of the influence of environmental temperature on calorigenesis of dairy cattl Yousef and Johnson (1966) and Moody et al. (1967) have reported a significant increase in the rectal temperature of cows when exposed to high ambient temperature (32°C) indicating a serious disturbance in the cows' thermal equilibrium. A highly significant positive correlation between rectal temperature and ambient temperature was reported by Pandey and Roy (1969) in buffalo cows. Studying the responses of Hereford and Brahman x Hereford steer calves to the climatic environment, Riggs (1969) has reported that of all the climatic factors studied, atmospheric temperature had the greatest association with body temperature of animals. Taneja (1969) has reported increase in rectal temperature of Marwari sheep with increasing environmental temperature.

By subjecting steer to summer (32°C and 58 to 92% RH) and winter (7°C and 58 to 92% RH) environments in a climatic chamber and three rations - high (73% TDN) Medium (67% TDN) and low (61% TDN) energy - Klett and Schilling (1970) observed that the body temperature of the animals tended to parallel increases in atmospheric temperature. Humidity did not appear to have an effect until the temperature rose to 25°C and above. Maust and McDowell (1971) have reported that more than 61 per cent of the variation in body temperature of cows was associated with the climatic variables when exposed to environments having mean daily temperature exceeding 27°C and relative humidity more than 60 per cent. When sheep were exposed to a hot environment (32°C and 88% RH) Hussain and Bhattacharya (1973) observed significant increase in the rectal temperature of the animals, compared to a cooler environment (22°C and 65% RH) and the effect was more in the animals fed a high roughage ration. Morrison <u>et</u> <u>al</u>. (1973) reported a significant reduction in the rectal temperature of cattle exposed to a temperature of 27°C and more, when sprinkled with water for one minute at an interval of 30 minutes. Comparing Scotch Highland and Zebu breeds of cattle, Olbrich <u>et</u> <u>al</u>. (1973) noticed increase in the rectal temperature of the Scotch Highland heifers when the atmospheric temperature was raised from 9°C to 31°C. Increase in the rectal temperature of Jersey cows exposed to an air temperature of 30°C was reported by Bandaranayaka and Holmes (1976).

Joshi <u>et</u> <u>al</u>. (1977) reported significant increase ($P < 0.01$) in the rectal temperature of Jamnapari bucks exposed to a controlled heat stress environment (45°C dry bulb temperature and 13.4 mm Hg. vapour pressure).

Respiration

Increased respiratory activity is an important means of heat dissipation in domestic livestock at high temperatur That was usually the first visible sign of response to heat stress, and was placed third in the sequence of adaptive reactions, as the unnoticed processes of vasodilation and sweating usually occured earlier (McDowell, 1972). Increasing the rate of respiration causes an increased dissipation of heat in two ways; at first by warming the inspired air and secondly by increasing evaporation from the respiratory passages and lungs. The greater the volume of air that could be breathed in, warmed and humidified, the greater the resultant heat loss.

The reaction of breathing to heat, is assumed to fall in two phases. In the first phase, respiratory rate increases (in cows to a maximum of 200 per minute) while the breathing becomes shallower. In the second phase, the opposite occurs and the air turnover increases. The change over from the first to the second phase took place in adult cattle at rectal temperatures of about 40.5°C (Herz and Steinhauf, 1978). Following exposure to severe heat stress, the respiration rate of calves rose rapidly at first from 88 to a maximum of 218 per minute and then fell to 167 per minute while breathing at first became shallower and then deeper. The change over took place at a rectal temperature of 40.6°C (Bianca, 1958).

The effect of the thermal environment on the respiration rate has been widely investigated for cattle, in the field as well as in the laboratory. Kibler et al. (1950) have shown that the respiratory rate of cattle enhanced with increasing air temperature in the range of 50° to 105°F (10° to 40.5°C),the visible rise in Holstein cows beginning at 60°F (15.5°C) being the steepest between 70°F (21.1°C) and 80°F (26.6°C) and reaching 3 to 4 times the level of 50°F (10°C) at 95° to 105°F (34.9° to 40.5°C); the rise in the Jersey cattle began at 70°F (21.1°C) and at 100°F (37.3°C) reached a level, 5 to 6 times more than the level at 50°F (10°C). Regan (1951) reported a double fold increase in respiration rate in Jersey and Guernsey cows for each 20°F (11.1°C) increase in the ambient temperature from 32° to 80°F (0° to 26.6°C). Sementovskaja and Garkavi (1951) reported a decline in the respiration rate of cows exposed to cooler temperatures (-0.2° to -13°C)

When Brown Swiss and Brahman cows and heifers were subjected to air temperature in the range of 40° to 105°F (4.4° to 40.5°C) Kibler and Brody (1952) observed steep rise in the respiration rate of all animals at an air temperature of 70°F (21.1°C) the rise being more rapid in the Brown swiss heifers. Rates as high as 160 and 130 were attained in the B.S. and Brahman heifers, respectively. Though the pattern of respiration rate was similar for cows, the maximum rate was not so high. Alcaide (1953) has reported the highest respiration rate for Philippine native bulls under natural environment as 29.1 per minute in May and the lowest as 26.0 per minute in January. He observed no difference in the respiration rate between the wet (June-December) and dry (January-May) seasons.

In an experiment with buffaloes, Egyptian, Jersey, Shorthorn and grade Shorthorn cows, Asker et al. (1953) noted increased respiration rate in all the animals following exposure to sun, the increase being the highest in pure Shorthorns and the least in the buffaloes. They have also reported that changes in the ambient temperature had a greater effect than changes in relative humidity. Findlay (1953) reported four to five times increase in the respiration rate of Ayreshire calves from the normal rate, when they were exposed to ambient temperature ranging from 30° to 40°C and low humidity, the maximum values being obtained at 40°C.

Comparing the respiratory activity of Jersey and Sindhi x Jersey (F1) crossbred cows, following exposure to 105°F (40.5°C) ambient temperature and 34 mm Hg.vapour pressure, McDowell et al. (1953) observed increased respiratory activity in both the breeds, the reaction being more prominent in the Jerseys. Robinson and Klemm (1953) have reported increased respiratory activity in a group of Australian Illawara Shorthorn cows following exposure to a hot and humid environment. When compared with a group of Jersey cows of similar status, the respiration rate was found to be increased in both the breeds following exposure, the increase being more pronounced in A.I.S. cows. Significant seasonal differences in the respiration rate of dairy bulls has been reported by Johnston and Branton (1954).

The respiratory reactions of 4 months old Ayreshire calves following exposure to varying combinations of ambient temperature and relative humidity have been reported by Beakley and Findlay (1955). Accordingly, the respiration rate of all the calves increased with increasing environmental temperature and humidity, the magnitude of the maximum value varying linearly with environmental temperature by 4.9 respirations per minute per °C. Ambient temperatures of 30° and 35°C at high humidity had the same effect on respiration rate as 33° and 46°C at low humidity. Significant effect of weather conditions on respiration rate of buffaloes and Friesian cows and calves has been reported by Alim and Ahmed (1956), the ambient temperature being significantly correlated with the respiration rate.

In a study of the respiratory activity of calves subjected to thermal stress, Findlay (1956) observed respiratory frequencies of 70, 120 and 140 per minute following exposure to ambient temperatures of 20°, 30° and 40°C. Johnston (1958) reported that there is a marked increase in the respiration rate of dairy cows subjected suddenly to hot weather without prior adaptation. Mullick and Kehar (1958) reported significant positive correlation between respiration rate and atmospheric temperature, in a group of exotic crossbred and Indian zebu cows. Following exposure of Ayreshire calves in a climatic chamber, to 45°C dry bulb temperature and 28°C wet bulb temperature with 28 per cent RH, Bianca (1959 a) observed rapid rise in the respiration rate from 63 per minute to 180-215 per minute.

Bhatnagar and Choudhury (1960) reported that respiratory rate of buffalo calves is the physiological reaction most sensitive to changes in ambient temperature. Increased respiration rate was noticed when lactating Holstein and Jersey cows were exposed to direct solar radiation (Harris _et al._, 1960). But air temperature variation was found to be the predominant cause of variation in respiration rate while solar radiation was of considerable importance as a direct cause of increase respiration rates of animals exposed to the sun. Comparing the performance of cows in an air conditioned barn (temp.62° to 72°F)

(16.6° to 22.2°C) with those in a shade barn (temp. 70° to 97°F) (21.1° to 36.1°C) Johnston *et al.* (1960) observed increased respiration rates for cows under hot conditions.

Mullick (1960) reported that the respiration rate of cattle and buffaloes remained unchanged during the summer months under low and high humid conditions. The report was based on a study conducted for three years on groups of cattle and buffaloes of both sexes.

Scott and Moody (1960) have reported a decline of 14.1 respirations per minute for cows maintained on a low roughage ration as against, those maintained on a high roughage ration, both groups being exposed to hot environment (80°F (26.6°C) minimum temperature and 105° to 110°F (40.5° to 43.3°C) maximum temperature). Shrode *et al.*(1960) have reported that a satisfactory explanation for variation in respiration rate of animals can be accomplished with air temperature taken as the independent variable. In a study of the influence of solar radiation, air temperature, vapour pressure and wind velocity on the physiological responses of dairy heifers, Williams *et al.* (1960) observed that the respiration rate was affected more by solar radiation than by the other weather influences. Johnson *et al.* (1961) have reported an increase of 28.84

respirations per minute in the case of cows exposed to ambient temperature of 88°F (31.1°C) in relation to those exposed to 65°F (18.3°C) ambient temperature. Statistically significant increase in the respiration rate of buffalo bulls exposed to high ambient temperature has been reported by Raghavan and Mullick (1961).

Comparing the effect of two housing systems on the physiological reactions of buffalo cows, Misra et al. (1962) have reported significant positive correlation between respiration rate and ambient temperature where as the effect of relative humidity was not significant. Thompson et al. (1962) also have reported significant adverse effect of hot conditions (75° to 90°F) (23.9° to 32.2°C) on the respiration rate of animals. In a study conducted by Thompson et al. (1963) the respiration rate of Holstein heifers was found to rise following initial exposure to hot (75°-95°F) (23.9°-34.9°C) conditions and then declined on continuous exposure.

Rao and Mullick (1965) have reported variations in the respiration rate of kids with the slightest variation of air temperature, relative humidity having least effect on respiration rate. Atmospheric temperature had significant positive correlation with respiration rate of Hereford steers, irrespective of altitude, rainfall and relative humidity of the locations (Riggs, 1966). Yousef and

Johnson (1966) have reported significant increase in the respiration rate of cows when exposed to ambient temperature of 32°C. Significant increase in the respiration rate of buffalo cows during summer has been reported by Pandey and Roy (1969). Comparing Hereford with the F1 Brahman x Hereford steer calves, Riggs (1969) reported significantly higher respiration rate for Herefords than crossbreds and of the climatic variables, atmospheric temperature had the greatest association with the respiration rate.

In a study of the physiological reactions of adult Marwari sheep during the period of one year, Taneja (1969) reported significant increase in the respiration rate of the animals with an increase in the ambient temperature. Klett and Schilling (1970) have shown that the respiration rate of steers tended to parallel increases in air temperature while humidity did not appear to have an effect until the temperature rose to 25°C and above. Higher ambient temperature increased the respiration rate of sheep and the influence was more pronounced in animals fed with a high roughage ration. (Hussain and Bhattacharya, 1973). In a study conducted by Morrison et al. (1973) it was shown that sprinkling cold water for one minute at every 30 minutes interval or housing in a refrigerated air conditioned barn during hot hours (temp. above 27°C) resulted in a lowered respiratory rates of steers.

Olbrich et al. (1973) have reported increase in the respiration rate of Zebu and Scotch high land heifers when exposed to increasing ambient temperature (9°-31°C) Bandaranayaka and Holmes (1976) also have reported increased respiration rate of Jersey cows subjected to increasing ambient temperature (15° and 30°C). Significantly increased respiration rate of Jamnapari bucks exposed to controlled heat stress (45°C dry bulb temperature and 13.4 mm Hg vapour pressure) have been reported by Joshi et al. (1977).

In a study of the respiratory responses of N'Dama and Boran cattle to climatic conditions in Nigeria, Yassen (1977) has reported that the respiration rates were closely associated with the ambient temperatures, the highest respiration rate being recorded at 14.00 hours when the air temperature was at the maximum.

Dry matter intake

Feed consumption (dry matter intake) is regulated by the hunger centre. The amount of food consumed is at least partly determined by the organisms ability to give off the heat produced by that food. The effect of the amount of feed consumed on metabolic heat and on heat tolerance depends partly on the quality of the feed. Herz and Steinhauf (1978) reported that a low crude fibre ration increased heat tolerance.

One of the first noticeable responses of most livestock to thermal stress was a decrease in food intake, the extent of the depression being directly related to the level of stress (McDowell, 1972). Kibler et al. (1950) have reported decline in the heat production of Jersey and Holstein cows subjected to increasing air temperature in a climatic chamber. The decline was noticed at chamber temperatures of 80°F (26.6°C) and above and that decline in heat production with rising ambient temperature was explained by referring to the rapid reduction in feed consumption above 80°F (26.6°C). Ragsdale et al. (1950) reported that increasing chamber temperature from 80°F to 95°F (26.6°C to 34.9°C) depressed feed consumption of Jersey and Holstein cows.

Comparing the responses of Brahman, Jersey and Holstein cows to changes in temperature, 50° to 105°F (10° to 40.5°C) and 50° to 8°F (10° to 13.3°C), Ragsdale et al. (1951) noted decline in the feed consumption of all the animals with increasing ambient temperature, the decline beginning at 75°F (23.9°C) in the European and 95°F (34.9°C) in the Brahman cows. Similarly, a declining temperature increased the hay dry matter intake of all the animals. Regan (195 also has reported a fall in the appetite of cows subjected to temperatures above 80°F (26.6°C).

In a comparative study of the responses of Brahman and Brown Swiss cows and heifers to heat stress, Ragsdale *et al.* (1952) observed the following changes. When the temperature had increased from 40° to 105°F (4.4° to 40.5°C), Brahmans maintained their initial level of feed consumption upto 100°F (37.7°C) whereas that of the Brown Swiss declined from 27 lb TDN at 80°F (26.6°C) to 2 lb at 105°F (40.5°C).

Johnston *et al.* (1957) reported that the dry matter intakes of two groups of cows - one kept in a climatic chamber at 70°F (21.1°C) and 15 mm Hg vapour pressure and the other kept in an open barn or pasture with tree shade at mean maximum temperature of 92.7°F (33.7°C) minimum temperature of 70°F (21.1°C) and vapour pressure of 19.7 mm of Hg - were 25.4 lbs and 25.2 lbs respectively.

Dipression in the feed consumption of cows subjected to hot weather has been reported by Johnston (1958). MacDonald and Bell (1959) have reported increased feed intake in cows exposed to declining ambient temperatures.

The stress enforced on the animal by a higher ambient temperature and a high level of relative humidity was much more than that caused by a low ambient temperature and high humidity or a high ambient temperature and low humidity. Thus Davis and Merilan (1960) observed that environments of 80°F (26.6°C) and 80 per cent relative humidity, 90°F (32.2°C) and 20 per cent relative humidity and 65°F (18.3°C) and 50 per cent relative humidity had very little effect on feed intake and digestability in a group of Holstein cows. But environments of 90°F (32.2°C) and 40 per cent relative humidity and 90°F (32.2°C) and 50 per cent relative humidity decreased the dry matter intake by 5.07 lb and 6.72 lb respectively, less than that of the animals maintained under normal environment.

By subjecting sheep to two temperature conditions (20° to 40°F Vs. 70° to 78°F) (-6.6° to 4.4°C Vs. 21.1° to 25.5°C) Choi and Butcher (1961) observed that the feed consumption of the two groups were 3.3 lb and 2.7 lb per day per sheep, respectively, the differences being highly significant. Quoting Brody and associates, Findlay (1961) reported that there was a rapid depression in the feed consumption of European cattle when the air temperature exceede 75°F (23.9°C). In a study of the factors affecting food and water intakes of European (Shorthorn) and Zebu (Boran) cattle, Horrocks and Phillips (1961) have reported that the feed intake did not vary significantly between the different seasons.

