EPIDEMIOLOGY AND CONTROL OF RUMINANT HELMINTHS IN THE KERICHO HIGHLANDS OF KENYA

MOSES KIPNGENO ARAP RUGUTT
BVM (Nairobi), M.Sc (Edinburgh)

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Abstract

The studies reported in this thesis have been conducted in a high potential area of the country where no previous studies had been undertaken. The two major components of the research were an epidemiology study and an intervention study, both of which were conducted on farms in the peri-urban area of Kericho. An initial background study was conducted to collect data from the local Veterinary Investigation Laboratory, from extension staff in a participatory rapid appraisal (PRA) study and a cross-sectional socio-economic survey was undertaken with local farmers. These provided some understanding of the problems caused by helminths and the approaches taken to control them, together with socioeconomic data relating to the keeping of livestock in the area. Disease appeared to be a major constraint affecting ruminant productivity, with nematodoses appearing to be the most important helminth disease in the area particularly in small ruminants. In the cross-sectional survey, more than 60 % of farmers reported that they administered anthelmintics therapeutically and over 30 % gave routine treatments. On average, cattle were reported as being given up to 1.5 treatments per year, sheep just over 1.1 and goats 0.9 treatments per annum. In general, extension workers recommend that animals are wormed every 3 - 4 months, however this practice was not adopted by the farmers because of the expense involved.

The epidemiology study conducted on 27 smallholder farms over a 22 month period obtained data on the prevalence of a) helminth ova in cattle, goat and sheep faeces b) helminth larvae on herbage and c) the different nematode species acquired by introduced Dorper tracer lambs which grazed on communal land. Grazing ruminants in Kericho appear to be exposed to infection with gastrointestinal nematodes throughout the year, there was no evidence of a marked seasonal influence on the availability of infective larvae on pasture. The two commonest genera *Trichostrongylus* and *Haemonchus* are both well adapted to the three ruminant species that are commonly grazed together.

Haemochus contortus was the predominant species in pasture samples and accounted for up to 88 % of the total worm populations recovered from the susceptible Dorper lambs used as tracers. However, *Haemonchus contortus* was not the predominant genera in the worm burdens recovered from locally purchased adult sheep where *Trichostrongylus* species predominated, *T.axei* accounting for about 66 % and *T.colubriformis* for 27 % of the average burden of local ewes. There was no indication that arrested development played a key role in the population dynamics of nematodes in the area although retarded populations of *T. axei* were found in both local and tracer sheep.

There was a marked similarity in the pattern of egg counts seen in goats and sheep in the epidemiology study and the faecal egg counts of lambs and kids mirrored those of adult goats and sheep. This apparent regulatory capacity may be due to innate resistance and/or the rapid acquisition of effective immunity. Calves passed significantly more eggs than adult cattle passing on average over five times as many extra eggs as adults.

The intervention study in which calves were treated on the basis of age confirmed the crucial role of acquired immunity in infrapopulation regulation. The faecal egg counts of treated calves aged between 6-9 months and 9-12 months were 50 % and 37.5 % lower than control counts respectively. These differences were attributable to the acquisition of immunity that reduced the impact of reinfection in the treated animals. A similar effect was not apparent in the small ruminants that were treated in May, August and November. Further studies are required to determine whether it would also be beneficial to treat young small ruminants on the basis of age.

A study of anthelmintic resistance on the small scale farms and 5 larger farms in the district was conducted according to the WAAVP guidelines. The quality of locally available anthelmintics was also assessed as part of this study. The use of adult goats which tend to have overdispersed populations appeared to have influenced the outcome of the trial since resistance was not confirmed but merely suspected. Levamisole resistance was suspected on 3 of the large scale farms and the smallholder farms, whereas resistance against ivermectin was suspected on three large scale farms

and benzimidazole resistance was suspected on one of the larger properties. Suppressive anthelmintic regimes and intensive treatment regimes do not appear to be a sustainable option for the control of nematodes in the region given the extent of suspected anthelmintic resistance on the large and small scale farms in the study area.

The problems of anthelmintic resistance in the imidazothiazole family will almost certainly have been exacerbated by the numbers of poor quality drugs on the market. Only 2 of the 9 levamisole containing drugs purchased locally fulfilled the expected quality criteria.

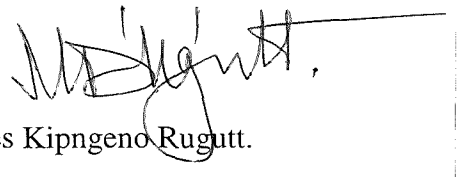
The average daily weight gains of calves, kids and lambs were relatively low in this study which is not surprising considering the relatively poor nutritional environment, tendency for overgrazing and background of disease in the locality. Socio-economic factors may also contribute to these low growth rates since emphasis is given to the numbers of animals rather than their performance.

Improving disease control is simply one of the many changes that are required in order to improve the productivity and quality of local livestock and thus create additional income for the smallholder farmers. Given the limited resources that are available these much needed changes can only be brought about through an integrated program which involves not only researchers and extension workers but also seeks to promote actively farmer education regarding these issues.

This thesis is dedicated to Obot Cheptoo, Cheptoo, Kipngetich and Cheruiyot.

Declaration

The work described in this thesis was undertaken by me as part of a wider study of the National Agricultural Research Programme at the National Veterinary Research Centre-Muguga, Kenya. I declare that the experimental designs, execution and interpretation of the data are my own unless stated otherwise. All contribution made by other people are fully acknowledged in the text.



Moses Kipngeno Rugutt.

April 1999.

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The field component went on well without any major problem. Thanks to the extension staff especially the District Veterinary Officer (DVO) for the support during selection of the study site and throughout the entire period. The support of Kericho Veterinary Investigation Laboratory (VIL) staff was foremost appreciated as they availed laboratory room for sample processing. The cooperation and support of Helminthology laboratory technical staff under the supervision of Mr. W. Chepkwony is acknowledged, as that of the animal attendants and the drivers. Of course without the farmers this work would not have been a success, thanks to the 75 small-scale farmers and 5 large estates who participated in the study, in particular, Farmer Number 29 who availed space to construct a pen to house the tracers. In Swahili language we say *AHSANTE SANAA*.

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The U.K part of the study was essentially analysis of data and writing up at the MRI, Edinburgh. I am greatly indebted to the Scientific Director, Prof. Q. McKellar for the use of excellent facilities especially the library, photography and graphics. Thanks a lot to those who assisted in these sections. Secondly, my supervisor Dr. Jackson for critically reading the manuscript and the support and encouragement from the Parasitology group. Thirdly, on analysis of data. This was in two components, one was effectively handled by Glasgow University Veterinary School; Division of Veterinary

Informatics and Epidemiology and the second component in MRI under Dr. Ian McKendrick and Ms Cathy Hau. I must single for praise Cathy who conscientiously went through all the data for the entire study period.

My employer, Kenya Agricultural Research Institute (KARI) supported the study by provision of support staff and facilities. Secondly the Department for International Development (DFID) of United Kingdom with the government of Kenya who provided financial support under the auspices of National Agricultural Research Programme (NARP)-a multi-donor agricultural project which also funded the U.K study period.

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Those who may not have been mentioned take heart as I appreciated your input and may God bless you all.

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ABBREVIATIONS

ACZ.....Agro-climatic zone

A.I.....Artificial insemination

AHA.....Animal Health Assistant

ANOVA.....Analysis of variance

DFID.....Department for International Development

EPG.....Eggs per gram

FAO.....Food and Agriculture Organisation

FEC.....Faecal egg count

FECRT.....Faecal egg count reduction test

KARI.....Kenya Agricultural Research Institute

Kg.....Kilogram

Km.....Kilometer

GDP.....Gross domestic product

G.I nematode.....Gastro-intesinal nematode

GPS.....Global positioning system

ILRAD.....International Laboratory for Research in Animal Diseases

MALDM.....Ministry of Agriculture, Livestock Development and Marketing

mm.....Millimeter

MRI.....Moredun Research Institute

NARP.....National agricultural research programme

NQCL.....National Quality Control Laboratory

NVRC.....National Veterinary Research Centre

NQCL.....National Quality Control Laboratory

PRA.....Participatory rapid appraisal

TLU.....Tropical livestock unit

TWC.....Total worm counts

SEA-goat.....Small east african -goat

V.I.L.....Veterinary Investigation Laboratory

WAAVP.....World association for the advancement of veterinary parasitology

CHAPTER 1

General Introduction

1.1 Introduction.

Helminth parasites are a major cause of economic loss in ruminants throughout the world (Brunsdon, 1980; Holmes; 1985, 1987; Fabiyi; 1987; Parkins and Holmes, 1989; Sykes, 1994; Gill and Le Jambre, 1996; Stear, Bairden, Duncan, Holmes, McKellar, Park, Strain and Murray, 1997; Vercruysse and Dorny, 1999). Although it is difficult to assess, workers in Australia (Anonymous, 1991) estimated the cost of parasitism to the sheep industry is in excess of 700 million dollars annually. In Western Europe, it is economically important in cattle and sheep (Bairden, 1991; Stear *et al*, 1997) with parasites such as the abomasal nematode *Ostertagia (Teladorsagia) circumcinta* being a major constraint on efficient sheep production in temperate areas of the world (Stear, Bairden, Bishop, Gettinby, McKellar, Park, Strain and Wallace, 1998; Stear, Strain and Bishop, 1999).

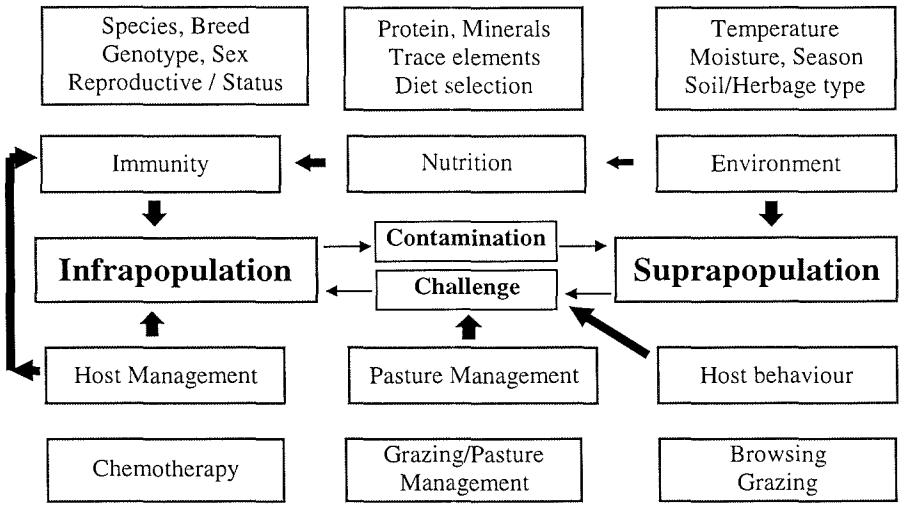
In Africa, helminthoses are also of considerable significance in a wide range of agro-climatic zones and represent one of the most important constraints to ruminant production. First, direct losses occur through mortalities (particularly in young stock), with additional cost for replacement of animals. Secondly, qualitative and quantitative reductions occur in liveweight gain, wool growth and reproductive efficiency. Aspects of the interactions between host nutritional status and gastrointestinal parasites have been reviewed by numerous authors including Parkins and Holmes (1989); Holmes (1993); MacRae (1993) and Coop and Holmes (1996). Thirdly, maintaining increased production through the use of anthelmintics imposes material and labour costs. Finally, there are opportunity costs foregone by avoiding or spelling pastures that are known to be contaminated (Allonby and Urquhart, 1975; Scott and Goll,1977; Preston and Allonby, 1979; Akerejola, Schillhorn van Veen and Njoku, 1979; Chiejina, 1987; Barger, Siale, Banks and Le Jambre, 1994, Barger, 1996).

Several factors determine the epidemiological patterns of the associated disease conditions (Armour, 1980). These include weather, husbandry practices, livestock production systems and physiological status of the animal.

A summary of these interactions is shown in Figure. 1.1 below.

Current strategies for the control of internal parasites in Africa are largely dependent on the use of anthelmintics in the absence of sound epidemiological data.

Figure 1.1 *Factors affecting nematode population dynamics*



1.2 Studies in Kenya.

Kenya lies on the equator on the eastern seaboard of Africa and has a climate that is considerably modified by altitude (Round, 1962). The wide diversity of environmental conditions ensures that results from studies carried out cannot be transposed to other areas. Areas relatively close together can have widely divergent climates and consequently varying agricultural potential. Over most of the country, rainfall comes in distinct seasons with marked regional and annual variation. In the higher rainfall regions, the long rains usually fall in March to June and the short rains from October to December (Anonymous, 1984). Land is categorised as high, medium or low potential depending on agro-ecological zones (ACZ) which are derived from a combination of climate, soil, topography and vegetation types (Jaetzold and Schmidt, 1983/1984).

The population of Kenya exceeds 24 million (Anonymous, 1994a) of which 85 % live in rural areas and depend on agriculture. The high potential land, which represents 7 % of total land mass, supports 80 % of the population. The remaining 20 % live in the arid and semi-arid zones and depend on pastoralism for their livelihood. The livestock industry plays a major role in the economic development of Kenya. It is estimated that the agricultural sector contributes about 25 % of the Gross Domestic Product (GDP, Anonymous, 1994b). Livestock accounts for nearly 26 % of this contribution with cattle making up a little over 80 % of the total livestock production (Abate, 1994). The ruminant livestock numbers are cattle 11,000,000, sheep 5,500,000 and goats 7,438,000 (FAO, 1994). More than 70% of the beef cattle and smallstock are found in low potential areas, whereas dairy cattle are concentrated in the high potential areas. As the population in Kenya increases, the demand for meat and milk is bound to rise and the livestock owners will be expected to increase production to aid the national economy. The present demand for meat and milk within the country has outstripped supply and will become worse as the country's population is expected to double by the year 2020 (Webb, 1996). There is a need to increase production by more efficient farming methods which will reduce losses due to animal diseases, of which endoparasitism features prominently. The loss attributable to helminths has been estimated to be 31 million US$ annually (Upton and Gathuma, 1992) while Mukhebi, Shavulimo, Ruvuna and Rurangirwa, (1985) suggested that returns of up to 47 % could be accrued by controlling haemonchosis alone.

1.2.1 Nematodes.

In Kenya and some neighbouring countries, gastrointestinal helminthiasis of domestic ruminants has increasingly become an important focus of research over the last two decades. In these countries research has been centred on the epidemiology of these parasites. Epidemiology as defined by Martin, Meek and Willeberg (1987) and by Thrusfield (1986) is the study of the frequency, distribution and determination of health and disease in populations. In parasitic

diseases in which the borderline between safe and dangerous worm burden is indefinite, and where the manifestations of disease are commonly subclinical and insidious in onset, it might be more desirable to think of epidemiology in terms of population dynamics (Gordon, 1948; Armour, 1980).

The studies which have been conducted in Kenya can best be presented in two sections, earlier studies up to the middle of the 1980s and those done in the last decade. Studies in 1920s to early 1930s were by Daubney (1926,1929,1933) and Daubney and Hudson (1932). These described the presence of various trichostrongylid nematodes of ruminants and stressed the fact that most of these were imported with sheep and cattle from the United Kingdom, Australia, New Zealand and South Africa at the turn of the century. Daubney (1933) attributed the presence of *Cooperia* species, which occurs in hosts other than sheep, as indigenous since it also occurred in wildlife. Most of the parasites described in these articles are shared between domesticated and wild ruminants and the focus was mainly description of taxonomy and predilection sites of the nematodes. The main genera reported were *Haemonchus*, *Trichostrongylus*, *Cooperia* and *Oesophagostomum* species. These data were gathered mainly from the highlands because of the advanced agricultural and husbandry development prevalent then. Dinnik (1954, 1961) and Dinnik and Dinnik (1958, 1961) studied parasite survival under various environmental conditions mainly in the highlands and made recommendations of treatments before the rainy warm season to avoid pasture contamination. All these studies were summarised in a review by Round (1962), firstly by giving an overview of the country's varied climatological zones and topograpy and their influence on patterns of helminth infection. Secondly, he noted that due to the more advanced agricultural and husbandry development in the highlands of Kenya, the majority of the helminth specimens for identification came from these areas. While in those parts of the country inhabited by the pastoralists, wild game animals may be numerous and will cause cross-infection amongst domesticated animals and wild game since they graze the same pastures. The author noted that it was unfortunate that a record of helminth parasites of

indigenous domesticated animals was not made before the introduction of large numbers of cattle and sheep which introduced exotic parasites. All helminth classes were recorded by Round (1962), who identified *H.contortus* as the key parasite since it had a widespread distribution.

As for the trematodes, *Paramphistomum, Callicophoron* and *Cotylophoron* (paramphistomes), *Fasciola gigantica* and *F. hepatica* (liver flukes) and *Schistosoma* species have been recorded in ruminants in various parts of the country. It was, however, noted that *F.gigantica* infections were very common in Kenya, particularly among cattle, and were responsible for much economic loss.

Detailed studies on gastrointestinal nematodes, especially *H. contortus,* were undertaken during the 1970s. Allonby and Urquhart (1973) described the phenomenon of self-cure in *H.contortus* during a field study in a semi- arid area of Kenya. In an epidemiology study, which extended over 21 months, Allonby and Urquhart (1975) reported the importance of *H.contortus* in the economy of sheep and goat production in the tropical and sub-tropical regions. Studies investigating breed susceptibilty by Preston and Allonby (1978, 1979) conducted in a semi-arid area, showed the Red Maasai breed of sheep had a greater resistance to *H.contortus* infection than the Black Head Persia, Dorper, Merino, Corridale and Hampshire Down breeds and that sheep were more resistant to this infection than goats.

During the 1980s relatively few epidemiological studies were carried out. A study on milk goats by Lutu (1983) in Kiambu district which lies on ACZ III-IV with a temperature range of 8 to 27 °C, showed at post-mortem that *Haemonchus, Trichuris* and *Oesophagostomum* species were the common nematodes present and that *Monieza* species was also common in the kids. Omara-Opyene (1985), working in a semi-arid northern part of the country under a nomadic management system, reported that strongyle eggs were most commonly seen in an investigation of helminthiasis and were a major constraint on production. Other studies in different agroclimatic zones were conducted by Gatongi, Gathuma and Munyua (1987, 1988) on Tetu Division of

Nyeri District, situated at an altitude of 2,000 metres with a mean annual rainfall of 900-1000 mm and mean temperature range of 10-25º C (ACZ III). A study on five farms over one year showed *Cooperia* to be predominant amongst four genera infecting cattle in the area. Other species recorded were *Haemonchus*, *Trichostrongylus* and *Oesophagostomum* and *Strongyloides* . The same study established that when the mean temperatures were at their highest, larval populations were at their lowest. The authors reported that high temperatures were detrimental to larval populations, although according to Ogunsusi (1979), temperature is not a limiting factor in larval development in the tropics as the temperature varies little throughout the year.

A survey (Ndarathi, Waghela and Semenye, 1989), carried out using an egg floatation method of diagnosis, examined the level of gastrointestinal parasite infections in cattle, sheep and goats in three Maasai group ranches. These ranches were in semi-arid to arid zones of Kajiado district, which have a total rainfall of 200-500mm, and provide evidence of strongylosis. Similar findings were reported by Omara-Opyene (1985) in a similar ACZ in Marsabit district. A previous study by Allonby and Urquhart (1975) in the same area, using coprocultures, found *H.contortus* to be the predominant species.

In the western part of the country which is more humid and generally has a higher rainfall, an 8 month study to assess disease as a constraint to the introduction of exotic goats to the small holder farms showed, on the basis of egg counts and larval cultures, that *H.contortus* was the predominant endoparasite in the region (Shavulimo, Rurangirwa, MacGuire and Chema, 1988). Other genera recorded included *Trichostrongylus, Oesophagostomum* and *Strongyloides.* A study by Shavulimo and Semenye (1990) in goats, showed strongyle egg counts were generally higher in the high rainfall areas than the semi-arid area in the central Rift Valley and confirms previous work (Shavulimo, Rurangirwa, Odero and McGuire, 1984).

Studies in calves based on districts in central Kenya showed the principal parasites seen on cultured pooled faecal samples were *Cooperia, Haemonchus*, *Trichostrongylus* and *Oesophagostomum* species in that order of prevalence

(Waruiru, Mbuthia and Kimoro, 1993a). These results are similar to those of Gatongi *et al* (1987) in the same study area. A case study in Kiambu district (Waruiru, Ayuya, Weda, Kimoro, 1993b), confirmed haemonchosis in heifers on a dairy farm. A survey of gastrointestinal nematodes in cattle on four farms in the same area reported that *Haemonchus* and *Trichostrongylus* species were predominant (Maingi and Gichigi, 1992). Other genera found in low numbers were *Cooperia, Oesophagostomum* and *Strongyloides*. An abattoir survey (Waruiru, Nansen, Kyvsgaard, Thamsborg, Munyua, Gathuma, Borgh, 1998a) of gastrointestinal nematode infections in cattle in the central highlands of Kenya, an area of annual bimodal rainfall of 600-1500 mm and mean monthly temperature of 10-25 C, found that control of helminthoses is largely based on anthelmintics and pasture management is rarely practised. *H.contortus* was the most common nematode occuring in all ages of cattle. Similar findings have been reportd by Mango, Mango, Esamal and Kariuki (1974) and Omara-Opyene (1985). The climatic conditions in the area also seem to be suited to the development and survival of the free living stages of *Cooperia* species and *Oesophagostomum radiatum*. Another survey in selected abattoirs around Nairobi (Githigia, Kimoro, Mwangi and Gichanga, 1995) showed that 11.8 % of condemnations in cattle, during the study period of 2 months, were due to helminths: mainly *Echinococcus*, *Fasciola gigantica*, *Oesophagostomum* species, *Cysticercus bovis* and paramphistomes.

Prevalence of gastrointestinal parasites of goats on single large scale farms in Kiambu, Nairobi, Muranga and Kajiado (ACZ range III-V) showed on faecal cultures that the genera *Haemonchus* and *Trichostrongylus* were predominant (Maingi, Gichanga, Gichohi, 1993). Coccidial oocysts were found mainly in kids and immature goats. A study in an institutional farm (Githigia, Okomo, Inyangala, Munyua, Okeyo, Otieno, 1996) in a semi-arid to arid area of Kenya in goats showed *H. contortus* was the most common nematode. Mbaria, McDermott, Kyule, Gichanga and Munyole (1995) showed, in an on farm study of sheep in the semi-temperate cool agroclimatic zone (ACZ I) of western Kenya, that *H.contortus* was the predominant species and

that the genera *Trichostrongylus*, *Oesophagostomum*, *Cooperia*, *Ostertagia*, *Bunostomum* and *Strongyloides* were also present. An abattoir survey of causes of ovine and caprine liver condemnations (Nginyi, Onyango-Abuje and Harrison, 1995) showed that 60 % of sheep and goat livers are condemned at slaughter as a result of various causes, both parasitic and non-parasitic. Helminth parasites inhabiting the liver, mainly *Stilesia hepatica,* were the highest contributor to these losses over the study period.

Other recent studies on gastrointestinal parasites of small ruminants have been undertaken by workers in the Helminthology division at the National Veterinary Research Centre-Muguga (NVRC) a semi-humid to semi-arid cool temperate agroclimatic zone. These studies include those of Mugambi, Wanyangu, Bain, Owango, Duncan and Stear (1996); Mugambi, Bain, Wanyangu, Ihiga, Duncan, Murray, Stear (1997); Wanyangu, Mugambi, Bain, Duncan, Murray and Stear (1997a) which confirmed earlier studies by Allonby and Urquhart (1975) and Preston and Allonby (1978, 1979) on the susceptibility of different breeds of sheep to naturally acquired *H.contortus* infection. Baker, Mwamachi, Audho, Aduda and Thorpe (1998) reported that peri-parturient rise in faecal egg counts in lactating animals does occur in a sub-humid coastal area and the predominant nematode recovered from coprocultures was *H.contortus*. Other genera present included *Oesophagostomum* and *Trichostrongylus.*

Wanyangu, Karimi, Mugambi and Bain (1997b), using tracer sheep in a semi-arid warm agroclimate, showed *H.contortus* larvae were only available on the pasture during the rainy season. Whereas sheep permanently grazed on the same pasture harboured adult *H.contortus* in their abomasa throughout the year, indicating that the perpetuation of haemonchosis in livestock in this area was greatly dependent on the ability of the parasite to survive in the host throughout the season. A plot study on the survival of infective larvae of *H.contortus* from sheep faeces, conducted at NVRC (Wanyangu, Sakwa, Mugambi and Bain 1996), suggested that larvae may survive on pasture for 2-23 weeks, depending on the rainfall pattern, and that larvae could withstand the hot dry periods for at

least 8 weeks and reappear on pasture when conditions were favourable. This study had similar results to those reported by Dinnik and Dinnik (1961) which also showed that months which had a mean total rainfall of 51mm or more and mean maximum and mean minimum temperatures not less than 23 ºC and 11 ºC respectively had the greatest potential to support prolonged survival of infective *H.contortus* larvae and their transmission to livestock. A similar plot study by Waruiru, Munyua, Thamsborg, Nansen, Bogh, Gathuma (1998b) using cattle faeces containing known numbers of strongylid eggs in a cooler ACZ in the same district showed that larval counts occurred almost invariably 2-6 weeks after contamination of pasture and that survival times throughout the year ranged from 12-16 weeks, which was relatively short compared to survival times of up to 9 months generally reported from temperate countries for *Ostertagia ostertagi* (Rose,1962).

All of the previous surveys in Kenya suggest that gastrointestinal nematode infections are common in ruminants in many parts of the country but that infections are variable between and within species.

1.2.2 Trematodes

Fasciolosis are the most common trematode infection of domestic ruminants throughout the world (Urquhart, Armour, Duncan, Dunn and Jennings, 1987; Fabiyi, 1987). In Kenya, the annual loss due to fasciolosis in cattle, sheep and goats has been estimated at Ksh. 326 Million (Anonymous, 1986). Froyd (1959) and Ogambo-Ongoma (1969), reported the presence of *Fasciola hepatica* but the most common species in ruminants is *Fasciola gigantica.* This species is endemic in most districts with a mean annual rainfall of over 1,000 mm (Bitakaramire, 1968a; Preston and Castelino, 1977; Cheruiyot and Wamae, 1988a). In an abattoir survey, Cheruiyot (1983) reported that condemnation of bovine livers due to fascioliosis was extremely variable from one area to another. He confirmed that the distribution of the snail vectors seemed to coincide with areas where fascioliasis was endemic. In a different survey of caprine and ovine facioliosis, Cheruiyot (1987), reported

that the pattern of variation in sheep and goats were similar to that in cattle. A study on the intermediate host, over a one year period, Wamae and Cheruiyot (1990) confirmed that infected snails were present most of the year hence susceptible hosts remain at risk of being infected. A study by Waruiru *et al* (1993a), in calves in the same area as the previous study, twelve percent of all samples contained liver fluke eggs.

Another epidemiological study on a ranch in the central Rift Valley (Wamae, Ongare, Ihiga and Mahaga, 1990) confirmed that all snails collected were *Lymnea natalensis* and were infected with *F. gigantica.* Wamae, Hammond, Harrison, Onyango-Abuje (1998) reported on production losses associated with fasciolosis in yearling cattle in a trial in NVRC and concluded that more epidemiological studies should be conducted to determine the prevalence of fascioloses in the cattle populations in various ACZs. Maingi and Mathenge (1995) described an outbreak of acute fascioloses in sheep in an endemic area of central Kenya where it was shown that substantial losses can occur if prompt intervention with anthelmintics is not instituted. The distribution of stomach flukes is similar to that of liver flukes and paramphistome species involved were first identified in Kenya between 1950 and 1967 (Cheruiyot and Wamae, 1988a) mainly due to the work and research of Dinnik (1954, 1956, 1961,1964a, 1964b, 1965) and Dinnik and Dinnik (1960, 1962, 1967). Cheruiyot and Wamae (1988a) reported that paramphistomiasis is far more prevalent than fascioliosis not only occurring in all the farms visited but also in the same animals which were infected by *Fasciola* species.

Because of these sporadic and scattered studies in the country, a consultancy by Upton and Gathuma (1992) recommended a detailed helminth epidemiology study on the different ACZs of Kenya. Studies were conducted on six sites under the auspices of the National Agricultural Research Programme (NARP) a multi-donor project of which the main objective was to improve the state of food security in the country. One of the sites, Kericho, is the subject of this study.

1.3 Studies on different agroclimatic zones in other tropical and subtropical countries.

In the highlands of Ethiopia where there are similar climatic conditions to the high production areas of Kenya, a study by Njau, Scholtens and Kasali (1990) using monthly faecal samples and necropsy data from sheep, showed strongylosis mainly in the wet to early dry season and fascioloses in the late dry to early wet season. Further studies in the same agroclimatic conditions by Bekele, Kasali and Woldemariam (1992) showed *T.colubriformis* was the most predominant parasite of sheep. Tembely, Lahlou-Kassi, Rege, Sovani, Diedhiou and Baker (1997), using tracer lambs, confirmed the presence of *Trichostrongylus*, *Haemonchus* and *Dictyocaulus* species, a similar finding to that reported by Njau *et al* (1990). Furthermore, under Ethiopian highlands conditions, temperature did not appear to be the limiting factor in the development and survival of the eggs and larvae of trichostrongylid nematodes, but rather rainfall and humidity seemed to have most effect on the development of eggs and free living stages. Tembely (1998), in a plot study in a dry agroclimatic zone showed the longevity of infective larvae of *Haemonchus contortus* varied between two and six weeks in the wet seasons, but eggs failed to develop in the dry season and they suggested that the long period (7-8 months) of lack of development of trichostrongylid larvae on the pasture can be efficiently used in a strategic treatment programme. Fasciolosis was reported as causing the highest number of deaths especially during the dry season in the highlands (Njau, Kasali, Scholtens, Degefa, 1988).

In Tanzania, a study by Connor, Munyuku, Mackyao and Halliwell (1990) found that *Haemonchus contortus* and *Oesophagostomum columbianum* were the significant species in goats, whereas a study in the northern part of Tanzania by Njau (1987) found that the most common worms present in small ruminants were *H.contortus*, *Oe. columbianum* and *Trichostrongylus colubriformis*. An earlier study by McCulloch and Kasimbla (1968) showed that goats had lower infections than sheep.

Further south, in South Africa, a study on a government farm by

Boomker, Horak and Ramsay (1994) on helminths of indigenous goats in the northern transvaal, concluded that *H. contortus* was the most common nematode. A study on goats (Pandey, Ndao and Kumar, 1994) in neighbouring Zimbabwe on highveld communal land found that *H. contortus*, *Trichostrongylus* species and *Oe. columbianum* were the main species present and concluded that there is a direct relationship between rainfall and the level of infection with gastrointestinal parasites. In the transvaal lowveld, a study by Malan, Reinecke and Roper (1982) showed that worm burdens increased markedly with the rains and the genera which predominated in calves were *Cooperia*, *Haemonchus* and *Oesophagostomum* species and that in Zimbabwe, a study on cattle from the highveld communal land suggested that lactating cows behave like calves as far as the level of worm infection is concerned (Pandey, Chitate, Nyanzunda, 1993) while Moyo, Bwangamoi, Hendrikx and Eysker (1996), in a study on highveld commercial beef cattle showed that *Cooperia*, *Haemonchus* and *Trichostrongylus* species were predominant and that *Haemonchus* species survived the dry season as inhibited early fourth stage larvae, whereas *Cooperia* and *Trichostrongylus* species survive as adults.

In the Haryana state in India, which has a similar subtropical climate to the coastal area of Kenya, tracer lambs were used to study pasture contamination with infective stages of parasites and showed, on post-mortem, low infections with *H .contortus* and *T .colubriformis* (Gupta, Yadav and Ruprah, 1988). In Malaysia, which has a warm and humid tropical climate, a study by Dorny, Symoens, Jalila, Vercruysse and Sani (1995) showed that *H.contortus* and *Trichostrongylus* species were the most important strongyles in sheep whilst in goats *H.contortus*, *Trichostrogylus* and *Oesophagostomum* species were most prevalent.

In a similar warm and humid tropical climate in Fiji, calves were infected with *Haemonchus, Oesophagostomum*, *Trichostrongylus*, *Cooperia* and *Strongyloides* species throughout the year with a limited increase during the season of heavy rains (Donald, Dineen, Turner & Wagland 1964). This study in an area of high rainfall and humidity with mean monthly maximum

temperatures ranging from 25.4-30.5ºC showed development and survival of *H.contortus* and *T.colubriformis* larvae on pasture throughout the year in the wet zone but that development was sporadic in the dry zone and larval counts generally declined below detectable levels within 9 weeks (Banks, Singh, Barger, Pratap and Le Jambre, 1990). This survival period may present opportunities for manipulation of parasite population dynamics in the wet tropics. These studies were confirmed by Barger, Siale, Banks and Le Jambre (1994) in Tongatapu, a wet tropical climate where they showed a short survival time on pasture of 3-7 weeks for infective larvae and discussed the potential of application of rotational grazing to control gastrointestinal nematodes.

1.4 Description of the study area-Kericho.

Kericho is about 300 kilometres west of Nairobi, the capital city of Kenya, with an average altitude of 2,000 metres above sea level. The climate in Kericho can best be described as cool and wet (ACZ I). The long term annual temperatures are a minimum of 8°C and a maximum of 24ºC. The distribution of rainfall is unlike that in other parts of the country where there are two distinct peaks of long and short rains. Rainfall in Kericho occurs throughout the year with the maximum between March and September and an annual average of 1400 mm. With these conditions, this area is described as a high potential area with the major farming enterprise being tea production.

The small-holder farms outside the tea estates have an active tea industry, coupled with small scale ruminant production with some portion of the land left for food crop production, mainly maize and horticulture. Ruminants are kept mainly in paddocks with little or no rotation except when animals can be turned on to post harvesting aftermath. Roadside grazing is important in some areas especially during the months when the land is occupied by food crops. Breeding takes place throughout the year with no attempt at seasonal control. In the study area a selection was made of small scale farmers with few resources whose strategies would differ from larger more intensive farms.

Except for the data available in the Veterinary Investigation Laboratory

(VIL), situated a short distance from the study area, and some small-scale snapshot surveys (Cheruiyot and Wamae, 1988a), little other detailed work has been conducted in this area. In the early 1980s, it was observed that frequent deaths occurred due to helminthoses in a flock of sheep on a tea estate despite treatments with the then current anthelmintics. The flock consisted of a Red Maasai cross Romney Marsh breed, which were reared and grazed on land close to the human living quarters. The problem persisted until the mid-1980s when the flock was disbanded and sold to neighbouring farmers. It is suspected that this flock harboured anthelmintic resistance and that the dispersal of the flock may have spread resistance to the study area and other large scale farms. This has been confirmed in a survey by Wanyangu, Bain, Rugutt, Nginyi and Mugambi (1996b). It is intended as part of the study to test for anthelmintic resistance in all 27 farms involved in the epidemiology project and some large scale farms and subsequently to institute relevant measures to alleviate the problem if resistance is confirmed.

1.5 Nematodoses.

Trichostrongyles belong to the superfamily Trichostrongyloidea and are a major cause of impaired productivity in ruminants. They are small-mouthed, slender, bursate nematodes infecting mainly the gastrointestinal tract and occurring in all vertebrate groups except fish (Noble, Noble, Schad and MacInnes, 1989). Gordon (1950) defined parasitic gastro-enteritis (PGE) as an inflammatory condition of the alimentary tract caused by nematodes. These nematodes are specifically adapted to inhabit particular regions of the digestive tract and are rarely found elsewhere

Worldwide, genera most commonly involved in PGE of ruminants include *Haemonchus*, *Ostertagia* species, and *Trichostrongylus axei* in the abomasum and *Cooperia*, *Trichostrongylus* and *Nematodirus* species in the small intestine. Of these, *Ostertagia* and *Cooperia* are the genera most widely incriminated in bovine PGE while *Haemonchus, Ostertagia*, *Trichostrongylus* and *Nematodirus* are regularly found in outbreaks of PGE in sheep (Bairden,

1991).

In Kenya, the most common genera involved in gastrointestinal parasitism are *Haemonchus* and *Trichostrongylus* in sheep and goats (Allonby and Urquhart, 1975; Shavulimo *et al*, 1988). In cattle, *Cooperia* appears to be the most common gastrointestinal parasite followed by *Trichostrongylus* species (Gatongi *et al*, 1987, 1988; Waruiru *et al*, 1993a). Waruiru *et al* (1998a), in an abattoir survey showed in order of prevalence *Haemonchus*, *Cooperia* and *Trichostrogylus* species to be the most commonly occurring species. All these studies have reported the presence of *Oesophagostomum* species in ruminants and that the genus *Nematodirus* is found least frequently.

1.5.1 The Life cycle

The life cycles of the numerous species of trichostrongyles are similar (Gordon, 1948, Noble *et al*, 1989). First, there is a free-living or pre-parasitic phase from egg deposition to the infective larval stage. This is followed by a parasitic phase which occurs within the host. At this stage, it is important to observe that two of the most important species of the genus *Haemonchus* are *H.contortus* which principally infects sheep and goats, while *H. placei* is specific for cattle (Herlich, Porter and Knight, 1958). However, Gibbons (1979) believed that the morphological differences between the two taxa were of little taxonomic significance and therefore synonymized *H.placei* with *H.contortus*. This has recently been confirmed by DNA sequencing (Stevenson, Chilton and Gasser, 1995). In this study, *H.contortus* refers to infection in both cattle and small ruminants. The life cycle of *H. contortus* (Figure 1.2) will be described in detail as many aspects of this cycle are common to other G.I. species.

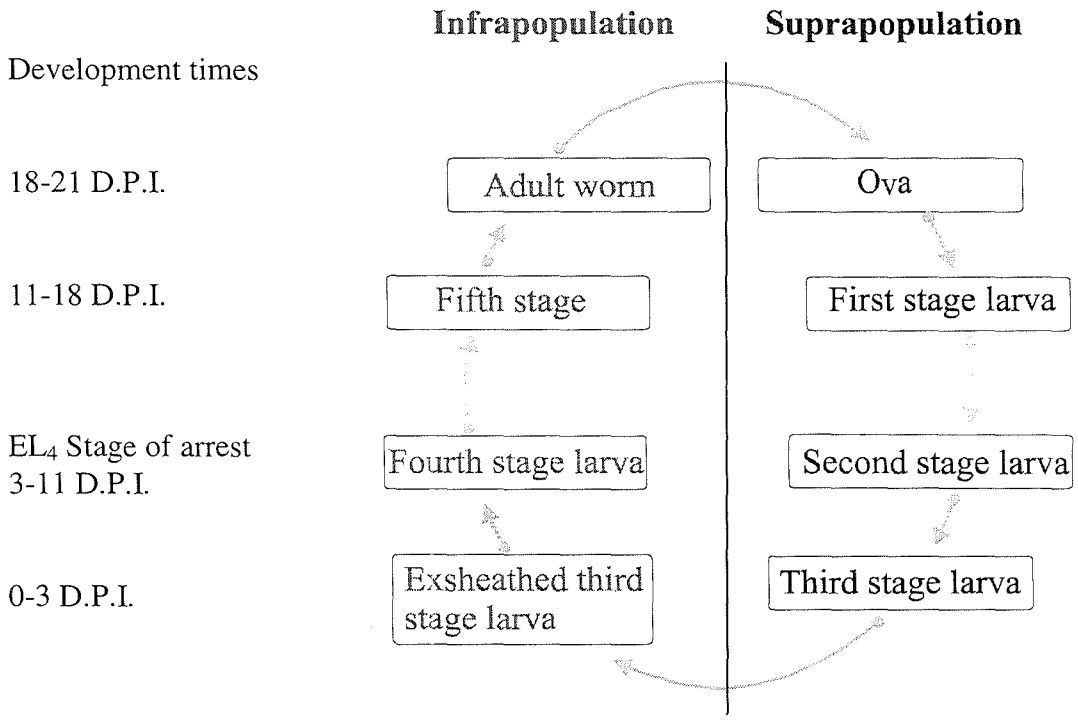


Figure 1.2 *Life cycle of Haemonchus contortus*

The parasitic stages of *H. contortus* occur in the abomasum of sheep, goats and several other ruminants worldwide and is most important in the tropical and subtropical areas (Monnig, 1934; Urquhart *et al*, 1987). The worms are unsegmented, cylindrical and elongate, the sexes separate and the females are larger than the males. They are 10-30 mm long, possessing small buccal cavities armed with a slender tooth or lancet. The male has an even reddish colour while in the female, the white ovaries are wound around the red intestine producing the appearance of a "barber's pole" (Lapage, 1962, Noble *et al,* 1989).

The life cycle of *H.contortus* is direct, that is to say there is no intermediate host. Eggs are passed in the faeces of infected animals. The females are prolific egg-layers frequently laying 5000-10,000 eggs a day per female (Gordon 1948, 1950; Lapage, 1955). In a few hours, eggs embryonate and hatch into the first stage (L_1) larvae. The L_1 larvae feed on faecal

microflora, develop, grow and moult to the second stage (L_2) larvae. After a further period of activity and growth, the third stage (L_3) is achieved. The larvae, in the third stage, fail to cast off the cuticle of the previous stage and are unensheathed, non-feeding form. Under favourable conditions, the infective stage will be present on the pasture within 4-6 days but may be delayed for weeks or months under cool conditions. The sheathed infective larva is resistant to desiccation and freezing. The larvae disperse from the faecal mass onto herbage where, while moisture is adequate, they survive until they invade the host. Infection of trichostrongylids is usually via the oral route.

After ingestion, the larvae exsheath in the gastrointestinal tract proximal to the parasite's predilection site, hence *H. contortus* and *T. axei* exsheath in the rumen and the *Trichostrongylus* species and other genera which inhabit the intestine, exsheath in the abomasum. The actual stimuli to exsheathment are unknown but are thought to be dissolved carbon dioxide and /or undissociated carbonic acid in the gut (Mapes, 1969). The now parasitic exsheathed L_3 migrate to the abomasum and become closely associated with the mucosa, where the third moult occurs and the fourth stage (L_4) larvae emerge. The L_4 is able to feed once the L_3 sheath is lost (Mapes, 1969) and, just before the time of the fourth moult, the piercing lancet which enables the larvae to penetrate the surface of the abomasal mucosa develops. Feeding commences and is soon followed by the fourth moult to the fifth or pre-adult stage. After further feeding, the fifth stage larvae mature into adult worms which are to be found moving freely on the surface of the mucosa. Differentiation into male and female begins around the time of the fourth moult. They reach maturity in 18-20 days, the first eggs appearing in the faeces of the host about 18-21 days after infection (Monnig, 1934).

As mentioned above, the life cycle of *H.contortus* comprises most of the features of all other gastrointestinal nematodes. Individual differences exist and each parasite has a specific association with the host, for example in the case of the abomasal dweller *Ostertagia*, the fourth stage larvae inhabit the glands before returning to the lumen as adults. Others, such as *T.axei,* have a

more superficial association with the host, unlike *H.contortus* which has a buccal lancet which enables haematophagic activities. Similarly, in the small intestine, adult worms of *T. colubriformis*, a major parasite of sheep, have an intraepithelial association with the host, while *Cooperia* species in cattle have a more superficial association, lying around the base of crypts (Skyes, 1994).

Trichostrongylus species are tiny (9-16 mm) hair-like worms. These species are poor egg-layers with up to 200 eggs per female per day (Gordon, 1950) and the free-living stages are relatively resistant to weather conditions. Both larval and adult stages burrow into the surface lining of the gut and occupy these channels as holdfasts while they utilise the ingesta in competition with the host, hence the overall effect is to cause widespread destruction and flattening of the infected gut (Linklater and Smith, 1993).

Oesophagostomum species inhabit the large intestine of ruminants and *Oe. columbianum* appears to be the species of greatest economic importance. The third stage infective larvae of *Oesophagostomum* species penetrate the colonic mucosa and submucosa. Granulomatous nodules project from the serous surface and many get calcified reflecting sites from which these stages have migrated giving rise to the name "Pimply gut." Similar nodules may be found in the mesentery and mesenteric lymph nodes. The adult worms reside in the lumen causing chronic mucoid colitis, diarrhoea and unthriftness.

In an evasive strategy to survive adverse weather conditions, i.e. cold or hot and dry, some trichostrongylids such as *H. contortus* undergo hypobiosis in the host. This has been defined as the temporary cessation of development by nematodes at a precise point in their early parasitic development, occurring only in certain hosts, certain circumstances or at certain times of the year and often affecting only a proportion of the worms (Michel, 1974). Reviews (Michel, 1974, 1976; Schad, 1977; Baker and Muller 1986) have suggested that waning of immunity or endocrine changes may be mitigating factors. In temperate areas, environmental influences, particularly declining temperatures have also been implicated in the process (Armour, Jennings, Murray, Selman, 1974). This arrested development of early fourth stage larvae, is also seen in

both the tropics (Allonby and Urquhart, 1975; Gatongi, 1995; Gatongi, Prichard, Ranjan, Gathuma, Munyua, Cheruiyot, Scott, 1998) and temperate areas (Connan, 1971). Gibbs (1986) describes the condition in nematodes as being equivalent to diapause in insects although it has unique features of its own, since it is variable and less predictable. It represents a modification of development that is primarily aimed at facilitation of survival or persistence of these parasitic nematodes over periods of adversity. The main significance of inhibition appears to be to synchronise the life cycle of the parasite with seasonal environmental conditions, so that reproductive activity coincides with conditions favourable to egg and larval development (Thomas, 1978) and that the maturation of the larvae is of considerable importance in the epidemiology of PGE, particularly ostertagiasis (Armour, 1978).

1.5.2 The Ecology of Infective Trichostrongylid Larvae.

The L3 is one of the most important stages in the life cycle of any trichostrongylid parasite. It is on this stage that the propagation of the species depends, since no further development takes place until ingestion by a suitable host. The infective larvae must be available, viable and present in sufficient numbers to complete the life cycle (Bairden, 1991). The factors that influence the development, survival, distribution or migratory behaviour of the free-living larvae on pasture are primarily weather related, especially moisture and temperature (Crofton, 1948; Durie, 1961; Gordon, 1948; Levine, 1963; Smith, Greenfell and Anderson, 1986; Stromberg, 1997).

Gordon (1948) reported that for optimal survival of *H.contortus* a monthly mean temperature of 18 degrees centigrade and minimal rainfall of 55 mm is necessary. Low temperatures retard development whilst extreme heat causes desiccation. Wharton (1982), reported that below 9 degrees centigrade, little or no pre-parasitic development takes place, although pre-hatch eggs are more resistant and can survive freezing and desiccation more readily than other stages. A study by Dinnik and Dinnik (1958), in the Kenya highlands indicated that the survival of *H. contortus* L_3 in pasture may be diminished during certain

times of the year depending on air temperatures and moisture and that longevity of infective larvae at best is probably several months.

When conditions are optimal, translation, as described by Michel and Parfitt (1956), occurs in a microclimate where humidity depends not only on rainfall but on elements influencing the amount of moisture which remains in the soil, for example the soil structure, vegetation type and drainage (Armour, 1980). The microhabitats of the free-living stages have been classified by Crofton (1963) into soil, root mat, herbage and host faeces. These microhabitats form a complex ecosystem in which parasitic larvae have to compete with free-living nematodes, predatory terrestrial fauna such as dung beetles, bacteria, fungi and viruses. The rate of evaporation and physical structure of the soil are also important in maintaining the moisture level and is related to the state of the mat. In general, in the arid tropics mat formation is negligible compared with humid areas or more temperate zones, hence development and survival in arid areas is limited.

The development and survival of eggs or larvae within faecal matter, though dependent on moisture and temperature, is also influenced by the type of faeces, hence cattle faeces remains in its original form for a considerable time compared to sheep pellets. The moisture content at the centre of a bovine faecal pat can remain high for several weeks of drought and so provide suitable shelter for the developing larvae. The consistency and disintegration of faeces may depend on some husbandry practices such as harrowing. Reinecke (1960) and Bryan (1972) showed that activity of certain dung beetles reduce the number of the gastrointestinal larvae in the pastures.

The migration of larvae from faeces to the herbage also depends on moisture and temperature (Silangwa and Todd, 1964; Rossanigo and Gruner, 1994). Wet conditions are necessary for larvae to migrate and in the absence of such conditions, faeces act as a reservoir of infection from which larvae are released when the environment is favourable. Waller and Donald (1972) reported that during hot, dry weather sheep pellets containing less than 5 per cent water by weight yielded viable *T.colubriformis* eggs for up to 3 weeks

when maximum temperatures in pellets exceeded 50 °C on several consecutive days. The availability of helminth infective larvae to grazing animals is also affected by certain management practices such as high density of stocking which increases the level of contamination per unit area.

1.5.3 Pathogenesis and Clinical Signs.

Generally ruminant hosts, harbouring light to moderate numbers of worms exhibit little obvious evidence of ill-health provided they have adequate nutrition. Where infection is heavy and clinical signs develop these differ according to genera of parasite and depend on the site of infection. Trichostrongylosis is associated with a range of clinical signs, including a failure to gain weight or weight loss, poor body condition, inappetance and usually diarrhoea. Diarrhoea is normally associated with trichostrongyle infections of veterinary importance such as *Ostertagia* species, *T .axei, T.colubriformis*, *Cooperia punctata* and *Nematodirus* species but is less common in animals infected with *H. contortus*, *C. oncophora* and *T. vitrinus* (Holmes, 1985). The genera involved in PGE in Kenya are *Haemonchus*, *Trichostrongylus*, *Cooperia* and *Oesophagostomum* in that order of importance. The clinical signs of the most common parasites are briefly covered below.

1.5.3.1 Haemonchosis

H.contortus is remarkable among the trichostrongyles because the late fourth stage larvae and adult worms are specialised blood suckers, having an oral lancet which is used to puncture the abomasal blood vessels. The adult worms each ingest about 0.05 ml of blood per day. Additionally, blood and plasma proteins are lost from the remaining lesions when the worms detach. The mucosa is therefore strongly irritated and the worms deprive the host of a large quantity of blood. Monnig (1934) and Gordon (1950), described various signs in different disease presentations, for example in acute cases, anaemia develops rapidly and progressively (Urquhart *et al*, 1987). This is seen as a dramatic fall in the packed cell volume (PCV). In more chronic cases, animals

lack stamina, spend less time feeding and tend to hang around camps and watering troughs. Anaemia is the main symptom and oedematous swelling is seen under the jaw, the so- called "bottle jaw" and sometimes along the ventral aspect of the abdomen. Animals become progressively weak with a swaying gait, the skin becomes pale and in sheep, the wool falls out in patches. Appetite is variable and although diarrhoea may occur (Lapage, 1962), it is not a common feature of haemonchosis (Charleston, 1965). Where very heavy infections have been acquired with great rapidity, that is hyperacute infections, lambs and even adult sheep may die suddenly because they have literally been bled to death so rapidly that they may not have had time to lose condition.

1.5.3.2 Trichostrongylosis/Cooperiasis

The main damage inflicted by the trichostrongyle species of the small intestine (*T. colubriformis* and *Cooperia* species) is derived from the activity of the parasites and often the proximal third of the small intestine is greatly damaged. Both larval and adult stages burrow into the surface of the gut and cause extensive villous atrophy, mucosal thickening and erosion of the villi and intestinal crypts. In heavy infections, diarrhoea and unthriftness is seen. More insidiously subclinical infections cause long term unthriftness with variable loss of appetite resulting in delayed growth, emaciation, the skin becomes dry and there may be alternating constipation and diarrhoea. Anaemia if present is normally mild.

In *T.axei* infection, which occurs in the abomasum, the larvae penetrate into the mucosa and produce irregular, circumscribed thickenings the clinical signs being similar to intestinal infections.

1.5.3.3 Oesophagostomiasis

Oesophagostomum species causes enteritis as a result of penetration of the exsheathed L_3 into the mucosa of the intestine provoking an inflammatory response with the formation of nodules (Urquhart *et al*, 1987). When the L_4 emerge, there may be ulceration of the mucosa resulting in diarrhoea. In heavy infections, there may be ulcerative colitis and the disease runs a debilitating

course (Urquhart *et al*, 1987). In addition to effects on production, the nodules in the gut wall also render the intestine useless for processing as sausage skins or surgical suture material (Urquhart *et al*, 1987) and because of condemnation of the intestines, it is a loss especially in Africa where this forms part of the diet (Fabiyi, 1987).

1.5.4 Pathological effects and influence on host nutrition.

Aspects of the interactions between host nutritional status and gastrointestinal nematode parasitism have been reviewed by numerous authors, including Symons (1985); Parkins and Holmes (1989); Poppi, Sykes and Dynes (1990); Holmes (1993); MacRae (1993); Coop and Holmes (1996). In general, infections with parasites may cause deaths but often adverse effects on productivity are manifested in a variety of ways with changes in body weight the most common feature. Reductions in live weight gain vary with the level of infection, species, age and nutritional and immunological status of the host (Holmes, 1987). In addition to changes in body weight, alterations in body composition also occur and are an important consideration in judging the economic impact of gastrointestinal helminths. The most common of these are decreases in the deposition of fat, protein and skeletal calcium and phosphorous together with increased body water as a percentage of body weight (Holmes, 1987). Considerable reductions in live weight gain have been reported in sheep infected with *T.colubriformis* (Sykes and Coop, 1976) and sheep infected with *H.contortus* (Allonby and Urquhart, 1975; Abbot, 1982; Abbot, Parkins, Holmes, 1986a, 1986b). Entrocasso, Parkins, Armour, Bairden and MacWilliam (1986) demonstrated that the carcasses of cattle exposed to natural infections had poorer killing-out percentages, reduced muscle and fat deposition and increased bone content, in comparison with animals protected by prophylactic treatment.

Conflicting results have emerged from studies on the effects of trichostrongylosis on milk production. Some have reported an increase (McBeath, Dean and Preston, 1979) while others have found no significant

beneficial effects following treatments (Michel, Richards, Altman, Mulholland, Gould, Armour, 1982). In an experiment where ewes were infected with *H. contortus*, Thomas and Ali (1983) reported a marked weight loss and a 23 % reduction in milk production compared to the control animals despite a similar feed intake.

The important established host/parasite interactions are summarised below:

1.5.4.1 Effects on Feed Intake.

An important reason for reduced performance of parasitised ruminants is depression in voluntary feed intake. Though not always observed (Sykes, Coop, Angus, 1979), reductions of between 10 and 30 % are commonly reported (Sykes and Coop, 1976; Coop, Sykes, Angus, 1982) and in severe cases, complete inappetance has been reported (Bown, Poppi and Sykes, 1989; Fox, Gerrelli, Pitt, Jacobs, Gill and Gale, 1989). Although little is known about the mechanisms responsible for the depression of feed intake in parasitised animals (Symons, 1985), there are several hypotheses postulated. Abdominal pain and gut inflammation, changes in the pH of gut contents, changes in protein to energy ratio of absorbed nutrients and changes in secretion of the gut hormone cholecystokinin have been suggested (Symons, 1985). Fox *et al* (1989) have shown in cattle experimentally infected with *Ostertagia ostertagi* that there is an elevation in blood gastrin concentrations and a reduction in the rate of passage of ingesta. This association between elevated gastrin and depression of appetite needs to be confirmed in other nematode infections (Coop and Holmes, 1996).

1.5.4.2 Effect on Nutrient Digestion and Absorption.

Fox (1993) reported that marked changes in gastrointestinal secretions accompany *Ostertagia* infection in ruminants including a reduction in gastric acid secretion and gastrin levels. The reduction in acid output is brought about by the replacement of functional parietal cells with those of reduced activity

(Murray, Jennings and Armour, 1970). Despite this however, the general consensus is that gross changes in the extent of digestion and absorption of energy and total protein are not the major causes of impaired animal productivity during parasitism (Parkins and Holmes, 1989). The implication for altered absorption of individual amino acids is suspected to be involved and this needs to be addressed (Houtert and Sykes, 1996).

Rumen function is critical to the supply of metabolisable energy and metabolisable protein in ruminants, but few studies have investigated the effects of nematodes on rumen function. Rowe, Nolan, Chaneet, Teleni and Holmes (1988) reported that in sheep infected with *H. contortus*, synthesis of microbial protein did not appear to be affected, in spite of changes in rumen outflow rate. This was in contrast to work by Coop and Field (1983), who reported that infection in the small intestine with *T.vitrinus* reduced the content and concentration of phosphorous in the rumen of young sheep.

1.5.4.3 Effect on Protein and Amino acid Metabolism.

The consequences of gastrointestinal parasitism on protein metabolism in ruminants have recently been reviewed (Holmes, 1993; MacRae, 1993). Parasitism induces an increase in the loss of endogenous proteins, namely blood, plasma, mucin and sloughed epithelium into the gut lumen (Poppi, MacRae, Brewer, Coop, 1986; Bown, Poppi and Sykes, 1991). The leakage of protein has been quantified (Parkins and Holmes, 1989), but due to technical difficulties, the protein losses arising from increased turnover of gastrointestinal tract in parasitised ruminants is unknown (Coop and Holmes, 1996). In abomasal infections, the majority of endogeneous losses will be reabsorbed (Rowe, Abbot, Dargie, Holmes, 1982) but in intestinal parasitism a greater proportion may be lost by the animal (Poppi, MacRae, Corrigall, 1981). The loss of protein in the gut causes a net movement of protein away from productive functions such as muscle, bone and wool growth towards repair functions of the gastrointestinal tract, mucus secretion and / or plasma and blood replacement (Jones and Symons, 1982; Symons, 1985; MacRae, 1993).

Fox (1993) reported that despite the marked changes in protein digestion and metabolism that accompany abomasal parasitism, there appears to be little or no effect on protein absorption *per se*. It should therefore be possible to meet the increased nutrient demand by improving the protein content of the diet according to Poppi *et al* (1990). This hypothesis is supported by the work of Abbot *et al* (1986a, 1986b, 1988) who increased protein deposition and live weight gain in sheep infected with *H.contortus* to levels similar to those in control animals by increasing intestinal protein supply. Wallace, Bairden, Duncan, Fishwick, Holmes, Gill, McKellar, Murray, Parkins and Stear (1996), showed that supplementing soya bean meal to lambs infected with *H. contortus* improves their carcass composition, ability to withstand the pathogenic effects of haemonchosis and also the ability to control infections in susceptible breeds. Indeed, use of protein supplements is currently being investigated by various workers with the aim of incorporating this in the management of helminthoses.

1.5.4.4 Effects on Mineral Metabolism.

There have been reports of impairment of bone growth in sheep infected by gastrointestinal parasites (Reveron, Topps and Selman, 1974; Sykes and Coop, 1976; Sykes, *et al*, 1977, 1979). The absorption and retention of phosphorous are reduced in sheep infected with the intestinal parasites *T.colubriformis* and *T.vitrinus* (Wilson and Field, 1983; Poppi, MacRae, Brewer, Dewey, Walker, 1985) but appear unaffected by infection with *Ostertagia circumcinta* (Bown *et al*, 1989). The consequence of this is low concentration of phosphorous in the plasma and a reduced salivary secretion (Coop and Field, 1983), it has also been linked to anorexia (Poppi *et al*, 1985; MacRae, 1993). Few studies have investigated phosphorous supplementation of animals with nematode infections. It may be difficult to increase the availability of phosphorous in tissue because of impaired functions due to these infections.

Abomasal infections have been shown to reduce considerably absorption of copper and have been associated with an elevated abomasal pH (Bang,

Familton and Sykes, 1990). Coop and Holmes (1996) suggest that the role of trace elements in the complex parasite/nutrition interaction merits further study.

1.5.4.5 Immunity and Factors Modulating Host Responses.

The earliest studies detailing immune responses of sheep to infection with *H. contortus* were primarily concerned with "self-cure" in which an established population of adult worms is effected by the host response to further larval challenge (Stoll, 1929; Gordon, 1948; Stewart, 1955). There have been numerous reviews in the subject including those by (Miller, 1984; Brophy and Pritchard, 1992; Klesius, 1993). The nature of the immune response to gastrointestinal nematodes varies considerably at different stages of infection. Effector mechanisms have been described that regulate parasite establishment, development, persistence and fecundity (Barger, 1987). Evidence exists that initial establishment of trichostrongylids of various species in previously uninfected ruminants is either dose related (Ross, 1963; Donald *et al*, 1964) or is not dose-related (Dineen and Wagland 1966; Michel, 1970; Barger, Le Jambre, Georgi, Davies, 1985). Barger *et al* (1985) working with *H. contortus* in lambs found establishment of new infection declined rapidly from around 50 % during the first four weeks to virtually zero after ten or more weeks of infection. Waller and Thomas (1981) reported field evidence consistent with density-dependant population regulation in a study where they showed that lambs exposed to high levels of larval intake at pasture were able to resist establishment of *T.axei* and *T. vitrinus* by five months of age, while lambs exposed to lower larval intakes were still accumulating burdens of both species at seven months of age. These reports are consistent with those of Gibson and Parfitt (1973), in which they showed that in lambs given *T. colubriformis* infection, resistance developed to new infections after 20 weeks. Effector mechanisms operating against existing mature infections have been described by Stewart (1955) who showed that the "self-cure" reaction was caused by an intake of larvae. It was more likely to follow frequent, spaced

doses of larvae than to occur as a result of exposure to adult worms. Miller (1984) reviewed the factors influencing parasite persistence in the host and considered that the most important was the susceptibility of the host; young, peri-parturient, lactating or malnourished livestock being least able to immuno-regulate gastrointestinal nematodes.

The majority of experimental studies have been conducted in young ruminants since the major effects are seen in them, however older animals, though immune to clinical disease, may suffer production losses when subjected to a heavy larval challenge (Anderson, 1973; Yakoob, Holmes, Parkins and Armour, 1983). It is generally accepted that well nourished animals resist parasitism better than those less adequately fed (Kates and Wilson, 1955; Gibson, 1963). Work done by Abbot *et al* (1986a,1986b), using *H.contortus* showed that lambs on low protein diets had more severe anaemia, hypoproteinaemia and hypoalbuminaemia than those in a high protein group.

1.6 Diagnosis of Nematodoses.

For a veterinarian or a farmer in the field, diagnosis is based on clinical signs but there are disease conditions which present similar signs hence the need for confirmation (Urquhart *et al*, 1987). The best known and the simplest of the diagnostic techniques used to detect parasitic infection are faecal egg or larval counts but these have their deficiencies as emphasised by Brundson (1971) and there are difficulties in interpreting the data (Rubin, 1967; Michel, 1968). In general, the significance of the faecal egg count depends on many factors including host immune status, faecal consistency and parasite species. The high fecundity of some parasite genera like *Haemonchus* and *Cooperia,* may mask the important effects caused by parasites such as *Ostertagia* and *T. axei* which have low egg output.

Serological examination has also been employed to detect parasitism. The estimation of plasma pepsinogen levels has been widely used as an indicator of abomasal damage in ostertagiasis (Armour *et al*, 1974; Ford, 1976; Berghen, Hilderson, Vercruysse and Dorny, 1993; Dorny and Vercruysse,

1998) although its usefulness as a diagnostic test has been questioned (Michel, Lancaster, Hong, Berwick, 1978). More recently, attention has been focused on serum or plasma gastrin as an indicator of abomasal dysfunction due to parasitism (McKellar, 1984; Entrocasso, McKellar, Parkins, Bairden, Armour, Kloosterman, 1985).

Several workers have attempted to develop an Enzyme Linked Immunosorbent Assay (ELISA) for the diagnosis of parasitism (Keus, Kloosterman and Van den Brinck, 1982) but this is complicated by the fact that gastrointestinal parasites have common antigens which make their specific diagnosis difficult, however, Poot, Kooyman, Dop, Schallig, Eysker and Cornelissen (1997) have developed a specific *C. oncophora* recombinant protein which is used in an ELISA. Their results show a good correlation between serum antibody titre and *C.oncophora* exposure levels in cattle. However its value for incorporation in herd health schemes needs to be evaluated at farm level.

1.7 Control of Nematodoses.

There have been several reviews of the epidemiology and control of nematode infections in grazing animals (Michel, 1969, 1976; Gordon, 1973; Barger and Southcott, 1978; Southcott and Barger, 1975). The main aim of control measures is to ensure that parasite populations do not exceed levels compatible with economic production (Brundson, 1980). This objective may best be achieved by an integrated approach using grazing management, chemotherapy/chemoprophylaxis, genetic selection, biological control and vaccination. Efficient control, however, can only be possible given a full understanding of the epidemiology of the principal parasites within the production system.

1.7.1 Grazing management methods

One approach involves the use of two or more different host species on

pasture alternately, with the changeover taking place when the pastures have become helminthologically safe for the alternate host. The most commonly used species are cattle and sheep and alternate or mixed grazing systems depend on the host specificity of the parasite species involved (Barger, 1996; Stromberg and Averbeck, 1999). Cattle and sheep parasites are relatively host specific so the pasture contaminated by sheep may be considered clean for cattle and vice versa and where infection occurs it rarely develops to patency (Thomas, 1982). The same author advocated a three year alternation of cattle, sheep and crops. The interval of changeovers should not be so long that one host is infected by its own parasites. In practice, control is best achieved in temperate climates by exchanging spring pastures grazed by sheep with beef cattle over the previous year, preferably combined with anthelmintic treatment at the time of exchange (Urquhart *et al*, 1987). The disadvantage of this method is that not all ruminant gastrointestinal nematodes are host specific, an example being *T. axei* which can be found in both cattle and sheep and can also infect other hosts including goats, horses and pigs. Another example which is of practical importance in the temperate areas is *Nematodirus battus* infection in lambs and calves (Bairden and Armour, 1987; Coop, Jackson and Jackson, 1988; Mitchell, Mathieson and Fitzsimons, 1985) on an alternate grazing system of husbandry.

Another grazing management method is rotational grazing which involves resting the pastures long enough for any residual contamination to decline to negligible levels before susceptible livestock is introduced. Barger *et al* (1994) showed the potential of rotational grazing to control nematode infections in goats in a wet tropical climate. He suggested that such systems are most likely to work in the tropics where the life expectancy of infective larvae in pasture is short (6-8 weeks), than in temperate areas where larvae can survive in reasonable numbers for as long as 3 to 9 months (Barger, 1996; Barger, 1999). Mitchell, Fitzsimons, Mathieson (1984) indicated that avoidance of autumn grazing is necessary to produce clean spring pasture. Cropping is another form of efficient utilisation of the pasture which, after it

becomes highly contaminated, is planted with crops or has a harvest of hay or silage taken from it. Rotational grazing is a specialised form of pasture spelling which is impractical where farmers own small pieces of land. The use of strip grazing, which involves confining animals along narrow strips in the field, is now less popular in temperate regions though the use of tethering is becoming popular in tropical areas where small scale farmers keep sheep and goats tethered, moving to a new grazing area every one to two days.

1.7.2 Control by a combination of anthelmintic treatment and grazing management.

In temperate regions of the world, a large number of recommendations aimed at improving efficiency of parasite control in livestock are based on combining anthelmintic treatment with some form of grazing management (Barger, 1997). In comparison, there are relatively few examples of such schemes in the tropics/subtropics but in these regions the potential for grazing management is possibly greater (Waller, 1997).

Grazing management schemes usually incorporate a limited number of anthelmintic treatments and the most widely used is the "dose and move" system (Michel, 1969, 1976). This system is sometimes referred to as an evasive strategy and is used in various agroclimatic zones but requires meteorological information to define periods of high risk when chemoprophylaxis becomes necessary (Michel, 1969). There are disadvantages to this system for example, Le Jambre (1978), suggested that the new generation of worms which appears after the move to clean pasture will consist entirely of the progeny of the parasites which survived treatment, thus this approach may select for anthelmintic resistance. This was further discussed by Donald (1983) who pointed out that selection for resistance will depend on many factors including the frequency of treatment and the "cleanliness" and grazing history of the pasture.

