

## Relative economic benefits of tactical anthelmintic treatment and urea-molasses block supplementation of Boer goats raised under extensive grazing conditions at Onderstepoort, Pretoria, South Africa

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### ABSTRACT

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The potential economic benefits of combining tactical anthelmintic treatment for gastrointestinal nematodes and nutritional supplementation with urea-molasses blocks were examined in Boer goats raised under extensive grazing conditions in the summer rainfall area of South Africa. Eight groups of nine goats were monitored over a 12-month period from 1 October 2002 to 9 October 2003. *Ad libitum* nutritional supplementation with urea-molasses blocks was provided when the goats were housed at night, during the summer (wet season—December 2002 to February 2003), and/or the winter (dry season—June 2003 to August 2003). All the goats were treated symptomatically for *Haemonchus contortus* infection when deemed necessary by clinical examination of the conjunctiva for anaemia using the FAMACHA® system. Half the groups were tactically treated for gastrointestinal nematodes in mid-summer (28 January 2003). Under the symptomatic treatment, climatic and extensive grazing conditions encountered during the trial, feed supplementation in the winter dry season had the greatest economic benefit and is therefore recommended. Tactical anthelmintic treatment afforded no additional advantage, but the nematode challenge was low.

**Keywords:** Boer goats, extensive grazing, *Haemonchus contortus*, symptomatic drenching, tactical drenching, urea-molasses blocks

### INTRODUCTION

Livestock disease caused by gastrointestinal nematodes is considered to have a major impact on the livelihoods of poor livestock keepers (Perry, Randolph, McDermott, Sones & Thornton 2002). The use of anthelmintics is currently the most common method of parasite control, but the continuing emergence of anthelmintic resistance seriously threatens long-term efficacy. Protein supplementation has been identified as an alternative approach in the management of nematodes (Coop & Kyriazakis 1999). Therefore, the aim of the current study was to obtain quantitative data on the economic benefits of tactical anthelmintic treatment combined with nutritional supplementation against gastrointestinal

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nematode infections in Boer goats. Here we define tactical anthelmintic treatment as the deworming of an entire flock when a large number of worms are expected, e.g. after good rains at a time when temperature and pasture conditions are ideal for the free-living stages (Van Schalkwyk, Schröder, Malan & Van Wyk 1995) and symptomatic treatment as the specific treatment of individual animals showing life-threatening clinical signs of worm infection.

## MATERIALS AND METHODS

### Climate data

The experiment ran from 1 October 2002 to 9 October 2003. Rainfall data were obtained from records kept on the Onderstepoort Veterinary Institute (OVI) experimental farm situated near Pretoria for the years 1991–2003. Temperature data for Pretoria were obtained from the South African Weather Service.

### Parasites and infection of goats

*Haemonchus contortus* third-stage nematode larvae ( $L_3$ ) of an anthelmintic-susceptible population (Moredun population) were obtained from the OVI bank of nematode larvae which are preserved in liquid nitrogen. Just prior to use, required numbers of cryopreserved larvae were thawed in lukewarm water. Their motility was checked and their concentration was adjusted to c. 1 000  $L_3$  per ml with tap water. They were kept in suspension by agitating their container. The goats were orally infected by slowly depositing the required amount of  $L_3$  suspension over the base of the tongue with the use of a plastic syringe, to ensure that all the infective larvae would be swallowed.

### Animal maintenance

Seventy-two 5 to 6-months-old male Boer goats were purchased from the Kuruman district, Northern Cape Province, South Africa and transported to the OVI near Pretoria in two batches during June and July 2002. They were housed in pens with concrete floors, which were cleaned daily from Monday to Friday. Intact goats were castrated. All were fed a commercial pelleted feed and hay and water *ad libitum*.

The animals were dewormed and artificially re-infected with *H. contortus* as set out in Table 1.

On 26 August 2002, the animals were moved to the OVI experimental farm 'Kaalplaas', where they grazed extensively in a paddock of c. 110 ha of

mixed grazing and browse. The pasture had apparently not been grazed by small ruminants for 6 years prior to the current study, but had been used for the grazing of cattle, which shared the paddock with a small number of impalas (*Aepyceros melampus*), common duikers (*Sylvicapra grimmia*), steenbok (*Raphicerus campestris*) and warthog (*Phacochoerus aethiopicus*). The cattle were removed from the paddock before the start of the experiment.

### Experimental design and monitoring

On 1 October 2002 the goats were allocated to eight groups each comprising nine animals (Table 2). The groups were balanced for live mass. This was done as follows: the goats were ranked in terms of live mass from highest to lowest live mass as determined on 25 September 2002. The eight goats with the highest live masses were then each randomly allocated to a group. The next eight goats were similarly randomly allocated to a group. This process was followed until all the goats had been allocated to a group. The goats were housed in sheds per feed group at night when urea-molasses block supplementation [Voermol Protein Blocks, Maidstone, South Africa; urea 67 g/kg dry matter (DM)] was provided *ad libitum* to the supplemented groups during the appropriate periods. About 10 kg of a commercially prepared pelleted feed (crude protein 174 g/kg DM) was scattered in the feed troughs each evening to lure the animals back into the sheds and its effect on the animals' nutrition was considered negligible. The goats were monitored throughout the experimental period and on 28 January 2003 some were either treated tactically with 0.4 mg/kg ivermectin administered orally, while others were not.

