Veterinary Research Communications, 21 (1997) 547–557

THE STRATEGIC USE OF CLOSANTEL AND ALBENDAZOLE IN CONTROLLING NATURALLY ACQUIRED GASTROINTESTINAL NEMATODES OF SHEEP IN THE KENYA HIGHLANDS

N. MAINGI[1], S.M. THAMSBORG[3*], V.M. GICHOHI[1], W.K. MUNYUA[1] AND J.M. GATHUMA[2]
Departments of [1]Veterinary Pathology and Microbiology and [2]Public Health, Faculty of Veterinary Medicine, University of Nairobi, Nairobi, Kenya; [3]Danish Centre for Experimental Parasitology, The Royal Veterinary and Agricultural University, Bulowsvej 13, DK 1870 Frederiksberg C, Denmark
*Correspondence

ABSTRACT

Maingi, N., Thamsborg, S.M., Gichohi, V.M., Munyua, W.K. and Gathuma, J.M., 1997. The strategic use of closantel and albendazole in controlling naturally acquired gastrointestinal nematodes of sheep in the Kenya highlands. *Veterinary Research Communication*, **21(8)**, 547–557

The strategic use of closantel, a narrow-spectrum salicylanilide anthelmintic against bloodsucking helminths, and of albendazole, a broad-spectrum benzimidazole anthelmintic, in the control of gastrointestinal nematodes of sheep was investigated on a farm in Nyandarua District in the highlands of Kenya. Thirty Corriedale female lambs aged between 9 and 12 months were assigned to three treatment groups of 10 lambs each. The three groups were set stocked on separate paddocks for 12 months. Lambs in group 1 (strategic treatment group) were treated with closantel and albendazole at the beginning and towards the end of the long rains (April and June, respectively) and towards the end of the short rains (December). During the intervening dry season, the lambs were treated with albendazole. Lambs in group 2 (suppressive treatment group) were kept ‘worm free’ by regular deworming with albendazole at 3-weekly intervals for 12 months. The third group of lambs remained untreated (control group). Gastrointestinal nematode infections and pasture infectivity were well controlled in the case of the strategic treatment group. This resulted in higher weight gains, wool production, packed cell volume, and serum albumin and protein concentrations compared with the untreated control lambs. These parameters were comparable between the strategic treatment and the suppressive treatment groups of lambs. It was concluded that worm control strategies based on the epidemiology of the parasites and the sustained anthelmintic action of closantel in combination with broad-spectrum anthelmintics can provide effective control of gastrointestinal nematodes of sheep in the study area.

Keywords: albendazole, anthelmintics, closantel, control, *Haemonchus*, sheep, *Trichostrongylus*

Abbreviations: EPG, eggs per gram of faeces; PCV, packed cell volume

INTRODUCTION

Haemonchus contortus and the intestinal nematode *Trichostrongylus colubriformis* are the most prevalent nematode parasites of sheep in Kenya (Allonby and Urquhart, 1975; Allonby, 1976; Gatongi, 1995). *H. contortus* is regarded as the most important of these parasites and it is against this species that worm control is primarily targeted.

The control is based mainly on the use of a wide range of anthelmintics (Kinoti *et al.*, 1994). The most effective control strategies for helminths, using anthelmintics, are usually those based on the epidemiology of the parasites, with the treatments being designed to reduce both pasture contamination and host infection (Brunsdon, 1980; Nansen, 1991). Improper timing of treatments and incorrect selection of anthelmintics are not only less effective in controlling the parasites, but are also costly and potentially harmful by selecting for anthelmintic resistance (Michel *et al.*, 1983; Waller, 1993). Until recently, information on the epidemiology of helminth infections in ruminants in Kenya was scanty and anthelmintics are therefore used at irregular intervals (Kinoti *et al.*, 1994). In areas of the country where two wet seasons occur, with relatively short dry periods intervening, the turnover of gastrointestinal nematode populations is high and the proportion of arrested larval development is low (Allonby and Urquhart, 1975). This necessitates regular anthelmintic treatments if mortalities due to haemonchosis are to be eliminated and satisfactory weight gains achieved. Regular treatments are, however, rarely applied by livestock owners because of the high cost of anthelmintics. Too frequent use of anthelmintics is also likely to select heavily for worms that develop resistance to the anthelmintics used (Waller, 1987). Strategic or integrated control programmes could minimize the number of anthelmintic treatments in such areas.