When Jersey, Holstein and Red Sindhi x Holstein crossbred heifers maintained in a cool atmosphere (60°-70°F) (15.5° to 21.1°C) were exposed to a hot atmosphere (75°-95°F) (23.9° to 34.9°C) for 40 days, Johnston et al.(1961) could observe a decline in dry matter intake during the first 20 days exposure, which rose to the normal level during the second 20 days. Johnson et al. (1962) have reported that among 31 weather measurements studied, the dry bulb temperature and maximum temperature had the most significant influence on the responses of the animal and they significantly reduced the feed consumption of the anima when elevated. Misra et al. (1962) have reported a 30.5 per cent decline in the fodder consumption of the buffalo cows when the ambient temperature exceeded 93.5°F (34.2°C). Reduction in the feed dry matter intake of cows under high ambient temperature has also been demonstrated by Wayman et al.(1962). Johnson et al.(1963) have reported that ambient temperature above 80°F (26.6°C) with varying combinations of relative humidity (25 per cent - 80 per cent) caused significant decline in the TDN consumption of lactating Holstein cows. They have reported an inversely proportional relationship between TDN consumption and rectal temperature, showing a 3 lb loss in TDN consumption for each degree rise in rectal temperature.

Randel and Rusoff (1963) observed that when calves, from birth to 90 days of age, were subjected to an environment of 70° to 95°F (21.1° to 34.9°C) ambient temperature and 20 mm Hg vapour pressure there was a significant reduction in their dry matter consumption compared to that of a control group subjected to a cooler environment. A similar observation was made by Thompson *et al*. (1963) when Holstein heifers were subjected to a cool (38°-65°F) (3.3°-18.3°C) and a controlled hot (75° to 95°F) (23.9° to 34.9°C) environments. Average daily feed consumption of these animals decreased from 15.7 lb to 14.7 lb.

Sims and Porter (1966) have reported that the dry matter intake of Holstein Friesian cows were depressed by 90 per cent and 71 per cent of the intake at temperature less than 75°F (23.9°C) by an ambient temperature more than 75°F (23.9°C) and 80°F (26.6°C) respectively, with a significant correlation of -0.36 between daily mean temperature and forage dry matter intake. Yousef and Johnson (1966) have reported 50 per cent reduction in the feed intake of Holstein cows subjected to high ambient temperature (32°C). Marked depression in the feed intake of Holstein cows was reported by Moody *et al*. (1967) when the animals were exposed to a hot environment (32°C and 60% RH) and fed a high fat diet, the effect on the feed intake was found to be indëpendent of the ration effect. In a study of the climatic effects on feed lot performance of steers, Klett *et al.*(1969) have reported that increased ambient temperature was not significantly related to feed intake. But there was significant increase in the feed intake with increase in the humidity of the atmosphere.

Comparing the feed intake of steers during summer (33°C) with that during winter (7°C), Klett and Schilling (1970) have reported significant decline in the feed intake during summer. Ray *et al.*(1970) have reported the average daily feed intake of three groups of steers as 9.39 kg, 9.19 kg and 10.75 kg in a study to evaluate two methods of alleviating heat stress. The maximum ambient temperature during the test period was 47.8°C. The first group had access to shade only (control); in the second group the roof and a portion of the lot was sprinkled with water and in the third group the animals were being cooled by forced movement of precooled air. The feed intake of group I and II did not differ significantly whereas the feed intake of group III showed significant difference from that of the other two groups. Maust and McDowell (1971) have reported that at a temperature of 27°C and 60 per cent relative humidity only 3 per cent of the variation in the feed intake of Holstein cows was associated with weather.

Hussain and Battacharya (1973) have reported that the feed intake of sheep decreased when they were exposed to high ambient temperature and humidity (32°C and 88 per cent, respectively). Sprinkling the cattle at shades during the summer in California or housing in refrigerated air conditioned barns at 24°C resulted in significantly higher feed consumption compared with cattle under shade and not sprinkled (Morrison et al., 1973). When Jersey cows were exposed to two ambient temperatures (15°C Vs. 30°C), Bandaranayaka and Holmes (1976) observed 11 and 21 per cent decrease in the feed intake of the two cows exposed to 30°C temperature compared to that of the cows at 15°C. No significant difference in the feed consumption of Holstein calves was observed by Lucci et al.(1976) when the calves were exposed to two environments (29.5° to 30.6°C air temperature at 62.3 to 70.2% RH Vs. 26.0° to 29.4°C at 52.3 to 68.3% RH). Significant decrease in the food consumption of Jamnapari bucks exposed to heat stress (45°C dry bulb temperature and 13.4 mm Hg vapour pressure) has been reported by Joshi et al. (1977).

Water consumption

The amount of water required by an animal varies with the type of animal, age, stage of productivity, type of feeding and the climatic environment (McDowell, 1972). Variation in water consumption could be regarded as a method of heat regulation. The rate of moisture vaporization from the body increased with increasing ambient temperature, and also tended to increase with increasing metabolic rate and therefore with increasing rates of productive processes and consequently with feed consumption (Hammond, 1954). Water intake was seen fundamentally dependent on water loss, which, in turn, was correlated to ambient temperature and other factors (Hafez, 1968).

Under normal conditions, water consumption appeared directly related to the dry matter intake. In a study of the water intake of lactating dairy cows, Little and Shaw (1978) have reported significant positive correlation between water consumption and dry matter intake.

Water consumption under heat stress conditions has been dealt with in previous studies. Comparing the influence of temperature 50°F to 0°F (10° to -17.7°C) and 50° to 95°F (10° to 34.9°C) on various functions of lactating Jersey and Holstein cows, Ragsdale _et al_. (1950) have reported that water consumption of the animals parallelled feed consumption, with greater individual variation, and tended to increase as temperature rose above 80°F (26.6°C). The tendency of animals to increase their water consumption has been demonstrated by Thompson _et al_. (1950) in an experiment in which six Holstein and six Jersey cows were exposed to temperatures 50°F and 100°F (10°C to 37.7°C) in a climatic laboratory. There was a significant increase in water consumption when the temperature was increased to 100°F (37.7°C) from 50°F (10°C).

Ragsdale _et al_. (1951) have reported that European cattle exposed to high ambient temperatures above 95°F (34.9°C) decreased their water consumption. Whereas, Brahmans exposed to the same temperature increased their water consumption. In all the animals, the frequency of drinking increased with increasing temperature. The same observations have been made by the authors in a later study with Brown Swiss and Brahman cows and heifers (Ragsdale _et al_. 1952).

Water consumption as a function of live weight and dry matter intake, and the unit increase in water consumption with rising ambient temperature were observed by Bailey and Broster (1958) in growing dairy heifers. They have reported positive partial regression coefficients of water consumption on mean temperature and mean live weight. These coefficients indicated that water consumption increase by 0.0355 gal. per °F rise in temperature and 0.0142 gal. per lb increase in live weight. Average water consumption ranged from 6.4 to 9.2 lb per 100 lb live weight.

Harbin _et al_. (1958) have reported significant positive correlation between water intake and ambient temperature, relative humidity having no significant effect on water intake when the ambient temperature was held constant. Bond _et al_. (1961) have reported that the water intake of heifers tended to increase with increasing ambient temperatu

Choi *et al.*(1961) have reported significant difference in the water intake of two groups of sheep - one maintained at 20-40°F (-6.6° to 4.4°C) ambient temperature and the other at 70-78°F (21.1° to 25.5°C) - the intake being more in the high temperature group. Comparing the reaction of European (Shorthorn) and Zebu (Boran) cattle under hot and cold environments, Horrocks and Phillips (1961) have concluded that increasing ambient temperature significantly increased the water intake of the animals, the increase being more obvious in the Shorthorn than the Boran cattle.

When two groups of lactating cows (*ad-libitum* fed Vs. control fed) were exposed to two environments (65°F (18.3°C) 50% RH and 88°F (31.1°C), 50% RH) the water consumption of the *ad libitum* fed animals decreased with increasing ambient temperature and that of the control fed animals increased (Johnson *et al.*, 1961). Johnston *et al.* (1961) have reported 17 per cent increase in the water consumption of heifers exposed to a hot environment (75° to 95°F) (23.9° to 34.9°C) over that at a cooler environment (60-70°F) (15.5° to 21.1°C

Misra *et al.*(1962) have reported that the water intake of buffalo cows increased by 13.5 per cent when the ambient temperature exceeded 93.5°F (34.2°C). Comparing the water intake of lactating cows during the wet and dry seasons in Trinidad, Wilson *et al.* (1962) have observed 24 per cent difference in total water intake between the two seasons. The mean daily intake was 18.5 lb per cow in the wet season. Yousef and Johnson (1966) reported 27 per cent decline in the water consumption of Holstein cows exposed to hot environment (32°C). Moody et al.(1967) have reported significant increase in the water intake of Holstein cows fed high fat ration when subjected to high ambient temperature (32.2°C). McDowell et al.(1969) have reported 28 per cent increase in the water consumption of Holstein cows exposed to 32.2°C ambient temperature. Taneja (1969) has reported that the water intake of Marwari sheep increased with increasing ambient temperature. The same observation has been made by Hussain and Bhatachary (1973) in Awasi sheep. Joshi et al. (1977) have reported that a controlled heat stress (45°C dry bulb temperature and 13.4 mm Hg vapour pressure) compared to a cool environment (18.5°C dry bulb temperature and 9.5 mm Hg vapour pressure), significantly increased the water consumption of bucks.

Growth

Growth is a complex set of metabolic events which are environmentally and genetically controlled (Hafez, 1968). Among the climatic conditions that impose stress on growth ambient temperature and relative humidity are the important ones. The climatic conditions also affect the amount of food and water intake, the availability of the potential energy in the ingested forage, the animals heat production system and the net energy available for productivity, the combined effect of all of them resulting in changes in the growth pattern.

Various workers have reported on the influence of ambient temperature and relative humidity on growth of cattle. Ragsdale et al. (1950) have reported that the body weights of Jersey and Holstein cows were decreased when the temperature of the climatic chamber was increased from 80° to 95°F (26.6° to 34.9°C). Comparing Brahman and European cattle, Ragsdale et al. (1951 and 1952) have reported that increasing temperatures had no effect on the body weight of the Brahmans upto 100°F (37.7°C), but depressed the body weight of European cattle, beginning at 80°F (26.6°C), and decreasing temperature had no significant effect. When cows fed normal rations were exposed to low ambient temperature (-0.2° to -13°C) Sementovskaja and Garkavi (1951) observed decline in the body weight of animal at the rate of 511 g daily. By feeding supplements at the rate of 25-30 per cent of normal diet the animals were able to maintain body weight. Bianca (1959a) has reported that the weight gain of calves exposed to high ambient temperature varied with the heat tolerance capacity of the animal, the gain being the minimum for the least heat tolerant anima

When calves were exposed daily in a climatic chamber to increased ambient temperatures, they lost 2.82 kg body weight on an average, during a single exposure (Bianca 1959

Quoting Brody and associates, Findlay (1961) has reported that when Brahman, Santa Gertrudis and Shorthorn cattle were exposed to environments of 50°F (10°C) and 80°F (26.6°C), the Santa Gertrudis and Brahman cattle were little affected by 80°F (26.6°C) environment as compared with the 50°F (10°C) environment. The elevated temperature had a profound depressive effect on the growth rate of the Shorthorns, them lagging behind the others by almost 200 lb in body weight at 8 months compared with only 50 lb at the same age at 50°F (10°C).

When two groups of lactating Holstein cows (<u>ad libitum</u> fed and control fed) were exposed alternately to two environments (65°F (18.3°C), 50% RH and 88°F (31.1°C), 50% RH). Johnson <u>et al</u>.(1961) observed 35.5 lb decline in the body weight of the <u>ad libitum</u> fed animals on exposure to the hot environment compared to 58.41 lb increase in the body weight of the control fed animals exposed to the same environment. Johnston <u>et al</u>. (1961) reported decline in the average daily gain of dairy heifers exposed to a hot environment (75° to 95°F) (23.9° to 34.9°C).

Comparing the responses of two groups of Holstein calves subjected to either a hot environment (75° to 95°F) (23.9° to 34.9°C), 20 mm Hg vapour pressure) or a cold environment (winter climate), Randel and Rusoff (1963) have reported significantly lower weight gain for the calves subjected to the hot environment. The average daily weight gain of dairy heifers subjected to hot environment (75 to 95°F) (23.9° to 34.9°C) decreased from 1.8 lb at a cold environment (38° to 65°F)(3.3° to 18.3°C) to 1.1 lb (Thompson <u>et al</u>., 1963). In a study of the effect of high fat ration under cool (15° to 24°C and 60% RH) and hot (32.2°C and 60% RH) environments, Moody <u>et al</u>. (1967) observed significant decline in the body weight of the animals when exposed to the hot environment.

Klett <u>et al</u>.(1969) have reported that elevated ambient temperatures had a depressing effect ($P < 0.01$) on total gain of feed lot steers. Comparing the effects of season, sex and hormonal growth stimulants on feed lot performances of beef cattle, Ray <u>et al</u>.(1969) have reported that seasonal differences were the most important source of variation in feed lot performance (Summer Vs. Winter), gains during winter being 14-24 per cent greater than during summer. Taneja (1969) has reported that the body weight of Marwari sheep was high during the rainy season and low during the dry season. Significant difference in the daily gain of steers which were either sprinkled with cold water or directly cooled by the circulation of precooled air with that of steers which had access to shade only during summer in Arizona has been reported by Ray et al. (1970), the gain being higher for the two groups which were cooled.

Morrison et al.(1973) have reported significantly higher rate of gain for cattle sprinkled during summer (temperature above 27°C) to alleviate heat stress.

Wheat (1970) has reported seasonal variations in the body weights of Nigerian cattle, the animals gaining weight during the wet season and losing weight during the dry season. No significant difference has been noticed in the daily gains of two groups of calves maintained under two environments - 29.5° to 30.6°C and 62.3 to 70.2% RH Vs. 26.0° to 29.4°C and 52.3 to 68.3% RH. (Lucci et al., 1976).

MATERIALS AND METHODS

MATERIALS AND METHODS

Location

Mannuthy, Trichur District, Kerala State, the location of the present study is geographically situated

at longitude 76°, 16" E

at latitude 10°, 32" N and

at an altitude of 22.25 metres above MSL.

Meteorological data

The meteorological data over a period of five years from 1974 to 1978 obtained from the Meteorological observatory Unit attached to District Agricultural Farm, Mannuthy were used to study the climatic picture of Mannuthy. Monthly averages of bright sunshine (hours per day), wind velocity (km per hour), maximum and minimum temperature (°C) relative humidity (%) and monthly total rainfall for this period were analysed to focus light on the various facets of the macroclimate at this locality.

Since ambient temperature and relative humidity are the important bioclimatic factors which impose stress on the animals, these and rainfall which affects the animals indirectly through influencing the fed supply are considered as the basis for the classification of the climatic environment.

Experimental animals

Crossbred calves, born and brought up in the University Livestock Farm, Mannuthy were used for the study. Eleven uncastrated male calves of 10-24 (Mean 17 months) months of age and five female calves of seven months of age were selected and stationed inside a conventional cattle shed.

Housing of animals

The conventional cattle shed in which the animals were housed comprised of concrete floor with tile roof and was well lighted and ventilated.

The animals were tied in a single row with double ropes to facilitate individual feeding and watering.

Feeding and watering

The feed given included a commercial concentrate mixture (pellets) and green grass or silage according to the availability. The concentrate ration was fixed in excess of their requirements, based on Morrison standards (Morrison, 1954) and fodder and water were given *ad libitum*.

Measured quantity of the concentrate was given individually in buckets at 7.30 a.m. immediately after noting the rectal temperature and respiration rate. All the animals consumed the entire quantity of concentrate offered to them by about half to one hour. If at all any quantity had been left over, it was offered after watering and was readily consumed.

Water was offered <u>ad libitum</u>,two times a day - by 8.30 a.m. in the morning and 2.30 p.m. in the afternoon. Measured quantity was offered and the actual quantity consumed was recorded.

Fodder was fed <u>ad libitum</u>. It was offered in two halves - one in the morning at 10 a.m. and the other in the evening by 4.30 p.m. Weighed quantity of fodder was offered and the quantity left over in each session of feeding was weighed seperately, to record the actual quantity consumed. The fodder left over in the morning feeding was weighed by 3.30 p.m. and that of the evening feeding was weighed in the early morning of the next day.