The goats were examined for anaemia according to the FAMACHA© system on a weekly basis (Vatta, Letty, Van der Linde, Van Wijk, Hansen & Krecek 2001). The FAMACHA© system allows an animal's mucous membrane colour to be classed into one of five colour categories, from 1 (non-anaemic) to 5 (severely anaemic). Symptomatic anthelmintic treatments with ivermectin (Ivomec Liquid™, Merial South Africa, 0.4 mg/kg) were given orally to those animals scored in Categories 3, 4 or 5, as these levels of anaemia are considered to be life-threatening.

On the same day that the goats were examined clinically for anaemia, they were weighed and scored for body condition. Faecal samples were collected to determine nematode egg counts (Reinecke 1983) and faecal cultures were prepared in order that differential third-stage nematode larval counts could

TABLE 1 Anthelmintic treatments administered to experimental Boer goats prior to artificial infection with *Haemonchus contortus* in preparation for the experiment

| Date               | Time of day | Treatment                                                                 |
|--------------------|-------------|---------------------------------------------------------------------------|
| 17 July 2002       | Morning     | 7.5 mg/kg oxfendazole (Oxfen™, Bayer Animal Health)                       |
| 18 July 2002       | Morning     | 5.0 mg/kg oxfendazole (Oxfen™, Bayer Animal Health)                       |
| 18 July 2002       | Afternoon   | 5.0 mg/kg oxfendazole (Oxfen™, Bayer Animal Health)                       |
| 19 July 2002       | Morning     | 12.0 mg/kg levamisole (Tramisol™, Intervet)                               |
| 30 or 31 July 2002 |             | Faecal flotations <sup>a</sup> positive for 23 of 72 goats                |
| 7–13 August 2002   | Morning     | 0.4 mg/kg ivermectin (Ivomec Liquid™, Merial South Africa)                |
| 19 August 2002     |             | Faecal flotations negative for all goats                                  |
| 23 August 2002     |             | Infection with c. 3 000 third-stage larvae of <i>Haemonchus contortus</i> |
| 26 August 2002     |             | Transfer to experimental paddocks                                         |

<sup>a</sup> Flat-sided medicine bottle flotation method (Reinecke 1983)

TABLE 2 A comparison of the market value per goat corrected as applicable for the costs of supplementation with urea-molasses blocks and tactical ivermectin treatment for gastrointestinal nematodes for eight groups of nine Boer goats. Each group was either tactically treated on 28 January 2003 (+) or not (–). All the goats were treated symptomatically with ivermectin as and when required. Supplementation with urea-molasses blocks was either not given or given in the dry winter season (June to August 2003), the wet summer season (December 2002 to February 2003), or both periods

| Group | Time of urea-molasses block supplementation | Tactical ivermectin treatment | Mean dressed-out carcass mass(kg) | Market value <sup>a</sup> | Cost of urea-molasses blocks per animal | Cost of ivermectin treatment per animal | Mean net value per animal | Net benefit over Group 1 controls |
|-------|---------------------------------------------|-------------------------------|-----------------------------------|---------------------------|-----------------------------------------|-----------------------------------------|---------------------------|-----------------------------------|
| 1     | Unsupplemented                              | –                             | 25.0                              | 54.98                     | 0                                       | 0                                       | 54.98                     | 0                                 |
| 2     | Unsupplemented                              | +                             | 24.4                              | 53.61                     | 0                                       | 0.69                                    | 52.92                     | –2.06                             |
| 3     | Dry season                                  | –                             | 27.6                              | 60.79                     | 2.51                                    | 0                                       | 58.28                     | 3.30                              |
| 4     | Dry season                                  | +                             | 25.1                              | 55.13                     | 2.51                                    | 0.68                                    | 51.94                     | –3.04                             |
| 5     | Wet season                                  | –                             | 23.1                              | 50.91                     | 2.15                                    | 0                                       | 48.76                     | –6.22                             |
| 6     | Wet season                                  | +                             | 23.5                              | 51.68                     | 2.15                                    | 0.69                                    | 48.84                     | –6.14                             |
| 7     | Wet-and-dry seasons                         | –                             | 23.8                              | 52.43                     | 4.66                                    | 0                                       | 47.77                     | –7.21                             |
| 8     | Wet-and-dry seasons                         | +                             | 25.4                              | 55.79                     | 4.66                                    | 0.71                                    | 50.42                     | –4.56                             |

All prices are stated in US\$. (US\$ 1.00 was approximately equal to R7.00 in January 2004)

<sup>a</sup> The market value of the carcass was estimated at US\$ 2.20/kg

be made (Reinecke 1983; Van Wyk, Cabaret & Michael 2004). However, the infective larvae of *Teladorsagia* and *Trichostrongylus* spp. were not differentiated. Blood was collected in tubes containing EDTA (Vacutainer™ tubes, Becton Dickinson, France) for haematocrit determination (Vatta 2001) and in tubes for serum analyses for total protein, albumin and urea. Serum total protein, albumin and urea were determined by means of colorimetric methods utilizing reflectance spectrophotometry (Vitros™, Johnson and Johnson Clinical Diagnostics).