Strategic control of *Haemonchus* and other nematodes in sheep using closantel, a long-acting narrow-spectrum salicylanilide anthelmintic against blood-sucking nematodes, in combination with broad-spectrum anthelmintics, has successfully been evaluated in Europe (Taylor *et al.*, 1991). Closantel also plays a pivotal role in the 'Wormkill' strategic control programme, implemented with success in the northern tablelands of Australia (Dash, 1986; Dash and Waller, 1987; Rolfe *et al.*, 1990; Waller, 1993). Hall and colleagues (1981) reported that a single oral dose of closantel at 10 mg/kg body weight provided almost complete protection (99.4%) against reinfection of sheep with *H. contortus* at 30 days after drug administration and substantial protection (62.8%) at 60 days. This prolonged anthelmintic effect of closantel allows the frequency of treatments with broad-spectrum anthelmintics to be reduced in areas where *H. contortus* predominates. The present study aimed at examining the effectiveness of strategic use of closantel and albendazole in the control of gastrointestinal nematodes of sheep in Nyandarua District of Kenya.

MATERIALS AND METHODS

The study was carried out on a farm situated approximately 85 km north-west of Nairobi in Kinangop Division of Nyandarua District at an altitude of approximately 2500 m above sea level. The area has a cool, wet climate and receives a mean rainfall of between 1780 and 2030 mm. The rainfall is bimodal, March to June (long rains) and October to December (short rains). The mean minimum monthly air temperature varies from 6°C to 10°C, while the mean maximum temperature varies from 22°C to 26°C. This climate is conducive for transmission of gastrointestinal nematodes throughout almost the whole of the year.

The farm was a 60-hectare arable and sheep and cattle rearing enterprise. The main type of grass on the pastures was Kikuyu grass (*Pennisetum clandestinum*). Sheep had been reared on the farm for 13 years and both benzimidazoles and levamisole had been used at some time. Oxyclosanide was used regularly on the farm against *Fasciola*.

Study design

Thirty female Corriedale lambs aged between 9 and 12 months and ranging in body weight between 17 and 26 kg were treated with albendazole (Valbazen, SmithKline Beecham) at 5 mg/kg body weight and grazed together on a 2.4 ha contaminated paddock for 1 month. The lambs were then ear-tagged, weighed and randomly allocated to three treatment groups of 10 animals each. The paddock was subdivided by wire fencing into three equal parts and the three groups of lambs were randomly assigned to the three plots. They then remained set stocked for the 12 month duration of the study. The lambs' diet was supplemented with minerals in the form of Maclik (Coopers, Nairobi) mineral blocks and tap water was provided *ad libitum* in metal troughs in each of the paddocks. The sheep in group 1 (strategic treatment group) were treated with albendazole at 5 mg/kg body weight and closantel (Flukiver, Janssen Pharmaceutica, Belgium) at 10 mg/kg body weight. These combined treatments were given at the beginning of the experiment (day 0, 27/04/94), 9 weeks later (29/06/94) and at week 33 (14/12/94) of the experiment. These treatment dates coincided with the start of the long rains, the end of the long rains and towards the end of the short rains, respectively. At week 18 (31/08/94), which was during the intervening dry season, the sheep were treated with albendazole alone. The sheep in group 2 (suppressive treatment group) were kept 'worm free' by treatment with albendazole at the start of the experiment (day 0) and every 3 weeks thereafter for the entire period of the study. For the sheep in group 3 (control), no treatments were given except salvage treatment with albendazole given to one animal when the number of strongyle eggs per gram (EPG) in its faeces was over 2000 on two consecutive sampling occasions (weeks 45 and 48). The treated animal was removed from the study after treatment. The efficacy on this farm of treatments with albendazole at 5 mg/kg was found to be 99% at the start of the experiment, using the faecal egg count reduction test (FECRT) as described in the recommendation of the World Association for the Advancement of Veterinary Parasitology (WAAVP) (Coles *et al.*, 1992). Fasciolosis is a common problem in the study area and prophylactic treatment with triclabendazole (Fasinex, Ciba-Geigy, Switzerland) was given at 10 mg/kg body weight to all the animals every 9 weeks.