All the animals were washed daily soon after the concentrate feeding and watering.

Observations

The rectal temperature, respiration rate, dry matter intake, water consumption and body weight of the animals were observed over a period of 12 months, from July 1978 to June 1979.

The rectal temperature and respiration rate of the animals were recorded two times daily - at 7.a.m. in the morning and at 2 p.m. in the afternoon. The actual quantity of feed (concentrate as well as roughage) and water consumed were also recorded. All these observations were made for six consecutive days in a month. The dry matter content of the concentrate as well as roughage fed was estimated on these days to assess the actual dry matter intake.

Body weights of the animals were recorded before the commencement of the study and then every month.

The maximum and minimum temperature and the relative humidity inside the shed where the animals were housed, were recorded daily throughout the experimental period.

Analysis of data

Correlations between the animal responses and the two important climatic variables - maximum temperature and relative humidity - were worked out to know the relationship between them. The regression of the animal responses on the climatic variables were also worked out to have an idea of the extent of influence the climatic variables have on the animal responses, under the conditions of the present study. Statistical methods of analysis of correlation and regression were worked out as suggested by Snedecor and Cochran (1967).

RESULTS

RESULTS

The climatic data over the period from 1974 to 1978 are presented in Table 1.and represented in Fig. 1. The climograph and hythergraph of Mannuthy, based on the above data are shown in Fig.2 and 3, respectively.

The classification of the climate of the locality is shown in Fig.4, taking into account the monthly distributions of ambient temperature, relative humidity and rainfall.

The mean daily ambient temperature and relative humidity during the period of this study (July, 1978 to June 1979) is presented in Table 2 and is represented in Fig.5.

Table 3 presents the mean daily rectal temperature of the animals, observed during the study and the mean daily respiration rates observed during this period is presented in Table 4. The effects of the monthly changes in ambient temperature and relative humidity on the above two physiological norms is prepresented in Fig. 6-10.

The average daily dry matter intake and the dry matter intake as a percentage of the body weight are presented in Tables 5 and 6 respectively. Fig. 11 and 12 represent the influence of ambient temperature and relative humidity on dry matter intake.

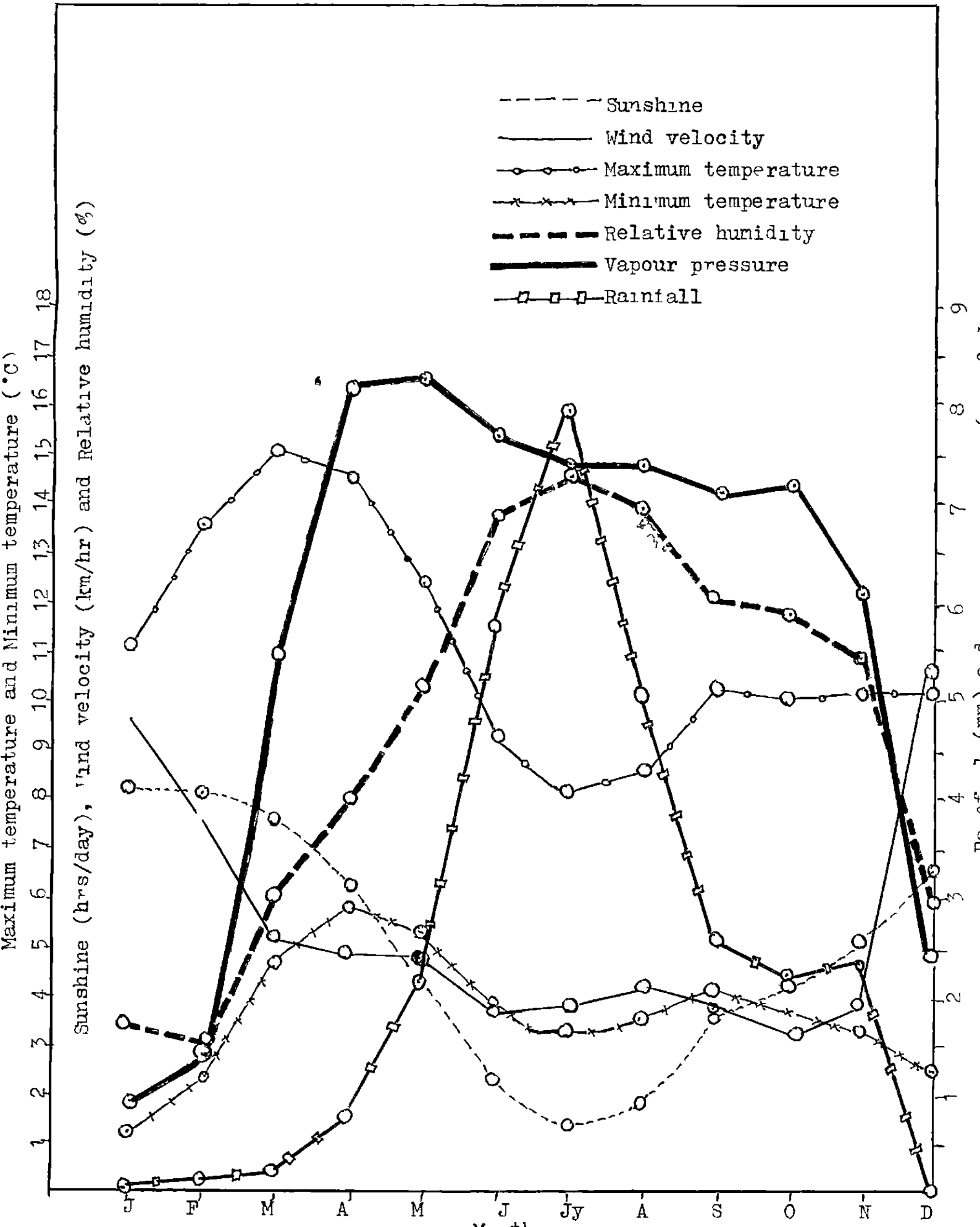
The mean daily water consumption and water consumption expressed as a function of the dry matter intake are shown in Tables 7 and 8 and fig. 13 and 14 represent the influence of ambient temperature and relative humidity on these two observations.

Tables 9 and 10 present the mean monthly body weight and monthly weight gain of the animals during the study. The influence of the climatic elements on monthly weight gain are shown in Fig. 15.

The correlation and regression coefficients have been worked out taking ambient temperature and relative humidity as the independent variables and rectal temperature, respiration rate, dry matter intake, water consumption and body weight as the dependent variables. The values are presented in Tables 11 to 19.

Table 1. Five year monthly average of meteorological data at Mannuthy (Latitude 10° 32"N; Longitude 76° 16"E; Altitude 22.25 meter above MSL)

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
No. of hours of bright sunshine (daily ave.)	8.16	8.11	7.64	6.29	4.44	2.31	1.38	1.67	3.61	4.15	5.21	6.69
Wind velocity km. per hour (daily ave.)	9.67	7.66	5.16	4.85	4.78	3.72	3.75	4.17	3.82	3.19	3.86	10.62
Maximum temperature °C (daily ave.)	31.14	33.63	35.14	34.55	32.35	29.26	28.15	28.55	30.25	30.13	30.23	30.21
Minimum temperature °C (daily ave.)	21.15	22.89	24.65	25.80	25.27	23.84	23.28	23.62	24.06	23.67	23.27	22.52
Relative humidity % (daily ave.)	58.49	57.54	64.98	70.03	75.68	84.39	86.52	84.92	80.26	79.60	77.92	64.84
Vapour pressure mm of Hg (daily ave.)	15.36	15.88	19.95	22.68	22.79	22.23	21.89	21.89	21.60	21.70	20.61	16.87
Rainfall mm (monthly total)	Nil	10.06	21.16	76.62	220.08	581.48	796.44	511.62	260.76	220.34	242.34	9.10


Sunshine
Wind velocity
Maximum temperature
Minimum temperature
Relative humidity
Vapour pressure
Rainfall
Maximum temperature and Minimum temperature (°C)
Sunshine (hrs/day), Wind velocity (km/hr) and Relative humidity (%)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
1 2 3 4 5 6 7 8 9
J F M A M J Jy A S O N D

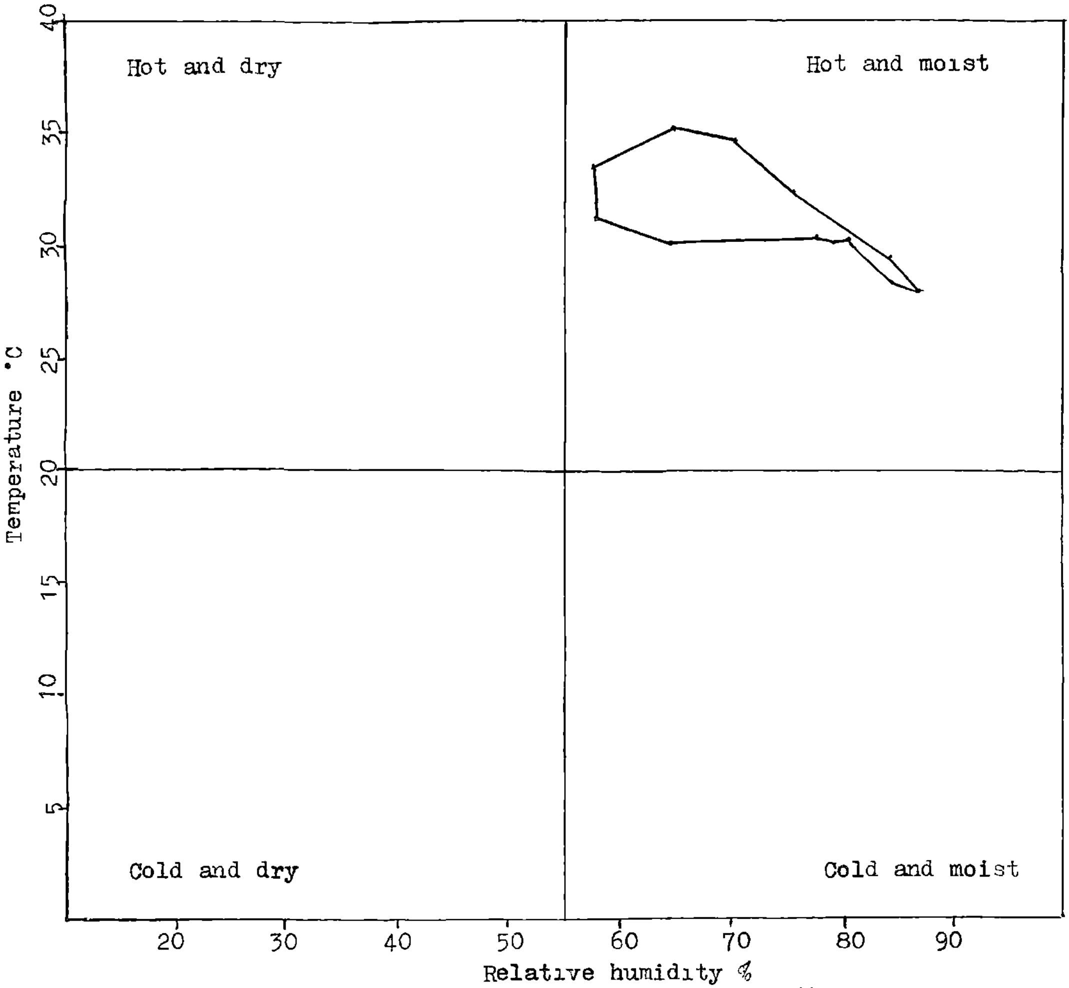
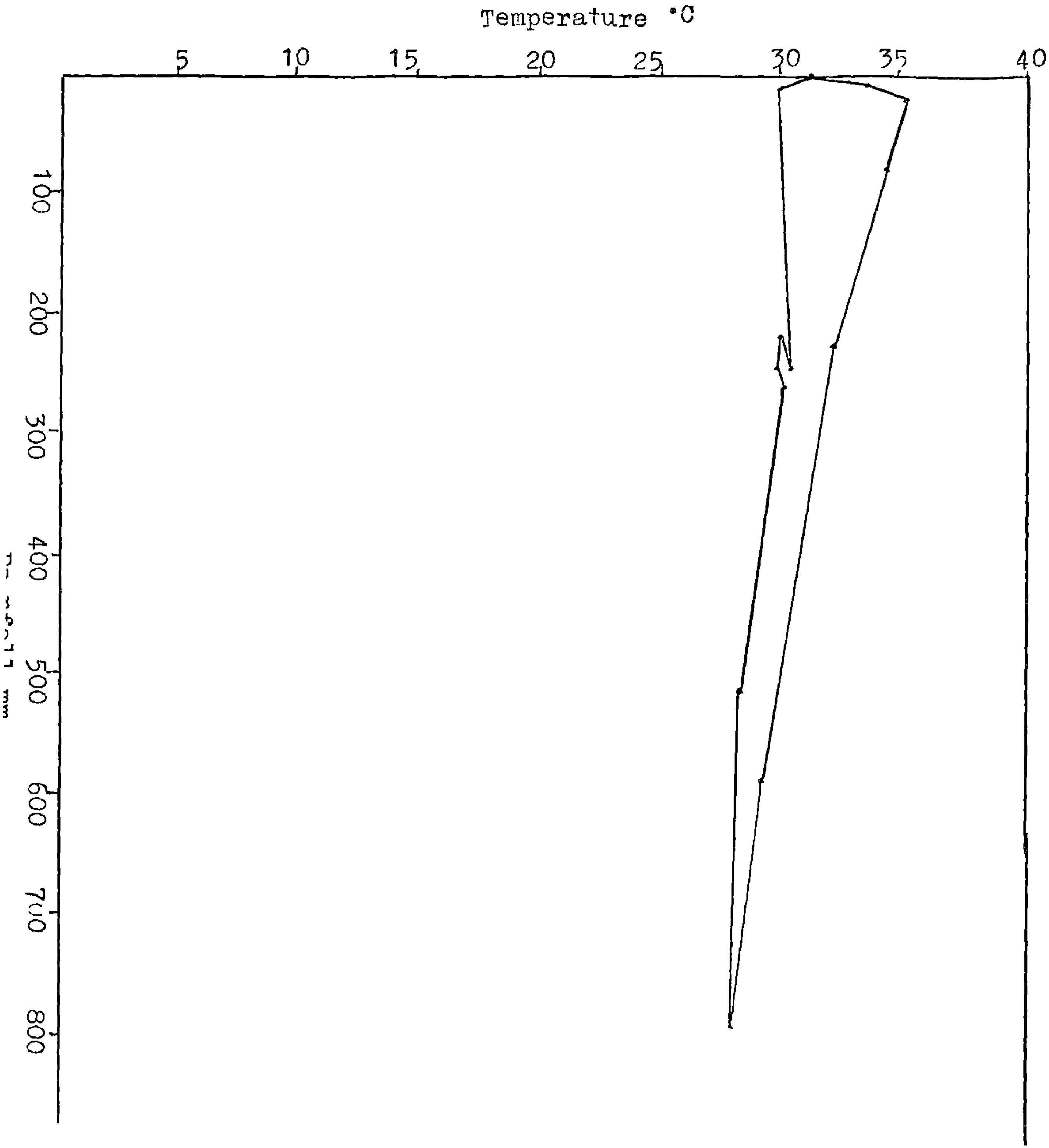


