

THE EPIDEMIOLOGY OF GASTROINTESTINAL NEMATODES IN GOATS IN THE TRADITIONAL GRASSLANDS OF ZAMBIA

By

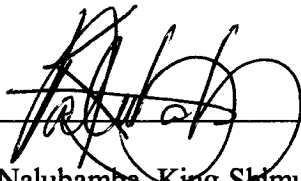
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Thesis submitted for the degree of Master of Science in Veterinary Medicine to the Samora
Machel School of Veterinary Medicine, Clinical Studies Department, University of Zambia.

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Declaration

The contents of this thesis are the work of the author. The thesis has not been
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previously submitted for the award of a degree to any University.



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Date:

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Dedication

To my parents, My father for giving me the ultimate goal of striving to be the best, and my mother for guiding me through a larger portion of my journey towards achieving that goal.

To my fiancée, Marjorie Kamyale Mwamba, for the patience, support and the understanding.

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Almighty God, bless them all.

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ABSTRACT

Monthly faecal gastrointestinal nematode egg counts, coprocultures, differential larval counts and packed cell volumes of goats (according to age classes <6 months, 6 months to 1 year, 1 year to 2 years, more than 2 years) from two traditional farming areas (Chipembi and Shibuyunji) in Central Province of Zambia, were monitored over a period of 15 months from July 1994 to September 1995. The levels of infective gastrointestinal nematode larvae on pasture and monthly larval intake were also estimated using tracer goats. Each month, from September 1994 to August 1995, six goats, less than 6-month-old (tracers) shown to be free of gastrointestinal nematodes after anthelmintic treatment were grazed with a flock of naturally infected goats in Chipembi. After a month's stay, these tracer goats were removed, placed on cement-floored pens and were maintained in such helminth-free conditions for at least 3 weeks prior to necropsy and examination for adult gastrointestinal nematodes. Abomasa from the tracers were artificially digested to recover inhibited larvae.

The faecal egg count pattern paralleled that of the total rainfall, being highest in the rainy season, and falling to very low levels during the dry season. The faecal egg counts from individual animals reached a peak in the middle of the rainy season (February, March) and lowest counts were observed from July to September. During all the months under study at least 80% of the adult goats had nematode eggs present in their faeces. Throughout the study period, goats less than one year old had faecal egg counts and prevalence which were significantly ($P>0.05$) lower than those found in more than one year old goats except during the rainy season when all animals were infected. Goats more than two years old had the highest intensity of infection as demonstrated by the higher faecal egg counts. Kids of less than six months revealed the lowest faecal egg counts and prevalence. The following species were identified on either postmortem worm count or by differential larval counts: *Haemonchus contortus*, *Trichostrongylus* spp., *Oesophagostomum*, *Cooperia* spp., *Bunostomum* spp., *Trichuris ovis*, and *Strongyloides papillosus*. *Gaigeria* eggs were also seen infrequently during the rainy season. *H. contortus* and *Trichostrongylus* were found to be the most predominant species observed, followed by *O. columbianum*. *Trichostrongylus* peaked during the dry season while *H. contortus* and *O. columbianum* both peaked during the rainy season when temperature and moisture conditions favoured their development and transmission. Other nematode species revealed less defined seasonal fluctuations.

Monthly larval intake of gastrointestinal nematodes was also monitored by the use of tracers which indicated a high larval intake mid-rainy season up to the end of the rainy season. No larvae were picked up during the dry season. Inhibited larvae were only found in the months of December and May.

Recommendations suitable for application in traditional areas, are made for the control of gastrointestinal nematodes.

PART ONE

GENERAL INTRODUCTION

1.1 World goat population

It is estimated that there are 404 million domestic goats, *Capra hircus* in the world (FAO, 1975). About two thirds of these are found in the tropics. The largest concentrations of goats is in Africa and in the Indian sub-continent (see Annex 1). India, with 71 million goats, has the highest documented goat population in the world. In tropical Africa and the Americas, goats are found in large numbers mainly in the drier steppe and savanna regions.

World livestock population statistics show that the goat ranks third after cattle and sheep worldwide. The exploitation of this animal for meat and milk production has generally been low (Devendra and McLeroy, 1982). Yet, goats have a number of beneficial characteristics which make them an extremely useful asset for small scale farmers. They generally use feed not being utilized by other animals, they have a short reproductive cycle with a high incidence of multiple births, and they are a convenient source of protein which come in a family-sized package (Lovelace *et al.*, 1993). In contrast to cattle, goats are often owned by the female members of the family or by young unmarried men. Goats are therefore less valued in terms of prestige and for the conservation of capital. The owner's relationship to goats is also less pronounced and thus goats are more easily and willingly slaughtered or sold to provide for daily requirements. The inherent characteristics of goats, such as resistance to dehydration, their preference for browse and wide-range feeding habits, enable them to thrive in regions that receive less than 750 mm of rainfall (Devendra and McLeroy, 1982). Sheep and goats play an important role in many different agricultural systems particularly in sub-Saharan Africa, where they are easily integrated in the small-scale traditional mixed crop and livestock farming systems (Moore *et al.*, 1991). Their small size and lower feed and managerial requirements allow for their use by poorer farming communities. Moreover, goats are able to occupy a wide range of ecological habitats including semi-arid, sub-humid and humid regions. Their ability to make optimal use of the relatively low

quality vegetation and their simple habits complements raising of cattle (Luckins, 1992).

More than 90% of sheep and goats in sub-Saharan Africa are found in East and West Africa where they provide 30% and 15% of milk consumed respectively (ILCA, 1989, 1990).

1.2 Breeds of goats

It is estimated that over 300 breeds and types of goats exist in the world, the majority of which are in the tropics and sub-tropics (see Annex 2.). While many of these breeds have been adequately described, there are many more which have not yet been described and thought of as nondescript and/or, are simply considered not to be important (Devendra and McLeroy, 1982).

1.3 Health

In contrast to the amount of information that is available on sheep, the health status of goats is much less clear (Shavulimo *et al.*, 1988). While sheep and goats are considered to share common susceptibility to many diseases, Smith *et al.*, (1986) observed that there is a significant difference in disease manifestation and resistance between the two species of small ruminants.

In most goat production systems being practised in the tropics, three major causes of death have been identified, perinatal diseases leading to high kid mortality (Borne and Monicat, 1991), poor management and other diseases (Yusuff, 1984).

Although certain diseases which affect goats are well documented, it is believed that many other diseases are prevalent and important yet still unknown (Obwolo, 1991). Overall, diseases, including parasites are considered to be one of the main constraints to goat production in many parts of the tropics (Devendra and McLeroy, 1982). On the basis of their manifestations in the host, disease conditions may be divided into two categories:

- (a) Acute (severe diseases which cause recognizable illness and possibly death, e.g. pneumonia) or,
- (b) Chronic sub-clinical conditions (characterized by gradual weight loss, poor performance and low production, e.g. moderate gastrointestinal parasitism).

The most important and common diseases of goats in the tropics are infectious diseases. The following bacterial diseases are well documented: caseous lymphadenitis, *Pasteurella* pneumonia, neonatal diarrhoea caused by *Escherichia coli* (superimposed by Rotavirus, and Corona viruses. Other bacterial diseases reported in goats are pink eye, brucellosis, dermatophilosis and contagious caprine pleural pneumonia. Dermatophytoses are also documented. Viral diseases are also reported with orf, peste de petit ruminants and foot and mouth disease being the most important. Parasitic diseases include gastrointestinal parasites especially helminths, intestinal coccidiosis, mange and a number of haemoparasites. (Devendra and McLeroy, 1982; Obwolo, 1991; Lovelace *et al.*, 1993; Ndamukong *et al.*, 1989).

In the tropics, non-infectious disease conditions of goats are not considered a serious problem (Devendra and McLeroy, 1982). Such conditions include metabolic disorders, enterotoxaemia, ketosis, pregnancy toxaemia, acidosis, indigestion, dietary deficiencies, parturition injuries, traumatic injuries, poisoning, lameness, broken mouth, and general debility.

1.4 Helminth diseases of goats

Helminth infections and their associated diseases are among the most prevalent and widely distributed of all the enzootic parasitoses of tropical livestock (Chiejina, 1995). The infections are probably the most serious cause of economic loss (Chambers, 1990; Ndamukong *et al.*, 1989; Hansen, 1995). Throughout the tropics, helminth infestations are prevalent and are a consistent problem affecting production adversely (Devendra and McLeroy, 1982). A large number of species of helminths affect goats and include cestodes, nematodes and trematodes. Some of the more common helminth genera are listed in Table 1 below.

Table 1 Common helminth genera of goats.

Class	Species
Nematodes	<i>Haemonchus</i> spp., <i>Trichostrongylus</i> spp., <i>Trichuris</i> spp., <i>Cooperia</i> spp., <i>Oesophagostomum</i> spp., <i>Gaigeria panchyscelis</i> , <i>Ostertagia</i> spp., <i>Strongyloides</i> spp., <i>Capillaria</i> spp., <i>Skrjabinema</i> spp., <i>Bunostomum</i> spp., <i>Nematodirus</i> spp., <i>Chabertia</i> spp.,
Cestodes	<i>Moniezia</i> spp., <i>Avitelina</i> spp., <i>Stilezia</i> spp., <i>Taenia</i> spp. (<i>Cysticercus</i> <i>tenuicollis</i>), <i>Hydatid</i> cysts
Trematodes	<i>Fasciola</i> spp., <i>Paramphistomum</i> spp., <i>Schistosoma</i> spp., <i>Paragonimus</i> spp.

1.5 Nematodes of goats

In contrast to sheep, information on the epidemiology of helminths in goats in the Tropics is scarce. Detailed epidemiological studies have been carried out in Mozambique (Specht, 1982), Senegal (Vercruysse, 1983), Sierra Leone (Asanji, 1988), Gambia (Fritsche *et al.*, 1993), Nigeria (Chiejina *et al.*, 1988; Fagibemi and Dipeolu, 1982), India (Gupta *et al.*, 1987), and Sri Lanka (Van Aken *et al.*, 1990). In areas of study in Africa with a prolonged dry season, *H. contortus* and *O. columbianum* were the most important species reported (Specht, 1982; Vercruysse, 1983). In northern India, in areas with less pronounced dry periods, *H. contortus* and *Trichostrongylus* spp. were the most important species of gastrointestinal nematodes observed (Gupta *et al.*, 1987). El-Azazy (1990) also made similar observations in Sharkia Province of Egypt. Fagibemi and Dipeolu (1982), using larval cultures encountered mainly *H. contortus*, *T. colubriformis* and *O. columbianum*. *T. colubriformis* was more predominant during the dry season, *H. contortus* in the early wet season and *O. columbianum* in the late wet season.

Most nematodes in the gastro-intestinal tract of sheep and goats belong to the super families *Strongyloidea* and *Trichostrongyloidea*. These worms have a direct life cycle which includes a free-living (non-parasitic) as well as a parasitic phase. Nematodes contaminate the environment through eggs which are passed out in the faeces of infected animals. The eggs develop, under suitable moisture and temperature conditions to produce first stage larvae (L₁) which develop through to L₃ (extra-host stage). The L₃ larvae are the infective form for the host and are usually ingested during grazing. In goats, gastrointestinal helminthiasis is usually a sub-clinical condition (Chiejina, 1995) causing reduced growth rates or general loss of body weight (Obwolo, 1991). Control of small ruminant helminthosis is therefore essential in order realise the full potential of small ruminant production.

rains-wave of herbage infestation (Chiejina, Fakae and Eze, 1988)

1.6 Life cycles of Gastrointestinal nematodes in small ruminants

Nematodes are free-living or parasitic. Morphologically these are unsegmented worms, usually cylindrical and elongate in shape with an alimentary canal present. With a few exceptions, the sexes are separate and their life-cycles may either be direct or may include an intermediate host (Soulsby, 1982). Gastrointestinal nematodes of ruminants usually have a direct life cycle. Eggs are shed in the faeces and under optimum conditions of temperature and humidity the eggs hatch to produce two successive non-parasitic larval stages and then a third infective larval stage. The pre-infective free-living larvae are very susceptible to desiccation while the infective larvae can withstand desiccation better. Their life cycles are similar but there are notable exceptions to this, and although there is a broad similarity among nematode species, the specific differences frequently have an important implication in their disease process, epidemiology and their control. The differences in life cycles depend, to some extent, on the degree of adaptation to a parasitic existence that has been reached (Soulsby, 1982). The life cycles may therefore be classified as follows:

1) *Direct (i.e. without an intermediate host)* In this case eggs hatch outside the host and the larvae are active and free-living for some time (e.g. most *Strongyloidea* and *Trichostrongyloidea*). Entry into the host is usually through the mouth via food and water, but infective larvae of some species (e.g. *Bunostomum* and *Strongyloides*) can also actively penetrate the host's skin. When the infective larva is ingested by the host, it exsheaths, usually in the organ before the predilection site for the adult form (see Annex 3), and it may enter the mucosa. In the mucosa it moults, returns to the lumen and after a fourth moult matures to the adult worm. The uncomplicated parasitic life cycle, from ingestion of larvae to egg laying females, takes about three weeks on average.

Bunostomum spp. and *Strongyloides papillosus* larvae are also capable of entering the body via cutaneous penetration. Inside the host, they enter the blood stream, go into the lungs and enter the alveoli where the L₄ develop. The L₄ then pass up the air passages and are swallowed to reach the small intestine. In the case of Ascarids, eggs develop outside the host but do not hatch; infective larvae remain passive inside the egg. Entry into the host occurs only through the mouth via contaminated water or feed (see Fig. 1).

2) Indirect (With an intermediate host)

In this case eggs are laid by the female worm and hatch outside the host or the worms are viviparous. The larvae enter the intermediate host after a short free existence. The intermediate host is then eaten by a definitive host (e.g. *Habronema*). In the case of *Spiruroidea* the eggs do not hatch to release infective larvae, rather they are ingested directly by the intermediate host. The life cycle is completed when the intermediate host is finally eaten by the definitive host (see Fig.2).