1.7.3 The use of vaccines.

This has a limited application. To date, the only helminth vaccine commercially in use in ruminants is that to *Dictyocaulus viviparous*, the bovine

lungworm (Clegg and Smith, 1978; Bain, 1999; Smith, 1993, 1999). Substantial effort is being put into the development of vaccines against nematodes (Miller, 1987, 1996; Smith, 1993, 1999) and candidate antigens have been identified in research into vaccination against *H.contortus* (Newton, 1995; Smith, 1999). *Haemonchus contortus* has been extensivly studied with some recent papers showing that gut membrane proteins are promising vaccine candidates. These antigens have been identified as proteases (Smith, 1999). Smith (1999) reported that if the rate of progress which has been achieved over the last 10 years can be sustained, then the next decade should see the launch of the first defined antigen helminth vaccine. Vaccines may be produced in the medium term but in many countries, the lack of suitable infrastructure, the expense, competition with modern anthelmintics and their doubtful value in malnourished stock may prevent their widespread application (Stear and Murray, 1994; Waller, 1997).

1.7.4 The use of nutrition supplementation.

This has gained importance recently because of widespread anthelmintic resistance. Houtert, Barger and Steel (1995) studied interactions between dietary supplementation and degree of nematode control on production responses in young grazing Merino sheep. They found that supplementary feeding with sunflower cake appeared more effective than treatment with anthelmintics in reducing production losses attributable to nematode infections. This confirmed the study of Jorgensen, Satrija, Monrad and Nansen (1992) which reported that supplementary feeding of young cattle with lucerne markedly reduced faecal egg counts in the ensuing period. Wallace *et al* (1996) showed that offering lambs, infected with *H.contortus,* a diet supplemented with soyabean meal improves their abilities to withstand the pathogenic effects of this nematode. Though this method is gaining acceptance as an alternative control strategy, dietary supplementation is currently more expensive than treatment with anthelmintics (Houtert and Sykes, 1996).

1.7.5 Control by using genetically resistant animals.

Genetic selection can also be used to alter the genotype of animals within the flock to make them more resistant to a disease. It is being increasingly recognised that the animal genetic resources of the tropics/subtropics are likely to provide the foundation of sustainable and environmentally sound solutions to helminthoses in these regions (Waller, 1997). The trait sought in selection studies is resistance, which is the ability of the host to regulate gastrointestinal nematodes. Another trait that has been considered is resilience, which has been defined as an enhanced ability of sheep to withstand the impact of nematodes on productivity when remaining undrenched (Douch, Green, Morris, McEwan and Windon, 1996). There is ample evidence that breeding for parasite resistance is possible (Albers and Gray, 1987). Stear and Murray (1994) suggested that the evidence for genetic variation in resistance to infection with nematodes come from three sources: variation among breeds, variation between breeds and the identification of genes contributing to variation. Research into selected lines of sheep with inherited ability to resist infections by nematode parasites is well advanced in Australia and New Zealand with flocks selected for resistance to *H.contortus*, *T.colubriformis*, *Ostertagia circumcinta* and mixed infection (Barger, 1993; Baker,1999). It is clear that the long duration of selective breeding may deter progress in this field, especially in Africa where little is known of the genetic variation of the indigenous breeds (Baker, 1995). Baker (1997) reported that in Africa some local breeds of cattle, sheep and goats are genetically resistant and/or tolerant to internal parasites. The Red Maasai sheep are more resistant than the Dorper sheep and the Small East African goats have been found to be more resistant than Galla. These results suggest that economic gains may result from the introduction of resistant sheep/goat breeds to some parts of the tropics where, unfortunately, the sheep industries are based on exotic European breeds which are not known for their high innate resistance to nematode parasites (Waller, 1997). With emerging problems in chemotherapy, prospects for exploiting genetic resistance to

nematode parasites represents the ultimate approach towards sustainable parasite control especially for resource- poor farmers (Waller, 1997).

1.7.6 Control by anthelmintic prophylaxis.

Since the introduction in 1962 of the first efficient broad spectrum anthelmintic, thiabendazole (Thibenzole, Merck Sharp and Dohme), antiparasitic drugs have been widely used as the primary means of parasite control (Prichard, 1990). Chemoprophylaxis is generally aimed at reducing herbage infectivity which is best achieved when anthelmintics are given in conjunction with transfer of livestock to safe pasture. There are many systems available for strategic anthelmintic control of parasites in cattle and sheep. All of them have advantages and disadvantages and it is up to the veterinarian to assess the management, economic constraints and the ability of the client to follow advice, when recommending a particular system (McKellar, 1988). New delivery systems including boluses have recently been introduced (McKellar, 1994). These are retained in the rumen by virtue of specific gravity and variable geometry. These contain either benzimidazoles, morantel, ivermectin or levamisole (McKellar, 1994). The development of these delivery systems is a response to the lack of novel broad-spectrum anthelmintic chemicals yet, despite their introduction, anthelmintic resistance is causing widespread concern in various parts of the world. The importance of anthelmintic resistance in the present study warrants detailed consideration.

1.8 Anthelmintic resistance

1.8.1 Introduction.

Anthelmintics are expensive not only in terms of material but also in the labour involved in gathering, handling and treating livestock regularly. The increasing prevalence of anthelmintic resistance has become the single most important problem confronting the control of nematode parasitic infection of ruminants in many regions of the world and has reached critical proportions in countries such as Australia (Barger, 1993) and Southern Latin America

(Waller, Eschevarria, Eddi, Maciel, Nari, Hansen, 1995a). Widespread high levels of resistance and the first cases of farmers having to abandon established sheep and goat management systems due to this problem have been reported in South Africa (Van Wyk, Malan, Gerber and Alves, 1989a; Van Wyk, Van Schalkwyk, Gerber, Visser, Alves, Van Schalkwyk, 1989b). Resistant strains of the genera *Haemonchus*, *Trichostrongylus*, *Ostertagia* and *Nematodirus* species have also been reported (Conder and Campbell, 1995).

Concerns over the problem of resistance are heightened by the limitations that development and registration costs place upon the research conducted by the pharmaceutical industry. These costs are enormous hence the rate of development of novel products will be limited (Witty, 1999; Geary, Thomson and Klein, 1999). The anthelmintic products which we have available today are valuable and scarce resources and these are unlikely to be replaced once they are rendered ineffective by the development of resistance.

1.8.2 Definition.

Anthelmintic resistance has been defined as the heritable change in the ability of some nematode parasites to survive treatment with anthelmintic drugs at the recommended therapeutic dose levels (Taylor and Hunt, 1989) or alternatively as a heritable reduction in the sensitivity of a parasite population to the action of the drug after repeated exposure (Conder and Campbell, 1995). Resistance should not be confused with tolerance which is conventionally defined as an innate unresponsiveness of a parasite population to a drug. Resistance becomes a problem when the proportion of the parasite population carrying the genes that enable survival increases in response to exposure to the drug.

There are five groups of anthelmintics in common use, based on mode of action and spectrum of activity (Prichard, Hall, Kelly, Martin, Donald, 1980; Waller, 1986). Some terms normally used in describing anthelmintic resistance need to be defined at this stage. First, side resistance is resistance to a compound resulting from selection using another compound with the same

mode of action. This is common especially within the benzimidazole group.

ANTHELMINTIC	MODE OF ACTION
A. BROAD SPECTRUM	
GROUP I (Benzimidazoles and Probenzimidazoles)	Tubulin binding.
GROUP II (Levamisole and Morantel)	Ganglion blocking.
GROUP III (Avermectins)	Alteration of chloride channels
B NARROW SPECTRUM	
GROUP IV (Salicylanilides and substituted nitrophenols)	Uncouple oxidative phosphorylation.
GROUP V (Organophosphates)	Acetylcholinesterase antagonists.

Cross resistance describes the ability of parasite strains to survive therapeutic doses of chemically unrelated drugs or drugs with a different mode of action whereas, multiple resistance is resistance to two or more anthelmintics with different mode of action.

1.8.3 Diagnosis.

A wide variety of *in vivo* and *in vitro* methods may be used to detect resistance and these have been reviewed by Presidente (1985), Johansen (1989), Taylor and Hunt (1989) and Coles (1990). Although controlled efficacy tests are clearly the definitive means to determine whether resistance is present in a population, this approach is prohibitively expensive and time

consuming. The use of faecal egg count reduction tests (Presidente, 1985; Webb and Ottaway, 1986; Vizard and Wallace, 1987; Martin, Anderson and Jarrett, 1989; McKenna, 1990), which compare pre-treatment egg count levels or untreated counts to those following treatment are predictive for all anthelmintic classes, species and hosts. This test has been widely used as a measure of treatment success and continues to be a mainstay due to its relative ease and versatility.

Standardisation of these tests has been proposed by the World Association for the Advancement of Veterinary Parasitology (Coles, Bauer, Borgsteede, Geerts, Klei, Taylor, Waller, 1992; Wood, Amaral, Bairden, Duncan, Kassai, Malone, Pankavich, Reinecke, Slocombe, Taylor and Vercruysse, 1995). Because of poor sensitivity, faecal egg count reduction tests (FECRT) are capable of detecting only high levels of resistance. In addition, for some parasites such as *Nematodirus* species, faecal egg counts may not be reliable indicators of infections (McKenna, 1981; Chalmers, 1985) and hence may be of questionable value in assessing resistance (Obendorf, Nicholls, Koen and Lacy, 1991). Larval culture can be used to enhance the sensitivity of FECRT where highly fecund species mask others with low fecundity (West, Pomroy, Probert and Charleston, 1989).

A number of *in vitro* assays, based on anthelmintic effects on normal physiological processes such as development, growth and / or movement have been developed to support FECRT. These include, egg hatch assay (EHA), larval development assay, larval paralysis, motility, larval migration assays and genetic screens. The EHA described by Le Jambre (1976), Coles and Simpkin (1977), Whitlock, Kelly, Porter, Griffin and Martin (1980), Cawthorne and Whitehead (1983), Smith-Buijs and Borgsteede (1986) is based on the ovicidal activity of the benzimidazoles and compares the ability of fresh, undeveloped eggs from the population under study to embryonate and hatch following exposure to various concentrations of anthelmintic.

The problem of getting undeveloped eggs to laboratory from the field has been discussed by Smith-Buijs and Borgsteede (1986) and Taylor and Hunt (1989).

In conclusion, it is obvious there is a need to develop better means of identifying resistance in the field but the available tests though expensive and cumbersome are still useful for surveillance programs.

1.8.4 Historical Perspective and Extent of Resistance.

"Anthelmintic resistance among nematode populations follows the development of anthelmintic drugs like a faithful shadow" (Lloyd and Soulsby, 1998) and the problem of resistance now affects most classes of livestock, all commercially available anthelmintics and has representatives from several genera and phyla of helminths (Sangster, 1999). Anthelmintic resistance was first reported from the United States of America by Drudge, Leland and Wyant (1957) who recorded resistance by *T.colubriformis* against phenothiazine. For modern anthelmintics, reports of resistance problems first began to appear soon after the introduction of thiabendazole, the first truly broad spectrum efficacious anthelmintic (Conway, 1964; Drudge, Szanto, Wyant, Elam, 1964). Documented cases of anthelmintic resistance have been recorded throughout the world against all the three broad spectrum families, the benzimidazoles, avermectins and imidazothiazoles which are commonly used by the livestock industry to control nematodoses and have been widely reviewed by Prichard *et al* (1980), Waller and Prichard (1986), Waller (1987), Boray, Martin and Roush (1990), Prichard (1990), Jackson (1993), Waller (1994), Conder and Campbell (1995). The reports of greatest concern are those involving multiple resistance especially in Australia (Barger, 1993; Waller, Dash, Barger, Le Jambre, Plant, 1995b), South Africa (Van Wyk, Malan, Randales, 1997) and in South America (Gill and Le Jambre, 1996; Waller *et al*, 1995; Waller, Larsen, 1996b; Eddi, Caracostantogolo, Pena, Schapiro, Marangunich, Waller and Hansen, 1996; Eschevaria, Borba, Pinheiro, Waller and Hansen, 1996; Maciel, Gimenez, Gaona, Waller and Hansen,1996; Nari, Salles, Gil, Waller and

Hansen, 1996). This is a threat to the sheep industry, which may collapse for want of an effective, sustainable parasite control scheme in the future. Resistance has also been recorded in drugs with a narrow spectrum of activity such as the salicylanilides (Rolfe, Boray, Fitzgibbon, Parsons, Kemsley and Sangster, 1990; Boray, 1997).

Many of the earliest reports of ruminant nematode strains resistant to broad spectrum anthelmintics emanated from the southern hemisphere and usually involved species with a high biotic potential such as *H. contortus* and *T. colubriformis* (Jackson,1993). The rate of emergence of resistance appears to vary geographically in accordance with the prevailing climate, parasite species and treatment regimes adopted in the region. Historically, resistance has emerged rapidly in goats and/or sheep for each new class of nematocidal drug. Although many factors contribute to nematode resistance in these host species, resistance is primarily due to two aspects of management, namely frequent dosing, particularly in warm, moist climates and the practice of running sheep and goats together without ensuring that goats are treated at a higher dose than sheep (Conder and Campbell, 1995; Coles, 1998). These factors will be discussed further but it is important to stress that treating goats as though they were sheep and grazing them together can contribute to anthelmintic resistance. In contrast to the situation in sheep and goats, resistance has been slow to develop in cattle (Prichard, 1990), but it is not clear whether this situation results largely from the host or parasite characteristics or simply reflects differences in bovine treatment regimes which may reduce parasite exposure to anthelmintics (Jackson, 1993). Barger (1993) suggested that a bovine dung-pat may provide a relatively larger refugia of susceptible infective larvae and hence, reduce the proportion of the population exposed to anthelmintic selection. Alternatively, the less frequent use of anthelmintics in this host may minimise selection pressure.

Although the rate of emergence of resistant strains has generally been slower in temperate zones in the northern hemisphere, the prevalence of resistance is also increasing throughout Europe (Borgsteede, 1990; Jackson,

Coop, Jackson, Scott, Russell, 1992; Jackson, Rugutt, Jackson, Coop, Russell 1993; Scott, McKellar, Armour, Coop, Jackson and Mitchell, 1990; Taylor,1990; Waller, 1990; Waller *et al*, 1995).

Although most resistance involves ruminants, resistance has also been reported in equidae (Lyons, Drudge, Tolliver and Granstrom, 1990) and porcidae/swine (Bjorn, Roepstorff, Nansen and Waller, 1990). In horses throughout the world strongyles have become resistant to the benzimidazoles (Conder and Campbell, 1995) and in pigs, resistance has been reported in ascarids and *Oesophagostomum.*

1.8.5 Situation in Africa and Kenya.

Before considering the situation in Kenya, it is necessary to mention briefly the state of anthelmintic resistance in the neighbouring countries, particularly South Africa, where there are some similarities in climate. Breeding rams and bucks are frequently imported from South Africa and there is a fear of importing resistance with them. Waller (1993a) was the first to note the role of research establishments/government farms in the selection/transmission of resistance. South Africa's reputation as a country where resistance developed rapidly was enhanced when it reported resistance to ivermectin only three years after this drug became available on the market (Carmichael, Visser, Schneider and Stoll, 1987; Van Wyk, Malan, Gerber, Alves, 1987; Van Wyk and Malan, 1988). Prior to this, there had been frequent reports involving the other anthelmintic families.

The situation in South Africa has progressed to a stage where some farmers have had to abandon sheep and goat rearing (Van Wyk *et al*, 1989a, 1989b). This has been made even worse with reports that the narrow spectrum salicylanilides, used almost exclusively to control strains of *H. contortus* resistant to broad-spectrum anthelmintics, are generating resistance in South Africa (Van Wyk and Gerber, 1980; Van Wyk, *et al*, 1987; Van Wyk, Malan, Bath, 1997). Van Wyk *et al* (1997) reported on a helminth strain that is resistant to compounds from all five anthelmintic groups and is also resistant to

the two substituted phenols, disophenol and nitroxynil.

Few reports on anthelmintic resistance are available from other neighbouring countries of East and Southern Africa. In Tanzania, a study by Bjorn, Monrad, Kassuku, Nansen, (1991) showed presence of benzimidazole resistance in an institutional farm which, despite stoppage of usage for about 10 years, showed no reversion to susceptibility (Kassuku, Keyyu and Makundi, 1997). In Zimbabwe, Boersema and Pandey (1997), in a study on commercial sheep farms in the highveld, reported benzimidazole, levamisole and rafoxanide resistance and concluded that the situation in Kenya, with regard to anthelmintic resistance, is comparable to the situation in neighbouring South Africa or perhaps even worse.

Kenya has an active livestock industry whose main method of control of nematodoses is the use of anthelmintics and all broad spectrum anthelmintics have a share of the lucrative market. A study by Kinoti, Maingi and Coles (1994) in the Central and Rift Valley regions showed that anthelmintics are used on a considerable scale and that large farms treat their animals at least quarterly, with exotic breeds being treated more regularly than the indigenous breeds. Treatment of cattle is mostly confined to calves. Another feature of the study was the widespread use of products combining nematocides and flukicides even when fascioliasis is limited in distribution. These findings were in agreement with results of a survey conducted in farms with close proximity to the veterinary investigation laboratories by Wanyangu, Bain, Rugutt, Nginyi and Mugambi (1996b) which showed that the range of dosing regimes practised by farmers vary widely with almost half of the farms dosed either three or four times a year.

With the use of all the anthelmintic families and given the climatic conditions, it was inevitable that reports of resistance would emerge from Kenya. Anthelmintic resistance was first reported by Njanja, Wescott and Ruvuna (1987) when they showed thiabendazole was ineffective against *H. contortus* in a goat farm. Subsequent studies (Maingi, 1991a, 1991b, 1991c; 1993a, 1993b; Waruiru, 1994; Waruiru, Maingi, Gichanga, 1991; Waruiru,

Ngotho, Gichanga, 1994) have reported further cases in sheep and goats carrying populations of *H. contortus* and *Trichostrongylus* species resistant to benzimidazoles and levamisoles. The survey by Wanyangu *et al* (1996b) showed that resistance is almost equally common to both benzimidazoles and levamisoles and that the commonest parasite involved is *H.contortus*. The high prevalence of resistance to levamisole in this survey, was attributed to the presence of a large number of generic products of questionable efficacy on the market.

Though the use of ivermectin is very low in the country, a study in the coastal region by Mwamachi, Audho, Thorpe and Baker (1995) showed the presence of resistance to this drug. This was also the first report of multiple resistance in Kenya. The extent of levamisole resistance in goats in that study was greater than in sheep, a finding similar to that of Gillham and Obendorf (1985). Waruiru, Kogi, Weda, Ngotho, (1998) in a study on a goat farm where the first resistance was recorded by Njanja *et al*(1987) reported the presence of multiple resistance to levamisole, benzimidazole and rafoxanide by *H.contortus* while *Trichostrongylus* and *Oesophagostomum* species were resistant to levamisole. Maingi, Bjorn, Gichohi, Munyua, Gathuma, (1998) reported on benzimidazole and levamisole resistance in sheep farms in the central part of Kenya, while Waruiru, Ngotho, Mukiri, (1998) showed the presence of multiple and multigeneric resistance in sheep on a commercial farm in the same area. In a controlled efficacy study, Waruiru (1997) confirmed ivermectin resistance in a population of *H. contortus* in sheep. This strain had also retained benzimidazole and levamisole resistance, despite the fact that these drugs had not been used for at least 4 years on that farm. This study also showed a difference in efficacy between two formulations of ivermectin, a finding consistant with those of McKellar and Marriner (1987) who found that treatment with injectable ivermectin resulted in higher and more sustained bio-availability than oral preparations.

The contents of some of the generic products, especially the levamisole based products have been proven to be of very poor quality and the controls on

their sales are inadequate (Monteiro, Wanyangu, Kariuki, Bain, Jackson and McKellar, 1998; Rugutt, Nginyi, Chuchu and Karekezi, Unpublished data). It therefore falls on the authorities to ensure proper quality control measures are put in place especially with the importation of these drugs which are sourced from some unscrupulous international brokers as it has been proven for example in South Africa to be of substandard efficacy (Van Wyk, Malan, Van Rensburg, Oberem, Allan, 1997)

All the above reports suggest that drug resistance is a problem that is growing in importance in the country and the situation needs to be monitored and strategies for avoidance be rigorously put in place. In the present work, an attempt was made to draw up relevant nematode control measures for the study area which incorporate minimal use of anthelmintics.

1.8.6 Mechanisms and Factors involved in Development of Resistance.

Anthelmintic resistance in nematodes is thought to be a pre-adaptive phenomenon (Prichard, 1990; Jackson, 1993) and so for many species of nematodes, the gene or genes conferring resistance are available within the population prior to first exposure to the drug. There appear to be three phases in the selection process (Prichard, 1990). First, an initial phase of anthelmintic susceptibility occurs where the frequency of resistant individuals within the population is low. Given continued exposure to a drug, an intermediate phase then occurs in which the frequency of heterozygous resistant individuals within the population increases. Finally, sustained selection pressure results in a resistant phase where homozygous resistant individuals predominate within the population.

Resistance may be expected to develop more slowly in nematodes than in bacteria, viruses, insects or protozoa because of longer generation times, a more limited range of mobility, selection generally being limited to parasitic stages and the high efficacy and non-persistent nature of most anthelmintics. Despite this, Waller (1990) points out that most of the important nematode

genera of domestic livestock have shown that they possess the genetic capacity to develop resistance.

It is important to note that once resistant parasite strains become predominant, ceasing the use of the drug does not necessarily result in a rapid reversion to susceptibility, at best this process is slow and the reintroduction of the selecting agent has been shown to select rapidly for resistance (Kelly and Hall, 1979). If reversion is to occur it is only likely to do so during the heterozygous resistant phase of development, before the selection pressure results in co-adaptation with general fitness characteristics (Maingi, Scott, Prichard, 1990; Scott, Baxter, Armour, 1991). Field studies in Australia have provided little or no evidence of reversion in the absence of the drug therapy (Martin, 1990). The same has been observed in studies in Europe (Borgsteede and Duyn, 1989, Coop, personal communication) and in Africa (Kassuku *et al*, 1997; Waruiru, 1997).

There are various factors other than simple drug resistance which contribute to treatment failure, some of the important factors are as follows:

a) Misdiagnosis is a common occurrence where drugs are used on the basis of clinical signs such as diarrhoea which are common to other infections or disease syndromes. Under these circumstances a nematocidal drug will be ineffective in relieving the symptoms.

b) Underdosing animals frequently occurs and in some cases is intentional, with intent to reduce the cost of treatment, but the main cause is underestimation of body weight, which leads to treatment failures. Such failures also allow, not only homozygous, but heterozygous resistant individuals to survive treatment and thus can increase the genetic resistance pool.

c) Physiological phenomena can also contribute to treatment failure, the oesophageal groove reflex can markedly alter drug pharmacokinetics and thus render treatments ineffective or less effective.

The tendency to treat goats as though they were sheep is inadvisable since studies with levamisole (McKenna and Watson, 1987, Coles, Giordano,

Tritschler, 1989) and benzimidazoles (Sangster, Richard, Hennessy, Steel, 1991) have demonstrated that higher doses are required for efficacy in goats than in sheep. This is not suprising given the differences in drug pharmacokinetics (Bogan, Benoit and Delatour, 1987; Gillham and Obendorf, 1985; Hennessy, Sangster, Steel and Collins, 1993) between the two host species and the degree of rumen by-pass in goats (Sangster *et al*, 1991). Scott *et al* (1991) also demonstrated that bio-availability of ivermectin may be reduced in goats compared with sheep.

Another factor which contributes to anthelmintic resistance is treatment frequency. Suppressive treatment regimes in which animals are treated within or close to the pre-patent period of the parasite population inevitably favour the selection of a parasite population (infrapopulation) which contains only resistant phenotypes. The continued use of such regimes in the New Zealand goat industry has resulted in a high incidence of resistance and the emergence of multiple resistance (Barger and McKenna, 1990; Watson and Hosking, 1990).

The population dynamics of the free living stages (suprapopulation) are another important factor that can influence the rate of development of resistance. The free living stages fluctuate in numbers both during the year and from year to year.

The stability of various epidemiological patterns may, when a drug is first used, slow the rate for selection of resistance. Initially they can provide a reservoir of susceptibility but, unfortunately, the converse is also true and highly selected resistant populations may survive for sometime on pasture in temperate climates (Jackson, 1993).

"Dose and move" strategies can similarly increase the rate of development of resistance (Taylor and Hunt, 1989). Treatments given during climatic extremes which reduce the size of the suprapopulation and hence alter the infrapopulation and suprapopulation ratio have been shown to increase the rate of development of anthelmmintic resistance (Donald and Waller, 1982; Martin *et al*, 1989).

The mechanisms involved in drug resistance may result from decreased drug uptake, increased metabolism of the drug or changes at the drug-receptor site (Prichard, 1990; Roush, 1990). To date, there is little evidence to indicate that changes in drug transport or drug metabolism in nematodes play any significant role in resistance to antinematodal drugs (Prichard, 1990). The influence on tubulin binding involved in benzimidazole resistance in trichostrongylid nematodes is controlled by more than one gene and is inherited as a co-dominant character with a strong maternal effect (Le Jambre, Royal, Martin, 1979; Martin, McKenzie, Stone, 1988). In the case of levamisole, Martin and McKenzie (1990) suggested it was sex-linked and recessive in nature, whereas Sangster (1990) suggested multigenic inheritance. The mechanism involved in ivermectin resistance remains elusive (Sangster and Gill, 1999)

1.8.7 Management of Resistance.

Research has been devoted to the search for preventive strategies to delay the onset of resistance. Preventive strategies inevitably incorporate minimal chemoprophylaxis, thus minimising the number of parasite generations exposed to a drug and also seek to maximise efficacy, thus effectively rendering the genes of resistance recessive. Preventive strategies need a sound knowledge of the epidemiology of the target parasite species so that dosing schedules can be strategically timed and integrated with other management practices to prevent disease, limit parasite proliferation and optimise production. This approach has been used successfully in developing epidemiologically based regimes (Dash, Newman and Hall, 1985) to conserve the efficacy of ivermectin in areas of Australia where *H.contortus* is the predominant parasite. Since these regimes involve the use of salicylanilides, such as closantel, and are tailored to suit haematophagous parasites they are not universally applicable.

Another strategy is to use only a single class of anthelmintic annually or within a parasite generation, so that multiple resistance is not generated, and to rotate anthelmintic classes on a yearly basis to limit the passage of resistant

genes early in the selection process while parasites are heterozygous for the trait allowing for reversion to susceptibility (Conder and Campbell, 1995). Use of any anthelmintic should be discontinued if resistance to it is detected and subsequent treatments should use a drug with a different mode of action.

Some studies have recommended the use of combinations of anthelmintics with different modes of action as preventive strategy (Martin, Anderson and McKenzie, 1990; Anderson, 1990; Lloyd and Soulsby, 1998) but this is limited, currently, to few countries. This strategy is based on the concept that it is unlikely that any individual in the population will carry resistance alleles for both classes if both are found at low frequency in the population.

Preventing the introduction of resistant parasite strains with new animals by quarantining, monitoring and treating all replacement stock is a critical management practice and this should critically be observed in sheep and goats especially in the tropics where they graze together.

1.8.8 Control of Anthelmintic Resistance.

Environmentally and/or immunologically based strategies seek to limit host/ parasite interaction and these have an obvious application in the avoidance and management of anthelmintic resistance alongside properly directed chemotherapy (Jackson, 1993). The management of single and multiple resistance imposes obvious constraints upon chemoprophylaxis since it dictates which families may be used with certainty of efficacy. Moreover, if selection of resistance to these families is to be avoided then it is clearly necessary also to limit the frequency of application (Aumont, 1999).

The fact that very few farmers routinely screen for anthelmintic resistance, coupled with the poor sensitivity of the most commonly used *in vivo* screening methods ensures that most cases of resistance are not detected at an early stage. This reduces the likelihood of reversion occurring and the only way to avoid increasing levels of resistance and / or the numbers of resistant parasite species, is the total withdrawal of the selecting family or families of drugs.

The emergence of multiple resistance which has been reported particularly in Australia and South America has focused attention on the use of "selected" drugs applied either at the recommended or at a higher dose rate or in extended treatment applications (Anderson, 1990; Sangster *et al*, 1991) or in use in combination with another family or families (Anderson, Martin, Jarrett, 1988). Waller *et al* (1995, 1996) reported that in South America particularly Paraguay and Southern Brazil, it was already too late to promote the widespread adoption of strategic parasite control programmes analogous to the approach taken to combat anthelmintic resistance in sheep flocks in Australia. In these countries the situation has progressed to one of widespread, high-level multiple resistance and farmers will need assistance from trained professionals in order to solve their parasite control problems on a case-by-case basis.

The use of drug combinations to control nematodoses is supported by studies in which drugs have been administered sequentially (Anderson *et al*, 1988), simultaneously (McKenna, 1990) or in divided doses over a short period (Sangster *et al*, 1991) and by simulation models (Barnes, Dobson and Barger, 1995; Martin, 1990).

The risks associated with the re-introduction of "selected" drugs for therapeutic and prophylactic purposes are influenced largely by the pathogenicity and fecundity of the prevailing resistant species and the extent of any increase in resistance that results from further exposure. It seems unlikely that an haematophagous pathogenic species such as *Haemonchus,* which has a high biotic potential, could be controlled using these "selected" drugs, but for those species with a low biotic potential, like *Teladorsagia*, they could be introduced under carefully monitored circumstances (Jackson, Barrett, Jackson, Coop, McKellar, 1997).

Studies on the management and control of anthelmintic resistance involving extending the period of drug administration by splitting the dose has been shown to increase the efficacy of benzimidazole anthelmintics. Bogan *et al* (1987), working with goats, demonstrated that the repetition of three administrations of oxfendazole over 24 hour intervals produced a significant

increase in the area under the curve compared to a single equivalent dose. This finding was confirmed in the field by Sangster *et al* (1991) and in Scotland (Rugutt, 1992; Barrett, Jackson, Patterson, Jackson and McKellar, 1998) and in India (Sanyal, 1998).

Altering feed intake has also been shown to enhance benzimidazole efficacy. Ali and Hennessy (1993) demonstrated that modified feed management can be used to restore the efficacy of compounds whose potency has been eroded by the development of resistance. Increased efficacy appears to be influenced by drug-digesta particle association in the rumen which regulates the rate and duration of metabolite absorption and is a major determinant of the pharmacokinetic disposition of oxfendazole in ruminants (Hennessy, Ali, Tremain, 1994). Similar results against resistant strains have been demonstrated with albendazole (Hennessy, Ali, Sillince, 1995).

Sustained or pulsed-release anthelmintics may also provide a useful tool in controlling resistant nematodes or preventing their selection (Sangster, Richard, Collins, Hennessy, Steel, 1992) if used in a judicious manner. This was in agreement with an earlier study by Delatour, Benoit, Lechenet and Basse (1990).

As for the future, Barger (1993) mentioned a revival of interest in the possibilities of biological control through agents as nematophagous fungi (Waller, 1993b) and in controlled release of growth regulators (Waller and Lacey, 1985). Significant progress has recently been made in the use of nematode destroying fungi which control the free-living stages of nematode parasites infecting a range of livestock species (Githigia, Thamsborg, Larsen, Kyvsgaard, Nansen, 1996; Larsen, Nansen, Gronvold, Wolstrup and Henriksen,1997; Larsen, 1999; Manueli, Waller, Faedo and Mahommed, 1999; Waller and Larsen, 1996; Waller and Faedo, 1996). This may be an important part of livestock parasite control in the future (Padilha, 1999). Waller *et al* (1995b) states that to achieve long-term sustainable parasite control, more sophisticated worm control procedures need to be developed. There are likely to be significant breakthroughs in the non-chemotherapeutic control of

parasites, such as the use of genetically engineered worm vaccines (Waller *et al*, 1995). The monitoring of anthelmintic resistance in animals will become more efficient, precise and cheaper when "diagnostic kits" such as larval development assay (Lacey, Redwin, Gill, Demargheriti and Waller, 1990) become commercially available.

In conclusion, control of gastrointestinal parasites will, at least for the foreseeable future, rely on the use of chemotherapeutic agents. There is a need for strategies involving an integrated approach incorporating environmental management, chemoprophylaxis and immunoprophylaxis and the selected "packages" of these approaches should be evaluated, particularly in livestock management situations which are under the greatest threat from anthelmintic resistance (Waller, 1999).

1.9 Fascioliasis.

1.9.1 Introduction

Although *Fasciola* infection is rare in the study area, a summary of the important factors involved in the epidemiology is discussed below. As mentioned earlier, the main species involved in Kenya is *Fasciola gigantica* (Bitakaramire, 1968a; Preston and Castelino, 1977; Cheruiyot and Wamae, 1988a). The major effects of the parasite include unthriftiness, loss in productivity, liver condemnation and deaths in domestic ruminants. The parasite is widespread and occurs wherever environmental conditions favour propagation of its snail host coupled with the presence of infected and susceptible hosts.

1.9.2 Life Cycle

The life cycle of this parasite involves mammals (typically cattle, sheep and goats) as definitive hosts. A characteristic feature of *F. gigantica* is its lack of specificity. This means a wide range of mammals become infected including wildlife (Hammond, 1972).

The adult parasite inhabits the bile ducts where it lays eggs which are

then passed with bile into the gastrointestinal tract and hence passed out with faeces. The eggs undergo development in the environment and give rise to miracidia which are infective to the intermediate host (*Lymnae natalensis*). A cycle of development which is temperature dependent (Dinnik and Dinnik, 1964), then follows with the parasite, going through sporocyst, rediae and daughter rediae stages. This development in the snail takes 45 to 100 days after which the snail releases the cerceriae. These encyst on vegetation giving rise to metacercariae which are infective to livestock when ingested. The ingested metacercariae then excyst in the presence of intestinal secretions giving rise to juveniles which penetrate the intestinal wall into the peritoneal cavity. The parasites eventually reach and penetrate the capsule and migrate in the liver tissue where just before maturation they enter the bile ducts where they mature and start producing eggs. The prepatent period varies from 13 to 16 weeks. Death usually results when large numbers of metacercariae are ingested over a short period (Boray, 1969; Urquhart *et al*, 1987). The acute disease is more common in small ruminants and mortalities are highest in these animals (Hammond, 1965) in Tanzania and in northern Nigeria (Schillhorn van Veen, 1979)

1.9.3 Epidemiology.

Liver fluke disease is endemic where suitable habitats with clean and slow moving streams are found. The occurrence of the fresh water snail, intermediate host *L. natalensis*, together with infected and susceptible hosts perpetuate fasciolosis in such areas. Dinnik and Dinnik (1963, 1964) in a series of experiments in an outdoor setting found that the shortest time for snails to start shedding cercariae after exposure to miracidia was 69 days at the hottest time of the year. They stated that in permanent bodies of water contaminated with dung from infected animals, infected snails normally started shedding cerceriae 100-120 days later. Temporary bodies of water which do not last more than three months were considered by the same authors to be of little importance as there was not enough time for development of the parasite

in the snail.

The snail hosts have been reported to survive under drought conditions when no surface water is present because they are able to aestivate (Bitakaramire, 1968b). A study in an endemic site in Kenya carried out by Wamae and Cheruiyot (1990) found infected snails present for most of the year with the highest infection rates of up to 40 %. Most snails were found after the rainy season, which means animals are at risk of infection during the dry periods of the year. Preston and Castelino (1977), however, found snails capable of shedding cercariae all year round in one area of study in Western Kenya.

1.9.4 Longevity of Metacercariae

Metacercariae are a resistant stage of *F.gigantica* and this feature ensures survival of the parasite under difficult conditions. Hammond (1970) showed metacercariae were found to be infective 9 days after emergence from the snails and encystation. Metacercariae have been shown to survive for up to 4 months in water- a feature of special significance on those farms in endemic areas where water troughs are used. The absence of snails in such troughs does not mean that viable metacercariae are not present (Bitakaramire, 1968c).

1.9.5 Clinical Signs and Pathology.

Studies on pathogenic effects have been conducted by various authors. Bitakaramire and Bwangamoi (1969), administered various numbers of metacercariae to 8 months old calves and reported signs of rough coat, pallor of mucus membranes, a moderate to severe normochromic normocytic anaemia as well as death. Hepatic fibrosis and ascites were present in some of the calves. Much of the liver was replaced by fibrous tissue while bile ducts were hyperplastic. No diarrhoea or submandibular oedema were observed. Hammond and Sewell (1974) reported high mortality in goats and suggested that the parasite is more pathogenic in them. The disease condition has three overlapping syndromes namely, acute condition caused by migration of large

numbers of immature flukes in the liver parenchyma. The subacute form is characterised by anaemia and is caused by young adults emerging from the liver tissue into the bile ducts. The chronic form is due to the presence of mature liver flukes in the bile ducts and is a wasting condition. Severity of these conditions therefore depends on the fluke burden as well as immunological/ nutritional status and age of the host (Urquhart *et al*, 1987).

1.9.6 Resistance to Infection.

Innate resistance to *F.gigantica* has been reported in both cattle and sheep. Hammond and Sewell (1974), working with cattle in Kenya mentioned the possibility of species and breed differences in susceptibility to liver fluke infections. Bitakaramire (1973), found prevalence of fasciolosis was lowest in the small zebu when compared to other breeds.

1.9.7 Diagnosis of Fascioliasis.

Diagnosis depends on observation of the clinical signs and detection of eggs in faeces. The clinical signs in the acute form may include depression, lethargy, sometimes jaundice and even death. In chronic forms of the disease, there is debility and anaemia with submandibular oedema (Urquhart *et al*, 1987). The clinical signs are not pathognomonic hence confirmatory diagnosis has traditionally depended on detection of parasite eggs in the faeces of infected animals. The method has drawbacks since it can only detect patent infections and most of damage is done before patency by the migrating parenchymal forms (Sewell, 1966). Flotation or sedimentation methods for diagnosis gives the number of eggs present which does not give an indication of the parasite burden since it is variable and egg numbers can even be very low for a heavily infected animal (Sewell, 1966).

The measuring of liver enzymes is another method of diagnosis. Sewell (1967), reported that Glutamate dehydrogenase was the best indicator of hepatic disturbance in ruminants infected with *F. hepatica.* A recent advance in diagnostic research is the use of immunological methods, such as the enzyme

linked immunosorbent assay (ELISA) which have been developed to detect circulating antibodies and for coproantibody detection.

1.9.8 Control of Fascioliasis

Control depends on an integrated approach because of the existence of an intermediate host in the liver fluke life cycle. The principle of snail control is to apply molluscicides when snail populations are confined in limited habitats and where water is available. Identification of the snail habitats is essential to successful control of the intermediate host. There are commercial molluscicides like N-Tritylmorpholine (Morpholine, *Frescon*, ICI) and Niclosamide (*Baylusade*, Bayer) but these are only practical for large commercialised concerns.

The use of plant molluscicides has been reported by many workers including Hammond (1970) who reported that it was difficult to find *L.natalensis* in Kenya in areas where *Eucalyptus* trees grew and Cheruiyot and Wamae (1988b) tested and reported various *Eucalyptus* tree species with molluscicidal properties. A study by Hammond, Fielding, Nuru, (1994) has observed that the use of plant molluscicides is a labour intensive undertaking and also requires skilled labour.

The most widely used method of control is chemotherapy. The available fascioliocides have evolved over the years from the earlier ones which were only active against mature liver flukes in the bile ducts to the new generation fasciolicides active against both mature and immature parasites (Chaundri and Gupta, 1990). Problems of anthelmintic resistance in these drugs have been reported by some workers but it is not as widespread as that of other anthelmintics (Boray, 1990, 1997; Overend and Bowen, 1995; Mitchell, Maris, Bonniwell, 1998). No new faciolicides are promised but some cocktails of less efficient drugs appear to have a high efficacy (Boray, 1997; Boray and Sluyter, 1997). Vercruysse, Copeman, De Bont, Boray, Malone and Willingham (1997) suggested that the use of synergistic drug combinations of different chemical groups are successful in the treatment of fasciolosis even in resistant strains.

1.10 Paramphistomes

1.10.1 Introduction

Paramphistome infection of sheep, goats, cattle and water buffalo is widespread (Horak, 1971). The disease paramphistomiasis is caused by massive infection of the small intestine with immature paramphistomes and is characterised by sporadic epizootics of acute parasitic gastroenteritis with high morbidity and mortality rates particularly in young stock (Butler and Yeoman, 1962; Horak, 1971, Urquhart *et al*, 1987). The most common species in Africa is *Paramphistomum microbothrium* (Dinnik, 1954, 1961, 1965; Dinnik and Dinnik, 1960, 1962, 1967).

1.10.2 Life cycle

This is similar to that of *Fasciola* species (Urquhart *et al*, 1987). The eggs are laid by adults present in the rumen and are evacuated with faeces. The eggs develop to miracidia which infect the snails. In Kenya, *Bulinus tropicus* (Dinnik, 1954) is the intermediate host snail. Within the snail, they develop to rediae then to cercariae and emerge from the snail after 43-46 days (Dinnik, 1954). Infected snails can live and shed cercariae for up to a year (Dinnik, 1954). After ingestion by the final host, excystment is accomplished during passage through rumen, abomasum and small intestine and attachment takes place in the first six meters of small intestine (Horak, 1971). The young paraphistomes migrate to the anterior small intestine and eventually to the rumen and continue growing for between 5 to 9 months after infection (Dinnik and Dinnik, 1962).

1.10.3 Epidemiology

Dinnik (1964a) reported that many cattle and small ruminants infected with adult paramphistomes which are acquired by ingestion of small numbers of metecercariae on one or several occasions cause no harm to the host and they mature to serve as source of infection for successive generations of snails.

Paramphistomes survive for some years in their hosts (Dinnik, 1964b) hence the source of infection is virtually constant. Paramphistomiasis outbreaks are sporadic and the effects in young animals are evident especially when they ingest many cercariae in a short period (Boray, 1959; Urquhart *et al*, 1987). Good immunity develops in cattle, however adults continue to harbour low burdens of adult parasites and are important reservoirs of infection of snails. In contrast, sheep and goats are relatively susceptible throughout their lives (Urquhart *et al*, 1987).

1.10.4 Clinical signs/pathogenesis.

The pathogenic effect is associated with the intestinal phase (young paramphistomes) as they cause severe erosions of the mucosa. In heavy infections, these cause enteritis (Butler and Yeoman, 1962; Urquhart *et al*, 1987) with the most obvious sign being diarrhoea accompanied by anorexia and intense thirst with mortality in acute outbreaks of up to 90 % (Butler and Yeoman, 1962; Urquhart *et al,* 1987).

1.10.5 Diagnosis

This is based on clinical signs and history of grazing around snail habitats especially during the dry weather (Butler and Yeoman, 1962). Faecal examination is of little value since the disease occurs during the prepatent period (Horak, 1971; Urquhart *et al*, 1987). Since the acute disease generally results in deaths, the most reliable method of diagnosis is by means of necropsy (Horak, 1971). The young paraphistomes are easily seen in or on the intestinal mucosa or lying loosely in the ingesta.

1.10.6 Control

This is largely based on attempting to keep susceptible livestock away from potentially dangerous areas. Secondly, the use of molluscicides as for fascioloses (Urquhart *et al*, 1987) is beneficial.

1.11 Aims of the study

The study of the epidemiology of helminthiasis in Kericho formed an important element of a national study covering Kenya's different agro-climatic zones. The long term aim of the National Agricultural Research Programme (NARP) was the development of appropriate sustainable production systems and disease control strategies. The development of a sustainable control regime for any parasitoses affecting livestock requires fundamental detailed knowledge not only of the epidemiology of the parasite and the available means of control but also the applied farming systems operating over the region of concern. A broad consensus now exists among experts in the field that one prerequisite of most sustainable regimes is an integrated approach which minimises reliance on any single control strategy such as chemotherapy. In the case of large agribusiness, animals are kept simply to provide saleable products such as milk, meat, fibre and skin/pelts. However, the situation for the smallholder farmers is much less simple since there are socio-economic factors that influence animal production and maintenance. For these reasons it was important that research in the study also included the gathering of socio-economic data from farmers involved in the parasitological studies.

The four major elements of the study were as follows:

1. An epidemiological survey of selected farms in the region to obtain data on the key helminths and their seasonal abundance

2. A detailed socio-economic survey together with one on helminth control strategies used by the farmers in the region. Since chemotherapy forms the main approach to control, preliminary studies to examine the efficacy of anthelmintics used in the region were also conducted together with an assesment of the state of anthelmintic resistance in the different farming systems in the region.

3. Using the preliminary results from the epidemiological and socio-economic survey an intervention trial was to be developed and tested in the region.

4. Dissemination of the results to the farmers and other stakeholders.

CHAPTER 2

General Materials and Methods

2.1 Study site:

Kenya, which is situated on the eastern seaboard of Africa, is administratively divided into 8 provinces which in turn are divided into 65 districts. The districts are administratively divided into divisions which are subdivided into locations and finally sublocations. The country is divided into 7 agro-climatic zones (ACZ I-VII, Figure 2.1) based on moisture availability with indices for rainfall, evaporation, vegetation, potential for growth and risk of crop failure (Jaetzold and Schimdt, 1983/1984).

Kericho district in the Rift valley province lies about 300 kilometres west of Nairobi on a latitude of 0^0 22'S and longitude of 35^0 21'E, has an average altitude of 2,000 metres above sea level and has a generally cool and wet climate. This area is classified as ACZ 1 (Jaetzold and Schmidt, 1983/1984) and most areas receive high rainfall of more than 1400 mm as an annual average. Rainfall tends to be well distributed except for a relatively dry period in January and February, temperatures can be described as cool with an annual minimum of 8 ^{0}C and a maximum of 24 ^{0}C (Anon,1984). Figure 2.2 shows the long term average data on mean monthly rainfall, maximum and minimum temperatures for the area and Appendix 2.1 weather data. The land topography is characterised by undulating hills and valleys with streams and rivers at the bottom of the valleys. The predominant grasses are Kikuyu (*Pennisetum clandestinum)* and star grass (C*ynodon dactylon*). The small-holder farms have an active tea industry coupled with some portion of land left for food production, mainly maize and horticulture.

Peeler and Omore (1997) classified livestock production systems for the area as small scale dairy cattle production (DACASS) and small scale dairy meat cattle production (DMCASS) while that for small ruminants is small scale meat goat production (MEGOSS) and small scale meat sheep production (MESHSS). It is estimated that these systems within the central Rift valley region, which is similar to the study area, hold a total of approximately 1.2 million cattle (9.3 % of the national herd) and approximately 1.2 million small ruminants (6.8 % of the national herd). In the DMCASS production system, the small holders generally keep Small East African (SEA) Zebu with other ruminant stock. Cattle are grazed on paddocks, tethered on the farm or taken to graze roadsides or communal areas.

Figure 2.1. *Map showing the agro-climatic zones in Kenya*

Table A MOISTURE AVAILABILITY ZONES with an indication of rainfall, evaporation, vegetation, potential for plant growth and risk of crop failure

zone	r/Eo (%)	classification	r average annual rainfall (mm)	Eo average annual potential evaporation (mm)	vegetation	potential for plant growth	risk of failure of an adapted maize crop
			excluding areas above 10,000 ft altitude			assuming that soil conditions are not limiting	
I	> 80	humid	1100 - 2700	1200 - 2000	moist forest	very high	extremely low (0 - 1%)
II	65 - 80	sub-humid	1000 - 1600	1300 - 2100	moist and dry forest	high	very low (1 - 5%)
III	50 - 65	semi-humid	800 - 1400	1450 - 2200	dry forest and moist woodland	high to medium	fairly low (5 - 10%)
IV	40 - 50	semi-humid to semi-arid	600 - 1100	1550 - 2200	dry woodland and bushland	medium	low (10 - 25%)
V	25 - 40	semi-arid	450 - 900	1650 - 2300	bushland	medium to low	high (25 - 75%)
VI	15 - 25	arid	300 - 550	1900 - 2400	bushland and scrubland	low	very high (75 - 95%)
VII	< 15	very arid	150 - 350	2100 - 2500	desert scrub	very low	extremely high (95 - 100%)

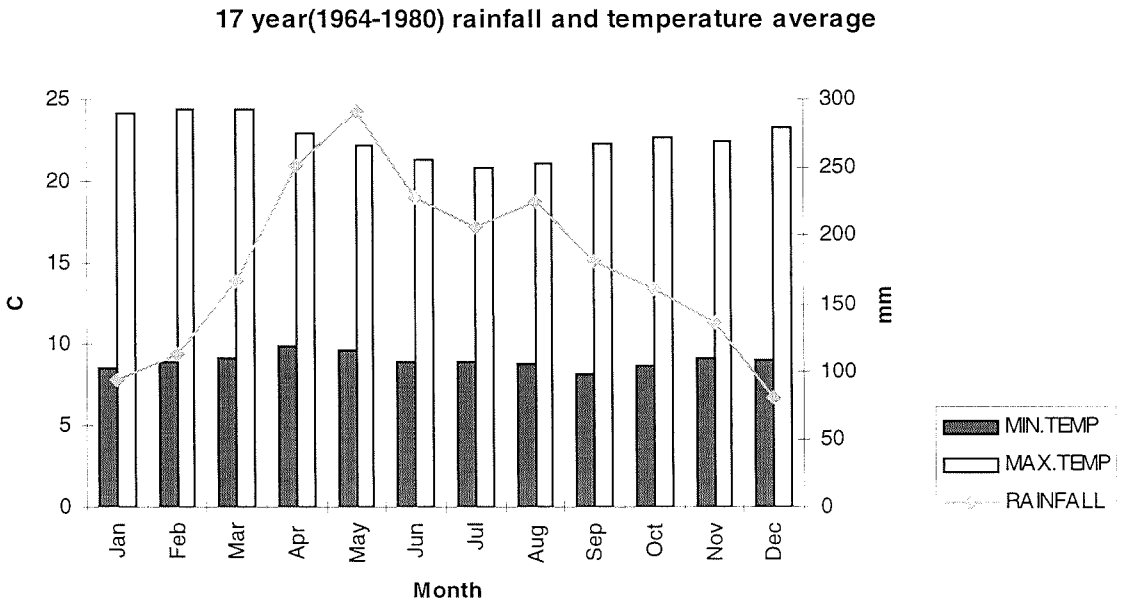


Figure 2.2 *Long term (1964-1980) average monthly rainfall and maximum and minimum temperature for the study area.*

The system has very low inputs, animal health interventions rarely being practised and little concentrate and mineral supplementation being purchased. The DACASS system is more popular in the peri-urban areas with easy access to milk marketing channels. The farmers typically keep 2 or 3 dairy cows with their followers and often small ruminants on approximately 2 hectares of land, whilst also engaging in arable agriculture. Cattle on these farms are mostly genetically heterogeneous *Bos taurus* breeds or a high proportion *Bos taurus* dairy crosses with *Bos indicus* (Plate 2.1). Concentrate and mineral supplementation is a common feature of the DACASS system. The small ruminants in the study area are mostly Red Maasai cross sheep (Plate 2.1) and Small East African (SEA) goats.

2.2 Background studies.

2.2.1 Review of ruminant helminthoses data in a laboratory near the study area.

Before embarking on the epidemiology study, a review of ruminants helminthoses using data held at the Kericho VIL for a period of 11 years (1983-1993)

was undertaken with a view of generating baseline data on the worm species prevalence and incidence in the area served by the laboratory. The materials used for the exercise were the monthly briefs, annual reports and disease surveys/surveillance reports which were studied and data for each ruminant species extracted. Although the sources of these data cover a wide area, the faecal samples presented at the VIL provide evidence of some of the helminth problems in the region.

2.2.2-Participatory rapid appraisal meeting with extension staff of veterinary department.

At the onset of the study, a participatory rapid appraisal (PRA) was conducted using separate meetings with veterinarians and animal health assistants (AHAS) working in the area. The aim of the PRA was to gain information on the livestock marketing patterns, price fluctuations and current and recommended anthelmintic usage. The sessions were conducted by staff of the socio-economics division of National Veterinary Research Centre (NVRC)-Muguga, who are experienced in conducting this type of meeting, and the author. A total of 6 local veterinarians and 8 AHAS participated in the PRA.

Plate 2.1 *Typical cattle and sheep breeds within the study area*

2.3 Epidemiology study and intervention trial

2.3.1 Selection of farms for epidemiology study

At the start of this study, a suitable transect on the peri-urban part of Kericho municipality was chosen with the main criteria being: (a) availability of sufficient communal and roadside grazing to accommodate the tracer sheep and (b) proximity to the VIL and a meteorology station. Administrative clearance was sought from the local District Veterinary Officer and this was followed by a meeting with the extension officers serving in the area to assist in recruiting the farmers for the study. The main criterion considered was that the farm should have a total flock containing less than 20 ruminants. A total of 45 farms were recruited and the herd structure recorded. Back at the NVRC-Muguga, 30 farms were randomly selected with a herd total of about 150 cattle, 120 goats and 50 sheep all of which were ear tagged. This study was conducted for a period of 22 months starting in March 1995 through to December of 1996.

2.3.2 Selection of farms for intervention trial.

The second phase of selecting farms for use in the anthelmintic intervention trial was based on the recommendations of Otte and Duncan (1996). To widen the study area a sampling frame consisting of 3 locations was chosen. To ensure randomization of farms, in the absence of organized milk collection centres in this area, seven tea collection centres serving these locations were chosen. The authority to use the records in these centres was sought from the Leaf Base Manager of the Kenya Tea Development Authority. The total number of farmers in each centre was recorded and a random number generator in Microsoft Excel (Microsoft corporation) used to generate 9 numbers representing the farms allocated to each tea collection center. In addition, a further 3 farms were selected to replace any non-response farms or those that were without animals. A visit was made to each centre to identify the farmers represented by the selected random numbers using the main record book maintained in each centre. A standard animal health questionnaire was given to the 27 original farms and 67 newly

selected farms. The standard animal health farm questionnaire (Appendix 3.1) was developed by the Socio-economic division of NVRC and pilot-tested in the neighboring farms. The questionnaires consisted of four main sections, the first covering ownership, type of farm and management practices especially grazing patterns. The second section dealt with general animal health issues like herd structure, common diseases and mortalities thereof. Farmers were asked to rank the constraints to production from 0 to 5, with 0 being completely unimportant while 5 was very important. They were then asked to list the 3 most important diseases affecting each livestock species. The third section was entirely on anthelmintic use to control worm infestation in livestock with emphasis on frequency of use, sourcing and administration. The last section dealt with other animal health practices, for example vaccinations and tick-borne disease control.

Each questionnaire took a minimum of 30 minutes to complete. The author was personally involved to ensure that there was no unwillingness to provide data. Particularly sensitive areas included the number of livestock carried by the small holder and the number of children in his family.

The data from the questionnaires were entered into Epi-Info program (CDC, Atlanta, USA) and analysed to choose farmers who would be involved in the intervention trial. A total of 70 farmers, comprising of the original 27 and 43 new farms, were selected to take part. An additional 6 farms were also included after another randomization from another blind selection of 30 random numbers from the tea collection centers. A further 76 farms produced a total of about 1,000 animals, 650 cattle and 350 small ruminants. The criterion which were considered when choosing the farms were, grazing method, helminth control strategy and herd size. The calculation of sample size i.e number of farms to be involved in the study was based on expected weight gains following intervention of 2 kg for sheep/goat and 8 kg for cattle (Otte and Duncan, 1996). These figures roughly represent the difference in weight gains between the control and the treated groups. At the start of the trial, all animals in the new farms were ear tagged and in each farm, each animal's details were recorded in a form specifically designed for this trial (Otte and Duncan, 1996) (Appendix 7.1). The global positions (Appendix 7.2) of these farms were established using a hand held Global

Positioning System (GPS) (GPS 45, Garmin corporation, USA) and these data were entered in a Microsoft Excel file (Microsoft corporation). In order to produce a map of the distribution of these farms, data had to be exported to MapInfo 4.5 for windows (Map Info Corporation). The map showing the distribution was created by overlaying points on background digitised boundary files for Kenya and specifically, Kericho district. Figure 2.3 shows the location of the selected farms at Kericho.

2.4 Animals and comparison of sheep and goats as tracers

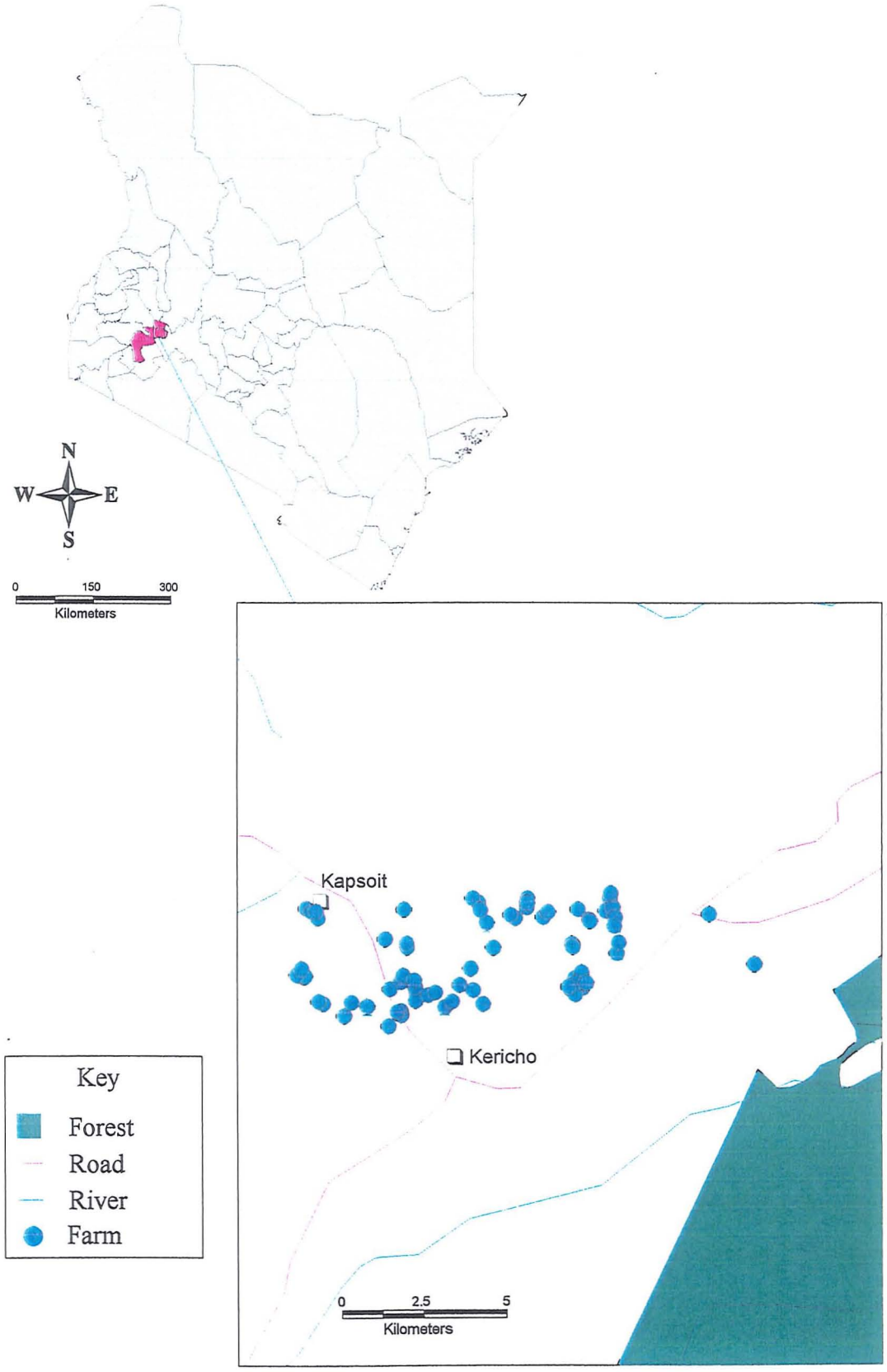
2.4.1 Tracer lambs

Dorper lambs, less than six months old, were purchased from an area of the country where fasciolosis does not occur and the contracted farm confirmed the absence of anthelmintic resistance. On arrival, the animals were weighed and treated with levamisole at 7.5 mg per kilogram live weight (Nilverm, Coopers Animal Health, Nairobi, Kenya) to remove nematode parasites and kept in worm free pens which were regularly cleaned. Approximately 2-3 days before every field visit, the animals were sampled and 6 lambs with negative counts were selected, transported to Kericho and introduced to the pasture where they grazed with the flocks on the common grazing grounds, including roadside, for a period of one month (Plate 2.2). At the end of this time they were transported back to NVRC where they were then housed under worm free conditions for three weeks until necropsy.

2.4.2 Permanent grazed sheep

Four adult ewes mainly crosses of the Red Maasai breeds were purchased from the flocks in the study area every month, transported with the tracers to NVRC where they were housed for three weeks prior to necropsy.

Figure 2.3. *Map showing the location of the farms used in the epidemiological and intervention studies.*



Map showing the distribution of study farms within Kericho district, Kenya.

Plate 2.2. *sampling animals on a typical farmstead in the study area (upper picture). Dorper tracer sheep grazing along the roadside in the study area (lower picture).*

2.4.3 Comparison of sheep and goats as tracers.

This experiment was carried out at the NVRC-Muguga from February to April 1998 which is normally a dry period but had abundant pastures following a higher than average rainfall during the later part of 1997. NVRC is situated at an altitude of about 2,100 metres and the mean ambient maximum and minimum temperatures are 23°C and 10°C respectively (Taylor, Robertshaw, Maloiy, Aseka, Kamoyo and Thuku, 1967). It is located in agro-climatic zone (ACZ IV) which is classified as a semi-humid to semi-arid cool temperate region (Jaetzold and Schmidt, 1983/1984). The grasses found in the area are mixed with a predominance of Kikuyu grass (*Pennisetum clandestinum*).

A total of 12 male SEA goats and 12 male Dorper lambs were purchased, transported to NVRC and treated as described previously for tracers. A group of 3-4 animals of each species were selected every month, dosed with a levamisole based anthelmintic (Nilverm, Cooper Animal Health, Nairobi) and introduced to the pasture to graze with the breeding flock of the centre for a period of one month after which they were withdrawn and kept indoors as described above for a period of 3 weeks when they were sacrificed for total worm counts (TWC). The differentiation of the TWC was done as described by Urquhart *et al* (1987) while making sure the worms were divided according to stage of development.

During housing, the sheep and goats were fed on a mixture of grass and lucerne hay and offered water *ad libitum*.

2.5 Parasitological techniques.

2.5.1. Preparation of helminthological solutions

Appendix 2.2 contains details of the methods used to prepare solutions used in the laboratory such as Saturated Salt Solution, Pepsin/HCl, Helminthological Iodine and Sodium Thiosulphate.

2.5.2. Collection of faecal samples

Faecal samples were collected from the rectum into labelled 12.5x12.5 cm polythene bags and held at 4°C in a cool box until they could be examined in the laboratory or stored at 4°C for no longer than 3 days.

2.5.3. Nematode faecal egg count

Rectal faecal samples, collected into labelled plastic bags, were examined using the following modification of the McMaster egg counting technique described by Gordon and Whitlock (1939). A 3 gram sample was weighed using a double pan balance and put into a plastic beaker containing 42 ml of tap water. The faeces was homogenized until it was completely emulsified. The mixture was then passed through a tea strainer (c 1mm mesh size) and the filtrate collected in a bowl. The filtrate was then mixed and a sub-sample poured into 15 ml tube and centrifuged at 1000 revolutions per minute (RPM) for 5 minutes (228 g). The supernatant was poured off and the pellet at the bottom of the tube loosened using a rota mixer (Whirlmixer scientific industries, England). Saturated salt (NaCl) solution was added to the sample up to the original suspension level on the tube and the contents mixed by inverting slowly six times. Using a disposable pipette both chambers of the McMaster slide (Weber scientific instruments, Middlesex, England) were filled with suspension. The slide was allowed to stand on the bench for five minutes and all of the eggs under the grid areas of the two chambers were counted. The number of eggs recorded was multiplied by 50 based on the following calculation:

3 grams of faeces in 42 ml	= 1 gram in 15 ml
volume under 1 square of the McMaster slide	= 0.15 ml
volume examined under two squares	= 0.30 ml or 1/50th of total
total number of eggs seen under 2 squares (T)	
Total no of eggs (T) x 50	= No eggs per gramme of faeces.

Examinations were carried out using a stereoscopic microscope at x 40 magnification and hand-held tally counter used to record the number of eggs present. Egg count results were immediately recorded in the McMaster book.

2.5.4. Trematode faecal egg counts.

A modification of the sedimentation technique described by Boray and Pearson (1960) was used to determine *Fasciola* egg counts. Three grams of faeces was weighted into a plastic tub to which approximately 200 ml tap water was added and the mixture homogenized. The mixture was passed through a tea strainer and the filtrate collected into a tub and allowed to sediment for 3 minutes. The supernatant was poured off, and the same volume of water added, mixed and allowed to sediment. Four sedimentation stages were usually necessary to clear the sample of the fine particulate matter, which makes optical examination difficult. At the end of these stages the supernatant was poured off to leave approximately 10 ml of sediment. This sample was examined at x160 magnification using a stereoscopic microscope. In practice about 4 ml can be examined at a time. All of the *Fasciola* eggs seen were counted, and the numbers of eggs per gram of faeces calculated and recorded.

2.5.5. Post-mortem worm recovery technique.

The animals were humanely killed using a captive bolt pistol and immediately exsanguinated. They were opened along the ventral midline and the entire gastro-intestinal tract removed, the pyloric/duodenal and ileo-caecal sphincter ligatured to prevent transfer of contents between different organs and then placed on a tray. The liver and gall bladder were removed and put into a labeled plastic bag. The abomasum, small and large intestines were separated and placed into labelled buckets.

2.5.6. Fluke recovery at post-mortem

The gall bladder was removed, opened into a separate container and the bile examined in a petri dish for the presence of fluke eggs and other parasites using a stereoscopic microscope at x160 magnification.

After trimming off the diaphragm, the liver was weighed and the weight recorded. It was then cut into small pieces, returned to the plastic bag and homogenized in a stomacher (Seward, Lab Blender 400) until completely macerated. The contents of the plastic bag were washed through a tea strainer and the retentate back washed into a tray.

Under light, the contents were examined for the presence of immature and adult liver flukes. These were collected, counted and kept in separate labeled containers in physiological saline for measurement of length and width. In the case of broken parasites, the heads and tails were counted separately. The higher of the two counts was taken as the number of broken parasites. The presence of other parasites such as *Stilesia hepatica* and tapeworm cysts was recorded.

2.5.7. Worm recoveries from the abomasum.

The abomasum was opened along its greater curvature and the contents emptied into a bucket. The abomasal mucosa was then washed under running tap water into the bucket and the volume made up to 2 litres. After mixing well in a figure of eight pattern, duplicate 200 ml (10 %) samples were transferred to labelled jars. These samples were preserved by adding 2-3 ml of helminthological (Lugol's) iodine.

The mucosal lining of the abomasum was removed by scraping with a scalpel blade, put into a labelled jar and 250 ml warm 1% pepsin/HCL solution added. This was incubated at 37 °C for four hours. The digest was passed through a 1mm sieve into a bucket and the volume made up to 2 litres. Duplicate samples of 200 ml were taken and fixed as above.

2.5.8. Worm recoveries from the small intestine.

The small intestine was separated from the mesenteric attachments and opened lengthwise using gut scissors, ensuring that all the contents remained in the bucket. The cut intestines were then pulled through the fingers with the thumb rubbing along the mucosal surface to ensure that the mucosal lining and remaining contents were retained in the bucket. The volume was made up to 2 litres and 10 % samples taken, preserved and stained as for the abomasum. No mucosal digests were carried out on small intestinal samples.

2.5.9. Worm recoveries from the large intestines.

The large intestine was opened and the contents washed onto a 1mm sieve. These

were then washed under running tap water and any macroscopically apparent worms picked out and transferred to a labelled universal bottle for counting and microscopic identification. The worms were fixed by adding 1 ml of Lugol's iodine.

