

# Effect of shade on various parameters of Friesian cows in a Mediterranean climate in South Africa. 1. Feed and water intake, milk production and milk composition

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*Received 15 January 1993; revised 5 August 1993; accepted 22 September 1993*

The effect of a shade structure on the feed intake, water intake, milk production and milk composition of Dutch-type Friesian cows in a temperate climate was determined over three summer seasons. The shade structure reduced ( $P < 0.01$ ) radiation as was indicated by lower black globe temperatures. Feed intake of shade cows was higher ( $P < 0.05$  during 1984/85 and  $P < 0.01$  during 1985/86) than that of no-shade cows. Regression analysis suggested that day-time feed intake was significantly ( $P < 0.05$  for shade cows and  $P < 0.01$  for no-shade cows) affected by increasing maximum ambient temperatures. No-shade cows had higher ( $P < 0.01$ ) free-water intakes than shade cows (114 vs. 97 l/day). Regression of total daily free-water intake of cows on daily maximum ambient temperatures indicated significant ( $P < 0.01$ ) increases in water intake of the no-shade cows with increasing ambient temperatures, although the relationship was not suitable for prediction ( $R^2 = 0.085$ ). The overall milk production of shade cows was 5.5% higher ( $P < 0.05$ ) than that of no-shade cows. High day-time ambient temperature did not affect ( $P > 0.05$ ) average daily milk production of cows in either treatment. No significant difference was found in milk composition of shade vs. no-shade cows. At prevailing prices and costs the improvement in milk production resulted in a nett return of 42% per annum on the capital outlay of the shade structure.

Die invloed van 'n skaduwee-afdak op die voerinnname, waterinnname, melkproduksie en melksamestelling van Hollandse-tipe Frieskoeie in 'n gematigde klimaat is oor drie somerperiodes bepaal. Die skaduwee-afdak het stralingswarmte verminder ( $P < 0.01$ ) soos aangedui is deur laer swartboltemperatuur. Koeie met toegang tot skaduwee het hoër ( $P < 0.05$  gedurende 1984/85 en  $P < 0.01$  gedurende 1985/86) voerinnames gehad as koeie sonder skaduwee. Die daaglikse voerinnames van koeie is betekenisvol ( $P < 0.05$  vir koeie met skaduwee en  $P < 0.01$  vir koeie sonder skaduwee) verlaag met toenemende maksimumtemperatuur. Koeie sonder skaduwee het bedags meer ( $P < 0.01$ ) water gedrink as koeie met skaduwee (114 vs. 97 l/dag). Daaglikse maksimum omgewingstemperatuur het die waterinnname van koeie met geen skaduwee verhoog ( $P < 0.01$ ), hoewel die effek op waterinnname nie baie groot was nie ( $R^2 = 0.085$ ). Koeie met vrye toegang tot skaduwee het 5.5% ( $P < 0.05$ ) meer melk geproduseer as koeie sonder skaduwee. Maksimum omgewingstemperatuur het geen betekenisvolle ( $P > 0.05$ ) invloed op die gemiddelde daaglikse melkproduksies van koeie met of sonder skaduwee gehad nie. Daar was geen betekenisvolle verskille in melksamestelling van koeie met of sonder skaduwee nie. Weens die verhoging in melkproduksie was die netto inkomste op die kapitale belegging vir die skaduwee-afdak, teen huidige pryse en kostes, 42% per jaar.

**Keywords:** Dairy cows, dry matter intake, economic evaluation, heat stress, milk production, shade, water requirement.