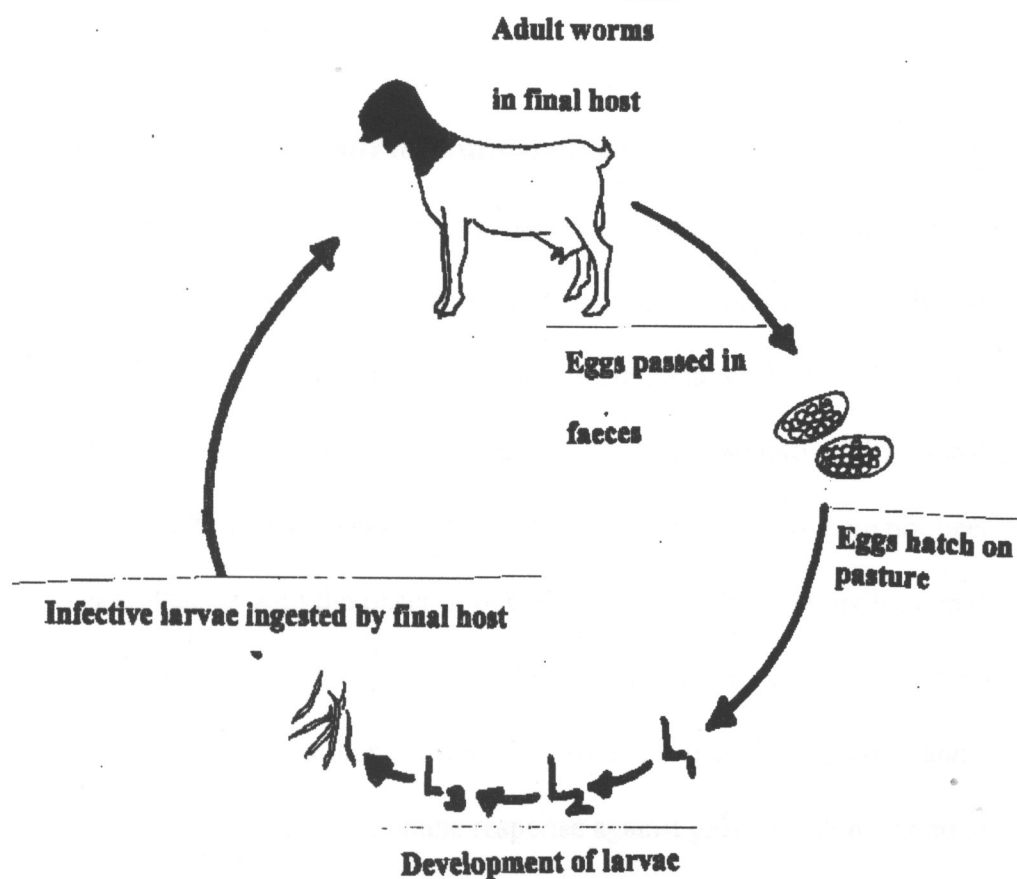


Figure 1. Direct life cycle of helminth parasites.

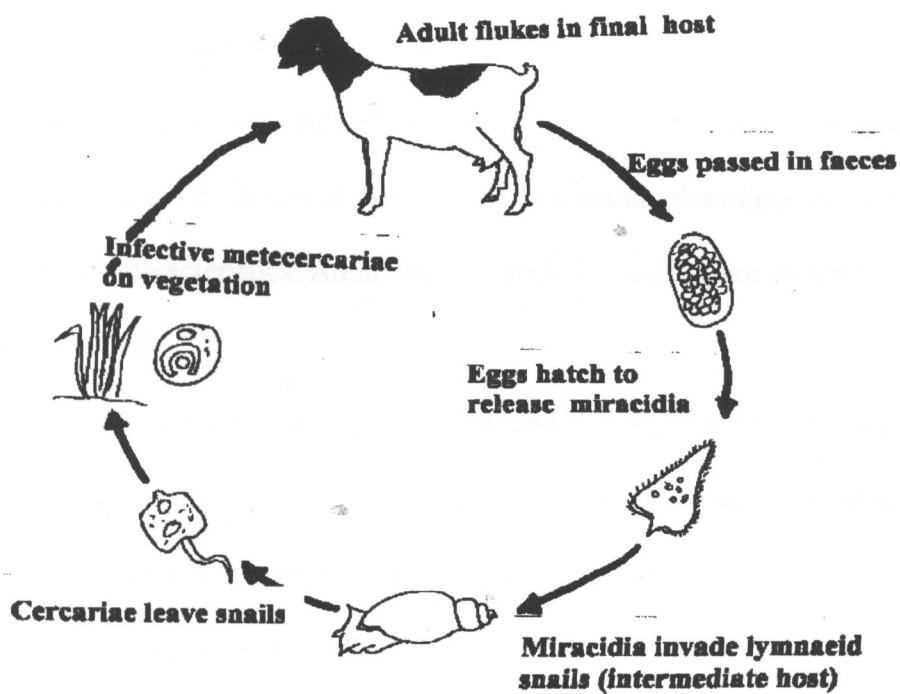


Figure 2. Indirect life cycle of helminth parasites which involve an intermediate host.

1.7 Development of immunity to gastrointestinal nematodes in small ruminants

The host's immune response to parasitic infection is an important phenomenon in the epidemiology, pathology and control of parasites (Soulsby, 1982). Immune responses to nematodes are complex, possibly depending on antigenic stimulation by secretory or excretory products released during the development of the L₃ larvae into adults (Schallig *et al.*, 1994). Factors which influence the onset of immunological responsiveness have not been clearly defined, but it is likely that, as with the onset of puberty, body weight and condition may be more critical than chronological age (Abbott *et al.*, 1988). However, immunity to helminths is usually less efficient and more transient than the immunity to micro-organisms (Blood and Radostitis, 1989). The expression of a protective immune response against gastrointestinal nematodes in ruminants presents itself as a spectrum of different effects depending on the immune status of the host.

- a) The development of immunity after a primary infection is invariably associated with an ability to expel the adult nematodes.
- b) Subsequently, the host can attempt to limit reinfection by preventing the migration and establishment of incoming larvae or, sometimes, by arresting their development.
- c) Changes in worm characteristics. Adult worms which do develop are stunted in size and their fecundity is reduced.

The immune response against gastrointestinal nematodes is influenced by a number of host factors which include genetic make-up, age, as well as hormonal and nutritional status of the host. Any of these factors can contribute to the non-responsiveness of the host to a gastrointestinal nematode infection (Hilderson, 1993).

Much of the seasonal variations and the rhythms of parasitism of gastrointestinal nematodes in small ruminants are mediated by the immunity of the host. One of the most obvious clinical features of immunity to gastrointestinal nematodes is the well-recognised ability of the older animals to resist clinical parasitic infection whereas younger animals often suffer severely from it. Under natural grazing conditions such immune status is ascribed to age immunity *per se* and due primarily to acquired immunity.

1.8 Self cure

Perhaps the best known phenomenon associated with gastro-intestinal nematodes is the self-cure mechanism which occurs in *H. contortus* infections (Stoll, 1929 cited by Soulsby 1965). Following infection of lambs, faecal egg counts rise to high levels but 10 weeks later, a dramatic fall in egg counts occur over a period of 2 to 3 weeks. This reduction in egg counts is associated with a loss of worms. Subsequently, despite frequent attempts at reinfection with large numbers of infective larvae, the lambs remain refractory (Soulsby, 1982). Self cure is a specific immunity of the type 1 hypersensitivity, which may or may not be accompanied by solid immunity (Blood and Radostitis, 1989). Classically, self-cure occurs in sheep when a dose of infective larvae is superimposed on an established worm burden in a sensitized animal. This results in expulsion of the adult worms and may also, although not invariably, eliminate the incoming larvae (Blood and Radostitis, 1989). Self-cure in goats has been demonstrated to occur six to seven weeks post-infection (Shavulimo *et al.*, 1988).

1.9 Arrested larval development (Hypobiosis)

Hypobiosis is a phenomenon that may be defined as the temporary cessation or interruption of a nematode's parasitic development at a precise phase of the larval development characteristic of that particular species. The accumulation of large numbers of hypobiotic nematode larvae in the gastrointestinal tracts of domestic animals has long been recognised as an important feature of the population structure in these nematode infections (Ikeme *et al.*, 1987). Many nematode parasites especially the trichostrongylid species found in grazing animals, are capable of hypobiosis (Schad, 1977). Development is resumed after a variable period of arrest or inhibition, the resumption often associated with stress of the host or onset of suitable environmental conditions (Blitz and Gibbs, 1971; Michel, 1971; Schad, 1977). The resumption of development and maturation of the inhibited larvae usually occur in small numbers at a time. Occasionally the inhibition is synchronously terminated, thereby resulting in a sudden increase in the numbers of pathogenic (developing and adult) worms and hence giving rise to overt clinical disease in the host (Anderson *et al.*, 1969; Chiejina *et al.*, 1988). Several factors are known to induce or influence hypobiosis in trichostrongylids. Exposure of the pre-parasitic larval stages to adverse environmental conditions such as low temperatures and extreme dryness appear to be the most important factors. Inevitably, the phenomenon of hypobiosis tends to be more common in cold or hot climates (Anderson *et al.*, 1969; Hart, 1964; Ogunsusi and Eysker, 1979). In temperate areas the onset of hypobiosis mainly coincides with declining temperature conditions. However, reports from the tropical areas (Ogunsusi and Eysker, 1979 in Nigeria) link hypobiosis with the onset of hot arid conditions. Hypobiosis was noted and reported in Senegal by Vercruysse (1983) and Sierra Leone by Asanji (1988). In northern India, in areas with less pronounced dry periods, hypobiosis was not observed (Gupta *et al.*, 1987). In all cases the seasonality and intensity of hypobiosis suggests that it is associated with climatic conditions which are unfavourable for the

continued development of the free-living stages of the nematodes whilst in their external environment (Armour, 1980). El-Azazy (1990) also demonstrated that hypobiosis of *H. contortus* occurs throughout the year in Egypt. Another factor which is often associated with hypobiosis is density dependence which is a regulatory mechanism (Michel, 1970 cited by Ikeme *et al.*, 1987) exerted by some nematodes on the structure of their populations under conditions of high infective dose (Ikeme *et al.*, 1987). Other factors which can attribute to hypobiosis include (1) age of the host, (2) the presence of adult worms, (3) the host's acquired resistance and (4) host pregnancy and lactation (Michel, 1971; Michel *et al.*, 1978). Little is known about how these and other factors induce and/or possibly help to maintain larval inhibition but their effectiveness seems to largely depend on the species and strain of parasite, host species and overall environmental conditions.

1.10 Periparturient rise in faecal egg counts.

This phenomenon refers to an increase in the number of nematode eggs in the faeces of a host female animal around parturition. Animals often show an increased faecal egg count beginning in late pregnancy and reaching a peak in early lactation (Obwolo, 1991; Michel *et al.*, 1979; Agyei *et al.*, 1991). This phenomenon is most marked in ewes, does and sows. The etiology of periparturient rise in faecal egg counts has been principally studied in sheep and seems to result from a temporary fall in immunity of the host associated with an increase in the circulating levels of the lactogenic hormone, prolactin (Urquhart *et al.*, 1987).

The source of peri-parturient rise in faecal egg counts is attributed to three factors: a) maturation of larvae arrested due to changes in the host immunity, b) an increased establishment of infections acquired from pastures and a reduced turnover of existing adult infections, c) an increased fecundity of existing adult worm populations (Urquhart *et al.*, 1987).

1.11 Pathogenesis of gastrointestinal nematodes

The major pathogenic effects of gastrointestinal nematodes are reduced feed intake reduced weight gain, weight loss, diarrhoea, blood and protein loss and eventual mortality (Symons, 1985). There is a decrease in the deposition of fat, protein and skeletal calcium and phosphorous (Holmes, 1987). *Bunostomum spp.* and *Haemonchus spp.* are active bloodsuckers which can cause severe anaemia in all host species (Al-Zubaidy *et al.*, 1987; Albers *et al.*, 1990). There is evident loss of whole blood (Rowe *et al.*, 1988) and hypoproteinemic oedema which may result in anasarca. With the presence of nematodes in the gastrointestinal tract irritation to the mucosa is inevitable and mild or intermittent diarrhoea may follow. The haemorrhage and/or blood clots noted in the lumen or on the mucosal surface of severely infected hosts may be due to an active feeding habit of the developing stages of the parasites which have well equipped mouth parts capable of causing traumatic (tearing) damage of host's tissue (Al-Zubaidy *et al.*, 1987). The migration of *Haemonchus* larvae into the pits of the gastric glands in the abomasal wall and the physical injury caused to the mucosa by the attachment of the adults causes abomasitis. While the pathogenicity of *H. contortus* has been studied in sheep by many workers in different countries, studies of caprine haemonchosis are few and, there is uncertainty over the extent of resistance to the parasite in goats (Al-Zubaidy *et al.*, 1987). Some believe that goats are more resistant to the parasite than sheep (McCullough and Kisambala, 1970; LeRiche *et al.*, 1973; Preston and Allonby, 1978; Al-Quaisy *et al.*, 1987), while others think otherwise (Lee and Armour, 1957, cited by Al-Zubaidy *et al.*, 1987). Infestations with the worms of *Trichostrongylus*, *Ostertagia*, *Cooperia* and *Nematodirus spp.* in the abomasum and small intestine of small ruminants also have similar pathological effects. Local effects on digestion, absorption and protein loss will depend on the organ affected and will interact with anorexia which is a primary feature of these infestations. Intestinal trichostrongylosis causes villous atrophy and plasma loss into the

intestinal lumen due to increased vascular permeability and discontinuity of the epithelium. Part of the dietary ill-effects may be due to the loss of enzymes normally found on the microvilli. Abomasal worms lead to a significant rise in abomasal pH due to the reduction in gastric acid production leading to reduced digestion (Holmes, 1987; Blood and Radostitis, 1989) .

There is a prominent eosinophilic response with associated mastocytosis noted in the parasitised abomasum and regional lymph nodes, especially in goats. This is attributable to the larval tissue invasion stage of the infection (Al-Zubaidy *al.*, 1987). The prominent tissue eosinophilia points to an immunological involvement- suggestive of Type 1 hypersensitivity (anaphylactic) reactions.

1.12 Clinical Signs

Naturally occurring parasitic gastroenteritis (PGE) is a gastro-enteropathy caused by mixed infections with several species of gastro-intestinal nematodes. Under traditional pastoral and sedentary village husbandry, PGE is generally manifested as a chronic or subclinical syndrome (Chiejina, 1995). However, clinical disease is rather common in intensive production systems (Chiejina, 1987) or when traditionally managed animals are inadvertently exposed to heavy infections, either through prolonged indoor confinement in unhygienic conditions or following restricted/zero-grazing of heavily contaminated pasture or fodder (Kaufmann and Pfister, 1990).