The study ran until 9 October 2003, when the animals were slaughtered, their dressed-out carcass masses determined and their nematodes recovered from the abomasum, small intestine, caecum and colon, following the methods of Van Wyk, Schröder, Van Schalkwyk & Horak (1987); Visser, Van Wyk &

Alves (1987); Wood, Amaral, Bairden, Duncan, Kas-sai, Malone, Pankavich, Reinecke, Slocombe, Taylor & Vercruysse (1995).

### Economic analysis

The most economically viable experimental treatment was determined by cost-benefit analysis (Table 2). The mean cold dressed-out carcass mass was determined for each group of goats and was multiplied by US\$ 2.20/kg, the market value per kilogram of meat at slaughter, to give the mean market value per carcass for each group. The calculation of the cost of urea-molasses block supplementation per goat was based on the amount of urea-molasses block consumed per goat per group, where applicable, and the cost of a urea-molasses block at purchase. This assumed that each goat consumed

the same amount of block, which is not usually the case. The cost of the tactical treatment per goat, where applicable, was calculated by determining the average amount of anthelmintic drenched per goat for that group and multiplying this value by the cost of anthelmintic at purchase. The costs of block supplementation and tactical treatment were then subtracted from the mean market value per carcass where applicable, and the corrected carcass value subtracted from the mean market value per carcass for Group 1. The resultant value indicated an increase or decrease in carcass value relative to Group 1.

### Herbage sampling

With the exception of the week of 23–29 December 2002, herbage samples were collected weekly from 31 October 2002 to 2 October 2003. These were collected by cutting or plucking the grass and herbs falling within a quadrat of 400 mm x 400 mm thrown at random on ten occasions during a walk-about [the method having been modified from that described by Smith (1999) for sward sampling]. The walk-about took the form of a route in the shape of a “W”, “X” or variation thereof within the paddocks grazed by the goats and was similar to the collecting route described by Hansen & Perry (1994) for isolating infective larvae from herbage. Six different routes were followed in rotation. During each walk-about, samples of browse leaves were also collected from shrubs falling within c. 3 m of the place where the quadrat fell. The samples were air-dried, coarsely milled to a diameter of c. 10 mm before being further milled through a 1 mm sieve in the labo-

ratory and analyzed for dry matter (Harris 1970), ash (Harris 1970), acid detergent fibre (Goering & Van Soest 1970) and neutral detergent fibre (Robertson & Van Soest 1981). Crude protein content was determined by the Dumas combustion method, using the Leco FP-2000 instrument (Leco Corporation, St Joseph, Michigan, USA).

### Data handling and analysis

The data were analysed statistically by means of a 2 x 4 factorial analysis of variance, testing both the main effects of tactical anthelmintic treatment and supplementary feeding and the treatment by feeding interaction. Means were separated using Fisher's protected t-test least significant difference (LSD) at the 5% level. All data were analysed using the GenStat statistical system (GenStat® for Windows™, 7<sup>th</sup> edition, VSN International Ltd). The data for the faecal egg counts and worm counts were log<sub>10</sub>-transformed for analysis to stabilize variances but the untransformed data are presented in the figures.

## RESULTS

### Rainfall and temperature

For the purposes of this experiment, summer is defined as running from 1 December to 28 February and winter from 1 June to 31 August. It was unusually dry in November 2002 (Fig. 1) and there was no rainfall from April to September 2003.

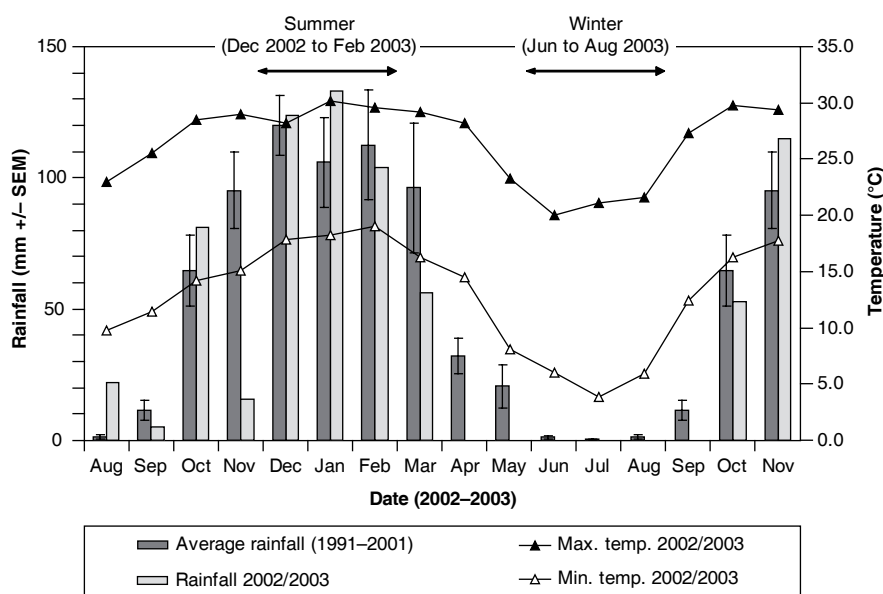


FIG. 1

The rainfall (compared with the average for 1991–2001  $\pm$  the standard error of the mean) and temperature data for the OVI experimental farm during the experimental period