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## Introduction

Dairy cattle were bred in cool to cold climatic regions and are therefore well adapted to withstand cold conditions. This characteristic, however, causes them to be highly sensitive to heat. Direct and indirect solar radiation are additional heat sources encountered by dairy cows in a hot environment. Lactating cows are particularly sensitive to thermal stress owing to their specialized productive function and to their efficiency of feed utilization (Hodgson, 1973). They have poor heat-regulating mechanisms because of a large body size and high feed intake. Heat stress is due mainly to high environmental temperatures, relative humidity, altitude, wind speed and solar radiation levels. Of these factors, air temperature is one of the most important bioclimatic factors that influence production (McDowell, 1972). The comfort range for dairy cows varies between  $-5$  and  $21$  °C. If an animal is subjected to temperatures outside this range, discomfort is caused and

certain reactive physiological processes are stimulated. There is also a change in general behaviour, a decreased food intake and a reduction in efficiency of the energy input-output ratio.

The main reason for providing livestock with some form of protection against adverse climatic conditions is to create an environment for them to express their biological potential for production (Bruce, 1987). A shade structure is one way of reducing the impact of heat stress. It changes the radiation balance of an animal but does not affect air temperature or relative humidity levels (Buffington *et al.*, 1983; Bond, 1967). It is generally regarded as the simplest and most cost-effective way of alleviating high temperature stress (Ames & Ray, 1983).

Research in this regard was started in 1946 at the University of California (Ittner & Kelly, 1951). Results suggested that beef cattle preferred shade structures with higher roofs. Further research concerning shade environmental modification

(Johnston, 1958; Guthrie *et al.*, 1967), evaporative cooling (Stott & Wiersma, 1974), total daily air conditioning (Thatcher *et al.*, 1974), shading the feed manger (Wiersma & Armstrong, 1985), corral manger misting (Armstrong & Wiersma, 1986), holding pen cooling and wetting of cows after milking (Armstrong & Wiersma, 1986) and tree shade (Davison & Silver, 1986) was conducted at other locations. The results indicated positive effects of environmental modification on the milk production capability of dairy cows.

The Western Cape has a temperate climate with cool, wet winters and long, hot, dry summers. At Elsenburg the average monthly maximum ambient temperature increases from 25.5 °C in November to 29.0 °C in February, with March having an average maximum temperature of 27.2 °C. The mean number of days that the maximum temperature exceeds 24 °C in the summer months (November to March) are 15, 21, 26, 24 and 23, respectively. Average minimum ambient temperatures during these months are 11.9, 13.4, 14.2, 14.6 and 13.2 °C, respectively. This indicates that summer days are characterized by intense heat periods varying in duration with relatively cool nights. Ames & Ray (1983) suggested that even in areas of less intense solar radiation a shade structure may be seen primarily as insurance against brief periods of heat.

Seen against this background, a study was undertaken to investigate the effects of shade on the milk production performance of lactating Friesian cows. The effect of maximum ambient temperatures on various dependent variables such as milk production and feed intake of cows was investigated. The economic feasibility of erecting a shade structure was also determined.

## Materials and Methods

The study was conducted in the Winter Rainfall Region at the Elsenburg Experimental Station of the Department of Agriculture over three consecutive summers from 1984/85 to 1986/87 inclusive. Elsenburg is situated approximately 50 km east of Cape Town at an altitude of 177 m, longitude 18° 50' and latitude 33° 51'. Experimental periods during each summer started on December 12, 1984, January 6, 1986 and November 26, 1986 and lasted for respectively 72, 76 and 95 days. At the beginning of each experimental period primiparous and multiparous Dutch-type Friesian cows were allocated in a completely randomized design to two treatments (shade and no shade) according to stage of lactation and average daily milk production during a 3-week preliminary period. Cows were at least four weeks but not more than 180 days into lactation, to ensure that none of the cows needed to be dried off before the completion of each experimental period. Average daily milk production of cows during the preliminary period in the shade and no-shade groups was 20.0 ± 4.9 and 19.8 ± 5.1 kg in 1984/85, 19.9 ± 6.5 and 17.9 ± 3.5 kg in 1985/86, as well as 23.0 ± 7.7 and 24.5 ± 5.9 kg in 1986/87. The average stage of lactation of the various groups during the different experimental periods was 160 ± 50, 162 ± 53; 154 ± 44, 148 ± 42; and 107 ± 56, 101 ± 54 days, respectively. During this preliminary period all cows received the same treatment in terms of feeding, housing and management. Except for the 1984/85 experimental period when 11 cows per treatment were used, there were at least 10 cows in each