2.5.10. Worm counting, recovery, identification and differentiation.

Following a thorough mixing ten 4 ml aliquots from the 10 % sub-samples of abomasal contents, abomasal digests and small intestinal contents were examined in a petri dish using the x 16 objective of a stereoscopic microscope. Sodium thiosulfate was added to the sample prior to examination to produce a clear background against which the stained parasites were readily visible. Nematodes were identified and staged by using morphological characteristics such as size, structure of mouth parts, bursal arrangement, shape and size of spicules and presence and form of vulval flaps as illustrated by Dunn (1978) and Urquhart *et al* (1987). Speciation was carried out by transferring 50 randomly selected male parasites to slides with cover slips and examining them under a compound microscope at x 100 magnification. Each species was counted and the figures multiplied by 50 to give the total numbers of males, females and immature worms.

2.5.11. Pasture larval recovery technique.

Collection of samples.

Pasture samples were collected every month from 12 sites on the communal open areas and along the roadside in the part of the study area where the tracers were kept. This sampling was done on the last day of the monthly visits before 10 a.m. when the pasture was still wet. Pasture was sampled by walking along a 'W' shaped traverse in the paddocks, stopping every ten steps to take plucks of grass (Taylor, 1939) or along a line for the roadsides. A pluck of grass was the amount of herbage that could be grasped between the thumb and the forefinger. At each stop, four plucks were taken; from front right, front left, rear right and rear left. The plucks were carried in a large polythene bag that was labeled with the site identity and date of collection. The collection along the

roadside was done by taking a pluck after 10 steps and crossing over to the other side in a zig zag manner. In both cases about 250 grams of herbage was collected, samples were transported to the laboratory in a coolbox for processing.

In the laboratory, was herbage analysed for the presence of trichostrongyle L_3 using techniques similar to those of Parfitt (1955). The sample was weighed and the wet weight recorded. The bag was then filled with warm water, leaving enough space to tie it, and a drop of 'tween' detergent added. The bag was tied and washed by giving a total of 200 revolutions (100 revolutions in each direction) in a Wonderwash^R hand operated washing machine. The bag with sample was removed from the machine and the contents passed over a 212, 150 and 38 micron sieve series, care being taken that the 38 micron sieve did not clog and overflow. The grass was rinsed twice with tap water, passing the washings through the series of sieves. The grass was then taken for drying outdoors in wire mesh basket that prevents losses, by wind. Once dried the dry weight of the sample was recorded.

The retentate in the 150 micron sieve was carefully washed with the wash bottle to ensure that no larvae were trapped in the debris. This retentate was eventually discarded while that in the 38 micron sieve was washed to the side of the sieve and poured off into a beaker. The larval suspension in the beaker was poured through a Whatman No. 113 grade filter paper using a Buchner apparatus. Once all the fluid was through the Whatman filter, a milk filter was placed on top and the whole inverted onto the top of Baermann apparatus. After 12 hours the material together with the filters was carefully lifted off the Baermann apparatus and the samples left for a further one hour to settle.

A 7 ml sample was drawn off from the bottom of the funnel, transferred to a universal bottle and stored at 4°C. Prior to examination 3 ml Lugol's iodine was added to the 7 ml sample, mixed well and an aliquot transferred to an eel worm counting slide (Weber Scientific Instruments, Middlesex, England). A further 3 aliquots were counted and the mean number of larvae per ml of original sample calculated. The total number of larvae in the sample (now 10 ml) was calculated and expressed as larvae per kilogram of dry herbage as follows:

L_3 per kg dry herbage = count x original volume (10) x 1000 divided by dry weight of samples.

Larval identification relied on examination of the size of larvae, prolongation of the L_3 sheath beyond the tail of the L_2, presence of refractile bodies and other morphological characteristics as described in the Manual of Veterinary Laboratory Techniques (Ministry of Agriculture Fisheries and Food (MAFF), 1986).

2.5.12. Nematode larval culture technique

Representative faecal samples from each animal were pooled and placed in a suitable container in a 26°C incubator. Following a 14 day incubation the jar was removed from the incubator and the faeces covered with warm water and allowed to soak for 2 hours. The fluid was then poured off into a Buchner funnel with a Whatmann grade 113 filter paper. The filter was removed from the Buchner funnel and placed on a Baermann apparatus supported by a milk filter (A. McLaskie Ltd, Stirling, Scotland.). After 4 hours, the filters were removed from the funnel and 10 ml of sediment was removed with a pipette and placed in a suitable capped container and stored at 4^0 C for counting and speciated as described in the larval counting technique (MAFF, 1986).

2.6. Investigation of anthelmintic resistance and the quality of anthelmintics used in the study area.

2.6.1. Investigation of anthelmintic resistance.

The study was done on a total of 23 small scale farms and 5 large farms based on WAAVP guidelines (Coles and Roush, 1992). The animals were weighed to the nearest kilogram using an electronic scale (Tru-test, Eziweigh, New Zealand) fitted to a platform and oral treatments were administered with a calibrated syringe over the back of the tongue. In the laboratory, faecal samples were processed for enumeration of eggs as described above. A representative sample of faeces from each animal in each group was taken on the day of treatment and pooled and cultured for larval recovery and

identification as described before.

Oral preparations were sourced from local suppliers. Levamisole (*Wormicid*, Cosmos Kenya Ltd) was given at a dose rate of 10 mg/ kg^{-1} bodyweight (BW) which was about 1.33 times the recommended dose of 7.5 mg/kg BW, a benzimidazole drug (*Valbazen*, Kenya Swiss Ltd, Nairobi, Kenya) was given at 5 mg/kg^{-1} BW and injectable ivermectin (*Ivomec*,Unga Ltd, Nairobi, Kenya) at 0.2 mg/kg^{-1} BW.

On the small farms an attempt was made to ensure that each drug family was represented within the random allocation of treatment and controls bringing the total number of animals to 120. On the large scale farms, the main criteria was to ensure a minimum of 15 animals per treatment group and control group. Adult animals were used for the trial because there were too few young animals aged between 3-6 months due to aseasonal breeding. Group mean pre-treatment egg counts always exceeded 150 EPG as recommended by WAAVP. The faecal egg count reduction percentages and the 95 % confidence interval limits were calculated according WAAVP recommendations on the detection of anthelmintic resistance (Coles and Roush, 1992) using arithmetic means and the standard formula:

FECRT % =100(1-Mean of Treated at Day 10) divided by Mean of Control at Day 10).

Any goat with a missing values for either the pre-treatment or post-treatment FEC were omitted from the analysis. An efficacy of less than 95 % and confidence limits of less than 90 % were taken as indicating presence of anthelmintic resistant nematodes. A representative sample of faeces from animals in each treatment and control group was pooled and cultured for larval identification and differential counting as described before.

2.6.2. Assay of anthelmintics.

A total of 27 products containing levamisoles, combinations of levamisole/fasciolicides and fasciolicides were purchased from the farmers' stores and

pharmacies in Kericho town and transported to NVRC-Muguga for onward delivery to the National Quality Control Laboratory (NQCL) where they were analyzed using standard practices in use in this laboratory. This involved running chromatographs which compare the different peak area ratios obtained between commercial solutions and the pure standards of the same anthelmintic. Assessment of impurities, colours, odour and containers used in relation to storage conditions was also performed.

A certificate of quality for each product submitted was issued duly signed by the authorities of the laboratory.

2.7 Meteorological data

These data for each sampling period were obtained from a weather station about 5 km from the study area, (Timbilil at the Tea Research foundation) with a latitude of 00° S 21'S and a longitude of 35 °21'E. The long term averages were obtained from the Kenya meteorological department, climatological statistics for Kenya (Anon, 1984).

2.8. Weighing of animals.

Cattle weights were estimated by placing a weighing tape around the heart girth and reading off the weight (Farmers' Boy, Dalton supplies, England) this being the standard method used at NVRC. Small ruminants were put in a sack and their weight recorded using a spring suspension balance (Salter, UK). Later in the course of the study, farmers were supplied with small spring balances to assist in recording the birth weights of the lambs and kids. The calves and small ruminants during the intervention study and anthelmintic resistance investigations were accurately weighed using an electronic balance (Trutest, Eziweigh, New Zealand) connected to a platform.

2.9. Software.

The study began in March 1995 when the epidemiology component and all the details pertaining to this were entered into Minitab statistical software (Minitab Corporation). The faecal egg count data for each animal species were transformed in the form Log 10 FEC +1 before subjecting it to analysis. The cross sectional survey data were entered into Epi info program (CDC, Atlanta) while the intervention trial study and the socio-

economic data were handled in Microsoft Access (a relational database management software) (Microsoft Corporation) which allows for the creation of tables linked by common fields, development of forms for data entry and analysis, graphical query design and output in the form of graphs and reports. The post-mortem worm recoveries, larval cultures and anthelmintic resistance investigation data were handled in the Microsoft Excel (spreadsheet software) (Micro soft corporation). Reports were handled in the Microsoft windows programme (Microsoft corporation). These programmes formed an integrated system with each component part able to link directly to any other, thus greatly enhancing the storage, manipulation, presentation and analysis of data.

2.10. Dissemination of the results.

At the end of the study, a two day meeting was held in June 1998 to disseminate the findings to extension workers and farmers in the study area. The first day was a scientific session where the extension staff were given an overview of epidemiology studies in other parts of the country and specifically the Kericho study. A total of 22 veterinarians attended including those in the VIL and private practioners. On the second day, a total of 200 farmers and 6 veterinarians, specifically the district administrative staff and those from the study area and the VIL attended the meeting. The main agenda was to give a general discussion on the effects of worms and advice on the control of helminthoses in all animal species. During this meeting, worm specimens and basic life cycles were prominently displayed and a team of technical staff from NVRC and VIL were at hand to talk to the farmers.

CHAPTER 3

Background studies: Baseline data from the Kericho Veterinary Investigation Laboratory (VIL), Participatory Rapid Appraisal (PRA) with the extension staff and Cross-sectional socio-economic survey.

3.1 Introduction.

Before starting any epidemiological survey it is useful to gather baseline data from extension staff and from local diagnostic laboratories on the common diseases in the study area. These data will provide some understanding of the regional disease problems and in this case specific problems attributable to helminthoses. The views of the extension staff of the veterinary department of the Ministry of Agriculture Livestock and Marketing (MALDM) were sought since, with their local knowledge, they were the most appropriate people to conduct a participatory rapid appraisal (PRA) and later to disseminate the findings and introduce any new technologies. Information was sought from the local farmers using standard animal health questionnaires to gain an appreciation of their perception of animal health issues and disease control strategies. The cross-sectional survey was part of an exercise to ensure that farms selected for intervention trials had as similar management systems as possible so that the results generated would be applicable not only for the study area but hopefully in other areas in similar agroclimatic zones with similar management systems. The three groups, Vets, AHAS and farmers were considered as stakeholders as far as the control of helminthoses was concerned since they would be the primary users of the information generated by the epidemiological survey.

3.2 Materials and methods.

3.2.1. Survey of VIL helminth data.

Data on bovine, caprine and ovine helminth infections between 1983 and 1993 was obtained from the records of the local VIL in Kericho. These years were chosen since the introduction of charges in 1993 led to a marked reduction in the number of samples submitted to the centre which may have introduced another element of bias.

3.2.2. Participatory rapid appraisal (PRA) with extension staff

The methods used to conduct and analyse the PRA are those described in Chapter 2. Kericho district lies in agro-climatic zone I (Jaetzold and Schmidt, 1983/1984). The divisions covered by the veterinarians and AHAs were Ainamoi, Sosiot and peri-urban Kericho. The predominant ruminant livestock are grade cattle, exotic crosses and a few sheep and goats. It was estimated that for every sheep or goat there are between 3 and 15 cattle. The MALDM Livestock Division report of 1993 estimated

the livestock populations of Kericho to be as follows: 156,020 dairy cattle, 143,980 zebu cattle, 68,000 sheep and 63,000 goats (Anon, 1993).

3.2.3. Cross sectional survey of Veterinarians, Animal Health Assistants and Farmers

An example of the questionnaire is shown in Appendix 3.1. Data generated from the survey was analysed using the methods described in Chapter 2.

The use of questionnaires to investigate certain aspects of animal production is a common feature worldwide but its use in evaluating the epidemiology of helminth infections in ruminant livestock owned by poor small holder farms in developing countries is confronted by difficulties. Unlike most studies conducted in the west, statistically significant sample sizes cannot be found within individual farms where average flock/ herd sizes are very small (Bain, Gatongi, Nginyi, Onyango-Abuje, Peeler, Rugutt, Wanyangu, 1997). In developing countries, farm sizes are often very small especially in integrated crop-livestock systems. Animals from these farms are often grazed on communal areas with different species and age groups grazing together. This makes it difficult to implement or even test strategic control practices (Kyvsgaard, Nansen, Willingham, Kassuku and Mukaratirwa, 1997). In order to get sufficient numbers of animals of all age groups for an intervention trial relatively large numbers of farms are needed all of which should lie within a homogenous boundary in order to provide some uniformity. A total of 94 farmers in 3 locations were given a questionnaire the results of which could be used to identify suitable farms for the epidemiological study and intervention trial.

3.3. Results.

3.3.1. Survey of VIL helminth data.

The data for the ten years preceding the introduction of charges for analyses was used in the survey and that on helminthoses is summarized in Table 3.1 a-c. The mode of recording data for faecal egg counts (FEC) in use in all the VILs in the country was as follows: + = low intensity, ++ = moderate intensity and +++ = high intensity. For the purpose of this review any animal with a positive sign was counted. The majority of the faecal samples submited to the VIL were from cattle, where on average 1,290 (± 317.8) samples were submitted each year. The numbers of sheep and goat samples were generally very low (averaging less than 50 per

annum except for three years samples when material from 2 large scale farms near the laboratory was analysed. The annual bovine positive samples ranged from 34.7 - 74.1 % and the main phyla recorded were nematodes (strongyle type eggs) followed by trematodes (*F.gigantica*). Eggs from stomach flukes (paramphistomes) were also common, other helminths such as tapeworms, ascarids, *Strongyloides* species and lungworms were only minor contributors to faecal egg counts. The majority of the small ruminant samples examined were positive. Positive sheep samples varied from 31.7 % to 91.8 % and goats samples between 54.4 %-98.3 %. The majority of helminth eggs recovered from small ruminant faeces were classified as strongyle type, followed by *Strongyloides* with a low incidence of eggs of other helminths.

Table 3.1 a-c *Sample submission, percent positive and differential identification.*

a-Bovine.

Year	No. Samples	Positive	%	Differential percentage			
				Strongyle	L. Fluke	S. Fluke	Other
1983	1163	679	58.4	40.1	53.8	1.6	4.5
1984	1606	1190	74.1	38.7	23.5	34.2	3.6
1985	1179	813	69.0	47.5	12.9	34.2	5.4
1986	895	562	62.8	48.2	8.0	35.9	7.9
1987	996	346	34.7	78.3	11.0	8.3	2.4
1988	1155	539	46.7	69.4	5.9	5.9	18.8
1989	1280	846	66.1	60.5	5.0	27.4	7.1
1990	1258	763	60.7	54.9	8.1	27.8	9.2
1991	1600	854	53.7	76.2	8.7	8.7	6.4
1992	1980	1142	57.7	70.7	13.4	6.5	9.4
1993	1071	550	51.4	76.5	14.2	1.1	8.2

* Samples came from 2 large scale farms (Chesumot and African Highlands Produce(AHP) for sheep and Chesumot for goats). AHP has since ceased rearing sheep after what appeared to have been anthelmintic resistance problems. The management disbanded this flock in 1984/1985 and it is believed some of these animals were sold to small scale farms in the study area.

b- Ovine

Year	No. Samples	Positive	%	Differential percentage				
				Strongyles	L.fluke	S.fluke	Strongy-loides	Other
1983	73	67	91.8	40.3	7.5	1.5	30.1	20.6
1984	63	35	55.6	31.7	0	0	5.7	62.6
1985	323*	153	47.4	66.0	0	0.7	20.9	12.4
1986	76	49	64.5	85.7	0	0	14.3	0
1987	423*	134	31.7	72.4	0	0	26.1	1.5
1988	33	29	87.9	93.1	0	0	6.9	0
1989	24	21	87.5	71.4	0	0	28.6	0
1990	49	42	85.7	59.2	0	0	40.8	0
1991	26	21	80.8	71.4	0	0	28.6	0
1992	312*	164	52.6	99.4	0	0	0	0.6
1993	68	47	69.1	95.7	0	0	0	4.3

c-Caprine.

Year	No. Samples	Positive	%	Differential percentage				
				Strongyle	L. Fluke	S.Fluke	Strongy-loides	Other
1983	298*	162	54.4	90.1	3.7	0	3.1	3.1
1984	543*	524	96.5	80.2	0	0.6	11.5	7.7
1985	32	28	87.5	64.3	0	0	25.0	10.7
1986	57	56	98.3	53.6	0	0	30.3	16.1
1987	47	40	85.1	87.5	0	0	7.5	5.0
1988	34	33	97.0	57.6	0	0	27.3	15.1
1989	49	24	49.0	58.3	4.2	0	20.8	16.7
1990	25	20	80.0	55.0	0	10.0	25.0	10.0
1991	315*	269	85.4	91.4	0	0	0.7	7.9
1992	12	11	91.7	90.9	0	0	9.1	0
1993	9	5	55.5	82.5	0	0	11.2	6.3

3.3.2. Participatory rapid appraisal (PRA) with extension staff.

Questions on livestock marketing, helminth control, adoption of new strategies and other issues were raised with the veterinarians and animal health assistants.

3.3.2.1.Livestock marketing

Reasons for keeping animals, reasons for sale, ages and weights of animals at time of disposal.

Veterinarians.

The veterinarians thought that although there were many social reasons for keeping livestock, about 80-90 % of livestock were kept for commercial reasons. Most sales were male cattle over one year old (dairy and beef) and were transacted through traders (middlemen) who are found in every village. Surplus males from dairy herds were castrated and sold at 1-2 years when they weigh 150-250 kg. There is a price premium over slaughter price of up to 150% for breeding (in calf) heifers.

The veterinarians estimated that cattle outnumber sheep and goats by a ratio of 3 to1. Sheep and goats were mostly kept for emergency expenditure, or for slaughter on social (ceremonial) occasions and for visitors, especially goat which is preferred by the community at large in the district. However, for sheep and goats, there is no difference between the prices per kg for breeding and slaughter animals.

Animal Health Assistants

The AHAs considered the ratio of cattle to sheep/goats was 50 cattle to 3 goats and 1 sheep. Male cattle are sold between 2-3 years while female cattle are usually only sold as culls due to chronic disease or low production. Sheep and goats are sold at 2.5-3yrs at 25-30 kg. The AHAs discourage farmers from keeping indigenous sheep because they consider them reservoirs for ticks and a source for cattle infection. Most beef animals from the dairy herds are Friesian crosses.

Changes in volume of sales and prices and factors affecting them.

Veterinarians

Volume of sales are highest during the end of year tea bonus payment period (November) and festivities (December). Higher than normal volume of sales are also recorded at the opening of school terms (January, May and September) when farmers need money for school fees and when they have to buy maize (staple diet) in time of

shortage in the market (May to July). The volume of sales for sheep and goats have a higher peak than for cattle.

AHAs

The AHAs gave the same information as the veterinarians. AHAs are instrumental in examining animals before sales. Some butchers buy animals in bulk at the time of highest supply/lowest price to maximise profit later when the demand is high and the prices are high.

Livestock markets

Veterinarians

The biggest market is at Sondu at the border of Rift valley and Nyanza provinces, but other smaller markets also exist in the area. Animals are often taken to market on foot and most of the sales transacted at these markets are for slaughter animals. Farmers will generally look for breeding animals directly from large scale farmers in the area or neighbouring districts.

AHAs

Since prices at the markets are highest in the morning the AHAs felt that traders came late to take advantage of the lower prices. Prices are determined by visual appraisal of livestock. Animals for breeding, especially heifers, have more value if they are pure or *Bos taurus* crosses. The source of animals also determines the price as some diseases are associated with particular areas and agroclimatic zones.

3.2.2.2. Helminth control

Current control strategies practised by farmers

Veterinarians

Farmers are mainly concerned about drenching cattle, and do so mostly when the animal looks emaciated. The famers generally buy a single dose for a sick animal and drench infrequently on a herd basis, although some farmers may target all calves for drenching, because they think calves are more at risk. Veterinarians considered that 15-20 % of farmers would drench the whole herd but only 5-10 % would do so regularly. Treatment frequency depended on the weather, being used most frequently in years of heavy rainfall. The farmers would generally treat every 3-4 months, and would call the veterinarian, though some veterinarians were pro-active and would remind the farmers. A minority of farmers would take faecal samples whenever animals have any sign of ill-health. Most farmers would personally buy anthelmintic

from the chemist and administer it themselves and most would underdose because of ignorance/underestimation of weights or fear of poisoning associated with overdosing. Social status (wealth and education) was not perceived to influence anthelmintic practices.

AHAs

According to the AHAs about 40 % of farmers de-wormed their cattle regularly. Others only de-wormed sickly animals using single dose packages which are popular in the market and which farmers can afford. The AHAs considered underdosing to be common.

Helminth control practices recommended by Veterinarians and AHAs.

Veterinarians

Veterinarians recommend drenching every 3-4 months for all classes of cattle especially before the onset of the wet months. One veteterinarian recommends more frequent drenching, every 2 months for calves less than 6 months of age. They only recommend use of anthelmintics containing both a wormer and flukicide if the animals go to the river since they associate it with *F.gigantica* habitats. Based on the samples submitted at the VIL, liverflukes are only prevalent in Londiani area to the east and Sotik to the south (not part of proposed study area). The veterinarians were unenthusiastic about laboratory confirmation before administering treatment though some did admit that misdiagnosis might occur.

AHAs

AHAs recommend 3 monthly drenching for free grazed animals and 6 monthly drenching for zero-grazed animals. Many AHAs do not know the added value of 'PLUS' in anthelmintics and often used them even where they knew there were no flukes. Most AHAs gave correct dosages and said that they submit samples in about 10 % of cases they attend to. According to these staff, unemployed veterinarians (recent graduates) do a good job but are inexperienced in some cases.

Brands, price and efficacy of anthelminthics used

Veterinarians

Farmers still perceive *Nilzan* (a combined product of levamisole and oxyclozanide, Coopers Kenya Ltd) as the only anthelmintic that is efficacious because of its purgative effect. However, presently, *Wormicid Plus* (same combination as the

former, Cosmos Kenya Ltd) is the most widely used and recommended anthelmintic because of its efficacy and relatively low cost. A benzimidazole, *Valbazen* (Kenya Swiss Ltd) is also frequently used. The main sources for both the farmers and veterinarians are the government drug supplies, chemist, and farmers cooperative stores. Drugs without added value to treat flukes (e.g *Dewormin,* Pharma and Horticultural Inputs Ltd and *Vetworm,* Laboratory and Allied Ltd) were perceived not to work. Average price charged is about Kenya shillings (Ksh) 120 for adult cattle and Ksh 70 for young stock i.e about half the cost of adult cattle dose. The cost of treating a small ruminant would vary according to the brand and size but was generally about half the calf dose.

AHAs

Farmers may use the brand name *Nilzan* to refer to any anthelmintic. AHAs mostly use *Wormicid Plus*. Some use *Fasinex* (Triclabendazole, Kenya Swiss Ltd, though it has recently been withdrawn from the Kenya market because it is marketed by the same company which distribute *Valbazen*) in areas with liver flukes. The AHAs thought about 60-70 % of cattle drenched responded well but that some "plain" anthelmintics did not appear to work well. Average price charged is about Ksh 90 for adult cattle and Ksh 50 for young stock and an average of Ksh. 20 for small ruminants.

Adoption of new control strategies

Veterinarians

Farmers would be prepared to change current strategies depending on economics and efficacy of alternative methods. They would also be happy to extend any new technologies.

AHAs

Felt that most farmers would readily embrace new technology and think that they would be the best people to deliver extension messages.

Other issues

Veterinarians

They felt that chemists not employing qualified AHAs at the dispensing counters may not be giving correct advice and that AHAs were perceived to be doing a good job. Paravets still existed in some remote areas in the district. Farmers at some places,

e.g. Kapsoit (part of the study area), are beginning to organise a self-help marketing organisation for their milk.

AHAs

The AHAs employed by MALDM thought that the money they make treating animals more than doubles their government salaries and that this motivates them to keep on checking on the farmers' animals for any ill health.

3.3.3. Cross-sectional survey.

All 94 farmers were in 10 sublocations of the 3 locations in Ainamoi and Belgut divisions of Kericho district. The household heads in these farms were mainly males (88.3 % and 11.7 % females) while the respondents were 56.4 % male and 43.6 % female. All the farms had a mean household size of over 9 people and an average farm size of 5.7 acres with the main farming activities being mixed livestock and crops (98.9 % of the farms) while the average herd sizes were 7.3 cattle, 3.0 sheep and 5.0 goats. The most important aspects of subsistence farming varied with the majority (50 %) depending on livestock, 38 % on crops and 12 % equally on both enterprises. The source of cash was mainly livestock which accounted for 64 %, while crops contributed 31 % with the rest (5 %) claiming that both were equally important. The farmers were also asked to give three reasons in order of importance for keeping livestock. For cattle the most important reason was milk for home consumption (89 % of the farmers), the second being sale of milk (77 % of the farmers) and thirdly was sale of livestock (77 % of the farmers). The reasons for keeping sheep were first for meat for the family (83 % of the farmers), secondly for sale (55 %) and thirdly for manure for use in crops (45 %). For goats, meat was a priority (66 %) followed by sale of animals (62 %) and thirdly for supply of manure (68 %).

3.3.3.1 Constraints acting to limit production

Farmers were asked to rank constraints to production on a scale of 5 to 0 (5 = very important, 0 = unimportant). Table 3.2 contains a summary of the findings.

3.3.3.2 Prevalence of different grazing systems

The prevalence of different types of grazing systems on the farms are summarised in Table 3.3 a and the off farm grazing in Table 3.3 b

Table 3.2 *Farmers assessment of the importance of various constraints upon production*

CONSTRAINT	CATTLE	SHEEP	GOATS
Disease	4.21	3.29	3.00
Feed	3.48	2.71	2.90
Water	1.23	1.10	1.15
Low genetic pot.[1]	1.10	1.00	1.03
Poor fertility	1.44	0.95	0.98
Labour	1.06	1.19	1.10
Marketing	1.83	0.95	0.98
Availability of L.s[2]	2.39	3.33	0.83
Access to A.I[3]	3.69	-	-

Key: 1- Low genetic potential, 2- Availability of livestock services, 3- Access to artificial insemination.

Table 3.3 a. *Type of grazing system (%) existing on the farms.*

GRAZ. SYSTEM	CATTLE [1]	SHEEP	GOATS
Free	76	88	84
Semi-zero grazed	19	6	10
Zero grazed	5	6	6

Key: 1- applies to dairy cattle only. All Zebu cattle are free grazed.

Table 3.3 b. *Percentage of off-farm grazing.*

SPECIES	NEVER	ALWAYS	MINORITY OF DAYS
Zebu cattle	90	1.0	9.0
Dairy cattle	97	1.5	1.5
Sheep	91	3.0	6.0
Goats	98	2.0	0.0

3.3.3.4 Anthelmintic usage.

Since mortalities due to helminthiasis in the 12 months prior to the survey were recorded on 35 % of the farms it was prudent to ask the farmers about anthelmintic usage. The farmers were also asked to name the sources of revenue for anthelmintic purchases and the majority (81 %) obtained resources through sales of livestock and/or livestock products, while 13 % came from crop sales and 6 % from other sources mainly from employment. Tables 4a and 4b contain details of the anthelmintics used on the farms. The farmers had used more than one brand of anthelmintic in the last 12 months (average 1.49) and 47 % of the farmers administer the drugs themselves with 53 % being done by other people, mostly AHAs or other members of the family, mainly the sons. The majority of farmers (65 %) sought advice from the extension staff on which anthelmintic to use, 25 % got advice from pharmacists and 10 % based their decision on personal experience or the price of the product. Anthelmintics were mainly obtained from the pharmacies (51.5 %), extension staff (30.5 %) with the remainder coming from farmers' co-operative stores. Although all of the farmers thought the anthelmintic they were using was effective, a minority (5.3 %) also reported using herbal cures for helminthiasis. All treatments were based on estimations of body weights i.e. none of the farmers weighed animals before drenching.

Table 4 a *Anthelmintic usage.*

USAGE OF DRUGS	CATTLE	SHEEP AND GOATS
Never	2.6	7.1
Use only for clinical cases	64.7	62.8
Routinely for prevention	32.7	30.1

Table 4 b *Mean number of anthelmintic treatments in the last 12 months based on age.*

ANIMAL TYPE	SUCKLING	WEANED	ADULT
Zebu cattle	1.2	1.1	1.1
Grade cattle	1.7	1.7	1.7
Sheep	1.0	1.0	1.1
Goat	0.9	0.9	0.9

3.4 Discussion.

Data form all three sources confirmed the importance of disease as a major constraint upon ruminant production in the Kericho area and have provided some insight into the management systems and approaches to helminth control operating on smallholder farms.

The data from the VIL gave some indication of the extent of the problem of helminthoses as perceived by the farmers submitting samples. Strongyle type eggs predominated in all ruminant species, with a higher incidence in small ruminants than in cattle. It was very evident from the numbers of samples submitted that the farmers give a higher priority to cattle than to small ruminants. A side from samples from the few large scale small ruminant farms in the district, most small ruminant samples were submitted by extension staff and came only from animals with obvious clinical signs of diarrhoea and unthriftyness.

There was a higher prevalence of paramphistome and *Fasciola* eggs in cattle than in small ruminants, with most of the samples positive for fascioliasis coming from specific areas of the district, mainly to the East (Londiani) and to the South (Sotik) of Kericho town where the laboratory is situated. The extremely low incidence of fascioliosis in sheep and goats may be attributed first to the use of tethering of small ruminants which may limit exposure to the parasites to those occasions when they are taken to water and secondly, to the fact that deaths attributable to fascioloses may occur rapidly in small ruminants without overt clinical signs.

The prevailing weather conditions seem to determine the submission of samples with the majority being submitted in May to August , following the long rainfall in this district. The farmers appear to associate helminthiasis with rainfall patterns, as do the extension staff who advise treatment during these periods.

The results of this study are in agreement with those of Lewa and Matete (1997) in a similar review in the Kabete VIL which serves peri-urban Nairobi and other neighbouring districts. Both studies have shown that in recent years, the number of faecal samples submitted by the farmers have drastically reduced. This follows a cost sharing exercise for sample analysis which was put in place in 1993 and which makes test costs prohibitive as far as the majority of the small scale farmers are concerned. For these reasons only samples from highly prized animals like dairy cows are likely to be submitted by the farmers.

The VIL as a whole would benefit considerably by dropping the practice of scoring rather than counting eggs and using a standardised method (MAFF, 1986) since it would enable comparison to be made between the findings from the different laboratories.

The survey of veterinarians and AHAs and the farmers in the PRA provided some insight into the key socio-economic factors which influence the management, health and marketing of stock and thus influence economic yields.

Although most of the farmers in the district of Kericho depend upon livestock for their livelihood productivity of livestock is not the only important criteria. Cattle have some considerable social value since they are used as a measure of social standing in the community. The ability to provide milk for ones family from ones own herd was viewed as a matter of pride. Although Zebu cattle are present in large numbers, *Bos taurus* crosses are increasingly popular despite recent increases in the costs of AI services to the small holder farmers as a result of privatisation of the service. Goats and to a lesser extent sheep are important, serving as a ready source of meat and through their disposal money. Farmers in the area do not appear to use production/marketing criteria to determine animal sales, animals are not sold on the basis of having achieved a certain weight or size but when cash is required. Since most farmers will face bills for services such as schooling at the same time (school fees are generally due in January) this can lead to a glut on the market and livestock prices tend to be low. The payment of the tea bonus in October can also lead to an

increased demand and higher prices in November and December. Smallholder farmers will often dispose of older animals, whilst retaining young animals simply because there is no premium for young animals sold for slaughter compared to older animals.

Small ruminants may be becoming more important to the local economy, the actual ratio of cattle/small ruminants was given as 7:8 by the farmers. This ratio is considerably higher than the estimated ratios given by the Veterinarians and AHA's both of whom had worked within the local environment who gave estimates of 3:1 and 12.5:1 respectively.

Although the farmers reported that the main grazing system is free grazing on the farms, this may not necessarily be wholly true, since it is an offence under the Animal Cleansing Act to graze roadsides. However because of the presence of food crops on the farms many animals spend the majority of their grazing time on roadsides and communal areas.

Disease was found to be a major constraint to production especially the tick borne and bacterial diseases, however the majority of farmers ranked helminthoses as the third most important disease though they associated it with emaciation. Farmers in the PRA reported that more than 60 % of the anthelmintic treatments were administered therapeutically but over 30 % gave routine preventative treatments. The veterinarians estimated that 15-20 % of farmers drenched all their stock regularly while the AHAs put the figure at 40 %. Data gathered from the farmers suggested that all ages of grade cattle received on average 1.7 treatments per annum compared to mean annual treatment rates of 1.13 (Zebu cattle) 1.03 (sheep) and 0.9 (goats). Questionnaires designed to produce data on the methods of worm control in use on ruminants have previously been used in surveys in the United Kingdom (Gettinby, Armour, Bairden and Plenderleith, 1987) and in Kenya (Kinoti *et al*, 1994, Wanyangu *et al*, 1996b; Maingi, Bjorn, Thamsborg, Munyua, Gathuma, Dangolla, 1997). The Kenyan studies showed that anthelmintics were used in all farms for control of nematodoses and one advocated drenching every 3 months (Kinoti *et al*, 1994).

In general AHAs and veterinarians recommend that all ruminant livestock are dewormed every three months with zero-grazed animals only every 6-12 months. During the AHA/Veterinarian meeting it was agreed by the participants that one

worm treatment should coincide with the start of the rains. *Nilzan, Wormicid* and *Valbazen* were the drugs most commonly prescribed by the Veterinarians and AHAs although the farmers in the PRA only reported using the first two drugs both of which contain levamisole as the anti-nematocidal drug. Although the farmers were using relatively few anthelmintic treatments per annum, they mainly used a single family and, since underdosing appears to be common, there may still be some risk of anthelmintic resistance in the area. For these reasons a survey of anthelmintic resistance on the smallholder farms was planned as part of the research programme.

The survey of VIL data, PRA and discussions with local practitioners and AHAs has provided valuable baseline data which will aid the design of the planned epidemiological and intervention studies. It has also provided a cautionary lesson on the benefits of seeking data from smallholder farmers rather than simply relying on information garnered from other local sources. Although helminthoses were only given third priority by the farmers, they also recognised its importance and hence may well be receptive to information and proposals derived from the study in Kericho. It is hoped that this information may also be broadcast more widely and be applied in other parts of the country with similar climatic and management systems.

CHAPTER 4

Field study: The pattern of infection in ruminants of gastrointestinal nematodes and trematodes in the Kericho highlands of Kenya.

4.1 Introduction

Knowledge concerning the extent to which helminth parasites limit production in the various agro-climatic zones (ACZ) of Kenya is vital for the development of sustainable control strategies. Helminthoses have considerable potential to reduce animal performance in many parts of Kenya, because ruminant livestock are kept on pasture throughout the year and climatic conditions favour the rapid development of the free-living stages of the parasites. Detailed epidemiological studies need to be conducted to provide information on the population dynamics of the key endoparasitic species in different ruminant hosts and age classes of animals. Previous reports describing the prevalence of parasites in Kenya in cattle (Cheruiyot, 1983; Omara-Opyene, 1985; Mango, Mango, Esamal and Kariuki, 1974. Anon, 1986; Gatongi, Gathuma, Munyua, 1987) and in small ruminants (Cheruiyot, 1987;Carles, 1993; Rey, 1991) suggest that helminth infections are an important constraint on animal production, that the nematode *H. contortus* is the most pathogenic nematode (Allonby and Urquhart, 1975; Preston and Allonby, 1978; Peeler and Wanyangu, 1998) and *F. gigantica* is the most important trematode (Anon, 1986). However, detailed studies have not been conducted in the Kericho highlands of Kenya, an important agro-climatic zone. In this area, the majority of animals are kept on small scale farms crucial to local and national production; yet the control measures advocated by extension workers are derived from studies on large farm establishments. In this study area, all ruminant species are kept on the same grazing grounds, and thus infection patterns are subject to influence not only by climatic conditions but also by different host species and their immunological status. In order to understand these interactions it is necessary to adapt the techniques used in classical studies on large flocks and herds to fit this particular farming system. Classical epidemiological studies have gathered information on species prevalence and intensity of infection using data obtained from permanently grazed and tracer animals, together with pasture larval counts. Infection pressure can only be determined by using naive young animals as tracers alongside permanently grazed stock. These tracers are introduced for a short period, then withdrawn and killed to provide data on specific availability. Comparison between the worm burden data from tracers and permanent stock provides some indication of the extent of acquired

immunity. In addition, pasture contamination can be monitored regularly by collection of pasture samples based on classical sampling techniques such as those described by Taylor (1939). These techniques are still being used today in studies of cattle (Claerebout, Dorny, Vercruysse, Agneessens and Demeulenaere, 1998; Claerebout, Dorny, Agneessens, Demeulnaere, Vercruysse, 1999; Shaw, Vercruysse, Claerebout and Dorny, 1998) and sheep (Miller, Bahirathan, Lemaire, Hembry, Kearney and Barras, 1998). In Kenya, tracers have generally been used to study the epidemiological patterns on large scale and research farms (Gatongi *et al,* 1998). Since small holder farms cannot provide sufficient acreage and animals to enable them to be treated as meaningful units for analysis an attempt was made in this study to pool data from adjoining farms sharing common grazing. Monthly prevalence data was obtained from the same 'permanent' stock, largely cattle and goats, from a series of identified farms. Worm burden data were obtained from sheep purchased from farms used in the survey, wherever possible, but supplemented as necessary with local stock obtained from the local market. Susceptible Dorper sheep were grazed alongside local stock on roadside common grazing and acted as tracers in providing details of specific infection patterns throughout the year. Although goats were the major small ruminant in the study area, sheep were used as tracers simply because they are much easier to handle and herd.

Larval infection patterns on herbage were examined using samples obtained from roadside grazing areas over a period of 22 months. These data were intended to enable the development of a chemoprophylactic intervention regime.

4.2 Material and Methods

4.2.1. Meterological data

Meteorological data were obtained from the nearest suitable collecting site (Tea Research Foundation, 5 km from the study area).

4.2.2. Pasture larval counts

Herbage samples were collected from 12 sampling sub-sites and analysed using the methods described in Chapter 2.

4.2.3. Collection of faecal samples

Faecal samples were taken from an average of 8 farms daily which had confined their animals. Sampling ended before 11 A.M in the morning and samples were transported to the laboratory as described earlier.

4.2.4. Faecal egg counts

In the laboratory, strongyle eggs were counted using the McMaster egg counting technique as described previously and data for other species were recorded separately. Trematode egg counts were performed on pooled faecal samples from cattle, goats and sheep using the methods described in Chapter 2.

4.2.5. Coprocultures

Pooled material containing a representative sample from all the individual cattle and small ruminants was used to provide coprocultures. The methods used to culture recover and identify nematode larvae were those described in the general materials and methods chapter.

4.2.6. Data recording and statistical analyses

The data generated were recorded into laboratory books and extracted and entered in Minitab program (Minitab Corporation) for basic statistical analysis. For EPG log transformed data (log n+1) were compared between farms and species using general linear models. Pasture larval counts were analysed using Mann-Whitney. The effect of climatological conditions on faecal egg counts was determined by comparing the EPG for each ruminant species in wet and dry periods.

4.3 Results.

4.3.1. Meteorological data.

During the study period, the meteorological data were consistent with the long term averages of the area (see Figure 2.1 and Appendix 4.1) with an average rainfall of 198 mm per month (69.5-411.9 mm), minimum temperature of 8.8 ^{0} C (8.3-9.7 ^{0} C) and maximum of 23.7 ^{0}C (21.9-25.2 ^{0} C). Figure 4.1 shows the monthly average temperature and rainfall patterns over the period of the study.

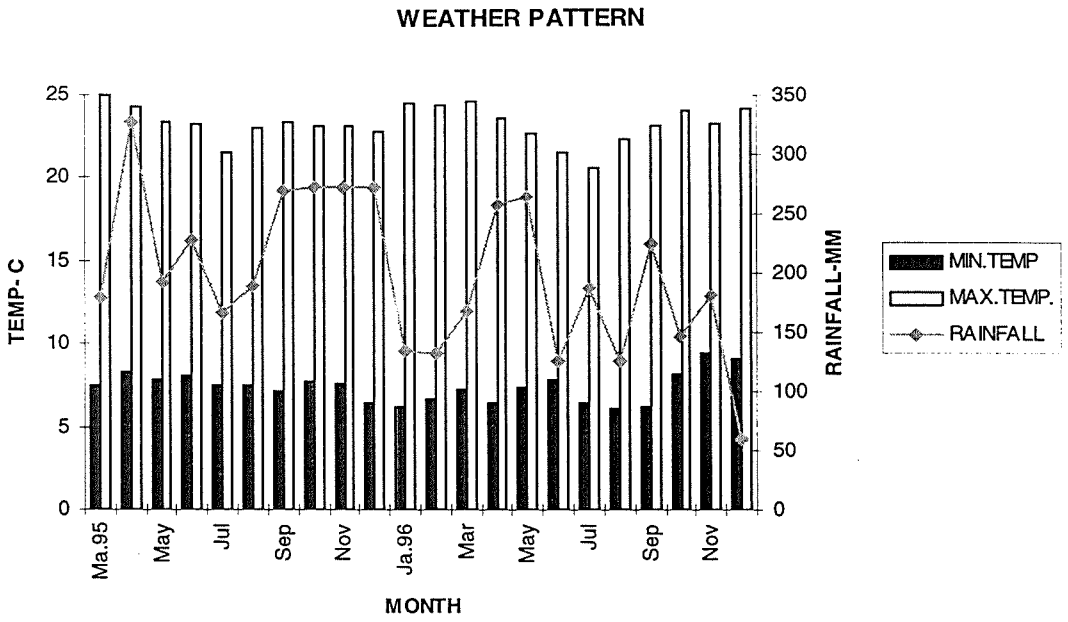


Figure 4.1. *Temperature and rainfall records during the study period*

4.3.2 Pasture larval counts

Pasture larval counts averages (Appendix 4.2) from the 12 sampling sites showed gastrointestinal parasites were present throughout the study. Figures 4.2 a-d show the distribution of infection. *H.contortus* was the predominant parasite with peak larval counts in May and August, followed by *Trichostrongylus* species which showed a similar pattern in lower proportions. *Oesophagostomum* and *Cooperia* species appeared in the lowest levels, with the former showing peaks in March to April, while the latter appeared sporadically without any specific pattern. Statistical analysis of the herbage larval loads between the sampling sites using Mann-Whitney test showed no evidence of any significant differences.

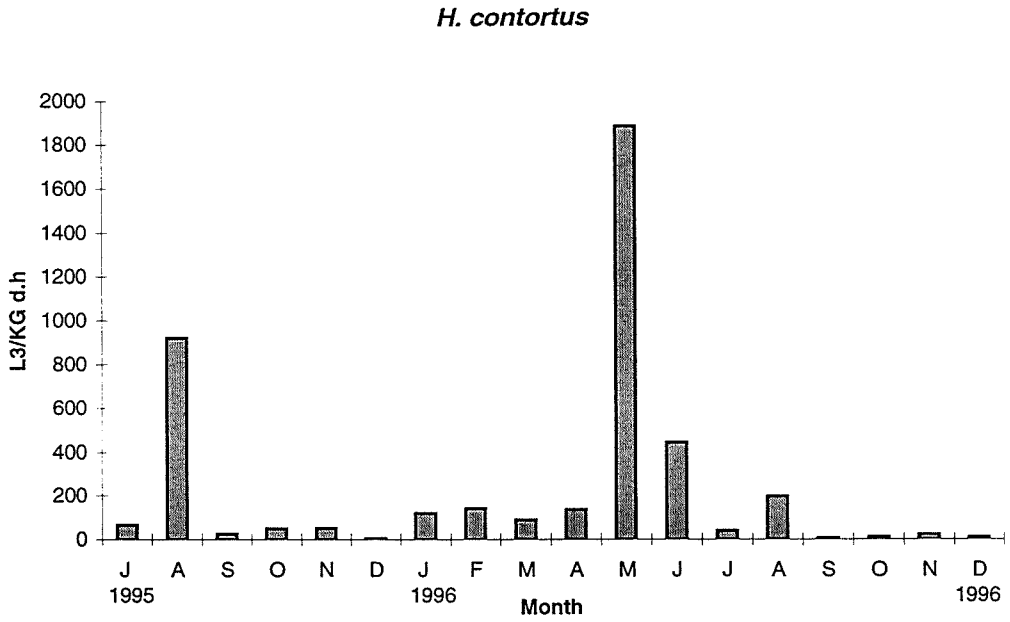


Figure 4.2 a. *Numbers of H.contortus larvae per kg of dry herbage*

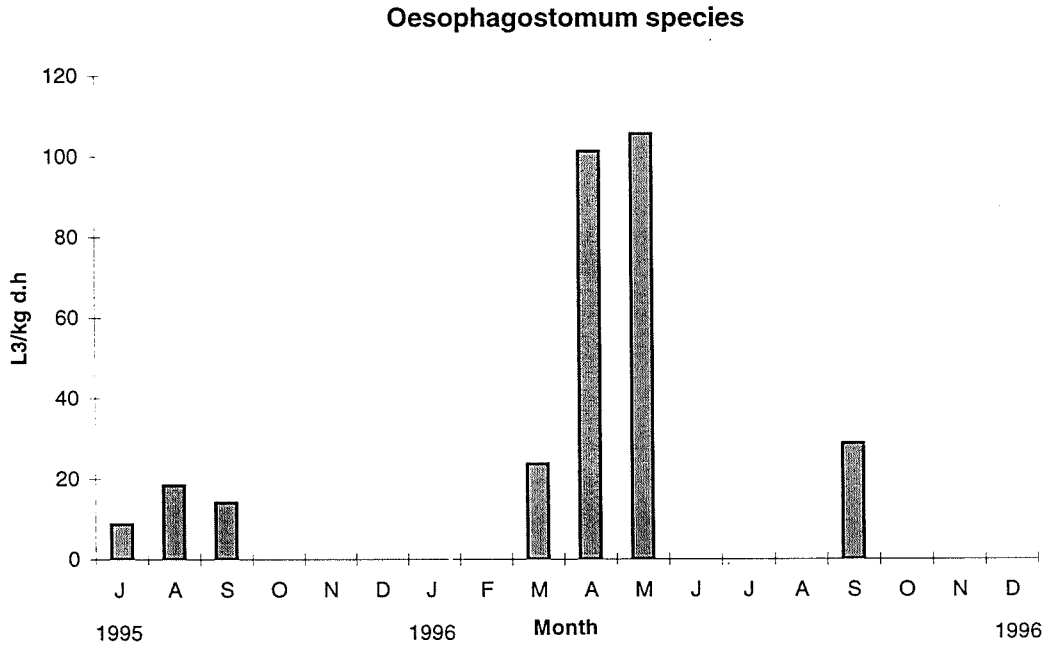


Figure 4.2 b. *Numbers of Oesophagostomum larvae per kg of dry herbage*

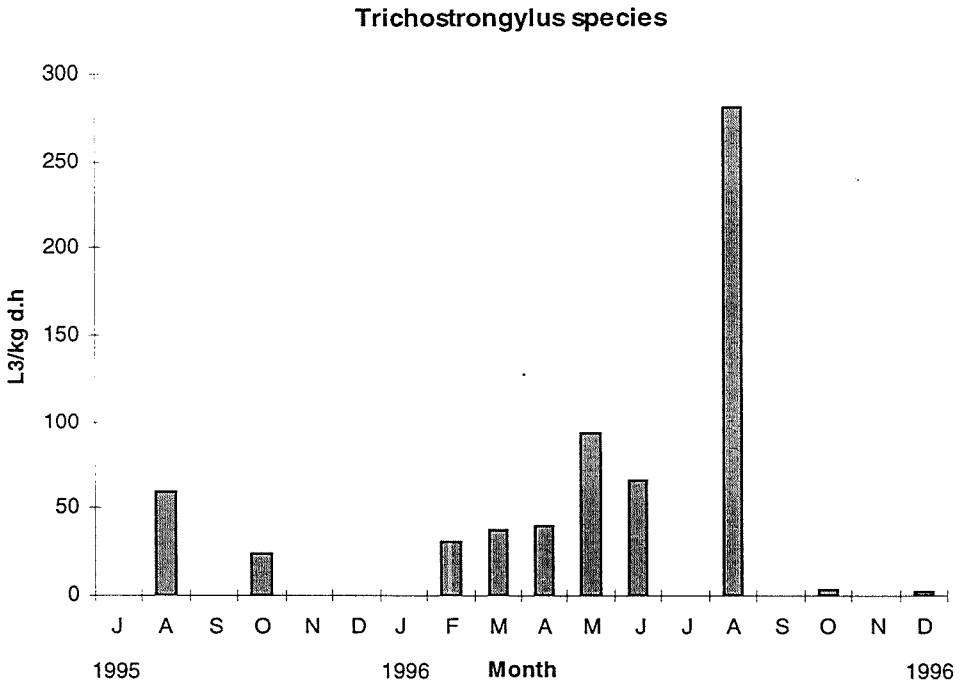


Figure 4.2 c. *Numbers of Trichostrongylus larvae per kg of dry herbage*

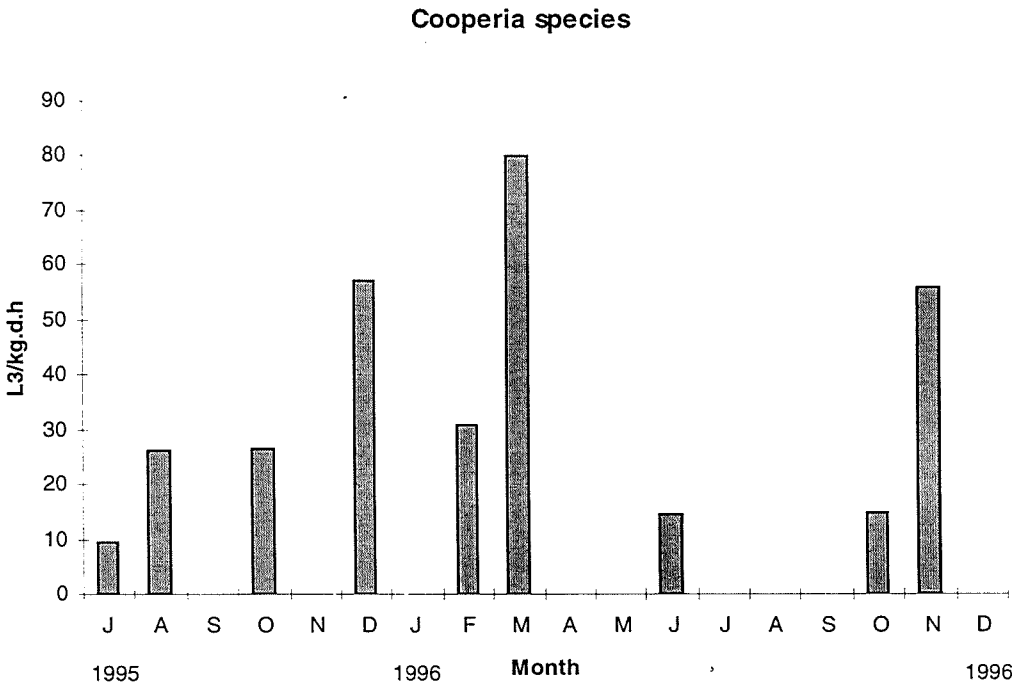


Figure 4.2 d. *Numbers of Cooperia larvae per kg of dry herbage*

4.3.3 Faecal egg counts for smallholder animals.

4.3.3.1 Nematodes

The strongyle egg count results for the first 4 months of the study are presented simply as species means, since during this period the animals had not been ear tagged and categorised into age groups. Initially the number of farms involved was 31 but when the ear tags were introduced 4 farmers opted out of the study. The results for the remaining part of the study are described on the basis of ruminant species.

4.3.3.2 Cattle

The monthly arithmetic mean EPG for calves and adults are plotted in Figure 4.3 and are shown (± SD) with data on the number of animals sampled in Table 4.1. The pattern of infection in calves was significantly higher than in adults (P= 0.001) although both age classes had peaks between April to June and September. The average EPG for calves for the whole study period was 694 (SD1009.0) while that of adults was 133 (SD 480.5). Statistical analysis also confirmed that there was a significant variation between farms (P=0.001).

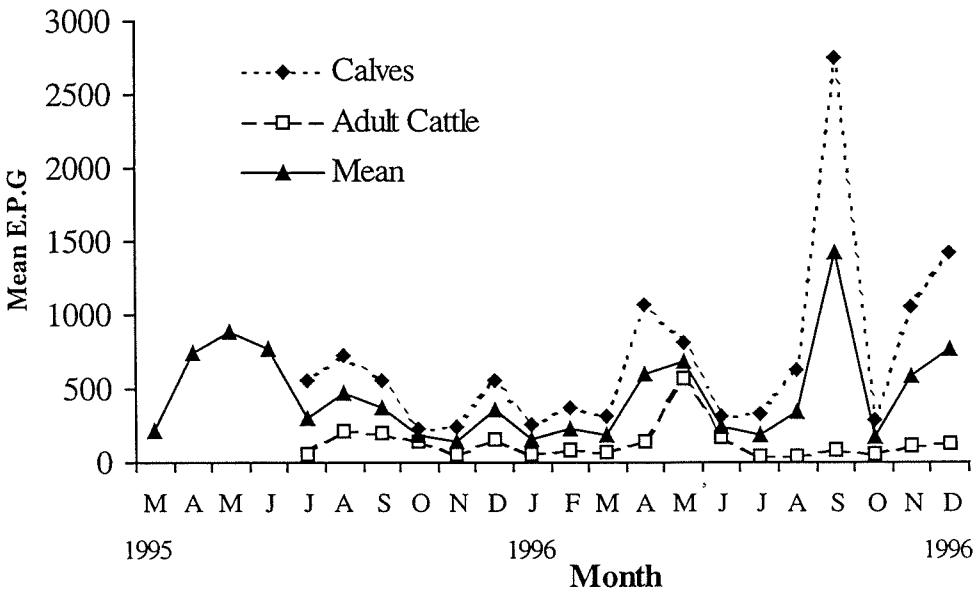


Figure 4.3. *Average faecal egg counts for calves and adult cattle*

Table 4.1 *Arithmetic mean EPG (±SD) for calves and cattle and number of samples.*

Month	No. of calves	Mean EPG (±SD) Calves	No. of adults	Mean EPG (±SD) Adults
July 1995	29	550.0 (1003.5)	111	57.4 (177.3)
August	23	721.7 (1543.9)	61	214.8 (578.7)
September	51	551.9 (1182.6)	124	199.2 (915.9)
October	26	225.0 (543.0)	95	140.5 (409.7)
November	31	242.1 (497.9)	95	53.4 (148.5)
December	38	559.0 (672.7)	107	150.9 (489.6)
January 1996	35	254.1 (416.7)	114	61.6 (175.1)
February	35	369.9 (578.3)	109	90.8 (290.4)
March	43	311.8 (625.0)	123	73.0 (177.3)
April	29	1066.7(2547.4)	120	145.7 (542.5)
May	13	815.4 (1471.9)	32	565.6 (1520.5)
June	33	308.6 (587.8)	116	175.4 (745.3)
July	28	324.5 (656.2)	127	37.1 (163.0)
August	27	635.3 (1132.4)	125	45.8 (203.2)
September	25	2762.5 (5318.4)	120	86.2 (268.0)
October	23	291.7 (546.8)	123	63.6 312.5)
November	20	1062.5 (922.6)	123	116.7 (336.2)
December	22	1433.3 (1575.0)	117	123.0 (514.3)

4.3.3.3 Goats

The monthly arithmetic mean EPG for kids and adult goats are plotted in Figure 4.4 and are shown (±SD) with data on the number of animals sampled in Table 4.2. On several occasions samples were obtained from only a small number of kids, too few to enable statistical analysis. Peak adult egg counts were seen in May to July and November to December. The overall arithmetic mean number of eggs per gram of

faeces for the adult goats was 1,006 (SD 2,138.8). Log transformed data showed that farm to farm variation in egg counts was significant (P=0.001).

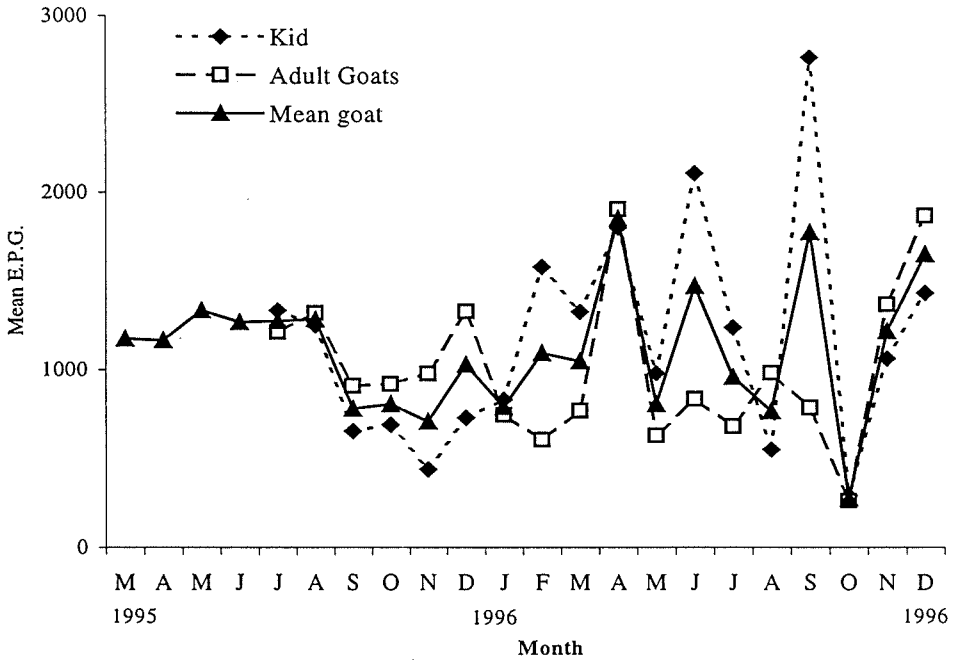


Figure 4.4 *Average faecal egg counts for kids and adult goats*

4.3.3.4 Sheep

The monthly arithmetic mean EPG for lambs and adult sheep are plotted in Figure 4.5. The data on the EPG (± SD) along with data on the number of animals sampled is shown in Table 4.3. Only small numbers of lambs were sampled during the study, insufficient to provide data for analysis. The mean EPG for the study period for the adult sheep was 1,331 EPG (SD 3,197.4) and there was a large between farm variation in egg count.

Table 4. 2 *Arithmetic mean EPG (±SD) for kids and goats and number of samples.*

Month	No. of kids	Mean EPG (±SD) Kids	Number of adults	Mean EPG (±SD) Adults
July 1995	3	1333.3 (1137.2)	69	1211.6 (1974.0)
August	6	1250.0 (1211.2)	37	1318.9 (2129.1)
September	11	654.5 (587.1)	72	908.3 (1398.0)
October	7	690.9 (1041.6)	55	919.6 (1200.0)
November	11	438.5 (697.1)	59	978.9 (1725.3)
December	10	730.0 (1089.4)	53	1328.3 (1811.6)
January 1996	14	831.2 (1044.1)	55	747.2 (1718.7)
February	5	1580.0 (3093.1)	58	606.9 (1504.4)
March	8	1327.3 (2337.1)	57	770.4 (1425.1)
April	3	1800.0 (2753.2)	64	1904.8 (3029.6)
May	2	980.0 (798.1)	29	630.8 (654.7)
June	10	2107.1 (3223.6)	63	835.6 (1495.0)
July	7	1237.6 (2077.7)	60	681.4 (1481.4)
August	5	550.0 (653.5)	58	982.5 (1263.1)
September	5	2762.5 (5318.4)	55	786.8 (863.6)
October	9	291.7 (546.8)	60	262.5 (442.1)
November	6	1062.5 (922.6)	59	1367.3 (3947.3)
December	11	1433.3 (1575.0)	57	1867.9 (4448.7)

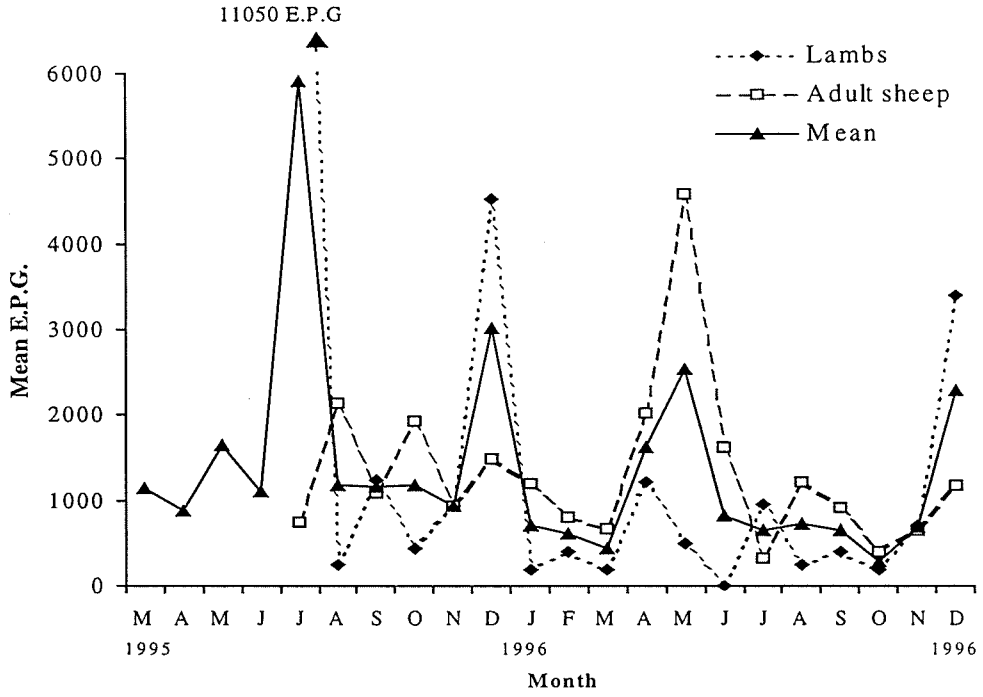


Figure 4.5 *Average faecal egg counts for lambs and adult sheep*

Table 4.3 *Arithmetic mean EPG (±SD) for lambs and sheep and number of samples.*

Month	No. of lambs	Mean EPG (±SD) Lambs	No. of adults	Mean EPG (±SD) Adults
July 1995	2	11050 (9263.1)	28	750.0 (878.8)
August	2	250.0 (353.6)	9	2133.3 (3036.0)
September	6	1250.0 (2455.8)	25	1096.0 (2169.6)
October	3	433.3 (750.6)	21	1936.4 (2040.2)
November	3	933.3 (642.9)	14	935.7 (1489.8)
December	3	4533.3 (4932.9)	20	1495.0 (1765.6)
January 1996	1	200	19	1211.8 (1643.1)
February	1	400	17	811.8 (1907.2)
March	1	200	15	661.9 (1007.7)
April	4	1225 (386.2)	23	2026.1 (4129.0)
May	3	500.0 (529.2)	10	4580.0 (12841.1
June	2	0(0)	24	1625.0 (6149.8)
July	2	950.0 (70.7)	24	333.3 (864.6)
August	2	250.0 (212.1)	19	1215.8 (1997.3)
September	3	400.0 (173.2)	21	909.5 (1728.6)
October	3	200.0 (346.4)	26	392.3 (632.4)
November	3	700.0 (755.0)	24	658.3 (1564.3)
December	3	3400.0 (1417.7)	28	1182.1 (2185.8)

4.3.4. Coproculture

The larval differential from bulk cultures for each species showed no evidence of any change in the proportion of larvae either between species or among sample times throughout the 21 months. The comparison of the larval identification between cattle and small ruminant cultures are shown in Figure 4.6 a-e and the details are shown in Appendix 4.3. The small ruminant data showed predominance of *Trichostrongylus* species throughout the study period, with peaks in periods of high rainfall in April to June and October to December, corresponding to the pattern seen

in the EPG. However, the cattle cultures showed *Haemonchus* as the predominant genera, followed by *Trichostrongylus*, with traces of *Cooperia* and *Oesophagostomum*. The small ruminants also had *Strongyloides* which was less evident in cattle cultures. The average for the whole study period are shown in Table 4.4

Table 4.4. *Mean differential larval identifications expressed as percentage of total*

NEMATODE	S.RUMINANTS MEAN (±SD)	CATTLE MEAN (±SD)
H.contortus	20.6 (28.7)	55.0 (81.4)
Trichostrongylus species	63.5 (36.0)	35.4 (39.3)
Oesophagostomum species	4.4 (15.0)	3.7 (12.9)
Strongyloides species	8.4 (20.4)	3.7 (16.4)
Cooperia species	1.1 (5.8)	2.2 (10.1)

4.3.5 Other genera in faecal egg count examination

The prevalence of positive samples are shown in Appendix 4.4 and the distribution patterns are shown in Figure 4.7 a-c. All genera were present in low amounts in all ruminant species.

4.3.5.1 Coccidia.

In calves the peak prevalence periods were March/April and September/October. In goats, the prevalence was similar in kids and adults, with peak values occurring in March 1996. In sheep noticeable numbers of coccidia were only seen between February and May.

