THE EPIDEMIOLOGY AND CONTROL OF GASTROINTESTINAL NEMATODE INFECTIONS OF GOATS IN KATHIANI DIVISION, MACHAKOS DISTRICT, KENYA

A completion report submitted to the Dean's Committee, University of Nairobi

By

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To my family, I owe a continuing debt of gratitude for your uninterrupted support and forbearance during the study.

DEDICATION

To the memory of my parents, **Dadson W. Wakanyi** and **Edith W. Waruiru**.

ABSTRACT

i) Field survey

A survey of gastrointestinal nematode infections of goats reared under extensive grazing conditions was conducted for 18 months on 4 farms in Kathiani Division of Machakos District, Kenya. The survey was based on monthly coproparasitological examination of kids (< 6 month), immature (6-12 months) and adult (> 12 month) goats. The effects of season and age on the prevalence and intensity of infection were determined. Faecal egg counts (FEC) revealed that the overall prevalence of strongyles was 52.0% and the wet season prevalence was significantly ($p<0.05$) higher than for the dry season in the 3 age groups on the 4 farms. Majority of the animals had FEC of below 400 eggs per gram and did not vary significantly ($p>0.05$) between the 3 age groups. The FEC followed a typical overdispersed distribution. *Haemonchus contortus* was the main nematode encountered in coprocultures (75%) and post mortem total worm counts. Other nematodes encountered included *Trichostrongylus axei*, *T. colubriformis*, *Bunostomum trigonocephalum*, *Oesophagostomum columbianum*, *O. venulosum* and *Trichuris ovis*. Based on these findings, it is now possible to explore the possibility of using strategic treatments for the control of strongylosis in the study area.

ii) Control experiments

The persistent anthelmintic effect of closantel (CLO) plus albendazole (ABZ) mixture against common gastrointestinal nematodes (GIN) of goats was evaluated in 2 experiments. In the 1st experiment, the suppresion of strongyle egg output in faeces was examined in goats treated orally with either ABZ or CLO plus ABZ liquid suspension. Sixty goats with naturally acquired infections were randomly assigned to 3 groups of 20 goats each. The 1st group served as the untreated controls and the other groups received respectively single doses of 5 mg kg^{-1} body weight ABZ or CLO (10 mg kg^{-1}) plus ABZ (5 mg kg^{-1}) orally. Faecal egg counts (FEC) and generic determination of third-stage larvae (L_3) were performed at weekly intervals, from the time of treatment (day 0) until week 7 post treatment. In the 2nd

experiment, a controlled trial was conducted in goats infected experimentally with GIN L_3 including a benzimidazole (BZ)-resistant isolate of *H. contortus*. Twenty-one goats were randomly assigned to 3 groups of 7 each and drenched with either ABZ (5 mg kg^{-1}), CLO (10 mg kg^{-1}) plus ABZ (5 mg kg^{-1}), or untreated controls. Ten days post treatment, goats were killed and necropsied for parasite recovery. Results revealed that a single dose of either CLO/ABZ mixture or ABZ were highly effective (100%) in suppressing faecal egg output up to 2 weeks post treatment, and FEC of CLO/ABZ treated groups remained significantly lower than those of ABZ treated group up to 4 weeks post treatment ($p < 0.05$). CLO/ABZ mixture was 99-100% effective against *H. contortus*, *T. axei*, *T. colubriformis* and *O. columbianum*. Efficacy of ABZ was poor for *H. contortus* (29%) but approached 100% for most of the other parasites. The results demonstrated an advantage of the CLO/ABZ mixture over ABZ in that excellent anthelmintic efficacy persisted for 3 weeks after treatment in preventing establishment of GIN of goats and, was highly effective against a BZ-resistant isolate of *H. contortus*.

In conclusion, the results of this study suggest that strongyle infections, especially haemonchosis, are major constraints to the health of goats of the study area. Most of the infections were subclinical and could indirectly cause production losses without attracting the farmer's attention to institute control measures. To increase the productivity of goats, helminthosis control should be based on epidemiological observations of an area before initiating strategic control programmes. Use of anthelmintic mixtures of different classes (i.e., CLO/ABZ) is one such programme.

GENERAL INTRODUCTION

The major national objectives in Kenya's development policy are food self-sufficiency, food security, employment creation, income generation, generation of foreign exchange earnings and overall growth. In view of the rapid population growth and the increasing demand for food, food production and food security will remain key priorities in the agricultural sector (Anonymous, 1997a). To achieve food security, output of cereals, milk and meat are crucial, since these products are the major sources of energy and protein in human diets (de Leeuw and Reynolds, 1994).

The goat is a key food animal in much of the Third World, since it is one of the most resourceful and efficient ruminants (Mussman, 1982; Semenye and Hutchcroft, 1992). Easy handling and the effective conversion of limited food resources into meat and milk are also important factors favouring the goat as a stock animal for smallholder farmers. There are about 10 million goats in Kenya (KARI, 1994; FAO, 1995). Most of these goats are kept by smallholder farmers in the arid and semi-arid lands (ASAL) where they serve various purposes like subsistence and as farmers "banks". They are also used for various cultural purposes (Anonymous, 1997b). Goats are particularly suited for the ASAL as they are able to walk for long distances in search of pasture and water. They can graze and also browse. They feed on dry pods, barks and high twigs and hence are less vulnerable to nutritional stress during prolonged dry periods (Carew *et al.*, 1980; Lu, 1988).

Helminthosis is of considerable significance in a wide range of agro-climatic zones in sub-Saharan Africa and constitutes one of the most important constraints to small ruminant production (FAO, 1992). The disease has been identified as a major constraint to productivity in goats in Kenya (Carles, 1992). The widespread occurrence of infection at subclinical levels with helminths (Githigia *et al.*, 1996; Mbae *et. al.*, 2004), the associated loss of production, the cost of anthelmintics and death of infected animals are some of the major concerns (Preston and Allonby, 1979; Carles, 1992; Githigia *et al.*, 2001).

Gastrointestinal nematode (GIN) parasitism, dominated by haemonchosis, is a major problem limiting profitable production of goats in Kenya (Carles, 1992; Gatongi, 1996; Githigia *et al.*, 2001). The species causes the death of large numbers of animals, reduction in weight gain and increased susceptibility to illness (Urquhart *et al.*, 1989). It is this species against which worm control programmes are primarily directed. Owing to favourable climatic conditions and because grazing management involving "clean" pastures is usually not practicable, the method of worm control most favoured by goat producers is frequent anthelmintic treatment using a wide range of anthelmintics (Kinoti *et al.*, 1994). The high frequency of treatment is attended by a high risk of rapid selection of anthelmintic resistance, especially in *H. contortus* (Waller, 1993). Strategic or integrated control programmes could minimize the number of anthelmintic treatments in the goat industry.

Widespread resistance to benzimidazole (BZ) and levamisole (LEV) anthelmintics has already emerged in *H. contortus* in goats in Kenya over the last few years (Njanja *et al.*, 1987; Wanyangu *et al.*, 1996). Recently, multiple resistant isolates to the three groups of broad spectrum anthelmintics, namely BZs, LEV and ivermectin (Mwamachi *et al.*, 1995) and BZ, LEV and rafoxanide (Waruiru *et al.*, 1998) have been identified.

The common occurrence of BZ and LEV resistant strains of *H. contortus* demonstrates the need for alternative anthelmintics with a different mode of action. One such drug is closantel (CLO), a long-acting narrow spectrum salicylanilide derivertive, which is reported to have a persistent anthelmintic activity against blood-sucking nematodes for several weeks (Hall *et al.*, 1981; Taylor *et al.*, 1991; Maingi *et al.*, 1997a; Khan *et al.*, 1999), possibly owing to its strong binding to plasma protein and prolonged plasma half-life (McKellar and Kinabo, 1991). This prolonged anthelmintic effect of CLO allows the frequency of treatments with broad spectrum anthelmintics to be reduced in areas where *H. contortus* predominates. A strategic "wormkill" control programme for *H. contortus*, based on the narrow spectrum and persistent activity of CLO and on epidemiological factors, has been widely adopted by sheep farmers in Australia since 1984 and has resulted in a marked reduction in the prevalence of haemonchosis in sheep (Dash, 1986; Waller *et al.*, 1995).

Although CLO is commonly used in sheep, especially in Australia (Barger *et al.*, 1991), the drug is also widely used for the control of haemonchosis in goats (Uppal *et al.*, 1993; Dorny *et al.*, 1994; Waruiru, 1997). However, little is known on its prolonged anthelmintic activity in this species. Hennessy *et al.* (1993) demonstrated a more rapid elimination of CLO in goats than in sheep and this could reduce the sustained action of CLO in goats.

This study was based on the following hypotheses:

1: That GIN infections of goats are widespread in the study area.

2: That season and age influences the prevalence and intensity of these infections.

3: That CLO has sustained activity in goats.

4: That there is potential utility of CLO as an alternative treatment for BZ resistant *H. contortus* strains.

1.1 Study objectives

The above hypotheses were tested with the aim of achieving the following objectives.

1: To determine the identity, prevalence and intensity of GIN infections in goats in a semi-arid area of Kathiani Division of Machakos District, Kenya.

2: To determine the influence of seasonal weather factors and age on the occurence and distribution of GIN of goats.

3: To evaluate the therapeutic and persistent efficacy of CLO against *H. contortus* in naturally infected goats.

-Chapter 2-

LITERATURE REVIEW

2.1 The place of small ruminants in livestock development in Kenya

The Kenyan Ministry of Agriculture, Livestock Development and Marketing estimates the present small ruminant population to be about 20 million (KARI, 1994). Over 80% of this population is found in the arid and semi-arid lands (ASAL) where they constitute an important source of dietary animal proteins primarily in the form of meat and milk (Anonymous, 1997b). They are also considered as means of socio-economic status as well as providing employment.

In maximizing the meagre resources in the ASAL, livestock production has been a success but currently it has become non-viable due to the changing land tenure system that has led to the subdivision of formerly vast ranches into small plots (Galaty, 1992). Consequently, small ruminants have become the best choice of livestock enterprise in these areas. Their small stature requires low feed intake and their feeding habits that enable them to access green shoots from poor quality shrubs make them suitable for small farmer situations (Carew *et al.*, 1980; Lu, 1988). However, the farmer has to content with husbandry problems such as bacterial, viral and parasitic diseases. The low off take of small ruminants in the ASAL is a direct result of high mortality (Shavulimo, 1987) with pre-weaning mortality accounting for up to 40% of losses (World Bank, 1983).

The population of goats stand at 10.5 million compared to 9.6 million sheep and 13.0 million cattle. Four million of the goats are found on smallholder farms in the pastoral areas and amongst these, less than twenty thousand can be classified as improved goats (Stotz, 1983;

KARI, 1994, FAO, 1995). If indigenous goats are improved for dual-porpose (meat and milk production), they would be an important source of the much needed animal protein in the rural population (Fitzhugh, 1982). Productivity of these animals is generally low due to a number of factors, which include inadequate feeding resources, poor management and diseases (Brumby and Scholtens, 1986). While poor nutrition is considered the most critical factor, parasitism particularly helminth infections constitute a major source of economic loss (FAO, 1991).

2.2 Impact of helminthosis in livestock production

Helminthosis remains one of the world's most prevalent and economically important parasitoses of man and his domesticated animals. This is particularly the case in the developing countries, much of which lies within the tropical regions of the world and where, for most part, systems of livestock production, environmental and socio-economic conditions are highly conducive for the development, maintenance and transmission of infection (FAO, 1992; Chiejina, 1994; Tembely and Hansen, 1996).

Parasitic diseases caused by helminth infections result in enormous economic loss in livestock specially in ruminants throughout the world (Fabiyi, 1986; Nansen, 1986; Craig, 1988; Chiejina, 1994). The economically important helminth parasites of domestic ruminants, their pathophysiological effects, epidemiology and strategies for effective control of these infections have been well studied and documented in most developed countries (Rickard and Zimmerman, 1992; Barger, 1993, Nansen, 1993; Homes, 1994; Miller, 1996). However, there have only been a few reports of detailed studies on all aspects of helminth parasitism from sub-Saharan Africa (Chiejina, 1991; Reinecke, 1994; Moyo *et al.*, 1996; Waruiru, 1998; Zinsstag *et. al.*, 1998; Nginyi *et. al.*, 2001; Ng'ang'a *et. al.*, 2004a). In East Africa, production losses due to helminth infections in ruminants are associated mainly with GIN infections (Magona and Musisi, 1999; Rubaire-Akiiki *et al.*, 1999; Githigia *et al.*, 2001; Keyyu *et al.*, 2002). However, in some areas, lungworm and trematode infections also have serious effects on ruminant production (Thamsborg *et al.*, 1998; Makundi, 2001).

2.3 Gastrointestinal nematode parasitism

Gastrointestinal nematode (GIN) parasitism is one of the most important diseases of livestock (Perry *et al.*, 2001), affecting pasture based production systems world-wide. Essentially all grazing cattle, sheep and goats are at risk from nematode infections with considerable morbidity being a consequence of such infections. Reduction in liveweight gain is the most common feature in GIN infections. They also cause reduction in milk production, poor wool growth and quality, condemnation of carcasses and viscera and impaired reproductive performance (FAO, 1991). The degree of physiological disturbance is determined by the intensity of infections, the species of parasites, and the age, the nutritional and immunological status of the host (Holmes, 1994). The epidemiology of GIN in heavily influenced by weather conditions (Wanyangu *et al.*, 1997; Gatongi *et. al.*, 1998a). In Kenya, different agro-ecological zones have been identified, which have relatively different climatic conditions (Sombroek *et al.* 1982). Available information indicates that GIN occur in all zones and production and economic losses may be high due to both clinical and subclinical infections (Lutu, 1983, Njanja, 1991, Shavulimo, 1993; Mwamachi *et al.*, 1995; Githigia *et al.*, 1996; 1998; Mbae *et. al.*, 2004).