group at the beginning of the 1985/86 and 1986/87 experimental periods. Three cows from the 1985/86 shade group and one cow from the 1986/87 no-shade group became sick and their experimental data were excluded from the statistical analysis. Milk production and milk composition data of respectively 22, 17 and 19 cows were therefore used during the three experimental periods.

Cows were kept under zero-grazing conditions in two open camps or dry lots adjacent to each other in all three years. A surface area of 75 m<sup>2</sup>/cow was provided in each camp (Wiersma *et al.*, 1984). Feeding space of 700 mm/cow was provided at the feeding trough. A 3-m concrete floor served as a feeding apron inside each camp along the feed manger. Feeding aprons were cleaned regularly while manure inside the camps was removed at the end of each experimental period. An overhead shade structure with asbestos roof, orientated lengthwise in a north-south direction, was put up near the centre of one of the camps. It provided an unbroken area of shade of 4.1 m<sup>2</sup>/cow. The shade structure was 4.5 m wide, 16.5 m long and 3.5 m high. The underside of the asbestos roof was painted black to reduce the reflection of radiation heat from the ground and environment. The upper surface of the roof was painted white to increase reflection of direct solar radiation. Another shade structure of 2.7 m wide and 2.9 m high, which provided a further 2.5 m<sup>2</sup> shade per cow, was erected over the feed trough. Water troughs, 2.0 × 0.5 × 0.4 m, were provided in each camp. Water troughs were not shaded although water supply lines were buried 0.5 m underground to ensure cool drinking water. Water-flow meters were installed in the water supply lines before the beginning of the 1986/87 experimental period to measure daily water intake.

A complete diet consisting of lucerne hay, wheat, maize, wheat bran and fish-meal providing 135 g crude protein and 9.62 MJ ME/kg was provided *ad libitum* twice a day in the feed troughs of both groups. Fresh feed was provided after refusals of the previous feeding were removed. Samples of fresh feed and refusals were taken at each feeding and the dry matter (DM) content was determined. In this way daily DM intakes of the cows in the two treatment groups were determined on a group basis for day and night feeding periods separately. The daily water consumption of cows on a group basis was determined during the 1986/87 experimental period only. Cows were milked daily between 05:00 and 06:00 and 15:00 and 16:30 in a milking parlour approximately 150 m from the open camps. Milk production of each cow was recorded at each milking. Individual milk samples were analysed for fat, protein and lactose content with a Milko-scan Infrared Analyser. The somatic cell count (SCC) of the milk for each cow was determined with a Fossomatic cell counter.

Black globe thermometers were put up at a height of 2.3 m above ground level under the shade structure and in direct sunlight next to the no-shade camp and recorded daily at 15:00. Daily maximum and minimum temperatures were recorded with a standard thermohygraph inside a Stevenson screen at a weather station of the Agrometeorology Section of the Soil and Irrigation Research Institute, located approximately 1.0 km from the experimental facilities.

Average daily milk production and milk composition of cows were compared between the shade and no-shade groups,

using a 3-week preliminary period as covariate. A combined analysis, pooling data over all three years, was carried out for milk production as well as milk composition, using a nested design with treatments and replicates randomized and nested within years. The average daily feed and water intake of cows and black globe temperatures measured under the shade and in the sun, were compared by pairwise *t*-test procedures (Snedecor & Cochran, 1980).