Fig. 2. Climograph of Mannuthy



Temperature °C
5
10
15
20
25
30
35
40
100
200
300
400
500
600
700
800

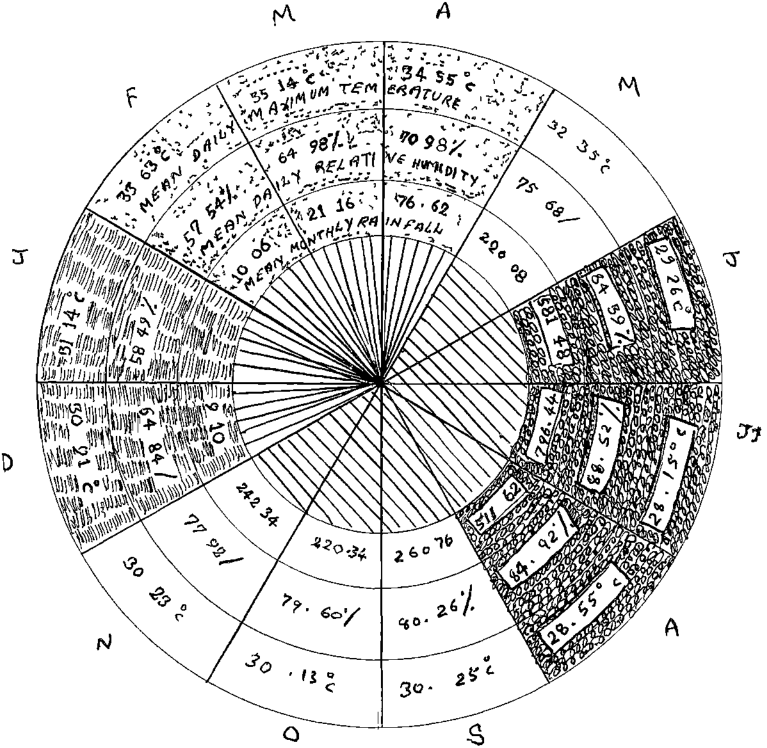


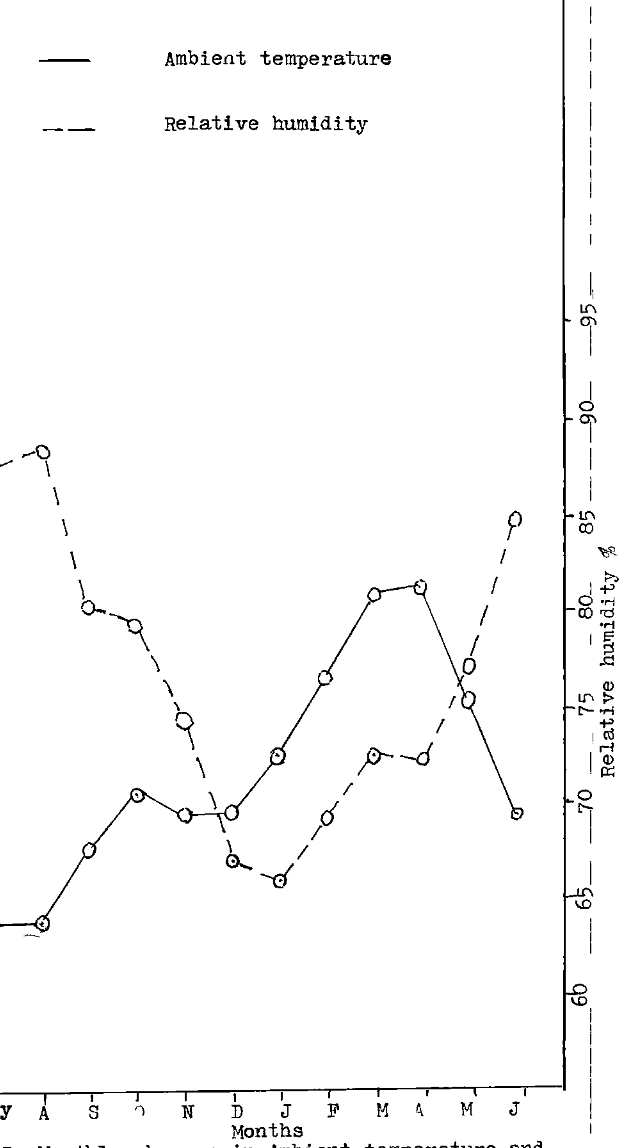
Fig. 4. Classification of the climate at Mannuthy.

<u>Rainy season</u> May to November
- Cold and wet (June to August)
- Warm and wet (May and Sept. to Nov.)

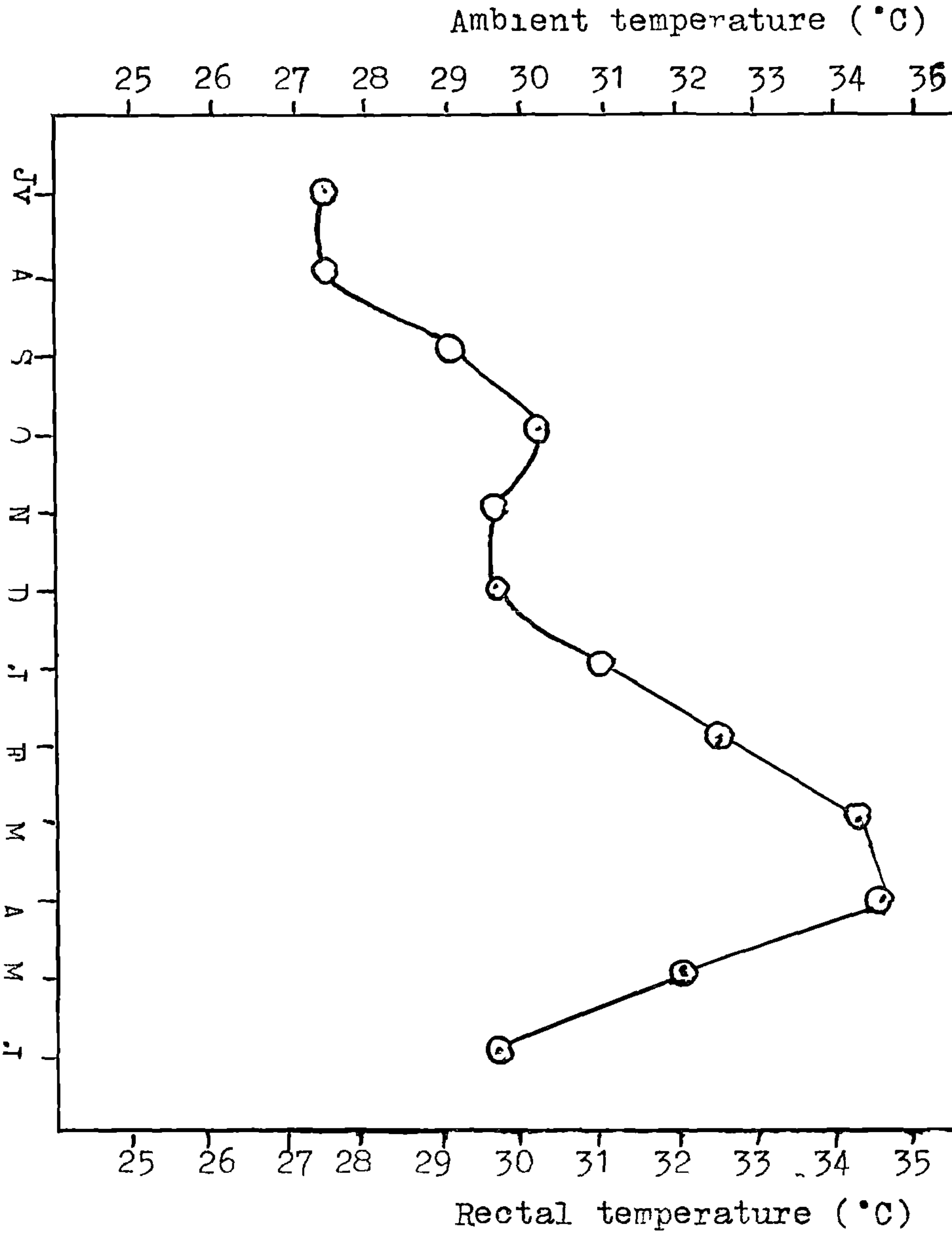
<u>Dry season</u> December to April
- Warm and dry (December and January)
- Hot and dry

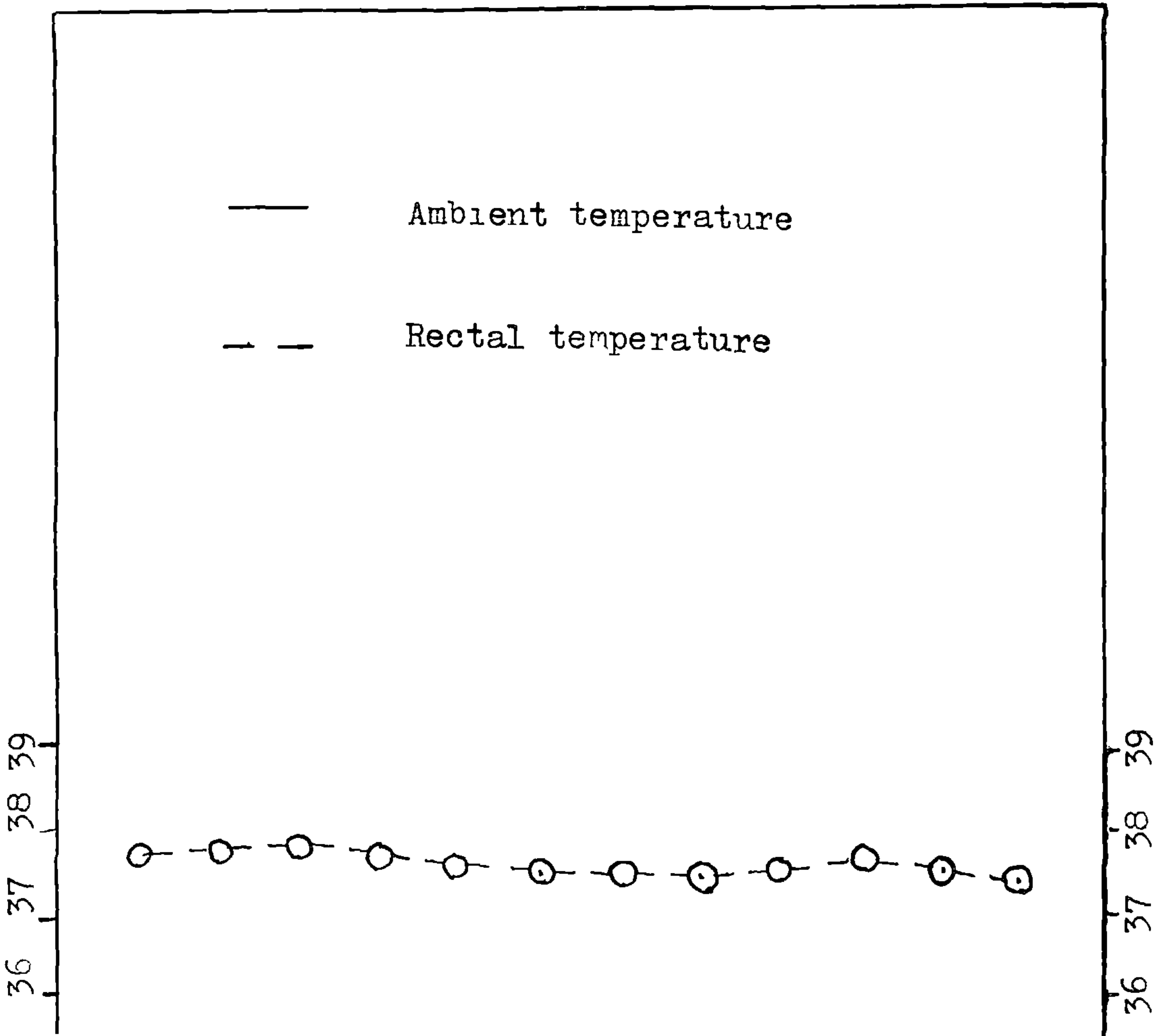
Table 2. Mean daily maximum temperature (°C) and relative humidity (%) during the period from July 1978 to June, 1979.

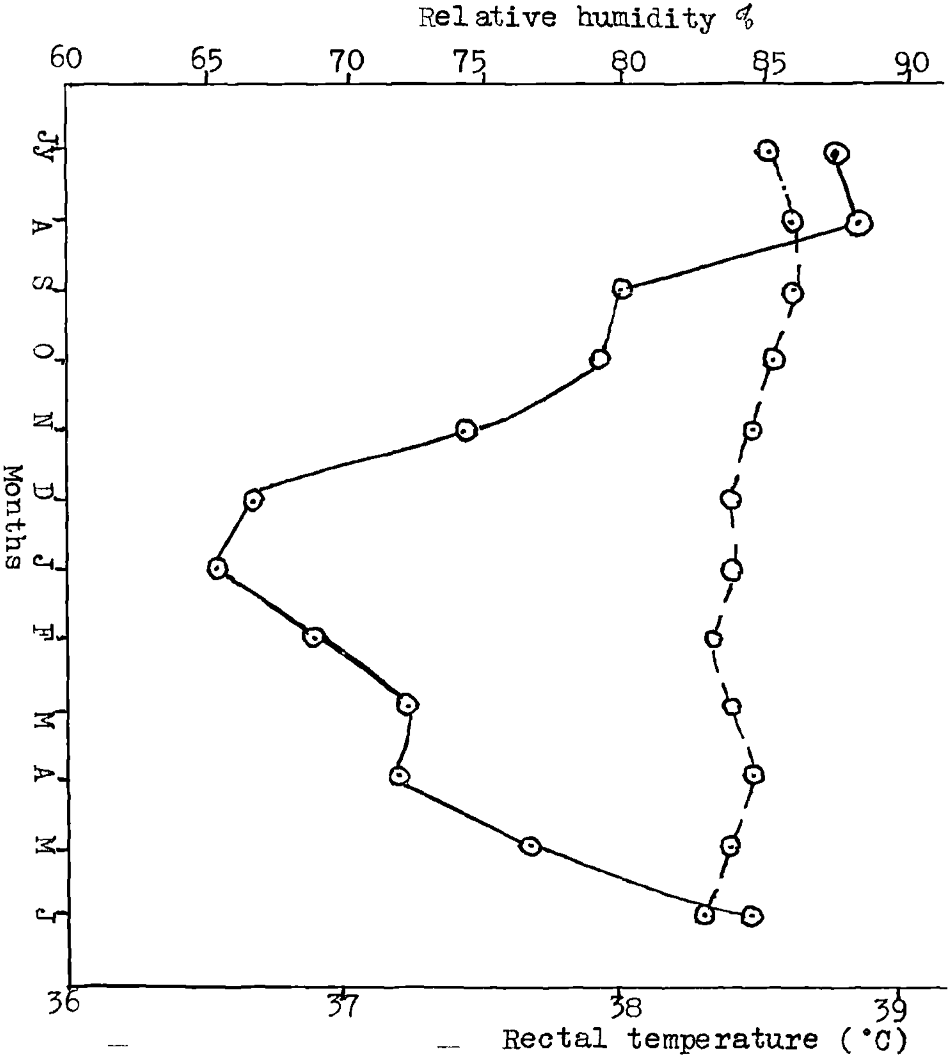
MONTH	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	MAY	JUNE	MEAN
Maximum tempera- ture	28.45	28.46	30.09	31.24	30.70	30.73	32.00	33.55	35.33	35.53	33.08	30.68	31.653 ±0.486
Relative humidity	87.61	88.53	80.02	79.42	74.57	66.90	65.84	69.29	72.48	72.23	77.05	84.78	76.56± 0.645



5. Monthly changes in Ambient temperature and Relative humidity


Ambient temperature (°C)
25 26 27 28 29 30 31 32 33 34 35
Jy
A
S
O
N
D
J
F
M
A
M
J
25 26 27 28 29 30 31 32 33 34 35
Rectal temperature (°C)


Ambient temperature
Rectal temperature
36
37
38
39
36
37
38
39


Relative humidity %
60
65
70
75
80
85
90
Jy
A
S
O
N
D
J
F
M
A
M
J
Months
36
37
38
39
Rectal temperature (°C)