Sampling and analysis

Egg counts and larval cultures

Rectal faecal samples were collected from all experimental lambs every 3 weeks. The strongyle-type EPG was determined for individual sheep by the modified McMaster technique (Whitlock, 1948), with a lower limit of detection of 100 eggs. When the faecal samples for any of the three groups were positive for nematode eggs, the samples were pooled for each group and cultured at 27°C for 10 days. Larvae isolated from the cultures were identified by their cuticular morphology and size, as described in the MAFF manual (1986).

Pasture infectivity

Herbage samples were collected from each of the three paddocks every 3 weeks using the W-transect procedure and the nematode larvae thereon were recovered, identified and counted as described by Hansen and Perry (1994).

Worm-free Corriedale male castrated lambs aged between 5 and 8 months were used as 'tracers'. Three lambs were introduced into each of the three paddocks during the wet season (May/June 1994) and also during the dry season (January/February 1995). The lambs were grazed for 3 weeks, kept indoors for 3 weeks and then killed. Total and differential worm counts from their abomasa and intestines were determined and the mucosa were digested for larvae as described by Hansen and Perry (1994).

Blood parameters and weight gains

Blood was collected from the jugular vein of each sheep starting 3 weeks before the beginning of the experiment and every 3 weeks thereafter during the entire period of the study. Blood (5 ml) was mixed with ethylenediaminetetraacetic acid (EDTA, Sigma, USA) and used to determine the packed cell volume (PCV) by a microhaematocrit method (Coles, 1986). The remaining 10 ml of blood was allowed to clot and the serum was obtained for the determination of the albumin and total protein concentrations. Total serum protein was measured by a Biuret method (Coles, 1986) using a standard kit from Boehringer Mannheim, Germany. Serum albumin was measured by the bromocresol green method using a standard kit from Biomerieux Company, France. All the sheep were weighed every 3 weeks during the period of the experiment.

Meteorological data

Daily air temperature and rainfall data were obtained from Sasumwa dam meteorological station, situated approximately 8 km from the study farm.

Statistical analysis

The faecal egg counts and worm burdens were log-transformed. Egg counts and other parameters were compared between the groups by the repeated measures analysis of variance (ANOVA) (SAS, 1990) using the general linear models (GLM) procedure with pairwise comparisons between the groups. Worm burdens were compared between groups by ANOVA. p values $\leqslant 0.5$ were considered significant.

RESULTS

The mean monthly rainfall and the mean maximum and minimum monthly air temperatures recorded at Sasumwa dam meteorological station during the study period are shown in Figure 1. March to June and October and November were the periods of the long and short rains, respectively.

Figure 2 shows the arithmetic mean faecal strongyle EPG for the three groups of lambs beginning on 16 March 1994, 6 weeks before the start of the experiment. The mean strongyle EPG for the suppressive treatment group remained low or zero throughout the study period. The mean strongyle EPG in the control group rose gradually to a maximum of 1750 ± 532 at week 36 (January 1995) of the study. For the strategic treatment group, the mean strongyle EPG remained low except at weeks 18 (August 1994) and 33 (December 1994), immediately before the treatments. Statistical analysis excluding the suppressive treatment group indicated that the strongyle egg counts in the control group were significantly higher ($p < 0.05$) than those in the strategic treatment group. The difference was significant from week 9 (June 1994) until the experiment was terminated, except at week 18 (August 1994).