## Results and Discussion

### Meteorological data

Meteorological data recorded at Elsenburg during the three experimental periods are presented in Table 1. Readings were consistent with long-term data for this region. Days were characterized by high day-time temperatures (27.75 °C) and low night-time temperatures (14.23 °C). Maximum ambient temperatures were higher than 25 °C on 74% of all test days. Berman *et al.* (1985) suggested 25 to 26 °C as the upper ambient temperature limit at which Holstein cattle are able to maintain stability of body temperature. An increase in body temperature above this temperature limits reproductive performance and milk yield. It therefore seems that husbandry procedures should intervene to prevent or reduce an increase in body temperature at ambient temperatures above 25 °C.

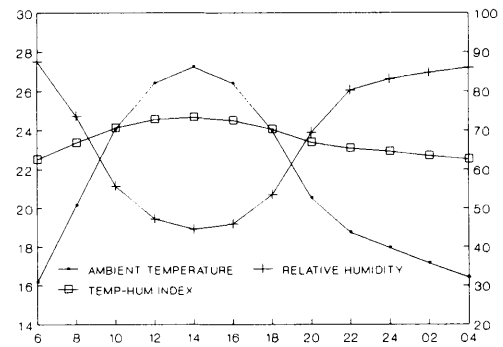
**Table 1** Meteorological data at Elsenburg during the different experimental periods

Parameter	Experimental period		
	1984/85	1985/86	1986/87
Max. temperature (°C)	27.49 (4.15) <sup>a</sup>	28.65 (4.23)	27.23 (3.80)
Min. temperature (°C)	14.92 (2.71)	14.20 (2.38)	13.74 (2.35)
Stress hours (> 25 °C)	7.73 (3.28)	7.93 (3.23)	6.57 (3.63)
Sun hours	9.7 (3.3)	10.5 (2.6)	10.3 (3.1)
Number (%) of days >25 °C	52 (72%)	59 (79%)	67 (71%)
Wind (km/24 h)	192.6 (79.7)	176.4 (64.1)	147.5 (63.3)
Max. humidity	90.7 (5.5)	91.0 (8.6)	95.4 (6.9)
Min. humidity	39.7 (10.5)	35.6 (10.6)	40.6 (10.2)
Total precipitation (mm)	76.6	42.3	67.1
Number of rainy days	17	7	13

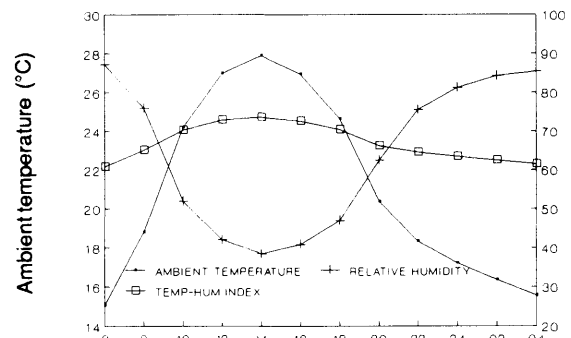
<sup>a</sup> Figures in brackets indicate standard deviations of parameters.

On days with maximum ambient temperatures above 25 °C, the average number of stress hours was 7.4. There was, however, considerable variation between days as indicated by the standard deviations for each experimental period. Maximum ambient temperatures were usually recorded at approximately 14:00 with temperatures exceeding 25 °C from about 10:30 to 18:00 (Figure 1). Number of stress hours per day was closely related ( $P < 0.01$ ) to maximum temperature ( $R^2 = 0.88$ ). Humidity levels were inversely ( $P < 0.01$ ) related to maximum temperatures. Temperature Humidity Index values ( $THI = T_a + 0.36T_{dp} + 41.2$ , where  $T_a$  is air temperature and  $T_{dp}$  is dew point temperature, both in degrees Celsius) higher than 72 were recorded between 11:00 and 17:00. At 18:00, ambient temperatures were usually 24 °C with relative humidity levels