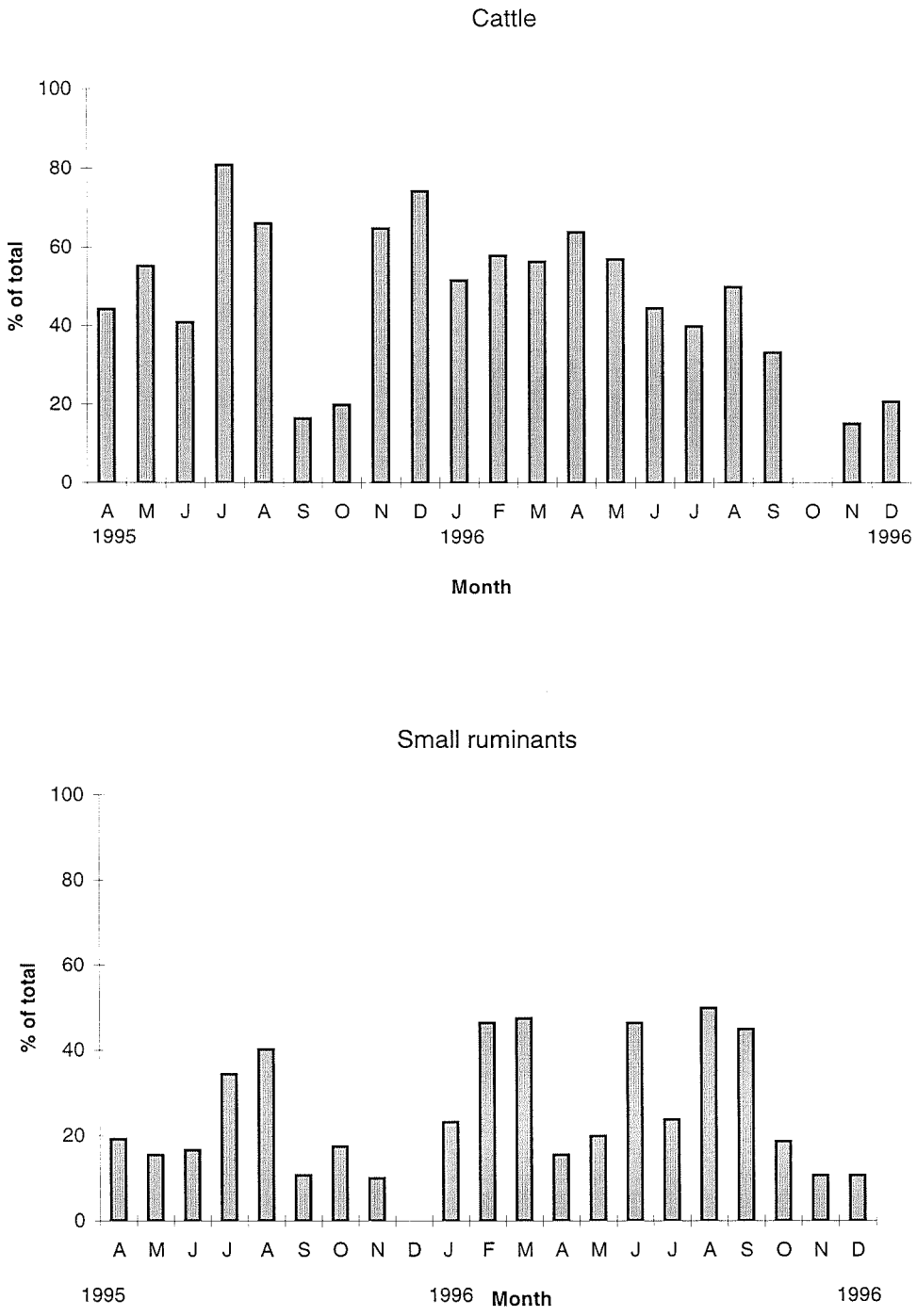
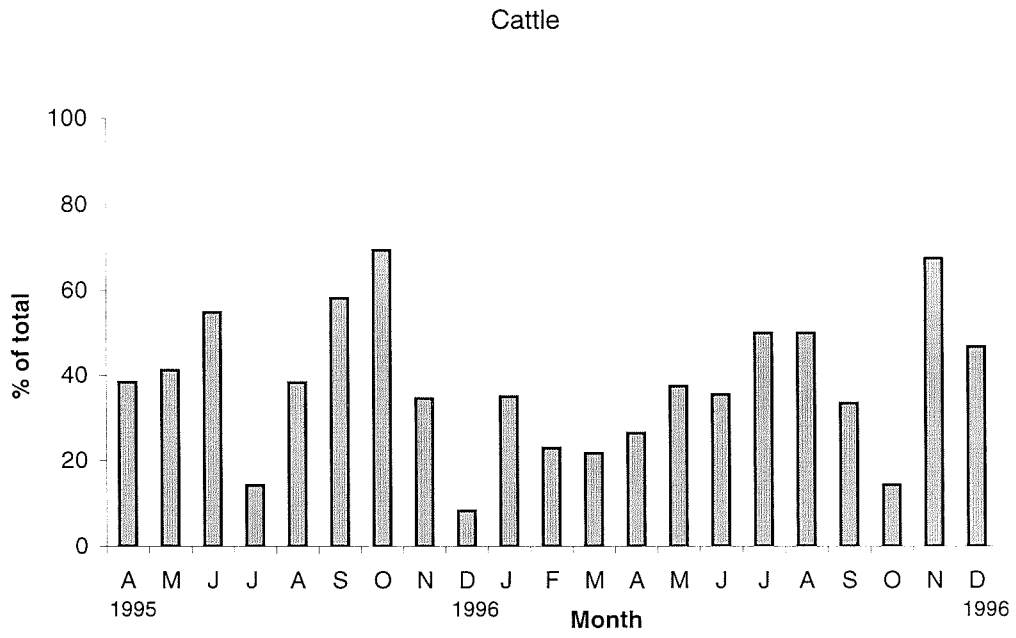


Figure 4.6.a *Percentage of Haemonchus larvae recovered from cattle and small ruminant coprocultures.*



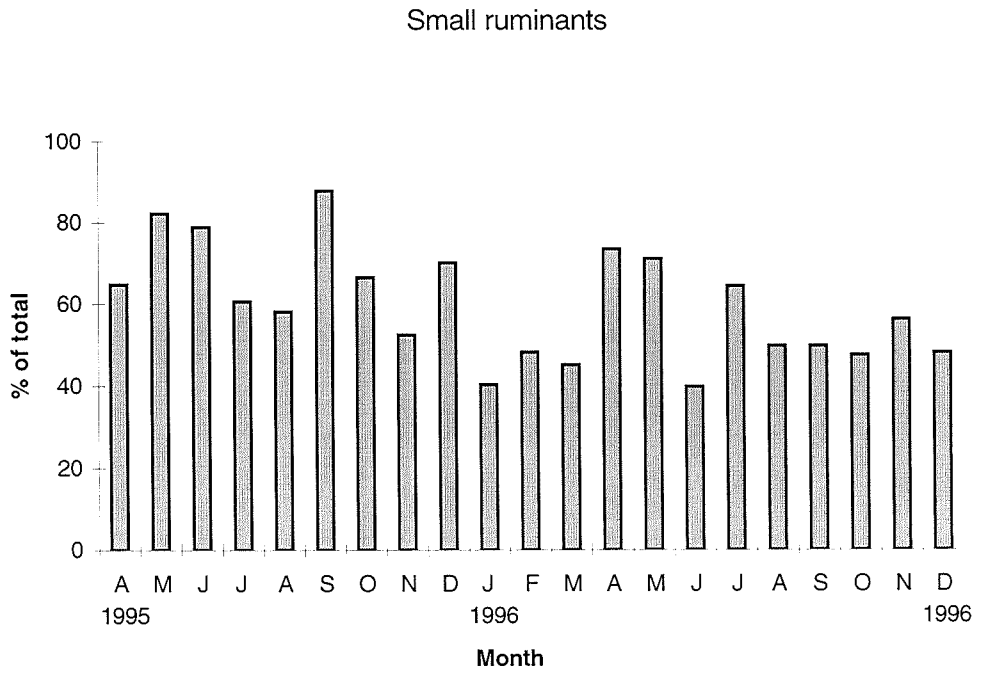


Figure 4.6.b *Percentage of Trichostrongylus larvae recovered from cattle and small ruminant coprocultures.*

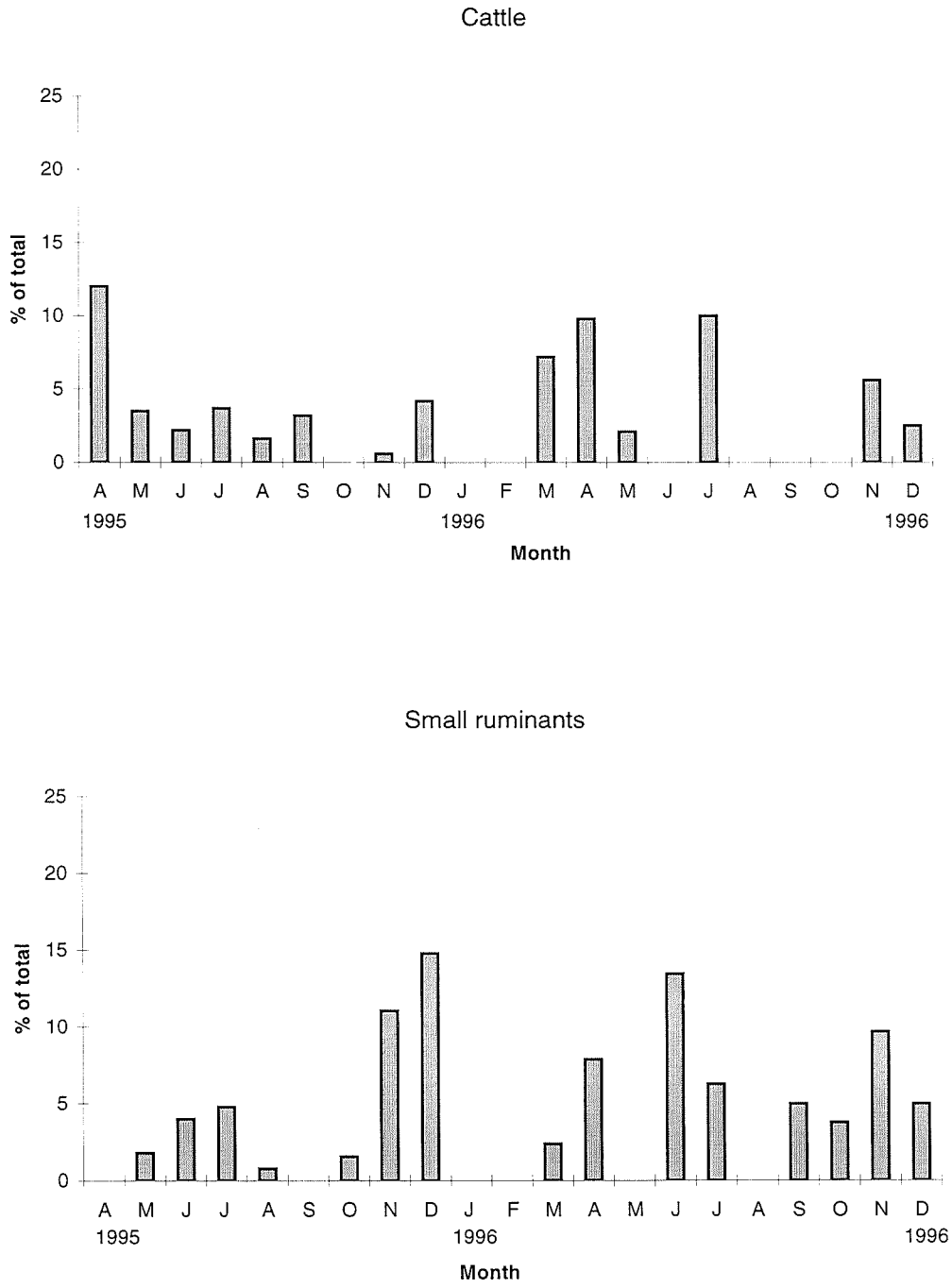
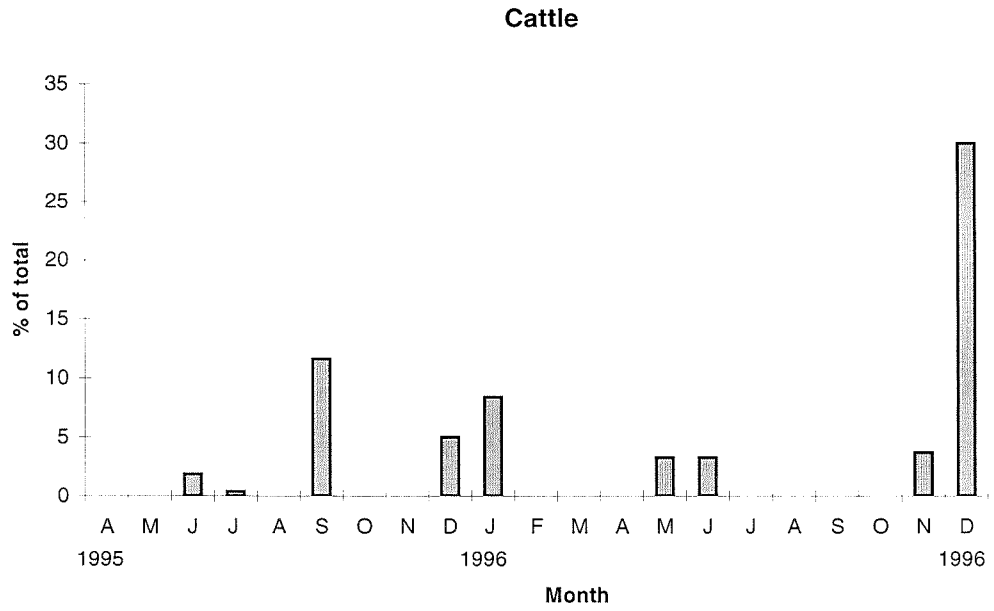


Figure 4.6.c *Percentage of Oesophagostomum larvae recovered from cattle and small ruminant coprocultures*



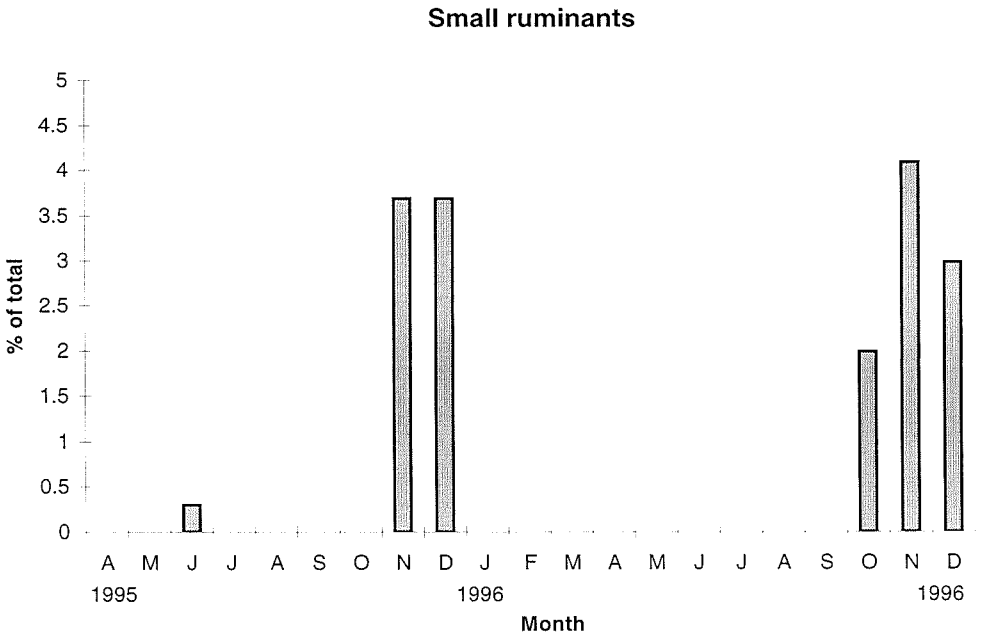


Figure 4.6.d *Percentage of Cooperia larvae recovered from cattle and small ruminant coprocultures*

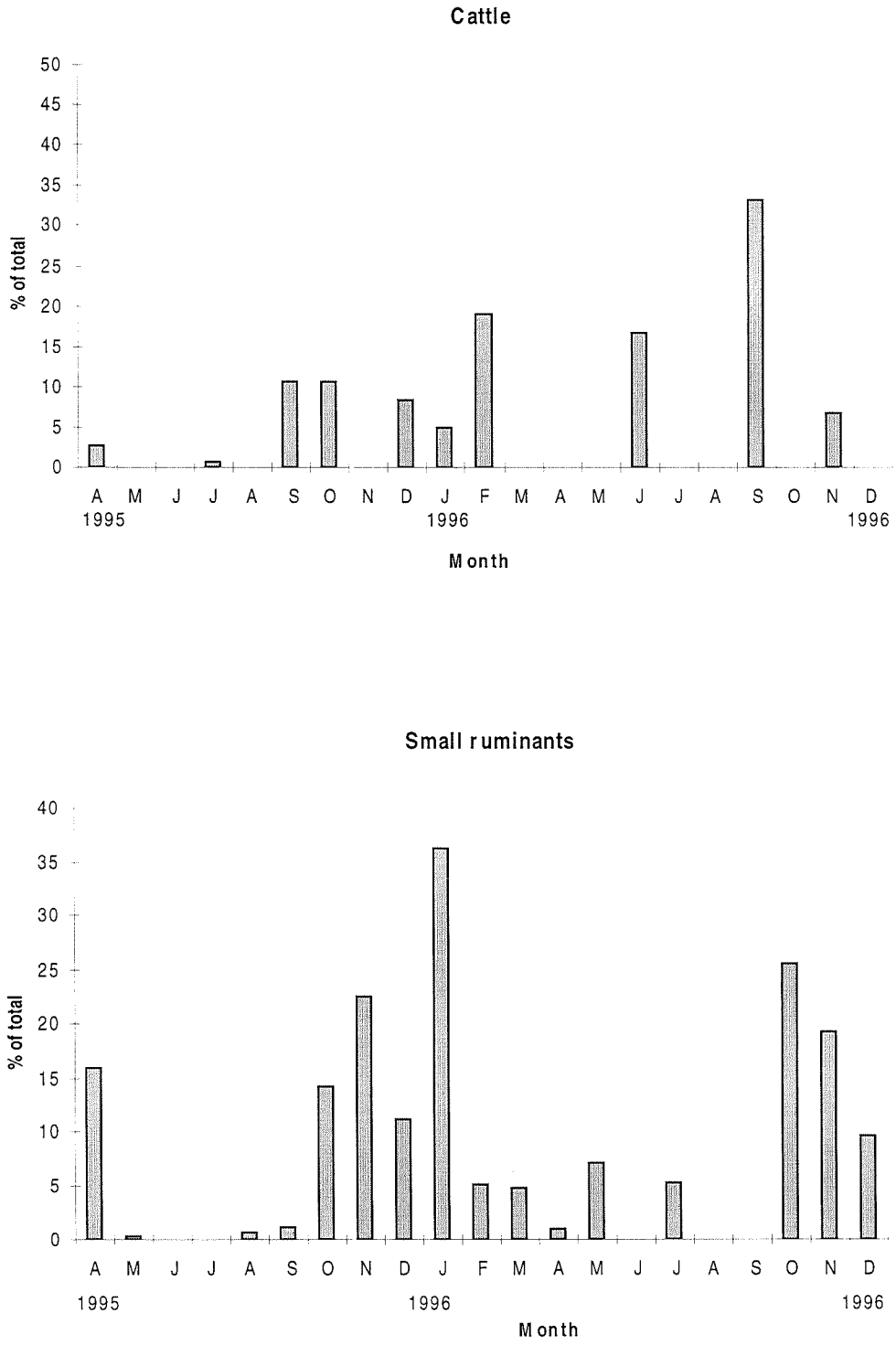


Figure 4.6.e *Percentage of Strongyloides larvae recovered from cattle and small ruminant coprocultures*

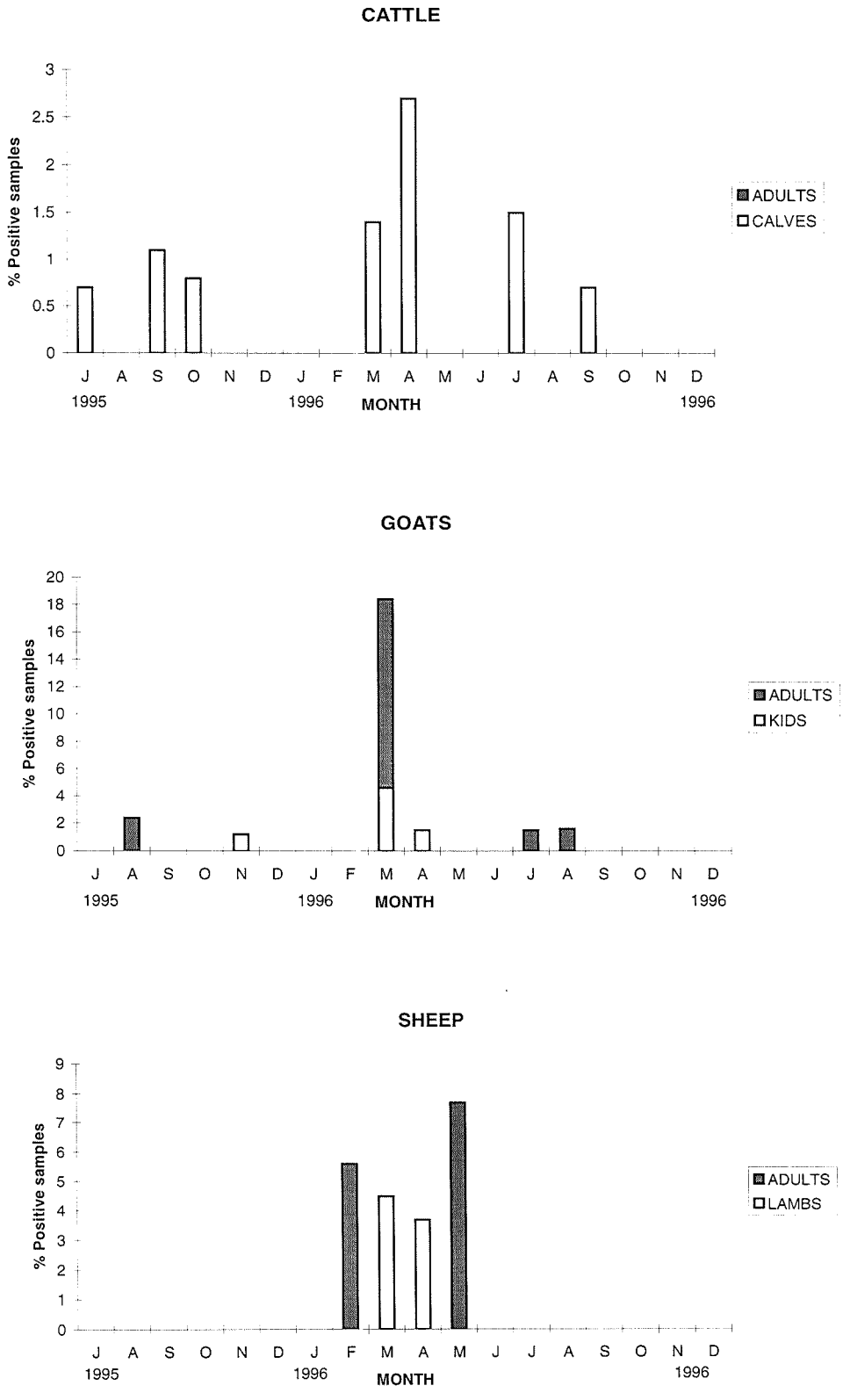


Figure 4.7.a *Percentage of cattle, goat and sheep samples in which Coccidia were recorded.*

4.3.5.2 Monieza

In cattle, *Monieza* was predominantly found in calves and appeared sporadically during the study. A similar prevalence pattern was evident in goats and sheep where infection was restricted to kids and lambs with no obvious seasonality. (Figure 4.7.b)

4.3.5.3 Nematodirus

Nematodirus infection was present in both age classes in all the ruminant species (Figure 4.7.c). *Nematodirus* infection was prevalent in goats, especially adults, where up to 20 % of the samples examined were positive. In cattle, the infection pattern was sporadic and similar to that seen in sheep. Lambs tended to shed more *Nematodirus* eggs, particularly during January and March to May.

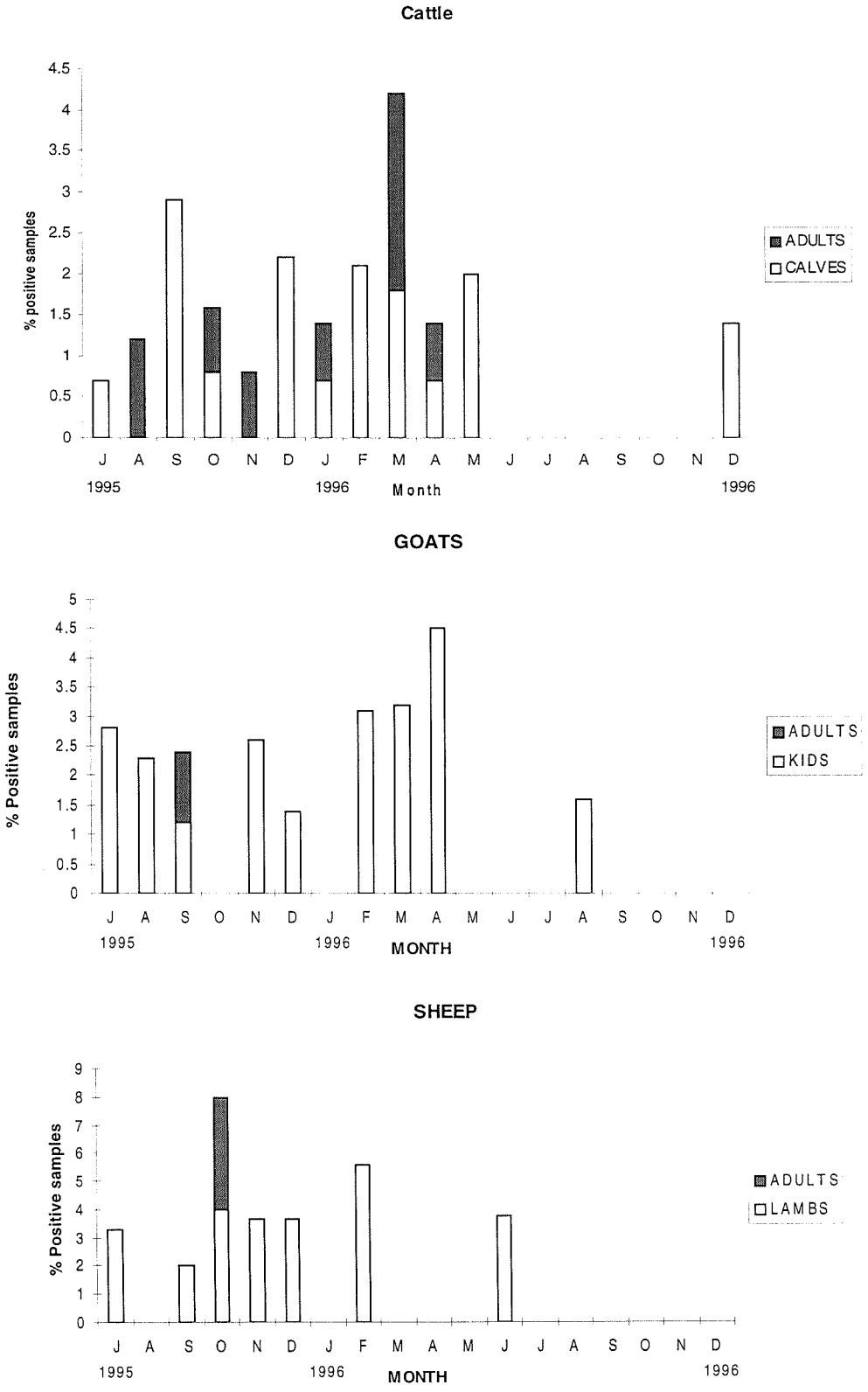


Figure 4.7 b *Percentage of cattle, goat and sheep samples in which Monieza were recorded*

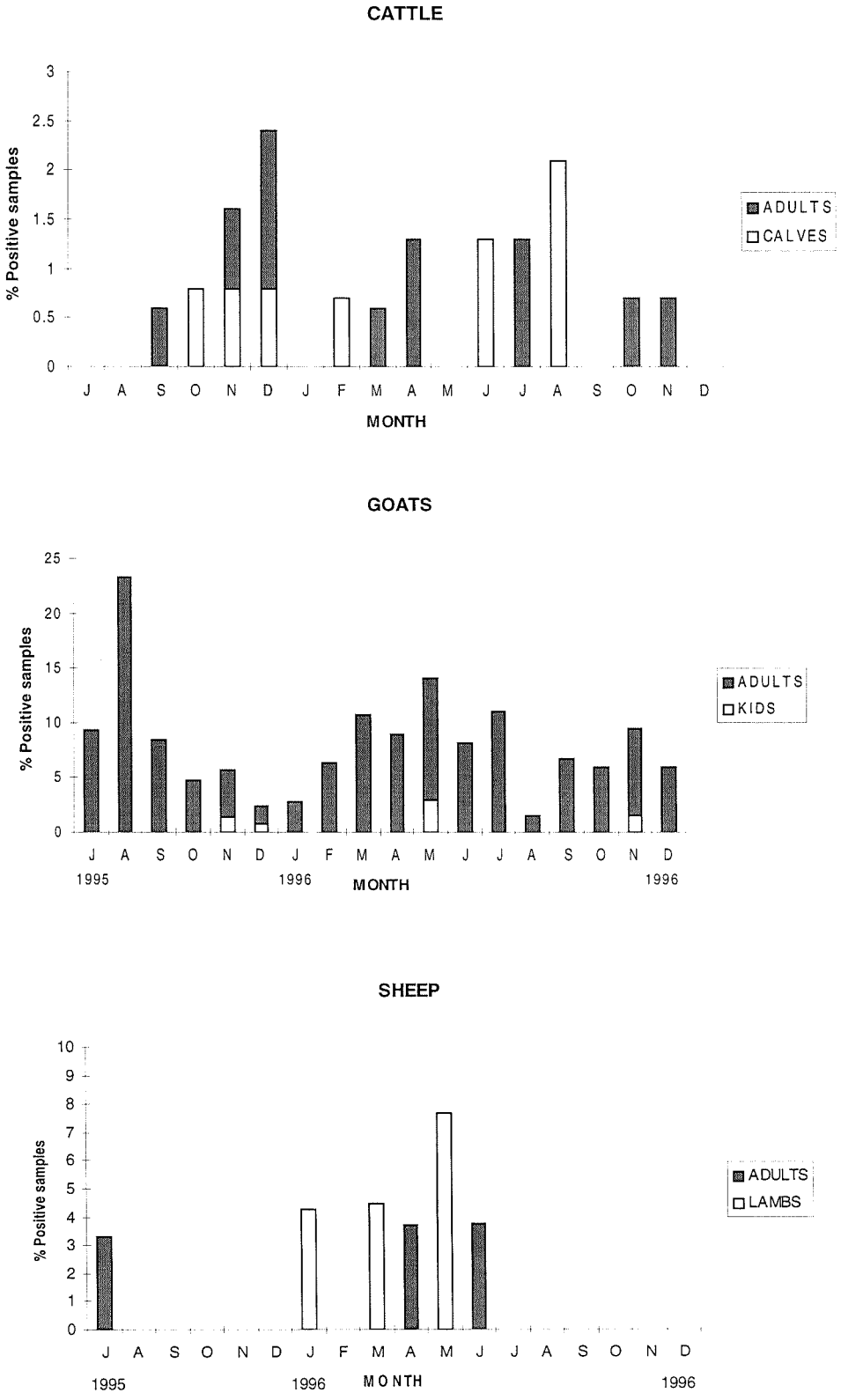


Figure 4.7 c *Percentage of cattle, goat and sheep samples in which Nematodirus were recorded.*

4.3.5.4 Trematodes

Full details of the monthly prevalence of trematodes are shown in Appendix 4.5. Figure 4.8 contains summary prevalence data for paramphistomes and *Fasciola* in cattle, goat and sheep faeces. The majority of farms had paramphistomes present in all animal hosts, but *Fasciola* were relatively rare, occurring on only a few farms usually in an animal newly introduced from outside the study area.

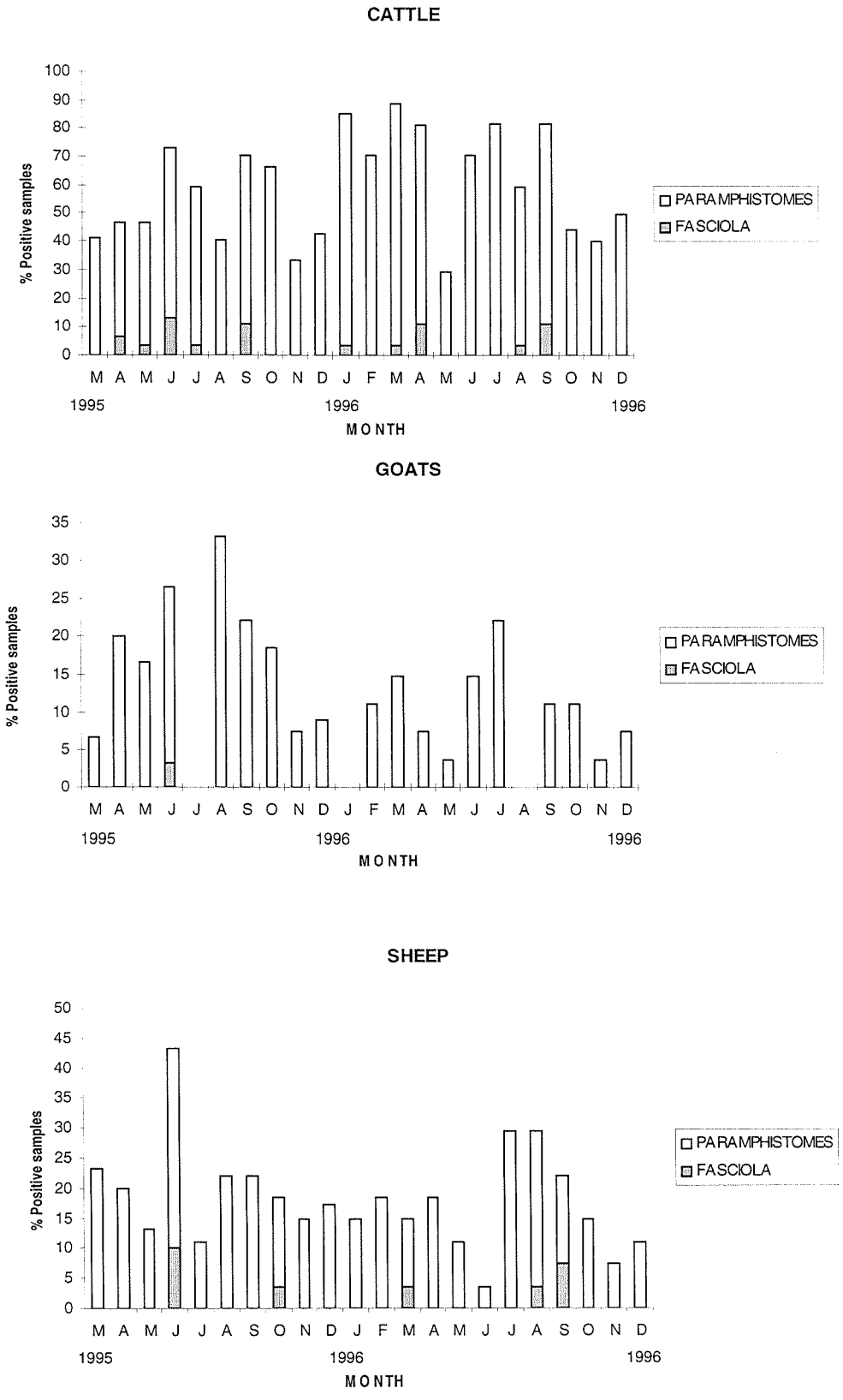


Figure 4.8. *Prevalence of Fasciola and paramphistomes in cattle, goat and sheep samples.*

4.3.6. Worm counts of tracer and purchased farm stock

Specific and total worm counts from individual tracer and permanent animals are shown in Appendices 4.6 and 4.7. Out of 120 Dorper lambs used as tracers, 5 died due to injuries, bloat or pneumonia. Four, out of 74 local sheep purchased to provide "permanent" data, died either in transit or shortly after arrival at NVRC. Specific tracer and permanent infection patterns for abomasal, small and large intestinal species are shown in Figures 4.9, 4.10 and 4.11

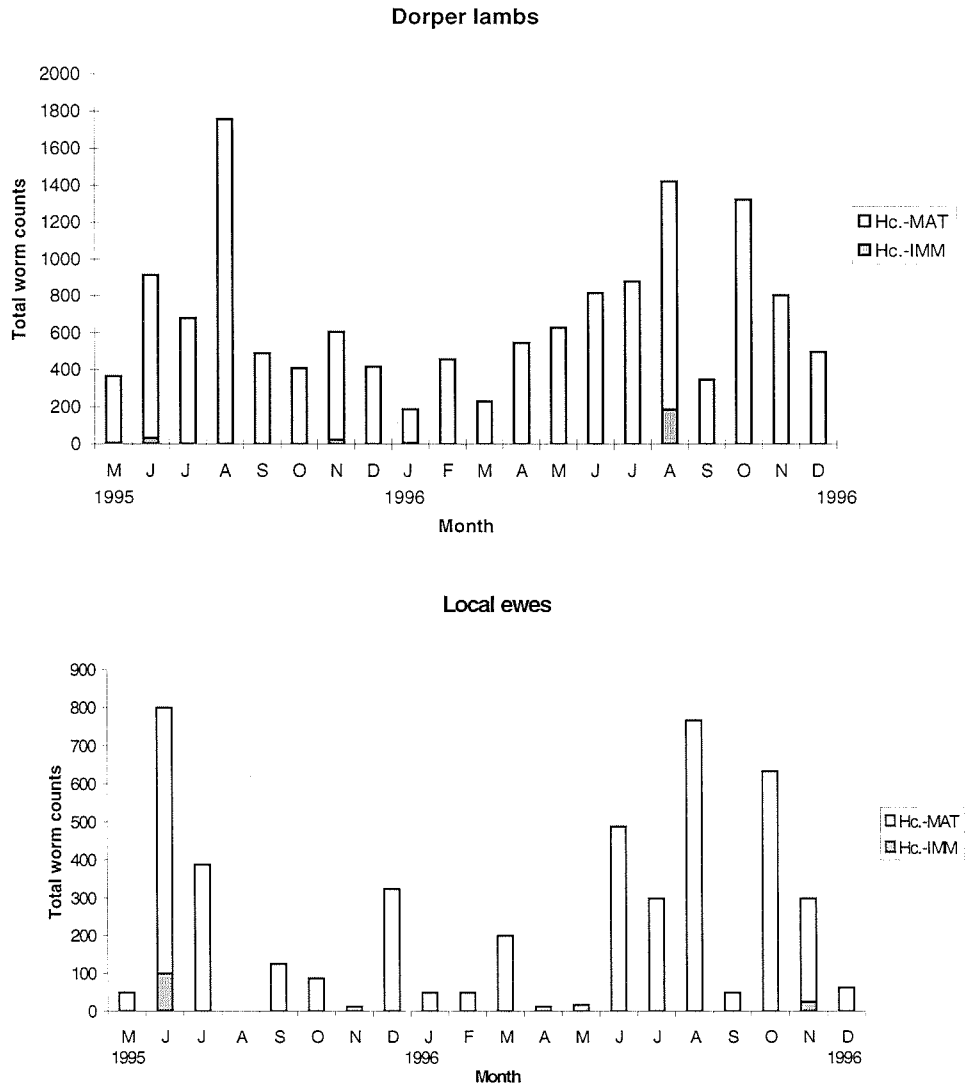


Figure 4.9 a *Pattern of abomasal infection in tracer and permanent stock Haemonchus contortus*

Key: Hc-MAT- mature *Haemonchus contortus*, H.c-IMM- immature .

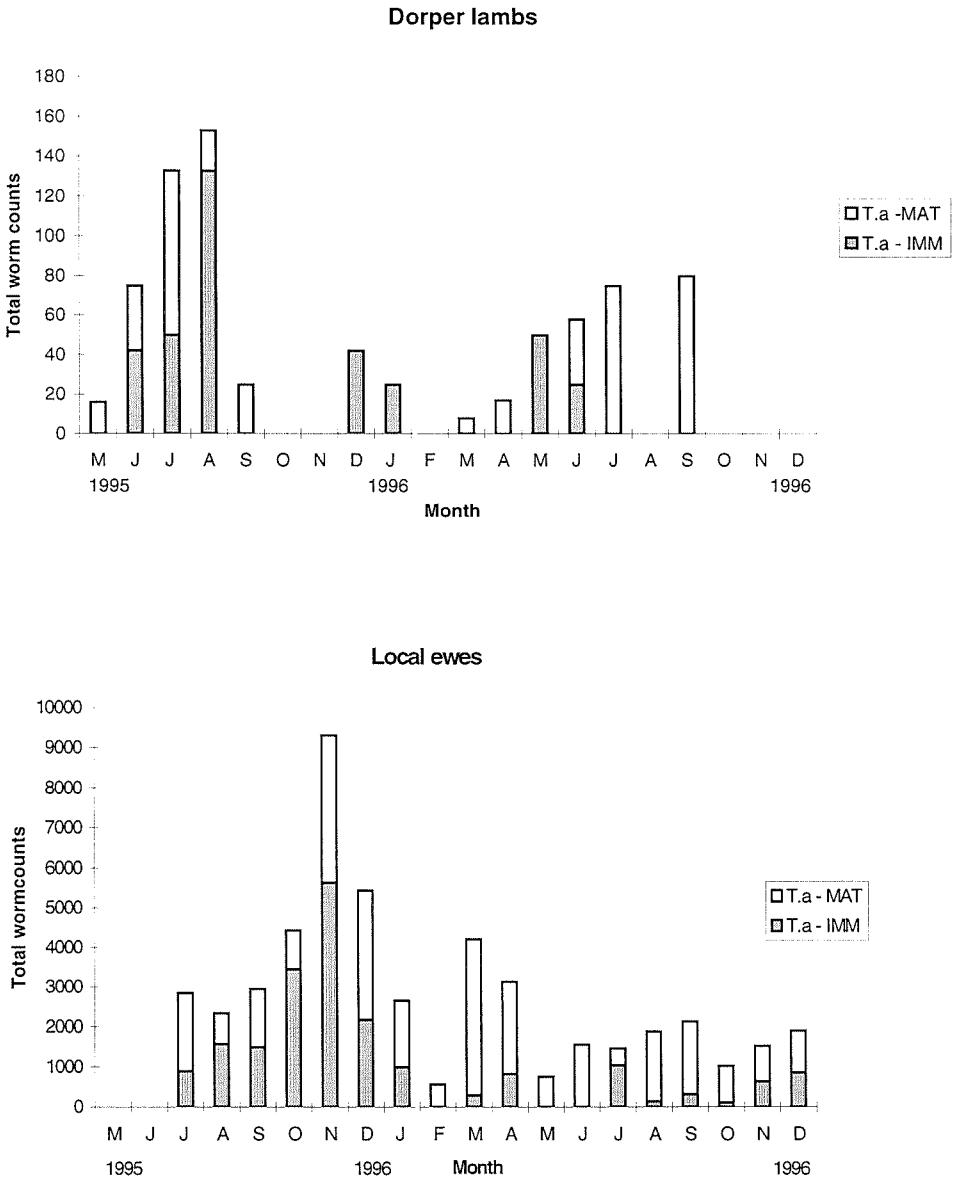


Figure 4.9 b *Pattern of abomasal infection in tracer and permanent stock Trichostrongylus axei*

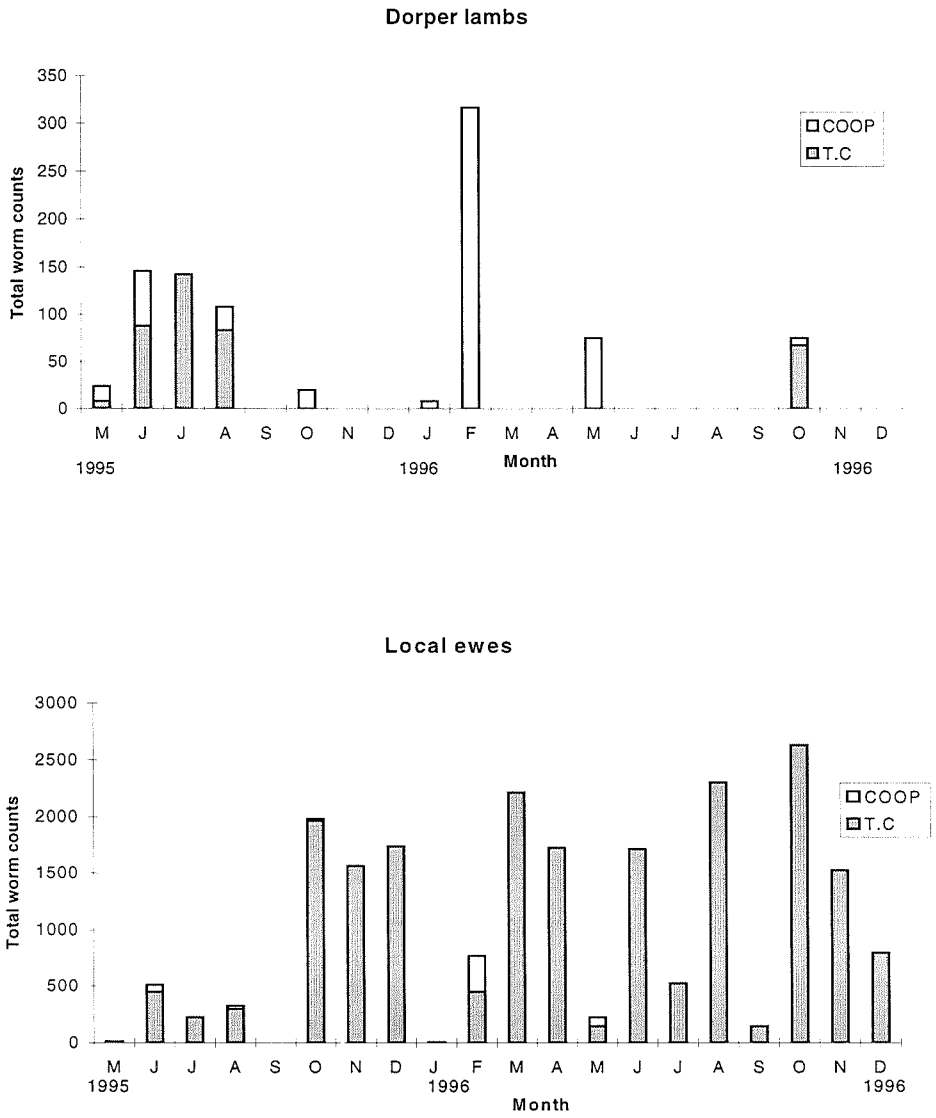


Figure 4.10 *Pattern of infection with small intestinal genera in tracer and permanent stock.*

Key: Coop- *Cooperia* species, T.C- *Trichostrongylus colubriformis.*

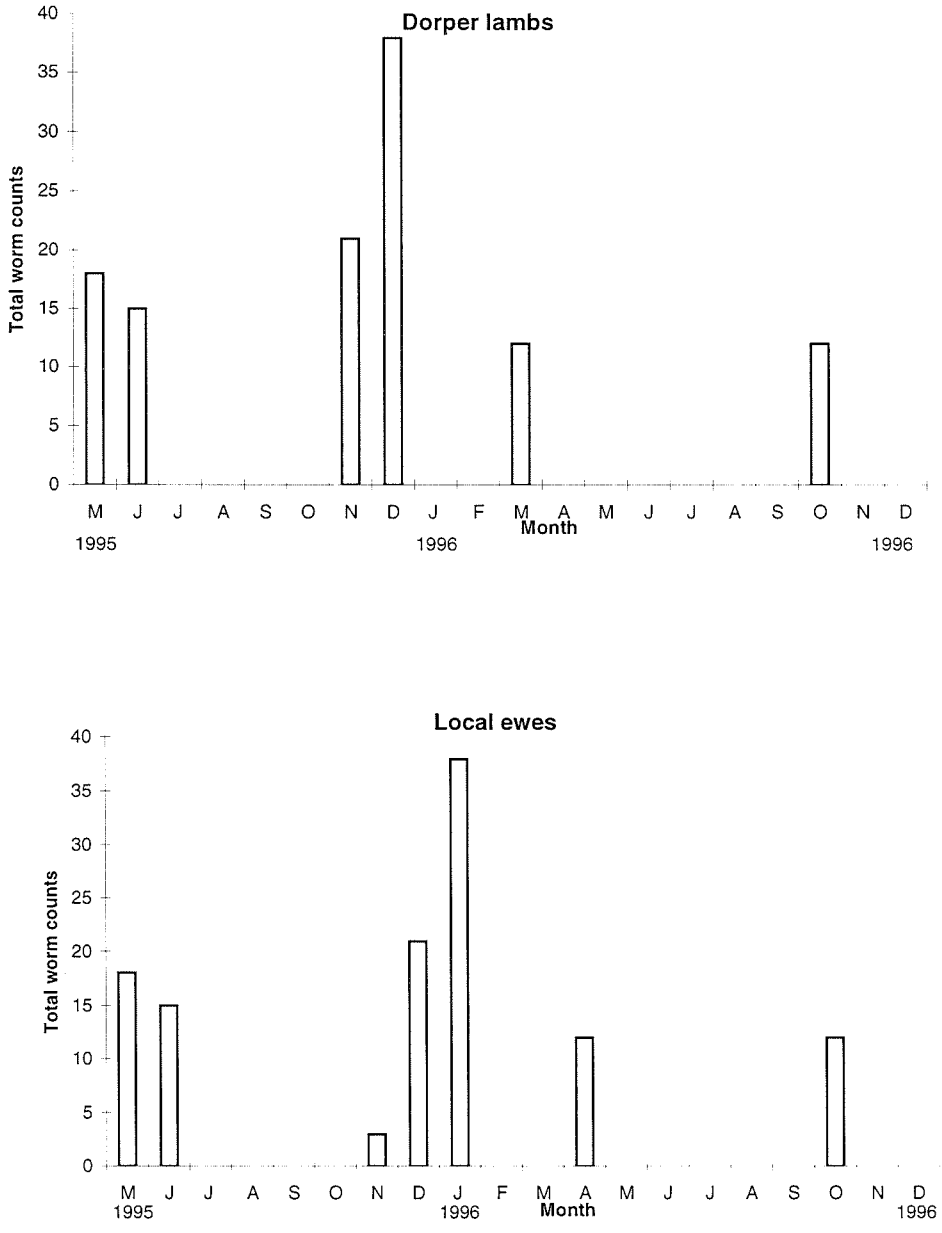


Figure 4.11 Pattern of infection with large intestinal genera in tracer and permanent stock

4.3.6.1. Tracer sheep

The tracers provided evidence of exposure to infection throughout the study period, particularly to *H.contortus,* where the average burden in tracer lambs was 690 and monthly averages ranged from a maximum of 1758 in August 1995 to a minimum of 183 in January 1996. Immature *Haemonchus* were rarely recovered from the tracer sheep, being recorded in small numbers on only three occasions. *T.axei* tracer counts were lower, only 50 % of the tracer samples had adult *T.axei* and

35 % had immature *Taxei.* However, immature *T.axei* were a notable feature in the burdens of tracer lambs accounting on average for 47.9 % of the total population. Most of the immature *T.axei* were fourth stage larvae rather than exsheathed third stage larvae.

Only 45% of the tracer samples were positive for intestinal species *Trichostrongylus* and *Cooperia. Trichostrongylus colubriformis* predominated in 5 of the 9 positive samples containing these small intestinal nematodes. Less than one third (6 from 20) of the tracer samples contained *Oesophagostomum* species and these only had small numbers of adult worms the minimum average burden being 12 and the maximum 38.

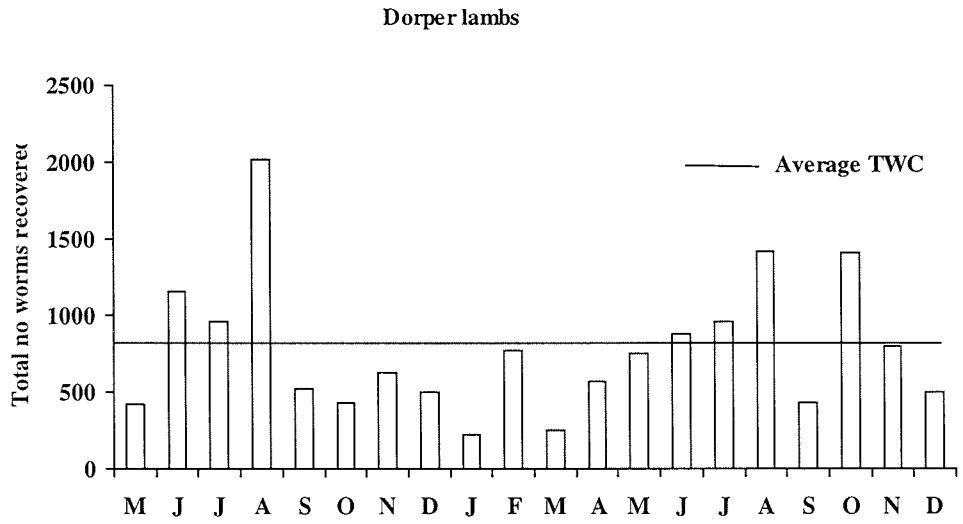


Figure 4.12 *Total worm burdens of Dorper lambs showing average worm count.*

4.3.6.2 "Permanent" sheep

In contrast to the tracers permanent stock carried very few *H,contortus*, on average having a mean burden of only 204 worms. Figure 4.13 shows the monthly average total worm burden. The predominant species recovered from locally purchased ewes (permanent sheep) was *T.axei* (average burden 2815) with an average burden of 1078 *T.colubriformis.* Ninety percent of the individual permanent sheep had *T.axei* burdens and 85 % had *T.colubriformis* adults. Immature *T.axei* accounted for 45.2 % of the average total population for this species.

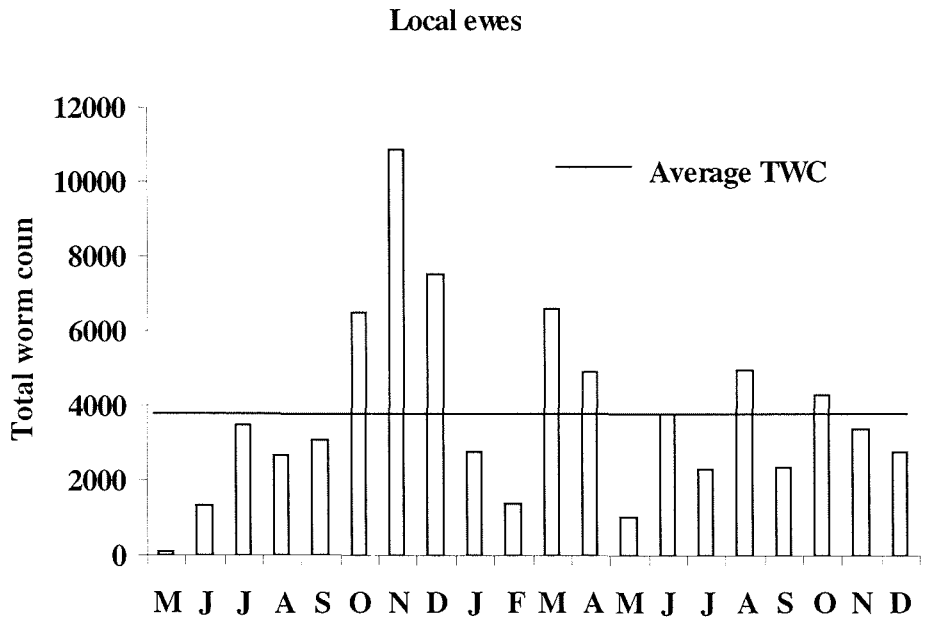


Figure 4.13 *Total worm burdens of permanent stock showing average monthly worm count*

Table 4.5 contains a summary of the mean recoveries of nematodes from the tracer and permanent animals for the study and Table 4.6 shows the results from statistical analysis comparing individual nematode infections between the two sets of animals.

Table 4.5. *Summary of the mean worm counts of tracer and permanent stock during the study period*

NEMATODE	DORPER TRACERS MEAN COUNTS (±SD)	PERMANENT STOCK MEAN COUNTS (±SD)
H.contortus-mature	690.0 (651.0)	204.0(355.0)
H.contortus-immature	12.2 (90.7)	2.9 (16.9)
T.axei-mature	21.7 (62.5)	1543.0 (2414.0)
T.axei –immature	20.0 (62.8)	1272.0 (2183.0)
T.colubriformis	21.7 (79.2)	1078.0 (1877.0)
Cooperia	25.0 (180.0)	86.0 (304.0)
Oesophagostomum	10.1 (26.6)	2.4 (9.5)

Table 4.6. *Statistical comparison between tracers and permanent stock*

WORM TYPE	ANIMALWITH HIGHEST LOAD	P-VALUE
H.contortus- mature	Dorper	0.00
H.contortus –immature	Dorper	0.29
T.axei- mature	Local	0.005
T.axei- immature	Local	0.005
T.colubriformis	Local	0.005
Oesophagostomum spp	Dorper	0.01
Cooperia species	Local	0.13

4.3.7 . Influence of climatic conditions on parasitological results

The results from analysis of patterns of egg output of the farm livestock in each species in relation to temperature, relative humidity and rainfall are summarised in Table 4.7. No relationship was evident between these climatic parameters and the coprological/larval culture data.

Table 4.7. *Relationship between climatic conditions and EPG of livestock*

Species	Condition	Comments
Sheep	Max temp.	No trend observed
	R. humidity	No trend observed
	Rainfall	No trend observed
Goats	Max temp.	No trend observed
	R. humidity	Some increase in log(EPG) with increasing humidity
	Rainfall	Some increase in log(EPG) with increasing rainfall
Cattle	Max temp.	No trend observed
	R. humidity	No trend observed
	Rainfall	No trend observed

4.4 Discussion.

This study has provided interesting data on the prevalence and seasonal incidence of different parasite species in smallholder cattle, goats and sheep grazing around Kericho. Despite the considerable between farm variation, patterns of infection seen in the pooled data from the smallholder farms still provided a useful insight into the population dynamics of ruminant gastrointestinal parasites. The introduction of roadside grazers as tracer animals proved to be a socially acceptable means of gathering data on the challenge faced by animals on common grazing. One of the risks inherent in conducting epidemiological studies in areas where there is

uncontrolled use of anthelmintics is that prevalence data and infection patterns may be modified by the application of anthelmintics. This risk was largely offset in the survey where accurate records of anthelmintic usage were obtained from the smallholder farmers. Although every effort was made to determine the origin and recent history of the purchased animals there was always the risk that recently administered anthelmintics may have influenced the degree and extent of infection recorded in permanent sheep.

One of the difficulties apparent in this study and demonstrated in Tables 4.2 and 4.3 was obtaining sufficient samples from young small ruminants. There were several reasons why this posed a problem, first any animal that had been given anthelmintic since the last treatment was not included that month to avoid biasing the data set. Secondly the small size of the youngest kids and lambs made it very difficult to obtain rectal samples and even when this was possible the sample sizes were often too small for use in the standard McMaster protocol. The need to follow a strict sampling schedule also contributed to the reduced number of samples since it did not allow time for animals that initially had no faeces in their recta to be re-sampled. For future studies the simplest possible solution to this fundamental problem appears to be simply to increase the numbers of animals included within the framework of the study. However, given the large between farm variation that was evident in this study, an alternative might be to seek improved sampling methods and FEC techniques that do not rely on large faecal volumes. It is clear that detailed information on the pattern of egg output and species prevalence in young small ruminants is only likely to be obtained from a dedicated study using these techniques and focusing solely on this age class of goats and sheep.

Grazing ruminants in the area appear to be exposed to infection with gastrointestinal nematodes throughout the year. There was no evidence that seasonal and/or climatological factors influenced the availability of infective larvae on pasture to such an extent that, at times, there was little or no challenge at grazing. Nor was there, with the possible exception of *T.axei*, any evidence that arrested development/inhibition was an important epidemiological component which enabled parasite survival during adverse climatic conditions. This situation differs from that in other ACZs in Kenya and in other surrounding countries where during the drier periods the challenge from pasture may be minimal (Gatongi, Scott, Ranjan,

Gathuma, Munyua, Cheruiyot, Prichard, 1997; Gatongi, Prichard, Ranjan, Gathuma, Munyua, Cheruiyot, Scott, 1998; Wanyangu *et al*, 1997b) and some species survive by arresting within the host (Chiejina *et al*, 1988; Eysker, 1981, 1993; Gatongi *et al*, 1998; Schad, 1977). The data from the coprocultures and the worm burdens of tracer and permanent sheep suggest that the predominant nematodes in both large and small ruminants are *Haemonchus* and *Trichostrongylus*. Short duration and abattoir surveys in Kenya have also shown *Haemonchus* and *Trichostrongylus* as the predominant genera (Mbaria *et a,l* 1995; Gatongi *et al*, 1987; Githigia *et al*, 1995, 1996). Other tropical studies in ruminants have shown a similar pattern of specific prevalence. A study on nematode infections in sheep in the Ethiopian highlands (Njau *et al*, 1990; Tembley *et al*, 1997), a cool tropical environment, showed *Trichostrongylus*, *Haemonchus* and *Dictyocaulus* to be the main parasites. In Zimbabwe, the most important species in cattle were *Cooperia, Haemonchus, Trichostrongylus* and *Oesophagostomum* (Moyo *et al*, 1996) while in the Gambia, Fritsche, Kaufman and Pfister (1993) showed *Trichostrongylus colubriformis*, *Oesophagostomum columbianum* and *H.contortus* as the predominant species in this region. In Malaysia's hot and humid conditions *H. contortus* and *Trichostrongylus* were the most important strongyles of sheep (Dorny *et al*, 1995).

In the Kericho district, *Haemonchus contortus* was the predominant species in the smallholder farmers' cattle, accounting on average for more than 50 % of the larvae identified in coproculture. *Haemonchus* was also apparently the commonest species on herbage since it was the predominant species in the pasture samples and accounted for 88 % of the total worm population recovered from the susceptible Dorper lambs used as tracers. Moreover it was the only parasite species recovered every month from pasture samples and from every batch of Dorper tracers. However, *Haemonchus* was not the predominant genera in small ruminant coprocultures or in the worm burdens recovered from locally purchased adult sheep where *Trichostrongylus* species predominated. In the small ruminant coprocultures to which adult animals were the major contributors, 63.5 % of the larvae recovered were *Trichostrongylus* species and 20.6 % were *Haemonchus*. In worm burdens recovered from locally purchased ewes *T.axei* larvae and adults accounted for 66 %, *T.colubriformis* for a further 27 % and *Haemonchus* for only an average of 6 % of the average total worm populations.

The differences in species distribution between the tracers and the permanent animals may be attributable to host resistance, the local ewes are Red Maasai crosses, a sheep breed acknowledged as being resistant to *Haemonchus* (Preston and Allonby, 1979; Mugambi *et a,l* 1997; Wanyangu *et al,*1997a). The locally purchased ewes may have been sold as cull animals and might therefore be expected to be in poorer condition and or suffering from other diseases, both of which could affect their resistance against nematodes (Armour, 1980). However as the worm burdens of these ewes shows this does not seem to have been the case as far as resistance against *Haemonchus* was concerned.

There were two interesting features of the epidemiology of gastrointestinal nematodes in ruminants in this region. Firstly there was a marked similarity in the responses of adult goats and sheep and an apparent lack of any pronounced age specific differences in susceptibility to infection in goats although this is based on a small number of samples. In adults of both small ruminant species, with only minor exceptions, the pattern of egg output was very similar with the faecal egg counts of the kids mirroring those of adult goats. Using the overall mean FEC data the calculated ratio of egg production in adults compared to juveniles was 1:1.16 (goats) compared to 1:5.2 (cattle). Studies in many temperate (Claerebout *et al,* 1998; Claerebout *et al,* 1999; Dorny, Shaw and Vercruysse, 1999; Gibson and Parfitt, 1972; Smith, Jackson, Jackson and Williams, 1985) and tropical regions (Schillhorn van, 1978; Sykes, 1994; Woolaston, 1992) have shown that young ruminant stock generally shed many more eggs than adults (Dineen, Gregg and Lascelle, 1978; Smith *et al,* 1985; Urquhart, Jarett, Jennings, McItyre and Mulligan, 1966), as was the case for the calves and adult cattle in this study. Calves in the current study passed significantly more eggs, on average almost four times as many as those shed by adults. Differences in parasite distribution between young and old animals are normally attributed to the acquisition and expression of immunity (Barger, 1987) with younger livestock generally requiring a prolonged period of exposure before being able to regulate their parasite populations.

The rate of acquisition of immunity appears to vary not only between different ruminant hosts but may also vary according to the species of parasite. Studies in Europe suggest that calves do not mount effective regulatory responses against some species until their second grazing season (Nansen, Gronvold,

Jorgensen, Henrikksen, Foldager and Sejrsen, 1989; Ploeger, Kloosterman, Rietveld, Berghen, Hiderson and Hollanders, 1994) but that at the end of their first grazing season most lambs may be capable of regulating some gastrointestinal nematode species (Waller & Thomas, 1981).

The pattern of faecal egg counts in this study suggest that SEA goat kids were possibly as capable of regulating faecal egg counts as adult goats. This apparent regulatory capacity in young small ruminants may be an artefact associated with year round breeding or may be accounted for by innate resistance and/or through the rapid acquisition of effective immunity. In tropical countries where breeding has no specific season then the impact on faecal egg counts of the youngest and most susceptible animals is less marked than that seen in countries where breeding is seasonal. Although this effect will almost certainly have occurred within this study, the potential contribution made by acquired immunity/innate resistance cannot be ignored. Changes that occur in specific resistance over time following exposure can provide useful evidence of acquired resistance, unfortunately the use of pooled coprocultures containing faeces from both young and adult animals in this study masked any age specific differences in parasite distribution. Moreover in the case of small ruminants, the use of pooled coprocultures masked not only age class differences but also any differences between host species.

There is evidence that Red Maasai sheep can mount rapid responses against *Haemonchus*, studies by Castellino (1976) and Preston and Allonby (1978) have shown worms being expelled within 15 days of infection. Studies using a susceptible breed of sheep, the Merino, have shown that resistance against *Haemonchus* is acquired more slowly (Barger 1987; Barger *et al*, 1985).

Previous comparative studies have shown that goats are more susceptible to infection with gastrointestinal nematodes than sheep (Chartier and Hoste, 1997; Jallow, McGregor, Anderson and Holmes, 1994; Huntley, Patterson, Mackellar, Jackson, Stevenson and Coop, 1995; Le Jambre and Royal, 1976; Le Jambre, 1984; Pomroy, Lambert, Betteridge, 1986). There are breed differences between local goat breeds in Kenya (Shavulimo *et al*, 1988, Baker *et al*, 1998) with the SEA goat being more responsive than Galla goats against gastrointestinal nematodes. The ability to regulate *Haemonchus* populations evident in SEA goats and Red Maasai cross sheep has presumably arisen through selection over time, possibly as a direct consequence

of the intense selection pressure that highly pathogenic species exert. In an environment where *Haemonchus* abounds, those animals with an ability to resist or tolerate haemonchosis have an obvious advantage. If such a trait is also heritable then over time one would expect indigenous stock to exhibit an increased tolerance and/or resistance to this species. There have been numerous studies demonstrating that responsiveness in sheep is a heritable phenomenon. Barger (1989) reported that estimates of heritability of resistance from various studies in sheep as 0.3-0.5 but less information exists on the heritability in goats. A study in Fiji suggested that the heritability of responsiveness against *Haemonchus* was negligible in goats (Woolaston, Singh, Tabunakawai, Le Jambre, Banks, Barger, 1992), however studies in Europe using cashmere goats suggest that responsiveness against *Teladorsagia* and *Trichostrongylus* is a heritable phenomenon (Patterson, Jackson, Huntley, Stevenson, Jones, Jackson and Russel, 1996).

One weakness of the current study was the use of sheep as tracer animals in an area where goats were the predominant small ruminant. Anticipated herding and handling difficulties prevented the use of goats as tracers in the area, however it is possible that differences in grazing behaviour and parasite uptake and establishment may mean that the two species would produce very different results if used together as tracers. For these reasons it was necessary to compare these animal species as tracers in a controlled study.

Although permanent sheep and goats had the ability to regulate their *Haemonchus* populations there was little evidence of a similar ability as far as *Trichostrongylus* was concerned. Populations of abomasal and intestinal *Trichostrongylus* reached peak levels during the last two to three months of the year. In the case of *T.axei* the maximum average total burden of over 9000 worms occurred in ewes killed in November 1995 with burdens also averaging in excess of 4000 worms in the preceding and following months and in ewes killed in March 1996. For *T.colubriformis* the peak average worm burden of more than 2000 worms was found in ewes killed in October 1996. These peak *Trichostrongylus* burdens were more than 11 times (*T.axei*) and 3 times (*T.colubriformis*) greater than the peak *Haemonchus* population recovered from the ewes. The fact that relatively large numbers of inhibited third stage or retarded fourth stage larvae were seen in both the permanent ewes and the Dorper tracers is interesting. Since they were present in both

susceptible and experienced animals it seems reasonable to assume that this inhibition/retardation is probably not associated with the expression of specific immunity, but may be a specific feature of the local *T.axei* populations or be induced by environmental factors affecting either the supra- and/or infrapopulation.

Comparison between the monthly worm recoveries from the Dorper tracers and the local ewes suggests that the *Trichostrongylus* burdens must have accumulated over several months. The average *T.axei* and *T.colubriformis* populations recovered from Dorper tracers were 38 *(T.axei)* and 19 *(T.colubriformis)* compared to average monthly burdens of 2,517 and 1,021 recovered from the ewes. For *Haemonchus* the situation was reversed the Dorpers having accumulated on average 691 *H.contortus* whereas the local ewes had an average burden of only 236 *H.contortus.* This difference suggests not only that the ewes could regulate their *Haemonchus* populations but also that this regulatory mechanism was specific since it did not apparently affect the recruitment and persistence of the other abomasal parasite *T.axei.* Given the relatively low average *Trichostrongylus* burdens recovered from the Dorper tracers which were some 50-60 times lower than the average burdens in permanent ewes it seems reasonable to suggest that some threshold dependant mechanism of the type first described by Dineen (1963) may have been in operation. In this type of mechanism immunoregulation would only occur in experienced animals if the parasite challenge or burden exceeded some antigenically mediated threshold value. This type of model, which allows for regulation of an abundant species, appears to offer a reasonable explanation for the specific differences in prevalence between tracer and permanent livestock.