Naturally-occuring caprine parasitic gastroenteritis (PGE) is a gastroenteropathy caused by mixed infections with several species of GIN. It is the commonest helminth polyparasitism of ruminants in the tropics (Tembely and Hansen, 1996), typically of young animals and may be acquired through a variety of ways (Soulsby, 1986). Recent research has confirmed that *H. contortus* is the most prevalent nematode in both sheep and goats and that it accounts for about 80% of all nematodes (Gatongi, 1996). Other major nematodes include *Trichostrongylus* spp., *Oesophagostomum* spp. and *Trichuris* spp. Additionally, *Cooperia*, *Nematodirus*, *Strongloides*and *Bunostomum* species have also been frequently observed in the cool tropical highlands of Kenya (Munyua *et. al.*, 1997; Gatongi *et al.*, 1998a).

Although several species of nematodes can contribute to PGE syndrome, only a few are primarily responsible for disease outbreaks under field conditions. For example, disease in goats is caused mainly by *H. contortus*, *T. colubriformis* and *O. columbianum* and these constitute a major source of economic losses (FAO, 1991). Losses may occur as a result of high mortality and reduced growth rate especially in kids. However, insidious productivity losses through reduced feed intake and decreased efficiency in feed utilization, associated with subclinical and chronic conditions, are often the largest economic losses (FAO, 1991; Coop and Kyriazakis, 1999).

An essential part of reducing these losses and improving animal productivity is through development of effective control strategies. The economics of such programmes appear to be favourable and benefits include: improved growth rate and/or reduced weight loss, increased lactation, providing more milk for better kid growth and survival, also milk for human consumption, improved reproduction performance, reduced mortality and reduced condemnations at slaughter, among others (Chiejina, 1994). Improving the health and profitability of small ruminants has a significant influence on the welfare of smallholders in Kenya (Odoi *et al.*, 1998).

2.3.1 *Nematode life cycle*

The life cycles of trichostrongylid nematodes, *Oesophagostomum* and *Bunostomum* are simple and direct, each adult worm being derived from an infective larva separately acquired from pasture. Adult nematodes inhabit the GI tract. Eggs produced by the female are passed out in the faeces and given appropriate environmental conditions, hatch in the faecal deposits to become first-stage larvae (L_1). The L_1 feed on bacteria, grow and moult to second-stage larvae (L_2), shedding their protective cuticle in the process. The L_2 larvae moult into third-stage larvae (L_3) but retain the cuticle from the previous moult. These double-cuticled L_3 are the infective larvae. The time required for the eggs to develop into infective larvae depends on temperature. Under optimal conditions (i.e., high humidity and warm temperatures), the development process requires 7 to 10 days (Hansen and Perry, 1994).

The parasitic phase of the life cycle begins with the ingestion of L_3. The protective sheath is shed in response to specific stimuli such as temperature, carbon dioxide concentration and pH which occur within the organs preceding the site where parasitic development is completed. The third moult takes place within a few days after exsheathment and fourth-stage larvae (L_4), either closely applied to or within the mucosal surface, undergo major changes in morphology, differentiate sexually and increase considerably in size. Further growth and maturation occurs after the final moult to the adult form and shortly afterwards female worms commence egg laying to complete the cycle. Generally, parasitic development in most trichostrongylids is completed within 3 to 4 weeks after infection but for *Oesophagostomum* spp. a longer period of 5 to 6 weeks is required (Anderson and Bremner, 1983).

There are some exceptions to the general pattern described as in species of *Nematodirus*, development to the L_3 stage occurs entirely within the egg; the larva then hatches and is infective to the host. Infective larvae of hookworms (*Bunostomum*) and *Strongyloides* can also infect the host by penetrating its skin; the worms reach the intestine via the blood stream and lungs. The infective larval stage of *Trichuris* is contained within the egg and is only released after the egg is ingested by the host (Hansen and Perry, 1994).

2.4 Anthelmintics for ruminants

Although, anthelmintics play a major role in parasite control programme in Kenya, their use is mainly curative in nature (Kinoti *et al.*, 1994). Treatments are given at scheduled intervals or on a sporadic basis. Sometimes the whole herd is treated, alternatively only animals showing signs of parasitic infection are treated. Thus, anthelmintic control programmes do not always produce the desired effect and become a costly exercise (Prichard, 1991; Mbaria *et al.*, 1995).

There are many factors which influence or limit the efficacy of anthelmintics used in any treatment programme. These are either factors connected with the host-parasite environment or factors connected with the pharmacology and therapeutic properties of the drug and/or a combination of both.

2.4.1 *Factors related to the host-parasite environment*

2.4.1.1 *Host physiology and anthelmintic efficacy*

Antiparasitic drugs must be conducted to the parasite by the host and are therefore subject to physiological and biochemical processes in the host. In ruminants, diet and certain disease states, including GI parasitism can cause reduction in the absorption and bioavailability of many anthelmintic drugs. This leads to reduced efficacy of the drug.

Many anthelmintics are administered without consideration being given to physiological differences between animal species. For example, treatment of goats is usually based on doses prescribed for sheep. Any control strategy should recognise the physiological differences between species and the current dose recommended for effective treatment.

2.4.1.2 *Epidemiological consideration in the use of anthelmintics*

It is well recognised that a basic understanding of the epidemiology of economically important helminth infections of ruminants is essential for devising rational control measures. It is now well recognised and documented (Vercruysee, 1983; Connor *et al.*, 1990) that some nematode (i.e., *H. contortus*) species experience inhibited development (hypobiosis in the host when climatic conditions are unfavourable for the survival and transmission of free living stages). Inhibited development of *H. contortus* has been demonstrated in Kenya at the onset of the dry season (Gatongi *et al.*, 1998b; Githigia *et al.*, 2001). Studies have shown that inhibited larvae which are usually deeply embedded in the mucosa are metabolically less active than normally developing larvae and are relatively less susceptible to many available anthelmintics. However, some of the newer more potent anthelmintics are effective against these stages as well as the adults. Inhibited larvae must be considered when planning control procedures in terms of the timing of treatment and the choice of anthelmintic. Although epidemiological studies are costly and time consuming, epidemiological details should be worked out for each agro-climatic (ecological) zone and husbandry system (Arambulo and Moran, 1981).

2.4.2 *Anthelmintics*

Anthelmintics for ruminants can be grouped according to their chemistry/mode of action and according to their activity spectrum, for example:

2.4.2.1 *Benzimidazoles (BZs)*

This large group of structurally related compounds, and pro-BZs which are converted in the host to BZs, act by binding to helminth tubulin, inhibiting the formation of microtubules (Lacey, 1990). They can be divided into two groups. Firstly, anthelmintics with a moderate spectrum, such as thiabendazole, mebendazole and thiophanate are effective against adult GIN, some but not all immature worms and hypobiotic larvae in ruminants. In some cases, they also control lungworms and tapeworms. These drugs must be given by oral administration. The second group of BZs and pro-BZs are more potent and have a broader spectrum of activity. This group includes albendazole (ABZ), fenbendazole, oxfendazole and the pro-BZs, febantel and netobimin. These more recently developed BZs are active against virtually all GIN of ruminants, including immature worms and hypobiotic larvae, tapeworms and in some cases adult *Fasciola gigantica*. However, activity depends on the dose rate in the host being treated. All of these BZs are given by oral administration and some of these are available as long-acting intra-ruminant boluses (Probert, 1994; Munyua *et al.*, 1997).

2.4.2.1.1 *Albendazole*

Albendazole, (methyl[5-(propylthio)-1H-benzimidazole-2-yl] carbamate is a potent member of the BZ group of anthelmintics with broad spectrum activity against GIN including larval stages, tapeworms, liver flukes, and lungworms in many host species (Theodorides *et al.*, 1976; Williams *et al.*, 1991). In addition to its vermicidal and larvicidal properties, ABZ is also ovicidal and attention has focused on its use in systemic helminth infections such as hydatid disease, cysticercosis and systemic nematode infections of man (Horton, 1990). The mode of action in such parasitic infections is believed to derive from the inhibition of tubulin polymerization into microtubules, with a cascade of other metabolic effects resulting from this (Lacey, 1990).

2.4.2.2 *Salicylanilides*

The salicylanilides were developed as anti-*Fasciola* spp. anthelmintics and act by uncoupling oxidative phophorylation (Kane *et al.*, 1980). However, they may have a narrow spectrum of activity against blood-sucking nematodes. Most notably, closantel and rafoxanide (RAF), which are absorbed from the GI tract or site of injection and bind strongly to plasma proteins to produce very long half-live (up to weeks), are also effective against blood-sucking nematodes, such as *H. contortus*. Closantel (CLO) has a longer half-life than RAF and so its long-acting effects against *Haemonchus* and *Fasciola* (4-6 wks, Hall *et al.*, 1981) are more pronounced than for RAF. However, they do not have activity against non blood-sucking nematodes or trematodes, nor generally (except for niclozamide) against cestodes. The activity of CLO and RAF against *Fasciola* spp. and blood-sucking nematodes can be very useful for specific prevention and treatment of anaemia producing infections in ruminants, particularly where resistance to broad spectrum anthelmitics has developed or is likely to develop upon high level use of the broad spectrum anthelmitics. Because of their long half-lives, associated with binding to plasma proteins, animals cannot be slaughtered for human consumption for several weeks after treatment with these salicylanilides (Anonymous, 1990).

2.4.2.2.1 *Closantel*

Closantel, N-(5-chloro-4[(4-chlorophenyl) cyanomethyl]-2-methyl(phenyl)-2-hydroxy-3,5-diiodobenzamide, is a salicylanilide antiparasitic compound with anthelmintic and ectoparasiticidal activity in different animal host species (Hall *et al.*, 1981; Guerrero *et al.*, 1982; Guerrero, 1984; Butler, 1986). The multiple antiparasitic activity of CLO seem to have the common denominator of being expressed against parasites which are either in close contact with circulating blood (i.e., larvae of *Strongylus vulgaris*) or that are haematophagous in nature (Guerrero *et al.*, 1982). The other marked characteristic of CLO is its prolonged effect which is variable depending on the host species (Hall *et al.*, 1981; Guerrero *et al.*, 1982).

Closantel has been reported to be very effective against BZ-resistant *H. contortus* in sheep in Australia ((Hall *et al.*, 1981) and Zimbabwe (Vassilev, 1985) and in goats in Malaysia (Dorny *et al.*, 1994). It was also, highly effective against levamisole (LEV)-resistant *H. contortus* in sheep in India (Yadav and Kumar, 1994) and against fenbendazole- and LEV-resistant *H. contortus* in sheep and goats in Kenya (Waruiru, 1997). Closantel binds strongly to plasma proteins and probably reaches *H. contortus* via the blood on which it feeds (Michiels, 1987; McKellar and Kinabo, 1991). This binding also serves to prolong drug levels in plasma and protects sheep and goats against re-infection for several weeks (Hall *et al.*, 1981; Dorny *et al.*, 1994).

-Chapter 3-

GASTROINTESTINAL NEMATODE INFECTIONS OF GOATS: A FIELD SURVEY

3.1 Introduction

Gastrointestinal nematode (GIN) infections of goats are thought to be widespread in all agro-climatic zones of Kenya (Lutu, 1983, Njanja, 1991, Shavulimo, 1993; Mwamachi *et al.*, 1995; Githigia *et al.*, 1996; 1998). However, information on the prevalence and intensity of subclinical infections is limited. Recent observations in situations of subclinical parasitism have shown that growth can be depressed by 23-30%, fecundity by 30%, and milk yields up to 30% (Carles, 1992). Among helminth diseases, haemonchosis, caused by *H. contortus* is one of the most important diseases of goats in Kenya resulting in high morbidity and mortality (Urquhart *et al.*, 1989; Gatongi, 1996; Githigia *et al.*, 2001). The control of GIN infections is therefore necessary.

Effective control strategies for GIN using anthelmintics are usually those based on the epidemiology of the parasites with tretments being designed to reduce pasture contamination and host infection (Arambulo and Moran, 1981; Nansen 991). Apart from the limited observations made by Githigia *et al.* (1996) no detailed epidemiological study has been conducted in eastern Kenya. For this reason, a preliminary survey was undertaken to provide basic information on the identity, prevalence and intensity of GIN infections in indigenous goats. The effect of season and age on the occurence and distribution of these parasites was also determined as this information is important in formulating control strategies.

3.2 Materials and Methods

3.2.1 *Study location, climate and vegetation*

This study was conducted between January 2002 and July 2003 on 4 farms in Kathiani Division of Machakos District, about 50 km south-east of Nairobi. The district shares common boundaries with several districts both within and outside Eastern Province (Fig. 3.1) and lies between latitude 0^{o} 45^{1} and 1^{0} 30^{1} south of the equator longitude 36^{o} 45^{1} and 37^{o} 45^{1} east of the Greenwish Meridian. The area is predominantly semi-arid and lies at an altitude of 1200 m above sea level. The rainfall has a bimodal pattern and varies from 500 mm in dry years to slightly over 1000 mm in wet years. The long rains occur between March and May while, the short rains fall from October to December, although it is not very reliable. Temperatures varies between 20 °C and 25 °C throughout the year, the coldest month being July and the warmest months being October and March prior to the rains (Anonymous 1997c).