## Herbage analysis

The average composition of the herbage samples collected throughout the period of the experiment is given in Table 3. The dry matter content of the herbage was lowest during the period of summer rainfall and increased in the dry winter season (Table 4). The crude protein content of the herbage was highest in the rainy season and decreased as the grazing matured (Table 4). The acid detergent fibre and neutral detergent fibre content remained relatively consistent throughout the period of the experiment (data not shown).

## Consumption of blocks

The consumption of block per goat per day for the wet-summer-season-supplementation period was estimated at 54 g (wet-season-supplemented group) and 62 g (wet-and-dry-season-supplemented group). During the dry winter season, the consumption per goat per day was 78 g (dry-season-supplemented group) and 77 g (wet-and-dry-season-supplemented group). The intake of block was lower than the man-

ufacturer's recommended daily intake of 100–140 g per sheep per day (Voermol Pasture Supplements Product Handbook, 2<sup>nd</sup> edition, Voermol, Maidstone, South Africa).

## Parasitological findings

While the goats were infected with *H. contortus* (Fig. 2), the egg counts were low throughout the study [ $< 400$  eggs per gram of faeces (epg)]. Before tactical treatment, there were no statistically significant differences in mean egg counts between tactically and non-tactically treated groups. The tactical treatment was effective ( $P < 0.001$ ), with the mean egg count dropping to almost zero in the tactically treated groups. There were generally no statistically significant differences between mean egg counts for the feed groups. After May 2003, all the groups had very low egg counts ( $< 150$  epg).

Third-stage larvae of *Haemonchus* spp. predominated in the faecal cultures from October 2002 to March 2003. During April and May 2003 larvae of *Haemonchus* and *Teladorsagia/Trichostrongylus*

TABLE 3 Average composition of herbage sampled weekly from 31 October 2002 to 2 October 2003 in the paddocks where the goats were grazed for the experiment

| Herbage samples | Dry matter (g/kg) | Moisture content (g/kg) | Crude protein (g/kg DM) | ADF (g/kg DM) | NDF (g/kg DM) | Ash (g/kg DM) |
|-----------------|-------------------|-------------------------|-------------------------|---------------|---------------|---------------|
| Mean            | 578               | 422                     | 69                      | 361           | 592           | 101           |
| SD              | 122               | 122                     | 15                      | 24            | 42            | 12            |
| SEM             | 18                | 18                      | 2                       | 4             | 6             | 2             |
| Minimum         | 328               | 207                     | 45                      | 307           | 508           | 81            |
| Maximum         | 793               | 672                     | 107                     | 409           | 666           | 139           |
| <i>n</i>        | 48                | 48                      | 48                      | 48            | 48            | 47            |

SD = standard deviation

SE = standard error of the mean

DM = dry matter

ADF = acid detergent fibre

NDF = neutral detergent fibre

TABLE 4 Seasonal mean pasture dry matter (DM), pasture crude protein (CP), body condition score, total serum protein, serum albumin, serum urea and haematocrit for spring 2002 (1 October to 30 November 2002), summer 2002/03 (1 December 2002 to 28 February 2003), autumn (1 March to 31 May 2003), winter (1 June to 31 August 2003) and spring 2003 (1 September to 9 October 2003)

| Season                                  | Spring 2002      | Summer 2002/03   | Autumn 2003      | Winter 2003      | Spring 2003      |
|-----------------------------------------|------------------|------------------|------------------|------------------|------------------|
| Mean pasture DM $\pm$ SD (g/kg)         | 519.4 $\pm$ 75.1 | 461.9 $\pm$ 70.9 | 551.2 $\pm$ 99.9 | 708.7 $\pm$ 49.9 | 649.8 $\pm$ 99.3 |
| Mean pasture CP $\pm$ SD (g/kg DM)      | 75.6 $\pm$ 9.3   | 81.9 $\pm$ 10.0  | 67.6 $\pm$ 9.0   | 54.1 $\pm$ 9.2   | 72.0 $\pm$ 19.9  |
| Mean body condition score $\pm$ SD      | 2.0 $\pm$ 0.3    | 2.6 $\pm$ 0.4    | 3.3 $\pm$ 0.5    | 3.1 $\pm$ 0.5    | 2.8 $\pm$ 0.5    |
| Mean total serum protein $\pm$ SD (g/l) | 63.5 $\pm$ 3.4   | 65.2 $\pm$ 3.2   | 64.4 $\pm$ 3.4   | 64.6 $\pm$ 4.1   | 64.3 $\pm$ 3.2   |
| Mean serum albumin $\pm$ SD (g/l)       | 24.9 $\pm$ 1.9   | 26.3 $\pm$ 2.1   | 27.1 $\pm$ 2.5   | 25.1 $\pm$ 1.9   | 26.1 $\pm$ 1.8   |
| Mean serum urea $\pm$ SD (mmol/l)       | 5.55 $\pm$ 1.23  | 5.91 $\pm$ 1.41  | 4.71 $\pm$ 1.32  | 2.59 $\pm$ 1.01  | 2.06 $\pm$ 0.61  |
| Mean haematocrit $\pm$ SD (%)           | 23.8 $\pm$ 2.1   | 24.2 $\pm$ 2.3   | 25.3 $\pm$ 2.3   | 25.5 $\pm$ 2.4   | 25.2 $\pm$ 2.2   |