As Figure 4.1 shows Kericho enjoys a relatively stable climate with some rainfall occurring throughout the year and only modest annual temperature fluctuations. Given that background it is hardly surprising that climatological factors exerted only a minimal effect on the patterns of infection, analysis showing that increasing rainfall and relative humidity were associated with an increase in the egg counts of goats. Controlling disease caused by nematodes on smallholder farms obviously offers a means of improving performance and hence economic yield. There are a number of limitations which reduce the options for control in the region, firstly there is little opportunity for using grazing management to limit exposure to infection on land under communal control. Improving host resistance to parasites

through genetic selection requires scientific services that are either not available or may be too expensive for the farmers to fund. Technologies currently under development such as vaccines (Emery, 1996; Miller, 1996; Newton, 1995; Smith,1993, 1999), nematophagous fungi (Larsen, 1999; Larsen *et al*, 1997; Padilha, 1999; Waller, 1993b; Waller and Larsen, 1996) and anthelmintic boluses may, when released, prove to be too expensive for smallholder farmers. The small scale farmers may however be able to afford to adopt limited chemoprophylaxis using the currently available anthelmintics. Suppressive anthelmintic regimes do not appear to be a feasible sustainable option for the region given the prevalence of anthelmintic resistance in Kenya and the financial limitations of the farmers.

It is generally accepted that sustainable chemoprophylactic control of nematodoses requires a detailed understanding of the epidemiology of those species of nematode implicated in the disease. An improved understanding of host and parasite biology and the seasonality of challenge from pasture, the susceptibility of livestock and contamination rates is also vital since it enables some precision in the timing of treatments. Studies in temperate climates have used this information to develop highly effective treatment regimes, such as dose and move (Armour, 1974, 1980; Eysker, Kooyman, van Amerogen, Kremer and Lam, 1997; Eysker, van Aar, Boersema, Dop and Kooyman, 1998; Michel, 1969, 1976). Nematode infections in small ruminants in temperate and sub-tropical climates often follow well defined patterns, largely due to the effects of seasonal breeding which provides a crop of susceptible stock (lactating adults, young ruminants) at the same time each season and to temperature changes which affect the development/translation and survival of the free living population. The patterns of infection in this study where ruminants bred throughout the year were less clear, particularly for small ruminants. In the tropics where temperature is rarely a major constraint on the development of eggs and larvae, the critical element is the availability of moisture in the faeces (Berbigier, Gruner, Mambrini and Sophie, 1990) and on herbage (Gruner, Berbigier, Cortet and Sauve, 1989; Besier and Dunsmore, 1993). The stable pattern of rainfall during the study clearly had relatively little impact in limiting development and translation of infective larvae and consequently animals faced some degree of challenge throughout the year. The tracer data shows that the challenge from pasture was above average in

June, July and August 1995 and June-August and October 1996. To some extent the data on challenge from pasture is in accord with the faecal egg count data.

For calves, whose egg counts were some five times greater than adult counts, the peak egg counts occurred in April to May each year with lower peaks in August. It would appear that strategic anthelmintic treatments aimed at improving performance should focus on calves, rather than adult cattle, as suggested by the farmers in the cross-sectional study and be given to reduce these peaks in egg output.

Patterns of contamination laid down by small ruminants showed relatively small differences between adults and young stock. Kid faecal egg counts exceeded the average in July and August 1995 and in March, June, July, September and December 1996. Adult goat counts exceeded the average in July, August and December 1995 and April, November and December 1996. For lambs the counts were above average in July and December 1995 and December 1996 while comparable months for adult sheep were August and October 95 and April 1996. Since the differences between the egg counts of young and adult small ruminants were less marked the targets and timing of strategic treatments for small ruminants is more complex. Benefits might be expected from treatments given to minimise the peak egg counts that occur around July to August and December. Clearly there is a requirement for a study examining the benefits of chemoprophylaxis for smallholder farmers in the region.

The other non-nematode phyla identified in the livestock faecal egg counts were not apparently associated with disease on the farms. One notable feature of the study was the low incidence of *Fasciola* infection in all ruminants, although there was a high incidence of paramphistome infections on all of the farms involved in the study. This was in agreement with the VIL data but the result for cattle *Fasciola* infection was lower in the present study than that of the VIL data since these were sourced from a smaller area than that covered by the laboratory. Cheruiyot and Wamae (1988a) reported that fascioloses was a problem to the east of Kericho municipality in Londiani area and to the south around the Sotik highlands. Although farmers and extension staff often treat animals for fascioloses this is certainly done without any laboratory confirmation. The presence of paramphistomes in all ruminant species throughout the study are attributed to the presence of intermediate host snails (*Bulinus tropicus*) in the area (Dinnik, 1954). Dinnik (1964b) stated that

all cases of paramphistomiases in Africa was caused by *Paramphistomum microbothrium* and that infected snails shed cercariae for up to 1 year (Dinnik, 1954). In the study area, no farmer or extension workers considered this condition of any importance in fact some farmers thought that this was a normal occurrence in animals especially cattle.

This study has provided useful baseline data on the population dynamics of the common parasites in the Kericho area which can be used in the development of control strategies and, through the extension services, to implement improved husbandry techniques, both of which may help smallholder farmers to maximise ruminant performance.

CHAPTER 5

Investigation of anthelmintic resistance in goats and the quality of drugs marketed in the Kericho area.

5.1 Introduction

Anthelmintic resistance is now a worldwide phenomenon particularly in goats (Jackson, Rugutt, Jackson, Coop and Russel, 1993, Waller *et al*, 1995, 1996, Condor and Campbell, 1995, Coles, 1998). There are several reasons why the selection of resistance appears to occur rapidly in goats. First they mount relatively poor immune responses against gastrointestinal nematodes and thus are often treated very frequently. Frequent treatments are thought to select strongly for resistance since they offer a considerable advantage to homozygous resistant individuals within the population. The recommended dose rates for goats are often the same as those for sheep, whereas studies suggest that they should in fact be higher (Hennessey *et al,* 1993, Gillham and Obendorf 1985, Coles *et al,* 1989, Sangster *et al,* 1991). Oesophageal groove closure also appears to occur more often in goats (Sangster *et al,* 1991, Scott *et al,* 1991) which may influence drug uptake and metabolism which also appears to occur more rapidly in goats than in sheep. For these reasons internal parasites may receive a sub-optimal shorter exposure to the drug. Underdosing has been recognised as an important factor in the selection of resistance since it enables the survival of heterozygous resistant individuals.

A recent investigation (Wanyangu *et al*, 1996b) showed the presence of anthelmintic resistance on some large scale farms carrying both goats and sheep in the Kericho highlands. Since these farms supply animals to the small scale farms in the area it seemed prudent to investigate anthelmintic resistance both on the smallholder and on some of the large scale farms in the area. Given that goats are the predominant small ruminants in the area, the study on anthelmintic resistance was solely restricted to that species. The indication from local extension staff, veterinarians and farmers (Chapter 3) was that the main drugs in use in the area belong to the imidazothiazole family and that farmers made little or no attempt to rotate between the drug families.

The secondary objective was to investigate the quality of anthelmintics available locally since, following the liberalisation of the livestock sector, there has been an upsurge in the number of generic products on the Kenyan market, especially those containing levamisole. Some of the manufacturers of these products are dubious companies whose operational locations are sometimes unknown. Moreover it is thought that whenever concern is raised the quality of these products may only

be improved transiently. The studies of Wanyangu *et al* (1996b) and Monteiro *et al* (1998), the latter of which confirmed the dubious nature of some locally available products, suggested the introduction and policing of appropriate quality control procedures. Despite these recommendations, new brand names appear regularly on the market and because, in most instances, these products are cheaper than those of the established reputable drug companies, farmers may fall prey to these products.

5.2 Materials and methods

5.2.1. Selected farms

The large scale farms used in the survey, Chesumot, Chebelion, Sigei, Too and Koske were located within Kericho district. The smallholder farms used in the survey were those used in the epidemiological study (Chapter 4).

5.2.2. Anthelmintic resistance assay: FECRT

The number of animals in each group and the procedures used in the FECRT were those recommended by the WAAVP (Coles *et al,* 1992; Wood *et al,* 1995) and described in detail in Chapter 2. The drugs were used at their manufacturers recommended dose rates, benzimidazoles at 5 mgs/kg and ivermectin at 0.2 mg/kg liveweight. However levamisole was administered to the test animals at 1.5 times the sheep dose rate ie at 11.25 mgs/kg liveweight. Locally manufactured and/or packaged products used in the trial had been analysed at the National Quality Control Laboratory and were found to meet their product specifications in terms of amount of active component. Wormicid drench (Cosmos Ltd, Nairobi) was used for groups treated with a levemisole based product. Valbazen (Kenya Swiss Ltd, Nairobi) was used in the benzimidazole treated groups and Ivomec (Merial, U.K, local agents Unga Ltd, Nairobi) was administered to the avermectin treated groups.

5.2.2. Analysis of anthelmintic quality

Anthelmintics were obtained from local agricultural suppliers and were analysed using the methods described in Chapter 2.

5.3 Results.

5.3.1. Investigation of anthelmintic resistance:FECRT

Individual goat numbers, bodyweights, dose size and pre and post treatment faecal egg counts for the goats on the large and the smallholder farms are shown according to their treatment groups in appendix 5.1. Table 5.1.a shows the average faecal egg counts of the three treatment groups (± SD) on the smallholdings and Table 5.1.b the same data for the large farms. Average pre-treatment faecal egg counts varied considerably both within and between farms. Tables 5.2 a-c show the calculated efficacy resulting from treatment and where that efficacy was below 95 %, the 90 % confidence intervals (CI's) estimated using the day 10 counts for controls and treated groups (WAAVP method). Tables 5.2. a-c also contain efficacy data and 90 % CI's estimated from the day 0 and day 10 post-treatment samples. Using the criteria laid down by the WAAVP, levamisole resistance was suspected at Chesumot, Chebelion, Koske and on the smallholder farms. Benzimidazole resistance was apparent only at Chesumot and Ivermectin resistance at Chesumot, Chebelion and Koske. Using the pre and post treatment samples to estimate efficacy produced an identical pattern of suspected resistance to that produced using the WAAVP guidelines.

Table 5.3 a shows the differential larval counts from pooled coproculture samples taken on day 0 of the study. The small holder farms had the broadest range of genera with 5 genera of larvae identified following coproculture. Four of the large scale farms had 3 genera and two had only one genus *Trichostrongylus* spp. *Haemonchus* was the predominant genera on Chesumot and Sigei with *Trichostrongylus* species predominating on the other farms and the smallholder farms. Table 5.3.b shows the differential larval counts from pooled coproculture samples taken on day 10 of the study. The percentage of *Haemonchus* larvae increased on all of the farms where resistance was suspected, by 18 % (Chesumot), 30.9 % (Chebelion), 10.6 % (Koske) and by 45.1% on the smallholder farms. Although *Trichostrongylus* larval recoveries fell on those farms, this genus still accounted for more than 20% of the larvae recovered from coprocultures.

Table 5.1 a *Small farms arithmetic mean EPG on Day 0 and Day 10.*

Anthelmintic	EPG Day 0 (±SD)	EPG Day 10 (±SD)
levamisole	1403.3 (1516.9)	163.3 (357.7)
benzimidazole	1481.5 (3388.3)	55.6 (251.7)
ivermectin	1251.9 (2057.9)	55.6 (128.1)
controls	803.3 (982.8)	1008.3 (1098.4)

Table 5.1 b. *Large farm arithmetic mean EPG (±SD) on Day 0 and Day 10*

Farm	Anthelmintic	EPG Day 0 (±SD)	EPG Day 10 (±SD)
Chesumot	levamisole	483.3 (656.4)	183.3 (393.0)
	benzimidazole	687.5 (534.0)	118.8 (283.4)
	ivermectin	344.4 (369.8)	50.0 (146.5)
	controls	494.1 (432.2)	1081.3 (1297.3)
Chebelion	levamisole	772.2 (679.8)	211.1 (372.4)
	benzimidazole	694.1 (577.1)	0
	ivermectin	1082.4 (2464.5)	64.7 (196.7)
	controls	1047.1 (1810.1)	864.7 (1409.3)
Sigei	levamisole	2007.7 (2699.8)	61.5 (160.2)
	benzimidazole	1536.0 (2203.8)	0
	ivermectin	2238.1 (3576.9)	52.4 (140.1)
	controls	2745.8 (6239.6)	1512.5 (3084.2)
Too	levamisole	595.2 (688.1)	15.0 (48.9)
	benzimidazole	595.2 (627.3)	0
	ivermectin	759.1 (912.2)	40.9 (114.1)
	controls	618.2 (867.7)	927.3 (1721.6)
Koske	levamisole	1046.7 (3023.7)	93.3 (271.2)
	benzimidazole	392.9 (356.2)	14.3 (53.5)
	ivermectin	653.3 (891.1)	60.0 (129.8)
	controls	500.0 (418.8)	478.6 (545.2)

Table 5.2 a-c *Efficacies calculated using the WAAVP method and treatments on day 0 and 10 for each drug family.*

a-Levamisole (Wormicid at 10mgs/kg BW)

Farm	Efficacy WAAVP method			Efficacy day 0 vs day 10		
	%	U.C	L.C	%	U.C	L.C
Chesumot	83.0	95.4	37.9	62.1	90.4	-49.2
Chebelion	75.5	93.1	13.1	72.7	90.8	18.7
Sigei	95.9			96.9		
Too	98.3			97.6		
Koske	80.5	96.3	-1.6	91.1	99.1	13.7
S.farms	83.8	95.6	40.9	88.4	97.3	50.0

b-Benzimidazole (Valbazen at 5mg/kgBW)

Farm	Efficacy WAAVP Method			Efficacy day 0 vs day 10		
	%	U.C	L.C	%	U.C	L.C
Chesumot	89.1	97.3	55.2	81.8	94.9	34.1
Chebelion	100			100		
Sigei	100			100		
Too	100			100		
Koske	97.0			96.4		
S.farms	94.5	97.6	-386.5	96.3	99.9	-51.8

c. Ivermectin (Ivomec injection at 0.2mg/kg BW)

Farm	Efficacy WAAVP Method			Efficacy day 0 vs day 10		
	%	U.C	L.C	%	U.C	L.C
Chesumot	95.1			85.5	97.4	18.3
Chebelion	92.5	98.7	53.6	94.0	99.3	49.6
Sigei	96.5			97.7		
Too	95.6			94.6	99.1	69.4
Koske	87.5	96.6	54.3	90.8	97.5	66.7
S.farms	94.4	98.6	78.8	95.6		

KEY: U.C- upper 95 % confidence limit, L.C- lower 95 % confidence limit

Table 5.3 a *Differential larval identification percentages on day of treatment*

Farm	*Haem.*	*Trich.*	*Oeso.*	*Stron.*	*Coop.*
Chesumot	54.5	36.4	0	0	9.1
Chebelion	33.3	46.7	20	0	0
Too	0	100	0	0	0
Sigei	58.4	23.6	0	0	18
Koske	17.6	76.5	0	0	5.9
S. farms	10.9	60.5	3.6	22.1	2.9

Table 5.3.b *Differential larval identification percentages on Day 10*

Farm	*Haem.*	*Trich.*	*Oeso.*	*Stron.*	*Coop.*
Chesumot	72.5	21.3	0	0	6.2
Chebelion	64.2	35.3	0.5	0	0
Too	0	0	0	0	0
Sigei	40.0	50.0	0	0	10.0
Koske	28.2	60.4	2.4	0	9.0
S. farms	56.0	42.5	1.5	0	0

Abbreviations: *Haem.* = *Haemonchus contortus*, *Trich.* = *Trichostrongylus* species, *Oeso.*= *Oesophagostomum* species, *Stron.*= *Strongloides* species *Coop.* = *Cooperia* species.

5.3.2. Investigations into the quality of the anthelmintics available locally

All of the products analysed were oral drenches in the locally preferred form of a suspension. The results from the analyses are summarised in Tables 5.4 a-d (levamisoles and benzimidazoles) and 5.5 a-b combination products. The majority of the drug combinations on the Kenyan market are levamisole/oxyclozanide and levamisole/biothional sulfoxide. Levamisole/rafoxanide is a recent addition as are benzimidazoles/levamisole combinations which were not available in Kericho.

Table 5.4 a-d *Details of anthelmintics and their analyses.*

a-Levamisoles, Maker, Batch number, Date of manufacture and expiry

Brand name	Maker	Batch no.	Date of Manufacture	Expiry Date
Dewormin	1	none	none	4.98
Dewormin	1	illegible	illegible	illegible
Vetworm	2	24250	11.97	11.00
Unitrax	3	9801065	01.98	12.00
Unizan	4	illegible	illegible	illegible
Wormicid	5	980016	01.98	01.00
Wormicid	5	971647	11.97	11.00
Wormicid	5	980025	01.98	01.01
Nilverm	6	CLO 1717	05.97	05.02

b-Levamisoles Claimed % solutions and Assay results

Anthelmintic	Label claim	Assay % of claim	Remark
Dewormin	1.5	0.0	Failed
Dewormin	1.5	0.0	Failed
Vetworm	1.5	96.1	Complied
Unitrax	1.5	88.4	Failed
Unizan	1.5	104.7	Complied
Wormicid	1.5	92.0	Failed
Wormicid	1.5	89.4	Failed
Wormicid	1.5	93.8	Failed
Nilverm	1.5	86.1	Failed

c-Benzimidazoles Maker, Batch number, Date of manufacture and expiry

Brand name	Manufacturer	Batch No.	Date of Manufacture	Expiry Date
Valbazen	7	none	none	None
Valbazen	7	none	none	None
Abezole	8	039742	03.97	03.2000
Albenol	9	970409	08.97	08.2000
Vermitan	10	001	01.97	01.2000

d. Benzimidazoles Claimed % solutions and Assay results

Anthelmintic	Label % claim	Assay % of claim	Remark
Valbazen	10	103.9	Complied
Valbazen	2.5	96.9	Complied
Abezole	2.5	106.5	Complied
Albenol	10	97.4	Complied
Vermitan	10	103.8	Complied

Table 5.5 a *Levamisole in combinations with either 8 % Biothional sulfoxide or 3.5 % Oxyclozanide or 1.5 % Rafoxanide.*

Brand name	Manufacturer	Batch No.	Date of Manufacture	Expiry date
Dewormin plus	1	100117	06.96	06.98
Wormicid plus	5	970771	06.97	06.00
Wormicid plus	5	970014	02.97	02.00
Livazide	2	16565	09.94	03.98
Dewormex*	11	130 ?	10.95	10.98
Levoxy	12	742190	10.97	10.99
Levafas	12	740191	09.97	09.99
Levafas **	12	729290	07.97	07.99
Nilzan	6	CL 1937	02.98	02.03
Flukazole	13	f10326	06.94	06.97
Multidose	14	6253	08.96	08.98

Table 5.5 b *Levamisole in combinations laboratory results*

Brand	Label % claim	Assay % of claim	Remark
Dewormin plus	lev 1.5 bio 8.0	lev 0.0 bio n.d	Failed
Wormicid plus	lev 1.5 bio 8.0	lev 2.3 bio 156	Very high
Wormicid plus	lev 1.5 bio 8.0	lev 2.1 bio 141	Very high
Livazide	lev 1.5 oxy 3.0	lev 2.6 oxy 1.1	Expired
Dewormex *	lev 1.5 oxy 3.0	lev 0.5 oxy 1.9	Failed
Levoxy	lev 1.5 oxy 3.0	lev 1.5 oxy 3.1	Complied
Levafas	lev 1.5 oxy 3.0	lev 1.4 oxy 2.9	Complied
Levafas **	lev 3.0 oxy 6.0	lev 5.9 oxy 2.9	Complied
Nilzan	lev 1.5 oxy 3.0	lev 1.3 oxy n.d	Failed
Flukazole	lev 1.5 raf 1.5	lev 1.5 raf n.d	Complied
Multidose	lev 1.5 raf 2.3	lev 1.5 raf n.d	Complied

Key: * Dewormex plus, ** levafas diamond, n.d = not done.

Other individual drug discrepancies are listed below:

a- Dewormin liquid and Dewormin plus did not have batch numbers, dates of manufacture and expiry or were poorly labelled for the latter. The former had visible particulate matter and it had a poor fitting screw cap which made it difficult to shake after the inner seal had been broken.

b- Valbazen 2.5 % suspension had no manufacturers date, expiry date and batch number and the label did not state w/v or v/v.

c- Vermitan 10 % suspension did not state w/v or v/v on the label

d- Flukazole had batch number and manufacturing date stamped on the label while

the expiry date was superimposed on another number. The presentation of this product in a translucent plastic container was wrong since levamisole hydrochloride and rafoxanide are light sensitive. An opaque container should have been used.

e- Nilzan plus was packed in a translucent container yet oxyclozanide and levamisole are also light sensitive.

d - The product Wormicid had variations with efficacy range of 89.4 % to 93.8 % which failed to comply with the monograph. The combination product, Wormicid plus had excess activity (see Table 5.4.c) which in the case of levamisole might result in goats being administered a toxic level of the drug.

e- The drug Dewormex plus suspension had no clear batch number and the identity of the manufacturer MSC+P was not obvious from the abbreviation. The distributing company Jeleviv pharmaceuticals could not be traced.

f- The products from Twiga Chemicals manufactured for Cooper Kenya Ltd (Nilverm and Nilzan drenches) have long expiry periods of up to 5 years yet other similar products from other companies mentioned a 3 year expiry period and a 2 year expiry period for suspensions from Norbrook Laboratories, Ireland (Levafas and Levoxy).

The tables containing the summary of results have the list of manufacturers denoted by a number as follows:

1. Pharma and Horticultural Inputs Ltd, Nairobi
2. Laboratory and Allied Ltd, Nairobi
3. Pharmaceutical Manufacturing Ltd, Nairobi
4. Not indicated but manufactured for Campbell Animal Health Products
5. Cosmos Ltd, Nairobi
6. Twiga Chemical Industries for Cooper Kenya Ltd, Nairobi
7. Kenya Swiss chemicals, Nairobi
8. Biodeal Laboratories Ltd, Nairobi
9. Interchemie Horster, Castenray, Holland
10 Phylaxia- Sanofi Veterinary Biologicals Ltd
11. MSC +P for Jeleviv Chemical Company
12.. Norbrook Laboratories Ltd, Ireland
13. Chanelle Pharmaceutical, Ireland
14. Univet Ltd, Ireland.

5.4 Discussion

Anthelmintics have been used as the primary method of controlling parasitic gastrointestinal nematodes in livestock for many years but unfortunately resistance of nematodes to these drugs, particularly to the benzimidazoles and imidazothiazoles/tetrahydropyrimidines has been recorded extensively in small ruminants from different parts of the world (Kelly and Hall, 1979; Prichard, 1990, 1994; Coles, 1992; Jackson, 1993; Condor and Campbell 1995, Waller et al, 1995, 1996). There are various *in vivo* and *in vitro* tests for detecting anthelmintic resistance but most studies throughout the world have relied upon an *in vivo* test, the faecal egg count reduction test (FECRT, Presidente, 1985, Coles, 1992; Coles *et al*, 1992; Scott *et al*, 1991; McKenna, 1994).

The main problem with the assay is its lack of sensitivity as it appears not to be able to detect resistance until about 25 % of the worms carry the genes for resistance (Coles, 1992). The timing of the post treatment sampling can also cause problems as a result of the different characteristics of the drugs. Levamisole may be poorly effective against inhibited (arrested) larvae of some nematodes including *Haemonchus contortus* (Grimshaw, Hong and Hunt, 1996). Maturation of the non-susceptible immature stages may provide positive faecal egg counts (FEC) within 11 days after treatment, thus giving rise to false positive results. Early studies (Presidente, 1985; Martin, Anderson and Jarrett, 1989) suggested that 7 days post treatment may be the minimum period that should elapse between the time of administration of anthelmintic and collection of faecal samples. This period allows for any transient suppression of faecal egg output to be overcome. However studies in Scotland (Jackson, 1993) have shown that suppression of egg output of ivermectin resistant *Teladorsagia* is not a temporary phenomenon but may extend to 14 days or more. For these reasons the timing of the second sampling in a FECRT is always a compromise. In the present study all farms were revisited for sampling 10 days post treatment. Dash *et al* (1988), McKenna (1990, 1996, 1997, 1998) have examined the different methods of calculating efficacy in FECRTs from a statistical and parasitological point of view.

The general consensus from these studies is that efficacy is best calculated using arithmetic means and that an efficacy of less than 95 %, together with 95 %

confidence intervals of less than or equal to 90 % suggest that resistant parasites are present on the property (Coles *et al*, 1992). If only one of these criteria is met then resistance is merely suspected rather than confirmed. In the current study, using the WAAVP criteria suggested that resistance was merely suspected and could not be confirmed. In all of the cases where efficacy was less than 95 % the upper 95 % CI exceeded 90 % largely as a result of the considerable variance that existed in the EPGs. Variance figures for the control counts ranged from 154,412 (Chesumot) to 9,512,446 (Sigei), these values are at least 10 times higher than the variance seen in the WAAVP guidelines (Coles *et al*, 1992). There are several factors that contributed to this variance. In this study the use of adult animals may have exerted considerable influence on the pattern of egg output. As the results from Chapter 4 show in regions such as Kericho where indigenous mature animals are capable of regulating certain species then parasite populations in these animals are likely to be highly overdispersed. The use of a relatively insensitive egg counting technique may have also made some contribution to the variance figures which influence the 95 % confidence intervals. Using data obtained from FECRTs conducted in New Zealand, a temperate climate, McKenna (1994) queried the value of estimating 95 % CI's. In his study in all cases where efficacy was less than 95 % then the upper 95 % CI's were always below 90 %. Clearly the situation in tropical environment is very different where the heterogenecity of adult egg counts is such that the confidence intervals are unlikely to fall within the defined range for confirming resistance. This problem might be overcome by using only young susceptible animals, which cannot regulate their worm populations, in FECRTs. This approach works well on large farms in temperate and or tropical areas where breeding is seasonal or synchronised since one can get large numbers of suitably aged animals to make different treatment groups. However, in an environment where breeding is aseasonal it would be very rare to find a farm with sufficient numbers of suitably aged animals to conduct a FECRT with several drugs. The WAAVP recommends the use of adult animals if their mean counts exceed 150 EPG, however, using adults also has, as the results of Chapter 4 show, the potential drawback of species restriction. Obviously if the key resistant species is one that adults can regulate then resistance may go undetected or only be suspected when adult animals are used in FECRT's.

The FECRT is also considerably strengthened by the incorporation of larval cultures. Cultures undertaken at the time of treatment provide valuable details of the genera at the time of treatment which is of considerable value where resistance is diagnosed (McKenna, 1996). Post treatment cultures obviously provide details of which species are resistant to the drugs used in the assay. In this study where resistance was suspected on 3 large scale farms and the small scale farms the proportions of *H.contortus* larvae increased from an average of 29.1 % in the pre-treatment cultures to 55.2 % in post-treatment coprocultures. This species appears to be the one most associated with resistance on the smallholder and large scale farms where there was some evidence for resistance although *T.colubriformis* was also present in samples from those farms. *T.colubriformis* larvae accounted for an average of 55 % of the larvae in pre-treatment samples from the farms with suspected resistance and 39.8 % of the larvae from post-treatment cultures.

Although only on a limited sample, the prevalence of suspected levamisole resistance in goats in this study (66.6 %) is higher than that of Wanyangu *et al* (1996b) which confirmed resistance on 40 % of sheep and goat farms in the area. Chesumot estate had evidence of suspected resistance in all three drug families whereas Wanyangu *et al* (1996b) showed suspected resistance against levamisole and a benzimidazole. This apparent worsening of the situation may be attributed to the intensive treatment regime used on the farm and to the fact that the estate imports breeding bucks and rams of unknown resistance status from elsewhere in the country. Chebelion estate showed suspected levamisole and ivermectin resistance which was attributed to long term use of these drug families. A sheep farm in the neighbouring district (Nakuru) owned by the same individual and used to source replacement animals also had an anecdotal history of suspected anthelmintic resistance. Koske estate also had suspected levamisole and ivermectin resistance but in its case the underlying reasons for this resistance were not clear.

On the small farms in the study area where suspected levamisole resistance was apparent and where farmers rarely treat the whole herd, there may be two reasons for the presence of resistance. First under dosing is a common feature as farmers seek to extend the number of animals that are treated by giving each a reduced dose. Secondly it is believed that importation of resistance from the local large scale farms

may also be important particularly since the smallholder farmers never treat and quarantine purchased animals.

The larval cultures from pre-treatment samples taken on the farms involved in the trial showed the predominant nematode genera was *Trichostrongylus* followed by *Haemonchus*. Although studies in other parts of Kenya (Maingi, 1991a; Maingi *et al*, 1998; Njanja *et al*, 1987; Wanyangu *et al*, 1996b; Waruiru, 1994; Waruiru *et al*, 1994, 1998) have generally shown the latter as the predominant genera, the epidemiology study (Chapter 4) also showed that in Kericho, the predominant nematode in small ruminants was *Trichostrongylus* followed by *Haemonchus* with traces of *Oesophagostomum* and *Cooperia* species.

The liberalisation of the livestock sector and drug industry in Kenya has led to a mushrooming in the number of generic anthelmintic products, especially those in the imidazothiazole family. Unfortunately this has been associated with a reduction in product quality as a result of lack of effective policing of the manufacturing plants and quality checks on imported products. Wanyangu *et al* (1996b) in a study covering 42 farms, reported a total of 24 different brand names of anthelmintic containing levamisole (12), benzimidazoles (9), avermecin (1) and salicylanilides (2). The authors also noted that their quality was suspect and that this may have led to the anthelmintic resistance witnessed in the study. Monteiro *et al* (1998) confirmed that many of the available products in Kenya were of poor quality and recommended the introduction and policing of appropriate control procedures in the production and distribution of anthelmintics. In the current study, out of the 9 levamisole products submitted to the NQCL- Nairobi, only 2 fully complied with quality requirements. A similar picture was seen in the levamisole combinations with fasciolicides, where only 4 out of 11 met quality criteria. Wormicid plus had high concentrations of levamisole which could cause toxicity and /or mortality if over administered. Studies with some goats breeds have shown toxicity to occur at about 20 mg/kg (Babish, Coles, Tritschler, Guatenmann and Lisk, 1990) however Rugutt, Nginyi, Bain, Wanyangu and Mugambi (1995) reported that SEA goats tolerated levamisole at 20 mg/kg BW.

Locally available benzimidazole products, containing albendazole, appeared to meet the required standards. The high quality of these products may be due to the

fact that the majority of them were imported, with the parent companies ensuring internationally accepted standards were met.

Nearly all the products analysed had deficiencies in one way or another especially when it came to labelling, expiry periods and packaging. It was surprising that a reputable market leader in Kenya, Coopers Kenya Ltd packed light sensitive products in translucent containers. The storage conditions of drugs in the farmers' stores and on farms under tropical conditions of high temperatures and humidity may well cause some products to expire earlier than the stipulated date. The effects of poor storage are difficult to quantify however, in this study as none of the products tested was close to its expiry date.

A common feature in Kenya is re-packing of anthelmintic by the pharmacies and other retailers in small containers for drenching individual cattle. Since this is often done in unhygienic conditions and using inappropriate packaging this may have further deleterious effects on the quality of the products. More recently the pharmaceutical companies have begun marketing packs containing a single cattle dose to meet the demands from the farming community.

The problem of generic products is not unique to Kenya as Van Wyk *et al* (1997) reported from South Africa that international brokers selling generic products do not disclose the source of supply of different batches of active ingredients, that the efficacy of such batches differ and that efficacy testing of individual batches, in some cases, is inadequate. They also suggested that registering authorities should consider simplified efficacy testing of each new batch of active ingredients before it is marketed. This process, if applied in Kenya as an adjunct to regular inspection of the manufacturing plants, should ensure that only good products find there way onto the market.

As these studies show suspected multiple anthelmintic resistance is a problem on some of the large farms in the study area and levamisole resistance is suspected on the smallholder farms. Adopting some of the recommended ways of avoiding anthelmintic resistance (Coles and Roush, 1992) might prove beneficial in Kenya, especially moving away from continous use of a single drug family. However, the recommendation that sheep and goats should not be kept together is culturally difficult, particularly for smallholder farmers, however it may be possible on large scale farms. The problem of importation of anthelmintic resistance (Varady, *et al*,

1993; Himonas and Papadopoulus, 1994) through animal movements is a difficult one to address particularly for smallholder farmers. Although large scale farms may be able to quarantine incoming stock and treat them with effective drug this approach may not be practical for smallholder farmers. The adoption where practical of these recommendation will only play a useful part in controlling the spread of anthelmintic resistance if the drug industry and policing authorities can ensure that only good quality products are availability on the market place.

CHAPTER 6

A comparison of Dorper sheep and small East African goats used as tracer animals.

6.1 Introduction.

One weakness of the epidemiology study in Kericho was the use of Dorper sheep as tracers in an area where SEA goats are the predominant small ruminant species. In view of the documented differences in susceptibility between the two small ruminant species this created concern that data gathered on larval uptake and hypobiosis using sheep might have little relevance as far as goats were concerned. Differences in the methods of management and in innate susceptibility and behaviour might exert considerable influence upon parasite intake, establishment, development and persistence in the two species.

At Kericho there appear to be only slight differences in the way that animals are managed. The main systems used in the management of ruminants inevitably involve mixed ruminants free-grazing on paddocks or aftermaths or the tethering of calves and small ruminants in the same area. Whenever the smallholder's land is occupied by food crops the different ruminant species may also be grazed on the road sides and communal areas. Ruminants are housed at night either in bomas, which tend to be used for cattle, or in semi-permanent structures in which small ruminants are housed along with calves. The predominant use of mixed grazing on restricted areas of land not only tends to favour those parasite species which can thrive in both large and small ruminants as seen in Chapter 4 but also limits grazing preferences.

Goats are highly prolific small ruminants which contribute significantly to rural household economies (Mukasa-Mugerwa and Tekelye, 1988), especially in the Savannah zones, but are generally thought to be more susceptible to gastrointestinal nematode infections (McKenna, 1984; Lloyd, 1987). Studies in Australia (Le Jambre and Royal, 1976; Le Jambre, 1984) , New Zealand (Pomroy *et al,* 1986) and Scotland (Huntley *et al,* 1995) have all shown that when non-lactating ewes and does are grazed together on contaminated pastures with ewes harbour significantly smaller proportions of nematodes and tend to have lower faecal egg counts. The nematode genera infecting goats are the same as those infecting sheep (McKenna and Watson, 1987) and include those commonly found at Kericho such as *Haemonchus* and *Trichostrongylus* (Pomroy and Charleston, 1987). Sheep can develop appreciable host resistance to *Haemonchus* from

about 7-8 months of age (Benitz-Usher, Armour, Duncan, Urquhart and Gettinby, 1977; Manton, Peacock, Poynter, Silverman and Terry, 1962; Urquhart *et al*, 1966). Goats are less able to mount an effective resistance against gastrointestinal nematodes and often only do so at 12 months of age or older (Lloyd and Soulsby, 1978; Pomroy *et al*, 1986). Pomroy and Charleston (1989) noted little evidence of an ability to resist infection in 18 month old naturally infected goats exposed to challenge with *Haemonchus*. However, the same authors also recorded that goats had some ability to resist challenge with *T.colubriformis*. Acquired immunity is not the only factor which influences the size of the parasite burden carried by an individual. Specific differences in grazing behaviour and preferences may also influence parasite uptake as shown by a study in Senegal in which goats, allowed to browse in the same area as sheep, had lower egg counts (Vercruysse, 1983). Differences in feed intake and feeding behaviour can also result in sheep and goats which graze on the same pastures not receiving the same exposure to infection (Jallow *et al*, 1994).

The aim of this study was to examine the responses of Dorper sheep and SEA goats when exposed to natural infection on a shared pasture. The paddock used in the study at NVRC is usually grazed by the breeding flock of the Institute and is known to be infected with gastrointestinal nematodes predominantly *H.contortus* (Mugambi *et al*, 1997; Wanyangu *et al*, 1997).

6.2 Materials and Methods.

6.2.1 Weather pattern

The data were collected from the nearest meteorology station situated about 5 Km from the study site.

6.2.2 Animals

Twelve 4-6 month old male SEA goats and 12 male Dorper lambs aged approximately 5 months were used in the study; the goats and the lambs were brought indoors, given anthelmintic (Levamisole 7.5 mgs/kg; *Nilverm*, Cooper Animal Health, Nairobi) and maintained indoors using the methods described in Chapter 2. In February, March and April, following their period at housing the animals were faecal sampled and those with zero counts were randomly selected. A total of 4 goats and 4 sheep were

grazed together, along with 30 animals from the breeding flock and turned out every day from 9 A.M to 3 P.M for a period of one month onto a one hectare paddock at the NVRC-Muguga known to be contaminated with gastrointestinal nematodes (predominantly *H. contortus*). After the period at grazing the animals were returned to housing where they were maintained for 3 weeks, in the manner described in Chapter 2, prior to necropsy. The pasture samples for larval counts and identification were collected during the middle period of each month from the paddock and processed as described in Chapter 2.

6.2.3 Pasture

Following the high rainfall, the pasture at the start of the trial in February was abundant and consisted predominantly of Kikuyu grass which was about one foot high. The hedges along the borders of the paddock had plenty of well leafed shrubs. The reduced rainfall in March and April together with the high stocking rate on the pasture resulted in a marked reduction in the amount of available herbage during the last two months of the study.

6.2.4 Necropsy and worm burden estimation

Following housing the animals were humanely killed and the abomasum, small intestine and large intestine removed and processed to provide samples for worm burden estimations using the methods described in Chapter 2. The methods used to count, identify and stage recovered worms were those described in Chapter 2.

6.2.5 Statistical analysis

Worm burdens were log transformed prior to analysis using the Minitab program as described in Chapter 2.

6.3 Results.

6.3.1 Weather pattern

The data for the first quarter of 1998 are shown in Appendix 6.1 and the monthly average maximum and minimum temperatures and rainfall are shown in Figure 6.1. This quarter was considerably different as far as rainfall was concerned from the long term averages for the study area which show that this is normally a dry period. The rainfall was higher than normal during January and the figures for February and March were 15-20 mm higher than those seen in the long term averages.

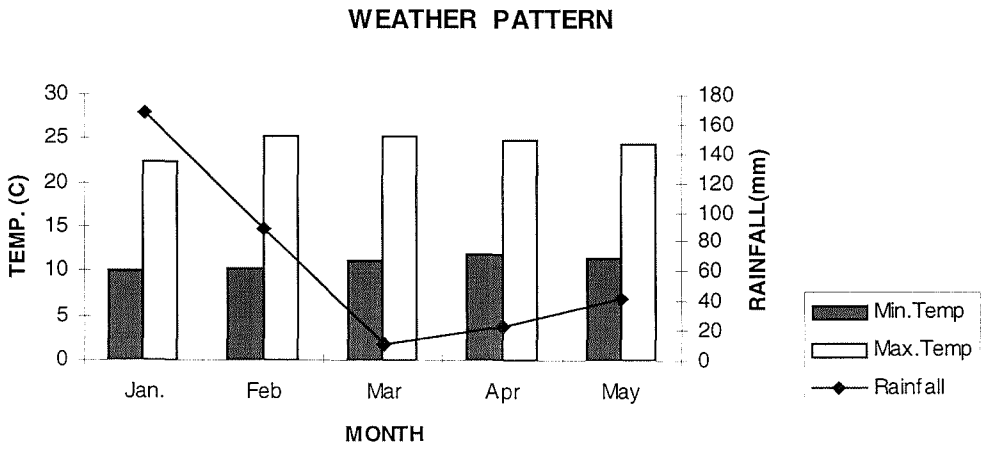


Figure 6.1 *Monthly mean maximum and minimum temperatures and average rainfall for the first quarter of 1998*

6.3.2 Pasture larval counts

Table 6.1 contains details of the numbers of larvae recovered from pasture and their identification; these results are also presented in Figure 6.2. *H.contortus* larvae predominated on the pasture in all the months of the study and reached their peak values in March. The counts in January and February were relatively low despite the high rainfall in the previous months.

Table 6.1 *Pasture larval counts (L3/Kg of dry herbage)*

Month	*H.contortus*	*Trichostrongylus. sp*	*Cooperia sp*
Jan	80	42	0
Feb	75	0	1
Mar	1172	169	0
Apr	293	86	0

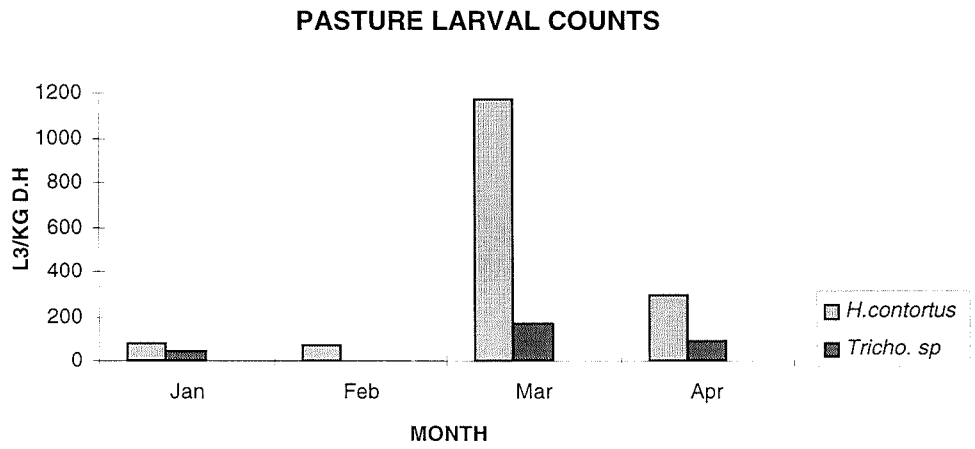


Figure 6.2 *Specific pasture larval counts during the study period and the preceding month.*

6.3.3 Clinical observations.

A total of 7 animals died during the course of the study from causes other than parasitism and no data from these animals were included in the study. Two goats died of bacterial pneumonia while the 5 sheep died of suspected Rift Valley Fever, a zoonotic viral infection that was responsible for an epidemic in both ruminants and humans in the district (Laikipia) at the time at which the Dorper lambs were purchased.

6.3.4 Worm burdens

The individual worm burdens for Dorper sheep and SEA goats are shown in Tables 6.2 (Dorpers) and 6.3. (Goats). No large bowel worms were recovered from any of the animals. The predominant species recovered was *H.contortus*, immature *H.contortus* were also recovered from the three sheep killed in March and one goat killed in February and three of the four goats killed in March. Two sheep carried small numbers of *T.colubriformis* and one goat had a small number of *T.axei.* Given the relatively low numbers of animals pooled sheep and goat data were used to compare mean TWC. On average sheep carried 1.5 times the adult burden of *H.contortus* and when immature worms were recovered sheep had burdens that were about 6 times greater than those of goats.

The statistical analysis of the data was based on a working hypothesis that TWC of goats were similar to those of sheep. Two sample t-tests showed that the burdens of

Haemonchus carried by sheep and goats were not significantly different. Analysis of the limited data set on the variation over time showed that sheep and goat TWC's were significantly lower in February ($p<0.05$) than in March and April. There were no significant differences in the numbers of mature and immature *Haemonchus* carried by sheep or goats.

Table 6.2 *Individual Total Worm Counts for the Dorper lambs*

Month	Animal No.	*H.c.M*	*H.c.I*	*T.a.*	*T.c.*
February	504	2200	0	0	0
	531	0	0	0	250
March	518	2100	1150	0	300
	552	6000	12100	0	0
	605	4700	14650	0	0
April	223	2250	0	0	0
	249	1150	0	0	0
	Mean	**2628.6**	**3985.7**	**0**	**78.6**
	SD	**2055.9**	**6469.8**	**0**	**134.9**

KEY: *H.cM* = mature *Haemonchus contortus*, *HcI* =immature *Haemonchus contortus*, *T.a.* = *Trichostrongylus axei* *T.c.* = *Trichostongylus colubriformis*

Table 6.3 *Individual Total Worm Counts for Small East African goats*

Month	Animal No.	*H.c.M*	*H.c.I*	*T.a.*	*T.c.*
February	559	0	0	0	0
	562	250	2700	0	0
	557	900	0	0	0
March	570	0	0	0	0
	560	1800	250	0	0
	565	1100	1650	0	0
	566	2900	2150	50	0
April	563	2800	0	0	0
	558	1850	0	0	0
	568	5400	0	0	0
	Mean	**1,700.0**	**675.0**	**5.0**	**0**
	SD	**1,675.0**	**1062.0**	**15.81**	**0**

KEY: *H.cM* = mature *Haemonchus contortus, HcI* =immature *Haemonchus contortus, T.a. = Trichostrongylus axei T.c. = Trichostongylus colubriformis.*

6.4 Discussion

The high mortalities, particularly those seen in the Dorper lambs used in this trial, reduced the data set to such an extent that it was difficult to draw all of the intended comparisons. Rift Valley Fever (RVF), the suspected causal agent of the losses in sheep is a viral disease and as such cannot be controlled chemotherapeutically. The disease appears to have been carried into the NVRC by the purchased Dorper sheep, since an epidemic was subsequently confirmed in the district where the tracers were purchased. Though RVF infects all ruminants, sheep appear to be most susceptible and goats least susceptible (Fields, Knipe, Chanock, Hirsch, Monath and Roizman, 1990). The disease is epizootic and is usually associated with the rainy season and a high mosquito density.

Haemonchus was the predominant species present in pasture samples and in worm counts, the other abomasal (*T.axei*) and intestinal species (*T.colubriformis, Cooperia*) appearing only sporadically. Sheep had higher overall mean *Haemonchus* burdens compared to SEA goats. For each adult *Haemonchus* carried by goats sheep carried 1.54 adult worms and in March, the only month with appreciable numbers of immature *H.contortus,* the ratio of immature *Haemonchus* in tracer goats and sheep was 1:9.2 . There are a number of key processes during the parasites development that may influence the worm burden carried by an individual, Figure 6.3 summarises these processes and some of the key factors that affect them.

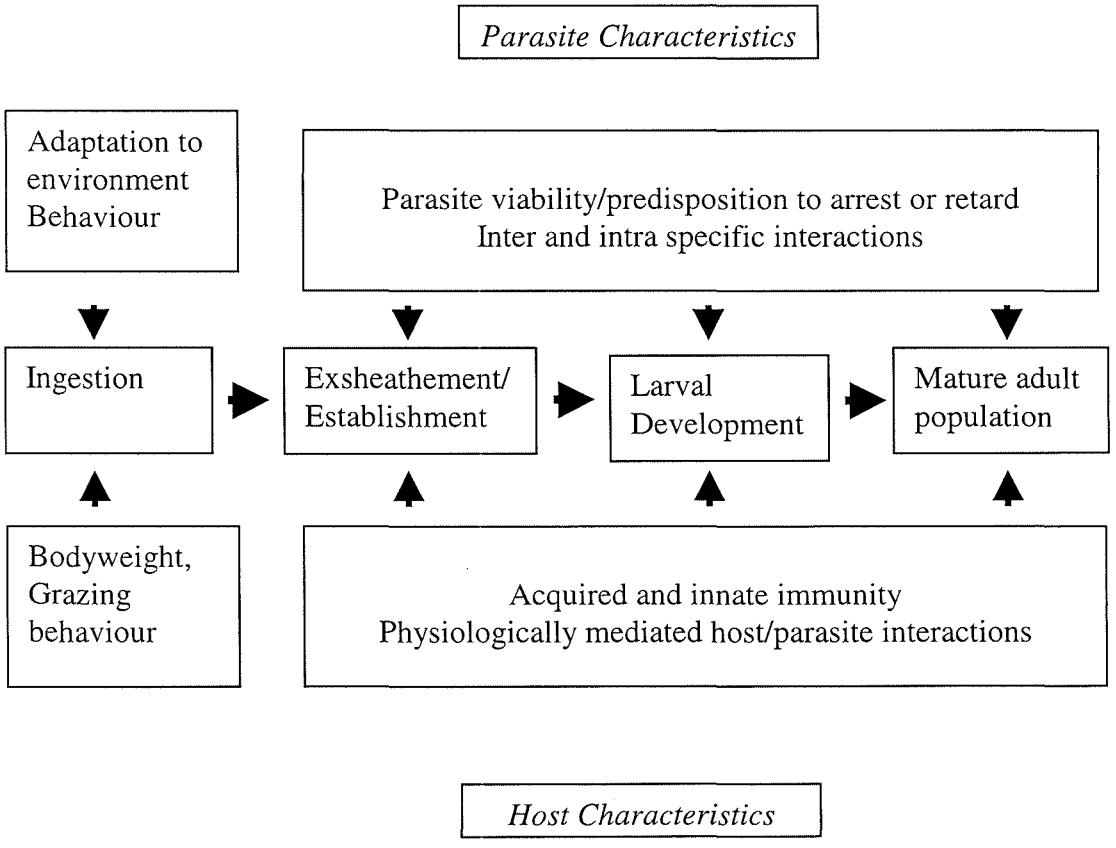


Figure 6.3 *Factors influencing the key parasite development processes*

The infection pressure on any sward is obviously influenced not only by contamination rates but also by the prevailing climate and the adaptation of the parasite

species to those conditions. Larval intake is influenced by parasite behaviour which influences exposure to the host and by the volume and type of herbage ingested which depends upon host size and grazing behaviour. The infrapopulation dynamics are affected by density dependant mechanisms which influence both inter and intraspecific parasite interactions and give rise to physiologically mediated and immunologically mediated innate and acquired responses that influence the processes of establishment, growth and maturation.

Generally the infections carried by the tracer animals in this study would be classified as "low" using the criteria of Kingsbury (1965) and McKenna (1981). These "low" burdens in tracer sheep and goats appear simply to be a reflection of the pasture larval counts. With the exception of March, where the pasture larval count was 1341 L_3 per kilogramme of dry herbage, counts in the other months were relatively low at 75 L_3 per kilogramme of dry herbage (February) and 339 L_3 per kilogramme of dry herbage (April). The specific tracer burden in sheep and goats where *Haemonchus* accounted for 98.82 % and 99.78 % respectively of the mean total populations was poorly representative of the species present on herbage where *Haemonchus* and *Trichostrongylus* larvae accounted for 84.4% and 15.5% respectively of the recovered larvae. The distribution of parasitic nematodes in their host will in principle, be due to variation in the exposure to infection, variation in resistance to infection and association amongst parasites especially competition (Stear *et al*, 1998).

Exposure to infection may vary between the two tracer species due to differences in herbage intake which would be expected to vary according to the bodyweight of the animals. The average weights of the tracer SEA goats when given anthelmintic on arrival was 12.5 kgs compared to 21 kgs for the Dorper lambs. Using Scottish Agricultural Colleges data (SAC Nutrient allowances for cattle and sheep 1978 publication No. 29) for sheep suggest that lambs of 12.5 kg may have a daily dry matter intake of 0.7 kg/day compared to 0.92 kg/day for animals of 21 kg i.e a ratio of 1:1.31. Estimated figures for total worm recovery/kg liveweight for goats and sheep in this study were 198.3 worms/kg liveweight in goats and 318.7 worms/kg liveweight in Dorper sheep a ratio for the two species of 1:1.61. Differences in bodyweight between the

tracer sheep and permanently grazed animals used in the epidemiological and intervention studies may help to explain some of their differences in worm burden. However, since Red Maasai sheep and SEA goats have a similar range of adult bodyweights this factor may have little relevance as far as differences in their worm burdens are concerned.

The three key host dependant factors which might be expected to affect parasite recoveries from the sheep and goats used in this study are immunity, physiologically mediated parasite interactions (PMPI) and grazing behaviour. In this study it is impossible to quantify the exact role played by these different components, but it seems reasonable to assume that they may have all been operating to some extent.

It is conceivable that acquired immunity/PMPI may have played some part, particularly in the case of tracers of the type used in this study, since these animals were not exclusively reared indoors and thus will have had some previous exposure to infection. Immunologically mediated interactions between *Haemonchus* and other gastric (*Teladorsagia* species.and *T.axei*) and intestinal (*T.colubriformis*) nematodes have been reported by Stewart (1955). Mapes and Coop (1971) reported a physiologically mediated interaction between *Haemonchus contortus* and *Nematodirus battus* and Jackson, Jackson, Coop and Huntley (1992) one between *Teladorsagia circumcincta* and *T.vitrinus.* In cattle, interactions between abomasal and intestinal species have also been reported between *O.ostertagi* and *Cooperia* species by Kloostermann, Albers and van Den Brink (1984) and Frankena (1987). The effect that these interactions exert is usually to suppress the minor species in the population or any species that arrives at its predeliction site after the predominant species has become established. Interactions such as these may help to explain some of the differences in the species represented in worm counts from tracers and those recorded from pasture samples.

Differences between the numbers of worms found in the two host species may also be accounted for by interspecific differences in either grazing behaviour and/or the expression of acquired or innate immunity. The non-random distribution of faeces and larvae (Boag, Topham and Webster, 1989) also influences exposure to infection

particularly when there are specific differences in grazing preference. The preference that goats have for browsing was evident in this study where they were observed to spend some time feeding on the hedging shrubs. In this way more susceptible species such as goats (Le Jambre and Royal, 1976; Preston and Allonby 1978; McKenna, 1984; Pomroy *et al*, 1986; Lloyd, 1987; Patterson *et al,* 1996) may limit exposure to the infective larvae of gastrointestinal nematodes since these larvae have a limited capacity for vertical migration (Rose and Small, 1985).

In tropical areas variation in rainfall is the major factor governing infection patterns of trichostrongyles in small ruminants (Dorny *et al*, 1995). It is also known that dry conditions have an adverse effect on the survival of free-living stages on pasture and that arrested development of trichostrongyles has been observed with onset of the dry season (Vercruysse, 1983; Connor *et al*, 1990). This arrested development is presumed to provide a means of survival within the host over the dry season. In this study the presence of immature *H.contortus* in both animal species during the dry month of March could not be simply explained by the advent of dry conditions which prevented the development, translation and survival of larvae since the peak pasture larval counts were recorded in March. However a previous study at NVRC using the same paddock (Mugambi; 1994) also recovered large numbers of fourth stage *H.contortus* from the abomasal mucosa of sheep grazing during this period. Given that this retardation occurred at a time when the challenge at pasture was at its greatest then it seems reasonable to assume that it may have been a density dependent phenomenon in which high larval challenge invoked changes in either the host/parasite and/or the intraspecific relationship.

Despite the fact that the results from this study have highlighted some of the differences in the host/parasite relationships in Dorper sheep and SEA goats, the study also shows that the two species also have sufficient similarities in susceptibility to the available species to enable some comparisons to be drawn between them. Using sheep in an area where goats are the predominant species may still provide a useful indication of the degree and extent of challenge faced by grazing ruminants particularly in areas such as Kericho where tethering restricts any grazing preferences.

CHAPTER 7

Intervention trial: The control of gastrointestinal nematodes of ruminants on smallholder farms in Kericho district.

7.1 Introduction

The control of nematodoses in ruminants is an essential component of modern farming management and is particularly practised on large scale establishments throughout the world. Currently, control is achieved largely through the use of chemoprophylaxis combined, where possible, with grazing and/or pasture management. The timing of treatments is usually based on a sound epidemiological knowledge of the parasite population dynamics in the particular environment. Nowadays it is accepted that eradication of gastrointestinal parasites is impracticable (Brundson, 1980) in grazing animals and so the main objective of control programmes is to minimise associated economic losses (Michel, 1969, 1976). There are a number of important reviews which have discussed the control of parasitic gastro-enteritis and its epidemiological backgrounds (Armour, 1980, Michel, 1976, Barger, 1999, Waller, 1999). Studies on the control of nematodes in Kenya are limited, covering few areas and often with a limited number of farms and animals (Gatongi *et al*, 1998, Maingi *et al*, 1997). Invariably these studies focus on larger establishments simply because of the numbers of animals they carry. Since smallholder farmers make a significant contribution to animal production in Kenya and, given that they see helminthoses as a major constraint, it is important to examine the potential for prophylaxis on these properties. In this study, a total of 75 farms with a total average herd of 650 cattle, 450 goats and 60 sheep were used in an intervention trial for a period of 16 months. The intervention trial was tailored with the main target being that of reducing both pasture contamination and host infection based on infection patterns observed for each ruminant species during a preceding epidemiology study (Chapter 4). In this study area like all other parts of Kenya, control is based mainly on the use of anthelmintics (Kinoti *et al,* 1994). Most small ruminant treatments administered in Kericho are therapeutic rather than prophylactic. The results from Chapter 4 where infection was apparent on pasture and in tracers throughout the year suggest that Kericho has apparently near ideal conditions for the development and survival of larval stages on pasture. The epidemiology study also established peak infection periods occurring in May to June following the long rains and in August - September and November - December in association with the short rains. Although the period from December to March is relatively the driest period,

with least pasture infectivity, average monthly rainfall over the period still exceeded 189.3 mm as compared to the long term average of 113.5 mm.

The results from the epidemiological study and from the VIL and PRA surveys suggested that nematodoses are a source of economic loss to the smallholder farmers and that some benefit might be obtained by adopting an affordable strategic treatment regime. Epidemiologically based worm control programmes have been developed and introduced into different regions in Australia in an effort to control anthelmintic resistance (Barger, 1993, Dash *et al*, 1985, Le Jambre, 1978). Attempting to prophylactically control infections in young ruminants that are reared on common grazing is obviously fraught with difficulty simply because other non-treated stock and wildlife may maintain infections. These difficulties notwithstanding it was decided to use the patterns of infection seen in cattle, sheep and goats in the epidemiological study as a template for developing non-intensive treatment regimes. For cattle, the egg count patterns suggested that treatments should be confined to calves since adults appeared to be largely capable of regulating their populations. Calf intervention was proposed at the periods of highest risk, before they develop immunity (Claerebout *et al*, 1998; Poot, Eysker and Lam, 1997; Shaw *et al*, 1998). Specifically, individual treatment was done based on age at 4, 6 and 12 months. For small ruminants treatments were scheduled for all ages of animals in the middle of May, August and November. Since one of the aims of the NARP II project on helminthoses was to transfer information from research to the small scale farmers it seemed appropriate to only use anthelmintics that would be available to the farmers. This ruled out the use of persistent anthelmintics such as moxidectin (McKellar, 1994) or long acting devices. Given the known prevalence of fake and adulterated drugs on the Kenyan market the study also used drugs of known pharmaceutical quality.

Benefits accruing from treatment were measured not only in terms of reductions in egg count but also as improvements in production and economic yield. Since the study was conducted over an extended period a further aim was to provide additional data on gastrointestinal parasite dynamics in the study area.

In order to assess the success of the treatment protocols, the following criteria were included in the analyses:

a) Comparison between mean EPG patterns in the control and treated animals within a specific age class.
b) Comparison of productivity data, specifically growth rate of the young animals of all ruminant species between the intervention groups.
c) Comparison between the offtake and survival rate of calves, kids and lambs amongst the intervention groups.
d) The cost analysis of the drug treatments and benefits to produce a cost benefit ratio for the intervention study.

7.2 Materials and Methods

7.2.1. Meteorological data

Meteorological data covering the period of the study was collected from a site at the Tea research foundation situated approximately 5 km from the farm sites

7.2.2. Pasture larval counts

The tracers grazed about 5 km along a road leading to communal grazing grounds within Kericho town. This distance was sub-divided into 3 sampling sites, which were each sub-divided into 4 subsites. Pasture samples were collected from each of the 12 sites monthly. The samples were collected, processed and analysed using the techniques described in Chapter 2. Pasture larval counts were analysed in Minitab using Mann-Whitney test.

7.2.3. Tracer and permanent stock

A total of 6 Dorper tracers were used in each month of the study, these animals were managed prior to, during and following grazing in the manner described in Chapter 2. Each month 4 Red Maasai cross ewes were purchased from local sources and taken to the NVRC to obtain data on their worm burdens. The animals were housed and maintained prior to autopsy in the manner described in Chapter 2, the methods used to recover, identify and determine the stage of development of the parasites were those described in the general materials and methods chapter.

7.2.4. Farms and Anthelmintics

Detailed individual animal record forms were maintained throughout the study, an example of which is shown in appendix 7.1. On each visit the animals' weight, and

any treatments that they had received was recorded and notes made of the reason for removing animals from the trial. The methods used to identify and select suitable farms were those described in Chapter 2. Thirty five farms were allocated into the treated group and 40 acted as control farms for the small ruminant trial while the corresponding figures for calves was 41 and 34 farms respectively. A levamisole based product, *Wormicid* (Cosmos, Nairobi) was used for the treatment of calves which were treated at the recommended dose of 7.5 mg/kg of body weight (BW). Calf bodyweights were determined prior to treatment using an electronic balance. In the small ruminant treatment trial, *Valbazen* (Kenya Swiss, Nairobi) was used at 2.5 mg/kg BW after establishing the weight accurately as for calves. The other product used, Closantel (*Flukiver*) was kindly donated by the local agents (Twiga Chemicals) of the manufacturer Janssen Pharmaceutica, Belgium. Closantel was administered at a dose rate of 10mg/ kg BW.

7.2.5. Faecal egg counts of cattle, goats and sheep and coprocultures.

The methods used to obtain and process faecal egg counts and coprocultures were those described in Chapter 2, except that the coprocultures were pooled on a species rather than species and age class basis. Data generated during the trial was entered and stored in a spreadsheet programme (Microsoft Excel).

7.2.6. Productivity

The methods used to collect or estimate bodyweight data were those described in Chapter 2. Data was entered and stored in a spreadsheet (Microsoft Excel) prior to analysis.

7.2.7. Offtake and survival rates

Data on offtake and mortality were gathered and entered into a database programme. (Microsoft Access).

7.2.8. Cost analysis

Data required for cost analysis such as cost of drugs and average market price for ruminants were entered and stored in Microsoft Access prior to being used in the cost analysis

7.2.9. Statistical analyses

Data sets containing parasitological and productivity details were exported to Minitab (Minitab Corporation, USA) for statistical analysis using, where applicable, a general linear model analysis of variance. Other analyses and calculations were performed using a spreadsheet package (Microsoft Excel).

7.3 Results

7.3.1 Weather data

These are illustrated in the Figure 7.1 below and the details in appendix 7.3. During the first half of the study period, the weather pattern corresponded with the long term averages but in the later part, there was abnormally high and prolonged rainfall during the short rains period of November to December with up to 436.5 mm in November 1997 and high rainfall in January and February which are normally much drier months. The start of the long rain period was delayed by about one month to April, March 1998 being particularly dry with only 33.9 mm of rain recorded. The consequence of this different pattern of rainfall was an abundance of grazing in the normally dry period between December and February.

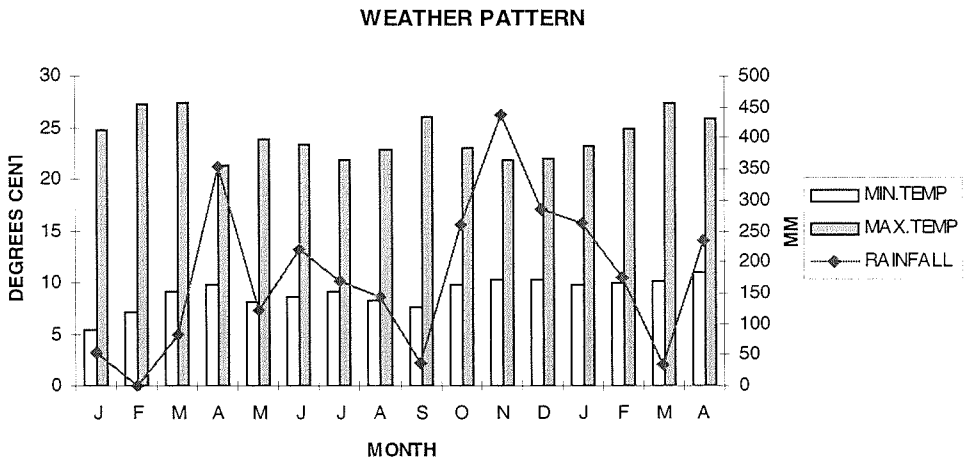


Figure 7.1 *Average monthly rainfall and average maximum and minimum temperatures during the intervention study.*

7.3.2 Pasture larval counts.

The pasture larval infection patterns for *Haemonchus, Trichostrongylus, Cooperia* and *Oesophagostomum* during the study period are shown in Figures 7.2 a-d, while the overall mean monthly counts for the 12 sampling sites are given in Appendix 7.4. The larval population on the pastures was very low except in April 1997 when

Haemonchus and *Trichostrongylus* species counts on pasture were 4500 and 975 L_3 kg^{-1} DH respectively. During the rest of the study period, pasture infection was at a much lower level only one pasture count, for *Oesophagostomum* in November, exceeded 100 L_3 kg^{-1} DH. No species was represented in every pasture sample. Average specific incidences for *Haemonchus, Trichostrongylus, Oesophagostomum* and *Cooperia* were 80 %, 66.6 %, 53.3 % and 46.6 % respectively. Due to the non-normality of the data between the sampling sites, Mann-Whitney test was used for statistical analysis. Table 7.1 contains p values estimated using Mann-Whitney test to compare differences between sampling sites.