The vegetation cover was mainly grasslands interrupted by short bushes, scattered acacia (*Acacia themeda*) trees and sisal (*Agave sisalana*) plants. The pasture was dominanted by the Red Oat grass (*Themeda triandra*) while, hibiscus and solanum were the most common shrubs (Anonymous, 1970; Ojany and Ogendo, 1973). The soils are shallow, poorly drained, of low fertility and their water-holding capacity is low (Sombroek *et. al.*, 1982). Due to unreliability of rainfall, crop failures are common. Drought resistant crops are grown and cattle, sheep and goats are reared in a traditional extensive husbandry system. Daily records of meteorological data were kept throughout the study period.

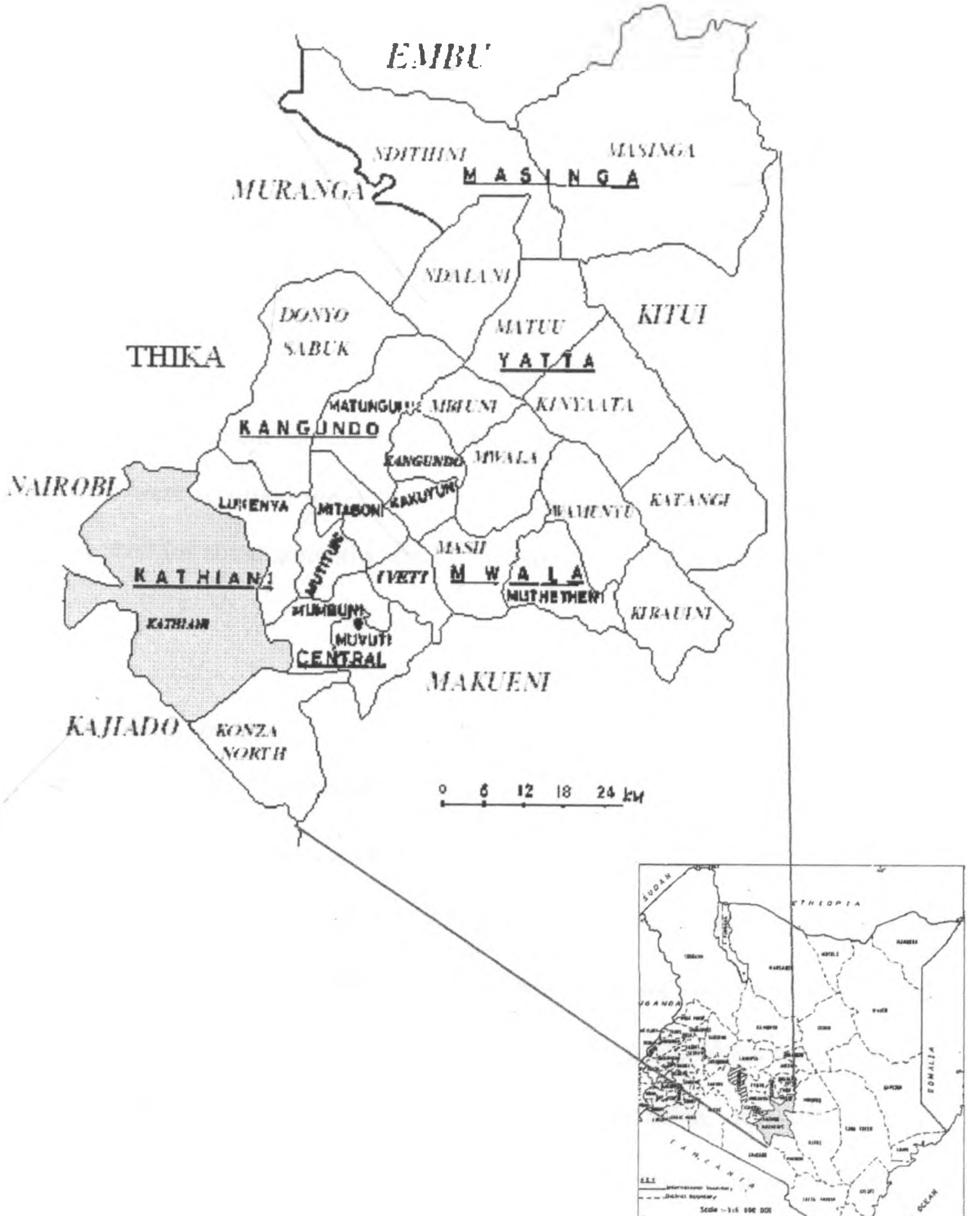

Fig. 3.1: A sketch map of Kenya showing location of Kathiani Division in Machakos District.

3.2.2 *Farms and herd management*

This study was undertaken on 4 farms of Messrs Maranga (Farm A), Mutinda (Farm B), Musyoka (Farm C) and Nzioka (Farm D), respectively. The farms (with more than 50 goats) were distributed within Katani location of Kathiani Division and were identified with the assistance of the local livestock extension officer. The study goats were mainly the small East African breed and were grazed for about 8 h during the day and penned at night in sheds. All the animals had access to water and salt from dams and in the sheds, respectively. They were not given any supplements during the period of study. There was no particular breeding season, but births were recorded throughout the year. Following births, the kids were kept in or around the shed for about 2 months, after which they followed their dams to the grazing areas.

3.2.3 *Epidemiological survey*

The survey was undertaken for 18 month and covered 3 dry (January-March, July-September 2002 and January-March 2003) and 3 rainy (April-June, October-December 2002 and April-June 2003) seasons. Three age groups of goats; kids (< 6 months of age), immatures (6-12 month old) and adults (> 12 months of age) were randomly selected on each farm, eartagged and sampled monthly. On each sampling occasion, goats which were older than their age group were moved to the next age group. When available, new kids were also recruited into the kids group during the sampling occasions to replace those moved to the immature group. On each farm, 20 to 40 goats, chosen at random, were sampled per age group. Goats drenched within the last 4 weeks were not sampled on any of the occasions. Faeces (3-5 g) were collected directly from the rectum of each goat, placed in labelled plastic containers and stored at 4 °C until examined.

3.2.4 *Parasitological methods*

The number of strongyle eggs per gram of faeces (epg) was determined for each sample by a modified McMaster technique (MAFF, 1986). The number of stronggyle eggs counted in a McMaster slide chamber were assigned values i.e., zero (0) to 100 eggs were assigned 0 value and so on to an assigned value of 10 for 2000 or more eggs (Fig. 3.3).

During the sampling occasions in the months of August-September 2002 and April-May 2003, which were in the dry and wet seasons, respectively, faecal samples were pooled for all age groups from each farm. These were cultured at room temperature for 14 days for differential larval counts (MAFF, 1986). Goats which died during the study period were necropsied to recover adult worms which were identified according to the criteria of MAFF (1986).

3.2.5 *Statistical analysis*

Faecal egg counts were normalized with logarithms transformation (ln (x+1)). Means are given after exponential reconversion. One-way analysis of variance (Instat software; Graph Pad Instat Inc; USA, 1990-1994) was used to examine for differences in epg between age groups and seasons. The prevalence rates of strongyle eggs were defined as described by Margolis *et al.* (1982), and the proportions of infected animals were compared using the χ^2 test.

3.3 Results

3.3.1 *Meteorological data*

Figure 3.2 summaries the mean monthly rainfall and mean monthly temperature during the study period. The distribution of rainfall was generally bimodal and the range of monthly temperature were normal for the area.

3.3.2 *Strongyle faecal egg counts*

A total of 711 animals, comprising of 363 for the dry season and 348 goats for the wet season were examined. Table 3.1 gives the prevalence of faecal strongyle eggs in kids, immature and adult goats on the 4 farms. Overall, eggs were detected in 370 (52.0%) samples examined and age prevalences were: kids (57.1%), immatures (53.3%) and adult goats (51.1%). These prenalences did not vary significantly ($p>0.05$) among goats in the 4 farms for any of the 3 age groups. Overall prevalence during the wet season (76.4%) was significantly ($p<0.05$) higher than for the dry season (31.3%). Other nematode genera eggs observed in a few faecal samples were *Strongloides*, *Nematodirus* and *Trichuris*.

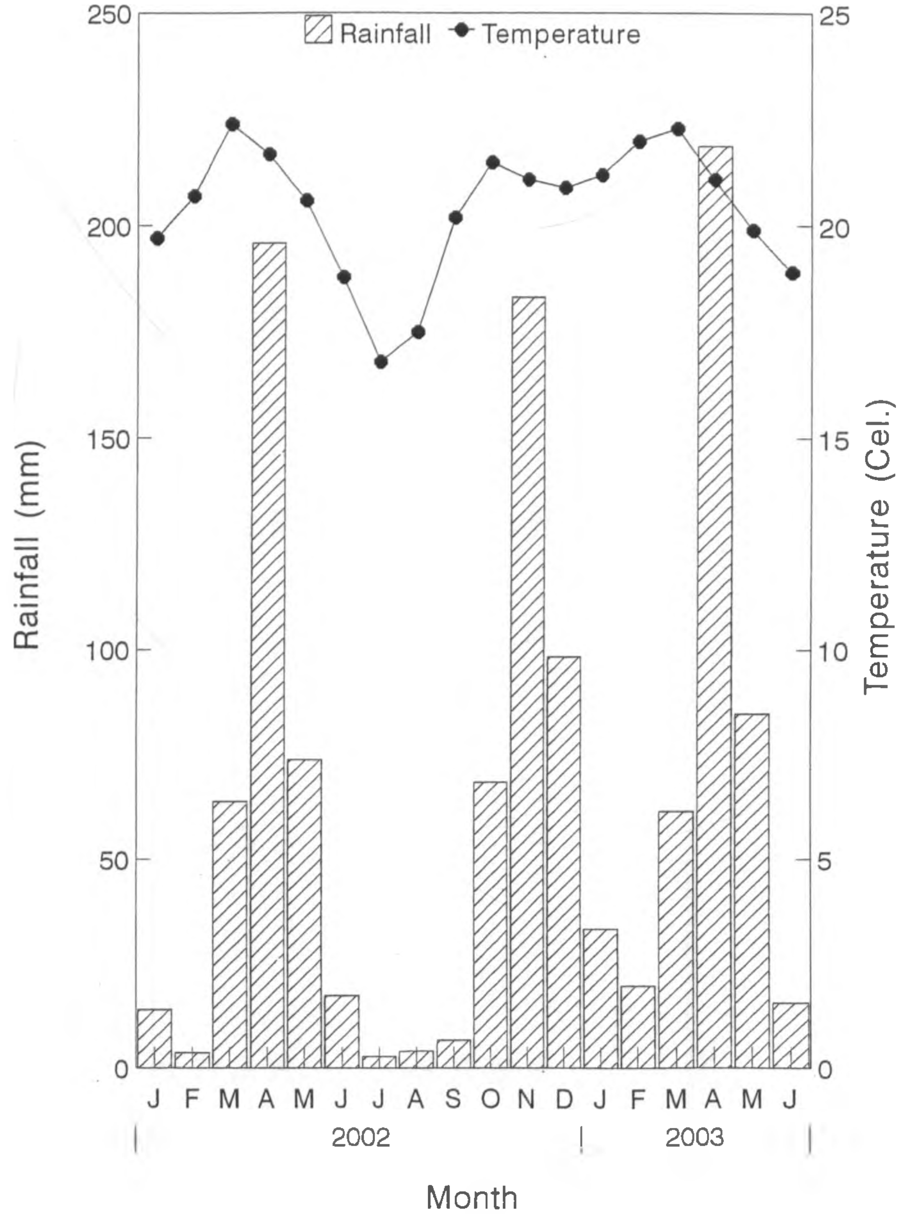

Fig. 3.2: Meteorological data for study area during 2002-2003.

Table 3.1: The prevalence percentages (PP) of faecal strongyle egg counts in kids, immature and adult goats on the four study farms

		AGE GROUP								
		KIDS			IMMATURES			ADULTS		
Season	Farm	[1]Number examined	Number infected	PP	Number examined	Number infected	PP	Number examined	Number infected	PP
Dry	A	30	10	33.3	31	9	29.0	30	9	30.0
	B	28	13	46.4	28	11	39.3	26	8	30.8
	C	22	8	36.4	34	14	41.2	23	6	26.1
	D	36	9	25.0	36	8	22.2	39	6	15.4
Group prevalence				35.3	-	-	32.9	-	-	25.6
Wet	A	28	19	67.9	26	17	65.4	30	21	68.9
	B	25	22	88.0	26	20	76.9	33	26	78.8
	C	30	24	80.0	36	18	69.2	25	18	72.0
	D	30	24	80.0	30	25	83.3	29	25	86.0
Group prevalence				78.9	-	-	73.7	-	-	76.5
Overall prevalence				57.1	-	-	53.3	-	-	51.1

[1]Number of animals examined per farm on each sampling period.

Table 3.2 gives the geometric mean faecal egg counts (FEC) for kids, immature and adult goats on the 4 farms. Most of the goats had FEC of below 400 and this did not vary significantly ($p>0.05$) within each age group and between the 3 age groups among the farms. Figure 3.3 shows the mean FEC for all the farms combined in relation to rainfall. Strongyle FEC increased significantly ($p<0.05$) after the onset of the long and short rains, respectively. The observed frequencies of FEC for all the 3 age groups combined are presented in Fig. 3.4.