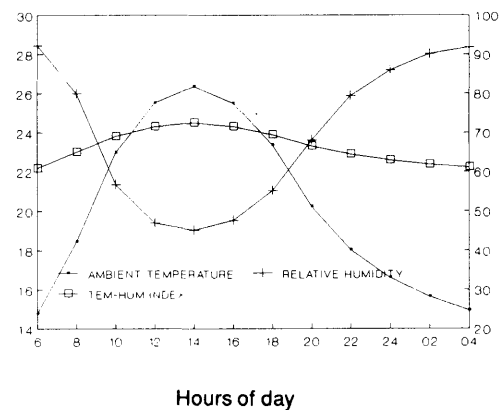
**FIGURE 1.1 : 1984/85**



**FIGURE 1.2 : 1985/86**



**FIGURE 1.3 : 1986/87**



**Figure 1** Mean ambient temperatures, relative humidity and Temperature Humidity Index levels on all days during the three experimental periods.

of approximately 52% ( $THI = 70.1$ ). This suggests that cows were only subjected to heat stress from solar radiation during day-light hours. Cows should also recover adequately during the night from excessive heat loads during the day.

It has been suggested that a given volume of air will be under a 11-m long shade (in the direction of the wind travel) for only 25 s with a wind speed of only 1.6 km/h (Kelly *et al.*, 1950). This time is too short for a significant reduction in air temperature because of the shade effect. Most of the benefit from a shade structure, as far as animal comfort is concerned, should thus be ascribed to a lowering of radiation heat load. According to Bond & Kelly (1955) a well-designed shade structure should reduce total heat load by 30 to 50%. Black globe temperatures (combining effects of net radiation

from the sun, horizon, ground and other objects, dry bulb temperatures and wind speed) suggested a difference of 10.1 °C ( $P < 0.01$ ) between the shade and no-shade areas over the three-year experimental period. Black globe temperatures on all days for the shade and no-shade areas were  $29.7 \pm 5.7$  and  $39.5 \pm 7.8$  in 1984/85,  $30.6 \pm 4.3$  and  $40.8 \pm 6.5$  in 1985/86 and  $29.4 \pm 4.4$  and  $39.6 \pm 6.20$  °C in 1986/87, respectively. These results are in agreement with black globe temperatures recorded by Kelly *et al.* (1950) and Roman-Ponce *et al.* (1977) in California and Florida, respectively. Californian temperatures differed by 15.8 °C at 15:00 while in Florida the average difference was 8.3 °C for hourly recordings between 09:00 and 18:00.

### Feed intake

The daily DM intake of cows (separated into day-time, night-time and total DM intake) in the shade and no-shade groups is presented in Table 2. Cows in these two groups consumed approximately 48 and 45%, respectively, of their total daily feed intake during the day-time feeding period. Total daily feed intake of shade and no-shade cows differed during 1984/85 ( $P < 0.05$ ) and 1985/86 ( $P < 0.01$ ). There was no significant difference in total daily feed intake between the two groups of cows during the 1986/87 experimental period. The higher feed intake at night could possibly be ascribed to a longer feeding period (12.5 vs. 9.5 h) and cooler environmental conditions. According to Figure 1 ambient temperatures were below 24 °C from 18:00. Feed intake during the night was not influenced by heat stress and cows could therefore maintain normal feeding activities.

**Table 2** Average ( $\pm$  SD) day, night and total daily feed intake of cows during experimental periods

Experimental period	Feed intake (kg DM/cow/day)		Significance
	Shade	No shade	
<b>Daytime feeding period</b> (06:00–15:00)			
1984/85	–	–	–
1985/86	$9.89 \pm 1.08$	$9.23 \pm 1.31$	$P < 0.01$
1986/87	$9.91 \pm 0.75$	$9.90 \pm 0.85$	$P > 0.05$
<b>Night-time feeding period</b> (16:30–05:00)			
1984/85	–	–	–
1985/86	$10.99 \pm 0.87$	$10.67 \pm 0.86$	$P < 0.01$
1986/87	$12.30 \pm 0.68$	$12.32 \pm 0.47$	$P > 0.05$
<b>Total</b>			
1984/85	$20.20 \pm 1.49$	$19.88 \pm 1.50$	$P < 0.05$
1985/86	$20.88 \pm 1.82$	$19.90 \pm 1.75$	$P < 0.01$
1986/87	$22.20 \pm 1.15$	$22.20 \pm 1.06$	$P > 0.05$