Table 7.1 *P-values using Mann-Whitney test to compare sampling sites*

Genera	P-value for comparison between sites		
	site 1 vs 2	site 1 vs 3	Site 2 vs 3
Haemonchus	0.7	0.9	0.6
Trichostrongylus	0.9	0.9	0.9
Cooperia	0.9	0.5	0.6
Oesophagostomum	1.0	0.8	0.8

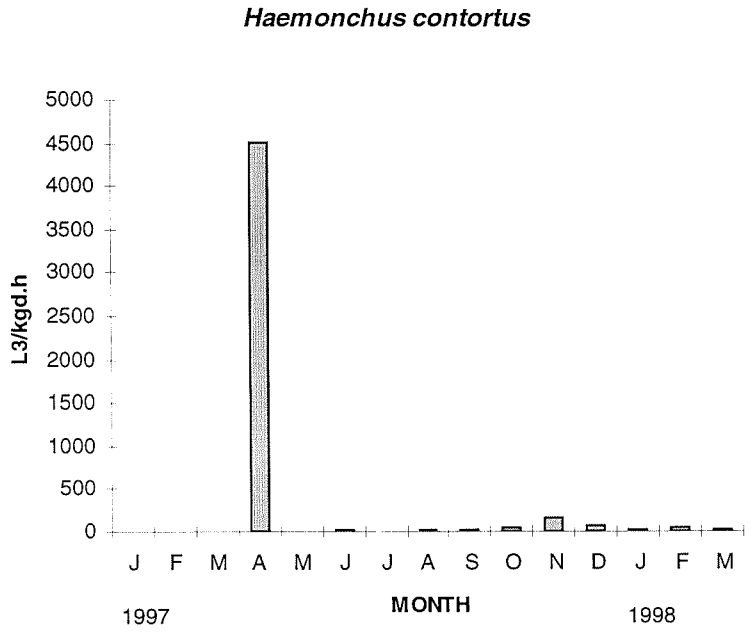


Figure 7.2.a *Haemonchus pasture larval counts (L_3/kg^{-1} of dry herbage)*

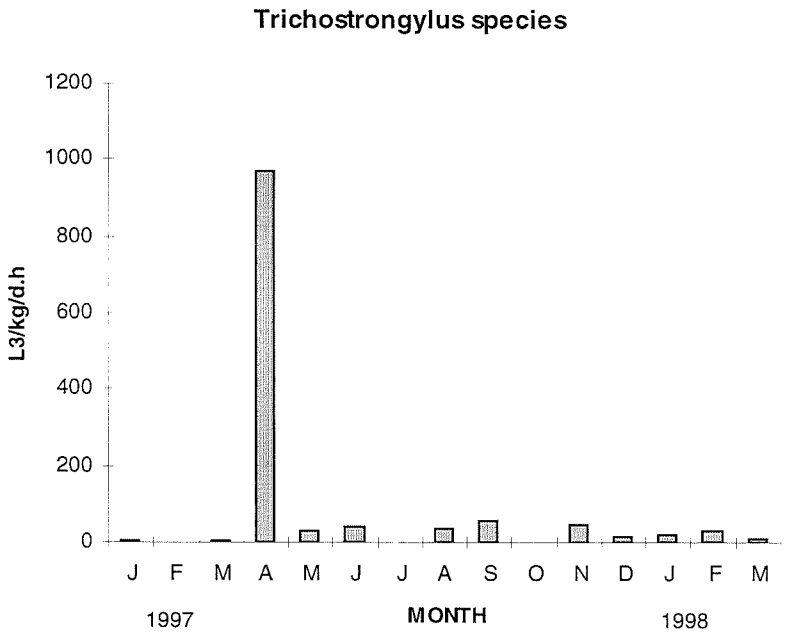


Figure 7.2.b *Trichostrongylus spp pasture larval counts (L_3/kg^{-1} of dry herbage)*

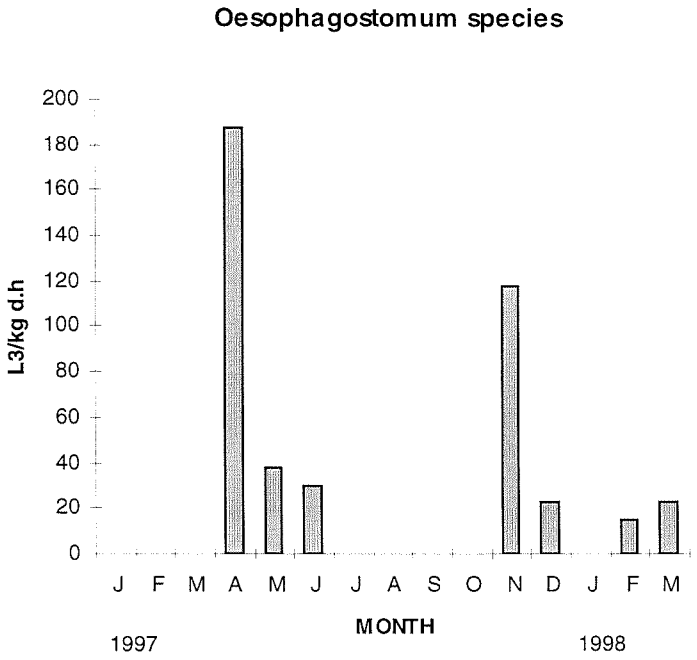


Figure 7.2.c *Oesophagostomum species pasture larval counts (L_3/kg^{-1} of dry herbage)*

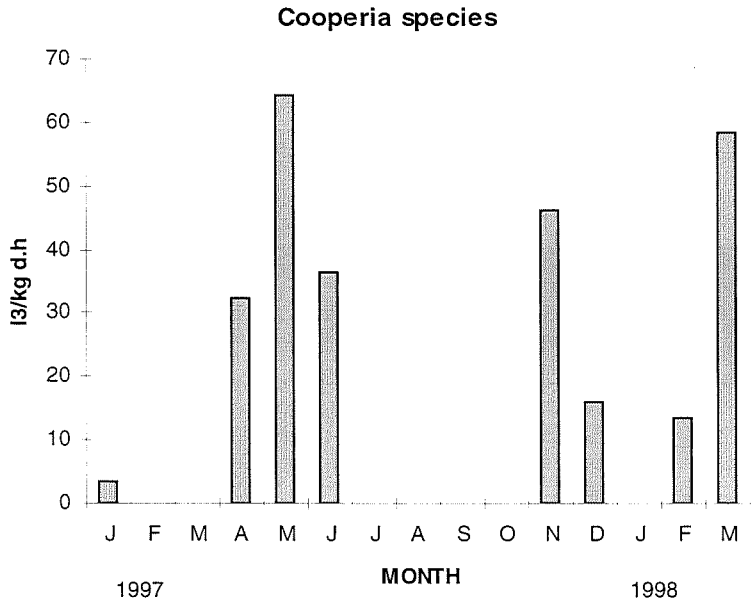


Figure 7.2.d *Cooperia species pasture larval counts (L_3/kg^{-1} of dry herbage)*

7.3.3 Total worm counts (TWC) from tracers and the permanent stock (local ewes)

The individual TWC for tracers and local ewes are shown in Appendix 7.6. A total of 93 tracers and 64 local sheep were selected for use in the study however because of mortalities (details in General Appendix) worm burdens were obtained from only 79 tracers and 49 local sheep. Figure 7.3 shows the average total worm burden carried by Dorper tracers and locally purchased Red Maasai cross ewes. Figures 7.4 a-e shows the monthly mean *Haemonchus, T.axei, T.colubriformis, Cooperia* and *Oesophagostomum* worm burdens recovered from tracers and permanent sheep.

7.3.3.1 Tracer sheep

The pattern of infection in the tracer sheep was similar to that seen during the epidemiological study with *H.contortus* and *T.axei* being the predominant species recorded at *post mortem*. *Haemonchus* was always present in the Dorper lambs where peak counts of more than 3000 worms occurred in February, March and April 1998. The incidence of infection with *T.axei* was lower at 62.5 % and the peak

counts for this species in May, June and July 1997 were lower than those for *Haemonchus*, ranging between 400-800 *T.axei.* Immature (L_4) *T.axei* were only recovered in May, June, July and November 1997, but in those months they were the predominant stage of this species. The other species appeared sporadically in much lower numbers, although *Oesophagostomum* was present in 43.5 % of the samples, the maximum average monthly count was only 14 worms. *T.colubriformis* and *Cooperia* were only recovered on a single occasion when the average count was less than 100 worms.

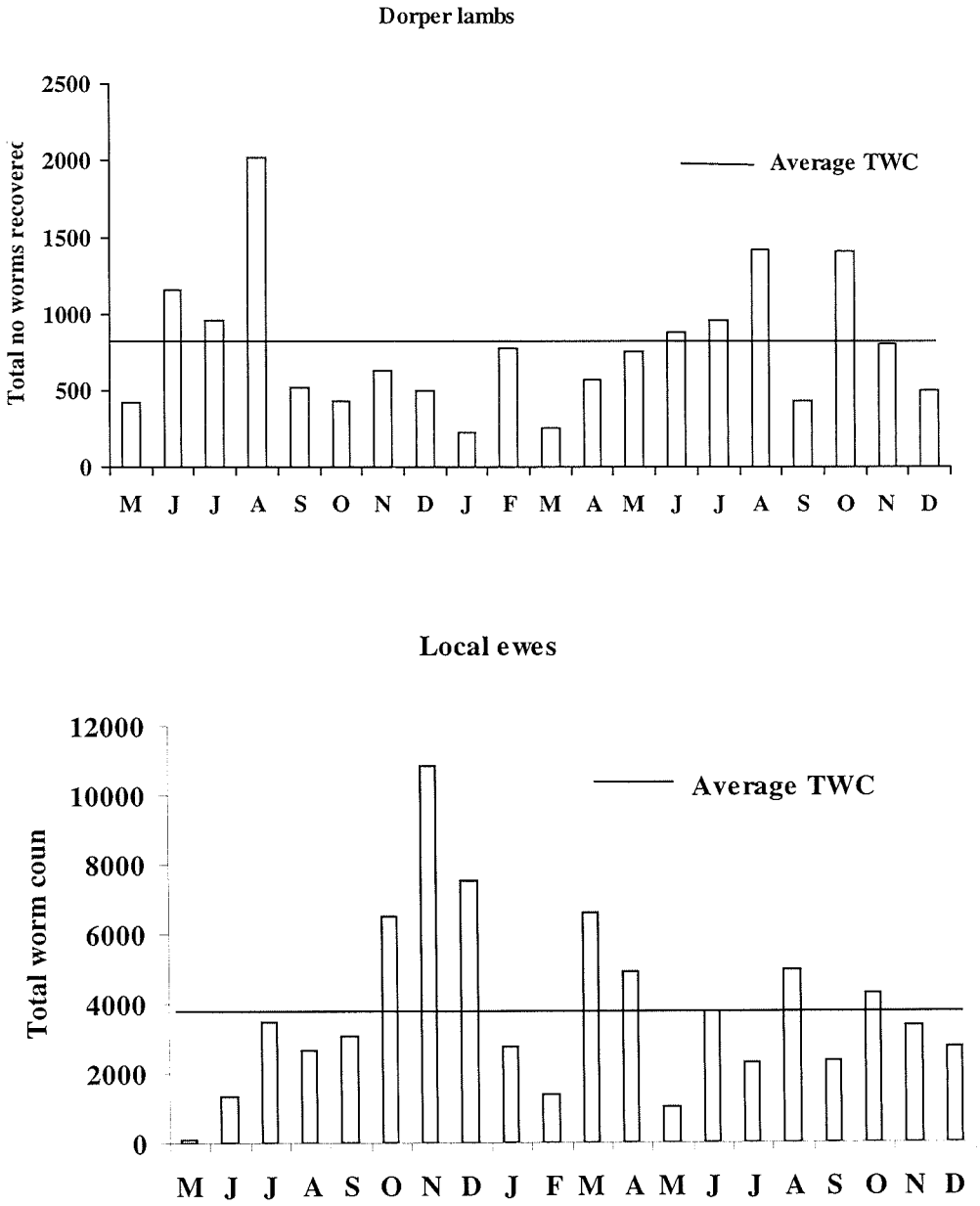


Figure 7.3. *Monthly and average total worm burdens of the Dorper tracer lambs (upper graph) and Red Maasai cross ewes (lower graph)*

7.3.3.2 Permanent sheep

T.axei and *T.colubriformis* predominated in the permanent sheep being recovered on all but two and four occasions respectively during the survey. At their peaks the average populations of these two species were more than 6000 and 4500 respectively. Immature stages of *T.axei* were recovered on all but 4 of the months when this species was present in local ewes. *Haemonchus* was recovered on 11 of the 16 months of the study but the maximum average burden was less than 500 worms. Small numbers of *Cooperia* (<100) were recovered on 5 of months during the study.

Oesophagostomum was present in ewes killed on 9 of the 16 months but the peak average population never exceeded 20 worms.

As might be expected the tracers had a lower average monthly mean count of (1,520.0 ± 1,591.0) than the local ewes which carried an average monthly mean burden of 2,850.0 (± 2997.0) worms. Table 7.2 contains details of the overall mean burdens of the different species carried by Dorper tracers and locally obtained Red Maasai cross ewes together with a P-value obtained from a t-test.

Table 7.2 *The overall mean specific total worm counts (±SD) of tracer and local sheep and comparison of burden.*

NEMATODE	TRACER MEAN TWC (±SD)	LOCAL MEAN TWC (±SD)	P VALUE
Haemonchus Mature stages	635.0(1007.0)	214.0(285.0)	0.007
Haemonchus Immature stages	81.0(411.0)	18.4(77.5)	0.19
T.axei Mature stages	92.0(400.0)	1434.0(2032.0)	<0.0005
T.axei Immature stages	70.0(288.0)	500.0(1158.0)	0.014
T.colubriformis	9.5(50.7)	1463.0(2745.0)	0.0005
Cooperia spp.	3.2(28.1)	18.4(57.5)	0.089
Oesophagostomum spp	5.0(8.0)	3.0(6.2)	0.13

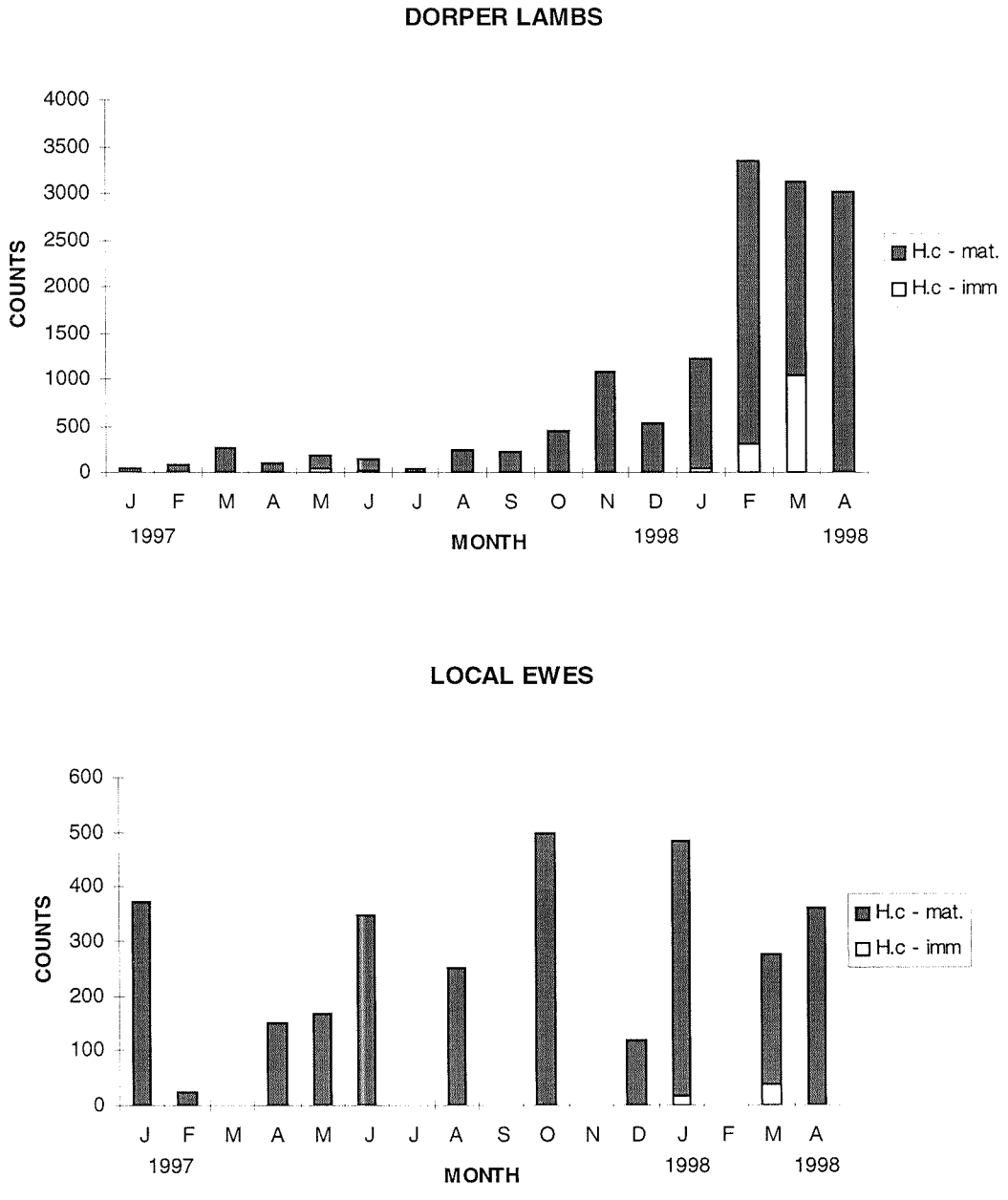


Figure 7.4.a *Average recoveries of mature and immature Haemonchus from Dorper Tracers and local Red Maasai cross ewes*

H.c mat=Haemochus contortus mature, imm= immature

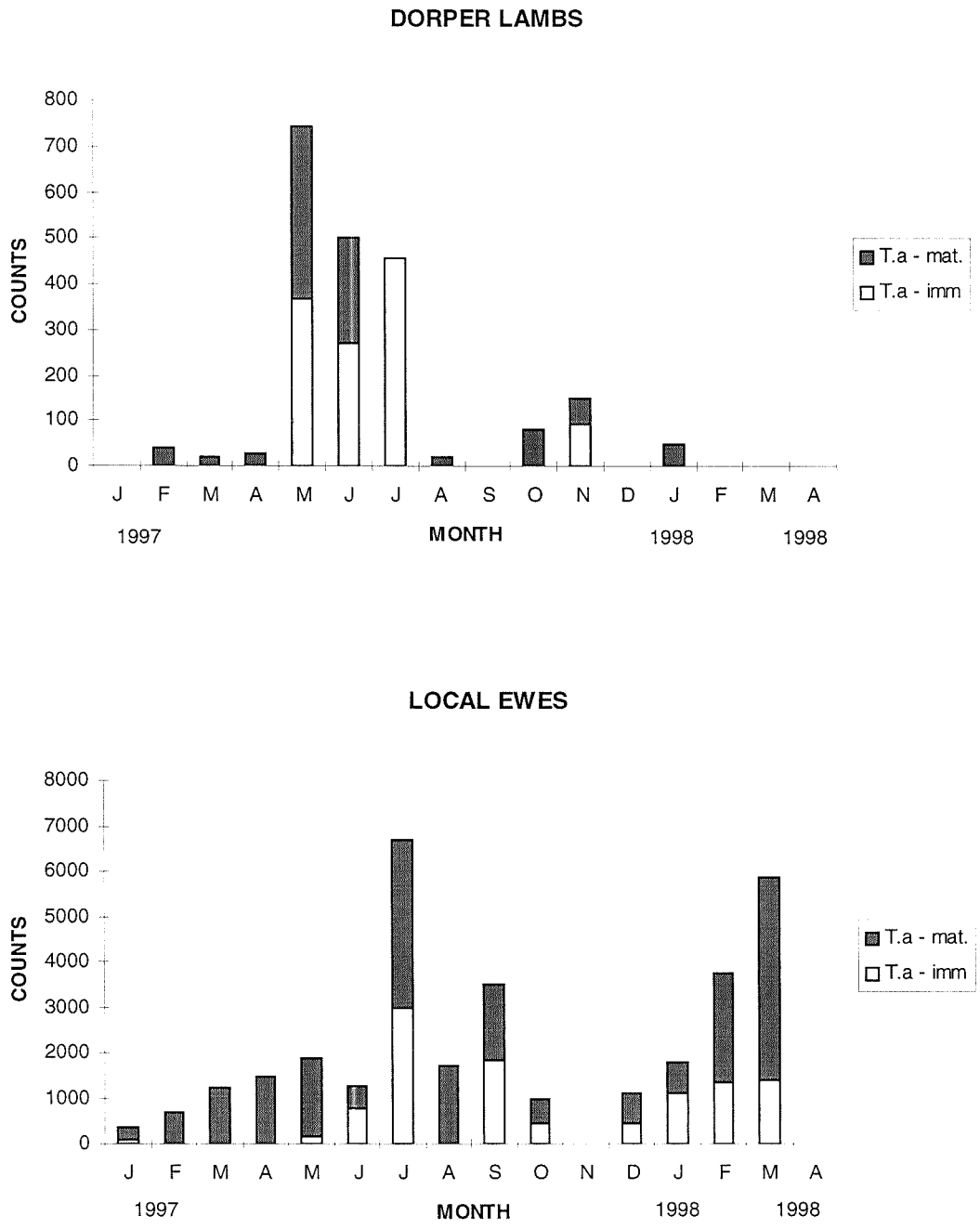


Figure 7.4.b. *Average recoveries of mature and immature T.axei from Dorper Tracers and local Red Maasai cross ewes*

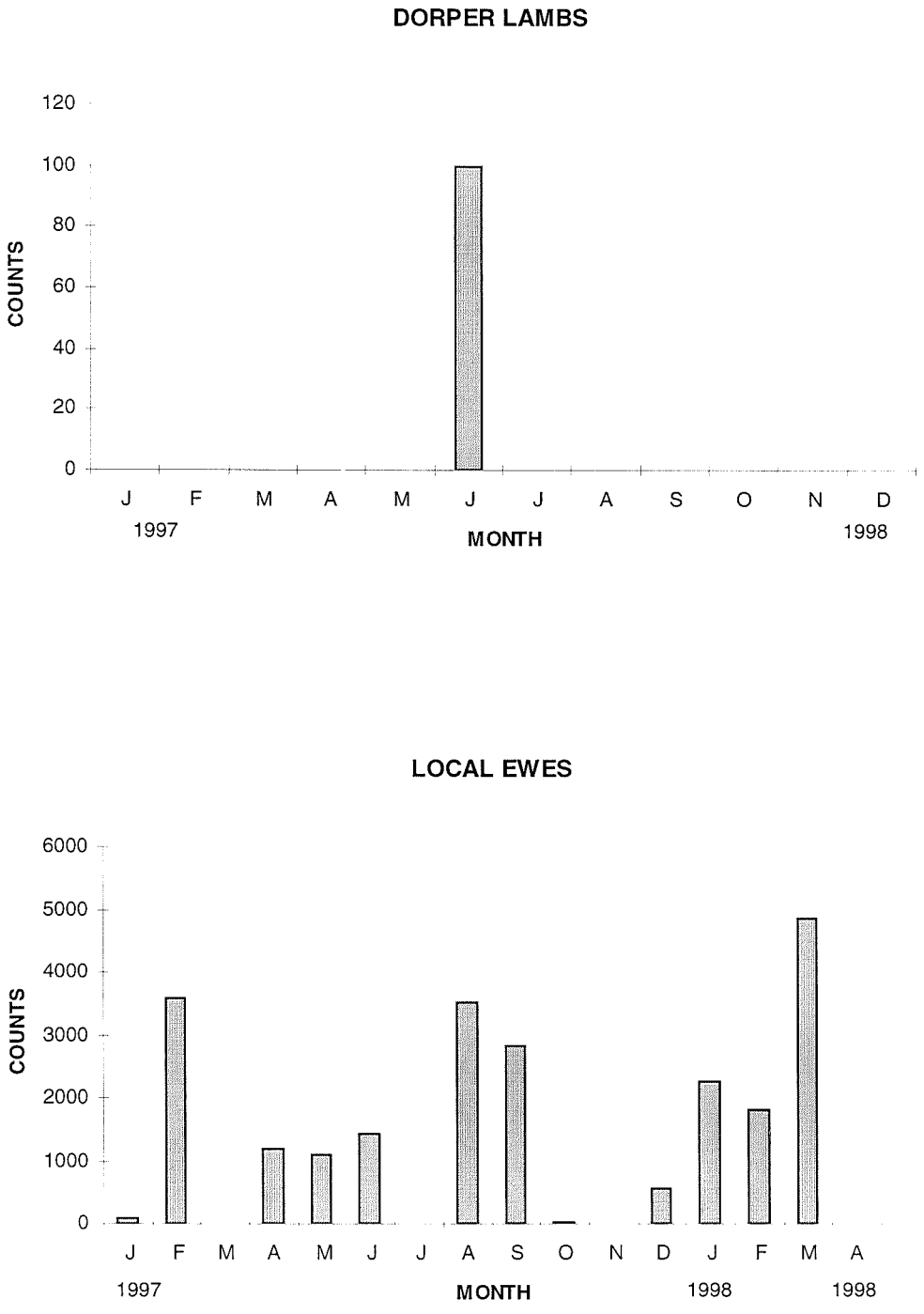
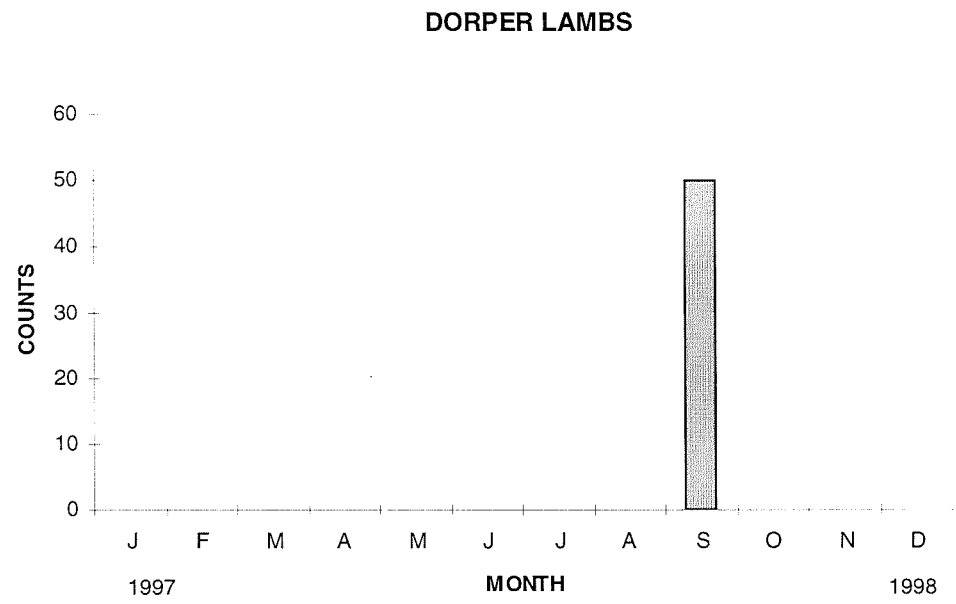


Figure 7.4.c *Average recoveries of T. colubriformis from Dorper Tracers and local Red Maasai cross ewes*



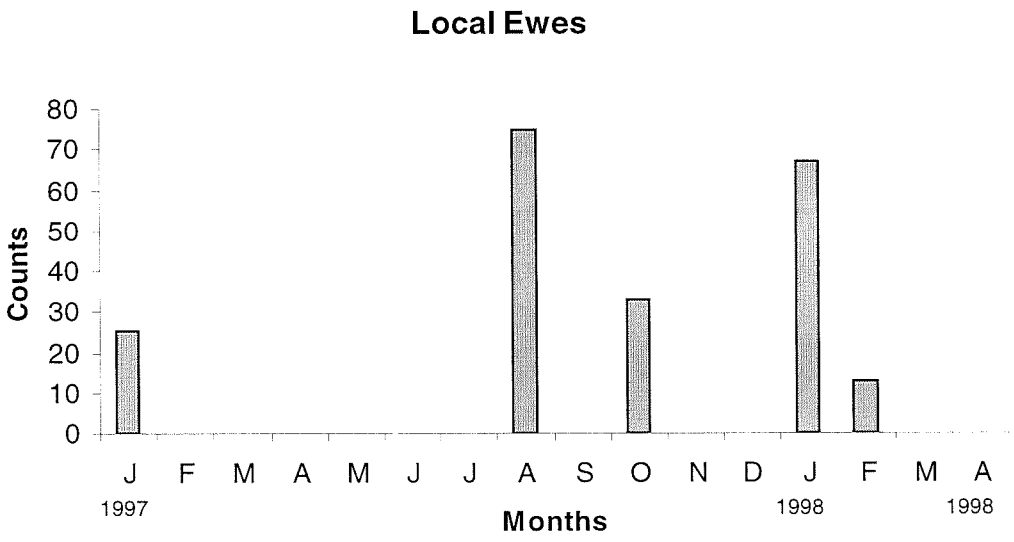


Figure 7.4.d *Average recoveries of Cooperia spp from Dorper Tracers and local Red Maasai cross ewes*

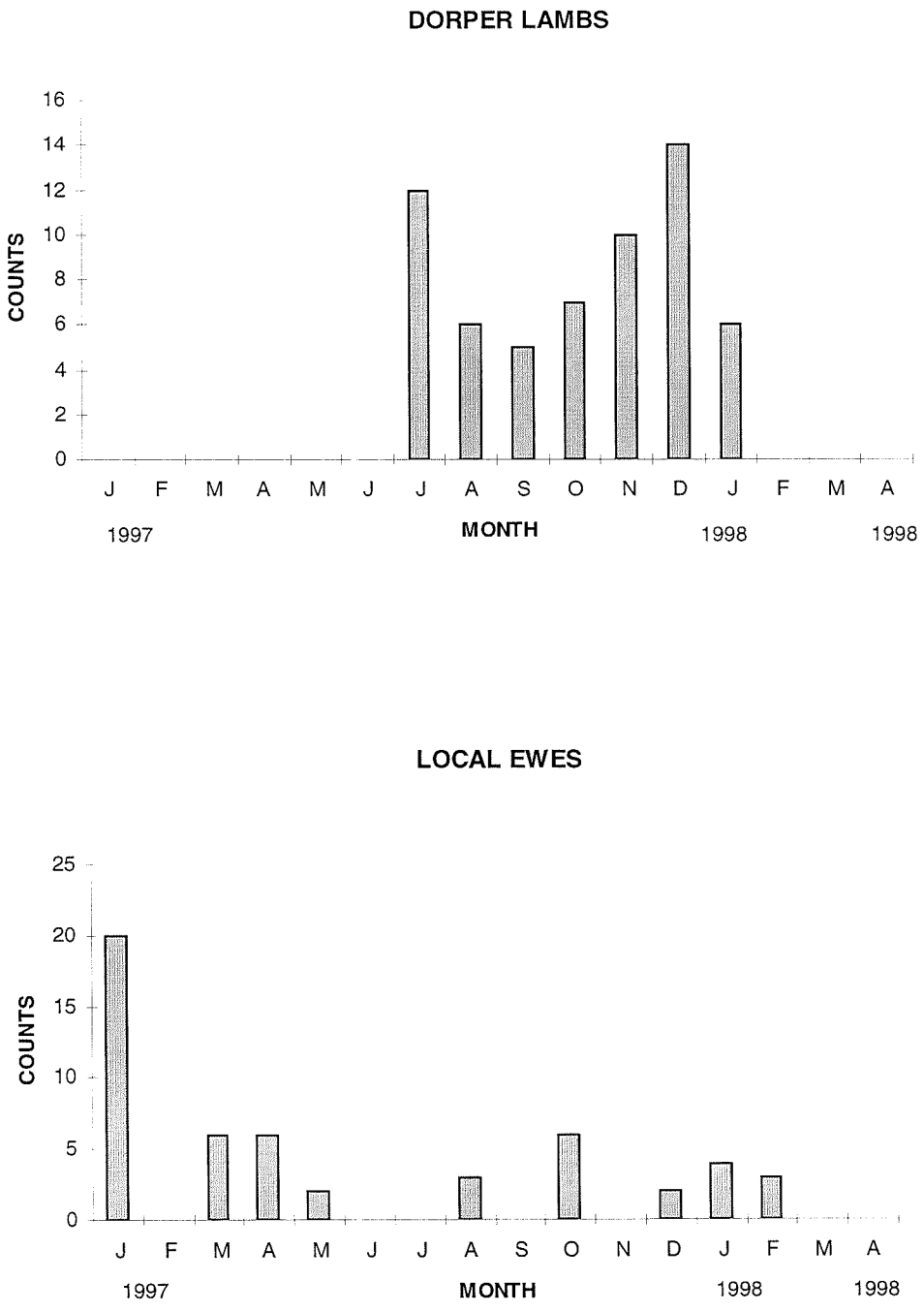


Figure 7.4.e *Average recoveries of Oesophagostomum from Dorper Tracers and local Red Maasai cross ewes*

7.3.4 Faecal egg counts of farm animals.

A total of 75 farms were involved in the study, the allocation of farms to the treatment groups are shown in Table 7.3. Figure 2.3 (Chapter 2) shows the distribution of the study farms within Kenya and the expanded view the distribution within Kericho district. Figures 7.5, 7.6 and 7.7 show the distribution of control and treated farms for cattle, goats and sheep and provides an indication of the numbers of animals on each farm and the proportion of adult and immature livestock. Appendix 7.5 shows the number of animals sampled every month in proportion to the total flock/herd. The proportion of small ruminants sampled each month was lower than that of cattle (about 60 % for small ruminants and 70 % for cattle). Animals that had been treated by the farmer since the previous visit were excluded from the sampling schedule on the next visit.

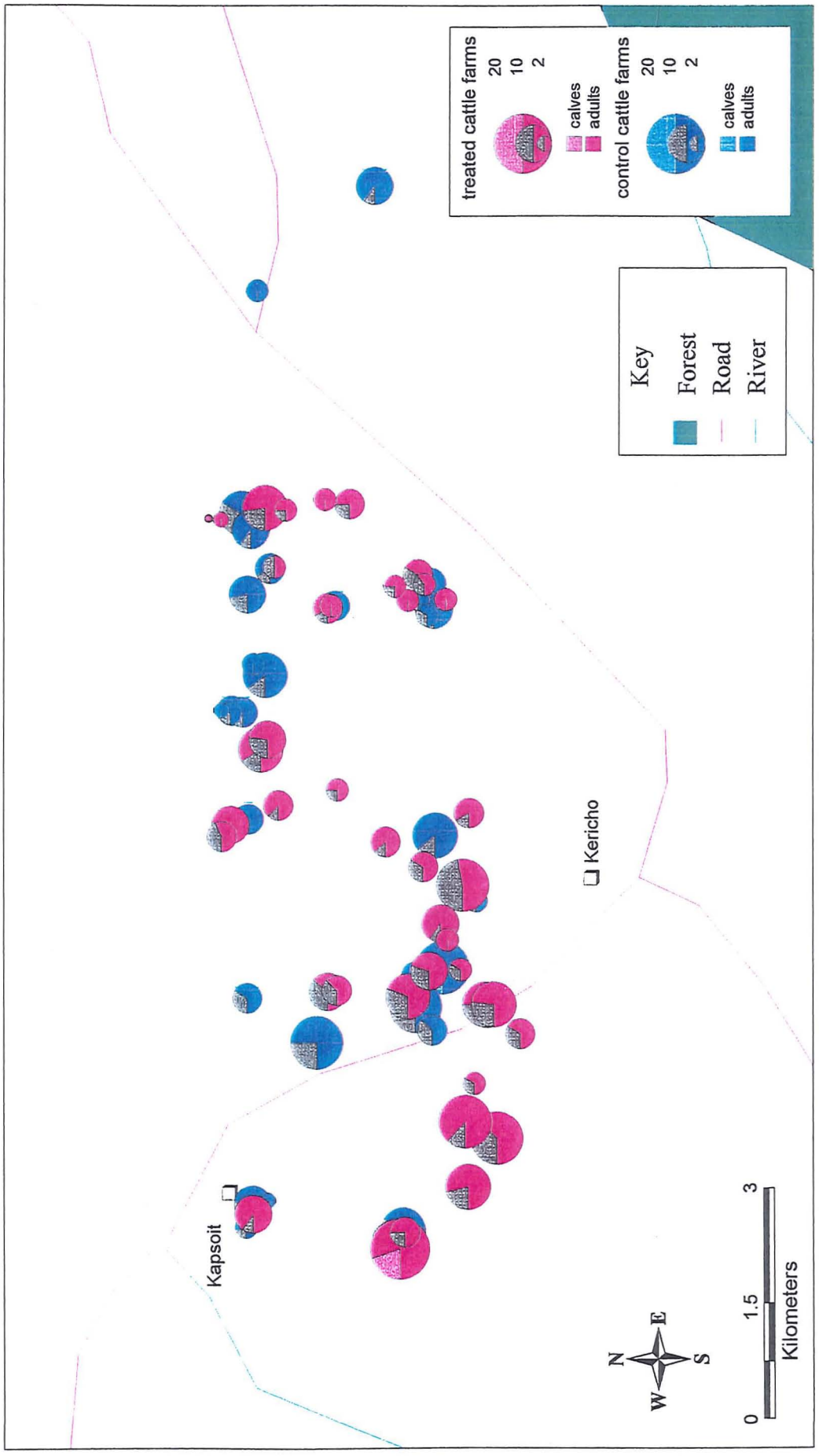
Table 7.3 *Allocation of farms to intervention groups*

Intervention status	Number of Small ruminant farms	Number of calves farms
Treated	35	41
Control	40	34

7.3.4.1. Cattle

The average faecal egg counts for calves and adult cattle for both intervention groups are shown in Tables 7.4 and 7.5 and the pattern of infection is shown in Figures 7.8 and 7.9. The mean EPG pattern for calves on control farms was similar to that for the treated farms, the mean EPG for control farms was 251.3 (±658.7) compared to a figure of 199.1 (±588.4) for the treated farms. Data was log transformed (log EPG + 1) prior to statistical analysis. Comparing the egg counts of calves on control and treated farms showed that treated farms had insignificantly lower mean egg counts than control farms (P=0.061 T-test and P=0.068 Mann-Whitney).

Figure 7.5 *Distribution of control and treated cattle study farms*



The distribution of cattle farms. Treated farms are shown by a red pie, control farms by a blue pie. Adults are shown with solid shading, calves diagonal line shading. Diameter of the pie is proportional to the number of animals on farm.

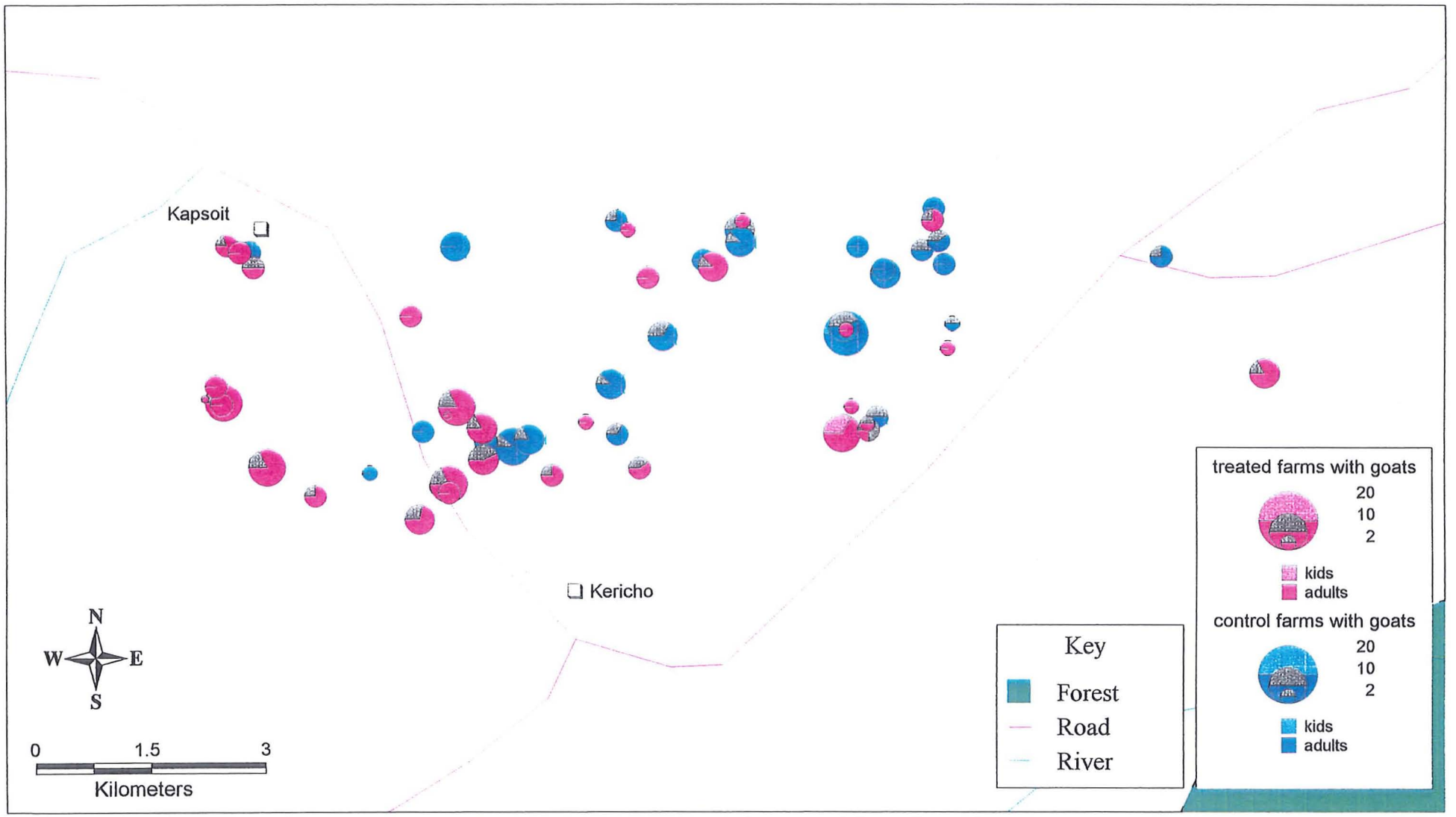
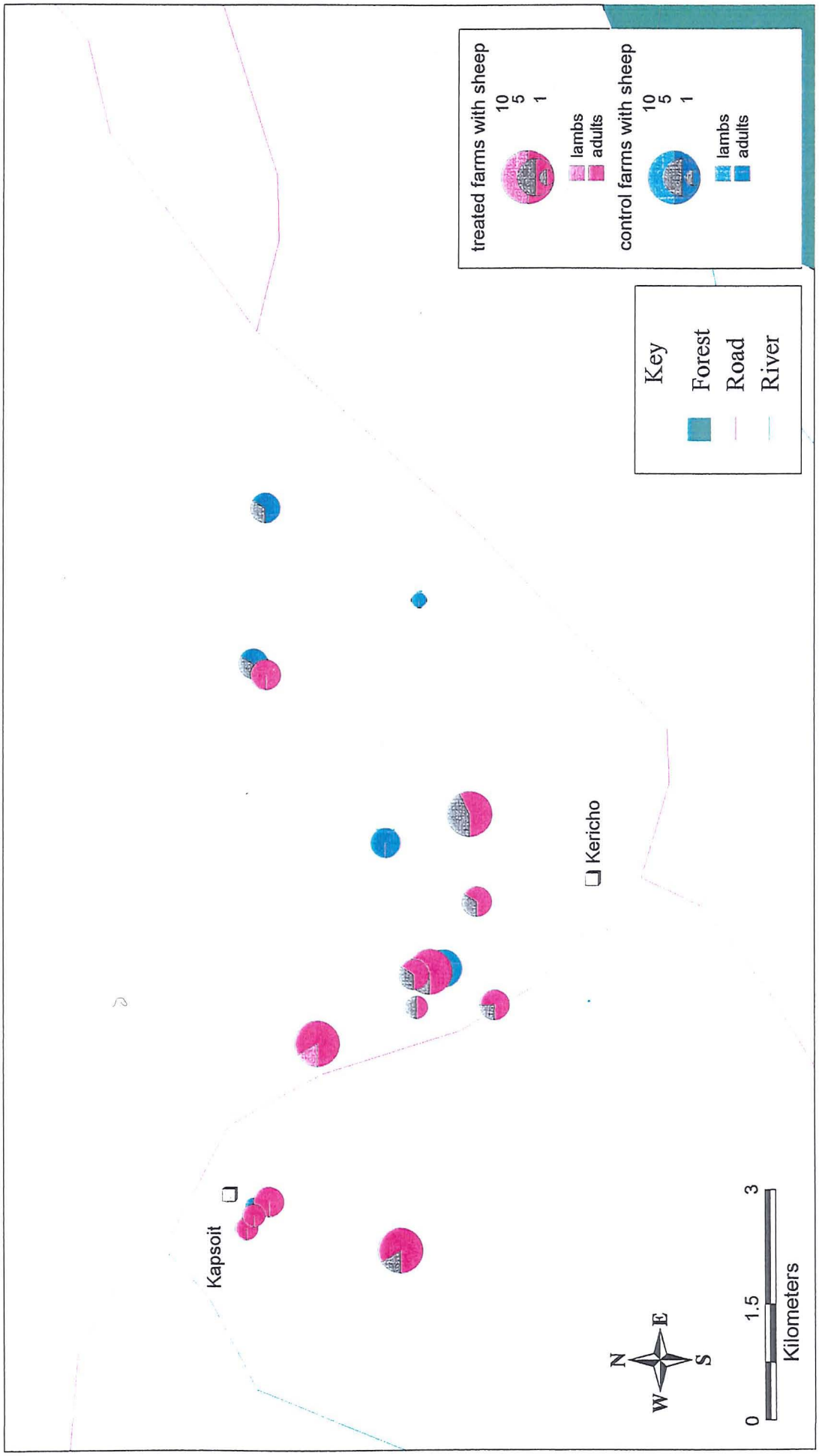


Figure 7.6 *Distribution of control and treated goat study farms*

The distribution of farms with goats. Treated farms are shown by a red pie, control farms by a blue pie. Adults are shown with solid shading, kids diagonal line shading. Diameter of the pie is proportional to the number of animals on farm.

Figure 7.7 *Distribution of control and treated sheep study farms*



The distribution of farms with sheep. Treated farms are shown by a red pie, control farms by a blue pie. Adults are shown with solid shading, lambs diagonal line shading. Diameter of the pie is proportional to the number of animals on farm.

Adult cattle generally had lower counts than calves and there was no clear difference between treated cattle whose mean egg count was 100.4 (±468.8) compared to 93.4 (±393.5) for the untreated cattle on the control farms.

Table 7.4 *Calf arithmetic mean egg counts (±SD)*

MONTH	CONTROL FARMS		TREATMENT FARMS	
	Number	EPG±(SD)	Number	EPG±(SD)
January 1997	38	352.6(668.9)	59	316.9(737.7)
February	41	53.7(155.1)	64	45.3(177.2)
March	33	393.9(1025.6)	64	309.4(1211.8)
April	31	109.7(164.0)	64	143.8(406.6)
May	38	73.7(158.9)	64	98.4(443.5)
June	27	177.8(377.6)	53	173.6(492.7)
July	25	336.0(1231.8)	47	206.4(346.7)
August	23	382.8(616.9)	53	494.3(876.1)
September	29	396.6(858.8)	50	134.0(321.7)
October	29	186.2(383.3)	49	242.9(513.6)
November	23	195.6(439.5)	46	373.9(828.8)
December	21	100.0(151.7)	48	58.3(100.0)
January 1998	30	140.0(249.9)	47	161.7(294.6)
February	26	173.1(366.1)	53	211.3(521.7)
March	26	369.2(584.3)	56	133.9(369.4)
April	30	650.0(1269.7)	44	102.3(192.3)

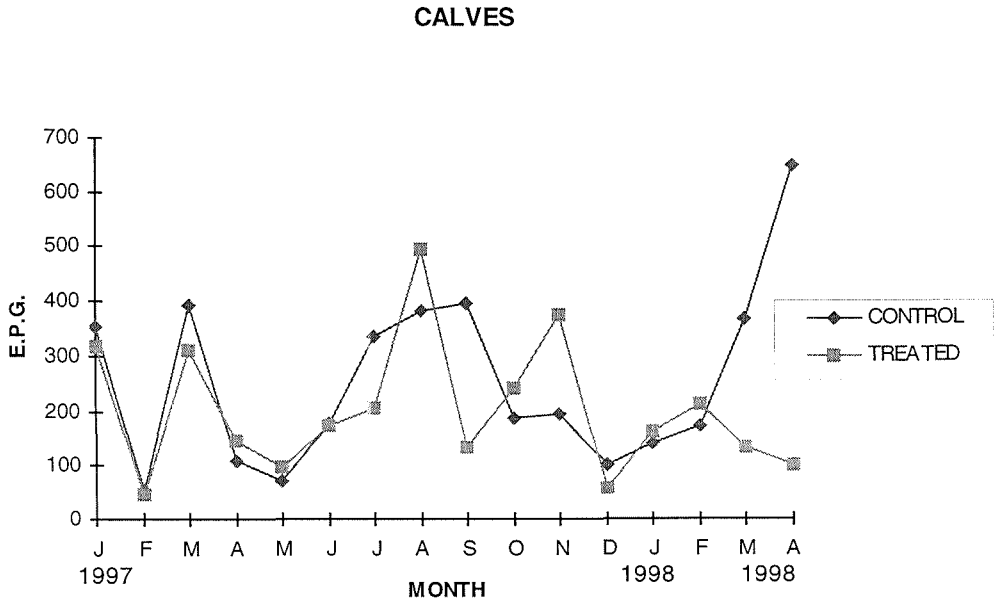


Figure 7.8. *Monthly mean egg counts of treated and control calves.*

Table 7.5 *Adult cattle arithmetic mean egg counts (±SD)*

MONTH	CONTROL FARMS		TREATMENT FARMS	
	Number	EPG ±(SD)	Number	EPG ±(SD)
January 1997	172	133.7(351.0)	213	135.2(426.2)
February	185	18.9(55.4)	229	23.1(73.4)
March	179	225.4(712.4)	234	122.2(387.3)
April	183	60.6(151.5)	212	104.3(423.0)
May	193	29.5(105.1)	218	29.8(159.4)
June	180	60.0(209.2)	210	66.7(340.8)
July	174	83.9(225.5)	219	90.8(386.7)
August	177	188.7(485.1)	206	254.9(917.2)
September	166	86.1(283.3)	192	72.4(205.0)
October	158	133.5(512.0)	208	240.4(1064.0)
November	162	56.8(166.8)	185	177.9(696.7)
December	149	47.0(172.3)	198	34.9(105.4)
January 1998	159	76.7(213.5)	199	64.3(186.1)
February	167	46.1(138.3)	199	47.2(118.4)
March	173	71.7(228.4)	215	54.9(253.1)
April	143	193.7(1035.2)	220	98.6(283.4)

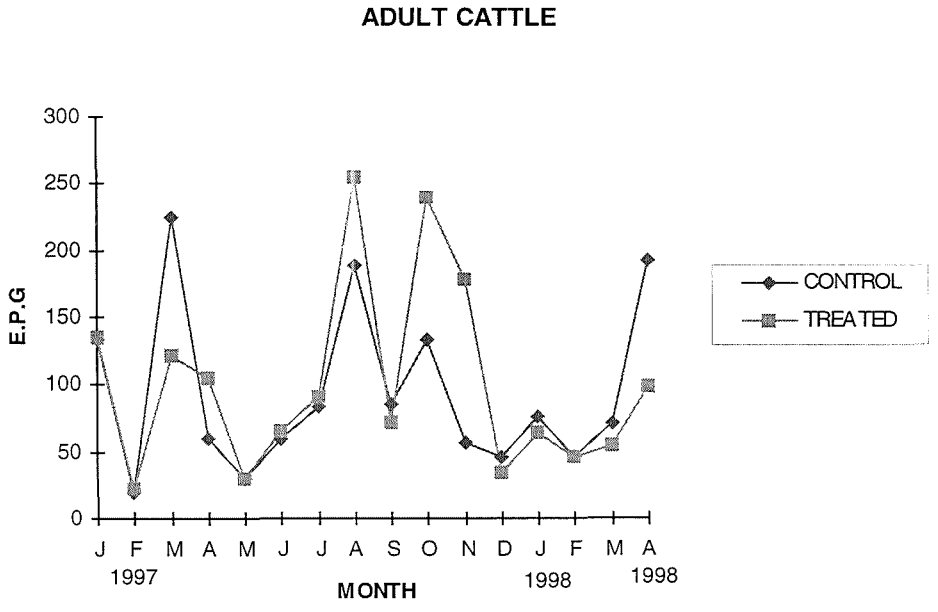


Figure 7.9. *Monthly mean egg counts of treated and control adult cattle.*

Effect of age on calf egg count

Table 7.6 contains the mean egg count data for calves aged 0-3, 3-6, 6-9 and 9-12 months of age together with details of the numbers of positive samples contributing to these means. The egg count data is also presented graphically in Figure 7.10

Table 7.6 *Arithmetic mean calf egg counts grouped according to age (±SD)*

AGE	TREATED ANIMALS		CONTROL ANIMALS	
	Observations	EPG±SD	Observations	EPG±SD
0-3 months	129	208.5(592.4)	78	220.5(416.3)
3-6	254	312.6(849.7)	120	294.2(888.6)
6-9	184	154.3(442.2)	129	309.3(711.2)
9-12	224	115.6(262.2)	137	184.7(468.2)

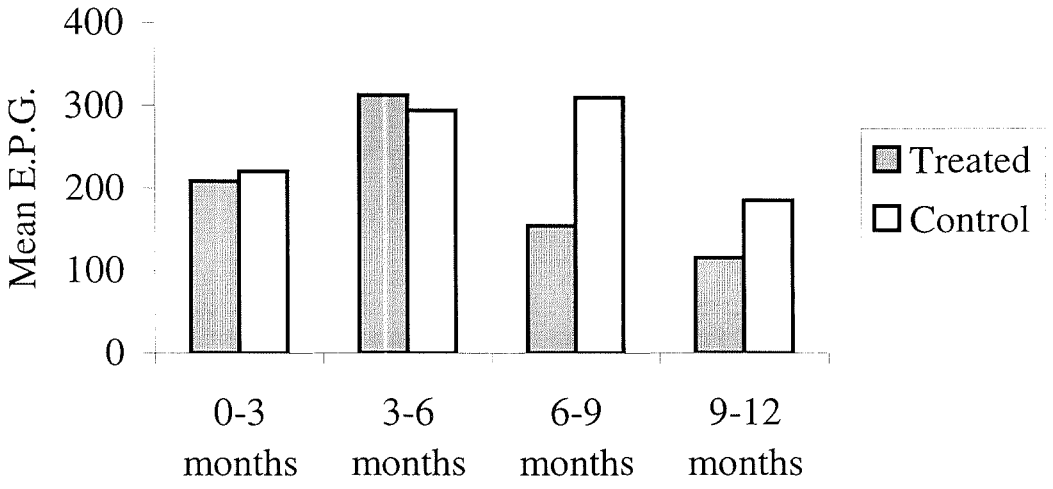


Figure 7.10. *Mean egg counts of treated and control calves grouped according to age.*

7.3.4.2. Goats

The monthly arithmetic mean egg counts for the control and treated farms are shown in Table 7.7 (kids) and in Table 7.8 (adults) and in Figures 7.11 and 7.12. The mean EPG for the kids on the control and treated farms were similar with averages of 624.0 (±1,118.3) and 596.7 (±996.0) respectively.

Adult goats on the control farms had significantly higher ($P<0.001$) mean counts than those on treated farms, (620.6 ±123.0 for treated farms vs 747.3 ±1646.6 control farms).

Table 7.7 *Arithmetic mean goat kid egg counts (±SD)*

MONTH	CONTROL FARMS		TREATMENT FARMS	
	Number	EPG ±(SD)	Number	EPG ±(SD)
January 1997	11	1236.4(1529.2)	12	541.7(806.2)
February	6	1266.7(970.9)	11	363.6(729.8)
March	1	0	7	914.3(935.3)
April	2	0	8	387.5(701.9)
May	11	145.5(206.7)	11	54.5(93.4)
June	9	566.7(829.2)	4	500.0(600.0)
July	10	510.0(734.0)	9	411.1(605.1)
August	11	427.3(605.1)	16	1718.8(1859.8)
September	11	1075.5(2075.5)	6	1466.7(1072.7)
October	13	515.4(618.9)	6	133.3(216.0)
November	9	977.8(1291.1)	6	33.3(81.6)
December	12	175.0(354.5)	15	193.3(386.3)
January 1998	13	646.2(847.2)	23	765.2(1598.2)
February	11	300.0(374.2)	14	728.6(1079.5)
March	9	744.4(961.9)	11	600.0(1040.2)
April	5	80.0(83.7)	7	385.7(612.2)

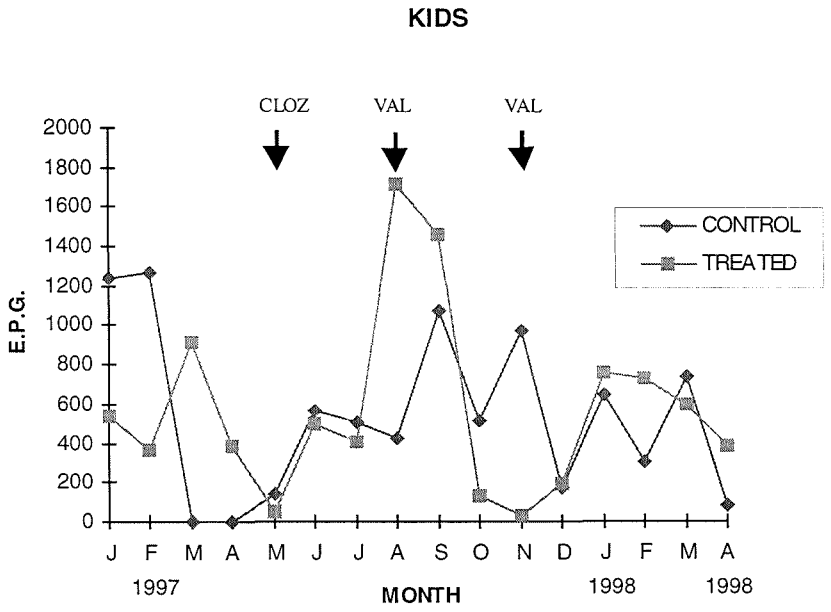


Figure 7.11 *Monthly mean egg counts of treated and control kids.*

Key : CLOZ – Clozantel, VAL – Valbazen

Table 7.8 *Arithmetic mean adult goat egg counts (±SD)*

MONTH	CONTROL FARMS		TREATMENT FARMS	
	Number	EPG ±(SD)	Number	EPG ±(SD)
January 1997	101	803.0(1367.9)	98	668.4(1453.2)
February	118	616.9(1629.7)	116	550.9(1037.4)
March	119	1126.5(2146.7)	113	892.9(1375.5)
April	114	714.9(910.4)	108	497.2(903.8)
May	121	548.8(1022.0)	117	300.0(1010.5)
June	102	671.6(1443.1)	103	615.5(908.0)
July	108	595.4(870.3)	107	1115.9(1465.4)
August	108	927.8(1225.9)	102	1418.6(2049.7)
September	108	903.7(1469.4)	100	390.0(943.7)
October	118	831.4(1453.7)	118	567.8(1025.6)
November	101	1390.1(3714.5)	111	309.0(508.0)
December	110	200.9(459.1)	109	53.2(227.5)
January 1998	128	1025.8(2498.8)	114	834.2(1483.9)
February	127	522.0(1074.9)	118	629.7(1378.7)
March	120	427.5(948.7)	123	497.6(690.5)
April	118	718.6(1160.2)	115	663.9(1386.0)

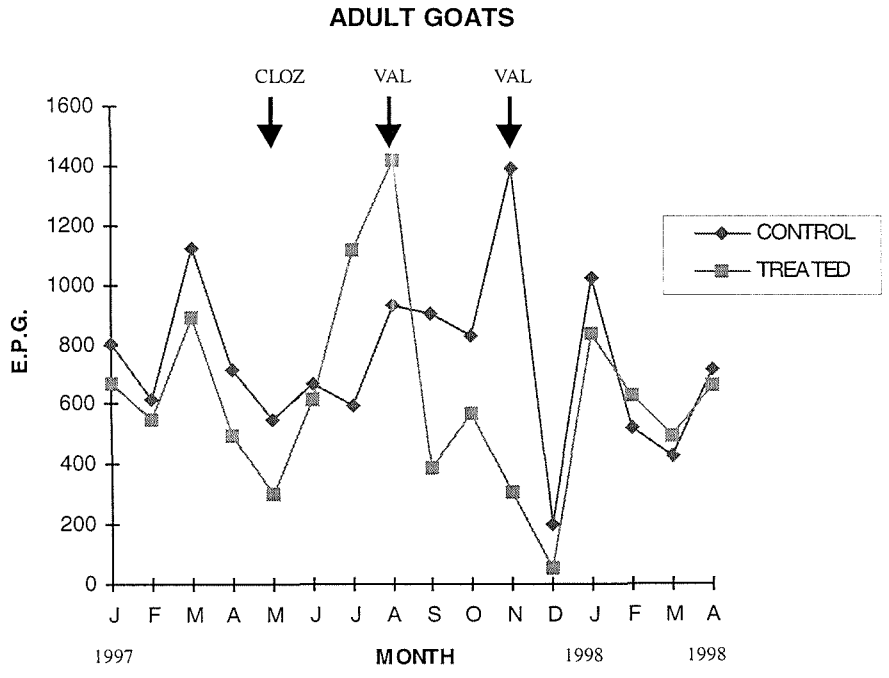


Figure 7.12 *Monthly mean egg counts of treated and control adult goats.*

Key : CLOZ – Clozantel, VAL - Valbazen

Effect of age on kid egg count

Table 7.9 contains the mean egg count data for kids aged 0-3, 3-6, 6-9 and 9-12 months of age together with details of the numbers of samples contributing to these means. The egg count data is also presented graphically in Figure 7.13

Table 7.9 *Arithmetic mean kid egg counts grouped according to age (±SD)*

AGE	TREATED ANIMALS		CONTROL ANIMALS	
	Observations	EPG±SD	Observations	EPG±SD
0-3 months	51	368.6(648.8)	27	203.7(357.9)
3-6	103	704.9(1260.3)	114	710.8(1220.1)
6-9	106	526.9(841.1)	137	945.3(1562.0)
9-12	80	604.5(1122.4)	110	809.1(1084.8)

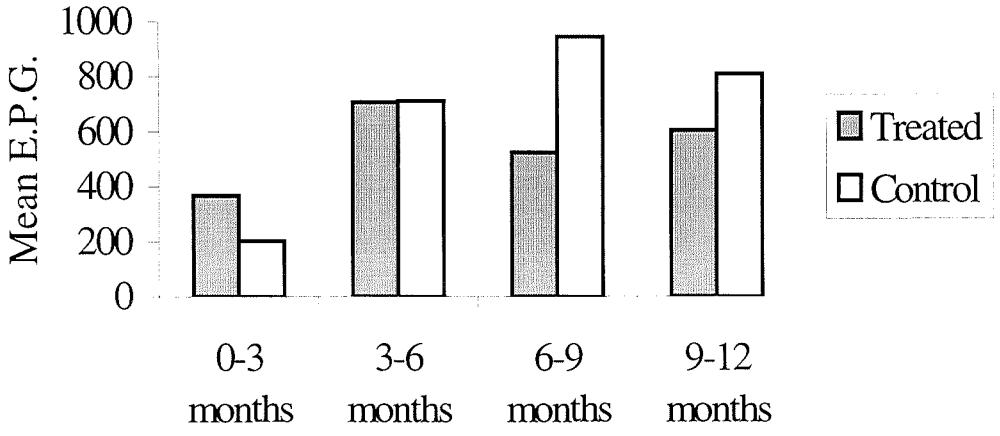


Figure 7.13. *Mean egg counts of treated and control kids grouped according to age.*

7.3.4.3. Sheep

The monthly arithmetic mean egg counts for lambs and adult sheep are shown in Tables 7.10 and 7.11 and the control and treated mean egg counts are plotted in Figures 7.14. and 7.15. Overall lamb monthly mean counts were similar but the mean count was higher in the treated lambs (616.4 ± 1225.3) than in the untreated lambs (585.2 ± 833.2). The pattern in adult sheep was similar overall with mean counts for treated and control sheep of 948.3 ±3191.8 and 522.0 ±1068.9 respectively. Because of the small sample size, statistical analysis was conducted

using pooled data from control lambs and sheep and treated lambs and sheep. There were no significant effects attributable to treatment.

Table 7.10 *Arithmetic mean lamb egg counts (±SD)*

MONTH	CONTROL FARMS		TREATMENT FARMS	
	Number	EPG ±(SD)	Number	EPG ±(SD)
January 1997	3	1366.7(1457.2)	1	0
February	1	0	6	416.7(407.0)
March	1	100.0	4	1075.0(1703.7)
April	1	0	6	366.7(898.1)
May	1	600.0	6	50.0(122.5)
June	1	0	4	75.0(150.0)
July	1	0	2	2250.0(2616.3)
August	3	533.3(57.7)	3	1200.0(1153.3)
September	2	1350.0(1343.5)	5	560.0(665.6)
October	2	650.0(353.6)	5	500.0(400.0)
November	3	100.0(173.2)	5	60.0(89.4)
December	2	300.0(424.3)	5	0
January 1998	0		7	1328.6(2711.5)
February	1	1400.0	5	1720.0(1602.2)
March	3	1033.3(1446.8)	6	500.0(737.6)
April	2	0	3	266.7(461.9)

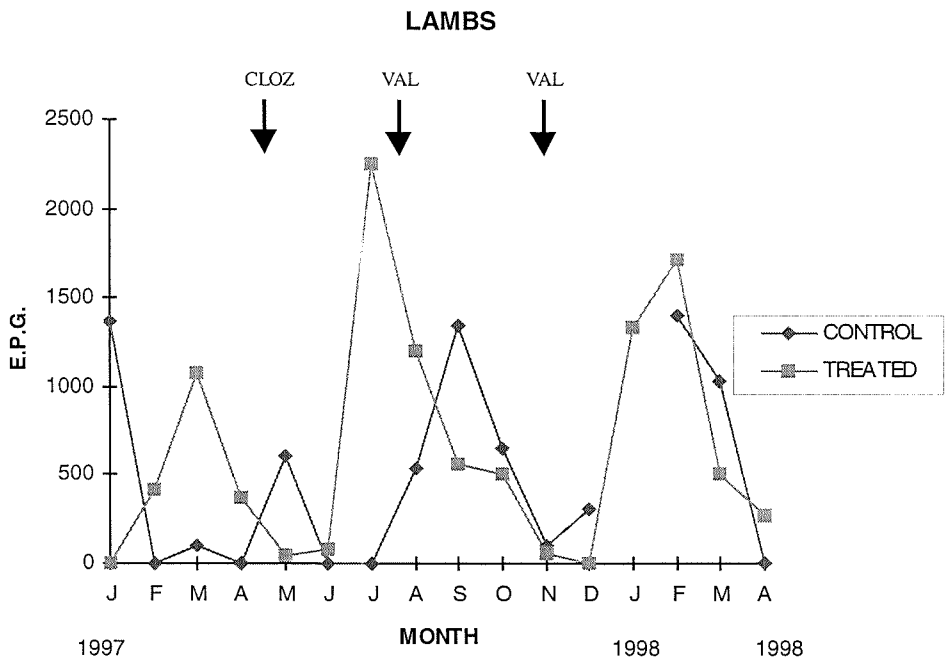


Figure 7.14 *Monthly mean egg counts of treated and control lambs.*

Key : CLOZ – Clozantel, VAL - Valbazen

Table 7.11 *Arithmetic mean adult sheep egg counts (±SD)*

MONTH	CONTROL FARMS		TREATMENT FARMS	
	Number	EPG ±(SD)	Number	EPG ±(SD)
January 1997	16	712.5(1014.5)	1	1000.0
February	19	868.4(1165.7)	2	14600.(18526)
March	17	1152.9(1685.6)	2	1900.0 (141.4)
April	19	836.8(1639.2)	3	0
May	15	113.3(304.4)	3	133.3 (230.9)
June	15	713.3(1495.6)	6	4016.7(5593.4)
July	14	378.6(960.9)	7	957.1(1975.6)
August	11	127.3(360.8)	8	1362.5(3115.8)
September	9	288.9(671.6)	10	70.0(163.6)
October	11	236.4(335.5)	12	108.3(223.4)
November	8	350.0(590.4)	10	20.0(63.2)
December	7	85.7(157.4)	13	69.2(110.9)
January 1998	7	428.6(558.9)	10	1380.0(2843.2)
February	7	614.3(922.7)	10	730.0(974.2)
March	8	112.5(210.0)	8	425.0 (660.6)
April	8	50.0(75.6)	10	535.0(865.4)

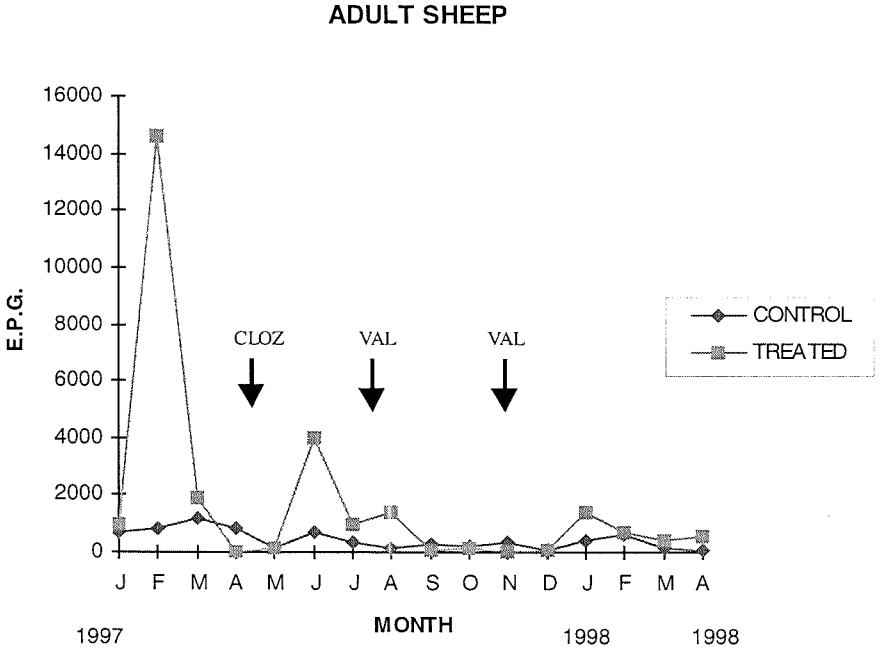


Figure 7.15 *Monthly mean egg counts of treated and control adult sheep.*
Key : CLOZ – Clozantel, VAL – Valbazen.