3.3.3 *Larval cultures and adult worms*

Table 3.3 and Fig. 3.5 gives the percentage distribution of the genera of nematode larvae identified in faecal cultures from each of the 4 farms. *Haemonchus*, *Trichostrongylus* and *Oesophagostomum* were the only 3 genera isolated from larval cultures. Seventy five percent of the goats surveyed were infected with *Haemonchus* while 20.0% had *Trichostrongylus* and 5.0% had *Oesophagostomum* infections, respectively. The proportion of *Trichostrongylus* was relatively higher during the dry season compared to the wet season while, that of *Haemonchus* and *Oesophagostomum* was higher during the wet season (Fig. 3.4). These differences however, were not significant ($p>0.05$).

Table 3.2: Geometric mean (range) faecal strongyle egg counts in kids, immature and adult goats on the four study farms

	GEOMETRIC MEAN STRONGYLE EGG COUNTS (RANGE)			
Season/Farm	Kids	Immatures	Adults	Farm means
Dry				
A	148 (0-700)	171 (0-700)	196 (0-600)	172
B	349 (0-900)	223 (0-400)	235 (0-400)	269
C	184 (0-800)	151 (0-400)	216 (0-800)	184
D	139 (0-800)	124 (0-500)	159 (0-300)	141
Group mean	205	167	202	
Wet				
A	298 (0-1500)	373 (0-1400)	322 (0-1600)	331
B	563 (0-2400)	545 (0-2600)	436 (0-1800)	515
C	381 (0-1900)	290 (0-1900)	344 (0-2200)	338
D	484 (0-1400)	404 (0-1200)	343 (0-1200)	410
Group mean	432	403	361	

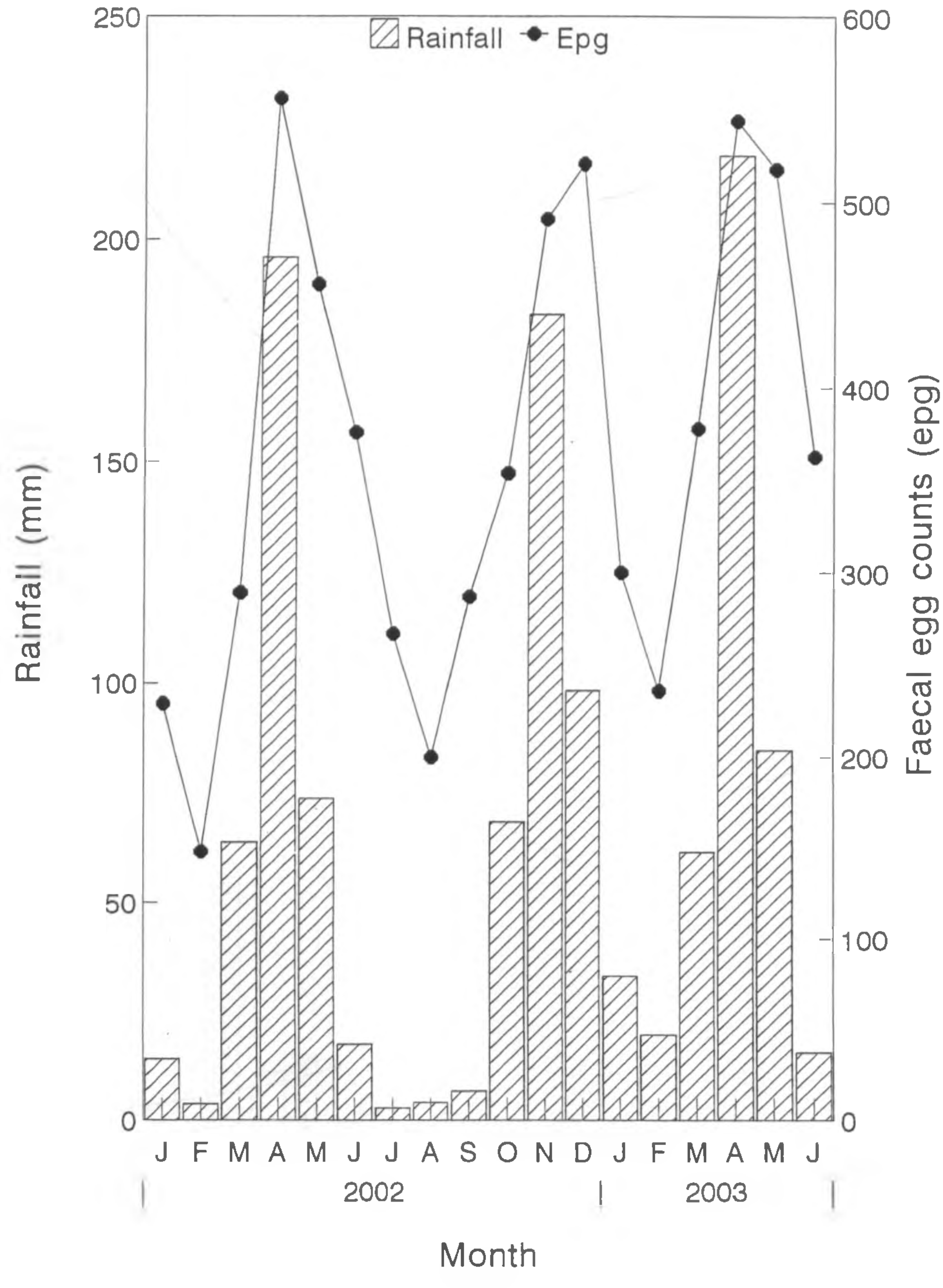

Fig. 3.3: Geometric mean faecal strongyle egg count for the four farms combined and total monthly rainfall figures.

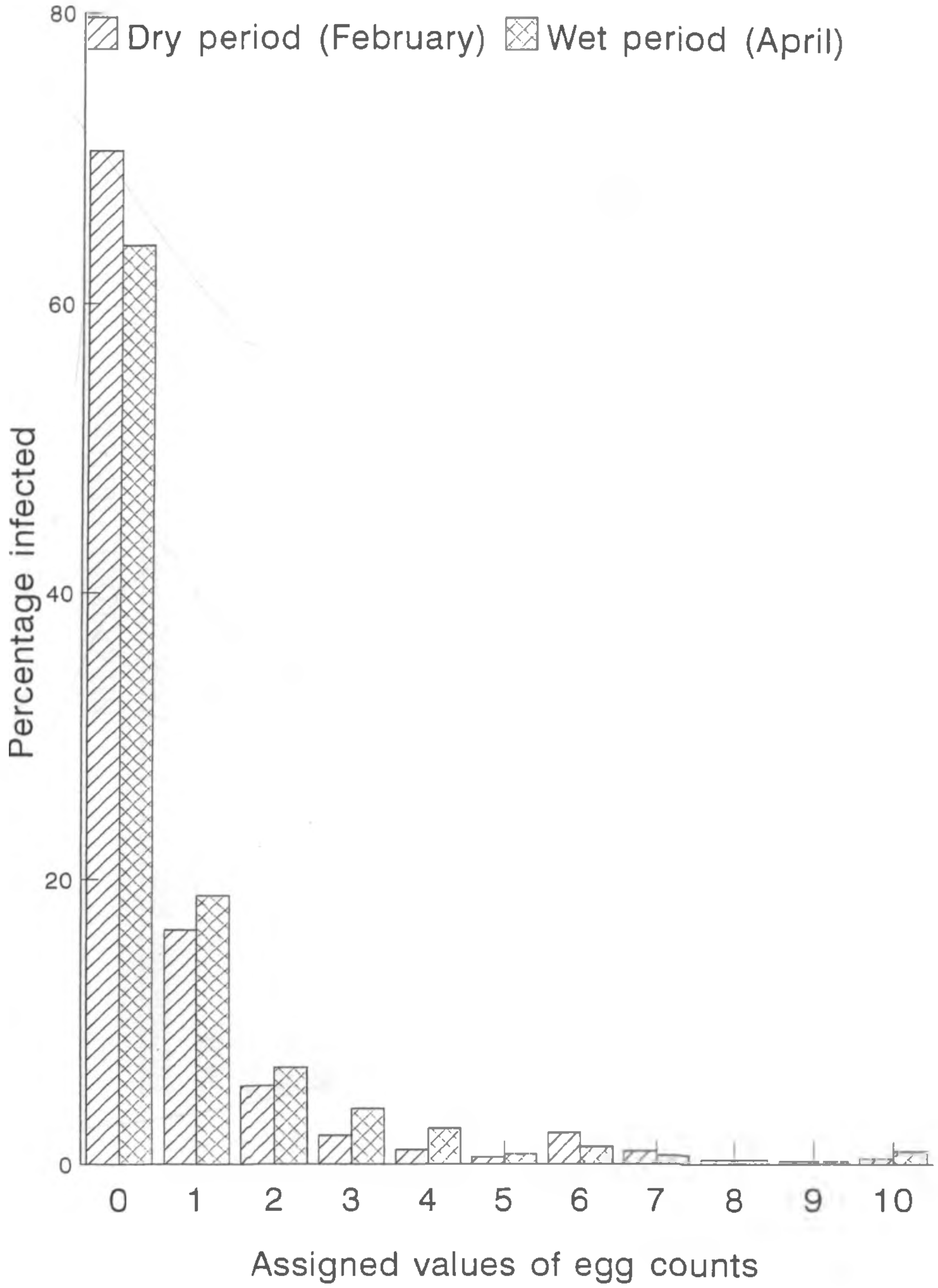

Fig. 3.4: Observed frequencies of faecal strongyle egg counts in goats during the dry and wet seasons.

Table 3.3: Percentage distribution of genera of gastrointestinal nematodes of goats isolated from faecal cultures from the four study farms during the dry and wet seasons

		NEMATODE GENERA		
Season	Farm	*Haemonchus* spp.	*Trichostrongylus* spp.	*Oesophagostomum* spp.
Dry	A	74.0	22.0	9.0
	B	68.0	20.0	0
	C	70.0	22.0	0
	D	60.0	31.0	0
Mean %		68.0	24.0	2.2
Wet	A	60.0	31.0	4.0
	B	77.0	23.0	12.0
	C	90.0	10.0	8.0
	D	99.0	1.0	9.0
Mean %		81.5	16.3	8.0
Overall mean %		74.8	20.1	5.1

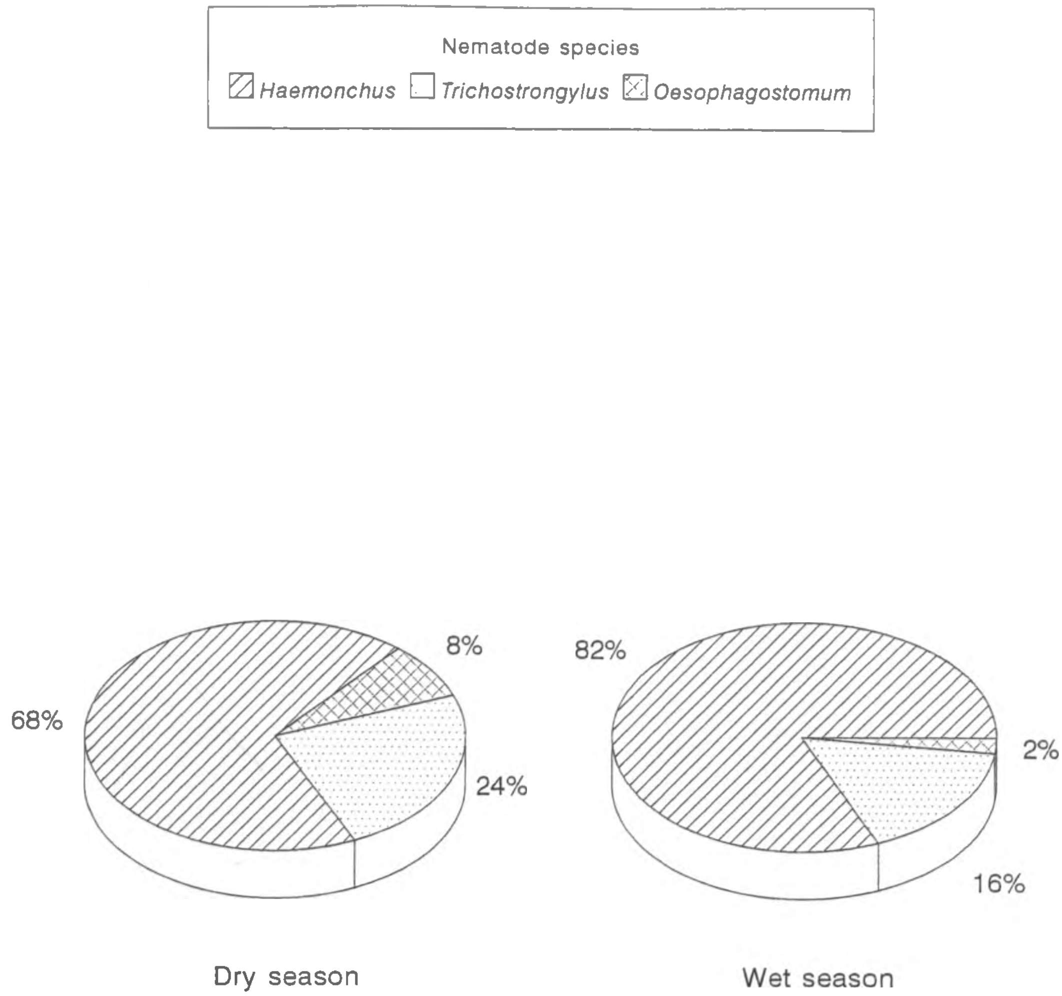

Fig. 3.5: Differential larval counts from goat faeces cultured in the dry and wet seasons.