Haemonchus was the predominant species in the faecal cultures from the control group at all sampling occasions except at week 39 (February 1995), when *Trichostrongylus* predominated with 86% occurrence. Other species identified in decreasing order of occurrence were ***Oesophagostomum***, ***Strongyloides*** and ***Nematodirus.*** In the strategic treatment group, *Trichostrongylus* predominated at weeks 15, 18 (August 1994) and 48 (March 1995), whereas the marked rise in November and December 1994 was due to ***Haemonchus.***

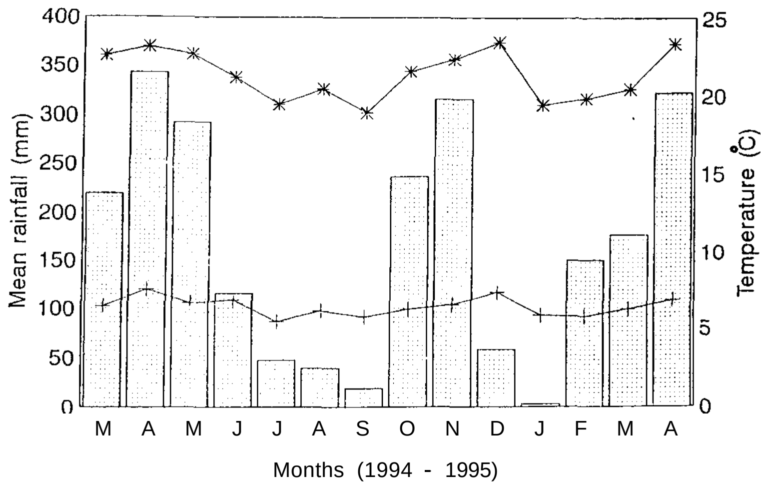

Figure 1. The mean monthly rainfall in mm (vertical bars) and the mean maximum and minimum monthly air temperature in °C (lines) recorded from Sasumwa dam meteorological station during the period March 1994 to April 1995

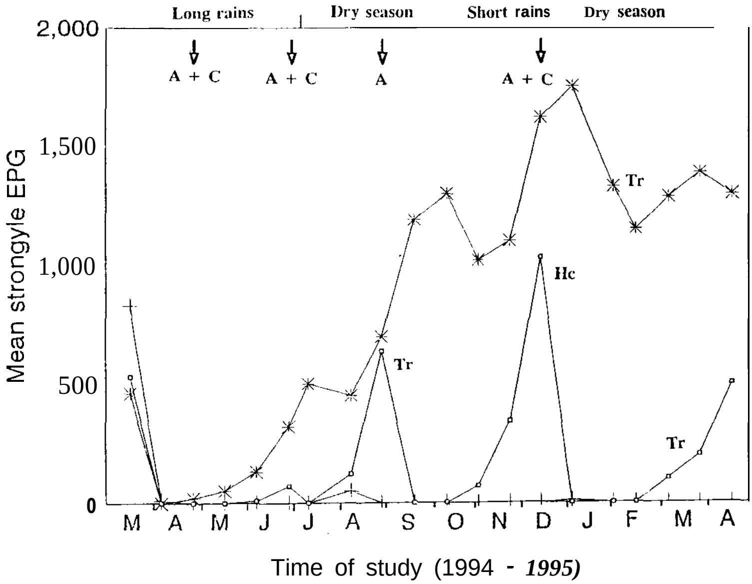

Figure 2. The arithmetic mean number of strongyle eggs per gram of faeces (EPG) for groups of lambs given strategic treatment (□) with albendazole (A) and closantel (C) or suppressive treatment (+) with albendazole every 3 weeks and an untreated control group (*) during the period March 1994 to April 1995. The arrows indicate when the treatments for the strategic treatment group were given. All groups received albendazole in March 1994. Hc and Tr indicate periods when larvae of ***Haemonchus contortus*** and ***Trichostrongylus*** species predominated in faecal cultures

The mean numbers of nematode larvae per kg of dry herbage from the three experimental paddocks are shown in Figure 3. At the beginning of the study, sufficient herbage could not be obtained from the paddocks for the determination of the number of larvae owing to the very dry conditions experienced in January and February 1994. The pasture larval counts on the paddock grazed by the control group of lambs increased during the wet seasons and subsequently decreased during the dry months. On the paddock grazed by the suppressive treatment group, the number of larvae decreased steadily from week 21 (September 1994), compared with the other groups. The larval counts from the herbage from the paddock grazed by the strategic treatment group were also markedly reduced from September 1994 (week 21) to the end of the experiment, as compared to the counts from the control group's paddock.