Effect of age on lamb egg count

Table 7.12 contains the mean egg count data for lambs aged 0-3, 3-6, 6-9 and 9-12 months of age together with details of the numbers of samples contributing to these means. The egg count data is also presented graphically in Figure 7.16

Table 7.12 *Arithmetic mean lamb egg counts grouped according to age (±SD)*

AGE	TREATED ANIMALS		CONTROL ANIMALS	
	Observations	EPG±SD	Observations	EPG±SD
0-3 months	6	643.5(1146.1)	23	866.7(838.3)
3-6	20	627.1(1292.7)	48	530.0(847.9)
6-9	9	1573.9(4860.7)	46	655.6(1289.5)
9-12	14	619.1(1209.8)	34	142.9(256.3)

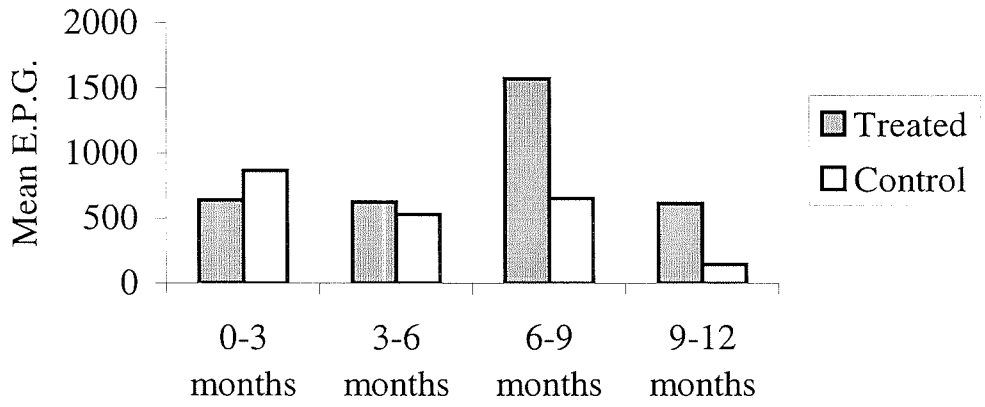


Figure 7.16. *Mean egg counts of treated and control lambs grouped according to age.*

7.3.5 Coproculture results

The monthly mean larval identification for the small ruminants and cattle are given in Appendix 7.7, Figures 7.17 (a-f) show the individual nematode species identified in cattle and small ruminant coprocultures.

Trichostrongylus species predominated in the cattle coprocultures accounting on average for 36.4 % (± 20.2%) of the population, *H.contortus* was the second commonest species (29.7 % ± 18.5%) followed by *Cooperia* species (14.3 % ± 12.9%). *Oesophagostomum*, *Strongyloides* and *Nematodirus* larvae were minor species recorded in almost equal proportions. In the small ruminants, *Trichostrongylus* species was predominant with a monthly mean of 47.2 % (±14.0%) followed by *H.contortus* (25.9 % ± 14.1%). *Cooperia, Oesophagostomum*, *Strongyloides* and *Nematodirus* accounted for the remaining 26.9%. The peak prevalence periods for *H.contortus* for both cattle and small ruminants were May to October and December to January. *Trichostrongylus* species predominated in cattle faeces from July to November, but had a seasonal distribution in small ruminant faeces. With the exception of January and February, *Cooperia* species appeared in

small proportions in all samples from both ruminant species. *Strongyloides* recoveries peaked in March, April and May in both cattle and small ruminant faeces. *Nematodirus* species peaked in small ruminant faeces in December but was present in much lower amounts in cattle faeces.

There were no significant differences between farms nor any association between larval prevalence data and climatic factors.

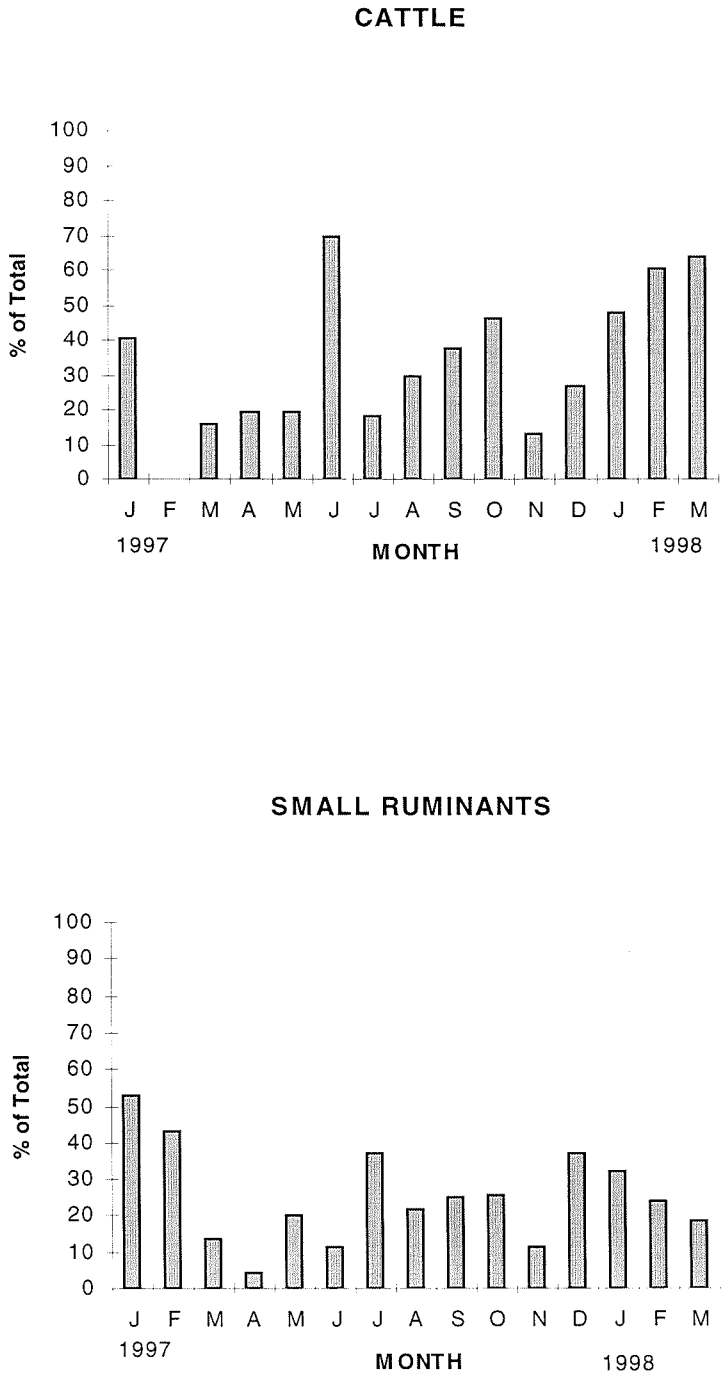
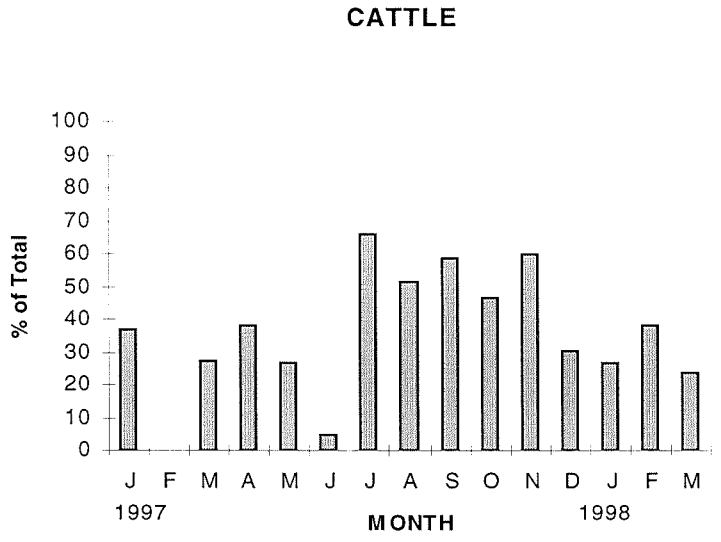


Figure 7.17.a *Haemonchus larval counts in cattle and small ruminants*



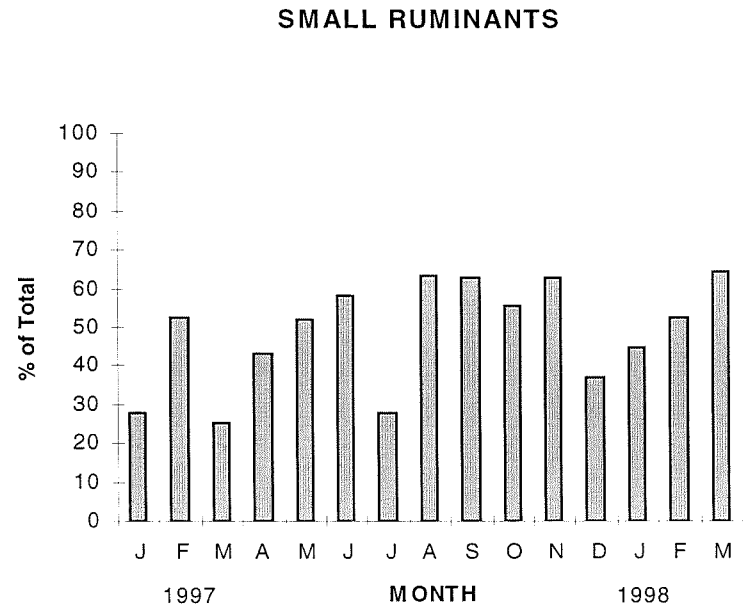
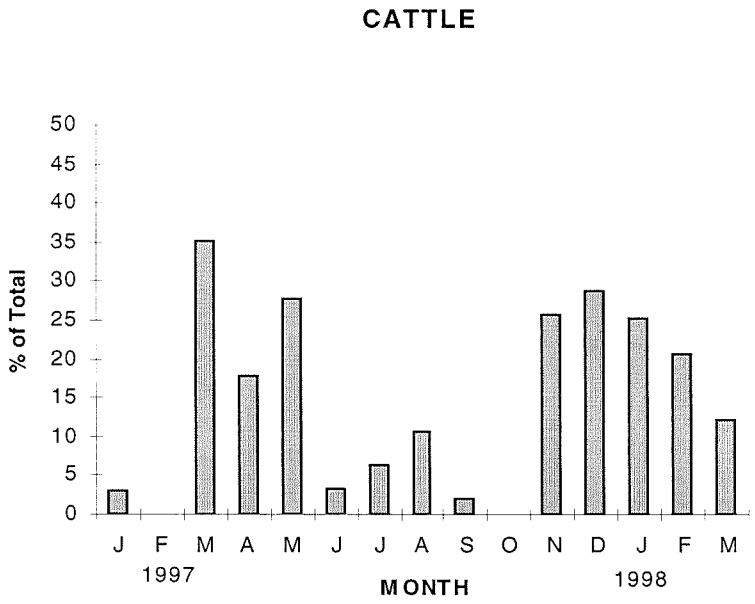


Figure 7.17.b *Trichostrongylus species larval counts in cattle and small ruminants*



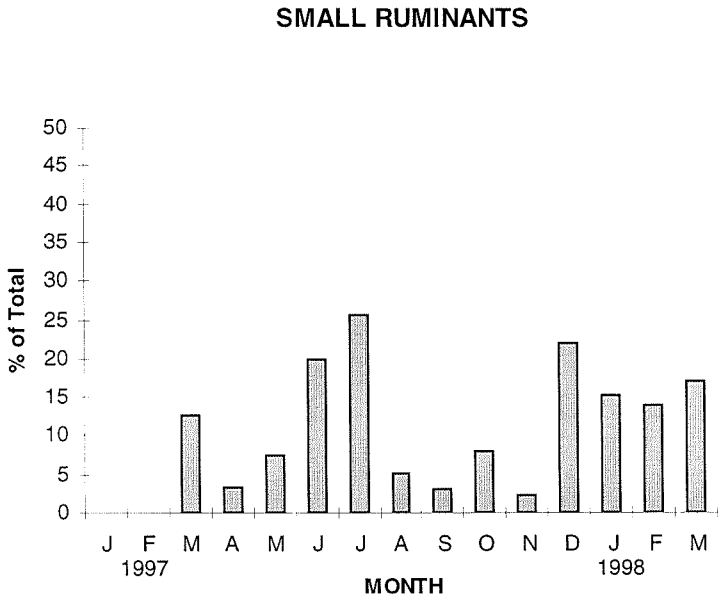


Figure 7.17.c *Cooperia larval counts in cattle and small ruminants*

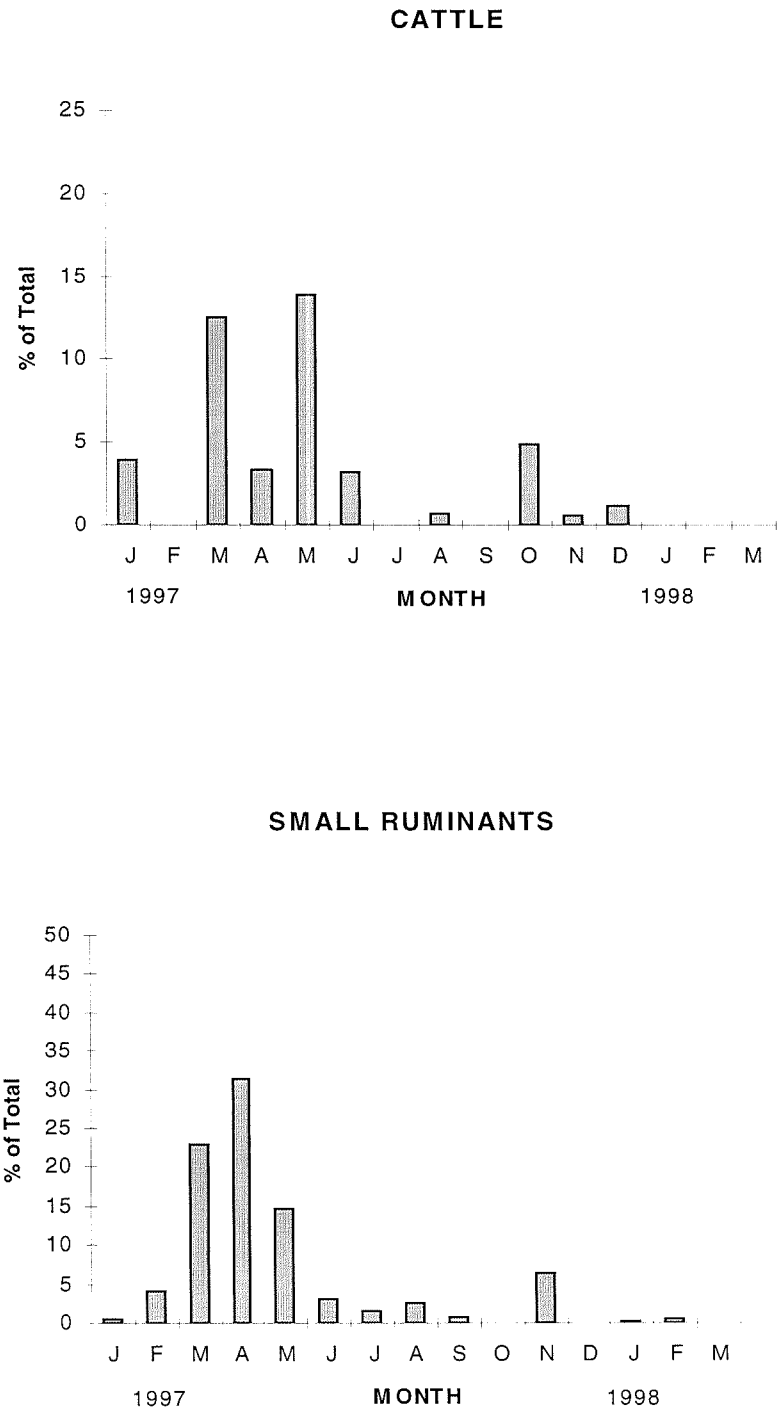
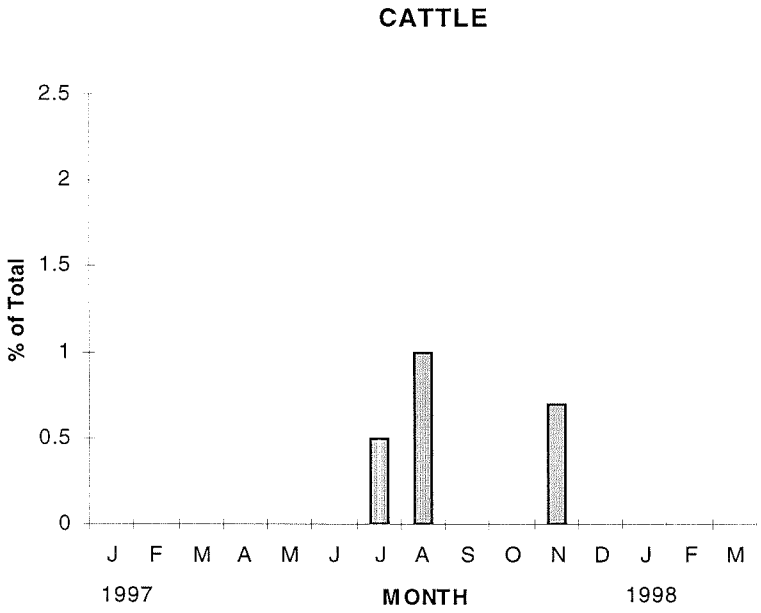


Figure 7.17.d *Strongyloides larval counts in cattle and small ruminants*



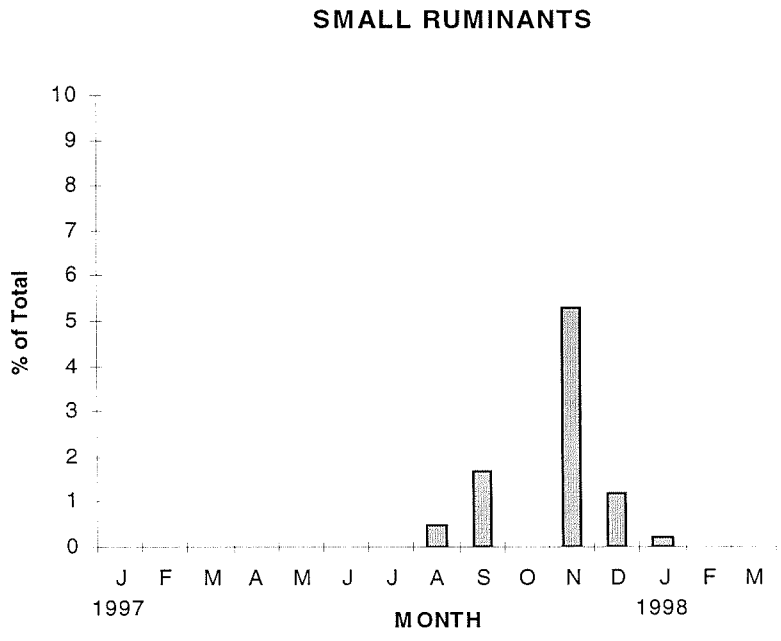


Figure 7.17.e *Nematodirus larval counts in cattle and small ruminants*

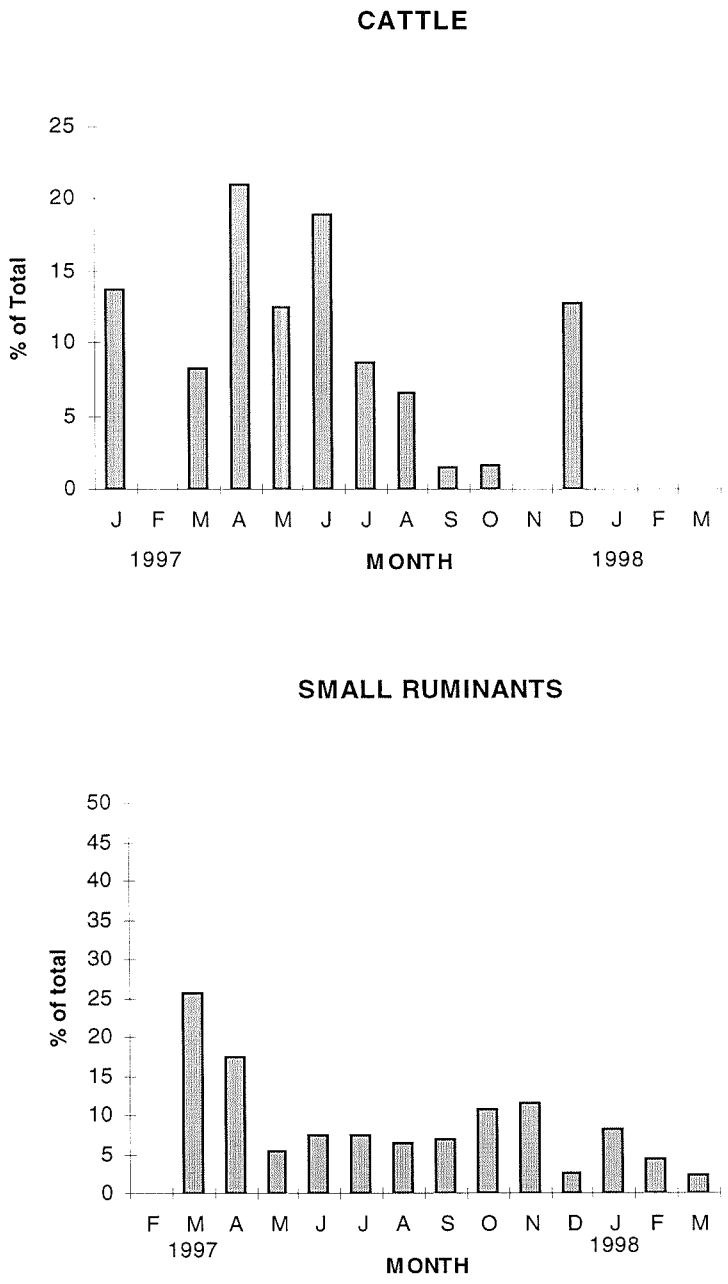


Figure 7.17.f *Oesophagostomum larval counts in cattle and small ruminants*

7.3.6. Productivity data based on growth rate

The weights of the young animals with known birth dates were monitored throughout the study period and the average growth rate per day calculated for each animal in grams per day.

7.3.6.1. Calves

320 calves were used in the trial, 194 on treated farms and 126 on control farms. The average growth rate per day for the treated farms was 168.1 ±125.3 grams compared to a figure of 153.2 ±116.4 for the control farms. Analysis of variance (ANOVA) for growth between the treatment groups revealed no significant differences.

Effect of age on calf growth rate

Table 7.13 contains the average weight data (SD) for calves at 0-3, 3-6, 6-9 and 9-12 months of age together with details on the numbers of observations contributing to these means. These are presented graphically in Figure 7.18.

Table 7.13 *Arithmetic mean calf weight (Kgs) grouped according to age (±SD)*

AGE	TREATED ANIMALS		CONTROL ANIMALS	
	Observations	Weight ±SD	Observations	Weight ±SD
0-3 months	304	42.8(10.2)	204	41.6(10.2)
3-6	304	59.5(29.5)	174	55.0(13.2)
6-9	280	75.3(30.3)	160	71.8(19.2)
9-12	247	93.0(27.4)	153	87.3(21.8)

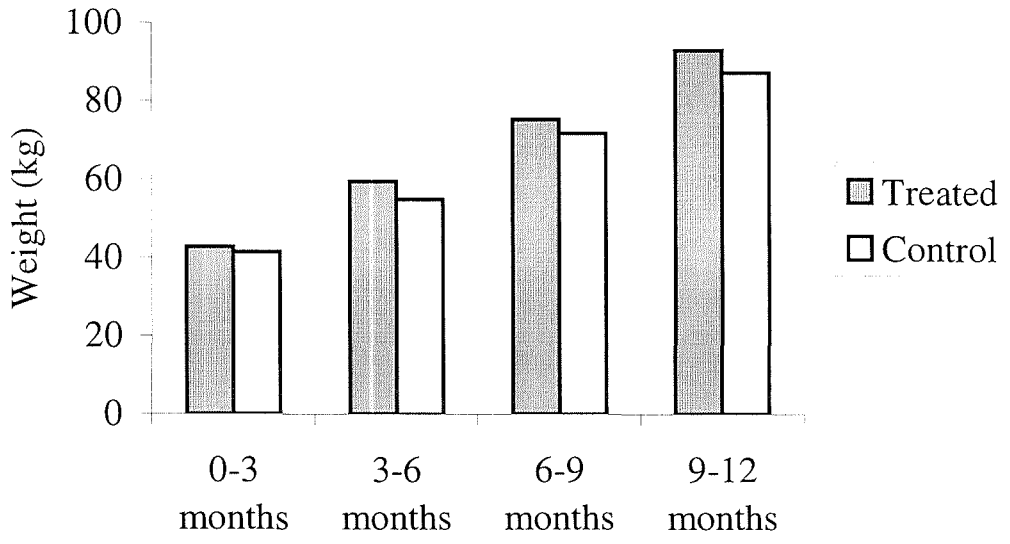


Figure 7.18. *Mean weights of treated and control calves grouped according to age.*

7.3.6.2. Kids

Ninety seven kids were present on the treated farms and 108 on the control farms. The average daily growth rates were 51.1 ±33.4 grams per day for treated kids and 45.1 ±28.8 grams per day for the control kids. There were no significant differences attributable to treatment.

Effect of age on kids growth rate

Table 7.14 contains the average weight data for kids at 0-3, 3-6, 6-9 and 9-12 months of age together with details of the numbers of observations contributing to these means. These are presented graphically in Figure 7.19.

Table 7.14 *Arithmetic mean kids weight (Kgs) grouped according to age (±SD)*

AGE	TREATED ANIMALS		CONTROL ANIMALS	
	Observations	Weight ±SD	Observations	Weight ±SD
0-3 months	214	6.7(3.7)	220	6.2(2.6)
3-6	182	11.1(4.2)	193	10.4(3.1)
6-9	149	13.2(3.7)	169	13.1(3.8)
9-12	99	14.9(3.5)	123	14.1(3.9)

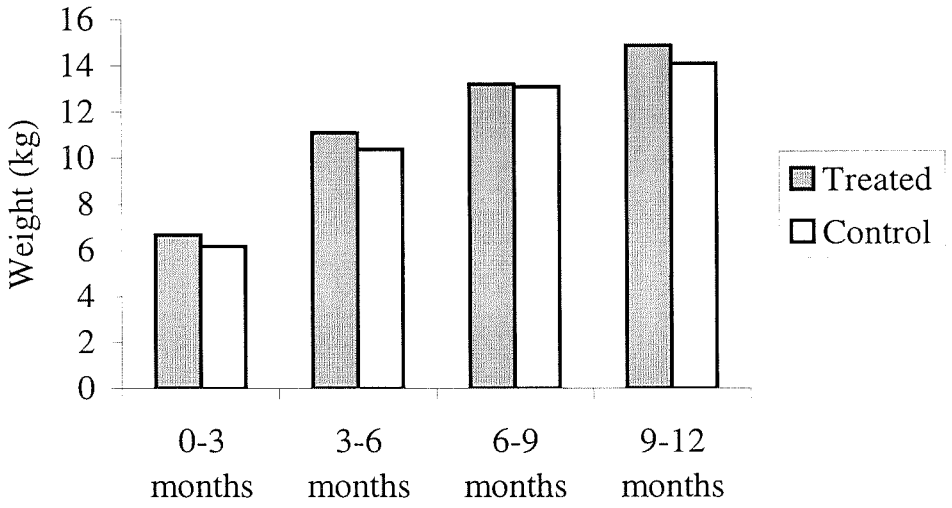


Figure 7.19. *Mean weights of treated and control kids grouped according to age*

7.3.6.3. Lambs

There were no significant differences in the daily weight gain of treated (n=31) lambs (55.8 ± 28.9 grams per day) compared to the control (n=13) lambs (55.5 ± 36.0 grams per day).

Effect of age on lamb growth rate

Table 7.15 contains the average weight data for lambs at 0-3, 3-6, 6-9 and 9-12 months of age together with details on the numbers of observations contributing to these means. These are presented graphically in Figure 7.20.

Table 7.15 *Arithmetic mean lamb weight(Kgs) grouped according to age (±SD)*

AGE	TREATED ANIMALS		CONTROL ANIMALS	
	Number	Weight ±SD	Number	Weight ±SD
0-3 months	57	9.4(3.6)	20	9.3(4.1)
3-6	62	15.6(4.3)	26	16.9(4.6)
6-9	56	18.9(4.6)	10	25.5(4.5)
9-12	41	21.4(4.8)	13	31.3(3.3)

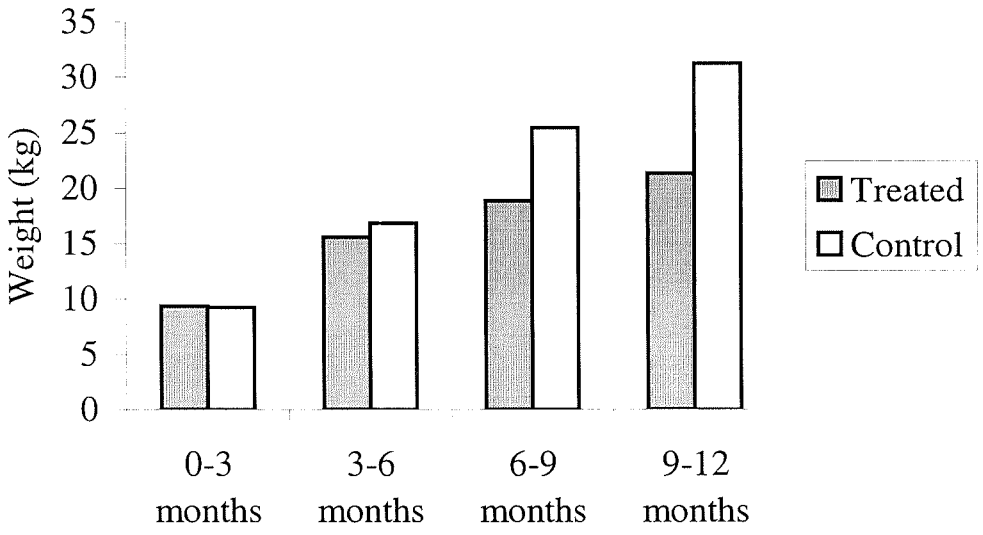


Figure 7.20. *Mean weights of treated and control lambs grouped according to age*

7.3.7 Anthelmintics used during the study and costs of treatment.

7.3.7.1. Cattle

Table 7.16 contains a summary of the anthelmintic usage and cost data for adult cattle and Table 7.17 for calves. Approximately 8 % of the adult cattle were given treatments during the trial period, out of a population of 620 adult cattle, 49 were treated. Sixty seven percent (214 out of a total of 319) of the calves were treated in the course of the trial. Details of the drugs used and the costs of the treatments given to cattle and calves are shown in Tables 7.18 and 7.19.

Table 7.16. *Anthelmintic usage-adult cattle*

NAME-SUPPLIER	CONTENTS	NUMBER OF DOSES
Wormicid-Cosmos	Levamisole	38
Nilzan- Cooper	Levamisole+oxyclozanide	3
Flukiver-Janssen	Closantel	7*
Vetworm-Lab and Allied	Levamisole	1
Valbazen-Kenya Swiss	Albendazole	4

Table 7.17 *Anthelmintic usage-calves*

NAME-SUPPLIER	CONTENT	NUMBER OF DOSES
Wormicid - Cosmos	Levamisole	199**
Nilzan - Cooper	Levamisole+Oxyclozanide	4
Flukiver - Janssen	Closantel	7*
Vetworm -Lab. and Allied	Levamisole	7
Vermisole -Bimeda	Levamisole	1
Vermitan - Sanofi	Levamisole	2
Wormita - Cosmos	Albendazole	1

*The 3 doses given on welfare grounds.

** 132 doses as intervention protocol, 33 administered by farmers on the treated farms and 34 on the control farms

The costs of drenches given to each cattle treatment group are shown in Table 7.18

Table 7.18 *Drenching adult cattle at an average cost of an adult dose of Kenya shillings.120. (£1.20)*

Anthelmintic name	Farm status	Number of doses	Total cost in Ksh.
Flukiver	control	1*	120
	treated	2*	240
Nilzan	control	2	240
	treated	1	120
Vetworm	control	0	
	treated	2	240
Valbazen	control	4	480
	treated	0	
Wormicid	control	8	960
	treated	30**	3,600

* Treatment on welfare grounds by the author

** Treatments administered by farmers

The total cost for the control farms was therefore Ksh 1,800 as compared with Ksh. 4,200 for the treated farms.

Table 7.19 *Drenching calves at an average cost of Ksh.50 (£ 0.50) per dose.(Wormicid-used as per protocol)*

Anthelmintic name	Farm status	Number of doses	Cost in K Sh.
Wormicid	control	34	1,700
	treated	165	8,250
Nilzan	control	2	100
	treated	2	100
Flukiver*	control	3	150
	treated	4	200
Vetworm	control	0	
	treated	7	350
Vermisole	control	0	
	treated	1	50
Vermitan	control	0	
	treated	2	100
Wormita	control	1	50
	treated	0	

The cost of drenching in the treated farms was Ksh. 9,000 while on the control farms the cost was Ksh. 2,050.

7.3.7.2. Small ruminants

Details of the drug treatments given to small ruminants during the trial are shown in Table 7.20. One hundred and ninety six doses were administered by farmers during the study compared to 423 doses given as part of the trial. Overall a total of 619 doses were given to 643 small ruminants (205 kids and 43 lambs and 395 adults) giving a coverage rate of about 96 %. The costs associated with these treatments are summarised in Table 7.21.

The cost of drenching on the treated farms were Ksh 2,350 while the control farms where individual clinical cases were treated the total cost was Ksh 745.

Table 7.20 *Anthelmintic usage-small ruminants*

NAME-SUPPLIER	CONTENT	NUMBER OF DOSES
Wormicid- Cosmos	Levamisole	133
Valbazen- Kenya Swiss	Albendazole	302***
Flukiver- Janssen	Closantel	158*
Nilzan- Cooper	Levamisole+Oxyclozanide	4
Vetworm-Lab. and Allied	Levamisole	16
Ranox-Unga feeds	Rafoxanide	3
Unitrax-P.M[1]	Levamisole	2
Vermisole-Bimeda	Levamisole	1

* Treatment initially given as part of the intervention trial (149 doses for small ruminants) and on welfare grounds in the control small ruminant farms (9 doses).

*** Treatment given as part of the intervention trial = 274 doses and 28 doses administered by farmers on the control farms.

P.M[1] Pharmaceutical Manufacturing, Nairobi.

Table 7.21 *Drenching small ruminants (all ages) at an average cost of Ksh. 5 (£0.05) per dose (Valbazen and Flukiver used as per protocol)*

Anthelmintic name	Farm status	Number of doses	Cost in Ksh.
Valbazen	control	28	140
	treated	**274**	1,370
Flukiver*	control	9	45
	treated	149	745
Wormicid	control	93	465
	treated	40	200
Nilzan	control	3	15
	treated	1	5
Vetworm	control	14	70
	treated	2	10
Ranox	control	0	
	treated	3	15
Unitrax	control	1	5
	treated	1	5
Vermisole	control	1	5
	treated	0	

7.3.8 Offtake and survival rates of calves, lambs and kids

In estimating the losses within the smallholder farms the death of an animal is treated as a loss to the farmer but home slaughter and gifts are considered a benefit within the system since, if no suitable animal had been available, one would have been purchased.

7.3.8.1. Cattle

Table 7.22 contains details of the off take on the treated and control farms. During the whole study a total of 129 cattle died (58 adults and 71 calves). The calf mortality rates were similar on both the treated (58.0 %) and control (51.7 %) farms. The main causes of cattle death on all the farms were tick borne diseases, with East Coast Fever being the major cause with 61 deaths (43 confirmed in the laboratory and 18 suspected cases based on clinical signs described by the farmers) 35 of which

were calves. Anaplasmosis caused a total of 9 cattle deaths (5 confirmed and 4 suspected cases) while gastrointestinal blockage in calves accounted for 8 deaths. The remaining 51 deaths were caused by miscellaneous conditions like pneumonia, strangulation, urethral blockage, metritis, anthelmintic overdose (1 case) and plant poisoning. The latter being suspected *Cestrum* poisoning, a plant that is commonly used in hedges in the area.

A total of 205 cattle were either sold (159), given as gifts (30) were mainly for dowry payments or were slaughtered (16). Most animals that were sold (59) were adult cattle with sales to cover school fees occurring mostly at the beginning of school terms. Seven animals were sold to pay medical bills, the rest (96 animal sales) was attributed to various reasons like cash requirement for land development for example planting tea and food crops, cash for purchasing replacement animals especially heifers from the proceeds of male sales. Overall, the total number of animals sold from the control farms was 74 giving a revenue of Ksh.740,000 (based on an average cost of Ksh.10,000 for a Tropical Livestock Unit (TLU) of 250 kg live weight) On the treated farms a total of 85 animals were sold yielding an estimated revenue of Ksh 850,000.

Off take for home consumption was mainly for social reasons to meet obligations to visitors and for weddings and funerals. In 2 cases tradition demanded that an old cow, which had been part of the homestead for years, must be sacrificed purely for family consumption. Table 7.23 contains a summary of the benefits and losses incurred in each of the cattle groups.

Table 7.22 *Summary of cattle off-take at Ksh. 10,000 based on the Tropical Livestock Unit of 250 kg live weight with calves at Ksh.5,000.*

Farm status	No./cost	Deaths young and adults		Sale	Gifts	Slaughter
Control	number	29 adults	31 calves	74	23	7
	cost in Ksh	290,000	155,000	740,000	230,000	70,000
Treated	number	29 adults	40 calves	85	7	9
	cost in Ksh.	290,000	200,000	850,000	70,000	60,000

Table 7.23 *Summary of benefit and losses for cattle.*

Benefits in Ksh.

ITEM	CONTROL FARMS	TREATED FARMS
Sales	740,000	850,000
Home slaughter	70,000	90,000
Gifts	230,000	70,000
TOTAL	1,040,000	1,010,000

Losses

ITEM	CONTROL FARMS	TREATED FARMS
Death of adults	290,000	290,000
Death of calves	155,000	200,000
Drenching adults	1,800	4,200
Drenching calves	2,050	9,000
TOTAL	448,850	503,200

The difference between the benefits and the losses were Ksh. 591,150 for the control farms and Ksh.506, 800 for the treated farms.

7.3.8.2. Small ruminants

Table 7.24 contains details of the off take of small ruminants from the treated and control farms. The main causes of death were strangulation (7 cases) by ropes during tethering, which is the main grazing system used in the study area, there were 2 cases each of pneumonia, bloat, and gastrointestinal blockage. The remaining deaths (23 cases) were attributed to various causes like ruminal stasis as a result of grain-overload, suspected helminthiasis, injuries by dogs and hailstones. Small ruminants (4) were given as dowry while sales (131) were essentially for cash to buy food, pay school fees and to meet various social expenditures like *Harrambees* (fund raising for communal projects). Small ruminants acted largely as the farmers' petty cash account. Off take for slaughter (32) was mainly for home consumption during festivities like Christmas and New year and for medicinal reasons since goat meat is considered to have medicinal properties throughout the region. The benefits and losses within the system are summarised in Table 7.25.

Table 7.24 *Summary of small ruminant off take and cost at an average cost of Ksh. 1,000.*

Farm status	No./cost	Deaths young and adults		Sale	Gifts	Slaughter
Control	Number	11 adults	4 Kids/lambs	61	2	21
	Cost in Ksh	11,000	4,000	61,000	2,000	21,000
Treated	Number	16 adults	5 kids/lambs	70	2	11
	Cost in Ksh.	16,000	5,000	70,000	2,000	11,000

Table 7.25 *Benefits and losses for small ruminants*

Benefits in Ksh.

ITEM	CONTROL FARMS	TREATED FARMS
Sales	84,000	83,000
Home slaughter	21,000	11,000
Gifts	2,000	2,000
TOTAL	107,000	96,000

Losses in Ksh

ITEM	CONTROL FARMS	TREATED FARMS
Death of adults	11,000	16,000
Death of kids/lambs	4,000	5,000
Drenching both ages	745	2,350
TOTAL	15,745	23,350

The difference between the benefits and the losses for the control farms was Ksh 91,255 and for the treated farms was Ksh.72,650.

7.4 Discussion

The intervention study has provided not only information on the impact of three annual treatments on the population dynamics of ruminant gastrointestinal nematodes but also additional epidemiological and socio-economic data.

Examination of the treatment records shows that additional treatments were administered by the farmers to control and treated group animals. Out of a total of 889 doses administered to cattle and small ruminants 83 were given to calves and cattle on control farms and 149 to small ruminants. This provides a graphic illustration of one of the most difficult problems in attempting to undertake control studies using subsistence farmers who are wholly dependant upon the output from their farms and will inevitably manage their livestock in their own best interests. Given that their co-operation depends upon establishing trust, they are mistrustful of government and its agencies and that they may know very little about endoparasitism it is difficult to simply institute strategies in the way that it has been done previously on large scale farms in more "traditional" control studies (Gettinby *et al*, 1987, Stear *et al*, 1998, Mitchel *et al*, 1984). Despite this complication the results from the study suggest that, as might be expected, a non-intensive regime involving three annual treatments has only relatively minor effects upon the epidemiology and performance of ruminants that for at least part of their time share common grazing.

Although there was an overall reduction of 21.6 % in egg counts of treated calves this effect was certainly not evident in kids and lambs where the treated animals had average egg counts that were 6.1 % and 130.7 % higher than those of control animals. Although it is difficult to understand why an oral drug that has little persistence in the host could have long term effects upon the egg output of calves but not small ruminants, these differences may be largely due to specific variation in the way that cattle, goats and sheep acquire and express their immunity against GI nematodes.

The results of the previous epidemiological study Chapter 4, where FEC data was analysed in two age classes i.e young and mature animals showed that whereas calves had little evidence of any acquired immunity operating against parasite fecundity, this was not the case in kids and lambs. However as discussed previously one of the principal effects that aseasonal breeding has upon patterns of faecal egg output is to diminish the contribution made by the youngest most susceptible animals, simply because the recruitment of young animals into the population occurs throughout the season. As the results from a more detailed examination of the effects of age upon the FEC of calves shows (Table 7.6 & Figure 7.10) when animals are assessed purely on the basis of age then a different FEC pattern emerges. Faecal egg counts of

calves appear to increase over the first three quarters of their first grazing season but fall in their final quarter. Obviously some caution regarding the interpretation of this data is necessary since calves of a single age class would have been challenged at different times in the season. However since the results from tracer animals suggest that challenge, at least with the two main genera *Haemonchus* and *Trichostrongylus,* was relatively consistent throughout the season it seems reasonable to assume that seasonal effects may not have been a major influence upon the egg output of the different age classes. Given that this is indeed the case then it appears that older calves may be beginning the process of regulating their GI nematode populations. Under these circumstances treatments given to animals that are in the process of acquiring and expressing immunity and thus may be less susceptible to re-infection, might have consequences that extend beyond the period of effectiveness of the administered drug(s). Evidence supporting this view comes from Figures 7.8 and 7.10 where there was some reduction of egg counts in the older treated calves, particularly those in the treated groups. For the young small ruminants where the expression of immunity appeared not to vary over time then anthelmintic treatments would not be expected to exert any persistent effects and if the treatments were closely spaced might even compromise the expression of immunity as has been seen previously (Barger, 1988).

The pattern of age related infection in small ruminants was quite different to that of calves. In this study and the previous epidemiological study there was little evidence of any increasing expression of acquired immunity in kids as the season progressed and generally their counts were of a similar magnitude to adult goat counts. The goat data from different age cohorts (Figure 7.13) shows a relatively homogenous pattern of egg counts in animals aged more than three months. The sheep data set is far too limited to be able to make any meaningful observations on the effects of age and the expression of acquired immunity. However the results from this study and the previous study support the view that small ruminants may have some ability to regulate *Haemonchus.* Since *Haemonchus* was the commonest genus recovered from tracers used in the studies at Kericho and it is recognised as a fecund species (Gordon, 1948, 1950, Lapage, 1955) one might expect *Haemonchus* larvae to predominate in coprocultures from animals grazing in the area. This was apparently not the case in the two studies at Kericho where this genus only accounted

for 25.9 % (Intervention study) and 20.6 % (Epidemiology study) of the larvae recovered from small ruminants. Unfortunately, since in both cases faeces from adult and young animals were pooled and adults outnumbered young stock, it is possible that *Haemonchus* counts may have been higher in young kids and lambs. Although this may have been the case the magnitude of the mean egg counts of young small ruminants was relatively low, in the current study the average kid and lambs counts were 558.3 and 571.8 EPG respectively. Counts in *Haemonchus* infections in exotic breeds of sheep and goats are often several degrees of magnitude greater than this (Jallow *et al*, 1994, Le Jambre, 1984) supporting the view that the young of indigenous breeds may have some capacity to regulate *Haemonchus*. If this is the case then host resistance against this genus in indigenous small ruminants is either acquired very rapidly or may be innate. The ability to regulate *Haemonchus* populations but not those of other gastrointestinal species suggests that the mechanisms operating in small ruminants in these studies may be parasite specific. These studies provided little evidence of polyspecific 'self-cure' reactions of the type first described by Stewart (1955). Early studies examining haemonchosis in Kenya identified differences in blood type in susceptible and resistant breeds of sheep (Allonby and Urquhart, 1976). These authors showed sheep with HbAA type had lower worm establishment compared to those of HbAB or HbBB types.

Given that the FEC and tracer data showed that anthelmintic treatment had little effect then it is not surprising that there were no statistically significant benefits from treatment on the growth of young ruminants. Although treated calves and kids had daily weight gains that were 9.7 % and 13.3 % greater than those of the untreated animals, the rates of daily weight gain in the smaller number of treated and control lambs were almost identical.

The cost analysis for the large and small ruminants is similar in that the treated groups showed a reduced total cash yield. In the case of cattle the yield on the treated farms was 14.3 % lower than that of the control farms, the corresponding figure for small ruminants was 20.4 %. These differences were not attributable solely to increased anthelmintic costs which accounted for 1.8 (cattle) and 2.2 % (small ruminants) of the total yields or 11.1 %(cattle) and 8.6 % (small ruminants) of the differences in yield. Differences in yield in the cattle groups were most affected by variation in the numbers of animals received as gifts (160,000 Ksh) which boosted

the control group income figures. This coupled with some additional calf deaths (45,000 Ksh) on the treated farms helped to account for the differences in yield. In the case of the small ruminants more than half of the difference in yield (53.7 %) between the treated and control groups was attributable to the higher numbers of animals slaughtered for home consumption on the control farms.

The first treatment administered to the goats and sheep on the smallholder farms in mid May 1997 was closantel, a narrow spectrum anthelmintic with some persistence against haematophagous parasites such as *Haemonchus*. Closantel has been used extensively in areas of Australia (Barger, Hall and Dash, 1991, Dash, 1986) and South Africa (Van Wyk *et al,* 1987, 1989a) where *Haemonchus* predominates. However as the results from the treated goats and sheep illustrate this drug had no persistent effects on the egg counts of the predominant species in Kericho. Goat egg counts in the month following treatment were x1 (adults) and x 8 (kids) times higher than pretreatment values. The corresponding figures for sheep were x 30 (adults) and x 1.5 (lambs). Since similar though smaller increases in egg counts were evident in the control small ruminants it suggests that susceptible non-haematophagous parasites were responsible for the bulk of the eggs passed at this time. This agrees with the results from coprocultures in May where *Haemonchus* larvae only accounted for about 20 % of the larvae recovered from cultures. Since these results confirmed the ineffectiveness of closantel all of the subsequent doses given to small ruminants as part of the study contained albendazole (*Valbazen*, Kenya Swiss Ltd).

The epidemiology of gastrointestinal nematodes in the intervention study was similar in most respects to that seen previously. Some inhibited development was evident in *Haemonchus* particularly in the tracers in March and in lower amounts in the preceding two months. Small numbers of early L_4s of *Haemonchus* were also recovered from the permanent sheep in January and March. Immature *T.axei* were common in both the tracer and permanent sheep but once again there was no evidence of inhibition at the L_3 stage.

The fact that growth rates, measured simply in terms of average daily weight gain, of local calves, kids and lambs were relatively low in this study is not surprising given the relatively poor nutritional environment, tendency for overgrazing and background of disease in the locality. The socio-economic importance of livestock

in the area is also a contributing factor since it places considerable emphasis on the numbers of animals rather than individual performance. Although examination of the causes of mortality confirms that nematodoses were not a major cause of mortality, the contribution that they make to poor performance remains to be determined. The interaction between poor nutrition and immunity is well documented (Coop & Holmes 1996, Van Houtert *et al*, 1996) as is the resistance and resilience of indigenous breeds such as the Red Maasai (Preston and Allonby, 1978, 1979) and SEA goats (Baker, 1997, Baker *et al*, 1998). However the cost to the host of maintaining resistance and the ability to perform under challenge (resilience) has yet to be determined. Studies examining resistant sheep challenged with *T.colubriformis* in Scotland have revealed considerable endogenous losses of nitrogen that are assumed to be associated with the maintenance of immunity (Kimambo, MacRae and Dewey, 1988; MacRae, 1993). One way of examining the cost to the host of endoparasitism (which include pathogenesis and the maintenance costs of immunity and resilience) in grazing animals would be to use continuous anthelmintic cover provided by a device such as the Ivomec bolus (Merial, Agvet). Although a suppressive treatment regime using conventional drenches might also be thought to offer the same potential, previous studies (Coop *et al,* 1982, Gibson, 1963, Michel, 1976) have shown that losses in production may still occur. A recent study in New Zealand (Sutherland, Leathwick, Brown and Miller, 1997) showed that a pulse release device containing albendazole allowed some development of host immunity. These results which confirmed the extent of parasite/host contact also suggest that under conditions of high challenge performance might be compromised.

CHAPTER 8

General Discussion

8.1. General discussion

The data generated within this study, have provided some insight into helminthiasis in ruminants on small holder farms in a peri-urban area of Kericho and of the socio-economic factors that maintain the established farming systems. During the course of the research some of the constraints affecting the gathering of suitable data from within these systems have been identified and wherever possible addressed. It is now widely accepted that small holder farms in ACZs 1-4, which include Kericho, make a significant contribution to the total livestock production in Kenya. These farmers produce about 40 % and 50 % of the country's total cattle and small ruminant herds respectively (Anonymous 1993; Peeler and Omore, 1997) and account for approximately 3 % of the gross domestic product (Anonymous, 1994b). Reducing losses attributable to disease within smallholder farming systems offers an important means of increasing wealth amongst some of the poorest people in Kenya. In the long term, reducing these losses will help to ensure that production will be able to meet an increasing national demand as a result of population increase and localisation around the major cities and towns.

Helminthoses are acknowledged as an important cause of lost production in the area by the farmers, AHAs and local veterinarians. In fact nematodoses seemed to be the most significant helminth disease there being no evidence of any disease attributable to liver fluke or cestodes in the study area. Although the results from the intervention study suggest that mortalities due to nematodoses were a relatively rare phenomenon, it is possible that some of the animals selected for home consumption were selected simply because they were displaying early evidence of acute infection. Most of the losses attributable to nematodoses were probably due to reductions in performance associated with chronic infections. However, the ever present threat that nematodes pose to young animals is illustrated by the numbers of therapeutic treatments administered by the farmers to control animals in the intervention study. Thirty point two percent of calves and 8.2 % of kids/lambs of the control animals received treatments during the study. About 10 % of the Dorper lambs used as tracers were sacrificed earlier than their alloted dates simply because they displayed signs of haemochosis following only 4 weeks of grazing at pasture. This reflects the high level of challenge at certain times of the year.

There can be little doubt that the sub-optimal growth rates that were evident in the young small ruminants in the area were in part attributable to nematodoses. The growth rates of the local calves and kids were 21 % and 17 % lower than the averages recorded for this production system elsewhere in the country in animals of the same breed (Peeler and Omore, 1997)

The traditional system of management in the area which involves the extensive use of mixed grazing appears, as one might expect, to have influenced the prevalent species of gastrointestinal nematodes found in ruminants at Kericho. The three commonest species *T.axei, T.colubriformis* and *H.contortus* are all well adapted to cattle, goats and sheep. One striking feature of the gastrointestinal nematode population dynamics in the epidemiology and intervention studies was the predominance of *Trichostrongylus* species (*T.axei* and *T.colubriformis*) which are accepted as having a lower biotic potential than *Haemonchus contortus* (Gordon, 1948, 1950; Lapage, 1955) which was arguably the commonest species on herbage. Most of the evidence gathered in studies at Kericho suggests that differences in specific immunoregulation may account for these difference in prevalence of these two genera.

The relatively stable climate in Kericho provided conditions that suited the development and translation of infective larvae so that animals were exposed to infection throughout the year. The lack of a marked climatic influence on larval availability and the availability of young stock throughout the year, which masked age dependant effects upon egg output, resulted in relatively constant patterns of infection throughout the season. However examination of data on an age class basis revealed the importance of age and period of exposure as determinants in the development and expression of immunity, particularly for calves. These effects did not appear to be so important in young small ruminants from the very limited data set that was available for these animals. Further studies focusing on young small ruminants of these local breeds will be required in order to confirm whether there are any marked age/experience related effects upon the acquisition and expression of immunity, particularly against *Haemonchus*. Studies using very young stock of breeds such as SEA goats and Red Maasai cross sheep which have low birth weights and slow rates of growth cannot easily be conducted using

rectal faecal samples in the standard McMaster technique. This is simply because of the difficulties of obtaining sufficient faeces from such small animals. This problem could be addressed in future studies by using 8mm optical density flexible plastic tubing to obtain rectal faecal samples which could be analysed using a sensitive flotation technique which only requires 1 gramme of faeces for a FEC.

The epidemiological patterns in both the epidemiological and intervention studies suggest that the population dynamics of ruminant gastrointestinal nematodes in Kericho are influenced primarily by the expression of immunity. This finding is in agreement with those from studies using cattle, sheep and goats in tropical, semi-tropical and temperate climates (Barger, 1999). In the current study, adults of the local breeds of cattle, goats and sheep appeared to be capable of expressing an adequate immunity against *Haemonchus,* even in an environment where overgrazing was common and the available forages may have been of low quality. The interaction between nutrition and the expression of immunity is well documented in laboratory studies (Coop and Kyriazakis, 1999) however at present there are no simple means of separating the effects of these two parameters in field studies. The studies at Kericho do however provide clear evidence of the superiority of local breeds as far as adaptation to parasite challenge in the nutritional environment of Kericho. Twenty one of the 213 Dorper tracer lambs that grazed for one month at Kericho showed severe signs of *Haemonchus* infection and were slaughtered before their 3 week period of housing was completed. Mortalities attributable to nematodoses accounted for 4.2 % of the control lambs in the intervention study. These differences in susceptibility were not apparent in a laboratory study at NVRC (Mugambi *et al*, 1997) which compared the susceptibility of ad-lib fed indigenous (Red Maasai cross) and exotic sheep (Dorper) to infection with *H. contortus.* The resistance and resilience of local small ruminants are extremely valuable characteristics which must be given prime consideration in smallholder production systems. Although exotic breeds offer higher rates of production than these local breeds, that production can probably only be maintained in the smallholder farm environment with frequent anthelmintic treatments, a situation which is neither desirable nor feasible due to costs involved.

As the results from Chapter 5 show there is already some evidence of resistance on the smallholder properties, particularly against drugs in the imidazothiazole and tetrahydropyrimidine family. Given this background it is unlikely that a strategy incorporating intensive chemoprophylaxis could be sustainable, even if it were affordable. Currently most smallholder farmers only treat those animals with overt signs of infection. However the results from the calves in the intervention study suggest that smallholder farmers might also gain by administering a limited number of treatments to young stock, treating them on the basis of age and season rather than on the basis of season alone. This approach would involve treating about 8.5 % of the total flock, which should, in comparison to a blanket treatment applied to the whole flock, produce some reduction in the selection pressure for the development of anthelmintic resistance. Detailed on farm studies are required in order to determine whether this approach does offer any benefits as far as small ruminants are concerned.

Although there may be some scope for the introduction of an age limited chemoprophylactic regime primarily aimed at improving the performance of young livestock, this approach may do little to alleviate the risk of nematodoses. Nematodoses may still be expected to occur at those times when their ability to acquire and maintain immunity is compromised or when climatic conditions provide an opportunity for the suprapopulation to expand. Under these circumstances therapeutic treatments are still a vital part of the control strategy, particularly given the limited resources of smallholder farmers. Treating only those animals with overt signs of parasitism may have cost advantages but it may be very difficult to maintain high rates of production within the flock with this approach since one of the first effects of parasitism may be to check growth rates. Previous production loss studies in sheep have demonstrated that compensatory growth does not occur in parasitised animals which have acquired an ability to regulate their populations (Coop *et al,* 1982; Holmes, 1987). An improved understanding of the diagnosis of parasitism and the interaction between nutrition and immunity would obviously be beneficial to smallholder farmers. Since the farmers at Kericho appear to be reluctant to use the diagnostic facility provided by the Veterinary Investigation Laboratories then other means of delivering this information will be needed

particularly for small ruminants. Obviously the AHAs and local veterinarians can do a great deal to promote awareness of helminth disease and good husbandry practice, but other methods and media can also be used to transfer this information. Local meetings given by specialists in different areas may also be valuable as can articles in the local press and on radio and television. Educational campaigns are clearly long term projects and must be aimed at all sectors of the community since women and the young play an important part in the rearing of livestock. For some parasitic diseases such as haemonchosis adopting a simple eye colour reference chart as proposed by Van Wyk *et al* (1997) and more recently by KARI/DFID (Anonymous, 1999) may provide a simple affordable means of improving diagnosis for *Haemonchus* infection. Until such time as regulations are introduced to improve the quality of drugs available on the market the farming community as a whole should also be made aware of the dangers inherent in some of the poor quality anthelmintics sold through local outlets (Monteiro *et al*, 1998; Rugutt, unpublished data). The increasing prevalence of drug resistance throughout the world has focused research into alternative approaches to the control of nematodes (Larsen, 1999; Waller, 1993b; Waller and Faedo, 1996; Waller and Larsen, 1996). However most of these approaches are tailored specifically to suit the needs of large scale producers and thus may not be affordable or appropriate for small scale farmers.

The studies at Kericho have confirmed the importance of host resistance in the population regulation of gastrointestinal parasites and the indigenous small ruminants are known to be responsive (Preston and Allonby, 1978, 1979; Baker 1999; Baker *et al*, 1998; Shavulimo *et al*, 1988). Although genetic selection may offer a long term solution to the problem (Gray, 1997), on farm genetic selection is clearly not a feasible option for small scale farmers. Improvements in this area can only be brought about through some form of co-operative scheme to identify and share suitable breeding males. At present neither the finances nor the infrastructure exists to support such a venture. Novel methods aiming to control the infrapopulation through the use of hidden antigen vaccines (Smith, 1999) or the suprapopulation through the use of nematophagous fungi (Gronvold, Nansen, Henriksen, Larsen, Wolstrup, Bresciani, Rawat and Fribert, 1996) may also prove to be too expensive for smallholder farmers. Although the technology

for spore retention and release is likely to be expensive in comparison to the costs of oral drenches, using grain as the medium for spore growth and delivery might have some potential on small scale farms if surplus maize were available.

For small-scale farmers appropriate technologies need to be simple, cheap and relatively effective. Improving host nutrition appears to offer at least a partial solution to the problems of nematodoses on small-scale farms, although the provision of suitable foodstuffs may be a problem for these farmers. Studies in the Pacific rim have shown considerable benefits in the production of small ruminants offered relatively cheap urea/molasses blocks (Knox and Steel, 1996). Another interesting approach is the use of plants which have anthelmintic properties or may promote improved host resistance. Studies in New Zealand have demonstrated that condensed tannins, found in a number of forage crops can reduce faecal egg counts of grazing animals (Niezen, Robertson, Waghorn and Charleston, 1998). Simple management strategies involving grazing rotation for tethered animals have also been shown to work in tropical countries such as Fiji where larvae have a relatively short life expectancy on herbage (Barger *et al*, 1994). However whether this approach is possible in Kericho is not clear since temperatures are lower and rainfall is relatively steady throughout the season.

The challenge of controlling nematodoses on resource poor small scale farms is clearly a difficult one, but one that must be met if small scale farms are to increase their production in line with national demand. This challenge is only likely to be confronted over the long term, moreover successful solutions are likely to involve an integrated approach developed through collaborative research and extension programmes.

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Appendices

Chapter 2

2.1 17 Year (1964-1980) rainfall and temperature averages for Kericho.

Month	Min temp	Max. temp	Rainfall	Rain days	R.hum.
January	8.5	24.2	94	8	46
February	8.9	24.4	112	11	47
March	9.2	24.4	167	15	50
April	9.9	22.9	251	21	68
May	9.6	22.2	291	22	75
June	8.9	21.4	228	20	69
July	8.9	20.8	206	20	69
August	8.8	21.1	226	21	69
September	8.2	22.3	181	19	66
October	8.7	22.7	161	20	64
November	9.2	22.5	136	15	63
Dececember	9.0	23.3	81	11	52

Key: Min.- minimum, Ma.-maximum, Temp-temperature in ^{0}C, R.hum- Relative humidity in percentage, Rainfall is recorded in mm

2.2 Preparation of standard helminthological chemicals

1-Saturated salt solution- this was done by adding salt to a container of hot water until no more dissolve leaving accumulation of salt to settle after shaking and checked for specific gravity of 1.200. This was stored at room temperature

2- Pepsin/HCL solution- 20 grammes of pepsin powder (BDH Prod. 39032) was dissolved in 750 ml cold water then 60 ml concentrated HCL slowly added and stirred well. The final volume was made up to 2 litres and maitained at 4°C until when it was warmed to 37 °C.

3- Sodium thiosulphate solution-20 grammes of sodium thiosulphate (Sigma S 1648) was dissolved in 1 litre of water prior to use the solution was stored at the room temperature.

4- Helminthological iodine- 225 grammes of potassium iodide was dissolved in 160 ml of boiling water then 125 grammes of iodine crystals was added and the volume was made up to 250 ml prior to use the solution was stored at the room temperature.