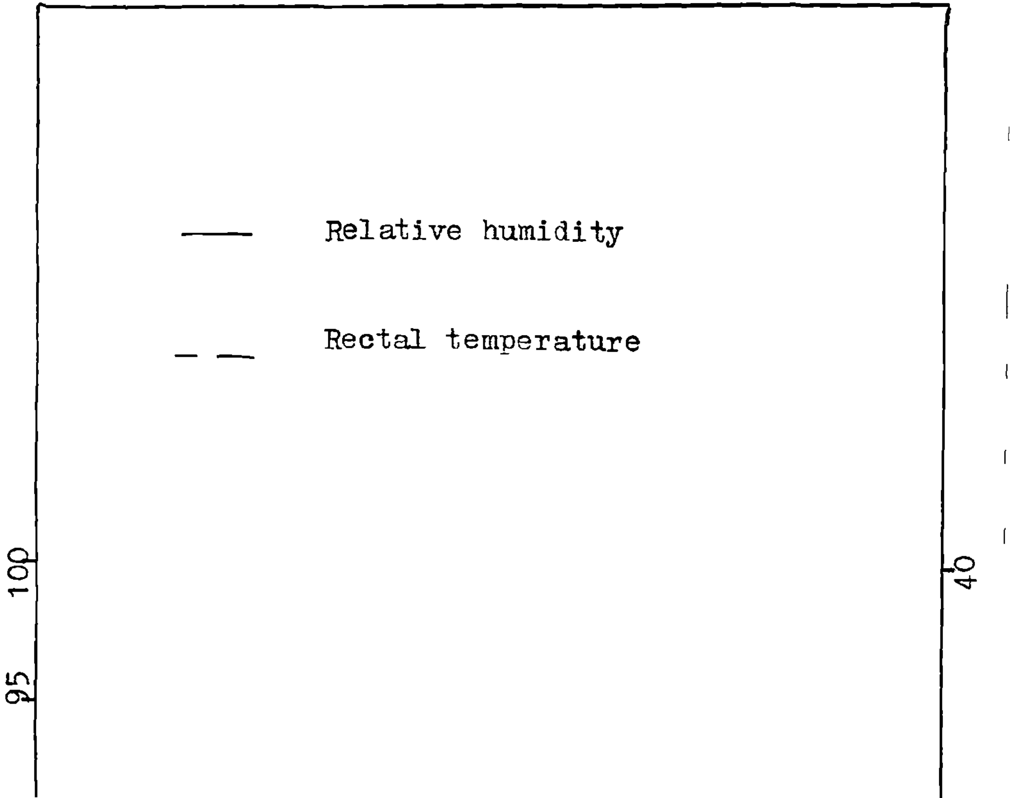
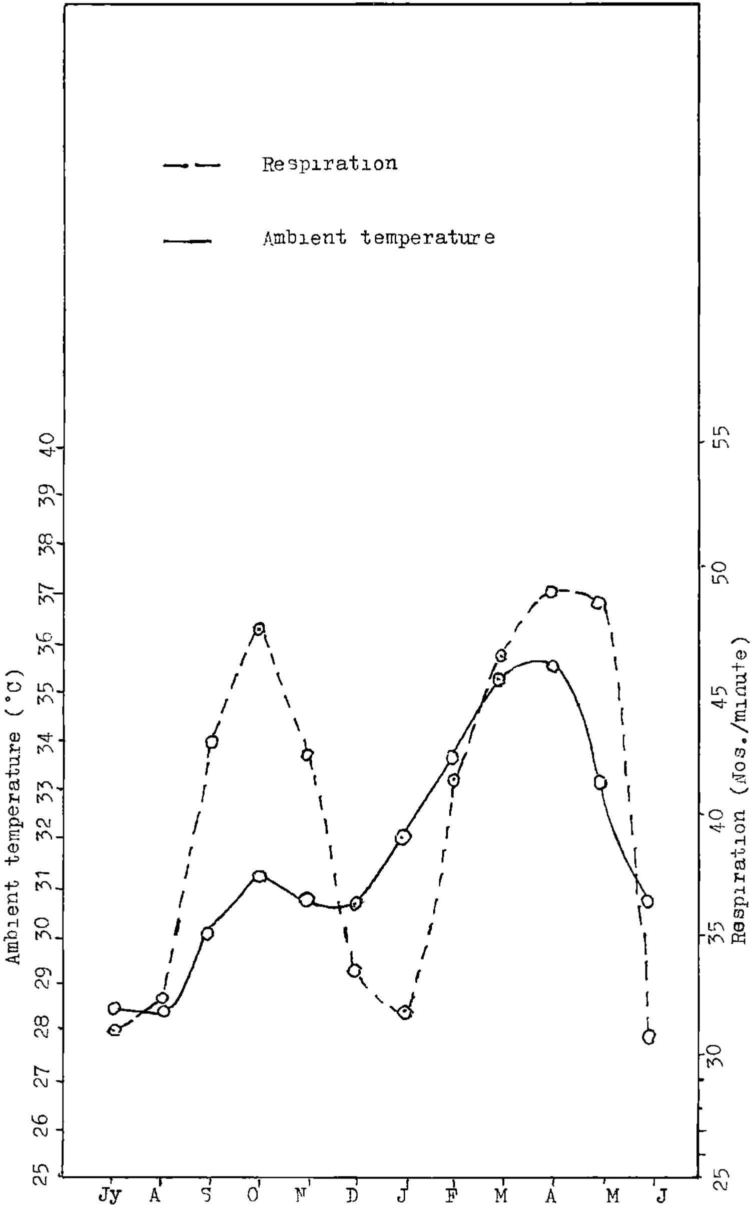
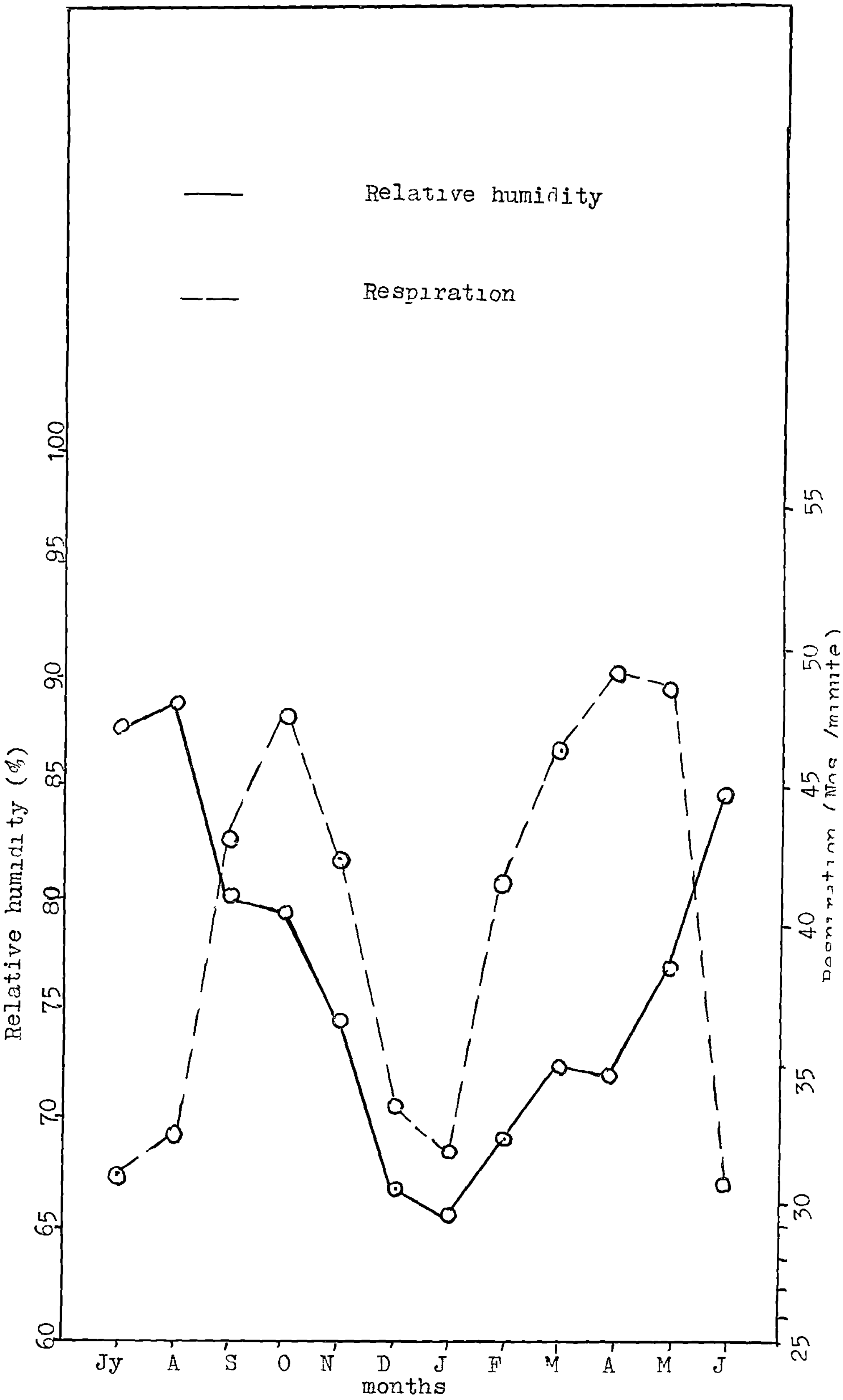

Relative humidity
Rectal temperature
100
95
40

Table 4. Mean daily respiration rate of animals (nos. per minute)

MONTH	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	MAY	JUNE	MEAN
Males	30.973	32.291	42.955	47.455	42.371	33.606	31.759	41.484	46.378	48.985	48.744	30.774	39.814 ±0.6728
Females	..	..	41.616	46.700	39.664	32.632	36.166	42.600	45.166	49.768	48.700	31.468	41.448 ±0.9969
Mean	30.973	32.291	42.536	47.219	41.525	33.302	33.136	41.833	45.999	49.230	48.730	30.991	40.263 ±6.9238



Respiration
Ambient temperature
Ambient temperature (°C)
25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Respiration (Nos./minute)
25 30 35 40 45 50 55
Jy A S O N D J F M A M J


Relative humidity
Respiration
Relative humidity (%)
60
65
70
75
80
85
90
95
1,00
25
30
35
40
45
50
55
Jy
A
S
O
N
D
J
F
M
A
M
J
months

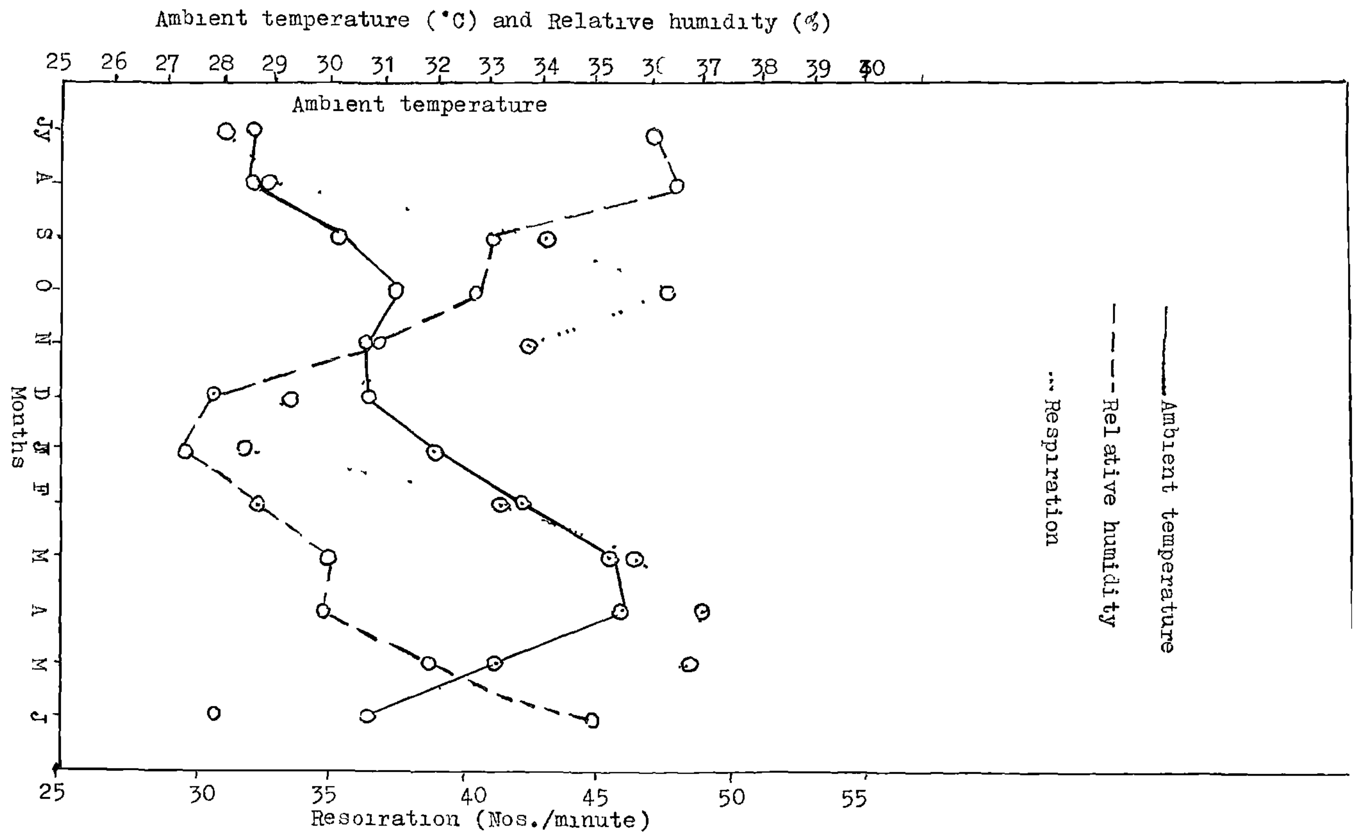

Ambient temperature (°C) and Relative humidity (%)
25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Ambient temperature
Jy A S O N D J F M A M J
Months
25 30 35 40 45 50 55
Resoiration (Nos./minute)
Ambient temperature
Relative humidity
Respiration

Table 5. Mean daily dry matter intake of animals (Kg/day)

MONTH	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	MEAN
Males	5.239	5.525	6.324	5.828	6.623	5.473	6.081	6.676	6.079	6.048	6.934	7.345	6.181 ± 0.0838
Females	..	..	3.497	3.466	4.488	4.186	4.391	4.799	4.469	4.934	5.316	5.938	4.549 ± 0.1141
Mean	5.239	5.525	5.441	5.090	5.956	5.071	5.553	6.090	5.576	5.700	6.428	6.718	5.733 ± 0.1482

Table 6. Dry matter intake as percentage of body weight.

MONTH	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	MEAN
Males	2.842	2.716	2.919	2.464	2.551	2.032	2.093	2.189	1.924	1.813	2.050	2.063	2.305 ± 0.041
Females	..	..	4.158	3.407	3.679	3.211	3.020	3.071	2.642	2.695	2.753	2.814	3.145 ± 0.375
Mean	2.842	2.716	3.306	2.759	2.904	2.400	2.383	2.465	2.149	2.088	2.270	2.298	2.536 ± 0.104

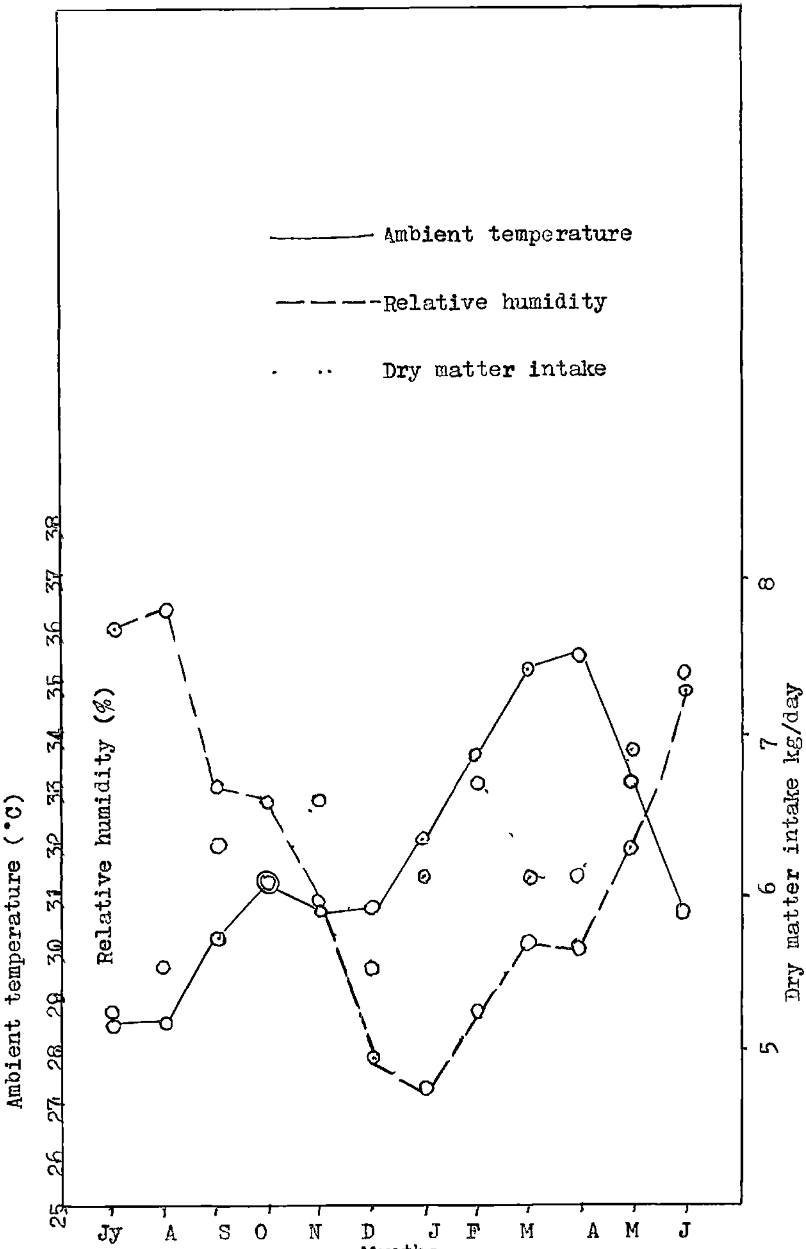


Fig.11. Influence of ambient temperature and relative humidity on dry matter intake.