SD = standard deviation



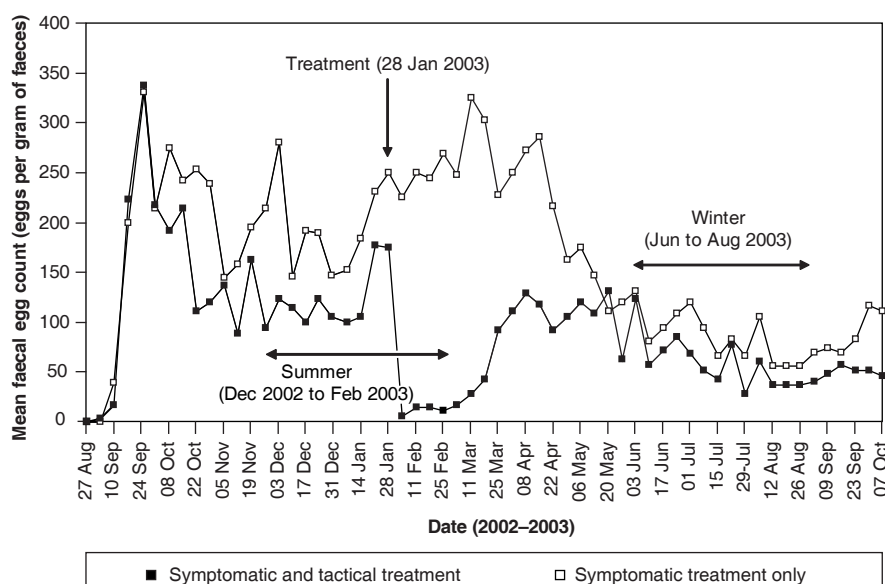


FIG. 2

Faecal egg counts (eggs per gram, epg) for the 36 Boer goats treated tactically and symptomatically (■) with ivermectin compared to the 36 goats given symptomatic treatment only (□)

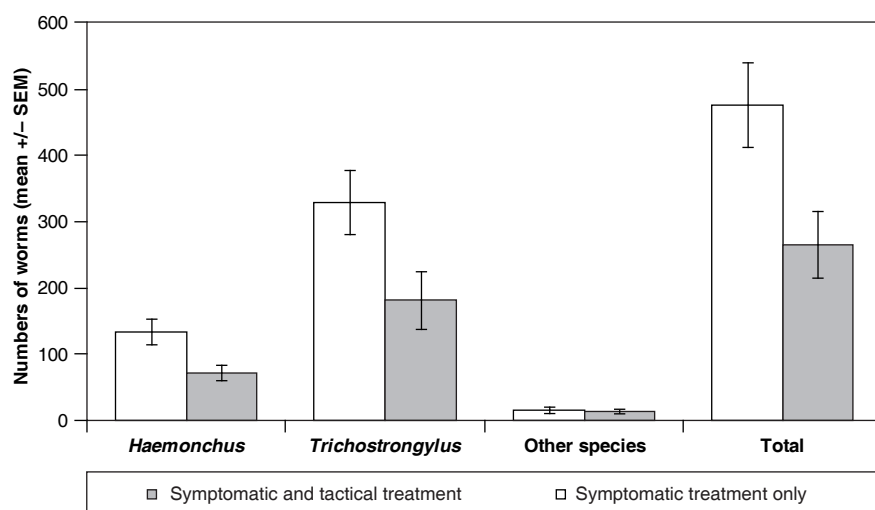


FIG. 3

Mean worm counts ( $\pm$  standard error of the mean) for the 36 Boer goats treated tactically and symptomatically with the anthelmintic ivermectin (shaded columns) compared to the 36 goats given symptomatic treatment only (non-shaded columns)

spp. occurred in approximately equal numbers in the cultures, while from June to October 2003 larvae of *Teladorsagia/Trichostrongylus* spp. were predominant (data not shown). Larvae of *Oesophagostomum* spp. were found in very low numbers in the cultures during one week in December 2003.