Total worm counts recovered from 12 goats necropsied during the study are shown in Table 3.4. Seven species of adult worms were recovered and differentiated. These were *H. contortus*, *T. axei*, *T. colubriformis*, *Bunostomum trigonocephalum*, *O. columbianum*, *O. venulosum* and *T. ovis*. Other helminths observed were *Moniezia expansa*, *Stilesia hepatica*, *Fasciola gigantica* and *Parampistomum microbothrium*. *Haemonchus contortus* and *Trichostrongylus* spp. were the most prevalent and were recovered from 91.7% and 68.0% of the animals, respectively (Table 3.4). Multiple infections were common and more than 4 species of worms were recovered from each animal.

Table 3.4: Species, prevalence and mean burdens of helminths found in goats (n=12) during the study period

Helminth species	Prevalence (%)	WORM BURDEN	
		Mean	Range[1]
Haemonchus contortus	91.7	1412	161-3215
Trichostrongylus axei	61.6	434	27-1870
T. colubriformis	74.3	635	109-2268
Bunostomum trigonocephalum	25.0	50	11-104
Oesophagostomum columbianum	41.7	109	21-147
O. venulosum	25.0	17	6-35
Trichuris ovis	25.0	12	7-18
Moniezia expansa	33.5		
Stilesia hepatica	16.7		
Fasciola gigantica	57.3		
Paramphistomum microbothrium	16.7		

[1]Range of positive cases

3.4 Discussion

This study clearly shows that strongyle infections are prevalent in goats within the study area and this conforms with other studies conducted in arid and semi-arid areas of Kenya (Ndarathi *et al.*, 1989; Waruiru *et al.*, 1994; Githigia *et al.*, 1996; 1998; Mbae *et al.*, 2004). The established mean FEC may be regarded as low to moderate that mainly manifests in subclinical infections (Soulsby, 1965). This is to be expected for animals which are reared in a traditional extensive husbandry system which precludes acquisition of heavy infection through grazing in confined areas (Fagbemi and Depeolu, 1982; Chiejina, 1994). Since > 50% of the animals were infected with strongyles, the levels of infection may be regarded as a potential problem in productivity of the animals due to stress which could lead to malnutrition and hence delay maturity of young stock. The effects of helminthosis further can be aggrevated by the frequent droughts that occur in this area (Anonymous 1997c).

Based on the results of the larval cultures and post mortem worm counts, *Haemonchus*, *Trichostrongylus*, *Oesophagostomum* and *Bunostomum* were the most important nematodes of goats. This observation is similar to that of Mbae *et al.* (2004) who recorded 7 species of GI nematodes in small ruminants in Turkana District, Kenya. *Haemonchus contortus* is generally considered to be the most prevalent and pathogenic nematode species of small ruminants in Kenya (Shavulimo, 1993; Gatongi, 1996; Githigia *et al.*, 2001) and elsewhere in Africa (Anene *et al.*, 1994; Pandey *et al.*, 1994; Magona and Musisi, 1999). Other helminth parasites like *Nematodirus*, *Strongyloides* and *Trichuris* species found during the survey are probably not important factors affecting goats in the study area. *Trichuris* infections have been reported to be of rare economic importance in Nigeria (Akerejole *et al.*, 1979).

As observed in this study, strongyle infections were heavier during the wet season than during the dry season. Similar observations have been recorded in other geographical areas of the country where rainfall rather than temperature has been shown to be a more imortant limiting factor in the development and survival of pre-parasitic stages of strongyles on pasture (Wanyangu *et al.*, 1997; Gatongi *et al.*, 1998a; Ng'ang'a *et al.*, 2004b). The reduced prevalence and intensity of infection during the dry season in spite of the absence of anthelmintic treatments might be due to hypobiosis (Gatongi *et al.*, 1998b; Githigia *et al.*, 2001) and/or prolonged survival of adult worms within their hosts (Jacquiet *et al.*, 1992). The relative importance of these two phenomena in the present study area requires further investigation.

Age did not have any effect on the prevalence and strongyle egg output as was reported in sheep studies conducted in a neighouring division (Kangundo) in Machakos District (Waruiru *et al.*, 1997). However, this finding disagrees with those of Anene *et al.* (1994), Maingi *et al.* (1997b) and Ndole *et al.* (2001) who reported that strongylosis was mainly a problem of the immature followed by adult animals. Ndarathi *et al.* (1989) and Jacquiet *et al.* (1995) did not observe any significant correlation between worm burdens and age in their respective studies.

The strongyle epg counts followed a typical overdispersed distribution. This observation was similar to that reported by Waruiru *et al.* (2000) in cattle, Roberts and Swan (1982) and Maingi *et al.* (1993) in sheep and goats, respectively. Thus, effective control of parasite transmission can be achieved by eliminating parasites in the most heavily infected individuals in the herd by selective anthelmintic treatment (Sreter *et al.*, 1994; Hoste *et al.*, 2002). Treatment should be undertaken at about 3-4 weeks into the rains, and where grazing is a shared resource, a second treatment may be required 4-6 weeks later (Bain, 1999). Use of combined anthelmintic classes (i.e., CLO-ABZ mixture) for the control of strongylosis in goats merit serious consideration (Cole, 1994; Miller and Craig, 1996).

EFFICACY OF CLOSANTEL PLUS ALBENDAZOLE COMBINATION AGAINST GIN INFECTIONS IN GOATS

4.1 Introduction

A major constraint to economic goat production in Kenya has been infection with GIN parasites, particularly *H. contortus*. The conventional method of GIN control by farmers is regular use of anthelmintics, sometimes monthly or even more frequently in the subhumid climatic zones (Bullerdieck *et al.*, 1990). Overuse and/or misuse of anthelmintics (Kinoti *et al.*, 1994; Monteiro *et al.*, 1998) has led to an increase in the incidence of anthelmintic resistance (AR) in GIN of goats in Kenya (Wanyangu *et al.*, 1996; Waruiru *et al.*, 1998). Closantel (CLO) is reported to have a persistent anthelmintic activity against haematophagous nematodes for several weeks in sheep (Hall *et al.*, 1981; Taylor *et al.*, 1991; Maingi *et al.*, 1997a; Khan *et al.*, 1999) and goats (Dorny *et al.*, 1994), possibly owing to its strong binding to plasma protein and prolonged plasma half-life (Michiels *et al.*, 1987; McKellar and Kinabo, 1991). This allows the frequency of treatments with broad spectrum anthelmintics to be reduced in areas where *H. contortus* predominates.

Recommendations for slowing the spread of resistance (which is predominantly to LEV and BZs (Wanyangu *et al.*, 1996)), thus conserving the efficacy of broad spectrum anthelmintics, have been outlined and include the use of anthelmintic mixtures, i.e., a mixture of anthelmintic classes (Coles, 1994). The aim of the present study was to examine the efficacy of CLO plus ABZ mixture against naturally occurring and exprimentally induced (including a BZ-resistant strain of *H. contortus*) nematode infections of goats.

4.2 Materials and Methods

4.2.1 *Experimental design*

The study was conducted on a commercial ranch (near Athi River town) with high stocking rates. Two experiments were performed. In the first experiment, 60 small East African crossbred goats of mixed sexes and aged between 9 and 18 months were maintained under a semi-extensive management on natural pasture during the day and housed at night. The goats were individually ear tagged, weighed and randomly divided into 3 groups of 20 before treatment on day zero (0) as follows: group 1, untreated conrols; group 2, CLO (Flukiver^{R}-Janssen Pharmaceutica, Belgium; 10 mg kg^{-1} bodyweight) plus ABZ (Valbazen^{R}-Novartis East Africa Ltd., Nairobi, Kenya; 5 mg kg^{-1} bodyweight) liquid suspension; group 3, ABZ (5 mg kg^{-1} bodyweight). All animals in a given group received a constant dose based on the heaviest animal in the group; average weight of the goats was 16.5 kg (range 13.3-20.1 kg). Faeces were collected from the rectum of each animal immediately prior to treatment (day 0) and then at weekly intervals for 7 weeks (wks) post treatment. Faecal egg counts (FEC) were performed using a modified McMaster technique (MAFF, 1986). Composite faecal samples were prepared from each group and cultured as described in Chapter 3.

In the second experiment, 21 kids (6 to 8 months old) were used in a controlled slaughter trial. When acquired, the goats were carrying natural infections and were drenched with lLEV (Wormicid^{R}-Cosmos, Nairobi, Kenya; 15 mg kg^{-1} bodyweight, as two doses 24 h apart) to remove these. They were maintained indoors on standard feed and water was provided *ad libutum*. On day 0, each goat was infected orally with approximately 5,000 freshly harvested mixed larval innoculum (70.0% *Haemonchus*, 20.0% *Trichostronylus* 3.0% *Cooperia* and

9.0% *Oesophagostomum* spp.) obtained from cultures of faeces from the farm animals, and 3,000 L_3 of a BZ-resistant *H. contortus* strain (Waruiru *et al.*, 1998). Twenty-one days later, the number of faecal strongyle eggs in each aniaml were counted by a modified McMaster technique (MAFF,1986). On the same day, all the goats were weighed, identified by ear tags and randomly assigned to 3 groups of 7 goats each. The goats of group 1 served as untreated controls. Those of group 2 were treated orally with CLO (10 mg kg^{-1}) plus ABZ (5 mg kg^{-1}) and those of group 3 were treated orally with ABZ (5 mg kg^{-1}). All animals were necropsied 10 days post treatment (day 31 post infection) and the worms present in the abomasum, small and large intestines were collected, enumerated and identified according to routine methods (MAFF, 1986).

4.2.2 *Statistical analysis*

Individual worm counts of the control and treated groups were transformed according to the expression $y = \log_{10}$ (count + 20) to calculate geometric means, used to calculate the reduction in worm counts as described by Presidente (1985). For between-group comparisons in each experiment, the means of epg and worm counts were compared for significance ($p<0.05$) by the non parametric Mann Whitney U test (Siegel, 1956) using Instat software (Graph Pad Instat Inc; USA, 1990-1994).

4.3 Results

4.3.1 *Experiment one*

The FEC from the 1st experiment revealed that the goats had moderate to high infections with GIN (mean 1787 $\pm$ 711 epg), and most samples haboured a few *Nematodirus* and *Trichuris* eggs. Faecal cultures made from the same samples indicated that *H. contortus* accounted for >70.0% of the total eggs present on all sampling dates. Other parasites observed included species of *Trichostrongylus*, *Cooperia* and *Oesophagostomum*.

The mean faecal strongyle egg counts are presented for each group in Fig. 4.1, with details of speciation shown in Table 1. Mean FEC counts were not significantly different in all the groups ($p > 0.05$) on day 0. Faecal egg counts in the ABZ treated group fell to zero within wk 1 of anthelmintic administration but became positive again between wks 2 and 3 (460$\pm$261) post treatment. Those of goats treated with CLO/ABZ mixture followed a similar pattern and did not become positive until wk 3 (15$\pm$20) post treatment. The positive FEC recorded in this group were, however, very low and represented only 100 epg in one goat on this occasion. Faecal egg counts increased gradually thereafter but remained significantly lower ($p < 0.05$) than those of ABZ group up to wk 4 post treatment (CLO/ABZ, 170$\pm$140; ABZ, 790$\pm$399). After wk 5, all the groups including the controls had similar FEC (Fig. 4.1). The percentage of *H. contortus* and other species L_3 in cultures dropped to nil, on wk 1 following ABZ and CLO/ABZ treatment. Larvae of all species began to reappear in the cultures in wk 3 post ABZ and in wk 5 post CLO/ABZ treatment (Table 4.1).

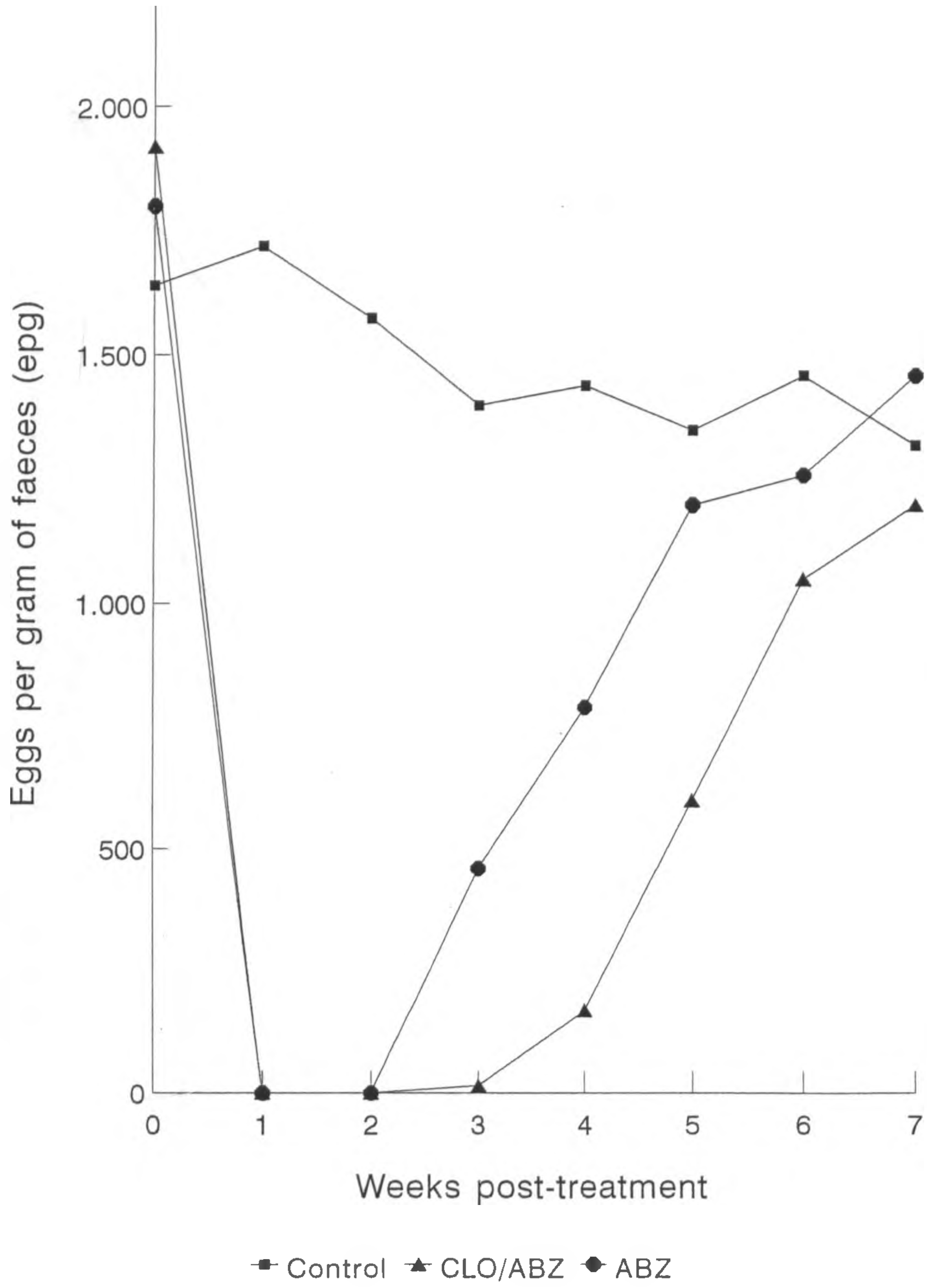

Fig. 4.1: Arithmetic mean faecal strongyle egg counts of goats after treatment with albendazole or a closantel/albendazole mixture.