The accumulated weight gains for the suppressive treatment (30.7 f4.9 kg) and strategic treatment (3 1.9 ± 2.4 kg) groups were significantly higher ($p < 0.05$) than for the control group of lambs (17.7 ± 3.2 kg) from week 18 (August 1994) onwards. The mean body weights for the suppressive treatment and strategic treatment groups did not differ significantly at any time.

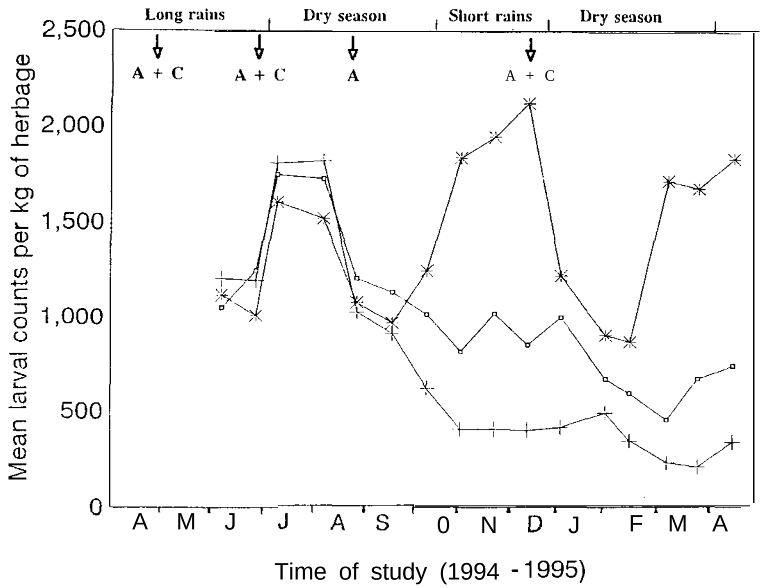

Figure 3. The mean number of infective nematode larvae per kilogram of dry herbage from paddocks grazed by groups of lambs given either strategic treatment (□) with albendazole (A) and closantel (C) or suppressive treatments (+) with albendazole every 3 weeks- and an untreated control group (m) during the period April 1994 to April 1995. The arrows indicate when treatments for the strategic treatment group were given. All groups received albendazole in March 1994

The PCV and the total serum protein and albumin concentrations were significantly lower ($p < 0.05$) in the control group of sheep compared to the strategic treatment and suppressive treatment groups. For the PCV and total serum protein concentrations, a significant difference was observed from week 15 (August 1994) onwards, while the difference for the albumin was significant from week 11 (July 1994). These parameters did not differ significantly between the strategic treatment and suppressive treatment groups.

Table I shows the mean worm burdens in the tracer lambs grazed with the experimental sheep during the wet and dry seasons. There was no significant difference in the total worm burdens in the tracer lambs grazed during the wet season. During the dry season, the burdens in the tracer lambs grazed with the control group were significantly higher ($p < 0.05$) than in those grazed with the other groups.

The total amount of wool produced by the strategic treatment group was 38 kg (mean 3.80 $\pm$ 0.5 kg), that by the suppressive treatment group 36.5 kg (mean 3.65 $\pm$0.6 kg) and that by the control group 32 kg (mean 3.20 $\pm$0.4 kg). These differences were not statistically significant.

The total costs for drugs and labour per animal for the strategic and suppressive treatment programmes were approximately US$3.6 and US$15.2, respectively. The

TABLE I
Worm burdens in tracer lambs ($n = 3$) grazed with lambs in the strategic treatment, suppressive treatment or control groups

Nematode genus	Mean ± s.d. worm burdens (minimum–maximum)					
	Strategic treatment		Suppresive treatment		Control	
Wet season (May/June 1994)						
Haemonchus	1145 ± 742	(500–1956)	1434 ± 559	(887–2005)	834 ± 257	(629–1122)
Trichostrongylus	393 ± 382	(138–832)	199 ± 102	(96–300)	350 ± 116	(217–414)
Oesophagostomum	184 ± 284	(18–512)	0		121 ± 191	(0–341)
Dry season (Jan/Feb 1995)						
Haemonchus	256 ± 140	(156–416)	19 ± 26	(0–48)	1794 ± 240	(511–4328)
Trichostrongylus	24 ± 21	(0–40)	12 ± 11	(0–16)	19 ± 14	(5–32)

estimated monetary gains per animal based on meat and wool production were equivalent to US$50, US$47, and US$33 for the strategic, suppressive and control animals, respectively.