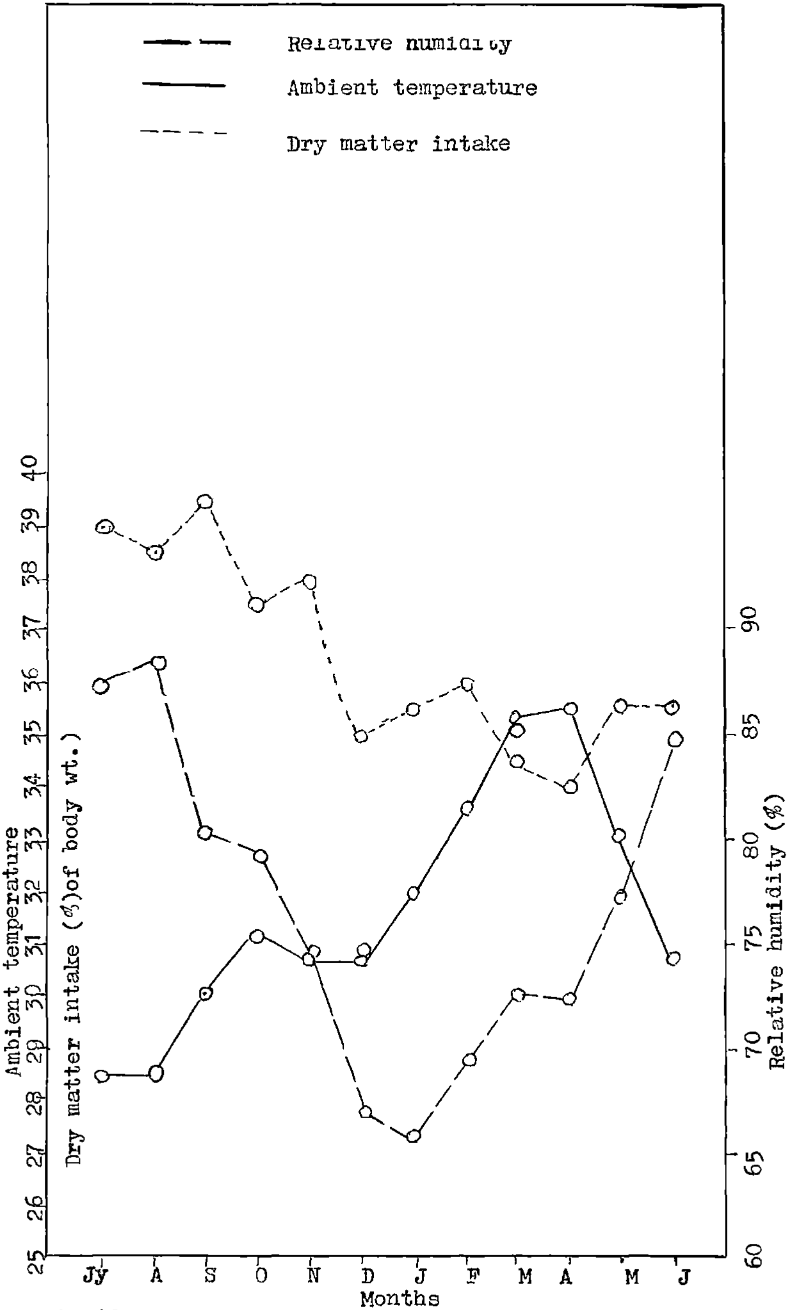


Fig.12. Dry matter intake

Table 7. Mean daily water consumption of animals (litres/day).

MONTH	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	MEAN
Males	5.555	6.732	13.496	15.318	15.856	14.758	18.985	16.992	21.564	18.561	17.292	10.621	14.664 ±0.4644
Females	..	..	8.325	9.958	12.767	12.716	16.767	14.942	19.533	17.283	15.375	11.600	13.927 ±0.5417
Mean	5.555	6.732	11.880	13.643	14.891	14.120	18.292	16.352	20.929	18.161	16.693	10.927	14.446 ±1.336

Table 8. Mean daily water consumption expressed as a function of dry matter intake.
(Water consumption (lit) ÷ Dry matter intake (kg))

MONTH	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	MEAN
Males	1.145	1.316	2.174	2.647	2.411	2.682	3.131	2.555	3.547	3.071	2.506	1.462	2.387 ± 0.181
Females	..	..	2.389	2.877	2.842	3.033	3.846	3.153	4.390	3.576	2.917	1.971	3.090 ± 0.393
Mean	1.145	1.316	2.241	2.719	2.546	2.792	3.355	2.742	3.811	3.229	2.634	1.621	2.583 ± 0.235

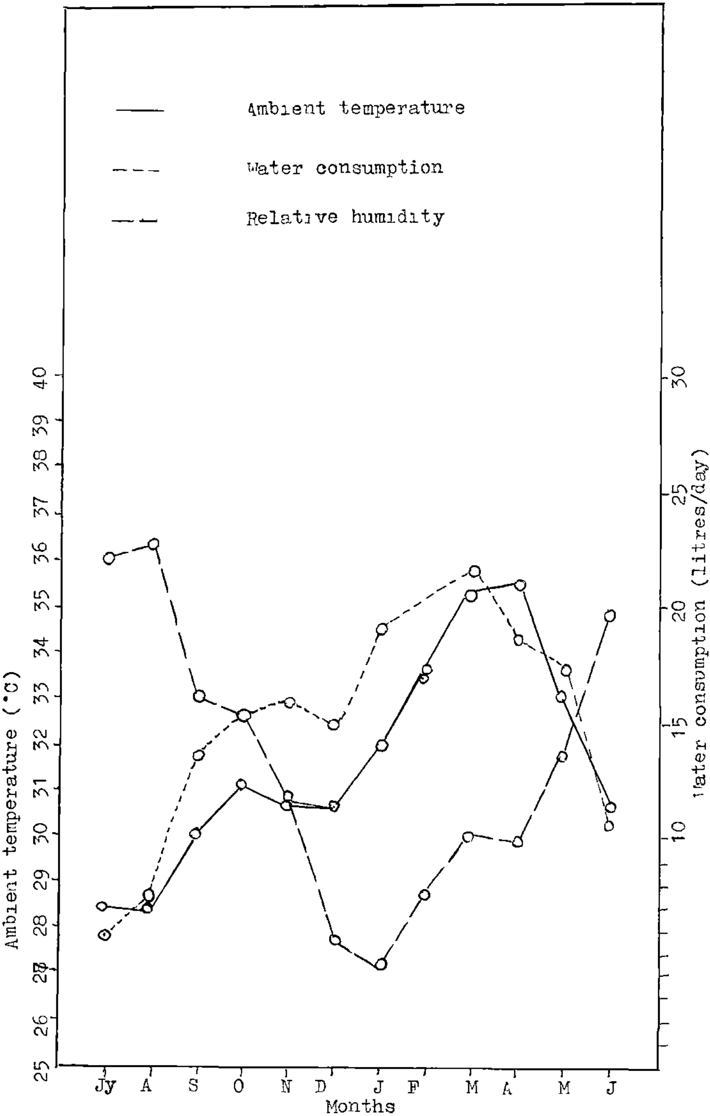
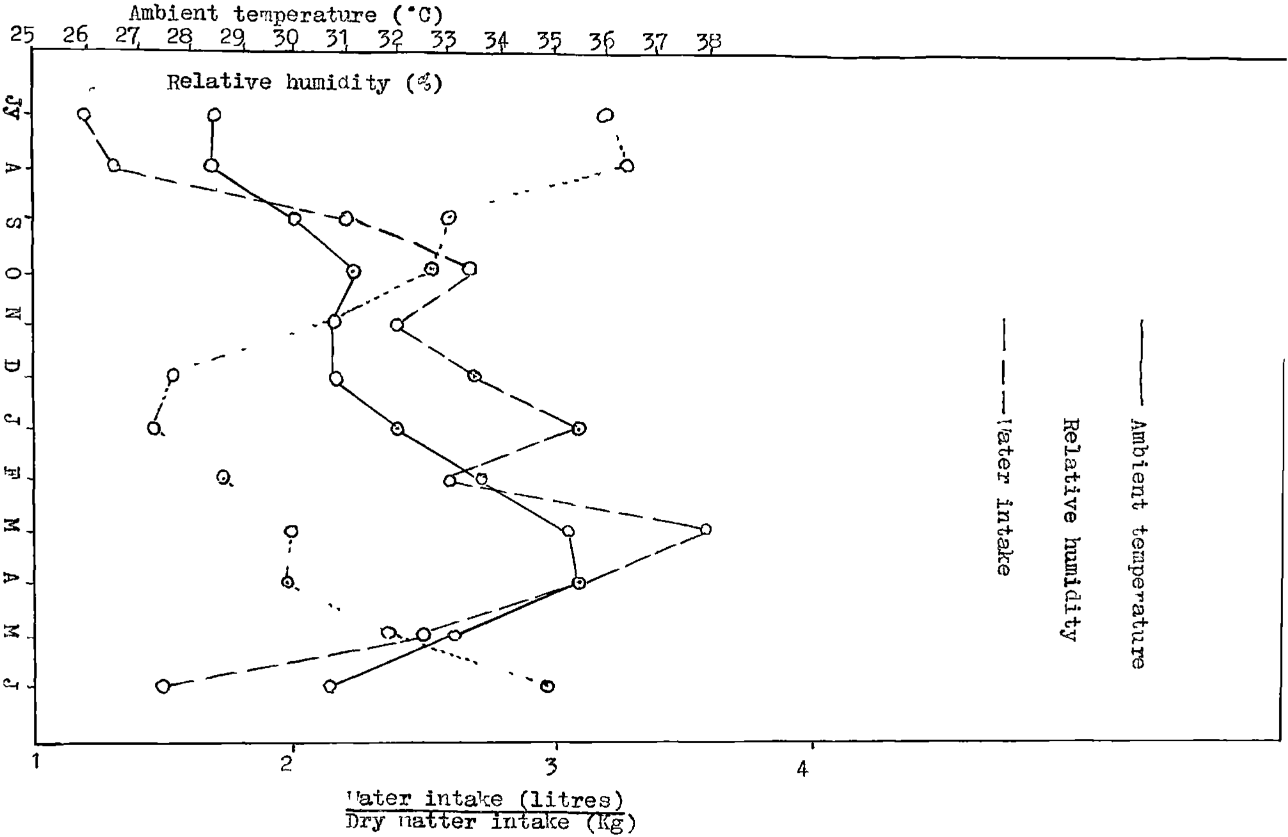


Fig.13. Influence of Ambient temperature and relative



Ambient temperature (°C)
25 26 27 28 29 30 31 32 33 34 35 36 37 38
Relative humidity (%)
JY A S O N D J F M A M J
Months
Ambient temperature
Relative humidity
Water intake
1 2 3 4
Water intake (litres)
Dry matter intake (Kg)

Table 9. Mean monthly body weight of animals (kg)

MONTH	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	MEAN
Males	187.42	207.14	222.82	241.97	265.40	278.24	297.07	311.80	322.20	339.67	342.22	359.35	281.274± 6.706
Females	..	..	84.16	102.04	122.64	131.16	145.80	156.80	170.08	183.08	193.04	211.28	150.008± 5.852
Mean	187.42	207.14	179.49	198.24	220.79	232.28	249.80	263.36	274.66	290.74	295.60	313.08	245.212± 12.483

Table 10. Mean monthly weight gain of animals (kg/month)

MONTH	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	MEAN
Males	28.60	19.72	15.68	19.16	23.43	12.84	18.84	14.73	10.40	17.47	2.55	17.13	16.711 ± 1.881
Females	..	..	2.56	17.88	20.60	8.52	14.64	11.00	13.28	13.00	9.96	18.24	12.968 ± 2.012
Mean	28.60	19.72	11.581	18.756	22.544	11.488	17.525	13.563	11.300	16.075	4.863	17.475	15.682 ± 1.782

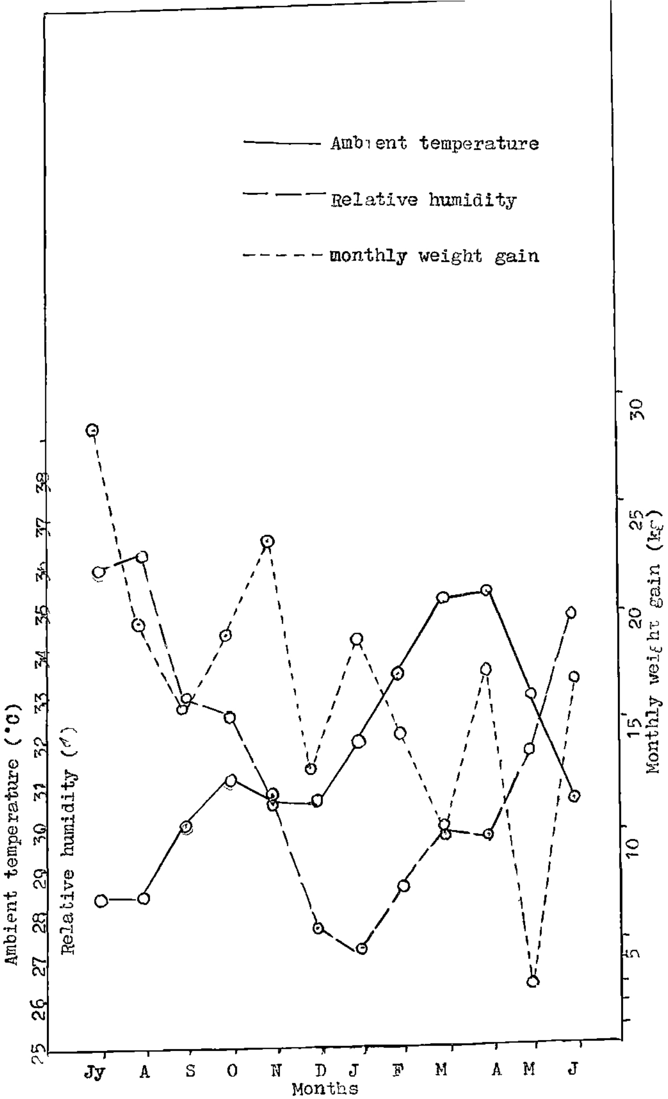

Amb:ent temperature
Relative humidity
monthly weight gain
Ambient temperature (°C)
Relative humidity (%)
Monthly weight gain (kg)
Months
Jy A S O N D J F M A M J
25 26 27 28 29 30 31 32 33 34 35 36 37 38
5 10 15 20 25 30

Table 11. Correlations between the climatic variables and animal responses

Climatic variables		Animal responses				
		Rectal temperature X_3	Respiration X_4	Dry matter intake X_5	Water consumption X_6	Body weight X_7
Ambient temperature X_1	Male	-0.357*	0.638*	-0.652*	0.763*	-0.372*
	Female	-0.207 N.S	0.561*	-0.685*	0.748*	-0.002 N.S
Relative humidity X_2	Male	0.416*	-0.253*	0.514*	-0.725*	0.246*
	Female	0.027 N.S	0.057 N.S	0.195 N.S	-0.503*	0.12 N.S

* Significant ($P < 0.01$)

N.S. Non significant.

