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HEAT STRESS IN DAIRY CATTLE AND OTHER LIVESTOCK UNDER SOUTHERN AFRICAN CONDITIONS. III. MONTHLY TEMPERATURE-HUMIDITY INDEX MEAN VALUES AND THEIR SIGNIFICANCE IN THE PERFORMANCE OF DAIRY CATTLE

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ABSTRACT

DU PREEZ, J. H., HATTINGH, P. J., GIESECKE, W. H. & EISENBERG, B. E., 1990. Heat stress in dairy cattle under southern African conditions. III. Monthly temperature-humidity index mean values and their significance in the performance of dairy cattle. *Onderstepoort Journal of Veterinary Research*, 57, 243–248 (1990)

Temperature-humidity index (THI) values applicable to South Africa and Namibia have been established during this investigation for each month of the year by means of computerized modelling and mapping techniques.

The data indicate that each year heat stress risk areas (HSRA's) expand from August to January and retract from February to July. The THI values classified according to the Livestock Weather Safety Index (LWSI) for lactating dairy cattle (LDC), suggest that, especially during November to March there is the risk of moderate to advanced heat stress in most South African dairy cows. This has important implications for their general health, udder health, production and reproduction. Careful planning of facilities and highly adaptable herd management are required to protect dairy cattle from heat stress.

INTRODUCTION

Stress, a general adaptation syndrome, thermoregulation, thermotolerance and heat stress, as well as related implications for the physiology, welfare, health performance and management of dairy cattle, were discussed in 2 preceding papers on temperature-humidity index mean values of the 4 main seasons (Du Preez, Giesecke & Hattingh, 1990a) and heat stress during summer (Du Preez, Giesecke, Hattingh & Eisenberg, 1990b). It is apparent that performance, well-being and health of the animal are influenced by biometeorological factors (Bianca, 1970; Hahn, 1976; Yousef, 1985a & b). The most important climatological factors are heat stress during the hot season and the wind-chill factor during the cold season of the year (Hahn, 1976).

Dairy cows can benefit from microclimatic modifications to improve their comfort and performance (Fuquay, Zook, Daniel, Brown & Poe, 1979), particularly under the climatic conditions prevailing in southern Africa. Such modifications require a generally more complete appreciation of the phenomenon, occurrence and prevention of heat stress.

The aim of this investigation was to determine and map South Africa and Namibia according to the monthly mean values of the "temperature-humidity index" (THI) for cattle (Bosen, 1959; Kibler, 1964) and to indicate which areas and times of the year present heat stress risks.

MATERIALS AND METHODS

Meteorological data and THI values

The acquisition of meteorological data, calculation and mapping of observed true and predicted THI values were indentical to the methods already described (Bosen, 1959; Du Preez *et al.*, 1990a & b; Kibler, 1964) with the exception that this investigation refers to the observed true and predicted monthly THI mean values applicable to 563 Weather Bureau stations.

Classification of THI values

The Livestock Weather Safety Index (LWSI) of the Livestock Conservation Institute (Anonymous, 1970) adapted by Du Preez *et al.* (1990a & b) to computer-aided contouring and mapping, as described by Du Preez *et al.* (1990a), for values was used to categorize the THI values for lactating dairy cows (LDC):

THI values	*LWSI (LDC) category*	*Colour codes*
70 or fewer	Normal	Blue
70,0–72,0	Alert, approaching critical index for milk production	
72,0–78,0	Alert and above critical index for milk production	Orange
78,0–82,0	Danger	Red
82,0 or above	Emergency	Purple

Interpretation of THI values

The results have been interpreted from the point of view of the classifications above as well as of the South African dairy cattle distribution (Du Preez *et al.*, 1990a).