A number of nematodes species are capable of producing clinical parasitic gastritis and enteritis in goats. The most important of these under Tropical conditions are *H. contortus*, *Trichostrongylus axei*, *Trichostrongylus colubriformis*, *Bunostomum trigonocephalus*, and *O. columbianum*. *Cooperia curticei*, *Trichuris ovis*, and *Chabertia ovina* may also be pathogenic especially in sheep. However, under natural conditions, parasitic gastro-enteritis is seldom caused

by a single species. Even where clinical entities can be ascribed to a single species, for example *H. contortus* or *T. axei*, a number of the other nematode species are usually involved. In many cases clinical parasitism is ascribable to the summation of a burden of intestinal nematodes. In mild infections gastrointestinal nematodes do not cause acute or specific clinical symptoms (Chiejina, 1987, 1995).

Clinical signs commonly associated with gastrointestinal nematode infections include anaemia, pale mucous membranes, profuse intermittent or chronic diarrhoea (which may be haemorrhagic, watery, dark green, frothy and foul smelling), anorexia, emaciation, constipation (which in some cases alternates with diarrhoea), reduced intestinal motility (which may rarely lead to intussusception or stenosis), hypoproteinemic oedema (which is usually present as bottle jaw or ventral abdominal oedema), verminous pneumonia, weakness and rough hair coat. Heavy infections can lead to sudden death.

1.13 Treatment and Control of Parasitic Gastroenteritis in Small Ruminants

1.13.1 Treatment

1.13.1.1 Anthelmintics

Efficient use of anthelmintics is an integral part of worm control strategies to prevent production losses from parasitic infections. A revolution in the therapy of nematode parasitism began with the discovery of thiabendazole in the early 1960's. This success stimulated active research and since then great advances are being made in the discovery of new anthelmintic drugs possessing increased efficacy and a broad-spectrum of activity. Many modern anthelmintics are effective against both adults and larval stages and an increasing proportion of them are effective

problem, but it is not yet a problem in cattle which do not usually receive such intensive anthelmintic treatment. Other reasons that can lead to the development of resistance include (a) the over use of anthelmintics (O'Brien, 1993); (b) under dosing; (c) the use of persistent anthelmintics; and (d) poor management procedures (Blood and Radostitis, 1989). Anthelmintic resistance in nematode parasites of small ruminants has been recorded in many areas of the world (Njanja *et al.*, 1987). Resistance to benzimidazoles of *H. contortus* in sheep has been reported worldwide (Webb *et al.*, 1978; McKenna, 1994; Le Jambre *et al.*, 1979; Cawthorne and Cheong, 1984, cited by Van Aken *et al.*, 1989; Webb and Ottaway, 1986). Unfortunately, documented reports on anthelmintic resistance in goats are scarce (Kettle *et al.*, 1983; Barton *et al.*, 1985, cited by Van Aken *et al.*, 1989; Kerboeuf and Hubert, 1985; Van Aken *et al.*, 1989). Some apparent failures of anthelmintics in goats have been proved to be due to inappropriate dose rates for this species in which a rapid breakdown of anthelmintics has been noted (Bogan *et al.*, 1987). Accurate diagnosis and measurement of the extent of anthelmintic resistance in parasitic populations is an important component in the development of control measures (Donald, 1983 cited by Lacey and Snowdon, 1988). Four tests are currently easily available for detecting anthelmintic resistance- faecal egg reduction tests; *in vivo* anthelmintic efficiency assay; *in vitro* egg hatch assays and tubulin binding assay (Martin *et al.*, 1989; Coles *et al.*, 1992).

If anthelmintic resistance is proved, then a drug with a different mode of action should be used, and thought should be given to the use of narrow spectrum drugs administered at appropriate times and doses to reduce selection pressure in the broad-spectrum compounds.

1.13.2 Control

Diseases caused by excessive burdens of endo- and ecto-parasites have traditionally been controlled by chemotherapy aimed at killing the parasite. Unfortunately the increasing prevalence of resistance to anthelmintics (Waller, 1987), allied with increasing costs of development and registration of new biocides, has led to a need for a change in the traditional parasite control methods. There is therefore much interest in developing parasite control methods that do not rely on biocide treatment. Foremost among these non-traditional control strategies are selective breeding for resistant hosts and the development of effective vaccines.

It is currently believed that effective helminth control cannot be achieved by anthelmintic use alone; but through careful coordination with other methods of control, such as alternate pasture grazing with different host species, integrated rotational grazing of different host species and other management techniques can give a greater economic advantage if practised and combined with strategic anthelmintic treatment (Fraser *et al.*, 1991). Attempts are being made to develop a vaccine but results have not been very promising. Despite the urgency for the development of immunological control methods, the mechanisms underlying acquired immunity against gastrointestinal nematodes, are not completely understood (Schallig *et al.*, 1995). Failure to successfully vaccinate animals against metazoan parasites is not necessarily attributable to the absence of an immune response provoked by natural infection, but more often due to the difficulties of stimulating a protective response in animals which are considerably younger than those in which the parasites occur naturally (Barger, 1989; O'Brien, 1993). Certain fungi of the *Arthrobotrys* species attack and kill nematode larvae in faecal pats but often they are killed by passage through the gut and so are not of great value, but recently a fungus *Duddingtonia flagrans* was found which will grow harmlessly on barley and which passes unharmed through the gut and is extremely active against larvae in faecal pats (Gronvold *et al.*, 1993).

Control of helminth infections requires a thorough knowledge of the types of parasites present (including their biology and epidemiology), the herd structure and grazing management, seasonal availability and the survival of the parasite and weather conditions in a particular area (Hansen and Perry, 1994; Aumont and Gruner, 1989). Infection patterns (infection levels and intensity) are affected by four primary factors which include: parasite contamination, environmental conditions, host resistance and management practices (Ashraf and Nepote, 1990). At our present state of knowledge of causes of parasitic disease, it is difficult and even dangerous to lay down rigid rules for their control which are applicable to all regions. For this reason, it is advisable that a study of the epidemiology of each parasitic disease should be carried out on a regional basis and recommended control measures should be similarly limited (Blood and Radostitis, 1989). Efforts should also be made to ensure that integrated control systems, which do not entirely rely on anthelmintics use are employed to reduce the frequencies of treatment (Dorny *et al.*, 1995). Control of helminths under the savanna conditions which have one or more distinct dry seasons should involve the following approaches-

a) Strategic use of anthelmintics

It is recommended that animals should be treated at the beginning of the dry season in order to eliminate their parasite burden (Hansen and Perry, 1994). Treatment prior to the onset of the favourable rainy season, using a larvicidal drug will prevent a "rain rise" due to activation and maturation of hypobiotic larvae and the subsequent contamination of pastures with eggs.

b) Grazing management

The short longevity of the L₃ larvae on pasture enables the use of rotational grazing as a means of gastrointestinal nematode control. Pasture change or rotation can effectively break the cycle of continuous infection between host and pasture (Dorny *et al.*, 1995). Where pastures are fenced, a rotational grazing system may under special circumstances be adapted to provide

parasitologically safe paddocks (Barger *et al.*, 1994). There are results to indicate that a rotational grazing system consisting of paddocks grazed at specified intervals, different for different climatic conditions, may permit a reduction in the incidence and prevalence of gastrointestinal nematodes. However, in general a rotational grazing system cannot be recommended for nematode control (Thamsborg, personal communications). Zero grazing reduces chances of infective larvae uptake and can thus be used as a control measure. Reduction in the stocking rate of the animals on pastures in order to reduce pasture contamination and the subsequent parasite burden of grazing animals is also a suitable method of parasite control (Thamsborg, 1996).

c) Use of resistant breeds

There is ample evidence that genetic variations for disease resistance in domestic animals exists (Richard *et al.*, 1990; Owen and Ashford, 1991). Some animals have been shown to be genetically resistant to helminth parasites (Shavulimo *et al.*, 1988; Hansen and Perry, 1994). Such animals may carry the parasites but do not show any overt clinical signs of parasitism or in certain cases tend to limit or eliminate parasitic worm burden altogether. It is now known that resistance of sheep to *H. contortus* is to some extent genetically controlled, this being related to such factors as the breed and haemoglobin type of the host (Al-Quaisy *et al.*, 1987). Baker (1995) concluded that the Small East African and West African dwarf breed of goats appear to be more resistant to infection by gastrointestinal nematodes than exotic breeds.

PART TWO

GOATS AND HELMINTHOSIS IN

ZAMBIA

2.1 Background Information

2.1.1 Geography

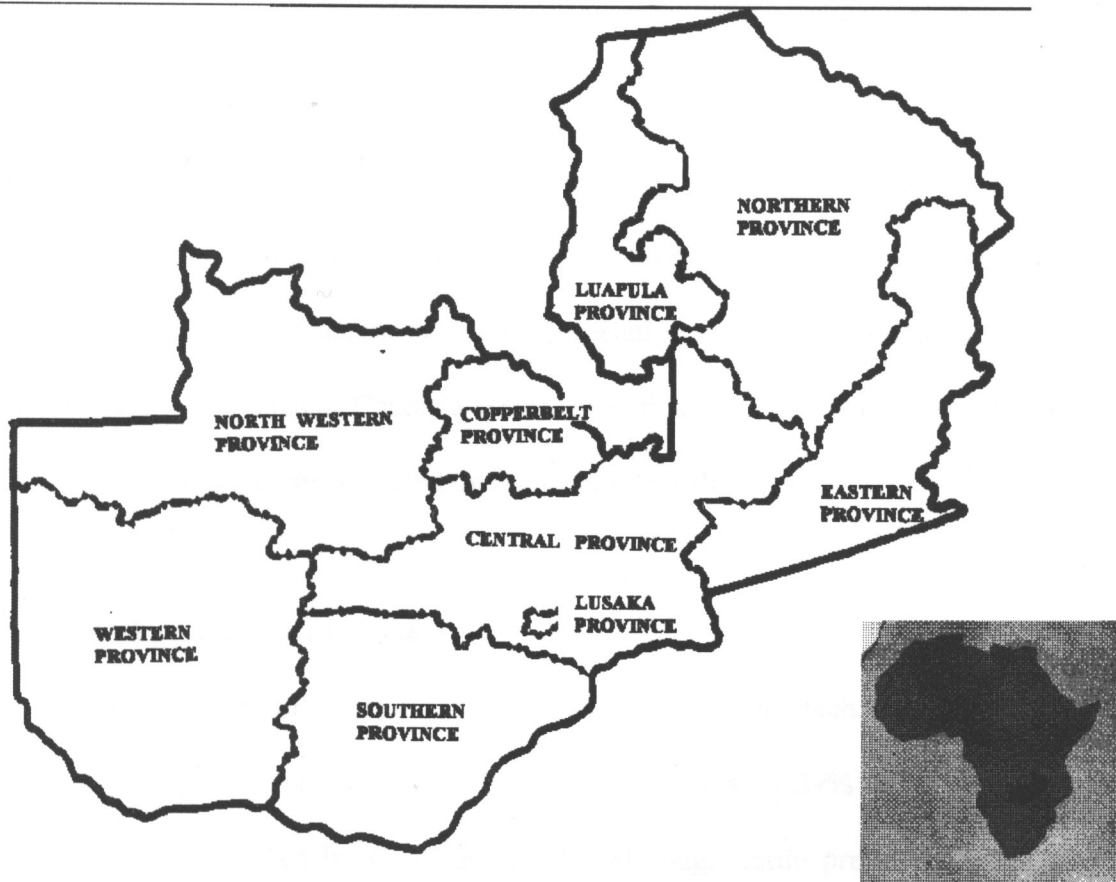
Zambia lies in central Africa, approximately between the latitudes 8°S, 18°S and the longitudes 22°E and 34°E. It is a landlocked country with seven neighbours. Zambia occupies an area of 75 million hectares (Map 1). It is composed of a series of plateaux which undulate between 900 and 1500 metres above sea level.

The country is administratively divided into nine provinces: i.e. Central, Copperbelt, Eastern, Luapula, Lusaka, Northern, Northwestern, Southern, and Western Provinces. Lusaka is the Capital city and is located in Lusaka province. English is the official language. The country has 73 languages which are spoken largely in rural areas. The Zambian Kwacha is the national currency and one United States Dollar is equivalent to 965 Kwacha.

2.1.2 Climate

The Zambian climate is characterized by a) a single rainy season from October to April, and b) a dry season from May to September. However, the country is said to have three main seasons, namely: a) the hot dry season (September to November), b) the warm and wet season (November to April), and c) the cool and dry season (May to September). The average temperature range is between 10°C to 25°C during the cool dry season and 18°C to 33°C during the hot dry and warm wet seasons. October is the hottest month which precedes the rainy season. Rainfall during the dry season is nil and the humidity is often below 20% for extended periods. The country has experienced severe partial drought for the last four years which has had a devastating effect on agriculture.

The country is divided into the following agroclimatic zones (Map 2.).



Map 1. Map of Zambia showing it's location and provincial boundaries



- Region 1 (1000-1600 mm annual rainfall)
- Region 2 (800-1000 mm annual rainfall)
- Region 3 (600-800 mm annual rainfall)

Map 2. Agroclimatic regions of Zambia

2.1.3 People

The population of Zambia was estimated at about 8.2 million people with a population density of 10.6 people per square kilometre. Population growth is estimated to be 3.6% per annum (Mukanda, 1992 cited by Chilonda 1994). The urban population was estimated at 53% in 1987 of which 20% were concentrated on the Copperbelt Province.

2.1.4 Livestock production in Zambia

The livestock sector is mainly based on cattle production which accounts for more than 35% of the total agricultural production. Beef alone accounts for 29% of the total agricultural exports (Huhn, 1991, cited by Chilonda, 1994). Although cattle production dominates the livestock sector, small ruminants also play an important economic and social role, mainly among the small scale traditional farmers. Livestock kept at small holder level in the traditional sector, accounts for 81% of the total national cattle population, 94% of the national goat population and 72% of the national sheep population (Anonymous, 1994a). It is however believed that the sheep population in the traditional sector is overinflated (personal observations).

2.1.4.1 Goat Production in Zambia

The population of goats in Zambia is estimated at 633,000 animals (Anonymous, 1994a). In Zambia, most of the goats unlike sheep are kept by traditional small-scale farmers (Anonymous, 1994), under village-level management. A few commercial farms keep goats which are mainly imported Boer goats and their crosses. As a percentage of the total ruminants, goats are of importance next to cattle, accounting for 21.4 % of the total ruminant population (Anonymous, 1994). Goats represent the major ruminant species reared in the dry valley areas of Siavonga and Gwembe of Southern province. In these river valley areas goats are of particular

interest due to their trypanotolerance (Lovelace *et al.*, 1993). The livestock census records for the years 1987-1993 are shown in Table 2. and the provincial livestock populations for 1993 are shown in Table 3. They show a steady decrease in the goat population from 1987 to 1991 and an increase thereafter.