DISCUSSION

The results of this trial demonstrated that strategic worm control programmes based on the use of closantel and albendazole can provide effective control of gastrointestinal nematodes of sheep in the study area. Gastrointestinal nematode infections are a major cause of lowered productivity in ruminants and the overall objective of control is to minimize such losses. One way of keeping worm burdens at a minimum level in small ruminants is by anthelmintic treatments. The effect of anthelmintic treatments is manifested in many ways, such as enhanced growth rate, reproductive performance and wool production (Darvil *et al.*, 1978). The effect could occur through an alteration in the onset, magnitude and duration of the availability of infective larvae on pasture (Darvil *et al.*, 1978), phenomena that determine the worm burdens. Treatment with albendazole once or twice during the dry season and with albendazole and closantel during the wet seasons resulted in reduced numbers of larvae on the pasture and lower levels of infection in the lambs, which then resulted in higher weight gains, wool production, PCV, and serum albumin and protein concentrations, compared to lambs that remained untreated.

The predominant nematode species in the study were *Haemonchus* and *Trichostrongylus* and the climatic conditions in the area allow transmission of the parasites throughout most of the year, although the levels of pasture infectivity during the dry periods may be relatively low. Treating the lambs in the strategic treatment group with closantel during the wet months, when the infectivity of the pasture was high, prevented them from acquiring large burdens of the blood-sucking parasite *Haemonchus* for at least 6 weeks (Hall *et al.*, 1981). This will have resulted in a reduction in the loss of blood that constitutes an important drain on the resources that the animal needs for productivity. It will also have resulted in reduced pasture contamination and subsequent reinfection. All the parameters monitored in this study were similar between this group of lambs and the suppressive treatment group, which was kept 'worm free' through the regular treatments. While affording good protection against gastrointestinal nematodes, suppressive use of anthelmintic is labour-intensive and not practical on farms in the study area owing to the high cost of anthelmintics. Control of gastrointestinal nematodes by frequent dosing with broad-spectrum anthelmintics has also been shown to increase the pressure for selection of worms resistant to the anthelmintics (Barton, 1983; Martin *et al.*, 1984). Strategic deworming programmes for the control of *H. contortus*, based on epidemiological studies and the sustained anthelmintic action of closantel, may therefore help to limit the rate of development of resistance to the broad-spectrum anthelmintic drugs.

The treatment with albendazole administered to all the lambs, during the dry season (March 1994) and before the long rains, was meant to clear them of any pre-existing nematode infections and so provide a starting point for the study. This treatment appears to have substantially reduced the contamination of the pasture in all the paddocks and subsequently resulted in the low worm egg counts in the control group from the beginning of the experiment and right through the rainy season. In August 1994, the strongyle EPG started to increase and the weight gain and blood parameters became lower in this group of lambs compared to the other two groups, even though the pasture larval counts were low and did not differ significantly between the three paddocks until this time. This suggests that an anthelmintic treatment given just before the rains in this area could control levels of infection for a substantial period of the time during the following wet season. Gatongi (1995) showed that treatment of sheep and goats with ivermectin at the end of the dry season in Naivasha, a semi-arid region of Kenya, reduced pasture infectivity during the subsequent wet seasons and improved flock performance. However, anthelmintic treatment when parasites have a low refugium, such as during a dry season, is thought to increase the selection pressure for anthelmintic resistance (Prichard *et al.*, 1980; Donald, 1983; Martin *et al.*, 1984). Although appearing to offer effective control of nematodes, anthelmintic treatment immediately before the rainy season may therefore not be an appropriate strategy. It would probably be better to give a combined closantel and broad-spectrum anthelmintic treatment 2–3 weeks after the onset of the rainy season and a broad-spectrum anthelmintic treatment at the beginning of the dry season. The effectiveness of such a control programme, however, needs to be evaluated.