As judged by the nematodes recovered following the slaughter of the goats, *Trichostrongylus* spp. were most abundant, followed by *Haemonchus* spp. and other species (Fig. 3). Of the *Trichostrongylus* spp., *T. falculatus* was the most common and only limited numbers of *T. axei* and *T. colubriformis* were recorded. The other species identified included small numbers of *Teladorsagia* spp., *Strongyloides papillosus*, *Impalaia tuberculata*, *Trichuris* spp. and *Oesophagostomum* spp. (on average, 14 nematodes of these other species). There were significant differences

between the tactically and non-tactically treated goats for *Haemonchus* spp. counts, *Trichostrongylus* spp. counts and total counts ( $P < 0.05$ ), but there were no significant differences between feed groups ( $P > 0.05$ ).

### Production parameters

With the exception of 11 March 2003, there were no significant differences in mean live mass between the tactically and non-tactically treated groups. Although the worm burdens between the tactically and non-tactically treated goats were significantly different ( $P < 0.05$ ), there were never any statistically significant differences in the live mass gain ( $P > 0.05$ ), in the body condition scores ( $P > 0.05$ ) or in the cold dressed-out carcass masses ( $P > 0.05$ ) between the tactically and non-tactically treated

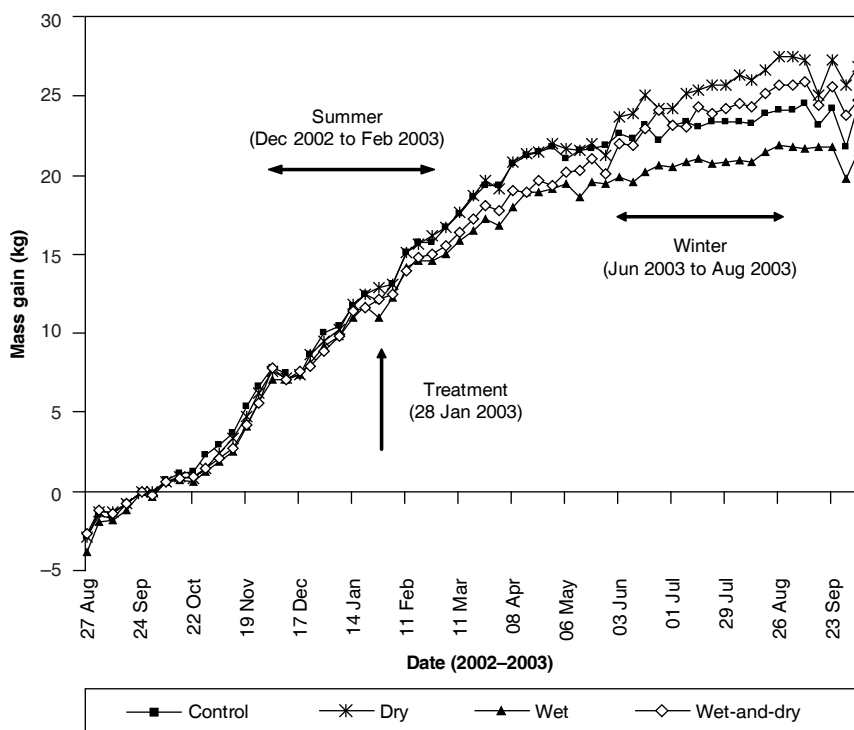


FIG. 4

Mass gains for the four different feed groups of 18 Boer goats each. One group received no urea-molasses block supplementation (Control, ■), a second group received urea-molasses block supplementation in the summer (Wet, ▲), a third group received urea-molasses block supplementation in the winter (Dry, \*) and a fourth group received urea-molasses block supplementation in the summer and winter (Wet-and-dry, ◇)

groups (data not shown). Therefore, the gastrointestinal parasites had no significant effect on the production parameters of the goats.

The dry-season-supplemented goats showed the greatest live mass gain overall (Fig. 4). From the end of July 2003 until the end of the experiment, the differences in mass gain by date between the controls and the dry-season-supplemented goats were generally significant ( $P < 0.05$ ). The mass gains by date for the wet-and-dry-season-supplemented goats were higher than those of the controls but lower than those of the dry-season-supplemented goats during this period and the differences were not significant. The wet-season supplemented goats had lower mass gains than the controls but the differences were also not significant.

Body condition improved during the wet season and was highest in the mid-autumn period, but declined slightly during the dry winter (Fig. 5). When the feed groups were compared, the body condition scores of the dry-season-supplemented and the wet-and-dry-season-supplemented groups were significantly higher than the scores of the controls on several occasions from, respectively, mid-December and mid-February onwards ( $P < 0.05$ ).

#### Anaemia levels and clinical biochemistry

Throughout the study period, the seasonal mean haematocrits were in the range of 23.8–25.5%

(Table 4) thus remaining within, but at the lower end of the normal haematocrit range for goats of 22–38% (Feldman, Zinkl & Jain 2000). Notably, the mean haematocrit readings were at their lowest when *Haemonchus* spp. were predominant, i.e. spring/summer 2002/2003 (Table 4 and Fig. 2). Any statistically significant differences between supplemented groups and controls and between tactically and non-tactically treated groups were always less than three percentage points and were considered clinically marginal as at no time did the mean of any of these groups fall below 22% (data not shown). The mean FAMACHA© scores for the groups were lower than 2.4 on all occasions and closely mirrored the trend in haematocrits (data not shown). Individual goats were treated as their FAMACHA© scores were “3” or “4”, but no scores of “5” were recorded and only on four occasions were goats scored as “4”. There were no significant differences between experimental groups in the average number of days on which goats received treatment for various conditions (including symptomatic treatment according to the FAMACHA© system) (Table 5).