Table 2. Livestock populations in Zambia (1987-1993)

YEAR	Cattle	Goats	Sheep	Pigs
1987	2542551	614227	46896	204909
1988	2637649	506687	53065	239820
1989	2678363	507181	55382	267204
1990	2707157	559958	59717	303152
1991	2540811	552065	99991	320862
1992	2424798	560071	63055	305954
1993	2267097	633213	63139	286054

Source: Department of Animal Production and Health (DAPH) livestock census report 1994.

Table 3. Livestock populations by province (1993)

Province	Cattle	Goats	Sheep	Pigs
Central	477948	50715	12150	23458
Copperbelt	62979	16393	3325	27711
Eastern	232807	166226	14331	120427
Luapula	13042	46861	8781	11633
Lusaka	35344	14566	225	4191
Northern	46707	27636	7698	3661
North Western	56857	29858	3853	10625
Southern	838447	271835	12776	77295
Western	502966	9123	0	7053
Total	2267097	633213	63139	286054

Source: Department of Animal Production and Health (DAPH) livestock census report 1994.

Goats in Zambia are gradually becoming important as a source of animal protein and income particularly in the traditional sector (personal communications with traditional farmers, May 1994). This trend has been attributed to special qualities exhibited by goats: hardiness, ability to live in semi-arid environments and their resistance to most disease in comparison to cattle. Many traditional households have therefore ventured into goat rearing (Personal communications with traditional farmers, May 1994). This may account for the increase in the number of goats since 1991, which has been a period of drought in Zambia. Goats in Zambia are mainly kept for meat production although goat milk is steadily being accepted.

2.1.4.1.1 Breeds of Goats

The goat population in Zambia can be differentiated into four different types of animals: 1) the indigenous Small East African breed (also locally known as the Gwembe dwarf breed), 2) The Bantu breed, 3) the crossbred goats of various grades and 4) the exotic purebreds (Lovelace, personal communications). The predominant breed in Zambia is the Small East African Breed as described by Mason and Maule (1960).

The indigenous breed is a small animal with an average body weight of 24 to 31 kg (Lovelace *et al.*, 1989). The animal has a relatively poor growth rate but is renowned for its prolificacy and fecundity. This breed is particularly adapted to the drier regions of the country with less than 750mm annual rainfall (Map 2.) and poor feeding regimes. No definite colours are apparent, they can be a mixture of black, brown, or white (Devendra and McLeroy, 1982).

The Bantu breed of goats are unimproved and resembles the Small East African breed to which it may be related. They are medium sized, 30 to 35kg, hardy goats with mixed colours. They are found in Malawi, Zimbabwe, Botswana, Zambia, and South Africa and, the similarities in their features, has led them to be described collectively as savanna goats. The coat is short and horns are present in both sexes. The breed is very fertile and are mainly kept for meat production.

The crossbred goats are of various grades and are genetically heterogenous animals. The phenotypic heterogenicity of these animals is related to the proportion of exotic genes imparted in the hybrid resulting from indiscriminate crossing and upgrading. Although not distinctly identifiable, these grades of animals are moderately stabilized and their distinctiveness in terms of colour patterns and performance are more associated with being naturally selected to adapt to a particular region or niche rather than due to any conscious efforts by the relevant authorities.

The most common exotic breed found in Zambia is the common Boer goats. This is a medium sized animal (30 to 55 kg) with a short glossy coat which is white in colour with brown spots on reddish brown head and neck. The Boer goats may either be polled or have horns. These goats are well muscled and tend to have strong bones. Fertility is often high, with 50% twin and 7% triplet potential (Devendra and McLeroy, 1982). This breed is valuable for meat, milk and skin production.

2.1.4.1.2 Management systems

In the traditional husbandry systems practised in most rural areas, sheep tend to graze more than goats, which prefer to browse and often feed on household wastes and sometimes even human food (Carew *et al.*, 1980). In a study carried out by Kyomo (1981) it was observed that goats are reluctant to graze or browse on vegetation which is below its neck from the ground. This grazing behaviour of the goat affects its nematode infection patterns. It has been suggested that due to lack of challenge resulting from their selective (browsing) habits, goats have not been subjected to natural genetic selection for resistance to gastrointestinal nematodes, especially haemonchosis (Shavulimo *et al.*, 1988).

The most predominant and popular goat management practice in Zambia is the semi-extensive system where the animals are allowed to freely graze on any surrounding land that is

available during the day. The general management interventions in such a system is minimal. These animals receive little or no veterinary care and are never routinely immunized and are seldom, if ever, treated against internal or external parasites. At night, the goats are kept in small purpose built enclosures. These range from wooden stake fences without a roof to a grass-thatched mud hut. Housing is a function of herd size and the management system employed. Housing of goats by farmers normally does not take into consideration such factors as separation units for kids, sexes, health reasons, etc. Thus, most housing units assume the size of large pens with no distinct separation.

Goats are however attracted by and become a nuisance to crops. Therefore, during the maize planting season until harvest (late October to May), the goats are either herded by young boys for the whole day, sometimes together with cattle, or are kept confined for most of the day and fed on cut herbage and only let out to graze when they can be supervised. During the post harvest period, the goats are released in the morning and left to roam freely and graze or browse on the natural pasture comprising dry grass, shrubs and harvest residues. The principal source of feed is the natural vegetation. Towards the end of the dry season, the nutritive value and availability of the vegetation declines to its lowest levels. Thus the dry season imposes substantial nutritional stress on the animals as no supplementary feeding is made available during this period. The goats are therefore reared on a low-input system that does not require extensive labour inputs. The pattern of goat keeping varies according to location. The goat management system adopted is related to social acceptance of the community to keeping goats, the availability of land, the human resource, the financial status of the owners and the availability of feed. There is no specific breeding season for goats, therefore breeding and kidding take place throughout the year. Management of goats in the traditional sectors thus, is generally characterized by seasonal confinement. To a large extent, such confinement is determined by the prevailing agricultural

practices in a given area. The seasonal confinement during the rainy season when there is an increase in the number of infective L_3 available on pasture may have a direct effect on the epidemiology of nematode infections. Since the goats graze over a restricted area, it becomes more contaminated and thus increases the probability of infective larval intake.

2.2 Economic Significance of goats

The economic significance of the goat industry in Zambia is mainly characterized by small, subsistence type operations. Goats are usually kept for meat production although milk, mainly fresh, is also consumed in certain poorer rural communities. The contribution of goat meat to total meat protein consumed in Zambia is difficult to estimate because there is no organized marketing system to generate such figures. The marketing structure for goat production is primarily the sale of slaughter stock, in which sales are usually transacted on the hoof. Sales are made on an irregular basis, depending on the needs of the individual farmers. Often, goats are sold directly to consumers or middlemen who transport them to urban areas for resale. Goat meat is now more widely accepted and consumed in the country. Roast goat meat is a commonplace delicacy at most bars, and the Muslim community are particularly renowned consumers of goat meat especially during their Eid-ul-fitr feasts. The Muslims procure the goats because they can easily kill them in their traditional way to get Halal meat. Young goats are also sacrificed for their Eid-ul-adha ceremony. Many rural households also consume a substantial amount of goat meat. The testicles of mature bucks are also in high demand as a constituent of traditional aphrodisiac mixtures.

Goat meat is also considerably cheaper than beef or mutton. On a live weight basis goats cost approximately ZK 500/Kg as compared to beef (ZK 1100/Kg) and mutton (ZK 1800/Kg).

2.3 *Gastrointestinal nematodes of goats*

The following genera of gastrointestinal nematodes have been reported in Zambia: *Haemonchus*, *Trichostrongylus*, *Strongyloides*, *Oesophagostomum*, *Trichuris*, *Cooperia*, and *Gaigeria* (Nakazawa *et al.*, 1989; J. Muimo, unpublished data, 1989; Nalubamba, 1995) . In Zambia, gastrointestinal helminthosis in small ruminants remains largely uncharacterized, although it is recognized as a serious disease of frequent occurrence (Islam, 1984), and a production constraint.

The seasonal variation of gastro-intestinal nematodes of ruminants has stimulated work by several authors. Seasonal changes in faecal egg counts in goats have previously been documented by many workers around the world but only limited work has been done on goat parasites in southern Africa (Pandey *et al.*, 1994), and particularly in Zambia (Islam, 1984; Nakazawa *et al.* 1989). Available data on the seasonal dynamics of worm populations in goats in Zambia is limited and all of it is solely based on faecal egg counts and coprocultures to estimate corresponding worm burdens.

2.4 Objectives of the Study

The present longitudinal study was designed to provide more information concerning gastrointestinal helminthosis of goats in Zambia. Fluctuations of naturally occurring gastrointestinal nematode infections of goats in two traditional farming areas were monitored by faecal egg counts and coprocultures during a fifteen month period. The possible effects of season, age and physiological status of the goats and intercurrent diseases such as trypanosomiasis on the level of infections were also investigated.

Tracer goats grazed on traditional grasslands were used to monitor a) seasonal fluctuations on the intake of nematode larvae under natural infections, b) to check for the presence of arrested development (hypobiosis) and c) to define the possible means of transmission of gastrointestinal nematodes from one favourable season to another. From the information collected, seasonal dynamics as well as quantitative and qualitative aspects of gastrointestinal nematodes were analysed and suggestions are being proposed on the possible effective control of gastrointestinal helminthiasis in goats in the traditional sector in Zambia.

PART THREE
MATERIALS AND METHODS

3.1 Study area

The investigation was carried out over a period of 15 months beginning July 1994 to September 1995 in two traditional areas, Chipembi ($14^{\circ}57' \text{ S}$, $28^{\circ}33' \text{ E}$) and Shibuyunji ($15^{\circ}28' \text{ S}$, $27^{\circ}50' \text{ E}$). Both of these areas lie in the Central Province of Zambia, Chipembi is located 90 km Northeast of Lusaka while Shibuyunji is located 70 km Southeast of Lusaka. Central province has an altitude range of 1150 to 1300 m above sea level with a typical tropical climate.

Both of these areas are similar in climate and grazing conditions. In Chipembi, trypanosome infections occur, whereas in Shibuyunji trypanosomiasis is not well established (Anonymous, 1994b). The two sites are located in Savanna woodland areas with a vegetation which is a mixture of deciduous and evergreen trees and shrubs and an annual herbaceous understorey with perennial grasses. (largely *Brachystegia* for Chipembi and *Acacias*, *Afromosia*, *Combretum*, *Diptorhynchus*, *Erytorynchus*, and *Pterocarpus* in Shibuyunji). Grazing and browsing potential for goats are good throughout the year in both of these study areas. The general climate is characterized with rainfall mostly during the Summer months of late October to late March. Average rainfall ranges from 800 to 1000 mm per annum. The mean monthly temperatures vary from approximately 18°C in June/July to approximately 33°C in October to March.

The people living in the study area comprise mainly of peasant farmers carrying out mixed type of agriculture. Small numbers of indigenous cattle are kept by most households as a source of draught power, milk and income. Maize and cotton are the main cash crops grown, using ox-drawn implements and depending on the annual rains. Other than the livestock kept to supplement family income, most peasant farmers have no other source of steady income.

3.2 Study animals

Goats used in this study were of the Small East African breed, the Bantu breed and crossbreeds of various grades. These goats were classified into the following two categories- farm animals and tracers.

3.2.1 Farm animals

These goats were indigenous to the area and belonged to the traditional farmers. Average flock size per household in the study areas ranges from 6 to 70 animals with 2 to 5 bucks in the flock. The flocks are composed of 80-100% females as males not required for breeding are promptly sold or consumed. Some farmers do not have bucks of their own. These goats were sampled from for 15 months during the study period. They were permanently based at the sampling sites. At the beginning of the study, 80 animals were selected in each of the two study areas from a number of flocks with similar management conditions. Each animal was ear-tagged for identification, and allowed to graze freely within its normal grazing area. The farm animals were allotted into the following categories, on the basis of their ages (with approximately 20 goats per group)

- a) Less than 6 months
- b) 6 months to 1 year
- c) 1 to 2 years
- d) Older than 2 years

As the study went on, animals changed age categories, and a regular re-tagging of younger animals was therefore necessary. In the following months, November 1994, January 1995, March 1995, May 1995, and July 1995 ten to fifteen young animals (less than 3 months) were added to the main study group.

3.2.2 Tracers

Tracer goats, of the Small East African breed and of mixed sexes, were purchased at the age of 4 to 6 months and treated with an oral benzimidazole at double the normal dose and levamisole. Following treatment, the goats were kept in helminth-free condition on concrete-floored pens for at least four weeks until use.

At least 6 tracer goats were introduced to Chipembi pastures every month. After one month the animals were removed from the pasture and again kept in worm-free conditions for at least 3 weeks. This was to prevent further uptake of infective larvae and to enable all ingested infective larvae to complete their parasitic development. All infective larvae that failed to develop into adult nematodes were considered as having undergone arrested development. These were recovered by the digestion of the abomasal mucosa.

3.2.2.1 Experimental Animal Selection

Tracer goats were purchased at the age of approximately 4 months, determined by combination of mouthing the animal and by the farmer's estimate of the age.

Initially, tracer goats were bought from Lisitu in Siavonga. However, a lot of mortalities were experienced due to erratic *Cysticercus tenuicollis* infections (Postmortem results from Paraclinical Studies Department, School of Veterinary Medicine UNZA). Later, tracer goats were bought from Kudu Walk Farm, a commercial farm near Lusaka.

3.2.2.2 Removal of gastrointestinal nematode parasites

After purchase, each goat was weighed and the dosage for anthelmintics determined for each. Animals often harbour several different species of helminths, which may not have the same sensitivity to a given anthelmintic. In addition, there is usually a difference in sensitivity between

adults and larval stages, with immature stages being less sensitive than adult parasites (Hansen and Perry, 1994). The goats were therefore given oral albendazole (Valbazen®, Smithkline Beecham Animal Health) at a dose of 15 mg/kg body weight, which is double the recommended dose, the day after purchase. The day after albendazole dosing the goats were given oral levamisole (Levicon®, Milborrow) at a dose of 10mg/kg body weight. A faecal flotation was performed at two weeks and four weeks to ascertain the helminth-free status of the tracers. The tracer goats were kept on a concrete floor for at least four weeks before being put out in the field. During this time they had a weekly spraying with amitraz 12.5% solution (Triatix®, Coopers) at 1:100 dilution to cure any subclinical mange or treat any existing mange. From previous skin scrapings, it was noticed that most goats carried a mixed mange and fungal infection. To treat the dermatophytosis the goats were put on an initial five day course of 1% chlorhexidine (Savlon®) washes and then weekly washes subsequently. The chlorhexidine washes preceded the amitraz washes, the latter formed by the chlorhexidine increasing the penetration of the amitraz.