RESULTS

Table 1

Table 1 lists selected examples of the complete monthly THI mean values calculated from true values observed at 226 weather stations and predicted from 337 weather stations with less complete recordings. This table is obtainable from the main author, because it is too lengthly to publish. The comparative listing of observed true and predicted THI mean values (Table 1) indicates the high degree of accuracy with which the THI mean values were predicted. The computer model was used for the predictions and applied to predict THI mean values for weather stations where observed true values were available for comparison with the corresponding predicted values.

Mapping of monthly THI values

The mapped presentations of the distribution of

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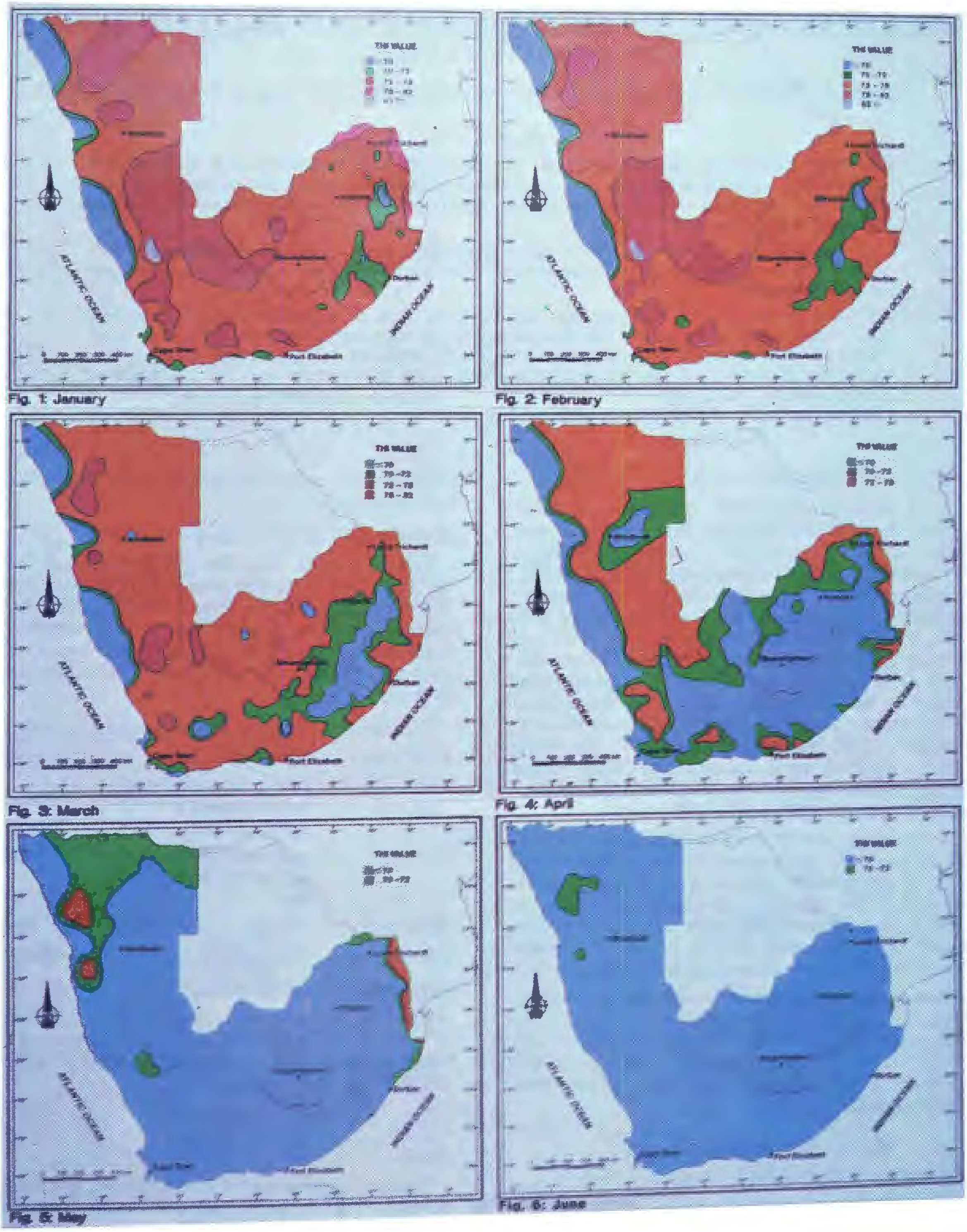