Table 4.1: The proportion of gastrointestinal nematode species (%) within faecal egg populations from goats treated with albendazole or a closantel/albendazole mixture

	Group	*H. contortus*	*Trichostrongylus* spp.	*Cooperia* spp.	*Nematodirus* spp.	*Oesophago-stomum* spp.
Pre-treatment (day 0)	Entire herd	73	16	4	2	5
Post-treatment (day 28)	Control	80	10	2	3	5
	CLO/ABZ	0	0	0	0	0
	ABZ	88	8	0	0	4

4.3.2 *Experiment two*

The geometric mean FEC for the artificially infected kids on day 21 post infection for control, CLO/ABZ and ABZ groups were 895, 490 and 620, respectively. Mean FEC 10 days later were 1,100, 0 and 455, respectively. The efficacy suggested by these counts (CLO/ABZ, 100%; ABZ, 40.3%) was substantiated in part, by the worm recoveries shown in Table 4.2. CLO/ABZ and ABZ treatments did not differ significantly ($p>0.05$) in terms of their efficacies (>99.0%) against *T. axei*, *T. colubriformis*, *C. curticei* and *O. columbianum*, however, CLO/ABZ was significantly more effective (100%) ($p<0.001$) than ABZ (29.0%) against *H. contortus* (Table 4.2). This reduced efficacy against *H. contortus*, was most probably attributable to the ABZ-resistant strain involved.

Table 4.2: Geometric mean number of nematodes recovered and efficacy (%) of treatment with closantel (10 mg kg^{-1}) plus albendazole (5.0 mg kg^{-1}) in experiment two

	Control group	Closantel/albendazole		Albendazole	
Nematode	Mean worm count (range)	Mean worm count (range)	[1]Efficacy (%)	Mean worm count (range)	Efficacy (%)
H. contortus	2747[a] 1243-3706)	0[b]	100	1950[a] (814-3372)	29.0
Trichostrongylus axei	119[a] (7-204)	0[b]	100	0[b]	100
T. colubriformis	847[a] (149-2340)	7[b] (0-41)	99.2	4[b] (0-20)	99.5
Cooperia curticei	130[a] (0-291)	0[b]	100	0[b]	100
Oesophagostomum columbiamum	218[a] (16-810)	0[b]	100	2[b] (0-11)	99.1

[1]Efficacy (%) = [(C-T/C) x 100] where C is control and T is treated geometric worm count. [a,b]Means with different superscripts are significantly different ($p<0.05$).

4.4 Discussion

The present study demonstrated the high efficacy of CLO given at a dose of 10 mg kg^{-1} plus ABZ given at a dose of 5 mg kg^{-1}, against common GIN of goats. It is noteworthy that this treatment eliminated all BZ-resistant *H. contortus*. Therefore, worm control strategies based on CLO could provide effective control of both BZ or LEV-susceptible and BZ- or LEV-resistant strains of *H. contortus* on goat farms in Kenya (Waruiru, 1997). The continous higher FEC counts from wk 3 onwards in the ABZ treated group showed the necessity for repeated suppressive dosing with this anthelmintic, which would obviously increase the risk of the emergency of AR (Scerrer *et al.*, 1990; Wanyangu *et al.*, 1996).

There has been concern about the safety of CLO in goats. Spongiform changes in the brain and retinal degeneration causing blindness have been associated with overdose of CLO in kids (Button *et al.*, 1987) and in adult goats and sheep (Obwolo *et al.*, 1989). Closantel did not cause any adverse effect in CLO/ABZ treated goats in the present study as observed by Dorny *et. al.* (1994) in goats and Al-Qudah *et al.* (1999) in camels.

A single treatment with CLO/ABZ mixture revealed that CLO could effectively prevent establishment of adult *H. contortus* in goats for up to 3 weeks. This persistent anthelmintic effect of CLO given orally was probably due to its extended half-life in the plasma of treated goats (Guerrero, 1984; McKellar and Kinabo, 1991) and was in agreement with findings obtained in goats treated with 5 mg kg^{-1} subcutaneously or 10 mg kg^{-1} oral dose of CLO (Dorny *et al.*, 1994). However, the present results contrasted with observations made in sheep where prolonged anthelmintic effect was for 4-6 wks (Hall *et al.*, 1981; Owen, 1988; Maingi *et al.*, 1997a; Khan *et al.*, 1999). The reported shortened protection against

-Chapter 5-

GENERAL DISCUSSION

The main objective of this work was to determine the seasonal prevalence, intensity and importance of GIN in goats in Kathiani Division, Machakos District, Kenya. The other objectives were were to evaluate the sustained activity of CLO in goats, and to quantify its potential utility as an alternative treatment for a BZ-resistant *H. contortus* strain.

In an effort to achieve the above objectives, two (2) studies were conducted as summarized herebelow:

Results in chapters 3 (field survey) demonstrate a generally moderate prevalence (52%) of strongyle infections of free-range goats of the study area. This finding may be expected as in general, the concentration of L_3 in the environment is usually very low in those systems which utilise extensive grazing, as they are thinly spread over a large area (Chiejina, 1994). Nevertheless, relative intensive traditional methods of production of small ruminants such as tethering and other forms of confinement, including those which rely on zero-grazing or other cut-and-carry feeding regimens (Reynolds and Adediran, 1987), may sometimes be associated with clinical PGE (Ademosum, 1987).

The degree of infection or the level of helminth-egg load was generally low to moderate in most cases; the infections therefore being subclinical (Soulsby, 1965; Magona and Musisi, 1999). Subclinical or economic parasitism is the level of infection that prevents the host from reaching its genetic potential in the production of meat, milk or other measureable criteria

(Craig, 1988). Economic parasitism is widespread, seasonal and often affected by other factors including quality and abundance of feed, stocking rate, age, sex, breed or acquired resistance. Compared to clinical parasitism, economic parasitism is the most difficult to assess because of the many factors that may be involved (Craig, 1988).

A higher prevalence and intensity of strongyle FEC were found in the wet season compared to the dry season. In the tropics where little variation in temperature occurs, variation in rainfall is a major factor governing infection patterns of strongyles of small ruminants (Arumbulo and Moran, 1981; Chiejina, 1994). Dry conditions have an adverse effect on the survival of free living stages on pasture and arrested development of strongyles has been observed with the onset of the dry season (Vercruysse, 1983; Connor *et al.*, 1990).

Age did not have any effect on the faecal strongyle egg output as reported by Waruiru *et al.* (1997). However, observations in other studies (Anene *et al.*, 1994; Dorny *et al.*, 1995; Maingi *et al.*, 1997b; Ndole *et al.*, 2001) suggest that strongyle infections start building up in young animals as they begin to graze and rely heavily on pasture. The levels of infection increase, with age, being highest in immature animals. As the animals grow, immunity develops, so that the levels of infection decline in adults (Omara-Opyene, 1985; Chiejina, 1994). Evidence of immunity build up to strongyle infections was shown in goats from the age of 12-18 months onwards (Dorny *et al.*, 1995).

The strongyle FEC followed the negative binomial pattern of distribution at each sampling, which suggests highly overdispersed worm burdens. Thus, by eliminating "wormy" individuals of the herd (i.e., by selective anthelmintic treatment), effective control of parasite transmission can be achieved (Sreter *et al.*, 1994; Hoste *et al.*, 2002).

Mixed strongyle infections were detected, with *Haemonchus*, *Trichostrongylus* and *Oesophagostomum* being the most frequently encountered genera throughout the study period. A recent sheep study conducted in the neighbouring Kajiado District showed that *Trichostrongylus* was the most prevalent genus (Ng'ang'a *et al.*, 2004a), and it was agued that *Trichostrongylus* spp. free-living stages are more resistant to dessication than *Haemonchus* and other species (Banks *et al.*, 1990).

In the second study, (Chapter 4) FEC were much higher because of differences in management and higher stocking rates (Chiejina, 1994). Five genera were observed from faecal cultures with *Haemonchus* accounting for > 70% of the L_3. Others were *Trichostronylus*, *Cooperia*, *Nematodirus* and *Oesophagostomum*. The study also confirmed the persistent efficacy of the CLO/ABZ mixture against major endoparasites of goats as was reported in camels (Al-Qudah *et al.*, 1999), and its high efficacy against BZ-resistant isolate of *H. contortus* confirming earlier findings of Waruiru (1997).

5.1 Conclusions

The following observations and conclusions were made from this study:

a) That GIN infections may be a major constraint to the health of goats of the study area.

b) That rainfall is a major epidemiological factor affecting the development and survival of GIN larvae on pasture, and the prevalence and intensity of infection with these parasites.

c) That the distribution of worms was overdispersed with a few individuals harbouring large worm populations.

d) That the above findings (c) have practical implications for genetic selection for resistance to worm infection and for selective administration of anthelmintics.

e) That control of established subclinical nematode infections is indicated.

f) That combined broad and narrow specrum anthemintics may be used strategically to control PGE in goats.

g) That CLO may be used for the control of BZ and- LEV-resistant strains of *H. contortus* in goats.

REFERENCES

Ademosum, A.A. (1987). Appropriate management systems for the West African Dwarf goat in the humid tropics. In: *Goat Production in the Humid Tropics*. Proc. Workshop, University of Ife, Nigeria, 20-24 July, pp. 21-28.

Akerejola, O.O., Scillhorn van Veen, T.W. and Njoku, C.O. (1979). Ovine and caprine diseases in Nigeria. A review of economic losses. *Bull. Anim. Hlth. Prod. Afr.* **22**: 65-70.

Al-Qudah, K.M., Sharif, L.A., Al-Rawashdeh, O.F. and Al-Ani, F.K. (1999). Efficacy of closantel plus albendazole liquid suspension against natural infection of gastrointestinal parasites in camels. *Vet. Parasitol.*, **82**: 173-178.

Anderson, N. and Bremner, K.C. (1983). Life cycle and pathogenesis of helminths of major economic importance. In: N. Anderson and P.J. Waller, (eds). *The Epidemiology and Control of Gastrointestinal Parasites of Cattle in Australia.* (CIRO), Melbourne, pp. 23-34.

Anene B.M., Onyekwodiri, E.O., Chime, A.B. and Anika, S.M. (1994). Gastrointestinal parasites in sheep and goats of southern Nigeria. *Sm. Rum. Res.*, **13**: 187-192.

Anonymous (1970). *The Atlas of Kenya*, Survey of Kenya, Nairobi.

Anonymous (1990). Evaluation of certain veterinary drug residues in food. *Thirty-sixth Report of the Joint FAO/WHO Expert Committee on Food Additives*, (WHO Technical report Series, No. 799).

Anonymous (1997a). *The 8th National Development Plan for the Period 1997-2001*, Goverment Printer, Nairobi, Kenya.

Anonymous (1997b). *Arid Lands Resource Management*, Drought Status Report, April 1997.

Anonymous (1997c). *Machakos District Development Plan 1997-2001*, (Rural Planning Department, Office of the Vice President and Ministry of Planning and National Development, pp. 2-5.

Arambulo, P.V. III and Moran, N. (1981). The tropics and parasitic diseases of animals-their impact on animal and human health. *Int. J. Zoon.* **8**: 5-19.

Bain, R.K. (1999). *Integrated Helminth Control*, (KARI Technical Note No. 2, KARI/DFID NARP II Project), p. 48.

Barger, I.A. (1993). Control of gastrointestinal nematodes in Australia in the 21st century. *Vet. Parasitol.*, **46**: 23-32.

Barger, I.A., Hall, E. and Dash, K.M. (1991). Local eradication of *Haemonchus contortus* using closantel. *Aust. Vet. J.*, **68**: 347-348.

Bjorn, H. (1994). Workshop summary: anthelmintic resistance. *Vet. Parasitol.*, **54**: 321-325.

Bullerdieck, K., Peters, K.J. and Thorpe, W. (1990). Importance of *Haemonchus contortus* in lambs rearing in subhumid environment in Kenya-preliminary results. In: *Proc. 8th Small Ruminant-CRSP Scientific Workshop*, ILRAD, Nairobi, Kenya, pp. 268-278.