The mean serum total protein values calculated for the goats in total remained within the normal reference range of 55.4–71.8 g/l (Johann Muller, personal communication 2002) and generally at a level of 64.4 g/l (Table 4). The overall mean serum albumin values also remained within the normal reference range of 20.1–29.4 g/l and generally at a level

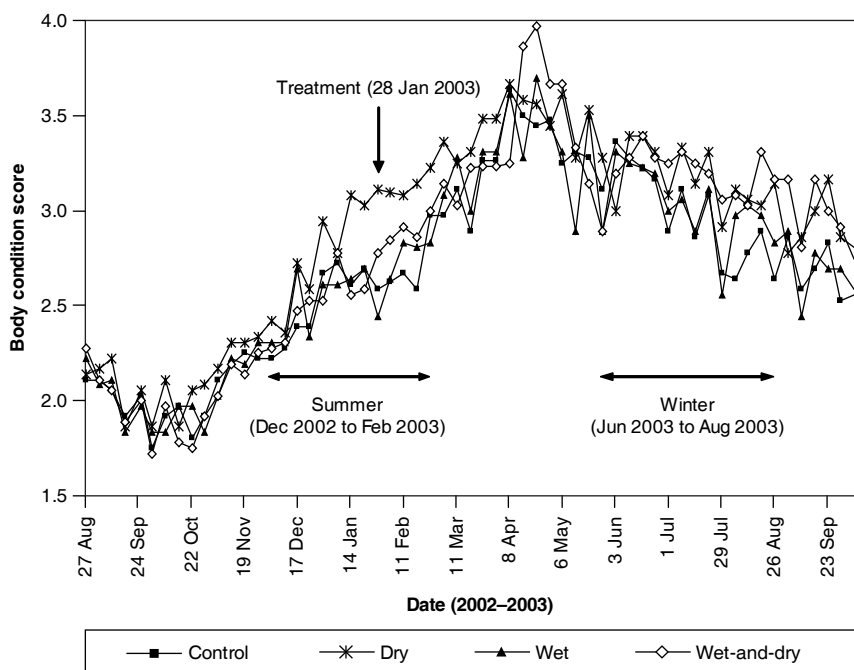


FIG. 5

Body condition scores for the four different feed groups of 18 Boer goats. One group received no urea-molasses block supplementation (Control, ■), a second group received urea-molasses block supplementation in the summer (Wet, ▲), a third group received urea-molasses block supplementation in the winter (Dry, \*) and a fourth group received urea-molasses block supplementation in the summer and winter (Wet-and-dry, ◇). Data for 4 February, 25 March and 1 April 2003 were not obtained and the values shown are averages between the available values immediately before and after the missing values

TABLE 5 Problems noted in the four feed groups of experimental goats. Each value represents the average number of days over the study period for which goats within each group were treated for a particular problem

| Problem                             | Treatment   |            |            |             |
|-------------------------------------|-------------|------------|------------|-------------|
|                                     | Control     | Dry        | Wet        | Wet-and-dry |
| Respiratory tract infections        | 0.7         | 0.2        | 0.7        | 0.6         |
| Coccidiosis and diarrhoea           | 0.1         | 0.9        | 0.2        | 0.2         |
| Abscesses                           | 6.6         | 7.1        | 5.1        | 3.0         |
| Joint problems/ lameness            | 1.8         | 0.2        | 1.1        | 3.7         |
| Anaemia (FAMACHA® 3 or 4; treated)  | 1.3         | 0.6        | 0.9        | 1.5         |
| Eye infections                      | 0.1         | 0.2        | 0.1        | 0.7         |
| Other problems (e.g. wounds, ticks) | 0.4         | 0.8        | 0.0        | 0.3         |
| <b>Total</b>                        | <b>10.6</b> | <b>9.6</b> | <b>7.9</b> | <b>9.6</b>  |

Dry = dry-season supplementation

Wet = wet-season supplementation

Wet-and-dry = wet-and-dry-season supplementation

of 25.9 g/l. Any statistically significant differences between supplemented groups and controls and between tactically and non-tactically treated groups were always less than 4 g/l for serum total protein and 3 g/l for serum albumin. The differences were considered clinically marginal as, with only a few exceptions when the means for albumin approached 30 g/l, the means were within the normal reference ranges. From October 2002 to the end of February 2003 the overall mean serum urea values were *c.* 5.77 mmol/l, with highest levels in the summer. However, from March 2003 onwards, the mean value declined to *c.* 3.35 mmol/l, which was below the normal range of 4.62–9.62 mmol/l. Any statistically significant differences in urea levels between sup-

plemented groups and controls and between tactically and non-tactically treated groups were again considered clinically marginal (maximum difference: 1.10 mmol/l), most of these differences occurring during the latter half of the study when the urea levels were low in all the goats.