Regressions of day-time feed intake of cows during the 1985/86 and 1986/87 experimental periods on daily dry bulb maximum ambient temperatures showed that feed intake was reduced during 1985/86 for shade ( $P < 0.05$ ) and no-shade cows ( $P < 0.01$ ) as well as during 1986/87 for no-shade cows

( $P < 0.05$ ). The day-time feed intake of shade cows during 1986/87 was not affected by maximum ambient temperatures. However, it seems that an increase in ambient temperature of 1 °C (above 21 °C) was associated with only a small linear decrease in day-time feed intake, *i.e.* 0.09, 0.09 and 0.06 kg/day for the 1985/86 shade and no-shade cows and for the 1986/87 no-shade cows, respectively. It must be mentioned that, although a significant relationship existed between ambient temperature and feed intake, the value of this relationship for predictive purposes was very limited, as depicted by  $R^2$  values of only 0.06 to 0.11. A large percentage of variation in day-time feed intake could thus be attributed to other factors.

### Free-water intake

The average total daily free-water intake of shade and of no-shade cows during the 1986/87 experimental period were  $96.8 \pm 11.1$  and  $114.0 \pm 17.3$  l, respectively ( $P < 0.01$ ). No-shade cows had higher ( $P < 0.01$ ) intakes of free water than shade cows during both the day- and night-time periods ( $55.7 \pm 10.6$  vs.  $47.8 \pm 7.0$  and  $58.3 \pm 9.5$  vs.  $48.9 \pm 7.1$  l). The free-water intake of the no-shade cows was higher during the night ( $P < 0.05$ ) than during the day, but there was no difference between the day and night free-water intake of shade cows. Water is regarded as one of the most important nutrients for dairy cattle. Milk production (Little & Shaw, 1978, Little *et al.*, 1979) as well as feed intake (Thornton & Yates, 1969 and Utley *et al.*, 1970) is decreased if the water intake of cows is restricted. Drinking water is quantitatively the most significant nutrient in meeting the needs of heat-stressed animals (Beede & Collier, 1986). Water consumption in the present study accorded with results obtained by Moran (1989) with Holstein-Friesian cows in a Mediterranean climate in Australia. The total free-water intakes of cows during summer in a free stall unit (providing shade) and open lots (no shade) were 72.2 and 86 l/day, respectively. McDowell (1972) similarly reported that the free-water intake of a lactating Holstein cow in climatic chambers at a comfortable environment (18 °C) was 57.9 l/day and at a hot environment (30 °C) 74.7 l/day.

The water intake of dairy cattle increases with increasing air temperatures (Winchester & Morris, 1956; McDowell, 1972; NRC, 1989). Regression of the total daily free-water intake of cows on daily dry bulb maximum temperatures showed that the free-water intake of no-shade cows increased ( $P < 0.01$ ) with increasing ambient temperatures in this study. A similar tendency was observed in shade cows although the increase was not significant. The relationship between maximum ambient temperature and free-water intake of the no-shade cows was, however, not of any value for predictions ( $R^2 = 0.09$ ), suggesting that factors other than maximum ambient temperature determine daily free-water intake.