Butler, A.R. (1986). Effect of closantel on face lice (*Linognathus ovillus*) of sheep. *Aust. Vet. J.*, **63**: 89-90.

Button, C., Jerret, I., Alexander, P. and Mizon, W. (1987). Blindness in kids associated with over dosage of closantel. *Aust. Vet. J.*, **64**: 226.

Brumby, P.J. and Sholtens, R.G. (1986). Management and health constraints of small scale dairy production in Africa. *ILCA Bulletin*, 25, ILCA, Addis Ababa, Ethiopia.

Carew, B.A.R., Mosi, A.K., Mba, A.U. and Egbunike, G.N. (1980). The potential of browse plants in the nutrition of small ruminants in the humid forest and derived savannah zones of Nigeria. *Proc. Symp. on Browse in Africa*, Addis Ababa, Ethiopia, 8-12 April.

Carles, A.B. (1992). Helminthosis as a constraint to livestock productivity in Kenya. In: J.A. Onyango-Abuje, R.K. Bain, S.W. Wanyangu and M.A. Ihiga (eds). *Progress Towards Control of Helminthosis in Kenya*. NVRC, Muguga, Kenya, 4-5 pp.

Chiejina, S.N. (1991). The status of the epidemiology, diagnosis and control of helminth infections of livestock in central and western Africa. *FAO Expert Consultation on Helminth Infections of Livestock in Developing Countries*. FAO (AGA/HIL/91/3), Rome, Italy.

Chiejina, S.N. (1994). Epidemiology of some helminth infections of domestic animals in the tropics with emphasis on fasciolosis and parasitic gastroenteritis. In: N. Chowdhury and I Tada (eds), *Helminthology*, Springer-verlag Narosa Publishing House, New Delhi, India, pp. 43-72.

Coles, G.C. (1994). Control of anthelmintic resistant nematodes. In: Coles, G.C., Borgsteede, F.H.M., Geerts, S. (eds), *Anthelmintic Resistant in Nematodes of Farm Animals*. Report of a seminar organised for the European Commision, Brussels, 8-9 November 1993. pp. 163-169.

Connor, R.J., Munyuku, A.P., Mackyao, E. and Halliwell, R.W. (1990). Helminthosis in goats in Southern Tanzania: investigations on epidemiology and control. *Trop. Anim. Hlth. Prod.* **22**: 1-6.

Coop, R.L. and Kyriazakis, I. (1999). Nutrition-parasite interaction. *Vet. Parasitol.*, **84**: 187-204.

Craig, T.M. (1988). Impact of internal parasites on beef cattle. *J. Anim. Sci.*, **66**: 1565-1569.

Dash, K.M. (1986). Control of helminthosis in lambs by strategic treatment with closantel and broad spectrum anthelmintics. *Aust. Vet. J.*, **63**: 4-9.

Dorny, P., Vercruysse, J., Jalila, A.; Sani, R. and Symoens, C. (1994). Control of haemonchosis in Malaysian goats with closantel. *Vet. Parasitol.*, **53**: 233-241.

Dorny, P., Symoens, C., Jalila, A., Vercruysse, J., and Sani, R. (1995). Strongyle infections in sheep and goats under the traditional husbandry system in peninsular Malaysia. *Vet. Parasitol.*, **56**: 121-136.

Fabiyi, J.B. (1986). Production losses and control of helminths in ruminants of tropical regions. *Int. J. Parasitol.*, **17**: 435-442.

Fagbemi, B.O. and Dipeolu, O.O. (1982). Strongyle infections of small ruminants in Nigeria. *Vet. Parasitol.*, **11**: 347-353.

FAO (1991). Report of the FAO expert consultation on health infections of livestock in developing countries. *Food and Agriculture Organization of the United Nations, Rome, Italy*, AGA-815.

FAO (1992). Distribution and impact of helminth diseases of livestock in developing countries. *FAO Animal Production and Health Paper*, vol. 96, Rome, Italy.

FAO (1995). Production Year Book, vol. 49, Rome, Italy.

Fitzhugh, H.A. (1982). Dual-purpose goat production systems for small holder agriculturists. *Proc. 2nd Small Ruminant-CRSP Scientific Workshop*, ILRAD, Nairobi, Kenya, pp. 10-11.

Galaty, J.G. (1992). The land is yours: social and economic factors in the privatization, sub-division and sale of Maasai ranches. *Nomadic Peoples*, **30**: 26-40.

Gatongi, P.M. (1996). Epidemiology and control of haemonchosis of small ruminants in semi-arid Kenya. *Kenya Agricultural Research Institute Information Bulletin No. 17*, April 1996.

Gatongi, P.M., Murilla, G.L., Mukasa, B. and Njanjom, S. (1998a). The dynamics of helminth infections in small ruminants in a high potential area of Kenya. In: *Proc. 9th Int. Congr. Parasitol. (ICOPA IX)*, Makuhari Messe, Chuba, Japan, pp. 753-758.

Gatongi, P.M., Prichard, R.K., Ranjans, S., Gathuma, J.M., Munyua, W.K., Cheruiyot, H., Scott, M.E. (1998b). Hypobiosis of *Haemonchus contortus* in natural infections of sheep and goats in a semi arid area of Kenya. *Vet. Parasitol.*, **77**: 49-61.

Githigia, S.M., Okomo, M.A., Inyangala, B.A., Munyua, S.J., OKeyo, M. and Otieno, R. (1996). Prevalence and infection levels of helminths in goats at Machanga Field Station over a period of one year. *Bull. Anim. Hlth. Prod. Afr.* **44**: 111-113.

Githigia, S.M., Munyua, W.K., Kyvsgaard, N.C. and Thamsborg, S.M. (1998). Helminth infection levels in goats in a semi arid area of Kenya. *Bull. Anim. Hlth. Prod. Afr.* **46**: 209-210.

Githigia, S.M., Thamsborg, S.M., Munyua, W.K. and Maingi, N. (2001). Impact of gastrointestinal helminths in production in goats in Kenya. *Sm. Rum. Res.*, **42**: 21-29.

Guerrero, J. (1984). Closantel: a review of its anti-parasitic activity. *Prev. Vet. Med.*, **2**: 317-327.

Guerrero, J., Page, M.R. and Scad, G.A. (1982). Anthelmintic activity of closantel against *Ancylostoma caninum* in dogs. *J. Parasitol.*, **68**: 616-619.

Hall, C.A., Kelly, J.D., Whitlock, H.V. and Ritchiek, K. (1981). Prolonged anthelmintic effect of closantel and disophenol against a thiabendazole selected resistant strain of *Haemonchus contortus* in sheep. *Res. Vet. Sci.*, **31**: 104-106.

Hansen, J. and Perry, B. (1994). *The Epidemiology, Diagnosis and Control of Gastrointestinal Parasites in Africa, a Hand Book*, ILRAD, Nairobi.

Hennessy, D.R., Sangster, N.C., Steel, J.W. and Collins, G.H. (1993). Comparative pharmacokinetic disposition of closantel in sheep and goats. *J. Vet. Pharmacol. Therap.*, **16**: 254-260.

Horton, R.J. (1990). Benzimidazoles in a wormy world. *Parasitol. Today*, **6**: 106.

Holmes, P.H. (1994). Pathophysiology of helminth infections. In: N. Chowdhury and I. Tada (eds). *Helminthology*. Springer-verlag, Marosa Publishing House, India, pp. 234-242.

Hoste, H., Chartier, C. and LeFrileux, Y. (2002). Control of gastrointestinal parasitism with nematodes in dairy goats by treating the host category at risk. *Vet. Res.* **33**: 531-545.

Jacquiet, P., Cabaret, J., Colas, F., Dia, M.L., Cheikh, D. and Thiam, A. (1992). Helminths of sheep and goats in desert areas of south-west Mauritania (Trarza). *Vet. Res. Comm.*, **16**: 437-444.

Jacquiet, P., Colas, F., Cabaret, J., Dia, M.L., Cheikh, D. and Thiam, A. (1995). Dry areas: an example of seasonal evolution of helminth infection of sheep and goats in southern Mauritania. *Vet. Parasitol.*, **56**: 137-148.

Kane, H.J., Behm, C.A. and Bryant, C. (1980). Metabolic studies on the new fasciolicidal drug, closantel. *Mol. Biochem. Parasitol.*, **1**: 347-355.

KARI (1994). National Agricultural Research Project: Phase II Project Preparation Report. (Kenya Agricultural Research Institute), p. 239.

Keyyu, J.D., Mahingika, H.M., Magwisha, H.B. and Kassuku, A.A. (2002). Efficacy of albendazole and levamisole against gastrointestinal nematodes of sheep and goats in Morogoro, Tanzania. *Trop. Anim. Hlth. Prod.* **34**: 115-120.

Khan, F.K., Sanyal, P.K., Swarnkar, C.P., Singh, D. and Bhagwan P.S.K. (1999). Comparative anthelmintic activity of strategic sustained low-level administration of albendazole and feed pellets compared to single doses of closantel and tetramisole against natural ovine parasitic gastroenteritis. *Trop. Anim. Hlth. Prod.*, **31**: 193-204.

Kinoti, G.K., Maingi, N. and Coles, G.C. (1994). Anthelmintic usage in Kenya and its implications. *Bull. Anim. Hlth Prod. Afr.*, **42**: 71-73.

Lacey, E. (1990). Mode of action of benzimidazoles. *Parasitol. Today*, **6**: 112-115.

Leeuw, P.N. de and Reynolds, L. (1994). Ruminant Livestock in Kenyan farming systems and their contribution to self-sufficiency in meat supply: an overview of past and current trends. *Prod. 12th Small Ruminant-CRSP Scientific Workshop*, ILRAD, Nairobi, pp. 86-94.

Lu, C.D. (1988). Grazing behaviour and diet selection of goats. *Sm. Rum. Res.*, **1**: 205-207.

Lutu, W.Z. (1983). Internal parasitism in milk goats in Kenya. *Trop. Anim. Hlth. Prod.*, **16**: 153-157.

MAFF. (1986). *Manual of Veterinary Parasitological Laboratory Techniques*, (Minstry of Agriculture, Fisheries and Food, Technical Bulletin no. **18**, London, HMSO).

Magona, J.W. and Musisi, G. (1999). Prevalence and infection levels of gastro-intestinal nematodes in Ugandan goats in different agroclimatic zones. *Bull. Anim. Hlth. Prod. Afr.*, **47**: 49-56.

Maingi, N., Gichanga, E.J. and Gichohi, V.M. (1993). Prevalence of gastrointestinal helminths and coccidial parasites and frequency distribution of some nematode genera of goats on some farms in four districts of Kenya. *Bull. Anim. Hlth. Prod. Afr.*, **41**: 285-290.

Maingi, N., Thamsborg S.M., Gichohi, V.M., Munyua, W.K. and Gathuma, J.M. (1997a). Strategic use of closantel and albendazole in controlling nematodes of sheep in the Kenyan highlands. *Vet. Res. Comm.*, **21**: 547-557.

Maingi, N., Gichohi, V.M., Munyua, W.K., Gathuma, J.M. and Thamsborg S.M. (1997b). The epidemiology of nematodes and liver fluke infections in sheep in Nyandarua District of Kenya. *Bull. Anim. Hlth. Prod. Afr.*, **45**: 27-34.

Makundi, A.E. (2001). Epidemiology and control of bovine fasciolosis and schistosomosis in Tanzania. *PhD Thesis*, Sokoine University of Agriculture (SUA), Morogoro, Tanzania.

Margolis, L., Esch, G.W., Holmes, J.C., Kuris, A.M. and Schad, G.A. (1982). The use of ecological terms in parasitology. (Report of an *ad hoc* committee of the American Society of Parasitologists). *J. Parasitol.*, **68**: 131-133.

Mbae, C.K., Githigia, S.M., Njoroge, E.M., Magambo, J.K. and Otieno, R.O. (2004). The prevalence of gastrointestinal nematodes in small ruminants in semi-arid Turkana District of Kenya. *Bull. Anim. Hlth. Prod. Afr.* **52**: 85-90.

Mbaria, J.M., McDermott, J.M., Kyule, M.N., Gichanga, E.J. and Munyole, P.N. (1995). Prevalence of helminths and helminth control practices in Molo Division, Nakuru District, Kenya. *Bull. Anim. Hlth. Prod. Afr.* **43**: 35-44.

McKellar, Q.A. and Kinabo, L.D.B. (1991). The pharmacology of flukicidal drugs. *Br. Vet. J.,* **147**: 306-321.

Michiels, M., Meuldermans, W. and Heykants, J. (1987). The metabolism and fate of closantel (Flukiver) in sheep and cattle. *Drug Metabolism Reviews*, **18**: 235-251.

Miller, J.E. (1996). Controlling goat parasites in the southeast. In: *Proc. Southeast Regional Meat Goat Prod. Symp.*, Florida A&M University, Tallahassee, FL, 21-24 February, pp. 80-82.

Miller, D.K. and Craig, T.M. (1996). Use of anthelmintic combinations against multiple resistant *Haemonchus contortus* in Angora goats. *Sm. Rum. Res.*, **19**: 281-283.

Monteiro, A.M., Wanyangu, S.W., Kariuki, D.P., Bain, R., Jackson, F. and McKellar, Q.A. (1998). Pharmaceutical quality of anthelmintics sold in Kenya. *Vet. Rec.*, **141**: 396-398.