3.2.2.3 Field Trials

Each month, from September 1994 to August 1995, six worm-free tracer goats were taken to Chipembi and grazed alongside a naturally infected goat flock for a period of one month. The goats were then withdrawn and kept on concrete floors, free from further helminth infestation, for at least three weeks until necropsy.

While being kept in their pens (before and after tracing period), the tracer goats were fed on a maintenance diet of 400g per day of an equal mixture of maize bran and dairy meal. Water was provided *ad libitum*.

3.3 Sampling

Sampling was carried out at 4-week interval for a period of 15 months. All samples were collected between 8:30 and 12:30 a.m. At each sampling session rectal faecal samples were collected from each ear-tagged animal for nematode egg counts and larval culture and blood was collected from the jugular vein into an evacuated 10 ml serum tube (Venoject®, Terumo) from which blood was further collected into two heparinized capillary tubes for packed cell volume (PCV) determination and to carry out the haematocrit centrifugation technique for detection of trypanosomes. Serum was extracted and stored at -20°C for future serological examination. The following parameters were also noted when possible: the period in pregnancy, the date at which female animals kidded, or any animals which were lactating.

Faecal samples were collected directly from the rectum of individual goats into plastic bags. This was done by wearing a polythene bag over the hand and moistening the index finger end of the bag in water in a bucket. The finger was introduced in the rectum of the animal and the rectal mucosa stimulated to encourage the release of faeces. In case of very small kids KY Jelly (Johnson&Johnson) was used to lubricate the finger before penetration of the anal sphincter for sample collection. Once the sample was collected, the polythene bag was turned inside out. Each sample bag was clearly labelled with the animal's identification. Air was squeezed out of the bag to reduce the rate of development and the consequent hatching of the nematode eggs. The bags were tied tightly, packed and transported on ice-packs loaded in a cooler box to prevent the eggs from developing and hatching. In the laboratory, the faecal samples were stored in a refrigerator at 4°C until analysis. All samples were analysed at the University of Zambia laboratory within 48 hours of collection.

3.4 Parasitological examinations

3.4.1 Faecal egg count

All faecal samples were examined for the presence of helminth eggs using the modified McMaster's technique utilising fully saturated sodium chloride solution (specific gravity 1.204) (Anon., 1977). Each egg counted represents 100 eggs per gram (EPG) faeces (Thienpont, Rochette and Vanparijs, 1979). Where necessary a correction factor was used according to the consistency of the faeces: x 1 for normal faecal pellets, x 1.5 for soft formed faeces in which the demarcation of the individual pellets could still be distinguished, and x 2 for soft formed, without demarcation or slurry pellets (Soulsby, 1982). All samples yielding a negative count on McMaster's technique were subjected to flotation examination to determine the presence of low egg counts.

3.4.1.1 Protocol for the Modified McMaster faecal egg counting method

EQUIPMENT- Plastic beakers, Measuring scale, Tea strainer, (sieve), Measuring cylinder, Stirring device, Pasteur pipette with rubber teat, Saturated salt (NaCl) solution, McMaster counting chamber, Microscope

PROCEDURE- Approximately 2 grams of faeces were weighed into a plastic beaker #1 and 60ml of saturated sodium chloride solution were added to the faeces in the plastic beaker. The faecal suspension/pellets was filtered through a tea strainer into another plastic beaker #2. The faecal pellets were pulverized in the tea strainer using a stirring device. The saturated sodium chloride solution was poured from beaker #2 through the pulverized faecal pellets into plastic beaker #1.

Straining and pulverising were repeated until only undigested herbage remained in the tea strainer. The suspension was mixed by decanting it from one beaker into the other repeatedly. Immediately after mixing thoroughly, a sub-sample was taken with a Pasteur pipette to fill one side of the McMaster counting chamber. The sample was mixed thoroughly again, to collect a

sub-sample, and fill the other side of the McMaster counting chamber. The charged McMaster counting chamber was allowed to stand for about 5 minutes. The sub-sample of the suspension was examined under a microscope at 10 X 10 magnification and all nematode eggs within the engraved area of both chambers were counted. The number of eggs per gram was determined as follows: The egg counts from both chambers of the McMaster's slide were summed and the total multiplied by 100. When no eggs were seen within the engraved area of the McMasters counting chamber, flotation method was performed using the same sample preparation. A coverslip was placed onto the surface of the suspension in the plastic beaker. Using a pair of thumb forceps, the coverslip was removed from the plastic beaker and mounted onto a clean glass slide. The sample was then examined thoroughly under a microscope at 100 magnification for the presence of nematode eggs.

3.4.2 Coproculture and differential larval count.

3.4.2.1 Incubation of larvae

After EPG determination, the faeces were pooled according to their age group class sources and cultured for infective larvae recovery, identification, and differential counts. Approximately 2 grams of faeces from each infected animal were placed into a 500 ml plastic jar with a lid clearly labelled according to age group. The faeces were broken up using a spatula and mixed with grade 3 vermiculite to obtain a moist crumbly mixture. The lid was replaced onto the plastic jar and the mixture was incubated in an incubator (Yamato incubator, model IS-61) at 27°C for 10 days to allow the larvae to reach their infective stage. During the incubation period, the faecal mixture was turned every day for the first three days and thereafter every other day to allow aeration of the lower layers of the mixture and also to inhibit the growth of fungi. Tap water was also added to the mixture regularly to maintain optimal moisture levels for larval

development. After 10 days of incubation the infective larvae were recovered using the Baermann apparatus.

3.4.2.2 Recovery using the Baermann apparatus

This apparatus is used for the recovery of active larvae from faeces, faecal cultures, or tissues. It consists of a large glass funnel supported by a stand. The stem of the funnel is fitted with a short piece of rubber tubing which is closed with a spring clip. The culture mixture is placed into a large sieve lined with a paper milk filter (aperture 0.15 mm) inside. This is placed on the open end of the funnel and tap water is poured into the Baermann apparatus till about 0.5 cm from the brim of the funnel. Care should be taken to avoid air bubbles being trapped in the apparatus. The culture mixture is then Baermannized overnight. The infective larvae free themselves from the culture material and fall through the screen to settle in the rubber tubing. The following morning the infective larvae are drawn into glass centrifuge tubes from the stem by opening the spring clip and collecting about 15 ml. The dirty infective larvae suspension was kept in a refrigerator at 4°C for 24 hours to allow the larvae to sediment before being washed the following day. Washing was achieved by aspirating the supernatant with a Pasteur pipette and adding some fresh tap water into the centrifuge tube. The larval suspension was kept in the refrigerator for another 24 hours. This washing procedure was repeated two times. The resultant clean larval suspension is kept at 4°C until the differential count is performed.

3.4.2.3 Differential larval count

To perform the differential count the clear supernatant was aspirated with a Pasteur pipette to leave only about 0.5 ml of the larval concentrate. Two to three drops of Lugol's iodine were added to the larval concentrate to kill and stain the larvae. A small aliquot of the stained

concentrate was then transferred to a micro slide using a Pasteur pipette. The aliquot was covered with a coverslip and examined under 10 X 10 magnification. The differentiation of the various species of infective larvae depends on the consideration of a number of morphological features rather than any single feature, since considerable overlapping occurs in total length, length of tail and length of tail sheath. Identification of the larvae was done using a key adapted from Dikmans and Andrew (1933) cited by Hansen and Perry, 1994, Table 4. and in combination with the figures in the Ministry of Agriculture Food and Fisheries (MAFF) Manual of Veterinary Parasitological Laboratory Techniques (Anonymous, 1977).

Table 4. KEY TO INFECTIVE NEMATODE LARVAE OF SHEEP AND GOATS
(Adapted from Dikmans and Andrew, 1933)

Total length of larvae (u)	Length, end of larvae to end of sheath (u)	Species, with range of total length(u)	Other differential features
Short 500-700	No sheath 85-115	<i>Strongyloides</i> 570-700	Slender body with oesophagus, 1/3 to 1/2 total length of larvae.
Short 500-700	Long 85-115	<i>Bunostomum</i> 510-670	*Wide body with sudden tapering to long thin tail. "Band" constriction on oesophagus.
Medium 650-900	Short 20-40	<i>Trichostrongylus</i> 620-910	Short straight larva, conical tail sheath. Tubercles on tail of larva. Intestinal cells usually prominent.
Medium 650-900	Short 20-40	<i>Ostertagia</i> 790-910	Long, conical, "finger-like" tail sheath.
Medium 650-900	Short 20-40	<i>Cooperia curticei</i> 710-850	Oval bodies at anterior end of larva. Tail of larva rounded.
Medium 650-900	Medium 30-60	<i>Haemonchus</i> 650-750	Tail sheath usually "kinked". Pointed tail of larva.
Medium 650-900	Medium 30-60	<i>Cooperia onchophora</i> 800-920	Oval bodies anterior end of larva. Tail of larva rounded.
Long 900-1200	Long 60-80	<i>Chabertia</i> 710-790	Stout body with 24 to 32 rectangular intestinal cells.
Long 900-1200	Long 60-80	<i>Oesophagostomum</i> 770-920	Usually longer than Chabertia. Has 16 to 24 Triangular intestinal cells.
Long 900-1200	Extremely long 250-290	<i>Nematodirus</i> 922-1180	Tail of larva is forked.

Source: Hansen and Perry, 1994.

Stained aliquots of the larval concentrate were examined until 100 larvae were identified. The counts for each species provided an estimate of the composition (%) of the parasite population of the host.

Some helminth parasite eggs can be unmistakably identified by their characteristic egg shape (Soulsby, 1982; Hansen and Perry, 1994). Among the gastrointestinal nematodes *Capillaria* spp., *Strongyloides* spp., *Trichuris* spp. *Nematodirus* spp. and *Gaigeria* spp. have very distinctly characteristic egg shape.

3.5 Postmortem procedure

The tracer goats were necropsied following standard procedures (Anonymous, 1977). The entire gastrointestinal tracts were removed and placed in labelled flat trays. Abomasa, small intestines and large intestines were ligated to prevent worms spilling from one location to another. The different sections were then separated for processing.

Thereafter, the abomasum was opened along the greater curvature with a pair of scissors and washed. The abomasal contents were collected in a tray and the abomasum washed gently with tap water to remove any parasites adhering to the abomasal mucosa. The abomasal contents and washings were put into a measuring cylinder, about 20 ml of 40% formalin were added, and the volume noted and marked on a plastic bottle. After thorough mixing of the abomasal washings using a magnetic stirrer, a representative sample of approximately 200 ml, representing at least 50% of the original volume, was taken and put in the marked plastic bottle and stored for eventual worm counts. The small intestine was processed in a similar manner. The entire contents of the large intestines were examined immediately for the presence of worms. This was done by washing the intestinal contents through a # 212 Endecott sieve until the washing water became clean. Water was squeezed out of the material and a worm count and enumeration performed.

In addition, to estimate the number of immature larvae, and thus the presence of hypobiosis, mucosal scrapings of each abomasum were digested in acid pepsin for examination. The mucosa of the abomasum was scraped off and placed in a labelled plastic bottle and stored in a deep freezer until digestion. The mucosae were artificially digested at 37°C for 10 h in a solution of 0.8% pepsin and 2.3% hydrochloric acid. When the digestion was complete, after thorough stirring, 50% of the volume of the digest was taken as an aliquot and fixed with formaldehyde to make a 20% concentration. From the digested material the larvae were counted and identified only to the stage of development. Identification of the early fourth stage larvae (EL₄), suggestive of larvae undergoing arrested development, was based on the description of Soulsby (1965). All the mucosal larvae falling within a measurement range of 1-1.2 mm were considered as EL₄ of *H. contortus* (Pandey *et al.*, 1994).

At least 20% aliquots of well-mixed suspensions of abomasum and small intestine contents were examined for the estimation of worm burden by dilution (Anon, 1977). After thorough mixing of the contents using a magnetic stirrer, a total of 20% of the original volume of contents were placed into worm counting chambers. The contents were processed by repeated washing through a # 106 Endecott sieve until they were clean enough to allow for easy worm counting and identification. In the case where worm counts were very low, 50% of the original volume of the abomasal/small intestine contents were processed and examined. Adult male and female worms as well as the immature stages of the worms were enumerated.

3.6 Haematological methods

Infection with certain gastrointestinal nematodes, particularly *Haemonchus*, *Bunostomum* and *Trichuris* can often lead to severe anaemia. The packed cell volume (PCV) technique, enables an estimation of the degree of anaemia present by measuring the volume occupied by the packed red blood cells in a sample of circulating blood.

However, anaemia can also be caused by haemoprotozoan parasites, in particular trypanosomiasis. Thus, goats exhibiting low PCVs were also examined for circulating haemoparasites (*Anaplasma* spp., *Babesia* spp. and *Trypanosoma* spp.) using thin and thick blood smear preparations. The packed cell volume of each sample was determined by the capillary haematocrit method.

Blood was collected by jugular venepuncture into labelled serum tubes using a vacutainer apparatus. Immediately following collection into the tube, the rubber lid of the tube was removed and some blood collected into two heparinised micro capillary tubes for PCV determination and for buffy coat preparations. The capillary tubes were then placed on a strip of masking tape, with a piece of labelled masking tape attached to each capillary tube for identification. The capillary tubes were stored and transported in a cooler box loaded with frozen ice-packs in transit to the laboratory for PCV determination.

In the laboratory, the capillary tubes were spun at 10,000 rpm for 10 minutes using a haematocrit centrifuge (Sigma 201 M). The PCVs were read using a KUBOTA Haematocrit Reader. All capillary tubes yielding a PCV of less than 20% had a thin smear made from the other tube to check for haemoparasites. The smear was fixed in methanol for 5 minutes and stained in freshly prepared 10% Giemsa for 30 minutes. After drying the stained blood smears were examined under oil immersion at x 1000 magnification. At least 20 microscopic fields were examined on each smear.

For all samples from Chipembi the buffy coats were routinely examined for trypanosomes. A diamond pencil was used to cut the capillary tube at the junction between the buffy coat and the erythrocytes. The buffy coat was then placed on a clean glass slide and a coverslip placed on the buffy coat. The buffy coat smear was examined under a low magnification (x 400) for motile trypanosomes.

3.7 Meteorology

Total monthly rainfall figures were collected from the agricultural extension officer at each site during the monthly sampling.