### Milk production

The average daily milk production of the shade and the no-shade cows during the three experimental periods and overall mean milk production, are presented in Table 3. The covariance analysis did not reveal a significant ( $P < 0.05$ ) effect of shading on milk production during any of the three experimental periods considered separately, although the 10.5%

**Table 3** Average daily milk production, adjusted by covariance, of shade and no-shade cows during three experimental periods

Experimental period	Milk production (kg/day)		$SE_d$	Significance
	Shade	No-shade		
1984/85	17.91	17.59	0.42	$P > 0.05$
1985/86	18.35	17.94	0.84	$P > 0.05$
1986/87	23.88	21.62	1.16	$P = 0.07$
Overall mean	20.07	19.03	0.48	$P < 0.05$

$SE_d$ : Standard error of difference.

improvement owing to the shading during the 1986/87 period was significant at  $P < 0.10$ . This response in milk yield during 1986/87 is in agreement with results obtained by Roman-Ponce *et al.* (1977) with dairy cows of four breeds (Holstein, Jersey, Guernsey and Brown Swiss) in a subtropical area of the United States of America. In the combined analysis the adjusted average daily milk production of shade cows was improved ( $P < 0.05$ ) by 5.5% compared to that of no-shade cows.

In the Western Cape only maximum temperature would have a major negative influence on the milk production of dairy cows since humidity levels of the air decrease with increasing ambient temperatures during the day (Figure 1). To determine the effect of high ambient temperatures on the milk production of dairy cows, the average daily milk production of the shade and no-shade cows was regressed on maximum ambient temperature recorded on the same day. Daily milk production was the total milk produced during the afternoon and next morning's milking. These regressions indicated that average daily milk production of dairy cows was not affected by high ambient temperatures. Johnston (1958) has also demonstrated in studies under natural hot conditions in Louisiana, USA, that there was no immediate effect of hot weather on milk production as long as feed consumption was not affected.

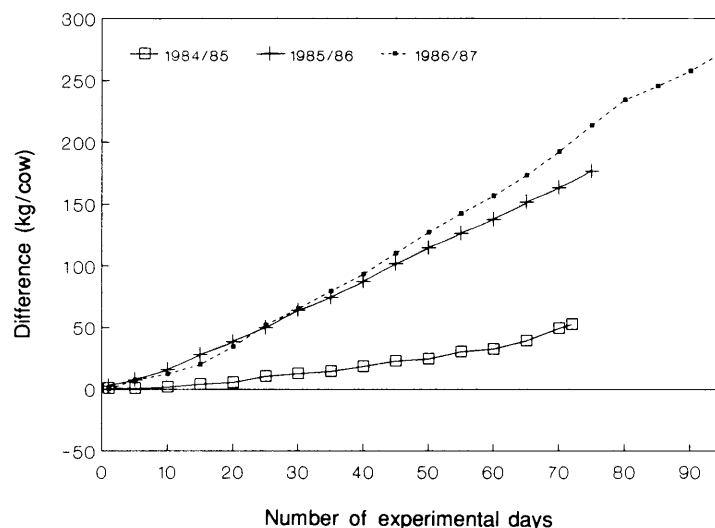
The lack in response of milk production to high environmental temperatures at Elsenburg was contrary to expectations. From Table 1 it is clear that although high day-time temperatures (above 25 °C) were experienced regularly, cows were only subjected to a short heat stress period (7.3 h) during the day with cool conditions at night. They could therefore recover from the high heat load encountered during the day. The cool conditions at night also enabled cows to maintain a normal feed intake, while the practice of providing feed during morning milking ensured that cows could eat before the onset of hot conditions at approximately 10:30.

The difference between the cumulative daily milk production of shade and no-shade cows is presented in Figure 2. From this it seems that the difference in milk production increased with time during the three experimental periods. Roman-Ponce *et al.* (1977) similarly found that lactation curves of shade and no-shade cows in a tropical climate differed, and that the difference between treatment means increased during the trial period. Johnston (1958) also pointed out that cows which are exposed to gradual temperature increases, do not respond with an immediate reduction in milk production, but show less persistency of production than cows protected from high temperatures. This effect does not show up until 30 days or more after initial exposure.