Chapter 3

3.1 STANDARD FARM QUESTIONNAIRE

Section 1 Introduction and location

1. Survey name
2a. Name of interviewer
2b Contact address
3. Date
4. District
5. Sublocation name
6. Village name
7. GPS reading

8. Name of house hold head

9. Sex of household head male ☐ female ☐

10. Name of respondent

11. Sex of respondent male ☐ female ☐

12. Relation of respondent to the household head

Section 2 Farming Activities

1 Would you characterise your farming activities as :(tick)

mainly livestock ☐ mixed livestock /crop ☐ mainly crop ☐

2 Do you sell the majority of your livestock products

yes ☐ no ☐

3 Do you sell the majority of your crop harvest

yes ☐ no ☐

4 What is most important for subsistence

livestock ☐ crops ☐

5 What is most important for cash income

livestock ☐ crops ☐

6a Please complete the table below

crop enterprise	manure used ? (tick)	acreage	tick main reason for production	
maize			sale	consumption
maize/crop1*				
maize/crop2*				
sorghum				
millet				
vegetables				
wheat				
barley				
cassava/potatoes				
fruit/tree crops				
pasture - natural				
pasture - sown				
napier/other fodder				
coffee				
tea				
multi - purpose trees				

6b. crops grown with maize crop 1 [ ] crop 2 [ ]

6b What is the total acreage farmed ? ----------

6c What is the TOTAL FARM HOLDING SIZE----------

7 Tick the livestock species kept:

zebu cattle		sheep		camels		chickens	
grade cattle		goats		pigs		other poultry	
donkeys		rabbits		bees		fish	

8. Please give the reasons, in order of importance, for keeping the following livestock species:

	cattle	sheep	goats
reason 1			
reason 2			
reason 3			

9. Is the household sedentary ? yes [ ] no [ ]

(if no go straight to question 12)

10 If sedentary please indicate the main grazing system for each of the following (please tick):

	zero-grazed	semi-zero grazed	free-grazing
zebu cattle			
grade cattle			
sheep			
goats			

zero-grazed - all fodder cut and carried
semi-zero grazed -majority of fodder cut and carried
free-grazing - majority of fodder by grazing

11 Please tick most appropriate answer for ADULT ruminant livestock:

livestock	**do the livestock graze - off farm**			
zebu cattle	always	majority of days	minority of days	never
grade cattle	always	majority of days	minority of days	never
sheep	always	majority of days	minority of days	never
goats	always	majority of days	minority of days	never

12 What is the main breeding system used (tick box):

	artificial insemination	natural service
grade cattle		
zebu cattle		

Section 3 Livestock management

1 Which member of household responsible for care , i.e. feeding , watering , of the following livestock ?

		member of house hold
sheep		
goats		
cattle	calves	
	adults	

2 Which member of the household is responsible for the health care (treatment of sick animals, vaccination, worming etc.) of the following livestock ?

		member of household
sheep		
goats		
cattle	calves	
	adults	

3 Which member of the household decides whether to sell the following classes of livestock ?

	member of household
poultry	
sheep	
goats	
cattle	

4 Which member of the household receives the proceeds from the sale of:

	member of household
poultry	
sheep	
goats	
cattle	

5 What expenditures are made with the proceeds of the sale of the following livestock ?

	expenditures
poultry	
sheep	
goats	
cattle	

6.What sources of revenue are used to buy anthelmintics ?

a)----------

b)----------

c)----------

7 Are any of the following livestock slaughtered on the farm for home consumption (excepting emergency slaughter of sick animals) ?

a) sheep	yes		no	
b) goats	yes		no	
c) cattle	yes		no	

8 How many times in the last year did you slaughter on the farm the following livestock?

a) sheep ----------
b) goats ----------
c) cattle ----------

9 On what occasions (Christmas, weddings etc.) do you slaughter livestock ?

a) sheep	
b) goats	
c)cattle	

Section 4 Household Information

1. Total number of people in house hold ☐

2. Number of adult[1] male in residence[2] ☐

3. Number of adult household members working on the farm (part -time or full time) ☐

4. Number of adult females in residence ☐

5. Number of adult female household members working on the farm (part - time or full time) ☐

6. Number of children[3] in residence ☐

7. Number of children working on the farm ☐

8. Total number of adult males employed outside the farm (part - time or full time) ☐

9. Total number of adult females employed outside the farm ☐

10. Number of people in paid employment on the farm (part - time or full - time) ☐

11. For what periods of the year do you employ non - family labour:

all year ☐

harvest time only ☐

other ☐

12 estimate the percentage of household cash income derived from non- farm sources:

<20 ☐ 20-40 ☐ 41-60 ☐ 61 -80 ☐ >80 ☐

[1] An adult is defined as any individual over the age of 18 years
[2] a person is in residence if they sleep in the house a majority of nights per week
[3] a child is an individual of or below 18 years of age

ANIMAL HEALTH

Section 1Livestock numbers and herd/flock structure at time of visit

1.cattle	zebu		grade	
	males	females	males	females
suckling				
weaned animals				
breeding				

breeding females have had at least one parturition

1.b. For each breeding female please note the following

cow id/name	date of last calving	is the calf sucking?				Total milk produced yesterday (litres)
		yes		no		
		yes		no		
		yes		no		
		yes		no		
		yes		no		
		yes		no		
		yes		no		
		yes		no		

2. Sheep	males	females
suckling		
weaned animals		
breeding		

3. Goat	males	females
suckling		
weaned animals		
breeding		

4. Pigs	breeding males	breeding females	suckers and weaners
number			

5. Chickens	local	exotic	
		layers	broilers
chicks			
adults			

Section 2 Constraints to production

1. score the following constraints to livestock production from 5 to 0 (5= very important, 0 = completely unimportant) (constraints not listed can be added *):

constraints	cattle	sheep	goats	poultry	pigs
disease					
feed					
water					
low genetic potential					
poor fertility					
labour					
marketing of livestock and livestock products					
lack of access to livestock services (incl. Vet services)					
lack of access to AI					
*					
*					

2. What are the three most important diseases affecting the following livestock (in order of importance):

CATTLE	disease 1	disease 2	disease 3
name			
clinical signs predisposing factors			
dte last case			
age last case			
treatments			
outcome	died survived	died survived	died survived
total no. of cases in the last 12 months			

SHEEP	disease 1	disease 2	disease 3
name			
clinical signs / predisposing factors			
dte last case			
age last case			
treatments			
outcome	died survived	died survived	died survived
total no. of cases in the last 12 months			

GOATS	disease 1	disease 2	disease 3
name			
clinical signs / predisposing factor			
dte last case			
age last case			
treatments			
outcome	died survived	died survived	died survived
total no. of cases in the last 12 months			
CHICKENS	disease 1	disease 2	disease 3
name			
clinical signs / predisposing factor			
dte last case			
age last case			
treatments			
outcome	died survived	died survived	died survived
total no. of cases in the last 12 months			
PIGS	disease 1	disease 2	disease 3
name			
clinical signs / predisposing factor			
dte last case			
age last case			
treatments			
outcome	died survived	died survived	died survived

Section 3 Helminthology

1. Do you a)never use anthelminthics — cattle ☐ sheep/goats ☐

or b) only use anthelmintic to treat individual sick animal ☐ ☐

or c) routinely use anthelmintics as a preventive measure ☐ ☐

2. If b) or c) do you administer the anthelmintic ? yes ☐ no ☐

3 If no who does administer the anthelmintic ?----------

4 When was the last time any of the following classes of livestock treated with anthelmintic ?

	month	year
zebu cattle		
grade cattle		
sheep		
goats		

5. Please state the number of treatments with anthelmintic in the last 12 months:

	Number of txs last 12 months			BRAND
	suckling	**weaned**	**adult**	**of anthelmintic last used**
zebu cattle				
grade cattle				
sheep				
goats				

6. Do you ever use local herbal cures to treat helminthiasis ? yes ☐ no ☐

7.How many different brands of anthelmintic have you used in the last 12 months ?-------

8. Where do you obtain your anthelmintic from ? vet /AHA. ☐

Pharmacy ☐

other (please note) ☐

9. How do you decide which anthelmintic to use

price ☐

advice from AHA / vet ☐

advice from shop owner ☐

other (please note) ☐

10. Do you think that the anthelmintic that you are currently using is effective yes ☐ no ☐

11.a. Have any of your livestock died from worms in the last two years ? yes ☐ no ☐

11.b. If yes which class of livestock died ?

	suckling	weaned	adult
zebu cattle			
grade cattle			
sheep			
goats			

Section 4 Other animal health practices

1. Have any animals in the following classes been vaccinated against any diseases in the last 12 months ?

zebu cattle	yes		no	
grade cattle	yes		no	
sheep	yes		no	
goats	yes		no	
pigs	yes		no	
poultry	yes		no	

2 Against which diseases were they vaccinated in the last year ?

	disease 1	disease 2	do not know (tick)
zebu cattle:			
grade cattle:			
sheep:			
goats:			
pigs:			
poultry:			

3 Which tick control practices are used for the following classes of livestock ?

a).Zebu cattle none ☐ acaricide ☐ grazing restriction ☐ hand picking ☐ traditional treatment ☐

b).grade cattle none ☐ acaricide ☐ grazing restriction ☐ hand picking ☐ traditional treatment ☐

c).sheep none ☐ acaricide ☐ grazing restriction ☐ hand picking ☐ traditional treatment ☐

d).goats none ☐ acaricide ☐ grazing restriction ☐ hand picking ☐ traditional treatment ☐

e).poultry none ☐ acaricide ☐ grazing restriction ☐ hand picking ☐ traditional treatment ☐

f).camels none ☐ acaricide ☐ grazing restriction ☐ hand picking ☐ traditional treatment ☐

4 If acaricide is used what is the brand name of the acaricide last purchased ?----------

5. If acaricide is used please indicate the method of application for each class of livestock

	dip	hand -spray	hand -wash	pour -on	other
zebu cattle					
grade cattle					
sheep					
goats					

6 Please note the number of acaricide treatments against ticks for each age group in the last month ?

	zebu cattle	grade cattle
suckling		
weaned		
adult		

7. At what age do you first treat calves with acaricide (months) ☐

Chapter 4

4.1. Weather data for the study period

Month	Min temp.	Max. temp.	Rainfall
March 1995	7.5	25.0	178.9
April	8.3	24.3	327.0
May	7.8	23.4	192.0
June	8.1	23.3	227.0
July	7.5	21.6	166.0
August	7.5	23.0	189.0
September	7.2	23.4	270.0
October	7.7	23.2	273.0
November	7.6	23.2	273.0
December	6.4	22.8	273.0
January 1996	6.2	24.5	134.0
February	6.7	24.4	132.0
March	7.3	24.6	167.0
April	6.4	23.6	258.0
May	7.4	22.7	264.0
June	7.8	21.5	126.0
July	6.4	20.6	187.9
August	6.1	22.4	125.9
September	6.2	23.1	223.9
October	8.2	24.1	146.2
November	9.4	23.3	181.4
December	9.1	24.2	60.0

Temperature in degrees centigrade and Rainfall in millimetres.

4.2 Pasture larval counts L_3 /kg of dry herbage averages for the 12 sampling sites

MONTH	HAEM.(SD)	TRICHO.(SD)	COOP.(SD)	OESO.(SD)
July 1995	66.6 (109.5)	0	9.3 (32.0)	8.7 (30.0)
August	921.3 (1083.2	59.3 (99.0)	26.1 (90.4)	18.5 (64.1)
September	26.1 (90.4)	0	0	14.1 (48.8)
October	50.3 (109.2)	23.8 (60.7)	26.7 (64.6)	0
November	51.6 (99.1)	0	0	0
December	6.1 (21.1)	0	57.3 (198.6)	0
Jan. 1996	120.6 (182.1)	0	0	0
February	142.8 (165.8)	30.8 (106.8)	30.8 (106.8)	0
March	89.5 (183.8)	37.9 (92.0)	80.3 (205.4)	23.8 (82.6)
April	137.1 (176.3)	39.6 (97.2)	0	101.5 (298.1)
May	1886.3(2906)	93.9 (211.3)	0	105.8 (204.0)
June	446.5(1413)	66.0 (133.1)	14.5 (34.0)	0
July	41.0 (74.2)	0	0	0
August	196.6 (264.1)	282.1 (906.0)	0	0
September	6.2 (21.7)	0	0	28.9 (68.8)
October	12.3 (32.8)	3.1 (10.7)	14.9 (34.3)	0
November	22.4 (41.2)	0	56.0 (133.4)	0
December	9.9 34.4)	2.7 (9.2)	0	0

Key: HAEM- Haemonchus contortus, TRICHO-Trichostrongylus species, COOP- Cooperia species OESO.- Oesophagostomum species

4.3 Coproculture (proportions in percentage)

Small ruminants

MONTH	HAEM (±SD)	TRICH (±SD)	OESO (±SD)	STRO (±SD)	COOP (±SD)
Apr-95	19.2(14.9)	64.9(17.7)	0	15.9(15.3)	0
May	15.4(27.8)	82.3(27.2)	1.8(2.9)	0.4(1.4)	0
Jun	16.7(25.1)	79.0(25.5)	4.0(11.0)	0	0.3(1.3)
Jul	34.4(35.6)	60.7(33.3)	4.8(13.5	0	0
Aug	40.2(32.7)	58.2(33.3)	0.8(3.0)	0.7(2.4))	0
Sep	10.7(13.5)	88.1(13.5)	0	1.2(2.1)	0
Oct	17.5(26.4)	66.7(35.6)	1.6(4.7)	14.3(33.5)	0
Nov	10.0(21.8)	52.7(42.3)	11.1(33.3)	22.6(30.1)	3.7(11.1)
Dec	O	70.3(41.2)	14.8(32.8)	11.2(22.1)	3.7(11.1)
Jan-96	23.2(22.8)	40.5(38.8)	0	36.3(43.8)	0
Feb	46.5(46.9)	48.4(43.7)	0	5.1(14.4)	0
Mar	47.5(40.6)	45.3(50.7)	2.4(3.4)	4.8(6.7)	0
Apr	15.6(19.0)	73.8(28.2)	7.9(12.0)	1.1(2.6)	0
May	20.0(36.1)	71.4(48.8)	0	7.1(18.9)	0
Jun	46.5(65.7)	40.0(56.6)	13.6(9.1)	0	0
Jul	23.8(37.5)	64.7(44.6)	6.3(17.7)	5.2(9.9)	0
Aug	50.0(70.7)	50.0(70.7)	0	0	0

MONTH	HAEM (±SD)	TRICH (±SD)	OESO (±SD)	STRO (±SD)	COOP (±SD)
Sep	45.0(7.1)	50.0(14.1)	5.0(7.1)	0	0
Oct	18.8(37.5)	47.8(43.4)	3.8(7.6)	25.6(33.0)	2.0(3.9)
Nov	10.7(15.5)	56.6(36.9)	9.7(25.6)	19.4(20.4)	4.1(13.4)
Dec	24.3(16.2)	48.3(41.8)	5.0(13.1)	19.4(20.4)	3.0(7.4)

cattle

MONTH	HAEM	TRICH	OESO	STRO	COOP
Apr-95	44.2(47.7)	38.4(44)	12.0(29.9)	2.8(5.6)	0.0
May	55.3(39.1)	41.2(363	3.5(9.6)	0.0	0.0
Jun	40.9(44.8)	54.9(43)	2.2(8.5)	0.0	1.9(5.5)
Jul	80.9(23.4)	14.2(22)	3.6(7.9)	0.7(3.5)	0.4(2.1)
Aug	66.1(35.5)	32.3(36)	1.6(4.4)	0.0	0.0
Sep	16.4(22.6)	58.2(39)	3.2(4.8)	10.6(29.9)	11.6(21.4)
Oct	19.9(36.7)	69.5(45)	0.0	10.6(29.90	0.0
Nov	64.9(36.1)	34.5(36)	0.6(2.1)	0.0	0.0
Dec	74.2(30.7)	8.3(15.2)	4.2(14.4)	8.3(28.9)	5.0(10.7)
Jan-96	51.6(42.3)	35.0(47)	0.0	5.0(10.0)	8.4(16.7)
Feb	58.0(42.7)	23.0(22)	0.0	19.0(20.7)	0.0
Mar	56.4(46.8)	21.7(38)	7.2(25.8)	0.0	0.0
Apr	64.0(35.7)	26.4(39)	9.8(11.2)	0.0	0.0

MONTH	HAEM	TRICH	OESO	STRO	COOP
May	57.1(41.5)	37.4(6.5)	2.1(5.1)	0.0	3.3(8.2)
Jun-96	44.6(48.4)	35.4(48)	0.0	16.7(40.8)	3.3(8.2)
Jul	40.0(54.8)	50.0(50)	10.0(22.4)	0.0	0.0
Aug	50.0	50.0(50)	0.0	0.0	0.0
Sep	33.3(57.7)	33.3(58)	0.0	33.3(57.7)	0.0
Oct	0.0	100.0	0.0	0.0	0.0
Nov	15.2(17.7)	67.5(30)	5.6(10.6)	6.9(18.4)	3.7(11.1)
Dec	20.8(41.7)	46.7(46)	2.5(5.0)	0.0	30.0(47.6)

Key: Haem-H.contortus, TRICH- Trichostrongylus species, OESO-Oesophagostomum species, STRO-Strongyloides species, COOP-Cooperia species, NEMA-Nematodirus species.

4.4 Other genera percentage of samples positive each month- Cattle

MONTH	COCCIDIA SPECIES		MONIEZA SPECIES		NEMATODIRUS SP	
	CALVES	ADULTS	CALVES	ADULTS	CALVES	ADULTS
Jul.95	0.7	0	0.7	0	0	0
Aug	0	0	0	1.2	0	0
Sep	1.1	0	2.9	0	0	0.6
Oct	0.8	0	0.8	0.8	0.8	0
Nov	0	0	0	0.8	0.8	0.8
Dec	0	0	2.2	0	0.8	1.6
Jan.96	0	0	0.7	0.7	0	0
Feb	0	0	2.1	0	0.7	0
Mar	1.4	0	1.8	2.4	0	0.6
Apr	2.7	0	0.7	0.7	0	1.3
May	0	0	2	0	0	0
Jun	0	0	0	0	1.3	0
Jul	1.5	0	0	0	0	1.3
Aug	0	0	0	0	2.1	0
Sep	0.7	0	0	0	0	0
Oct	0	0	0	0	0	0.7
Nov	0	0	0	0	0	0.7
Dec	0	0	1.4	0	0	0

Goats

MONTH	COCCIDIA SPECIES		MONIEZA SPECIES		NEMATODIRUS SPECIES	
	KIDS	ADULTS	KIDS	ADULTS	KIDS	ADULTS
Jul.95	0	0	2.8	0	0	9.3
Aug	0	2.4	2.3	0	0	23.3
Sep	0	0	1.2	1.2	0	8.4
Oct	0	0	0	0	0	4.8
Nov	1.2	0	2.6	0	1.4	4.3
Dec	0	0	1.4	0	0.8	1.6
Jan.96	0	0	0	0	0	2.9
Feb	0	0	3.1	0	0	6.3
Mar	4.6	13.8	3.2	0	0	10.8
Apr	1.5	0	4.5	0	0	8.9
May	0	0	0	0	3	11.1
Jun	0	0	0	0	0	8.2
Jul	0	1.5	0	0	0	11
Aug	0	1.6	1.6	0	0	1.6
Sep	0	0	0	0	0	6.7
Oct	0	0	0	0	0	5.9
Nov	0	0	0	0	1.6	7.8
Dec	0	0	0	0	0	5.9

Sheep

MONTH	COCIDIA SPECIES		MONIEZA SPECIES		NEMATODIRUS SPECIES	
	LAMBS	ADULTS	LAMBS	ADULTS	LAMBS	ADULTS
Jul.95	0	0	3.3	0	0	3.3
Aug	0	0	0	0	0	0
Sep	0	0	2	0	0	0
Oct	0	0	4	4	0	0
Nov	0	0	3.7	0	0	0
Dec	0	0	3.7	0	0	0
Jan.96	0	0	0	0	4.3	0
Feb	0	5.6	5.6	0	0	0
Mar	4.5	0	0	0	4.5	0
Apr	3.7	0	0	0	0	3.7
May	0	7.7	0	0	7.7	0
Jun	0	0	3.8	0	0	3.8
Jul	0	0	0	0	0	0
Aug	0	0	0	0	0	0
Sep	0	0	0	0	0	0
Oct	0	0	0	0	0	0
Nov	0	0	0	0	0	0
Dec	0	0	0	0	0	0

4.5 Percentage of farms positive for trematodes each month

MONTH	CATTLE		GOATS		SHEEP	
	L.FLUKES	S.FLUKES	L.FLUKES	S.FLUKES	L.FLUKES	S.FLUKES
March.'95	0	41	0	6.7	0	23.3
Apr	6.7	40	0	20	0	20
May	3.3	43.3	0	16.7	0	13.3
Jun	13.3	60	3.3	23.3	10	33.3
Jul	3.7	55.6	0	0	0	11.1
Aug	0	40.7	0	33.3	0	22.2
Sep	11.1	59.3	0	22.2	0	22.2
Oct	0	66.7	0	18.5	3.7	14.8
Nov	0	33.3	0	7.4	0	14.8
Dec	0	42.8	0	8.9	0	17.3
Ja.96	3.7	81.5	0	0	0	14.8
Feb	0	70.4	0	11.1	0	18.5
Mar	3.7	85.2	0	14.8	3.7	11.1
Apr	11.1	70	0	7.4	0	18.5
May	0	29.6	0	3.7	0	11.1
Jun	0	70.4	0	14.8	0	3.7
Jul	0	81.5	0	22.2	0	29.6
Aug	3.7	55.6	0	0	3.7	25.9
Sep	11.1	70.4	0	11.1	7.4	14.8
Oct	0	44.4	0	11.1	0	14.8
Nov	0	40	0	3.7	0	7.4
Dec	0	49.8	0	7.4	0	11.1

4.6 Total worm counts-individual animals and monthly means-

Dorper tracer lambs (6 used every month, * deaths, details in the General appendix)

Month	Tag No.	H.contort	T.axei	T.columb	Oesop. sp	Stron. sp	Coop. sp	Others
May '95	404	100	0	50	70	0	50	4
	756	550	100	0	23	0	50	0
	783	500	0	0	7	0	0	1
	769	250	0	0	0	0	0	0
	789	600	0	0	5	0	0	4
	762	200	00	0	0	0	0	0
	Mean	**367**	**26**	**8**	**18**	**0**	**16**	**1**
June	753	100	0	0	0	0	100	0
	755	950	250	250	27	0	0	0
	780	1050	100	50	8	0	150	0
	797	1150	0	0	0	0	0	0
	409	2100	0	150	27	0	50	4
	410	150	100	0	26	0	0	3
	Mean	**917**	**75**	**88**	**15**	**0**	**58**	**1**
July	775	250	300	0	0	0	0	0
	798	450	0	200	0	0	0	0
	782	600	50	0	0	0	0	0
	796	600	0	0	0	0	0	0
	406	1600	350	650	0	0	0	0
	402	600	100	0	0	0	0	0
	Mean	**683**	**133**	**142**	**0**	**0**	**0**	**0**
August	4386	4000	200	50	0	0	50	0
	4387	1500	50	50	0	0	100	0
	4384	1250	400	50	0	0	0	0
	4368	500	0	150	0	0	0	0
	4398	1200	0	0	0	0	0	0
	4382	2100	300	200	0	0	0	0
	Mean	**1758**	**158**	**83**	**0**	**0**	**25**	**0**
Septemb.	3964	500	0	0	0	0	0	0
	3939	500	0	0	0	0	0	0
	3981	800	100	0	0	0	0	0
	4372	300	0	0	0	0	0	0
	4392	100	50	0	0	0	0	0
	4393	750	0	0	0	0	0	0
	Mean	**492**	**25**	**0**	**0**	**0**	**0**	**0**

Month	Tag No.	H.contort.	Taxei	T.columb	Oesop.sp	Stron. Sp	Coop. sp	Others
October	572	350	0	0	0	0	100	0
	573	200	0	0	0	0	0	0
	591	850	0	0	0	0	0	0
	585	250	0	0	0	0	0	0
	596	400	0	0	0	0	0	0
	588*							
	Mean	**410**	**0**	**0**	**0**	**0**	**20**	**0**
Nov	4829	150	0	0	2	0	0	2
	2647	200	0	0	1	0	0	9
	2651	350	0	0	8	0	0	0
	2654	450	0	0	1	0	0	13
	2650	1750	0	0	2	0	0	2
	2610	750	0	0	0	0	0	0
	Mean	**608**	**0**	**0**	**3**	**0**	**0**	**4**
Dec	211	200	100	0	20	0	0	0
	206	600	150	0	37	0	0	0
	258	550	0	0	13	0	0	4
	227	0	0	0	33	0	0	0
	234	750	0	0	0	0	0	0
	252*							
	Mean	**420**	**50**	**0**	**21**	**0**	**0**	**0**
Jan. 96	255	200	100	0	40	0	50	0
	267	150	50	0	35	0	0	0
	230	250	0	0	25	0	0	0
	270	350	0	0	32	0	0	0
	231	50	0	0	32	0	0	0
	239	350	100	0	31	0	0	0
	Mean	**225**	**42**	**0**	**38**	**0**	**8**	**0**
February	240	0	0	0	0	0	0	0
	251	1600	0	250	0	0	1900	0
	257	450	0	0	0	0	0	0
	223	500	0	0	0	0	0	0
	236	0	0	0	0	0	0	0
	0177	200	0	0	0	0	0	0
	Mean	**458**	**0**	**0**	**0**	**0**	**317**	**0**

Month	Tag No.	H.contort.	T.axei	T.columb.	Oesop. sp	Stron. sp	Coop. sp	Others
March	0342	500	0	0	0	0	0	0
	0319	0	0	0	0	0	0	0
	0327	400	50	0	0	0	0	0
	0366	500	0	0	0	0	0	0
	0343	0	0	0	0	0	0	0
	0344	0	0	0	0	0	0	0
	Mean	**233**	**8**	**0**	**0**	**0**	**0**	**0**
April	0323	850	0	0	0	0	0	0
	0359	850	0	0	0	0	0	0
	0352	300	0	0	0	0	0	0
	0339	200	0	0	71	0	0	0
	0335	150	100	0	0	0	0	0
	0337	950	0	0	0	0	0	0
	Mean	**550**	**17**	**0**	**12**	**0**	**0**	**0**
May '96	845	700	300	0	0	0	250	0
	775	400	0	0	0	0	200	0
	789	300	0	0	0	0	0	0
	782	400	0	0	0	0	0	0
	788	450	0	0	0	0	0	0
	790	1550	0	0	0	0	0	0
	Mean	**633**	**50**	**0**	**0**	**0**	**75**	**0**
June	983	700	0	0	0	0	0	0
	947	400	0	0	0	0	0	0
	980	700	0	0	0	0	0	0
	942	250	350	0	0	0	0	0
	970	2050	0	0	0	0	0	0
	973*							
	Mean	**820**	**70**	**0**	**0**	**0**	**0**	**0**
July	0927	400	0	0	0	0	0	0
	0944	2100	0	0	0	0	0	0
	0989	600	0	0	0	0	0	0
	0988	1100	350	0	0	0	0	0
	0953	850	100	0	0	0	0	0
	0945	250	0	0	0	0	0	0
	Mean	**883**	**75**	**0**	**0**	**0**	**0**	**0**

Month	Tag No.	H.contort	T.axei	T.columb	Oesop. sp	Stron. Sp	Coop. sp	Others
August	0952	2150	0	0	0	0	0	0
	0962	750	0	0	0	0	0	0
	0932	2400	0	0	0	0	0	0
	0918	2100	0	0	0	0	0	0
	0943	950	0	0	0	0	0	0
	0969*							
	Mean	**1670**	**0**	**0**	**0**	**0**	**0**	**0**
Septemb.	713	650	250	0	0	0	0	0
	728	0	0	0	0	0	0	0
	712	300	0	0	0	0	0	0
	726	0	0	0	0	0	0	0
	729	800	150	0	0	0	0	0
	714*							
	Mean	**350**	**80**	**0**	**0**	**0**	**0**	**0**
October	339	700	0	0	0	0	0	0
	312	2700	0	250	0	0	50	0
	350	1050	0	0	0	0	0	0
	397	1650	0	0	0	0	0	0
	378	1350	0	150	0	0	0	0
	337	500	0	0	0	0	0	0
	Mean	**1325**	**0**	**67**	**12**	**0**	**8**	**0**
Nov	391	250	0	0	0	0	0	0
	327	200	0	0	0	0	0	0
	369	1100	0	0	0	0	0	0
	374	750	0	0	0	0	0	0
	379	1600	0	0	0	0	0	0
	356	950	0	0	0	0	0	0
	Mean	**808**	**0**	**0**	**0**	**0**	**0**	**0**
Dec. '96	322	250	0	0	0	0	0	0
	352	850	0	0	0	0	0	0
	390	700	0	0	0	0	0	0
	320	350	0	0	0	0	0	0
	372	550	0	0	0	0	0	0
	320	300	0	0	0	0	0	0
	Mean	**500**	**0**	**0**	**0**	**0**	**0**	**0**

4.7 ***Local ewes (Permanent stock) TWC***-4 purchased each month, except in May and June 1995 (1)

Month	Tag No.	H.contort	T.axei	T.columb	Oesop. sp	Stron. Sp	Coop. sp	Others
May-'95	801	50	0	0	16	0	0	7
	Mean	**50**	**0**	**0**	**16**	**0**	**0**	**7**
June	002	800	0	450	0	0	0	0
	Mean	**800**	**0**	**450**	**0**	**0**	**0**	**0**
July	3912	200	3050	0	0	0	0	0
	3913	50	300	0	0	0	0	0
	3915	1250	7650	0	0	0	0	0
	3914	50	350	900	0	0	0	0
	Mean	**388**	**2828**	**225**	**0**	**0**	**0**	**0**
August	222	0	1650	500	0	0	0	0
	111	0	3450	500	0	0	0	0
	3957	0	500	200	0	0	0	0
	3968	0	3800	0	0	0	0	0
	Mean	**0**	**2350**	**300**	**0**	**0**	**0**	**0**
Septemb.	3852	100	1100	0	0	0	0	0
	3853	50	2700	0	0	0	0	0
	3854	0	7150	0	0	0	0	0
	3855	350	900	0	0	0	0	0
	Mean	**125**	**2963**	**0**	**0**	**0**	**0**	**0**
October	272	0	4500	4350	0	0	50	0
	273	0	10750	1300	0	0	100	0
	274	300	450	2200	0	0	700	0
	275	50	1550	0	0	0	0	0
	Mean	**88**	**4313**	**1963**	**0**	**0**	**213**	**0**
Nov.	298	0	8700	0	33	0	0	8
	299	0	8650	6250	68	0	0	11
	300	0	10700	0	19	0	0	0
	297	50	9200	0	0	0	0	0
	Mean	**13**	**9313**	**1563**	**30**	**0**	**0**	**5**
Dec	595	0	1100	0	0	0	0	0
	592	1150	10750	6650	0	0	0	0
	593	150	3800	0	3	0	0	0
	594	0	6100	300	4	0	0	0
	Mean	**325**	**5438**	**1738**	**2**	**0**	**0**	**0**

Month	Tag No.	H.contort	T.axei	T.columb	Oesop. sp	Stron. Sp	Coop. sp	Others
Jan. 1996	843	50	50	0	0	0	0	0
	844	150	1000	0	0	0	0	0
	841	0	1450	0	0	0	0	0
	842	0	8150	300	0	0	0	0
	Mean	**50**	**2663**	**75**	**0**	**0**	**0**	**0**
Feb.1996	725	50	400	1150	0	0	1200	0
	721	0	900	0	0	0	0	0
	722	0	650	0	0	0	0	0
	723	150	350	650	0	0	50	0
	Mean	**50**	**575**	**450**	**0**	**0**	**313**	**0**
March	773	450	400	0	0	0	0	0
	774	350	1400	0	0	0	0	0
	772	0	14150	8550	0	0	350	4
	771	0	950	0	0	0	200	0
	Mean	**200**	**4225**	**2213**	**0**	**0**	**138**	**1**
April	498	0	3550	2500	0	0	2000	0
	0991	50	600	950	0	0	700	0
	0986	0	5700	0	0	0	0	0
	0987	0	2750	3450	0	0	0	0
	Mean	**13**	**3150**	**1725**	**0**	**0**	**675**	**0**
May	801	0	1400	350	0	0	0	0
	802	0	550	250	0	0	0	0
	0821	50	350	0	0	0	0	0
	0822*							
	Mean	**17**	**767**	**150**	**0**	**0**	**0**	**0**
June	0857	650	400	0	0	0	0	0
	0855	0	0	0	0	0	0	0
	0856	550	2000	5600	0	0	2150	0
	0858	750	3900	1250	0	0	0	0
	Mean	**488**	**1575**	**1713**	**0**	**0**	**538**	**0**
July	782	300	1950	1050	0	0	0	0
	730	300	1000	0	0	0	0	0
	781*							
	783*							
	Mean	**300**	**1475**	**525**	**0**	**0**	**0**	**0**
August	753	0	3500	5500	0	0	0	0
	771	650	1450	400	0	0	400	0
	752	1650	750	1000	0	0	0	0
	751*							
	Mean	**767**	**1900**	**2300**	**0**	**0**	**133**	**0**

Month	Tag No.	H.contort	T.axei	T.columb	Oesop. sp	Stron. Sp	Coop. sp	Others
Septemb.	766	0	0	0	0	0	0	0
	769	200	2800	600	0	0	1650	0
	770	0	1300	0	0	0	300	0
	768	0	4500	0	0	0	0	0
	Mean	**50**	**2150**	**150**	**0**	**0**	**488**	**0**
October	011	1300	0	1700	0	0	0	0
	012	0	2300	3200	0	0	0	0
	014	600	750	3000	0	0	0	0
	015*							
	Mean	**633**	**1017**	**2633**	**0**	**0**	**0**	**0**
Nov.	783	0	900	4650	5	0	0	0
	781	700	400	350	6	0	350	0
	782	500	0	0	0	0	0	0
	784	0	4850	1100	0	0	0	0
	Mean	**300**	**1540**	**1525**	**3**	**0**	**88**	**0**
Dec '96	527	0	1800	1800	0	0	0	25
	530	0	2100	950	0	0	250	4
	529	250	200	450	13	0	0	0
	528	0	3600	0	0	0	0	0
	Mean	**63**	**1925**	**800**	**3**	**0**	**63**	**7**

Chapter 5

5.1 Individual animal data of the small and large holder farms

Small farms- P.FEC-Primary faecal egg counts, S.FEC-Secondary faecal egg counts
a-Levamisole

FARM NO.	GOAT NO.	WEIGHT	DOSE-ML	P. FEC	S.FEC
1	39	23	15	500	0
1	28	11	7	1400	0
1	19	19	13	1300	0
2	21	16	11	400	0
3	26	22	15	1000	0
5	66	22	15	400	0
6	34	16	11	2400	0
7	100	12	8	1300	0
8	25	22	15	6100	800
9	32	19	13	1000	0
9	49	12	8	100	200
10	79	10	7	100	0
10	407	11	7	0	0
11	455	19	13	4700	1500
11	409	15	10	1900	500
13	479	11	7	0	0
13	441	16	11	1400	0
16	73	18	12	2000	0
16	426	29	19	200	0
17	492	30	20	0	0
18	464	12	8	100	0
18	71	26	17	800	0
18	442	32	21	3800	400
18	419	12	8	2600	0
18	500	18	12	600	0
19	74	16	11	500	0
20	474	25	17	2500	600
22	436	17	11	0	0
23	75	23	15	1500	0
23	497	25	17	3500	900

b- Benzimidazole (Valbazen)

FARM NO.	GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
1	78	28	9	1400	0
1	43	25	6	3200	0
2	38	8	1.5	500	0
2	24	24	5	1000	0
5	27	24	5	200	0
6	50	19	4	900	0
7	2	26	6	100	0
8	33	19	4	0	0
9	4	11	2	1800	0
10	3	25	5	500	0
11	98	22	5	1900	0
11	404	28	6	200	0
13	424	34	7	700	0
14	91	13	2.5	1900	0
15	444	30	6	300	0
16	485	28	6	0	0
17	486	28	6	0	0
18	461	30	6	0	0
18	432	26	5	400	0
18	93	18	3	6100	0
19	414	21	4	0	0
19	427	17	3	0	0
20	450	16	3	1500	200
20	447	23	5	0	0
21	423	24	5	300	0
22	413	28	6	0	0
23	466	6	1	17100	1300

c- Ivermectin (Ivomec)

FARM NO.	GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
1	30	19	0.4	1000	0
2	17	23	0.5	300	0
3	77	21	0.5	300	0
4	35	19	0.4	200	0
5	29	13	0.25	200	0
5	31	25	0.5	600	0
6	37	20	0.4	2400	0
7	80	21	0.4	0	0
8	42	25	0.5	700	0
9	81	27	0.5	700	500
10	9	14	0.3	1000	200
11	451	30	0.6	2000	0
12	406	15	0.3	0	0
13	69	28	0.5	400	0
14	482	23	0.5	200	0
15	67	12	0.25	1100	0
16	95	18	0.4	0	0
17	421	16	0.3	100	0
17	439	24	0.5	0	0
18	467	14	0.3	5300	100
18	431	19	0.4	2600	200
19	475	28	0.6	600	100
20	452	23	0.5	1100	0
21	462	24	0.5	600	0
22	498	37	0.7	100	0
23	429	32	0.6	2600	0
23	487	18	0.4	9700	400

d- Control

FARM NO.	GOAT NO.	WEIGHT	P.FEC	S.FEC
1	44	12	1100	1350
1	84	16	800	850
3	22	13	1400	1800
4	20	21	300	350
4	97	15	100	250
6	90	21	400	600
7	8	32	4300	3500
8	86	25	1300	600
8	76	11	300	100
9	88	24	800	900
9	96	12	1600	5300
10	82	13	600	1350
10	410	12	700	700
11	491	26	1900	1000
11	408	16	2600	1500
11	402	7	500	300
12	405	30	0	300
13	415	22	700	1200
14	433	18	500	600
15	428	11	100	300
15	480	18	0	250
16	443	11	800	1000
17	422	14	0	150
17	425	18	100	200
18	446	25	400	1200
18	401	12	2600	2200
18	72	21	0	500
18	477	15	200	300
19	411	23	0	100
19	460	11	0	1500

Large farms.
1 Chebelion estate
a-Levamisole

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
401	45	20	1000	100
405	24	13	1500	400
409	23	12	100	100
413	28	15	100	0
417	22	12	400	0
421	30	15	100	0
425	20	10	400	100
429	32	17	1600	0
433	36.5	18	100	300
437	38	18	1400	0
441	19.5	12	1000	100
445	18	12	600	0
449	12.5	6	1200	0
453	5	3	2600	0
457	12	6	700	1500
461	21.5	13	300	100
465	24.5	13	400	500
469	26	14	400	600

b-Benzimidazole

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
402	21	1	300	0
406	21	1	800	0
410	33	2	300	0
414	40	3	0	0
418	21	1	500	0
422	29	2	0	0
426	21	1	2300	0
430	37.5	3	1600	0
434	25	2	700	0
438	17	1	800	0
442	21.5	1	100	0
446	20.5	1	1000	0
450	10	0.5	500	0
454	14	0.5	600	0
458	17.5	0.8	1000	0
462	13	0.7	600	0
466	32	2	700	0

c- Ivermectin

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
403	27	0.6	100	100
407	14	0.3	200	0
411	16	0.3	200	0
415	17	0.3	0	0
419	32	0.7	400	0
423	30	0.6	0	0
427	21.5	0.4	10100	800
431	12	0.2	800	0
435	40.5	0.9	1100	200
439	37	0.8	200	0
444	11	0.2	300	0
447	27	0.6	3500	0
451	15	0.3	200	0
455	17.5	0.3	400	0
459	17.5	0.3	0	0
463	28	0.6	500	0
467	28	0.6	0	0

d-Control

GOAT NO.	WEIGHT	P.FEC	S.FEC
404	25	7300	6000
408	15	1000	0
412	32	0	200
416	15	1000	1000
420	25	0	0
424	23	300	500
428	16.5	300	700
432	32	1400	1500
436	14.5	100	1200
440	38	600	1000
443	28	1100	600
448	12	100	100
452	6.5	400	1200
456	14.5	400	0
460	17	400	100
464	23.5	3400	400
468	20	0	200

b- Too estate-Levamisole

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
781	19	10	900	0
786	20	10	0	0
789	21	10	0	0
793	31	15	400	0
798	30	15	100	0
901	19	10	600	0
905	24	12	1000	0
909	27	14	0	0
913	17	10	0	0
917	30	15	0	0
921	22	11	1900	0
929	26	14	600	0
933	24	13	0	200
937	24	13	600	0
941	27	14	600	100
946	13	8	2500	0
950	20	10	700	0
954	26	14	0	0
958	17	10	1300	0
962	21	10	1200	0
965	14	8	100	0

Benzimidazole

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
782	25	2	0	0
787	19	1.5	100	0
790	33	2.5	800	0
794	29	2	1400	0
799	59	4	0	0
902	31	2	800	0
906	25	1.5	400	0
910	19	1	1000	0
914	26	2	0	0
918	22	1.5	0	0
922	29	2	400	0
926	21	1	0	0
930	17	1	200	0
934	24	1.5	200	0
938	23	1.5	1600	0
942	36	2.5	500	0
947	12	0.8	400	0
949	19	1	2000	0
957	19	1	1800	0
958	23	2	600	0
960	13	0.8	300	0

Ivermectin

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
783	24	0.5	200	0
788	23	0.5	200	0
791	16	0.3	500	0
795	19	0.4	800	0
800	24	0.5	3300	200
903	28	0.6	0	0
907	23	0.4	1600	0
911	23	0.4	400	0
915	32	0.7	600	0
919	28	0.6	0	0
923	22	0.4	1000	0
927	23	0.4	100	0
931	19	0.3	200	100
935	29	0.6	100	0
939	26	0.5	300	0
943	24	0.5	800	100
945	19	0.3	300	500
952	16	0.3	2000	0
959	26	0.6	0	0
953	35	0.7	100	0
963	18	0.3	1600	0
967	27	0.6	2600	0

Control.

GOAT NO.	WEIGHT	P.FEC	S.FEC
784	23	800	1000
785	40	0	100
792	24	600	0
796	20	2000	2500
797	36	0	7900
904	27	0	0
908	20	0	500
912	17	0	1500
916	29	800	1000
920	19	3000	600
924	30	900	0
928	30	2000	200
932	35	200	500
936	25	200	2400
940	24	0	0
944	26	0	200
948	24	200	0
951	26	2000	1100
956	20	100	200
961	20	800	0
964	29	0	200
968	28	0	500

C- Chesumot estate

Levamisole

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
471	38.5	18	200	800
151	24	11	2000	0
473	42	20	0	0
168	21	10	500	0
180	33	15	0	1500
179	32.5	15	400	0
148	26.5	12	1100	0
98317	34	16	0	0
480	39	20	0	0
84	42	20	2000	100
99690	28	13	100	400
482	42	20	0	0
484	33	15	500	0
80	29	14	0	100
196	14	8	0	0
150	21	10	200	400
205	21	10	1100	0
206	33	11	600	0

Benzimidazole.

GOAT NO	WEIGHT	DOSE-ML	P.FEC	S.FEC
193	18.5	1	0	0
214	25	1.5	800	0
178	29	2	500	400
476	45	3	200	0
138	27	2	1000	100
140	37	2.5	600	200
479	38	2.5	200	0
174	25.5	1.5	2000	0
86	51	3.5	1000	0
85	39	2.5	1000	0
184	28	2	1500	1100
483	45	3.5	600	0
165	28.5	2	800	100
152	28	2	400	0
199	15	1	100	0
209	18	1	300	0

Ivermectin

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
83	38.5	0.8	300	0
156	24	0.5	200	0
474	31.5	0.7	500	0
477	57.5	1.1	0	0
478	69.5	1.5	200	0
141	41.5	0.8	0	0
162	20.5	0.4	500	0
164	28	0.6	400	0
99654	32	0.7	0	0
158	27	0.6	600	200
186	17	0.3	500	0
145	30	0.7	600	600
172	26	0.6	0	100
485	36	0.8	0	0
82	35	0.8	400	0
204	21	0.4	500	0
194	15	0.3	1500	0
215	15	0.3	0	0

Control

GOAT NO.	WEIGHT	P.FEC	S.FEC
98333	38	900	200
99	40	1000	1000
475	42	200	1000
99669	33.5	1500	4000
81	31	0	200
170	28	100	1000
191	18.5	700	3600
195	19	400	800
481	40	1000	600
187	30	600	0
99634	54	600	2900
155	23	400	0
486	32	0	0
157	25	500	0
197	21	0	0
211	16	500	1500

d-Sigei estate.
Levamisole

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
971	25	12	9900	0
976	37	16	2500	0
981	32	15	3700	200
989	40	20	0	0
997	13	8	3000	0
202	40	20	100	0
206	9	4	0	0
220	31	15	0	300
243	13	5	0	0
238	20	10	1200	0
236	26	12	500	0
242	21	10	500	0
215	18	10	800	0
234	15	8	300	500
213	23	11	1500	0
222	41	20	600	0
280	23	11	200	0
285	30	15	1000	600
247	50	25	1300	0
251	28	12	6600	0
261	29	15	2900	0
262	15	8	3000	0
259	36	18	800	0
253	48	22	9200	0
271	27	12	2400	0
273	36	18	200	0

Benzimidazole.

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
972	32	2	7500	0
978	31	2	500	0
982	26	2	700	0
986	22	2	0	0
990	14	1	1700	0
994	36	3	500	0
998	17	1	5600	0
203	8	0.5	6800	0
207	27	2.5	300	0
977	20	2	1300	0
225	59	4	500	0
219	10	1	1500	0
214	16	1.5	0	0
211	49	3	200	0
212	59	4	800	0
224	24	2	700	0
240	14	1.5	100	0
282	36	2	700	0
235	25	2	600	0
245	67	4	100	0
257	28	2	5300	0
248	45	3	200	0
264	29	2	400	0
254	31	2	1600	0
267	41	3	800	0

Ivermectin.

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
970	38	0.8	0	0
973	25	0.5	10500	500
988	29	0.7	2800	0
991	15	0.3	3300	0
995	15	0.3	1900	0
226	32	0.7	400	400
241	14	0.3	0	0
239	45	0.9	400	0
233	27	0.6	400	0
218	43	0.9	700	0
230	24	0.5	1500	0
209	72	1.5	500	0
223	29	0.7	500	0
228	37	0.8	200	200
281	26	0.6	500	0
255	28	0.7	500	0
252	29	0.7	700	0
256	51.5	1.0	0	0
260	32	0.7	11800	0
249	28	0.6	9100	0
204	30	0.7	1300	0

Control

GOAT NO.	WEIGHT	P.FEC	S.FEC
975	34	900	1000
980	31	200	0
984	10	1700	400
987	27	2800	2000
992	22	2600	3500
996	19	1700	1800
999	7	0	0
201	29	2500	2000
205	17	2700	1000
210	17	800	1200
231	11	400	2000
227	33	200	0
232	29	800	1000
244	15	0	800
237	30	700	400
216	26	200	0
229	26	800	400
230	22	1500	2000
283	38	500	15000
284	32	200	800
258	18	16400	4000
250	48	200	0
265	21	27700	0
266	27	400	0
270	37	200	0
263	43	400	0

e- Koske estate.
Levamisole

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
494	29	15	100	0
498	27	15	200	0
291	41	20	11900	1000
295	42	20	900	0
299	35	18	400	0
403	20	10	200	0
407	32	17	0	0
411	13.5	8	1200	0
415	25.5	14	0	0
419	18	10	0	0
423	31	15	0	0
427	26.5	14	0	0
431	12	8	400	0
435	26.5	14	400	400
439	9.5	5	0	0

Benzimidazole.

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
495	17	1.0	200	0
499	20	1.5	0	0
288	25	1.5	500	0
292	42.5	3.0	600	0
296	14	1.0	800	0
300	24.5	1.5	300	0
404	24.5	1.5	0	0
408	32	2.5	100	200
412	28	2	1100	0
416	25	1.5	0	0
420	15.5	1.0	200	0
424	33	2.5	700	0
428	13	1.0	200	0
432	22	1.5	800	0

Ivermectin

GOAT NO.	WEIGHT	DOSE-ML	P.FEC	S.FEC
496	27	0.6	500	0
500	24.5	0.5	300	400
289	29	0.7	500	0
293	50.5	1.0	900	0
297	37.5	0.8	2000	0
401	30	0.7	300	0
405	25	0.5	0	200
409	27	0.6	0	300
413	14	0.3	200	0
417	27	0.6	200	0
421	28.5	0.6	300	0
425	31.5	0.7	900	0
429	14	0.3	400	0
433	18.5	0.3	3300	0
437	18.5	0.3	0	0

Control

GOAT NO.	WEIGHT	P.FEC	S.FEC
497	32	600	100
286	30.5	0	600
290	19	200	0
294	36	200	0
298	20	1000	600
402	24	500	1500
406	25	0	0
410	29	0	0
414	28.5	1000	800
418	22	1300	1000
422	17	600	200
430	16	200	0
434	12.5	600	1500
438	15.5	800	400

Chapter 6

6.1 Weather data (January to May 1998)- NVRC-Muguga

Month	**Min. temp (c)**	**Max. temp (c)**	**Rainfall (mm)**
January	10.1	22.3	168.0
February	10.4	25.4	88.5
March	11.2	25.2	42.1
April	11.8	24.8	0
May	11.4	24.4	0

Chapter 7

7.1 Individual animal record used every month of visit

KERICHO INTERVENTION TRIALS

Farmer's Name

Species	Entry date
Ear-tag No.	bought Gift born on farm
Ear-tag colour	Birth date
Sex	estimate exact

Male, Female, Castrate Birth weight (kids and lambs)

Date of visit	Weight (Kgs)	Anthelmintic use		Event[4] and date of event	EPG	Fluke EPG
		Name	Dose (mls)			

If animal not present , reason for absence: death slaughter gift sale

If sold , sold to butcher trader market neighbour relative

If sold or slaughtered, reason for slaughter:

[4]Parturition, weaning, disease injury, treatment, vaccination, etc

7.2 Individual farm locations globally and the intervention status for calves and small ruminants

FARM NO.	GLOBAL POSITION EAST	SOUTH	ALTITUDE -MTS-ASL	INT-SR	INT-CALF
1	0.35129	35.24808	2033	1	1
2	0.34923	35.24834	2037	2	2
3	0.34977	35.25153	1849	2	1
4	0.34761	35.24794	1912	1	1
5	0.34895	35.25347	1849	2	1
6	0.35312	35.25607	2028	1	2
7	0.35226	35.26637	2039	1	1
9	0.34836	35.26377	2038	2	2
10	0.34694	35.26008	2063	1	1
11	0.34252	35.26301	2127	2	1
12	0.33691	35.26916	2091	2	1
13	0.32849	35.28258	2062	1	2
14	0.32707	35.28388	2121	2	2
16	0.32873	35.27501	2026	1	1
18	0.33618	35.29066	2003	1	1
20	0.33579	35.29035	2054	2	1
21	0.32906	35.29501	2174	2	2
22	0.32677	35.29951	2157	2	2
23	0.32571	35.30144	2204	2	2
24	0.32845	35.30211	2126	2	1
25	0.33089	35.30187	2158	2	1
26	0.33544	35.30308	2081	2	1
27	0.33835	35.30253	2018	1	1
28	0.34785	35.29325	2057	1	2
29	0.34957	35.29134	2090	2	1
30	0.34361	35.29292	1989	2	1
31	0.34644	35.29127	2127	2	2
32	0.34706	35.29311	2084	1	1
33	0.34823	35.29012	2048	1	2
34	0.34741	35.28951	2008	2	2
35	0.34631	35.29429	2154	2	1
36	0.34511	35.29122	2015	1	1
37	0.32187	35.30084	2190	2	1
38	0.32327	35.30068	2191	1	1
39	0.32796	35.27385	1984	2	1

FARM NO.	GLOBAL EAST	POSITION SOUTH	ALTITUDE -MTS-ASL	INT-SR	INT-CALF
40	0.32959	35.29521	2150	2	1
41	0.33663	35.29064	2202	2	2
42	0.32439	35.27811	2002	2	2
43	0.32335	35.27841	2075	1	2
44	0.32584	35.27818	2057	2	2
45	0.33004	35.26736	2154	1	1
46	0.34476	35.21754	1934	1	1
47	0.34452	35.21781	1970	1	2
48	0.34415	35.21561	2017	1	1
49	0.34268	35.21693	1938	1	2
50	0.32874	35.22134	1998	1	2
51	0.32616	35.21818	1937	1	2
52	0.32695	35.22086	2011	2	2
53	0.32701	35.21971	1932	1	1
54	0.33447	35.23965	2051	1	2
55	0.34121	35.33971	2032	1	2
56	0.32637	35.24486	1982	2	2
57	0.34511	35.24498	2088	1	1
58	0.32339	35.26367	2069	2	1
59	0.32441	35.26503	1987	1	1
60	0.35822	35.24061	1983	1	1
61	0.34801	35.24103	2071	2	2
62	0.35413	35.24401	2014	1	1
63	0.34578	35.24765	2054	1	2
65	0.35549	35.22847	1945	1	1
66	0.35212	35.22282	1974	1	1
67	0.35151	35.22155	1993	2	2
68	0.35179	35.23039	1991	2	1
69	0.35284	35.23481	1983	2	1
70	0.32641	35.29197	2202	2	2
71	0.34608	35.24384	2061	1	2
72	0.34442	35.24463	2057	2	2
73	0.32657	35.26571	2038	2	2
74	0.32751	35.32751	2083	2	2
75	0.35437	35.24302	2025	2	2
76	0.35155	35.25794	1931	1	1
77	0.32454	35.27837	2085	2	2
78	0.33682	35.24571	2071	2	1
79	0.35517	35.24404	1935	1	1
80	0.33572	35.24558	1989	2	1

Other points and large farms used for FECRT

NAME	EAST	SOUTH	ALTITUDE
Koske	0.26406	35.22451	2021
Too	0.25931	35.22482	2029
Sigei	0.35301	35.26401	1993
Chebelion	0.35316	35.26706	1986
Chesumot	0.30341	35.36555	2091
T.R.F	0.37238	35.34812	2201
V.I.Laboratory	0.37079	35.26974	2006
Kericho town	0.36909	35.28553	2040

Key *ASL- altitutude above sea level, INT-SR-Intervention status small ruminants INT-CALF- Intervention status calves.*
T.R.F-Tea Research Foundation-Source of weather data, VIL-laboratory where samples were processed

7.3 Weather data during the study period

MONTH.	MIN.TEMP(C)	MAX.TEMP (C)	RAINFALL(mm)
January 1997	5.5	24.8	52.8
February	7.2	27.3	0.0
March	9.2	27.5	77.1
April	9.9	21.3	351.7
May	8.1	23.9	121.7
June	8.7	23.4	220.1
July	9.2	21.8	170.3
August	8.3	22.9	143.6
September	7.7	26.1	35.5
October	9.8	23.1	260.6
November	10.3	21.8	436.5
December	10.4	22.1	285.3
Jan.1998	9.9	23.2	262.0
February	10.0	25.0	176.1
March	10.2	27.4	33.9
April	11	26.0	234.8
May	11.1	24.4	266.4

7.4 Pasture larval counts L_3/kg of dry herbage

Month	H.contortus (±SD)	Trichostrong.sp (±SD)	Cooperia. ssp (±SD)	Oesophagost.sp (±SD)
January 1997	6.6 (22.8).	6.4 (15.0)	3.3 (11.5)	0
February	0	0	0	0
March	0	7.4 (25.7)	0	0
April	4522.8(14096.2	802.2 (1753.8)	32.4 (60.0)	187.6 (310.7)
May	3.9 (13.6)	30.8 (68.1)	64.5 (117.2)	37.7 (85.1)
June	23.6 (42.9)	39..6 (61.3)	36.3 (84.3)	30.3 (75.9)
July	0	0	0	0
August	16.4 (56.9)	37.7 (88.8)	0	0
September	16.4 (56.9)	58.9 (152.9)	0	0
October	37.6 (80.2)	0	0	0
November	151.6 (234.8)	46.3 (109..1)	46.3 (109.1)	118.4 (297.3)
December	61.3 (142.7)	16.0 (55.4)	16.0 (55.4)	22.5 (52.6)
January 1998	18.3 (34.6)	19.2 (45.4)	0	0
February	37.2 (94.9)	31.8 (90.7)	13.5 (33.0)	14.6 (34.8)
March.	12.5(43.3)	12.5 (43.3)	58.3 (202.1)	23.2 (54.4)

7.5 Shows the total number of animals sampled and percentage of the total flock each month

1-Small ruminants

Month	Number of sheep sampled	Number of goats sampled	Total sampled	Total flock each month	Percentage
January 1997	46	222	268	357	62.2
February	58	251	309	387	64.9
March	5	240	290	402	59.7
April	55	232	287	402	57.7
May	51	260	311	417	62.4
June	44	218	262	412	52.9
July	53	234	287	425	55.1
August	41	237	278	421	56.3
September	42	225	267	422	53.3
October	49	255	304	426	59.9
November	43	227	270	430	52.8
December	40	246	286	435	56.6
January 1998	31	278	309	427	65.1
February	32	270	302	428	63.1
March	41	263	304	420	62.6
April	34	245	279	408	68.4

Cattle

Month	Number of cattle sampled	Total flock each month	Percentage
January 1997	482	624	77.2
February	519	671	77.3
March	510	665	76.7
April	490	659	74.4
May	513	654	78.4
June	470	634	74.1
July	465	650	71.5
August	459	637	72.1
September	437	629	69.5
October	444	633	70.1
November	416	608	68.4
December	416	627	66.8
January 1998	435	602	72.3
February	445	615	72.4
March	470	589	79.8
April	437	579	75.9

7.6 Individual TWC(* *denotes animals which died, see appendix-general.)*

Dorper tracers

Month	Tag No.	H.contort.	T.axei	T.columb	Oeso. sp.	Strong sp	Coop. sp	Others
Janu.'97	218	0	0	0	0	0	0	0
	361	0	0	0	0	0	0	0
	341	0	0	0	0	0	0	0
	333	0	0	0	0	0	0	0
	311	250	0	0	0	0	0	0
	370	0	0	0	0	0	0	0
	Mean	**42**	**0**	**0**	**0**	**0**	**0**	**0**
February	113	0	0	0	0	0	0	0
	150	0	0	0	0	0	0	0
	159	350	0	0	0	0	0	0
	132	250	0	0	0	0	0	0
	124	100	0	0	0	0	0	0
	030	0	0	0	0	0	0	0
	Mean	**117**	**0**	**0**	**0**	**0**	**0**	**0**
March	161	450	0	0	0	0	0	0
	135	200	100	0	0	0	0	0
	147	150	0	0	0	0	0	0
	157	200	0	0	0	0	0	0
	172	300	0	0	0	0	0	0
	397*							
	Mean	**260**	**20**	**0**	**0**	**0**	**0**	**0**
April	163	0	0	0	0	0	0	0
	158	100	0	0	0	0	0	0
	145	50	0	0	0	0	0	0
	117	150	50	0	0	0	0	0
	121	0	0	0	0	0	0	0
	108	0	0	0	0	0	0	0
	Mean	**50**	**8**	**0**	**0**	**0**	**0**	**0**
May	156	150	150	0	0	0	0	0
	133	0	0	0	0	0	0	0
	143	600	4400	0	0	0	0	0
	195	0	0	0	0	0	0	0
	154	50	0	0	0	0	0	0
	101	200	0	0	0	0	0	0
	Mean	**167**	**758**	**0**	**0**	**0**	**0**	**0**

Month	Tag No.	H.contort.	T.axei	T.columb	Oesop. sp	Strong sp	Coop. sp	Others
Jun 1997	526	500	850	0	0	0	0	0
	518	0	800	350	0	0	0	0
	539	400	250	0	0	0	0	0
	599	250	600	150	0	0	0	0
	590	0	0	0	0	0	0	0
	554*							
	Mean	**230**	**500**	**100**	**0**	**0**	**0**	**0**
July	523	0	0	0	25	0	0	0
	506	200	0	0	0	0	0	0
	589	0	0	0	26	0	0	0
	515	100	2750	0	0	0	0	0
	595	0	0	0	0	0	0	0
	550	0	0	0	20	0	0	0
	Mean	**50**	**458**	**0**	**12**	**0**	**0**	**0**
August	585*							
	573	300	0	0	0	0	0	0
	501	350	0	0	5	0	0	0
	524	0	0	0	0	0	0	0
	525	300	0	0	0	0	0	0
	583	300	100	0	24	0	0	0
	Mean	**250**	**20**	**0**	**6**	**0**	**0**	**0**
Septemb.	534*							
	522	0	0	0	0	0	0	0
	584	350	0	0	0	0	0	0
	502	350	0	0	0	0	0	0
	551	250	0	0	24	0	250	0
	572	150	0	0	0	0	0	0
	Mean	**220**	**0**	**0**	**5**	**0**	**50**	**0**
October	590	450	300	0	0	0	0	0
	506	300	0	0	17	0	0	0
	573	1050	0	0	18	0	0	0
	587	450	0	0	0	0	0	0
	596	500	100	0	0	0	0	0
	602*							
	Mean	**550**	**80**	**0**	**7**	**0**	**0**	**0**

Month	Tag No.	H.contort	T.axei	T.colum	Oesop.sp	Strong.sp	Coop.sp	Others
Nov	598	200	0	0	9	0	0	0
	551	1950	350	0	24	0	0	0
	526	950	0	0	10	0	0	0
	542	2200	550	0	9	0	0	0
	503	1250	0	0	0	0	0	0
	538	0	0	0	7	0	0	0
	Mean	**1092**	**150**	**0**	**10**	**0**	**0**	**0**
Dec.1997	507	300	250	0	13	0	0	0
	572	200	150	0	18	0	0	0
	592	250	0	0	6	0	0	0
	574	1050	0	0	14	0	0	0
	599	850	0	0	21	0	0	0
	520*							
	Mean	**530**	**80**	**0**	**14**	**0**	**0**	**0**
Jan. 1998	522	1800	0	0	0	0	0	0
	539	2400	0	0	10	0	0	0
	548	900	0	0	0	0	0	0
	580	1350	550	0	20	0	0	0
	516	600	250	0	0	0	0	0
	589*							
	Mean	**1410**	**160**	**0**	**6**	**0**	**0**	**0**
February	898*							
	850*							
	890*							
	036							
	897	2050	0	0	0	0	0	0
	894	4650	0	0	0	0	0	0
	Mean	**3350**	**0**	**0**	**0**	**0**	**0**	**0**
March	250*							
	245	2750	0	0	0	0	0	0
	235	6000	0	0	22	0	0	0
	241	2950	0	0	0	0	0	0
	239	2250	0	0	0	0	0	0
	224	1800	0	0	0	0	0	0
	Mean	**3150**	**0**	**0**	**4**	**0**	**0**	**0**
April	221	2350	0	0	0	0	0	0
	224	1000	0	0	0	0	0	0
	222	5700	0	0	0	0	0	0
	n.a							
	n.a							
	n.a							
	Mean	**3017**	**0**	**0**	**0**	**0**	**0**	**0**

Local ewes (Permanent stock)

MONTH	Tag No.	Haem	T.axei	T.columb	Oesop. sp	Stron Sp	Coop.sp	Others
Jan 1997	516	600	250	0	11	0	0	0
	517	300	350	400	30	0	100	0
	518	400	650	0	19	0	0	0
	519	200	150	0	18	0	0	0
	Mean	**375**	**350**	**100**	**20**	**0**	**25**	**0**
February	030	0	350	250	0	0	0	0
	031	0	500	0	0	0	0	0
	477	0	1300	9650	0	0	0	0
	033	100	650	4400	0	0	0	0
	Mean	**25**	**700**	**3575**	**0**	**0**	**0**	**0**
March	447*							
	448	0	1150	0	19	0	0	0
	449	0	150	0	0	0	0	0
	450	0	3600	0	0	0	0	0
	Mean	**0**	**1633**	**0**	**6**	**0**	**0**	**0**
April	036	50	2350	2250	0	0	150	0
	039	250	600	150	11	0	0	0
	037*							
	038*							
	Mean	**150**	**1475**	**1200**	**6**	**0**	**0**	**0**
May	083*							
	084	0	0	2500	7	0	0	0
	085	450	750	800	0	0	0	0
	090	50	4850	0	0	0	0	0
	Mean	**167**	**1867**	**1100**	**2**	**0**	**0**	**0**
June	601	700	0	0	0	0	0	0
	602	400	3150	4550	0	0	0	0
	603	150	250	0	0	0	0	0
	604	150	1600	0	0	0	0	0
	Mean	**350**	**1250**	**1438**	**0**	**0**	**0**	**0**
July	777*							
	778*							
	779	0	9300	0	0	0	0	0
	780	0	4050	0	0	0	0	0
	Mean	**0**	**6675**	**0**	**0**	**0**	**0**	**0**

MONTH	Tag No.	Haem	T.axei	T.columb	Oesop. sp	Stron Sp	Coop.sp	Others
August	697	100	2750	1800	0	0	0	0
	696	450	350	0	11	0	0	0
	698	450	1550	0	0	0	0	0
	699	0	2200	12300	0	0	300	0
	Mean	**250**	**1713**	**3525**	**3**	**0**	**75**	**0**
Septemb.	485*							
	488*							
	486	0	3700	0	0	0	0	0
	487	0	3350	5650	0	0	0	0
	Mean	**0**	**3525**	**2825**	**0**	**0**	**0**	**0**
October	508	350	700	0	3	0	0	0
	510	700	0	0	11	0	0	0
	511	450	1350	100	3	0	100	0
	509*							
	Mean	**500**	**683**	**33**	**6**	**0**	**33**	**0**
Nov	541*							
	542*							
	543*							
	544*							
	Mean							
Dec	201	350	500	250	5	0	0	0
	202	50	1850	1450	2	0	0	0
	204	0	0	0	0	0	0	0
	203*							
	Mean	**133**	**783**	**567**	**2**	**0**	**0**	**0**
Janu.'98..	217	1400	2050	0	7	0	0	0
	218	50	1950	1250	0	0	200	0
	220	0	1400	5600	5	0	0	0
	219*							
	Mean	**500**	**1800**	**2283**	**4**	**0**	**67**	**0**
February	270	0	450	1750	0	0	50	0
	271	0	1800	5550	0	0	0	0
	272	0	2800	0	11	0	0	0
	273	0	7350	0	0	0	0	0
	Mean	**0**	**3100**	**1825**	**3**	**0**	**13**	**0**
March	278	900	3650	10250	0	50	0	0
	276	50	10050	2400	0	0	0	0
	277	150	0	0	0	0	0	0
	279	9850	0	6850	0	0	0	0

MONTH	Tag No.	Haem	T.axei	T.columb	Oesop. sp	Stron Sp	Coop.sp	Others
	Mean	**2738**	**3425**	**4875**	**0**	**13**	**0**	**0**
April	281	250	0	0	0	0	0	0
	282	300	0	0	0	0	0	0
	283	450	0	0	0	0	0	0
	284	450	0	0	0	0	0	0
	Mean	**363**	**0**	**0**	**0**	**0**	**0**	**0**

7.7 Coproculture results

cattle

Month	H.cont. (±SD)	Trich.sp (±SD)	Oeso.sp. (±SD)	Stro.sp (±SD)	Coop.sp (±SD)	Nem. sp (±SD)
Jan. 1997	40.6 (36.6	36.8 (37.5	13.8 (27.6	3.9 (18.9)	3.0 (10.9)	1.8 (6.5)
Feb	0	0	0	0	0	0
Mar	16.2 (25.6	27.2 (38.8	8.3 (23.1)	12.6 (31.1	35.3 (43.0	0
Apr	19.2 (24.7	38.4 (40.1	21.0 (27.4	3.3 (8.5	17.8 (27.7	0
May	19.4 (36.0	26.4 (45.6	12.5 (23.3	13.9 (35.0	27.8 (45.2	0
Jun	69.8 (4.8)	4.8 (10.1)	19.0 (35.7	3.2 (9.5)	3.2 (9.6)	0
Jul	18.5 (27.1	66.1 (34.6	8.6 (21.4	0	6.3 (15.1)	0.5 (2.8)
Aug	29.8 (32.3	51.3 (37.1	6.6 (13.8)	0.7 (4.1)	10.6 (25.1	1.0 (4.2)
Sep	37.8 (32.0	58.7 (24.7	1.5 (4.9)	0	2.0 (7.8)	0
Oct	46.5 (24.0	46.8 (28.3	1.7 (5.3)	4.9 (13.0)	0	0
Nov	13.1 (25.6	59.8 (42.7	0	0.6 (2.0)	25.8 (40.4	0.7
Dec	26.9 (32.3	30.5 (35.4	12.8 (19.1	1.2 (3.1)	28.7 (37.9	0
Jan. 1998	47.8 (35.6	26.8 (33.2	0	0	25.3 (33.2	0

Small ruminants

Month	H.cont. (±SD)	Trich.sp. (±SD)	Oeso.sp. (±SD)	Stro.sp (±SD)	Coop.sp (±SD)	Nem. sp (±SD)
Jan. 1997	53.0(36.7)	28.0(28.3)	18.4(33.1)	0.4(1.2)	0	0
Feb	43.0(48.4)	52.8(45.5)	0	4.2(11.8)	0	0
Mar	13.5(17.3)	25.2(23.7)	25.7(32.3)	22.9(23.6)	12.7(18.9)	0
Apr	4.5 (10.4)	43.2(36.9)	17.5(18.7)	31.4(35.3)	3.4(5.3)	0
May	20.4(28.9)	52.1(38.5)	5.4(11.6)	14.8(31.3)	7.4(12.8)	0
Jun	11.5(18.5)	58.1(33.9)	7.4(17.2)	3.0 (6.1)	20.0(23.1)	0
Jul	37.3(20.9)	27.9(26.4)	7.4(7.8)	1.6 (4.8)	25.7(14.1)	0
Aug	22.0(18.9)	63.3(30.7)	6.5(9.5)	2.6 (5.9)	5.1(16.8)	0.5(1.8)
Sep	25.0(28.9)	62.7(33.5)	7.0(13.4)	0.7 (3.1)	3.2(11.1)	1.7(5.5)
Oct	25.5(28.4)	55.5(30.4)	10.7(16.9)	0	8.0(13.9)	0
Nov	11.5(15.9)	63.0(34.3)	11.5(10.4)	6.4 (12.6)	2.3(2.5)	5.3(9.5)
Dec	37.3(32.6)	37.0(35.3)	2.6 (6.4)	0	21.9(29.5)	1.2(4.1)
Jan. 1998	32.3(25.4)	44.6(71.4)	8.1(19.3)	0.2 (0.7)	15.2(18.4)	0.2(1.2)

General - Mortalities for the tracers used for total worm counts.

MONTH SHEEP DIED	ANIMAL NUMBER	TYPE: 1=Dorper, 2=Local ewes -	WHERE: 1= Field 2=NVRC.
0ct'95	588	1	1
Dec'95	252	1	*
May' 96	822	2	2
Jun' 96	973	1	1
Jul'96	781&783	2	2
Aug'96	751	2	2
Aug'96	969	1	1
Sep'96	714	1	1
Oct'96	015	2	2
Mar'97	447	2	2
Mar'97	397	1	1
Apr'97	037&038	2	2
May 97	125	1	2
May 97	083	2	2
Jun'97	554	1	1
Jul'97	777&778	2	2
Aug'97	585	1	1
Sep'97	485&488	2	2
Sep'97	534	1	1
Oct'97	509	2	2
Oct'97	602	1	1
Nov'97	541& 542	2	2**
Nov'97	541&542,	2	2**
Dec'97	203	2	2
Dec'97	520	1	1
Jan'98	219	2	2
Jan'98	589	1	1
Feb'98	850 &890	1	1***
Feb'98	898 &036	1	1***
Mar'98	250	1	1

NOTE * -Taken by mistake to another study site in the country (Karatina)
**-Animals reported dead during the Dec.1997 to Jan.1998 but suspects theft or slaughter since the station was virtually closed for the General Election break. Most deaths in the field of Dorper lambs due to pneumonia, bloat and injury. NVRC-most animals died during the weekend or holidays and were decomposed and local ewes were mainly the victims because of "shock" due to confinement and unfamiliarity to dry hay.
*** The animals were generally weak.

Presentation of results arising from this thesis

Rugutt, M.K, McKellar, Q.A, Jackson, F and Bain, R.K 1997. The pattern of infection of ruminants with gastro-intestinal nematodes in the Kericho highlands of Kenya. In: *The Abstracts of 16th WAAVP, scientific conference,* pp.76, Sun city, South Africa

Bain, R.K, Gatongi, P.M, Nginyi, J.M, Oyango-Abuje, J.A, Peeler, E.J, **Rugutt, M.K** and Wanyangu, S.W. 1997. Conducting epidemiology studies on helminthiasis amongst small holder farms-problems and possible solutions from Kenya. In: *The Abstracts of 16th WAAVP scientific conference*, pp.6, Sun city, South Africa.