3.8 Statistical Analyses

The results were analysed in relation to age, and season. Analysis of variance (2 way) was used to compare statistical significance of the mean monthly eggs between different age groups and mean monthly worm uptake. The study period was divided into dry season (July 1994 to October 1994 and April 1995 to September 1995) and wet season (November 1994 to March 1995) for analysing differences between seasons. All analyses were performed with the Statistix® computer package (1992) taking a P value of 0.05.

Individual egg counts were transformed to the logarithm (count+25) to stabilize variances for statistical analysis. The transformed means were then back transformed for tabulation and graphing. The difference in total worm counts of tracers between the dry (April to October) and the rainy (November to March) seasons was also compared statistically by analysing the variances based on logarithmic transformation. Mean worm uptake data were square root transformed for presentation. However, untransformed worm uptake data were analysed.

Prevalence (P) is synonymous to point prevalence which is the proportion of the animals infected by a particular disease at one particular time

Therefore: $P = r/n$

where P = point prevalence

r =number of animals affected

n = total number of animals examined

The initial study group of 80 goats on each site which were ear-tagged was balanced for age groups. Unfortunately however, due to drought conditions many goats were either sold or consumed or died during the course of the study such that at the end of the study sampling was unbalanced.

PART FOUR

RESULTS

4.1 Meteorological data

The monthly rainfall figures over the study period commencing July 1994 to September 1995 are shown in Fig.5 and Fig. 6. From the rainfall pattern for the two areas, rain was recorded for the months of November to April (Chipembi) and October to March (Shibuyunji). Total annual rainfall for Chipembi and Shibuyunji were 355.8 and 303.5 mm, respectively. The number of rain days for these months were 2,10,6,8,3, and 1 (Chipembi) respectively and 4,1,4,4,5, and 3 (Shibuyunji) respectively. The period between June to October 1994 and April to September 1995 constituted the drier seasons during the study period. No rain was recorded during this dry season in both study areas. These in general follow the typical Zambian pattern of a single rainy season of five to six months per year.

Bioclimatographs with mean monthly temperatures and total precipitation from 1989-1995 (Figs. 3 and 4) were prepared to demonstrate the unusually dry conditions prevalent in the province in the past two years and the resultant limitations in the development of the free living stages of the ruminant nematodes. The data were obtained from the Zambia Meteorological Department Office in Lusaka.

4.2 Parasite spectrum

The nematodes species present in the faeces of farmed goats were identified either by faecal culture or by their characteristic eggs. From coprocultures and differential larval counts the following nematode species were identified: *H. contortus*, *Cooperia* spp., *Bunostomum* spp., *Strongyloides papillosus*, *Trichostrongylus* spp., and *Oesophagostomum* spp. *Gaigeria* spp. eggs were present in the faeces of farm goats but were seen infrequently, only during the rainy season. No *Trichuris* eggs were seen in all the faecal samples examined from farm goats although adult *Trichuris ovis* worms were found in tracer goats.

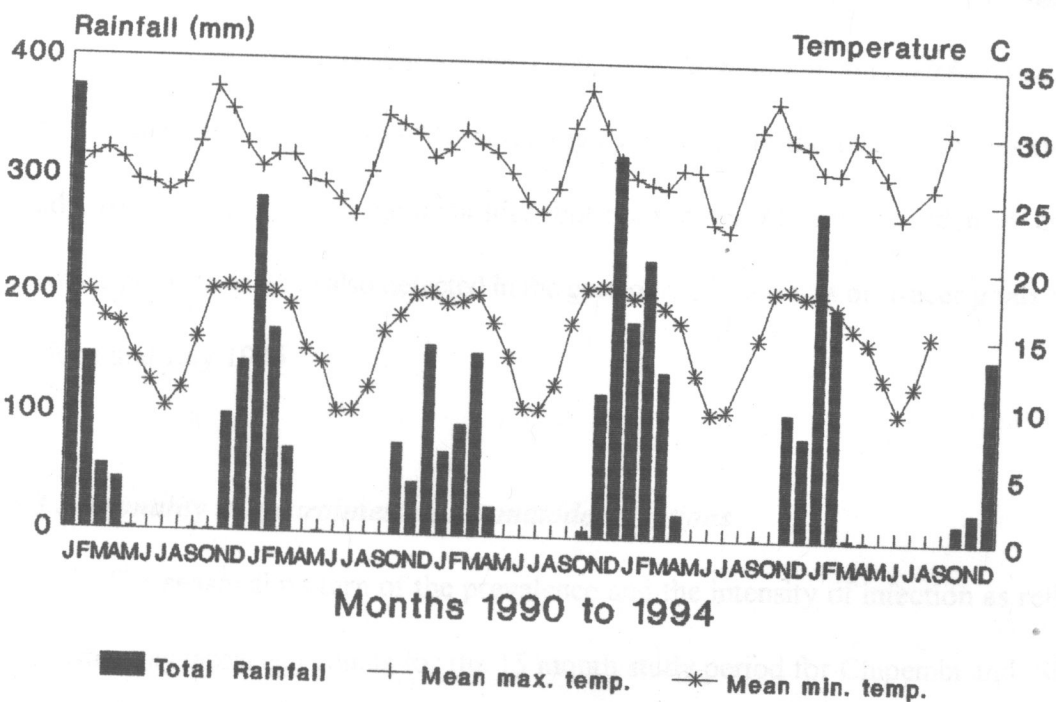


Figure 3. Bioclimatograph of Kabwe (1989 - 1994) representing Chipembi.

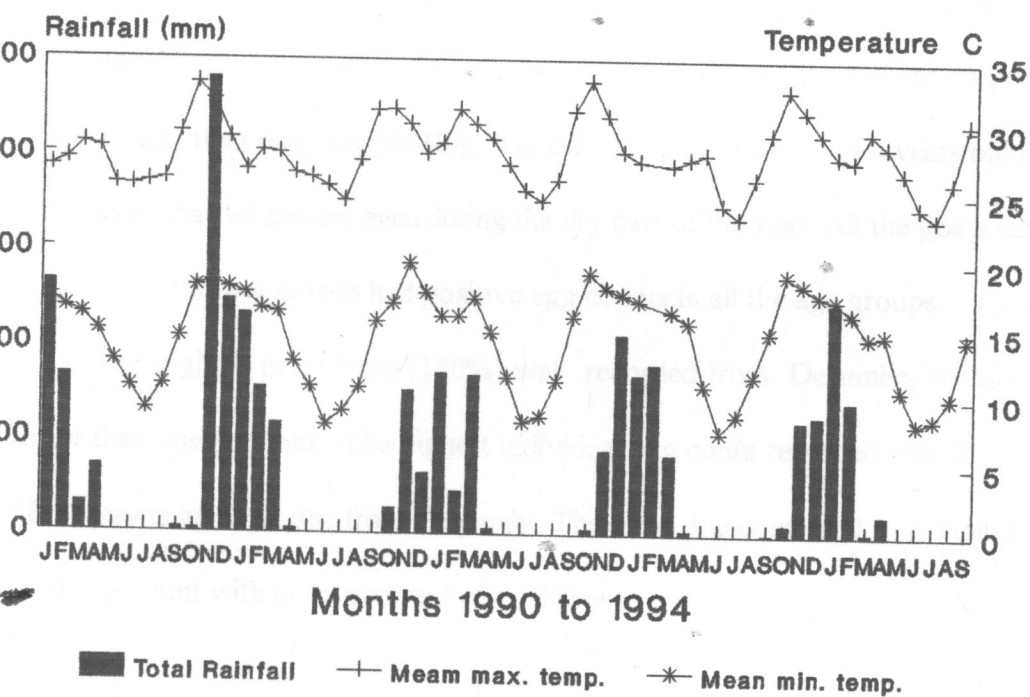


Figure 4. Bioclimatograph of Mount Makulu (1989 - 1994) representing Shibuyunji.

The following gastrointestinal nematode species were recovered from tracer goats, *H. contortus*, *T. colubriformis*, *Bunostomum* spp, *O. columbianum* and *Trichuris ovis*.

Coccidian oocysts and *Moniezia* eggs were seen in the faecal samples throughout the study, sometimes in very large quantities, but no attempt was made to identify or count them. Cestode proglottids were also detected in the gastrointestinal tracts of tracer goats in the months of June and July 1995.

4.3 Seasonality in gastrointestinal nematode infections

The seasonal pattern of the prevalence and the intensity of infection as reflected by the mean monthly faecal egg counts for the 15 month study period for Chipembi and Shibuyunji are summarised in Figures 5,7 and 6,8 respectively and Tables 8 to 11 of Annex 5. Egg counts were made on a total of 1,852 faecal samples. Statistical analysis demonstrated that there was a significant positive correlation ($P < 0.05$) between the mean monthly EPG and the rainfall pattern.

Prevalence rates during the dry season were in the range of 0 to 85 percent in young animals of less than one year old (Fig. 7 and 8). Goats more than two years old had prevalence rates of more than 80 percent even during the dry part of the year. All the goats examined during the middle of the wet season had positive egg counts in all the age groups.

The highest prevalence (100%) was recorded from December to July 1995 in goats greater than one year old. The highest individual egg count recorded was 15,700 in the month of February in an adult doe from Chipembi. The same doe continued to exhibit a relatively high faecal egg count with no concurrent clinical signs.

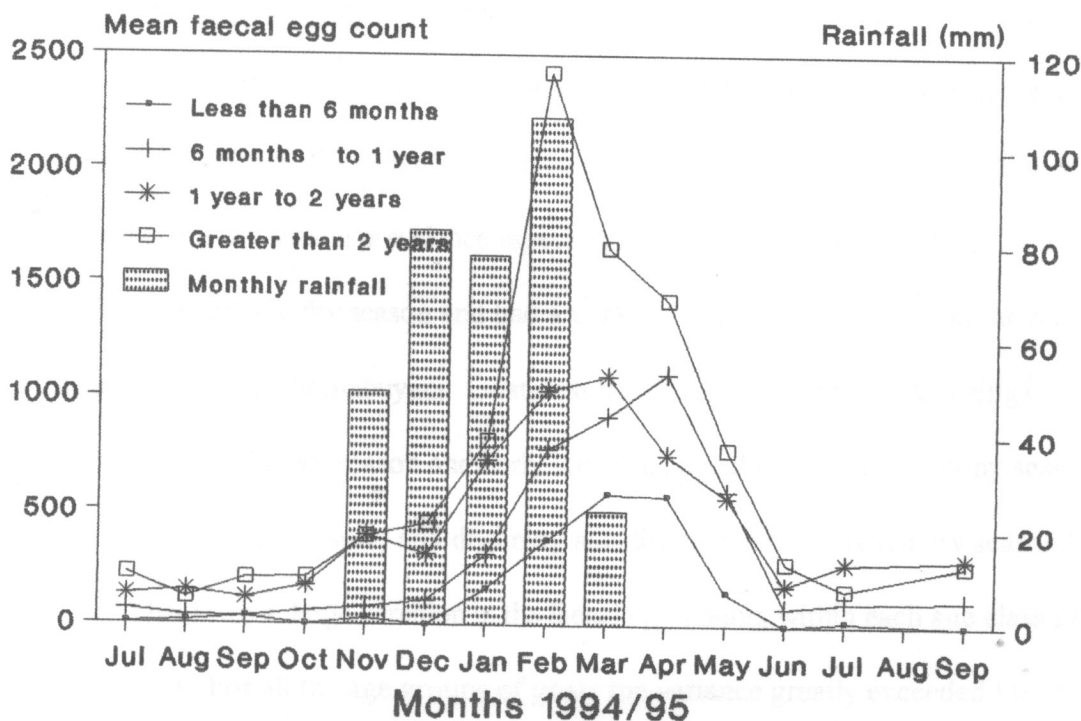


Figure 5. Mean (geometric) monthly eggs per gram (EPG) for farm goats in Chipembi according to age groups.

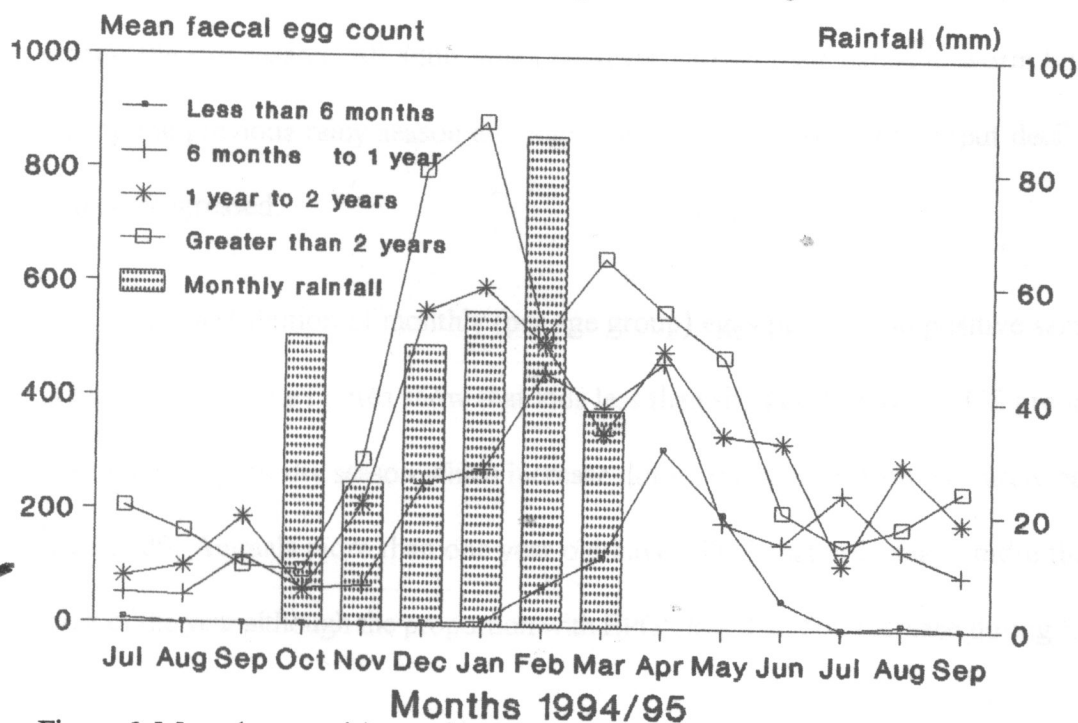


Figure 6. Mean (geometric) monthly eggs per gram (EPG) for farm goats in Shibuyunji according to age groups.

The prevalence and mean monthly eggs values were highest in January for Shibuyunji (100 and 884 respectively) and February for Chipembi (100 and 2418 respectively) in goats greater than 2 years. Wet season prevalence of strongyle infections were significantly ($P<0.05$) higher than for dry season prevalence especially for kids less than six months which were generally uninfected during the dry season and had a peak in the faecal egg counts in the month March for Chipembi and April for Shibuyunji. Goats less than six months had very low Eggs tending towards zero throughout the dry season and early wet season and only rose mid-rainy season, peaking at the end of the rainy season, and declining steadily thereafter to reach dry season levels in June.