FIG. 1–6 January to June observed true and predicted THI mean values applicable to 563 Weather Bureau stations and mapped according to the LWSI(LDC) categories to indicate the potential for heat stress in dairy cattle in South Africa and Namibia

monthly THI mean values illustrate the changing patterns of the THI values during the 12 months of a year (Fig. 1–12).

DISCUSSION

Few appropriate South African data are available on heat tolerance and related genetic, physiological, health, reproduction, production, engineering, economic and other aspects of dairy and feedlot cattle. However, from literature referred to by Giesecke (1985), Giesecke, Van Staden, Barnard & Petzer (1988) and Du Preez *et al.* (1990a & b) it is apparent that thermal conditions are a constraint on the performance of farm animals, particularly in high-yield-

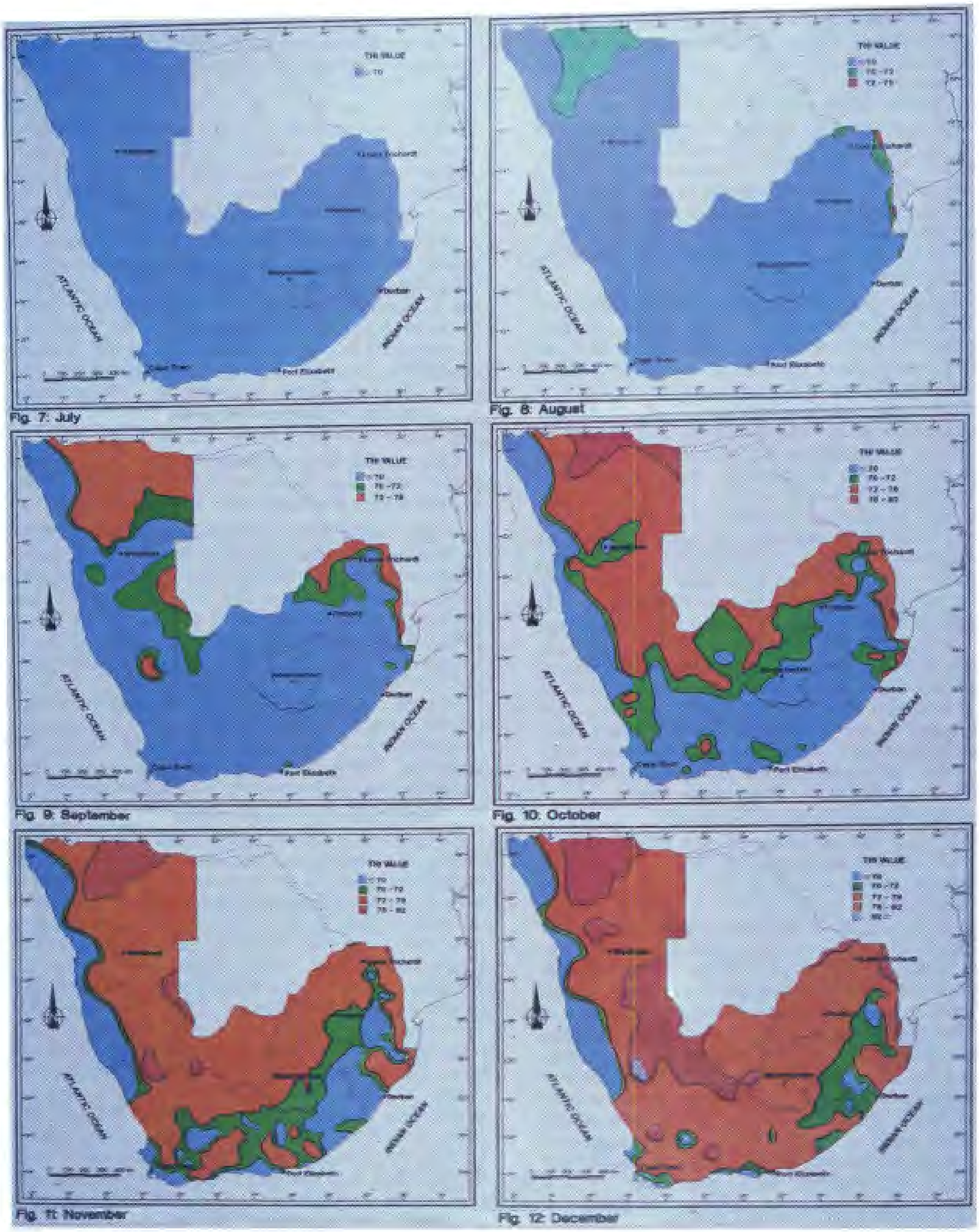

Fig. 7: July

Fig. 8: August

Fig. 9: September

Fig. 10: October

Fig. 11: November

Fig. 12: December

FIG. 7–12 July to December observed true and predicted THI mean values applicable to 563 Weather Bureau stations and mapped according to the LWSI(LDC) categories to indicate the potential for heat stress in dairy cattle in South Africa and Namibia

ing dairy cattle. The 4 most important environmental determinants of the temperature perceived by animals are dry-bulb temperature, relative humidity, radiation and wind. Each of these factors can be readily measured with instruments. However, a single index in which all the above-mentioned climatic parameters are expressed as an index of stress, does not exist. At present the THI values are the most practical means for assessing the exposure of cattle to heat stress in a given area (Yousef, 1985a).