### Economic analysis

Although the difference was not significant at the 5% level, at the 10% level the mean cold dressed-out carcass mass of the winter dry-season-supplemented group (26.4 kg) was statistically significantly greater than that of the control group (24.7 kg). The wet-season-supplemented group had the lowest



mean dressed-out carcass mass (23.3 kg), while the mean carcass mass of the wet-and-dry-season-supplemented group was similar to that of the control group (24.6 kg). When the cost-benefit analysis was carried out, and the cost of tactical drug treatment and urea-molasses block supplementation considered, only winter dry-season supplementation without tactical treatment (Group 3) proved economically viable.

## DISCUSSION

The occurrence of larvae of *Haemonchus* during October to March and larvae of *Teladorsagia/Trichostrongylus* during June to October agrees with the results of previously published studies on the occurrence of these parasites in sheep and goats in the summer rainfall area of South Africa (Horak & Louw 1977; Horak 1978; Boomker, Horak & Ramsay 1994). The origin of the other species was probably from the cattle which had previously grazed the paddock and the impalas which continued to graze the paddock throughout the experiment (Horak 1981; Soulsby 1968).

The degree of infection established in the goats in the present study was low as noted both by the faecal egg counts and by nematode recovery (Hansen & Perry 1994). While the unusually dry weather during November 2002 was most probably detrimental to the survival of *Haemonchus* larvae on the pasture, the grazing area was probably too large, relative to the number of goats grazed on it, to allow adequate infection of the pasture for the experiment. The infection of the goats could probably have been exacerbated by establishing a heavy infection on the pasture by grazing small ruminants on it for 1–2 years before the experiment, by using a trickle infection to infect the goats (Barger, Le Jambre, Georgi & Davies 1985), and by utilizing a pasture with fewer or no browse species in order to encourage the goats to graze.

The general finding in this study was that since the parasite burdens were low, the tactical treatment of the gastrointestinal nematode infections had no significant effect on the production parameters of the goats but that the nutritional factors probably had a relatively bigger impact.

The paddocks where the goats grazed can best be described within Acocks's (1988) classification as Other Turf Thornveld, specifically Norite Black Turfveld. These paddocks had a range of bush species available, which the goats were assumed to have

browsed throughout the year. The availability of these browse species in the herbage may have accounted for the fact that the acid detergent fibre and neutral detergent content of the herbage remained relatively consistent throughout the year. As is to be expected, the dry matter and crude protein of the herbage varied with the seasons, being lowest and highest, respectively, during the wet summer period (Table 4). During the winter period, the dry matter was highest and the crude protein lowest. The serum urea values gave an immediate indication of the availability of crude protein in the pasture as it was highest during the summer period and lowest during the winter and subsequent spring. The serum albumin and body condition scores also reflected the availability of crude protein in the pasture, but there was a lag period before a change became evident. For example, highest values of crude protein recorded in the summer period were only reflected in highest values for albumin and body condition scores in the autumn. Although the mean haematocrits were at the lower end of the haematocrit range for goats as given by Feldman *et al.* (2000), the values are similar to normal values reported for goats 1–2 years old from India (22.6%) and Nigeria (26.9 ± 3.8%), but lower than values reported for adult wethers from the UK (34.8 ± 3.8%) and adult goats from the United States (34.0 ± 4.9%) (Smith & Sherman 1994).

The crude protein content of the herbage during summer was probably sufficient to fulfil the goats' growth needs, as shown by increasing body condition scores during this period. As such, any additional urea intake will have been inefficiently utilized and lost in the urine. In the winter, however, the crude protein of the herbage had declined and there was an apparent shortage of dietary crude protein as evidenced by a decrease in body condition and in low serum-urea levels. As a result, supplementation of the goats during this period was beneficial. However, intake of the urea-molasses blocks was low. The reasons for this are unclear, but an improved intake of the blocks may have resulted in a better effect on the growth of the goats and the resultant dressed-out carcass masses.

An alternative to urea-molasses block supplementation for parasitized ruminants is the use of bypass protein which is found in the by-products of vegetable oil extraction, i.e. oil cake meals. Magaya, Mukaratirwa, Willingham, Kyvsgaard & Thamsborg (2000) showed a beneficial effect of cottonseed meal supplement with or without anthelmintic treatment on growth performance of parasitized weaner steers in

Zimbabwe. Supplementation of ruminants with oil cake meal tends to be expensive and researchers have thus examined the use of locally available sources of protein as dry-season supplements, including leguminous browse species and their pods (Aganga & Wani 1998; Sikosana, Smith, Mlambo, Owen, Mueller-Harvey, Mould & Maphosa 2004). Harvesting of the leaves and pods of such leguminous plants may be feasible on a sustainable basis in areas of the summer rainfall area of southern Africa where they occur.

The cost-benefit analysis of the present study, nevertheless, indicated that dry-season winter supplementation of Boer goats with urea-molasses blocks from June to August without tactical anthelmintic treatment, was associated with a 6% increase in carcass value over the corresponding controls. This equated to US\$ 3.30 per animal which is considered economically viable and worthwhile.

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