#### Milk composition

Milk composition (Table 4) did not differ between groups, although protein percentage tended to be lower ( $P < 0.14$ ) and SCC tended to be higher ( $P < 0.15$ ) for the no-shade groups. The SCC between individual cows within each treatment, however, differed to a great extent (coefficient of variance of 145 and 198% for the shade and no-shade cows, respectively).

Regan & Richardson (1938) showed that the fat content of the milk of cows did not change with increasing temperatures up to 35 °C. High ambient temperatures in their study had a more marked effect on the solids-not-fat content of milk, with a parallel decrease in casein content. Roman-Ponce *et al.* (1977) also found no significant differences in fat and protein percentages although solids-not-fat was lower ( $P < 0.10$ ) for



**Figure 2** Difference in the accumulative milk production of shade cows as deviation from no-shade cows during summer.

**Table 4** Overall daily mean fat, protein and lactose content and somatic cell counts (SCC) of shade and no-shade groups

Parameter	Milk composition (%)		SE <sub>d</sub>	Significance
	Shade	No shade		
Fat	3.42	3.41	0.12	<i>P</i> > 0.05
Protein	3.62	3.53	0.06	<i>P</i> > 0.05
Lactose	5.11	5.09	0.03	<i>P</i> > 0.05
SCC (× 1000)	120	242	82.6	<i>P</i> > 0.05

SE<sub>d</sub>: Standard error of difference.

shade and no-shade cows in a subtropical climate area. Bandaranayaka & Holmes (1976) reported a lower (*P* < 0.05) protein content in the milk of dairy cows kept in environmentally controlled rooms at 30 °C in comparison to 15 °C. In this experiment, however, food intake was reduced by 16% at a temperature of 30 °C. According to Flux & Patchell (1954) decreased levels of food intake during lactation are usually associated with an increased fat content but a decreased protein content. In the present study food intake was reduced by only about 3% during two of the three experimental periods.

#### Economic analysis

Building a shade structure involves a capital investment. During 1984 the material cost of the shade structures in the open camp and over the feed trough was R135/cow. Using four people, the labour cost was estimated at R40/cow. The only annual benefit of a shade structure would be an increased milk production and reproduction rate. The economic return from a shade structure depends on the depreciation time and number of heat stress days during summer. A shade structure would be in use in the Western Cape for up to 150 days/year (November to March) and would have a lifetime of 10 to 15 years.

One method of evaluating the desirability of a prospective investment is to calculate the internal rate of return of the investment (Strickland *et al.*, 1989). For a shade structure that is in use for 150 days (during summer only) and with a lifetime of 10 years, the internal rate of return would be 48% (personal communication: J. Stander, Private Bag, Elsenburg, 1991). This is in agreement with results obtained by Strickland *et al.* (1989) which indicated that the internal rate of return of a sprinkler and fan cooling system is 43% at 150 days of operation and with a 10-year lifetime. The nett farming income on the capital outlay of a shade structure of this kind which results in an improvement of 5.5% in a herd producing 20 kg milk/cow/day at a price of 45c/kg, will be 42% (personal communication: J. Stander, 1991). This indicates that a shade structure in a dry lot system would be a good investment, since the projected rate of return is higher than prevailing interest rates.

#### Conclusions

The provision of shade to lactating Friesian cows resulted in a 5.5% increase of milk production, associated with higher intake levels of feed and water. An economic analysis

suggested that even with this modest increase in milk production, the cost involved in the construction of such a structure could, depending on current milk prices, be recovered within one to two summer seasons. The internal rate of return was calculated at more than 40% which shows a shade structure to be an excellent investment.

#### Acknowledgements

The authors thank the Elsenburg Bio- and Datametrical Section, particularly Mr D. Capatos, for statistical advice, and Mr A. van Rooyen for datametrical services. Mr A.H.C. Shipman and his milkers are also thanked for their help with the practical execution of the experiment.

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