It is noteworthy that the use of closantel during the long rains in the strategic treatment group resulted in *Trichostrongylus* replacing *Haemonchus* as the predominant parasite during part of the study, whereas *Haemonchus* predominated during the short rains when closantel and albendazole were given late in the season. The proposed combined anthelmintic treatment 2–3 weeks after the onset of the rainy season should effectively control this build up of *Haemonchus*.

A cost–benefit analysis of the proposed strategic programme indicated that it would be beneficial to the farmers. The estimated monetary benefits of the programme were above those of the untreated control and suppressive treatment by approximately US$17 and US$18 per sheep, respectively.

It is concluded that worm control strategies based on the use of closantel and broad-spectrum anthelmintics could provide effective control of gastrointestinal nematodes of sheep in the study area. However, further field trials are required before any final recommendations can be made. For instance, the number of treatments given in the first year may be too many. Apart from being expensive, frequent use of both closantel and broad-spectrum anthelmintics could select for resistance. Resistance to closantel has already been reported in Australia (Rolfe *et al.*, 1990) since the introduction of the 'Wormkill' programme, which is based on the use of closantel at 7- to 8-week intervals during the wet season. The more effective a programme is in controlling the parasites, the stronger the selection for drug resistance, and this could apply to the proposed programme if it were widely adopted. However, as pointed out by Dash (1986), after a series of treatments with closantel, the number of *H. contortus* larvae on pasture would be substantially reduced. Such a reduction in pasture contamination resulting from the initial treatments, as observed in the present study, might allow even fewer treatments in subsequent years, so reducing both the costs and selection pressure for resistance.

ACKNOWLEDGEMENTS

This study was financed by DANIDA through the Ruminant Helminth Collaborative Research Project. The donation of closantel (Flukiver) by Janssen Pharmaceutica, Belgium, is appreciated and acknowledged. Dr P. Waller of the CSIRO Division of Animal Health in Australia assisted in the design of this study for which we are grateful. We would also like to thank the farmer on whose property this study was carried out for allowing us to use his animals and other facilities.

REFERENCES

Allonby, E.W., 1976. *Annual Report of the Sheep Development Project in Kenya*, (East African Veterinary Research Organization (EAVRO), 50

Allonby, E.W. and Urquhart, G.M., 1975. The epidemiology and pathogenic significance of haemonchosis in a Merino flock in East Africa. *Veterinary Parasitology*, **1**, 129–143

Barton, N.J., 1983. Development of anthelmintic resistance in nematodes of sheep in Australia subjected to different treatment frequencies. *International Journal for Parasitology*, **13**, 125–132

Brunsdon, R.V., 1980. Principles of helminth control. *Veterinary Parasitology*, **6**, 185–215

Coles, E.H., 1986. *Veterinary Clinical Parasitology*, 4th edn, (W.B. Saunders, Philadelphia)

Coles, G.C., Bauer, C., Borgsteede, F.H.M., Geerts, S., Taylor, M.A. and Waller, P.J., 1992. World Association for Advancement of Veterinary Parasitology (WAAVP) method for detection of anthelmintic resistance in nematodes of veterinary importance. *Veterinary Parasitology*, **44**, 35–44

Darvil, F.M., Arundel, J.H. and Brown, P.B., 1978. Effects of anthelmintic treatment of maiden ewes in the periparturient period on pasture contamination and production of prime lambs. *Australian Veterinary Journal*, **54**, 575–584

Dash, K.M., 1986. Control of helminthosis in lambs by strategic treatment with closantel and broad-spectrum anthelmintics. *Australian Veterinary Journal*, **63**, 4–8

Dash, K.M. and Waller, P., 1987 (Winter). Drenchplan: research-based worm control. *Rural Research*, **135**, 4–9.