Table 12. Regression of Rectal temperature (X_3) on Ambient temperature (X_1) Relative humidity (X_2) and Respiration (X_4)– Males .

Regression coefficients	-0.03490	0.00586	0.00795
S.D. of Regression coefficients	0.01075	0.00259	0.00249
T. values	-3.24508	2.26031	3.18967
Intercept constant	38.91883		

<u>Model</u>: $X_3 = 38.91883 - 0.03490X_1 + 0.00586X_2 + 0.00795X_4$

($R^2 = 0.24720$)

ANOVA

Source	S.S.	d.f.	M.S.	F	R = SE(R)=
Regression	1.13141	3	0.37714	14.01032*	0.49719
Error	3.44556	128	0.02692	$F_{3,128}$	0.16407
Total	4.57697	131			

* Significant ($P < 0.01$)

Table 13. Regression of Rectal temperature (X_3) on Ambient temperature (X_1) Relative humidity (X_2) and Respiration (X_4)– Females .

Regression coefficients	-0.05795	-0.00686	0.01605
S.D. of regression coefficients	0.01351	0.00365	0.00343
T. values	-4.28922	-1.87973	4.67795
Intercept constant	40.55828		

<u>Model</u>: $X_3 = 40.55828 - 0.05795X_1 - 0.00686X_2 + 0.01605\ X_4$

(R^2 = 0.35286)

ANOVA

Source	SS	d.f.	M.S	F	R= SE(R)
Regression	0.44196	3	0.14732	8.36082*	0.54902
Error	0.81053	46	0.01762	$F_{3,46}$	0.13274
Total	1.25249	49			

* Significant (P ∠0.01)

Table 14. Regression of Respiration rate (X_4) on Ambient temperature (X_1) Relative humidity (X_2) and Rectal temperature (X_3)- Males .

Regression coefficients	2.87868	0.19385	9.25934
S.D. of regression coefficients	0.28461	0.08861	2.90295
T. Values	10.11441	2.18756	3.18963
Intercept constant	-423.44319		

Model: $X_4 = -423.44319 + 2.87868X_1 + 0.19385X_2 + 9.25934X_3$

(R^2=0.48750)

ANOVA

Source	SS	d.f.	M.S	F	R = SE(R)
Regression	3816.34357	3	1272.11452	40.58555*	0.69821
Error	4012.03548	128	31.34403	$F_{3,128}$	5.59827
Total	7828.37905	131			

* significant (P $\angle$0.01)

Table 15. Regression of Respiration rate(X_4) on Ambient temperature (X_1), Relative humidity (X_2) and Rectal temperature (X_3) → Females.

Regression coefficients	2.81566	0.36931	20.08443
S.D. of regression coefficients	0.38392	0.12230	4.29352
T. Values	7.33405	3.01976	4.67784

Intercept constant -857.04561

Model: $X_4 = -857.04561 + 2.81566X_1 + 0.36931X_2 + 20.08443X_3$

($R^2 = 0.58341$)

ANOVA

Source	SS	d.f	M.S	F	R = SE(R)=
Regression	1420.43513	3	473.47838	21.47351*	0.76381
Error	1014.27307	46	22.04941	$F_{3,46}$	4.69568
Total	2434.70820	49			

* Significant (P ∠0.01)

Table 16. Regression of Dry matter intake (X_5) on Ambient temperature (X_1), Relative humidity (X_2) water consumption (X_6) and Body Weight (X_7) - Males.

Regression coefficients	-0.11429	0.02119	0.01715	0.01157
S.D. of regression coefficients	0.03552	0.00973	0.01641	0.00077
T. values	-3.21790	2.17699	1.04516	15.10528

Intercept constant = 4.67177

Model: $X_5 = 4.67177 - 0.11429X_1 + 0.02119X_2 + 0.01715X_6 + 0.01157X_7$

(R^2=0.67733)

ANOVA

Source	SS	d.f.	MS	F	R = SE(R) =
Regression	82.29994	4	20.57948	66.64705*	0.82300
Error	39.20688	127	0.30872	$F_{4,127}$	0.55562
Total	121.50682	131			

* Significant ($P < 0.01$)

Table 17. Regression Dry matter intake (X_5) on Ambient temperature (X_1), Relative humidity (X_2), Water consumption (X_6) and Body Weight (X_7) - Females

Regression coefficients	-0.09232	-0.00333	-0.01571	0.02082
S.D. of regression coefficients	0.02949	0.00773	0.01624	0.00110
T.values	-3.13078	-0.43122	-0.96747	19.01211

Intercept constant = 4.88510

<u>Model</u>: $X_5 = 4.88510 - 0.09232X_1 - 0.00333X_2 - 0.01571X_6 + 0.02082X_7$

(R^2=0.90998)

ANOVA

Source	SS	d.f	MS	F	R = SE(R)=
Regression	29.01088	4	7.25272	113.71716*	0.95393
Error	2.87004	45	0.06378	F4,45.	0.25254
Total	31.88092	49			

*Significant (P $\angle$0.01)

Table 18. Regression of water consumption (X_6) on Ambient temperature (X_1), Relative humidity (X_2), Dry matter intake (X_5) and Body weight (X_7) - Males

Regression coefficients	1.07219	-0.29825	0.49709	0.00388
S.D. of regression coefficients	0.17460	0.04634	0.47563	0.00689
T. value	6.14101	-6.43682	1.04511	0.56360

Intercept constant = -0.62421

<u>Model</u>: $X_6 = -0.62421 + 1.07219X_1 - 0.29825X_2 + 0.49709X_5 + 0.00388X_7$

(R^2=0.69536)

ANOVA

Source	SS	df	MS	F	R = SE(R)
Regression	2593.27058	4	648.31765	72.47002*	0.83388
Error	1136.14353	127	8.94601	$F_{4,127}$	2.99099
Total	3729.41411	131			

*Significant ($P < 0.01$)

Table 19. Regression of water consumption (X_6) on Ambient Temperature (X_1) Relative humidity (X_2), Dry matter intake (X_5) and Body Weight (X_7) - Females.

Regression coefficients	0.90877	-0.22046	-1.29700	0.04750
S.D. of regression coefficients	0.26278	0.06222	1.34050	0.02905
T.values	3.45835	-3.54299	-0.96755	1.63468

Intercept constant = -0.24612

Model: $X_6 = -0.24612 + 0.90877X_1 - 0.22046\ X_2 - 1.29700X_5 + 0.04750X_7$

($R^2 = 0.67052$)

ANOVA

Source	SS	d.f.	MS	F	R = SE(R)
Regression	482.08716	4	120.52179	22.89378*	0.81885
Error	236.89757	45	5.26439	$F_{4,45}$	2.29443
Total	718.98473	49			

* Significant ($P < 0.01$)

DISCUSSION

extensively used in India for crossbreeding with the native cattle. Though the temperate dairy breeds have good production potential they possess only poor adaptability to the environmental conditions prevailing in the tropics. The Indian cattle, on the contrary, are well adapted to the extreme environments of the tropics but are poor producers. Hence, it is only natural to assume that the high production potential of the temperate breeds and the adaptability of the Indian cattle can be combined in the crossbreds. And we have achieved considerable progress in this field of dairy cattle crossbreeding.

Performance of many of the crossbreds in this country is not upto the expected level. The role of the climatic environment on the performance of crossbred cattle in this country has been receiving considerable attention in recent years. Many published reports on this subject are available from foreign countries and comparatively few reports are available from India. The present study was carried out to provide informations on the performance of crossbred cattle under the prevailing climatic conditions of this locality. An attempt has also been made to classify the distribution of climate in this locality.

Climatic picture

The average meteorological data, over a period of five years, showed that there are two distinct seasons prevailing in this locality, namely the rainy and the dry seasons. The rainy season was from May to November and the dry season was seen spread over the months of December, January, February, March and April. The rainy season was characterised by a monthly rain fall above 200 mm. The relative humidit and vapour pressure were the highest during that period and the ambient temperature, sunshine hours and wind velocity were the lowest.

The reverse picture was seen in the dry season - ambient temperature, hours of sunshine and wind velocity were the highest, coupled with comparatively low relative humidity and vapour pressure. Average monthly rainfall durin this period has been negligible except during the month of April when the average rainfall was 76.62 mm. This can be attributed to the pre-monsoon showers received towards the end of April. But that rainfall did not affect the ambient temperature and hours of sunshine.

To be more specific, each season was further subdivided into two groups, based on the prevailing ambient temperature

(Fig.4). Thus the rainy season was divided into:

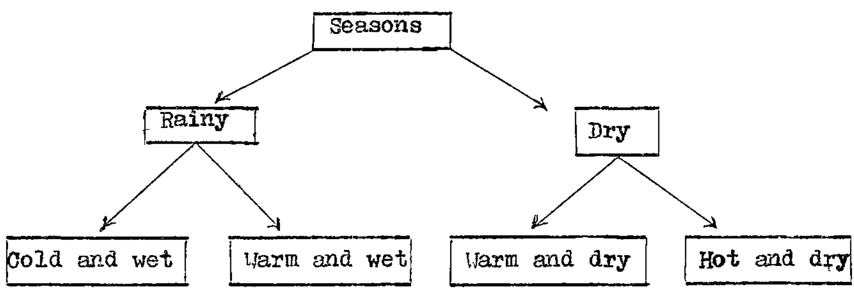
a) Cold and wet characterised by a maximum temperature below 30°C and a rainfall above 500 mm (June-August).

b) Warm and wet characterised by a maximum temperature above 30°C and a rainfall below 500 mm (May, September to November).

Similarly, the dry season is divided into;

a) Warm and dry where the maximum temperature did not exceed 32°C (December and January)

b) Hot and dry where the maximum temperature was above 32°C (February-April).



This classification roughly agrees with the classification of Indian climate (ICAR, 1977) in which the climate was divided into three seasons - winter (October to February), summer (March to June) and rainy (July to September). But the cool winter season did not appear in this locality since the ambient temperature never fell below 25°C.

From Fig. 2 it can be seen that the climograph of this locality falls within the upper right hand section of the diagram which corresponds to hot and moist climate. This reveals that the area is unsuited for the temperate breeds of cattle. This result is in agreement with the report of Hammond (1954).

The hythergraph of this locality shown in Fig.3 represents a typical hythergraph of a hot-wet area which is unsuited for rearing sheep for wool production. The hythergraph in this study is similar to the one shown by Hammond (1954) for Colombo, Ceylon which is representative of a hot-wet area.

Animal responses

Many workers had reported that ambient temperature and relative humidity were the two important climatic elements which exert pressure on animals in the tropics (Hammond, 1954 Brody, 1956; Williamson and Payne, 1959 and McDowell, 1972). So the influence of those two climatic elements on the performance of animals was observed in the present study.

Rectal temperature

The means of rectal temperature of the animals observed during the study were 38.579±0.187°C in the males and 38.843±0.160°C in the females. The monthly mean values of the rectal temperature (Table 3) indicated that the rectal temperature showed very little variation between the months whereas the ambient temperature and relative humidity during this period (Table 2), showed very great variation between the months.

The ambient temperature was found to be the highest (35.53°C) during April and the lowest (28.45°C) during July. The relative humidity was the highest (88.53%) during August and the lowest (65.84%) during January. The mean value of the rectal temperature was the highest (38.855°C) during September and the lowest (38.478°C) during June. This shows that irrespective of the wide variation in the ambient temperature and relative humidity, the rectal temperature showed only very slight variation and it did not follow the changes in ambient temperature and relative humidity.

This is not in agreement with the reports of previous workers, in which, cattle exposed to higher ambient temperatures showed increased rectal temperature (Kibler et al. 1950; Regan, 1951; Kibler and Brody, 1952; Findlay, 1953; Johnston and Branton, 1954; Brody, 1956; Bianca, 1959 a & b; Harris et al. 1960; Shrode et al. 1960; Riggs, 1969; Olbrich et al. 1973; Bandaranayaka and Holmes, 1976). But most of those observations were made in climatic chambers using temperate breeds of cattle.

In Philippine cattle, Alcaide (1953) sobserved that the rectal temperature of the animals did not vary significantly between the dry and wet seasons. Similarly, a decrease in the rectal temperature of cows during summer has been reported by Mullick (1960) when the humidity was high. Both those reports relate to the reaction of the animals under natural conditions where the air temperature did not reach any harmful level for a prolonged time. But that was not the same with chamber conditions where the temperature ranged from 10-40°C with usually low humidity and animals were exposed to constant temperatures for prolonged period. Moreover, most of the workers have agreed to the fact that the animals showed increased temperature at chamber temperatures above 80°F (26.6°C) (Kibler et al., 1950; Regan, 1951; Kibler and Brody, 1952; Findlay, 1953; Robinson and Klem, 1953; Brody, 1956; Johnson et al.1961; Yousef and Johnson, 1966; Moody et al. 1967; Bandaranayaka and Holmes, 1976). So it can be safely assumed that under the prevailing micro-climate of the cattle sheds, the animals are not subjected to any heat stress amounting to derangement in their thermo regulatory mechanism, manifested by an increase in their rectal temperature.

Apart from this, some of the workers have reported that comparing the temperate breeds of cattle, the Zebu and their crosses with temperate cattle were more heat tolerant than the temperate cattle and they could withstand higher ambient temperature without any apparent change in their rectal temperature. (Kibler and Brody, 1952; Asker *et al*.1953; McDowell *et al*.1953; Brody, 1956; Olbrich *et al*.1973).

In the present study also, the crossbred animals maintained their rectal temperature throughout the year without much appreciable variation.

The coefficient of correlations of rectal temperature with ambient temperature were -0.357 in males and -0.207 in the females and significant correlation was observed only in the males ($P < 0.01$) and the difference between the male and female was found to be non significant. The same with relative humidity were 0.416 in the males and 0.027 in the females, that being significant ($P < 0.01$) in the males only. The difference between the male and female was found to be significant ($P < 0.01$). The regression coefficients of rectal temperature on ambient temperature and relative humidity were -0.035 ± 0.011 and 0.006 ± 0.003, respectively in males and -0.058 ± 0.014 and -0.007 ± 0.004 respectively in the females.

Here also the findings are not in agreement with earlier reports. Significant positive correlations between air temperature and rectal temperature were reported by

Asket *et al.*(1953), Alim and Ahmed (1956), Mullick and Kehar (1958) and Pandey and Roy (1969). But as stated earlier, the studies were conducted in climatic chambers and the animals had not been adapted to a hot environment.

When buffaloes and Holstein cows were exposed to high ambient temperature, Alim and Ahmed (1956) observed a positive relation between ambient temperature and rectal temperature, in the Holstein cows only. The buffalo, which is adapted to a hot and humid environment did not show any significant reaction. Johnston (1958) has reported that hot and humid conditions have very little effect on cows which have been previously adapted to such conditions by a gradual exposure. Thompson *et al.* (1963) have reported that initial exposure to a hot environment resulted in an increase in the rectal temperature of Holstein heifers and there was a decline on continuous exposure. Based on those reports and from the results of the study, it becomes evident that the crossbred animals born and brought up in this locality are well adapted to the climatic conditions of this locality.

From table 3, it may be seen that the rectal temperatures of the animals were the highest at the beginning of the study and gradually declined towards the end of the study. The mean age of the male calves was 17 months and that of the female calves 7 months at the beginning of the study.

Hafez (1968) has reported that the body temperatures of animals were affected by age, the foetus having a higher temperature which gradually declined after birth and advancing age to attain the level characteristic of the species; the magnitude of decline in cattle was 39.1° to 38.3

The above mentioned fact explains the gradual decline in the rectal temperature of the animals, inspite of the increase in the ambient temperature and this may be the possible reason for the negative values of the correlation and regression obtained in this case. Combined with this are the facts that the crossbred animals are well adapted to the climatic conditions of this locality and the micro-climate of the cattle shed is not so stress producing as to cause wide variations in the rectal temperature of the animals.