There was a large variation in the faecal egg counts within each age class throughout the study period. For all the age groups of goats the variance greatly exceeded the monthly means. The small rise of the EPGs in goats of Chipembi greater than 2 years a month before the first rains is unexpectedly surprising. This rise was however not statistically ($P>0.05$) significant. Of all the young, uninfected kids introduced to the main group only three managed to get infected during the dry season. All adult goats however carried their parasitic worm burden acquired during the previous rainy season although the faecal nematode egg output declined as the dry season progressed.

The distribution of monthly (per age group) eggs per gram in positive samples is shown in Figures 9-16. The figures show that kids less than six months have EPGS predominantly less than 200 during the dry season which increase during the rainy season but rarely becoming more than 1000. Animals more than one year old have EPGS that are usually more than 500 during most of the year although the proportion with EPGS less than 500 increase during the dry season.

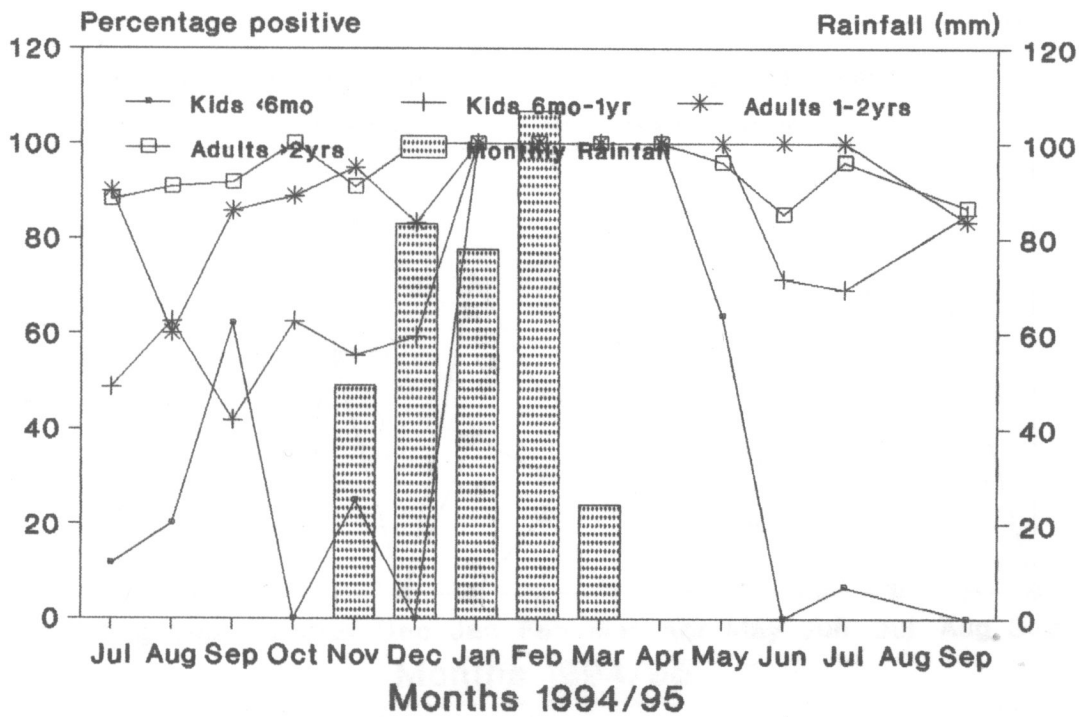


Figure 7. Prevalence of strongyle eggs in faeces of goats in Chipembi, 1994/95.

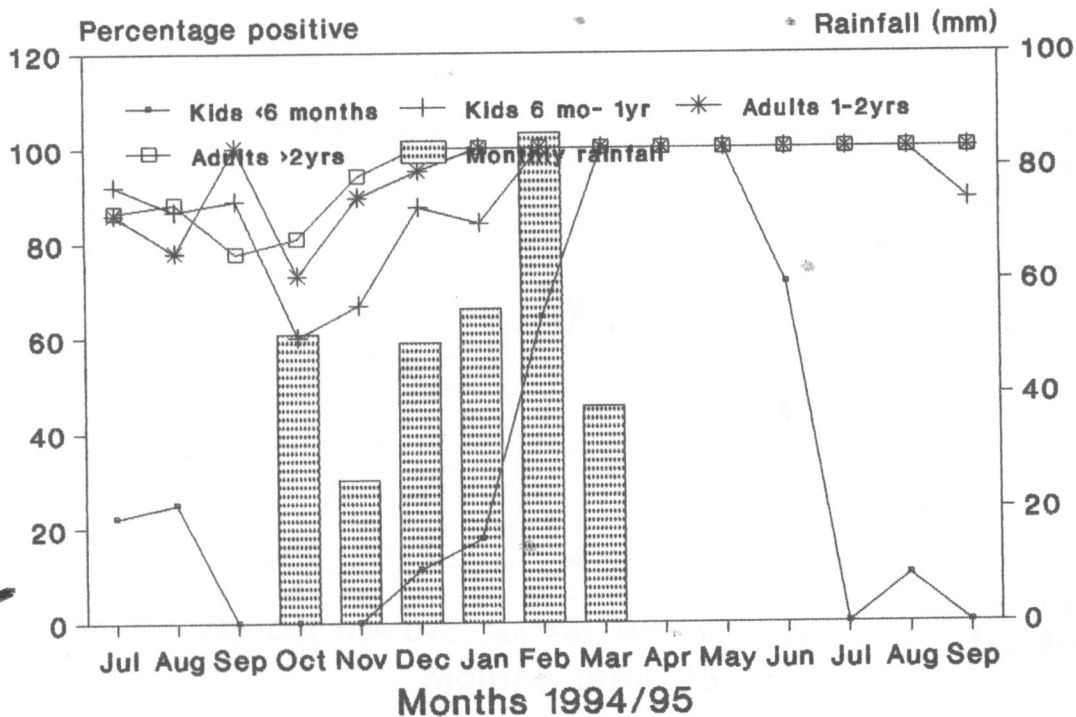


Figure 8. Prevalence of strongyle eggs in faeces of goats in Shibuyunji, 1994/95.

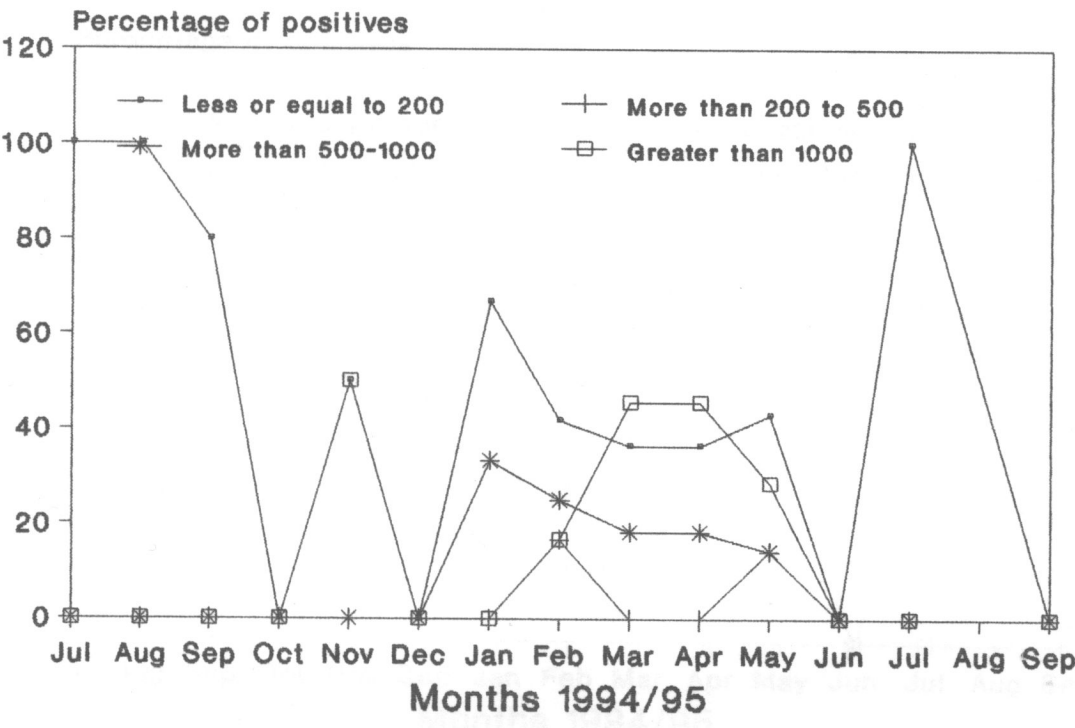


Figure 9. Distribution of faecal egg counts for goats in Chipembi aged less than six months.

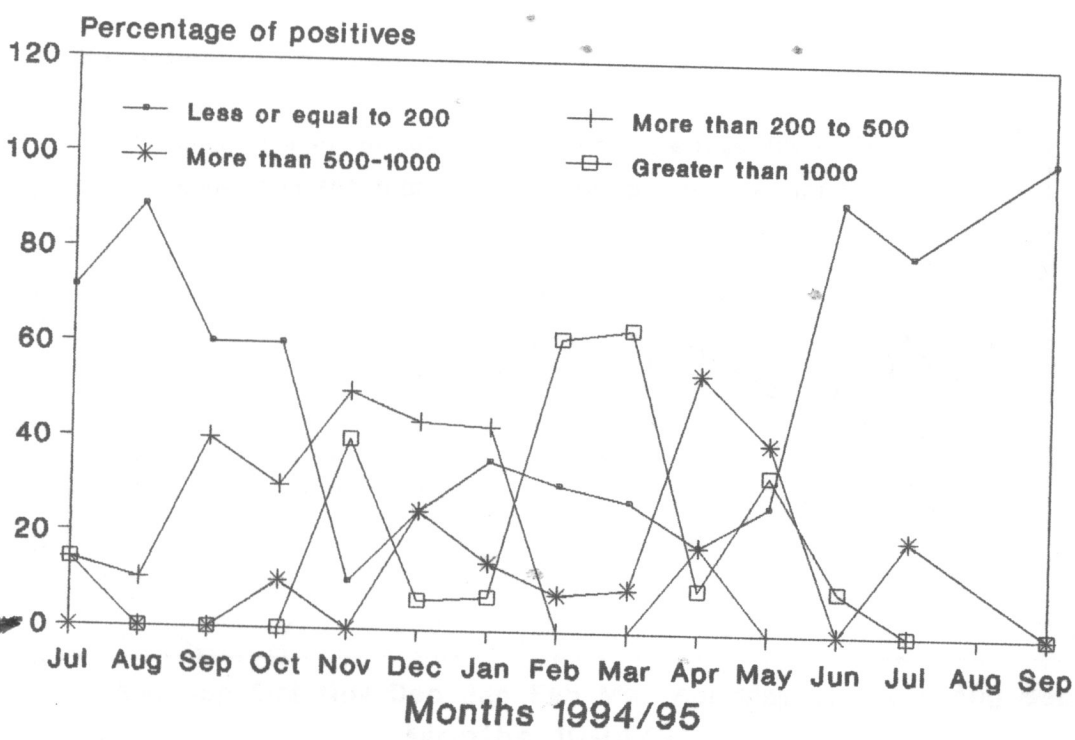


Figure 10. Distribution of faecal egg counts for goats in Chipembi aged six months to one year.

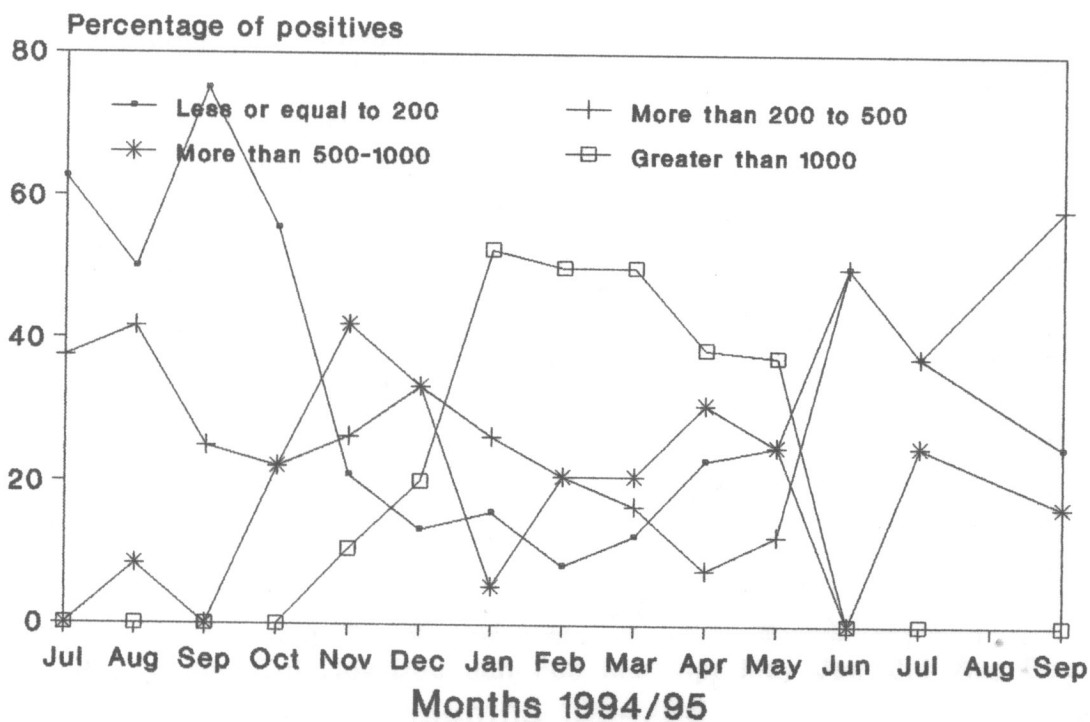


Figure 11. Distribution of faecal egg counts for goats in Chipembi aged one year to two years.