Moyo, D.Z., Bwangamoi, O., Hendrikx, W.M.L., Eysker, M. (1996). The epidemiology of gastrointestinal nematode infections in communal cattle on the highveld of Zimbabwe. *Vet. Parasitol.*, **67**: 105-120.

Munyua, W.K., Githigia, S.M., Mwangi, D.M., Kimoro, C.O. and Ayuya, J.M. (1997). The effects of a controlled-release albendazole capsule (Profril-Captec) on parasitism in grazing Corriedale ewes in Nyandarua District of Kenya. *Vet. Res. Comm.*, **21**: 85-99.

Mussman, H.C. (1982). The animal as food resource for man with special reference to the role of animal disease. *Proc. Third Int. Conf. on Goat Prod. Dis.*, Tuscon, AZ., pp. 9-14.

Mwamachi, D.M., Oudho, J.O., Thorpe, W. and Baker, R.C. (1995). Evidence for multiple anthelmintic resistance in sheep and goats reared under the same management in coastal Kenya. *Vet. Parasitol.*, **60**: 303-313.

Nansen, P. (1986). Production loses and control of helminths in ruminants of temperate regions. *Int. J. Parasitol.*, **17**: 425-433.

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

Nansen, P. (1993). Current and future prospects for control of ostertagiosis in northern Europe-examples from Denmark. *Vet. Parasitol.*, **46**: 3-21.

Ndarathi, C. M., Waghela, S. and Semenye, P. P. (1989). Helminthiasis in Maasai ranches in Kenya. *Bull. Anim. Hlth. Prod. Afr.*, **37**: 205-208.

Ng'ang'a, C.J., Maingi, N., Munyua, W.K. and Kanyari, P.W.N. (2004a). Epidemiology of gastrointestinal helminths infections in Dorper sheep in a semi-arid area of Kenya. *Ondersteport. J. Vet. Res..*, **71**: 219-226.

Ng'ang'a, C.J., Maingi, N., Kanyari, P.W.N. and Munyua, W.K. (2004b). Development, survival and availability of gastrointestinal nematodes of sheep on pastures in a semi-arid area of Kajiado District of Kenya. *Vet. Res. Comm.*, **28**: 491-501.

Nginyi, J.M., Duncan, J.L., Mellor, D.J., Stear, M.J., Wanyangu, S.W., Bain, R.K. and Gatongi, P.M. (2001). Epidemiology of parasitic gastrointestinal nematode infections of ruminants on smallholder farms in central Kenya. *Res. Vet. Sci.*, **70**: 33-39.

Ngole, U.I., Ndamukong, K.J.N. and Mbuh, J.V. (2001). Intestinal parasites and blood picture of Dwarf forest goats slaughtered in Buea subdivision of south-west Cameroon. *Bull. Anim. Hlth. Prod. Afr.*, **49**: 134-392.

Njanja, J.C. 1991. Livestock ecology in central Turkana. *TREMU Technical Report E-1*, Unesco, Nairobi, Kenya.

Njanja, C., Wescott, R.B. and Ruvuna, F. (1987). Comparison of ivermectin and thiabendazole for treatment of naturally occurring infections of goats in Kenya. *Vet. Parasitol.,* **23**: 205-209.

Obwolo, M.J., Odiawo, G.O. and Ogga, J.S. (1989). Toxicity of closantel-albendazole mixture in a flock of sheep and goats. *Aust. Vet. J.*, **66**: 228-229.

Odoi, A.I., Gathuma, J.M., Gachuiri, C.K., Omore, A., Gitau, T., Wanyangu, S.W. and Murage, E. (1998). Constraints to small ruminant production in smallholder mixed farms in Kiambu District, Kenya. *The Kenya Vet.*, **23**: 145-147.

Ojany, F.F. and Ogendo, R.B. (1973). *Kenya: A study in Physical and Human Geography*, Longman Kenya Ltd., Nairobi.

Omara-Opyene, A.L. (1985). A survey of gastrointestinal parasitism in cattle under nomadic management in Marsabit District of northern Kenya. *Bull. Anim. Hlth. Prod. Afr.*, **33**: 107-112.

Owen, I.L. (1988). Field trials with closantel and *Haemonchus contortus* in Papua New Guinea. *Aust. Vet. J.*, **65**: 267-270.

Pandey, V.S., Ndao, M. and Kumar, V. (1994). Seasonal prevalence of gastrointestinal nematodes in communal land goats from the highveld of Zimbabwe. *Vet. Parasitol.*, **51**: 241-248.

Perry, B.D., McDermott, J,J., Randolph, T.F., Jones, K.R. and Thornton, P.K. (2002). Investing in animal health research to alleviate poverty. *International Livestock Research Institute, Nairobi, Kenya*, p. 148.

Presidente, P.J.A. (1985). Methods for detection of resistance to anthelmintics. In: N. Anderson and P.J. Waller (eds). *Resistance in Nematodes to Anthelmintic Drugs.* (CSIRO) Glebe, N.S.W, Australia, pp. 13-28.

Preston, J.M. and Allonby, E.W. (1979). The influence of breed on the susceptibility of sheep to *Haemonchus contortus* infection in Kenya. *Res. Vet. Sci.*, **26**: 134-139.

Prichard, R.K. (1991). Strategies for securing the supply of reliable and inexpensive anthelmintics for developing countries. *FAO Expert Consultation on Helminth Infections of Livestock in Developing Countries*. FAO (AGA/HIL/91/15), Rome, Italy.

Probert, A.J. (1994). Chemotherapy of helminth of livestock and man. In: N. Chowdhury and I. Tada (eds). *Helminthology*, Springer-Verlag, Narosa Publishing House, New Delhi, India, pp. 315-334.

Reinecke, R.K. (1994). Parasitic control in intensive vs non-intensive systems-ruminants. *Vet. Parasitol.*, **54**: 49-67.

Reynolds, L. and Adediran, S.O. (1987). The effects of browse supplementation on the productivity of West African Dwaft sheep over two reproductive cycles. In: *Goat Production in the Humid Tropics*. Proc. Workshop, University of Ife, Nigeria, 20-24 July, pp. 83-91.

Rickard, L.G. and Zimmerman, G.L. (1992). The epizootiology of gastrointestinal nematodes of cattle in selected areas of Oregon. *Vet. Parasitol.*, **43**: 271-291.

Roberts, J.L. and Swan, R.A., 1982. Quantitative studies on ovine haemonchosis. 3. The interpretation and diagnostic significance of the changes in serial egg counts of *Haemonchus contortus* in a sheep flock. *Vet. Parasitol.*, **9**: 211-216.

Rubaire-Akiiki, C.M., Opuda-Asibo, J. and Horchner, F. (1999). Gastro-intestinal tract (GIT) nematode infections in dairy cattle in the lake victoria basin (Uganda). *Bull. Anim. Hlth. Prod. Afr.*, **47**: 61-70.

Scherrer, A.M., Pomroy, W.E. and Charleston, W.A.G. (1990). Anthelmintic usage on goat farms in New Zealand. Results of a postal survey. *N.Z. Vet. J.*, **38**: 133-135.

Semenye, P.P. and Hutchcroft, T. (1992). *On Farm Research and Technology for Dual-Purpose Goats*. SR-CRSP National Printing Press Ltd., Kisumu, Kenya.

Shavulimo, R. (1987). Control of endoparasites in small ruminants - an overview. In: *Proc. of the sixth Kenya Vet. Asso./Small Ruminant-CRSP Scientific Workshop*, Kabete, Kenya, pp. 44-52.

Shavulimo, R.S. (1993). Animal diseases of gastrointestinal tract and the liver-*An African perspective IFS/SIPATH Workshop*, Addis Ababa, Ethiopia.

Siegel, S. (1956). *Non-Parametric Statistics for the Behavioral Sciences*. McGraw-Hill, Kogakusha Ltd., Tokyo, p. 312.

Sombroek, W.C., Vraun, M.H. and van der Pouw, E.J. (1982). *Exploratory Soil Map and Agro-climatic Zone Map of Kenya*. Report B5A, National Agricultural Research Laboratories, Soil Survey Unit, Nairobi, Kenya.

Soulsby, E.J.L. (1965). *Textbook of Veterinary clinical Parasitology*, vol. 1, Helminth, (Blackwell Scientific Publications, Oxford).

Soulsby, E.J.L. (1986). *Helminths, Arthropods and Protozoa of Domesticated Animals*, (6th ed). London, Bailliere and Tindall.

Stotz, D. (1983). *Farm Management Handbook of Kenya*, vol. IV, pp. 82-92.

Taylor, M.A., Hunt, K.R., Wilson, C.A. and Quick, J.M. (1991). Effectiveness of strategic anthelmintic dosing in controlling *Haemonchus contortus* infections in sheep in the United Kingdom. *Vet. Rec.*, **129**: 189-192.

Tembely, S. and Hansen, J.W. (1996). Helminth diseases of small ruminants in the tropics: a review of epidemiology and control strategies. In: L.F. Le Jambre and M.R. Knox (eds). *Sustainable Parasite Control in Small Ruminants*, Bogor, Indonesia, pp.-123-127.

Thamsborg, S.M., Boa, M.E., Makundi, A.E. and Kassuku, A.A. (1998). Lungworm infection (*Dictyocaulus viviparus*) on dairy cattle farms in tropical highlands of Tanzania. *Trop. Anim. Hlth. Prod.*, **30**: 93-96.

Theodorides, V.J., Gyurik, R.J., Kingsbury, W.D. and Parish, R.C. (1976). Anthelmintic activity of albendazole against liver flukes, tapeworms, lungworms and gastrointestinal roundworms. *Experientia*, **32**: 702-703.

Uppal, R.P., Yadav, C.L. and Bhushan, C. (1993). Efficacy of closantel against fenbendazole and levamisole resistant *Haemonchus contortus* in small ruminants. *Trop. Anim. Hlth., Prod.*, **25**: 30-32.

Urquhart, G.M., Armour, J., Duncan, A.M. and Jennings, F.W. (1989). *Veterinary Parasitology*, Longman, Barking, UK.

Vassilev, G.D. (1995). Control of haemonchosis in sheep by strategic treatment with closantel. *Zimbabwe Vet. J.*, **26**: 33-60.

Vercruysse, J. (1983). A survey of seasonal changes in nematode faecal egg count levels of sheep and goats in Senegal. *Vet. Parasitol.*, **13**: 239-244.

Waller, P.J. (1993). Towards sustainable nematode parasite control of livestock. *Vet. Parasitol.*, **48**: 295-309.

Waller, P.J., Dash, K.M., Barger, I.A., Le Jambre, L.F. and Plant, J. (1995). Anthelmintic resistance in nematode parasites of sheep: learning from the Australian experience. *Vet. Rec.*, **136**: 411-413.

Wanyangu, S.W., Bain, R.K., Rugutt, M.K., Nginyi, J.M. and Mugambi, J.M. (1996). Anthelmintic resistance amongst sheep and goats in Kenya. *Prev. Vet. Med.*, **25**: 285-290.

Wanyangu, S.W.. Karimi, S., Mugambi, J.M. and Bain, R.K. (1997). Availability of *Haemonchus contortus* L_3 larvae in pasture at Kiboko: a semi-arid warm agro-climatic zone in Kenya. *Acta Trop.*, **68**: 183-189.

Waruiru, R.M. (1997). The efficacy of closantel and rafoxanide against fenbendazole- and levamisole-resistant *Haemonchus contortus* in small ruminants. *Vet. Res. Comm.*, **21**: 493-497.

Waruiru, R. M., Gichanga, E.J., Kimoro, C.O. and Karanu, F.N. (1994). The prevalence of gastrointestinal nematodes, coccidia and lungworms in Ol'Magogo dairy goats. *Bull. Anim. Hlth. Prod. Afr.*, **42**: 291-295.

Waruiru, R. M., Mbuthia, P. G., Karanja, D.N., Ngotho, J.W., Weda, E.H. and Otieno, R.O. (1997). Helminth parasite infections of sheep in Kangundo Division of Machakos District, Kenya. *Bull. Anim. Hlth. Prod. Afr.*, **45**: 115-119.

Waruiru, R.M. (1998). Epidemiology and control of gastrointestinal parasite infections of dairy cattle in Kiambu District and in Denmark with emphasis on parasitic gastroenteritis. *PhD Thesis*, University of Nairobi, Kenya.

Waruiru, R.M., Kogi, J.K., Weda, E.H. and Ngotho, J.W. (1998). Multiple anthelmintic resistance on a goat farm in Kenya. *Vet. Parasitol.*, **75**: 191-197.

Waruiru, R.M., Kyvsgaard, N.C., Thamsborg, S.M., Nansen, P., Borgh, H.O., Munyua, W.K. and Gathuma, J.M. (2000). The prevalence and intensity of helminth and coccidial infections in dairy cattle in central Kenya. *Vet. Res. Comm.*, **24**: 39-53.

Williams, J.C. (1991). Efficacy of albendazole, levamisole and fenbendazole against gastrointestinal nematodes of cattle, with emphasis on inhibited early fourth stage *Ostertagia ostertagi* larvae. *Vet. Parasitol.*, **40**: 59-71.

World Bank (1983). Sheep and goats in developing countries: their present and potential role. *A World Bank Technical Paper*, pp. 1-74.

Yadav, V.C. and Kumar, R. (1994). Efficacy of rafoxanide and closantel against-levamisole-resistant *Haemonchus contortus* of sheep. *J. Vet. Parasitol.*, **8**: 53-55.

Zinsstag, J., Ankers, P., Ndao, M., Bonfoh, B. and Pfister, K. (1998) Multiparasitism production and economics in domestic animals in sub-Saharan West Africa. *Parasitol. Today*, **14**: 46-49.