From the data (Fig. 1–12) it is apparent that during a year the distribution of THI mean values and their practical implications for lactating dairy cattle are characterized by 2 major developments, namely: (1) progressive expansion of heat stress risk areas (HSRA's) commencing during August (Fig. 8) and peaking during January (Fig. 1), and (2) progressive contraction of HSRA's commencing during February (Fig. 2) and bottoming during July (Fig. 7). From conditions applicable to South Africa it is obvious that from December to February (Fig. 12, 1 & 2) there is a generally elevated risk of heat stress in lactating dairy cattle.

THI values, grouped according to the classes of the LWSI (LDC) (Du Preez *et al.*, 1990), suggest that within the normal range of THI values of up to 70, dairy cattle show optimal performance, experience no significant heat stress and are not adversely affected by handling (Yousef, 1985a). In the alert (warning) to critical range of THI values of 70–72, dairy cattle already experience a fair amount of heat stress, their performance is inhibited, handling becomes detrimental to their performance and cooling of the animals becomes desirable (Hahn, 1976 & 1985). The same criteria apply to the alert (warning) to above critical LWSI (LDC) category at THI values of 72–78, but here milk production is seriously affected. In the dangerous category at THI values of 78–82, the animals experience severe heat stress, their performance is severely affected, handling should take place only early in the morning, and cooling of the animals and diet adaptations become essential. All the adverse effects of the dangerous category are present in the emergency category at THI values of 82 and above, deaths may easily occur and cooling of the animals is absolutely essential (Du Preez *et al.*, 1990; Hahn, 1985).