Donald, A.D., 1983. Anthelmintic resistance in relation to helminth control and grazing systems. In: F.H.M. Borgsteede, Sv. Aa Henriksen and H.J. Over (eds), *Facts and Reflections. IV. Resistance of Parasites to Anthelmintics*, (Central Veterinary Institute, Lelysted, The Netherlands), 187–198

Gatongi, P.M., 1995. *The epidemiology and control of gastrointestinal nematodes of small ruminants in a semi-arid area of Kenya with emphasis on hypobiosis of* Haemonchus contortus. (PhD thesis, McGill University)

Hall, C.A., Kelly, J.D., Whitlock, H.V. and Ritchie, L., 1981. The prolonged anthelmintic effect of closantel and disophenol against a thiabendazole selected resistant strain of *Haemonchus contortus* in sheep. *Research in Veterinary Science*, **31**, 104–106

Hansen, J.W. and Perry, B., 1994. *The Epidemiology, Diagnosis and Control of Gastrointestinal Parasites of Ruminants in Africa* (ILRAD, Nairobi), 171

Kinoti, G.K., Maingi, N. and Coles, G.C., 1994. Anthelmintic usage in Kenya and its implications. *Bulletin of Animal Health and Production in Africa*, **42**, 71–73

MAFF (Ministry of Agriculture, Fisheries and Food), 1986. *Manual of Veterinary Parasitological Techniques*, (Technical Bulletin No. 18, HMSO, London), 131

Martin, P.J., Anderson, N., Jarret, R.G., Brown, T.H. and Lord, G.E., 1982. Effects of a preventive and suppressive control scheme on the development of thiabendazole resistance in *Ostertagia* spp. *Australian Veterinary Journal*, **58**, 185–190

Martin, P.J., Anderson, N., Lwin, T., Nelson, G. and Morgan, T.E., 1984. The association between frequency of thiabendazole treatments and the development of resistance in field isolates of *Ostertagia* species of sheep. *International Journal for Parasitology*, **14**, 177–181

Michel, J.F., Cawthorne, R.J.G., Anderson, R.M., Armour, J., Clarkson, M.J. and Thomas, R.J., 1983. Resistance to anthelmintics in Britain: husbandry practices and selective pressure. In: F.H.M. Borgsteede, Sv. Aa. Henriksen and H.J. Over (eds), *Facts and Reflections. IV. Resistance of Parasites to Anthelmintics*, (Central Veterinary Institute, Lelystad, The Netherlands), 41–59

Nansen, P., 1991. Strategies for development and establishment of cost-efficient and sustainable control programmes for helminth infections in the developing countries. *FAO Expert Consultation on Helminth Infections of Livestock in Developing Countries* (FAO (AGA)/HIL/91/14, Rome), 17

Prichard, R.K., Hall, C.A., Kelly, J.D., Martin, I.C.A. and Donald, A.D., 1980. The problem of anthelmintic resistance in nematodes. *Australian Veterinary Journal*, **56**, 239–250

Rolfe, P.F., Boray, J.C., Fitzgibbon, C., Parsons, G., Kemsley, P. and Sangster, N., 1990. Closantel resistance in *Haemonchus contortus* from sheep. *Australian Veterinary Journal*, **67**, 29–31

SAS (Statistical Analysis Systems), 1990. Users' guide, Release 6.04 (SAS Institute, Cary, NC), 1028

Taylor, M.A., Hunt, K.R., Wilson, C.A. and Quick, J.M., 1991. Effectiveness of strategic anthelmintic dosing in controlling *Haemonchus contortus* infections in sheep in the United Kingdom. *Veterinary Record*, **129**, 189–192

Waller, P.J., 1987. Anthelmintic resistance and the future for roundworm control. *Veterinary Parasitology*, **25**, 177–191

Waller, P.J., 1993. Towards sustainable nematode parasite control of livestock. *Veterinary Parasitology*, **48**, 295–309

Whitlock, H.V., 1948. Some modifications of the McMaster helminth egg counting technique and apparatus. *Journal of the Council of Science and Industrial Research*, **21**, 177–190

(Accepted: 14 April 1997)