Respiration rate

The mean respiration rate of the animals was 30.973 per minute during July, which rose to 47.219 per minute during October, gradually declined to 33.137 per minute during January, again rose to a peak value of 49.230 per minute during April and finally declined to 30.991 per minute during June. Thus it is evident from Fig. 8, 9 and 10 that the respiration rate strictly followed the changes in the ambient temperature, which agrees with the report of McDowell (1972) that increased respiratory activity was the first visible sign of heat stress in cattle.

Kibler *et al*.(1950), Regan (1951), Kibler and Brody (1952) Asker *et al*.(1953), Findlay (1953), McDowell *et al*.(1953), Robinson and Klem (1953), Beakley and Findlay (1955), Alim and Ahmed (1956), Bianca (1959), Johnson *et al*.(1961), Yousef and Johnson (1966), Kleit and Schilling (1970), Olbrich *et al*.(1973), Bandaranayaka and Holmes (1976) and Yassen (1977) have reported that cattle when exposed to high ambient temperatures exhibited increased respiratory activit In the present study, also the animals reacted to high ambient temperatures with an increase in their respiration rate.

Correlation coefficients of 0.638 in the male and 0.561 in the female, between ambient temperature and respiration rate were obtained, both the values being significant ($P < 0.01$). The sex difference in the correlation coefficient was non-significant. The regression coefficients of respiration rate on ambient temperature were found to be 2.879 ± 0.285 in the male and 2.816 ± 0.384 in the females. Those results are in agreement with the findings of Alim and Ahmed (1956), Mullick and Kehar (1958), Misra *et al*. (1962) and Riggs (1966) who have reported significant positive correlation between ambient temperature and respiration rate in cattle.

The correlation between relative humidity and respiration rate was found to be significant ($P < 0.01$) only in the males (-0.253). The regression coefficient of respiration rate on relative humidity was found to be 0.194±0.089 in the males and 0.369±0.122 in the females.

The relative humidity alone is not a stress imposing factor when the ambient temperature is not very high. Thus Beakley and Findlay (1955) have reported that ambient temperatures of 30°C and 35°C at high humidity had the same effect on respiration rate as 33°C and 46°C at low humidity. Mullick (1960) has reported that the respiration rate of Zebu cattle and buffaloes did not vary during the summer months under low and high humid conditions. Asker <u>et al.</u> (1953), Misra <u>et al.</u>(1962) and Klett and Schilling (1970) have reported that changes in the ambient temperatures had a greater effect on the respiration rate than changes in the relative humidity. In the present study also, the respiration rate tended to parallel changes in the ambient temperature as evidenced by a positive correlation between the respiration rate and the ambient temperature.

The significant negative correlation between the respiration rate and relative humidity observed in the males can be explained by the fact that highest relative humiditie were observed during the peak rainy months of June, July and August when the ambient temperatures were the lowest.

During those months, the respiration rates also were the lowest indicating the tendency of the respiration rate to follow the ambient temperature. The regression coefficients confirm the view that ambient temperature had greater effect on the respiration rate than relative humidity.

The correlationbetween relative humidity and respiration rate was not significant in the females. This may be due to the fact that the observations on the females did not include the peak rainy months of July and August, with the highest relative humidity.

Dry matter intake

The mean daily dry matter intake of the animals was 5.733±0.148 kg. In males that was 6.181±0.084 kg and in females 4.549±0.114 kg. The dry matter intakes as a percentage of the body weight were 2.305±0.041 per cent in the males and 3.145±0.375 per cent in the females, the overall average being 2.536±0.104 per cent.

From Table 6, it may be seen that the percentage dry matter intake was the lowest during the months of March and April (2.149 per cent and 2.088 per cent) and the ambient temperature was the highest during those months. Therefore, it may be assumed that the higher ambient temperature had a dipressing effect on the dry matter intake. McDowell (1972) has reported that most livestock reacted to thermal stress by a decrease in their food intake. The works of Kibler et a (1950), Ragsdale et al.(1950, 1951 and 1952); Regan (1951), Johnston (1958), Davis and Merilan (1960), Findlay (1961), Johnston et al.(1961 and 1962), Johnson et al.(1963), Randal and Rusoff (1963), Thompson et al.(1963), Sims and Porter (1966), Yousef and Johnson (1966), Moody et al. (1967), Roy et al.(1970), and Bandaranayaka and Holmes (1976) have confirmed that in the case of cattle. They have uniformly reported that higher ambient temperature caused significant reduction in the feed dry matter intake of cattle. The result of the present study is in agreement with the previous reports.

The percentage dry matter intake showed a strong negative correlation with ambient temperature in both males and females (-0.652 and -0.685), the values being highly significant (P /0.01). The negative association between ambient temperature and percentage dry matter intake obtained in this study agrees with the earlier reports.

Relative humidity was found to have positive correlation with the percentage dry matter intake. The correlation coefficient was significant only in the case of males (0.514). As mentioned earlier, the absence of significant correlation in the females may be due to the fact that the females were not included in the study during the peak rainy months when the relative humidity was the maximum.

The regression coefficients of percentage dry matter intake on ambient temperature were -0.114±0.036 in the males and -0.092±0.029 in the females. The difference between the sex was found to be non-significant. The regression coefficient of the percentage dry matter intake on relative humidity was 0.021±0.01 in the males. All these results confirm the view that increased ambient temperature has got a dipressing effect on the feed dry matter intake.

Water consumption

Mean daily water consumption observed in the present study was the highest during the month of March and the lowest during the month of July (20.929 liters per day and 5.555 litres per day, respectively). The mean daily water consumption expressed as a function of the dry matter intake i.e. the ratio of dry matter intake to water consumption was also found to be in the same order. It was 1:3.811 during March and 1:1.145 during July.

These results indicate that the animals increased their water consumption when the ambient temperature was increased. It is in agreement with the reports of

Ragsdale *et al.*(1950, 1951 and 1952), Thompson *et al.* (1950), Horrocks and Phillips (1961), Johnson *et al.* (1961), Johnston *et al.* (1961), Misra *et al.* (1962), Wilson *et al.* (1962), Moody *et al.* (1967) and McDowell *et al.* (1969) who have uniformly reported that cattle exposed to hot environments significantly increased their water consumption.

Highly significant positive correlation was obtained between ambient temperature and water consumption in the present study. This was 0.763 in the males and 0.748 in the females. It is in agreement with the report of Harbin *et al.* (1958) that water consumption significantly correlated with ambient temperature and is in general agreement with the results of the previous studies.

The relative humidity was found to be negatively correlated with water consumption and the correlation coefficients were highly significant (-0.725 in the males and -0.503 in the females). This negative association between the relative humidity and water consumption can be explained by the fact that, maximum relative humidity is observed during the peak rainy months of June, July and August when the ambient temperature was the lowest and water consumption has got a strong positive association with ambient temperature. Hence it may be safely assumed that, when the ambient temperature is low, water consumption also is lowered. Moreover, an inverse relationship can be seen between ambient temperature and relative humidity from Table 2 and Fig.5.

The regression coefficients of water consumption on ambient temperature were 1.072±0.175 in the males and 0.909±0.263 in the females. Those of water consumption on relative humidity were -0.298±0.046 in the males and -0.220±0.062 in the females. From the items studied, it could be noticed that the sex difference was non significant

Growth and Body weight gain

Means of monthly weight gains were 16.711±1.881 kg in the males and 12.968±2.012 kg in the females during the period of study. An irregular trend in the monthly weight gain of the animals can be seen from Table 10 and Fig.15. Initially during the month of July, the gain was the highest which declined slightly during August and September to rise again during October and November. The monthly body weight gain declined during December, followed by an increase during January and slight decline during February and March. During the month of April the average weight gain increased and there was a sharp decline during May which was followed by an increased rate during June.

The ambient temperature and relative humidity during this period showed definite trends. The ambient temperature was the lowest during July and August, increased during September and October followed by a slight decline during December. Then that gradually increased, reaching a peak level during March and April and then gradually declined to a lower level during June.

Similarly, the relative humidity was the highest during July and August which gradually declined to the lowest level during January and thereafter gradually rose to a higher level during June.

So, it becomes evident that the growth rate of the animal as indicated by the monthly gain was not following the trends in the ambient temperature or relative humidity.

This finding is not in line with the different reports in this field of study. Ragsdale et al. (1950, 1951 and 1952) Bianca (1959 a and b), Findlay (1961), Johnson et al.(1961), Johnston et al. (1961), Randal and Rousoff (1963), Thompson et al.(1963), Moody et al. (1967), Klett et al. (1969) and Ray et al.(1969) have reported significant decline in the body weight gain of European cattle exposed to hot environment.

But Ragsdale et al.(1951 and 1952) and Findlay (1961) have reported that, when ambient temperatures above 80°F (26.6°C) depressed the body weight of European cattle, no effect on the body weight of Brahmans and their crosses were noticed upto 100°F (37.8°C). The better performance of the Brahmans and their crosses in a hot environment can be attributed to their better heat tolerance capacity.

Wheat (1970) has reported that grazing Nigerian cattle gained weight during the wet season and lost weight during the dry season. This difference in the weight gain between the dry and wet seasons was attributed to the differences in the quality and availability of fodder between the two seasons both being poorer during the dry season.

When the correlation coefficients were worked out, a significant ($P < 0.01$) negative correlation between ambient temperature and monthly weight gain (-0.372) and positive correlation between relative humidity and monthly weight gain (0.246) were obtained in the males only. Both these correlations were non-significant in the females. Even in the case of males, it can be seen that the values of the correlation coefficient are very low.

From the results of the present study, it can be assumed that the weight gain of the crossbred cattle is not significantly affected by the prevailing ambient temperature of this locality. The fluctuations in the monthly weight gain can mainly be attributed to the differences in the quality of roughage fed to the animals. This is confirmed by the fact that during the period from December to May, the animals were fed silage as the only source of roughage and during that period the weight gain was most irregular. The silage fed to those animals during that period was of poor quality.

The change over from green grass to silage is reflected as a sudden drop in the monthly weight gain during December. By the end of April and during May, the silage fed was of very poor quality and that explains the sharp decline on the monthly weight gain during May. By June, the rainy season was on and good quality green grass was available and it is reflected upon the increased weight gain during June.

SUMMARY

SUMMARY

In the present study, investigations were carried out on the distribution of climate at Mannuthy, Trichur and the influence of ambient temperature and relative humidity on the performance of crossbred cattle, as measured by rectal temperature, respiration rate, dry matter intake, water consumption and growth.

Analysis of the meteorological data revealed the occurrence of two distinct seasons in a year - the rainy and the dry seasons. The rainy season was characterised by monthly rainfall of over 200 mm and that extended from May to November. That could be further sub divided into two - 'cold and wet' and 'warm and wet' seasons based upon the prevailing maximum temperature and the extent of the monthly rain fall.

The dry season was seen spread over to the months of December, January, February, March and April and was characterised by very little rainfall, the maximum being 76.62 mm during the month of April. That was sub divided into 'warm and dry' and 'hot and dry' seasons, the maximum temperatures during the former was below 32°C and above 32°C during the latter.

The climograph and hythergraph of the locality clearly brought Mannuthy under a hot and humid area.

The rectal temperature of the animals showed very little variation during the period of this study with the maximum value (38.855°C) observed during September and the minimum value (38.478°C) during June, whereas the ambient temperature during those periods showed wide variation (28.45°C during July and 35.53°C during April). A significant negative correlation was found between ambient temperature and rectal temperature and positive correlation between relative humidity and rectal temperature. The regression coefficients of rectal temperature on ambient temperature and relative humidity were to the extent of -0.035 ± 0.01 and 0.006 ± 0.003 respectively, in males and -0.058 ± 0.014 and -0.007 ± 0.004 respectively, in females.

The respiration rate was found to be the maximum during April (49.230 per minute) and the minimum during July (30.973 per minute). Significant positive correlation was obtained between the ambient temperature and respiration rate (0.638 in the males and 0.561 in the females). Significant negative correlation between respiration rate and relative humidity was noticed in the males only (-0.253). The regression coefficients of respiration rate on ambient temperature and relative humidity were 2.879 ± 0.285 and 0.194 ± 0.089 respectively, in the males and 2.816 ± 0.384 and 0.369 ± 0.122 respectively, in the females.

Significant negative correlation was obtained between the ambient temperature and percentage dry matter intake (-0.652 in males and -0.685 in females). Percentage dry matter intake and relative humidity of the atmosphere were positively correlated, being significant in males only. The regression coefficient of percentage dry matter intake on ambient temperature and relative humidity were -0.114±0.036 and 0.021±0.01 respectively, in males and 0.092±0.029 in femal

The daily water consumption has been the highest (20.929 litres) during March and the lowest (5.555 litres) during July. Significant positive correlations were obtained between ambient temperature and daily water consumption (0.763 in males and 0.748 in females) and negative correlations between relative humidity and water intake. The regression coefficients of water consumption on ambient temperature and relative humidity were 1.072±0.175 and -0.298±0.046 respectively, in males and 0.909±0.263 and -0.220±0.062 respectively, in females.

The monthly body weight gains showed negative association with ambient temperature and positive association with relative humidity and the correlation coefficients were significant only in males. But from fig. 15, it is evident that the monthly gains did not follow the trends in the ambient temperature or relative humidity. Hence it is more appropriate to say that some factor over and above the ambient temperature is influencing the monthly weight gain and it is presumed to be the changes in the quality of the roughage.

From the results of the study the following conclusions were drawn. Under the prevailing microclimate of the cattle shed,

1. The rectal temperature of the animals did not show much variation.
2. The respiration rate showed an increasing trend with increasing ambient temperature.
3. The percentage dry matter intake declined with increasing ambient temperature.
4. Daily water consumption increased with increasing ambient temperature and
5. The weight gains of the animals were not much influenced by the ambient temperature or relative humidity directly.

Thus it could be concluded that under the conditions prevailed at the present study, the ambient temperature appeared to be the only factor which imposed certain amount of stress on the animals and it did not affect the production performance of the animals directly.

Feeding of good quality feed to the crossbred cattle is envisaged to ward off the adverse influence of the ambient temperature on production performance.

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BIO-CLIMATOLOGICAL STUDIES ON DRY MATTER INTAKE AND WATER CONSUMPTION OF GROWING LIVESTOCK

BY

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ABSTRACT OF A THESIS

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ABSTRACT

The present work was undertaken to study the distribution of climate at Mannuthy and to study the effect of the prevailing ambient temperature and relative humidity on the performance of growing crossbred cattle.

The meteorological data over a period of five years (1974-1978) were analysed to study the climatic picture of this locality. The rectal temperature, respiration rate, dry matter intake, water consumption and growth rate of eleven male and five female calves were observed for a period of twelve months.

The climatic picture showed that there are two distinct seasons prevailing in this locality, namely, the dry and the rainy seasons, which are further sub divided into 'Warm and dry', 'Hot and dry','Cold and wet' and 'Warm and wet' seasons, respectively.

The rectal temperature of the animals remained fairly constant throughout the year, inspite of wide variations in the ambient temperature. It showed negative correlation with ambient temperature (-0.357 in males and -0.207 in females) and positive correlation with relative humidity which was significant only in males (0.416).

The respiration rate varied from 30.973 per minute during July (lowest) to 49.230 per minute during April (highest). It showed positive correlation with ambient

temperature (0.638 in males and 0.561 in females). Significant negative correlation between respiration rate and relative humidity was observed in males only (-0.253).

The percentage dry matter intake was found to have a strong negative correlation with ambient temperature (-0.652 in males and -0.685 in females). Whereas with the relative humidity, the correlation was positive and was significant only in males (0.514).

Highly significant positive correlation between ambient temperature and daily water consumption (0.763 in males and 0.748 in females) and negative correlation between relative humidity and water consumption (-0.725 in males and -0.503 in females) were obtained in this study.

There was negative correlation between ambient temperature and monthly weight gain and positive correlation between relative humidity and monthly weight gain, but was significant only in males. The negative correlation obtained in this case can be attributed to the poor quality of the roughage during the summer months rather than the direct effect of ambient temperature.