From the observed true and predicted THI values, (Table 1) and the mapping of the LWSI (LDC) groups of THI values applicable (Fig. 1–12) to this investigation, it is apparent that during a year HSRA's expand in southern Africa from August to January (Fig. 8–12 & 1) and retract from February to July (Fig. 2–7). The extensive HSRA's during November to March (Fig. 11, 12, 1–3) suggest that during each summer most dairy cattle in South Africa and Namibia are subjected to variable levels of heat stress. Judging from the data referred to initially, this situation has critical implications for the performance of the cattle, as well as for the economics of dairy farming and the dairy industry, because heat stress in dairy cattle has a range of adverse effects (Giesecke, 1985; Giesecke *et al.*, 1988). Improvements required under South African conditions should therefore address 3 major questions:

- ⋆ How can each dairy farmer assess practically in the field the occurrence of heat-stress-promoting thermal conditions?
- ⋆ What major disadvantages of heat stress in dairy cattle require particular attention in HSRA's?
- ⋆ What minimum precautions against heat stress in dairy cattle can be recommended?

The occurrence of heat stress can of course be determined by monitoring weather conditions and measuring in the dairy cattle a range of parameters (e.g. rectal temperature, respiration rate, water intake, milk yield, rumination, standing and lying behaviour, etc.). Irrespective of the different measurements possible it seems just as important to assess the occurrence of heat stress in the cattle from one's personal perception of the thermal environment that affects the cattle.

Human discomfort index (HDI) values can be calculated according to the equation $HDI = 24 + 2T + (RH \times T)/100$, where T is the dry-bulb or air temperature in °C and RH = % relative humidity (Weather Bureau, Department of Environmental Affairs, undated). HDI values of 80–90, 90–100, 100–110, 110 and more indicate moderately uncomfortable, very uncomfortable, extremely uncomfortable and health-hazard conditions, respectively.

When meteorological data for calculating THI values are also used in the HDI equation to assess them from the point of view of human discomfort, the THI values applicable to dairy cattle are similar to the HDI values applicable to humans. Thus, it can be expected that under conditions in which humans experience temperature-related discomfort, dairy cows will experience heat stress. This provides a practical way to determine in the field whether animals experience heat stress.

Concerning major disadvantages of heat stress in dairy cattle one should appreciate that the performance of the cows is affected at several levels.

Udder health and milk production: The incidence of new udder infections and frequency of mastitis increase during the hot summer months (Nickerson, 1987), because the udder's defence mechanisms become deficient (Giesecke 1985; Giesecke *et al.*, 1988). Milk production decreases by 10–40 %. The composition of the milk changes: butter fat is reduced by 20–40 %, solids-not-fat by 10–20 %, and total milk protein by 10–20 %, whereas somatic cell counts increase. There is an increase in necrobiosis of udder tissue (Giesecke *et al.*, 1988; Hahn, 1985; Johnson, 1985). Work by Hahn & Osburn (1969) suggests that the higher the THI values the higher is the loss in milk production, and vice versa.

Reproduction: Heat stress lengthens the oestrus cycle and shortens the period of oestrus; conception is reduced; there is an increase in embryo mortality with a corresponding decrease in fertility and placental malfunction. Fetal growth is retarded, the gestation period is reduced and the calves produced show a correspondingly lower birth mass as well as decreased ability to survive (Brody, Worstell, Ragdale & Kibler, 1948; Fuquay, 1981; Thatcher, 1974). The maximum sensible temperature on the day after insemination has the greatest influence on conception. The critical period for embryo survival with regard to heat stress is between 4 and 6 days after conception (Gwazdauskas, Thatcher, Wilcox, 1973; Johnson, 1985). Furthermore, libido of bulls is lowered by heat stress, sperm concentration and mobility decrease, and the percentage of abnormal sperm cells increases (Johnson, 1985). If THI values are available, the equation $CR = 388{,}3-4{,}62\ THI$ (Hahn, 1981; Ingraham, 1974) can be used to determine the conception rate (CR) in dairy cattle (Holsteins) exposed to a specific thermal environment. Available data suggest that the higher the THI for an area the lower the conception rate, and vice versa.

Feeding: Heat stress causes a decrease in feed intake, reduces roughage and increases concentrate requirements. The decrease in roughage consumption may be responsible for the decrease in the percentage butterfat in the milk. There is also a decrease in rumination. Cattle feeding at a high environmental temperature show increased heat increments. It seems also that under warm conditions animals require more potassium in their rations (Conrad, 1985; Johnson, 1985). They increase their water intake and their evaporative loss through sweating (Drost & Thatcher, 1987).

Growth: Heat stress inhibits growth and mass increase in cattle, depending on genotype, age and adaptibility (Hahn, 1985; Johnson, 1985).

Behaviour and health status: In order to maintain homeostasis, behavioural changes occur. These include postural adjustments, wetting of the skin's surface where possible, lying in wet places and shorter feeding periods during peak temperatures. Latent virusses may be activated, thus causing favourable conditions for secondary infections (Hahn & Bond, 1977; Hahn, 1985).

Mortality: Mortality in hot environments is usually associated with handling and transportation of animals. Hot temperatures aggravated by high humidity play a cardinal role in animal mortality. Mortalities increase at THI values in the emergency category of the LWSI(LDC) (Hahn, 1985; Oliver, Hellman, Bishop, Pellisier & Bennett, 1979).

Regarding the minimum precautions against heat stress (Du Preez *et al.,* 1990b) one should bear in mind a range of short, medium and longer term zootechnological measures. Their main aim should be to keep dairy cattle cool and to protect them from any unnecessary exertion. Aspects of prophylactic herd management, animal husbandry and engineering are involved and differ, depending on the LWSI(LDC) categories (Du Preez *et al.,* 1990b) of the THI values.

Pertaining to the precautions discussed by Du Preez *et al.* (1990b) one should particularly appreciate that the yearly expansion and retraction of the HSRA's (Fig. 1–12) indicate the annual baseline pattern of heat-stress-promoting climatic conditions. Short-term changes of weather are usually superimposed on the annual baseline pattern of the HSRA's. This means in practice that facilities for protecting dairy cattle against heat stress should be provided according to the baseline pattern of the HSRA's (Fig. 1–12), whereas such facilities should be used according to short to medium-term weather changes. Consequently, effective control and prevention of heat stress in dairy cattle requires particularly careful planning of facilities as well as highly adaptable herd management.

Appropriate facilities to protect cattle from climatic extremes are of cardinal importance for optimal performance (Bond, Kelly, Garrett & Hahn, 1961; Hahn, 1985). Protection includes trees, shade nets or roofed shades. The most effective shades are trees as they provide protection from sunlight combined with beneficial cooling since moisture evaporates from the leaves (Bond *et al.,* 1961). Farmers should therefore be encouraged to plant proper trees for shade. However, trees are not always available for livestock shades. In the absence of trees, hay or straw shades are most effective, while solid shade provided by sheet metal, painted white on top, is next in effectiveness (Bond *et al.,* 1961). Direct wetting of cattle by sprinkling combined with air movement by fans, ensures evaporative cooling which is ideal for protection against heat stress (Hahn, 1985). Good management includes the provision of adequate feed and water at all times, reduction of the ratio of roughages to concentrates in hot-weather rations and recognition of the need for increased feed at the end of a heat wave to permit production recovery (Hahn, 1981).

Irrespective of the shortage of South African data it cannot be over-emphasized that homeothermy in dairy cattle must be maintained in areas where the cows are subject to heat stress. The prevention and control of the detrimental effects of heat stress in dairy cattle are of vital importance. Zootechnological precautions are thus essential during the hottest months of the year to enable the animals to maintain homeothermy within physiological limits as well as to improve udder and general health, production and reproduction. For protecting dairy cows in South Africa and Namibia against heat stress, several practical minimum precautions have been proposed by Du Preez *et al.* (1990b). However, further research on heat stress on dairy cattle is essential if the South African dairy industry is determined to achieve more cost-effective milk production, improved herd and udder health and adequate supplies of high-quality raw milk.

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