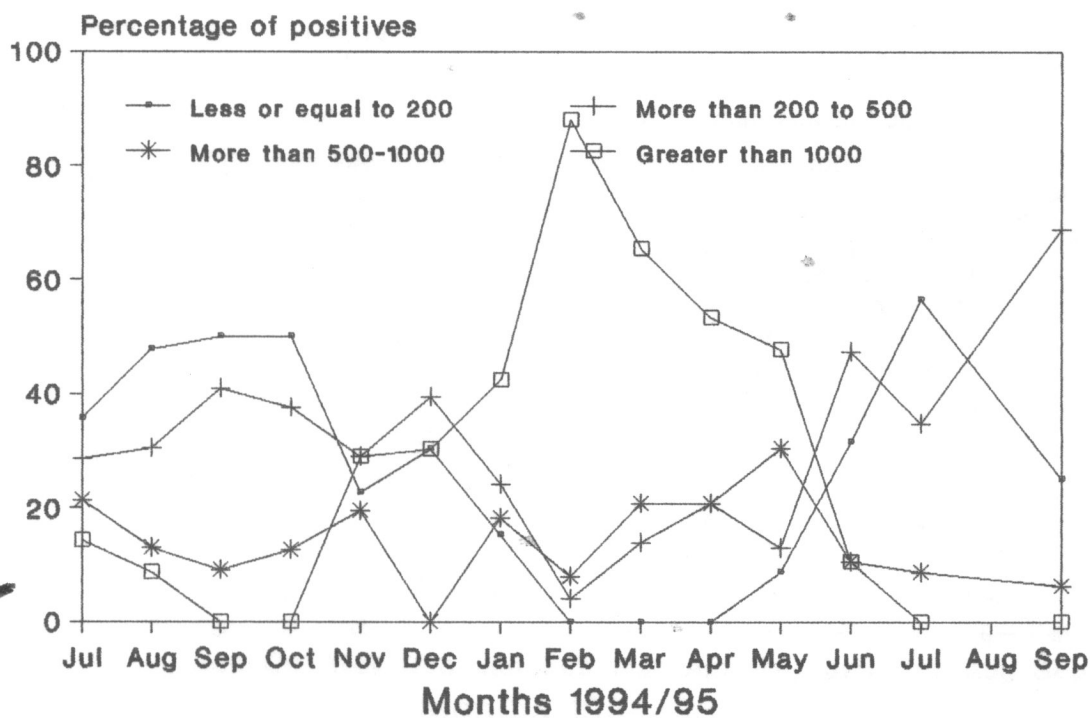


Figure 12. Distribution of faecal egg counts for goats in Chipembi aged more than two years.

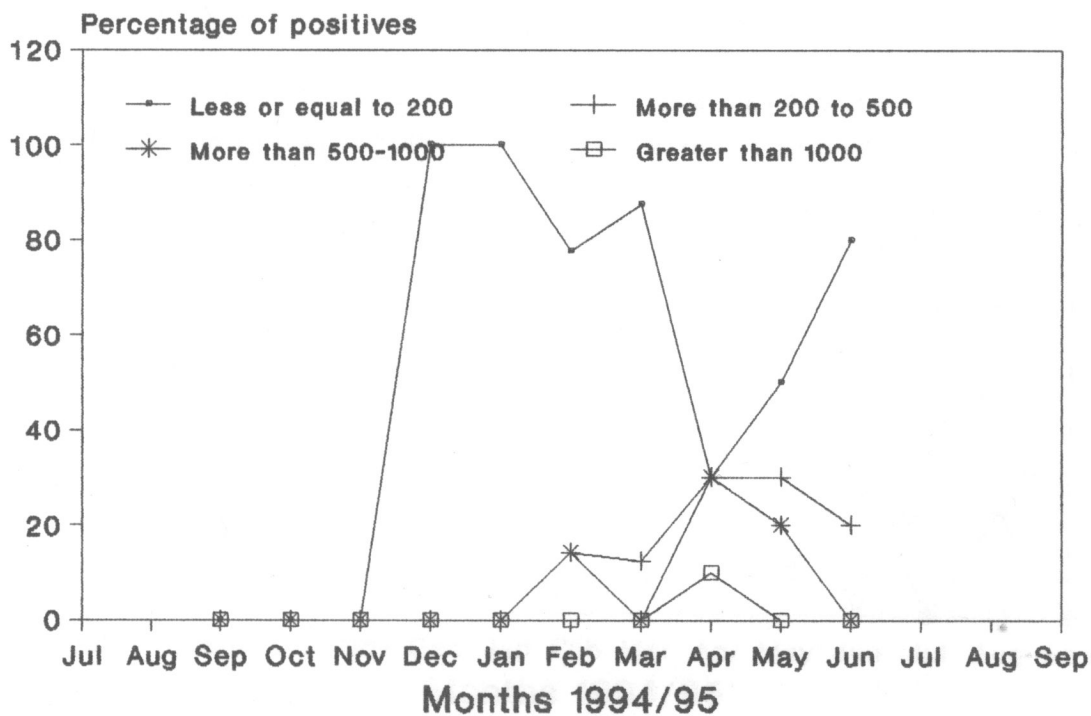


Figure 13. Distribution of faecal egg counts for goats in Shibuyunji aged less than six months.

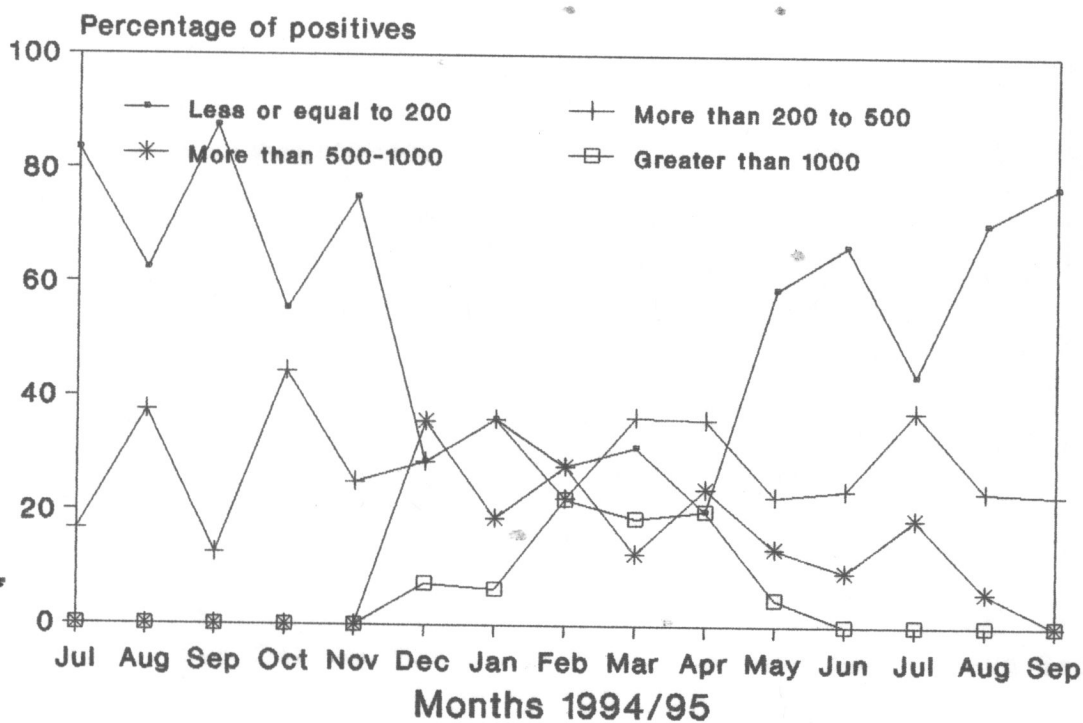


Figure 14. Distribution of faecal egg counts for goats in Shibuyunji aged six months to one year.

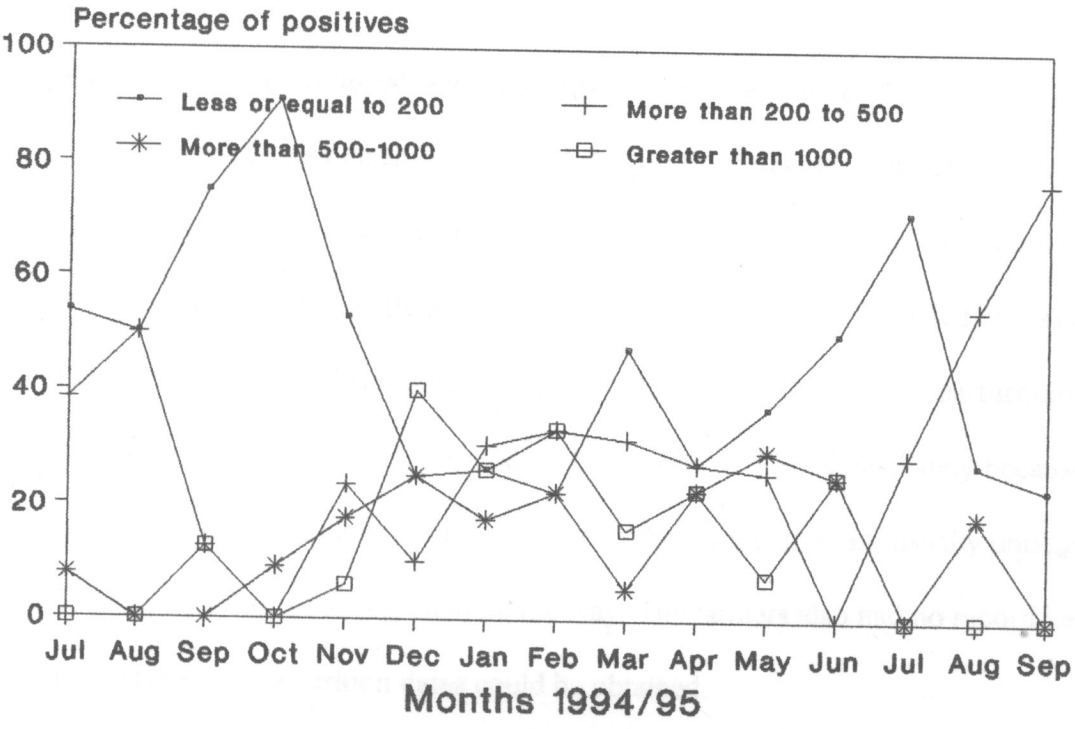


Figure 15. Distribution of faecal egg counts for goats in Shibuyunji aged one year to two years.

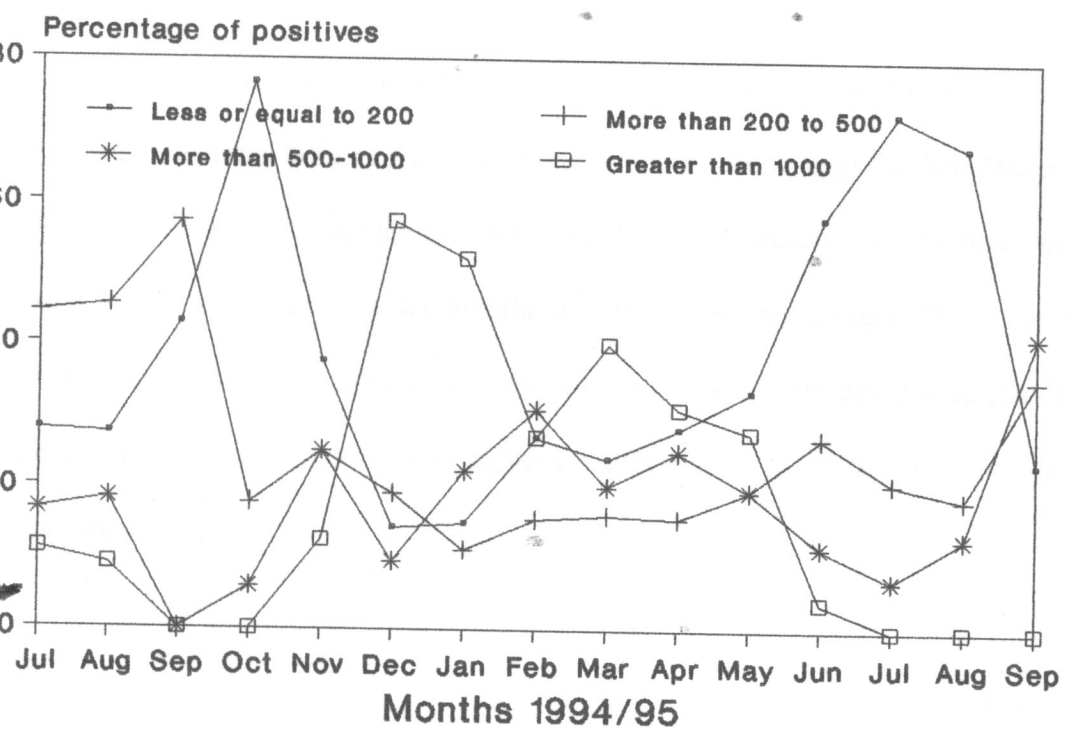


Figure 16. Distribution of faecal egg counts for goats in Shibuyunji aged more than two years.

4.4 Effect of reproductional status and age on faecal egg output

Due to the poor quality data collected from the farmers in relation to reproductive status (date of kidding, lactation stage etc.) the effect of parturition on faecal egg counts of does could not be assessed. When an attempt was made to analyse the data provided, it was noticed that a lot of contradictory and inaccurate information was given on the dates of parturition and lactation status. Data provided at sampling time could not be verified immediately because most of the farmers had to walk a considerable distance to the sampling point, usually untagged kids were left at home for fear of losing them on the way. The farmers also had no record keeping system from which exact parturition dates could be obtained.

As indicated by Figs. 5 and 6 goats greater than 2 years had higher eggs and prevalence throughout the year followed by those from one year to two years. Goats less than 6 months largely had zero EPGS during the dry season and early wet season with peaks mid-rainy season and a steady decline after the end of the rains to reach dry season levels again by June. During the dry season at least 80% of the adult goats were excreting eggs in their faeces with a large proportion having EPGS greater than 500. The largest difference thus, was observed between the goats which were less than six months and the other age groups. There was a significant difference ($P < 0.05$) in the mean monthly EPGS for all age groups during the dry season but during the rainy season there was no significant difference ($P > 0.05$) between the age groups more than six months.

4.5 Haematology

The changes in mean monthly packed cell volume (PCV) values observed per age class during the study period are shown in Figs. 17 and 18 (Tables 12 and 13 of the Annex 6). From this it is apparent that PCVs do not show any strong seasonal variation nor any correlation to faecal egg counts. The haematocrit values do not differ significantly ($P>0.05$) between the dry season and the rainy season. Only a few individual animals showed a marked reduction in packed cell volume as can be seen from the range of values. However, the goats with the lowest PCVs did not necessarily have very high faecal egg counts.

From all blood smears examined no haemoparasites were observed. In particular for Chipembi no trypanosomes were seen on the buffy coats throughout the entire study period, although trypanosome infections are recorded in cattle in the area (Anonymous, 1994b).

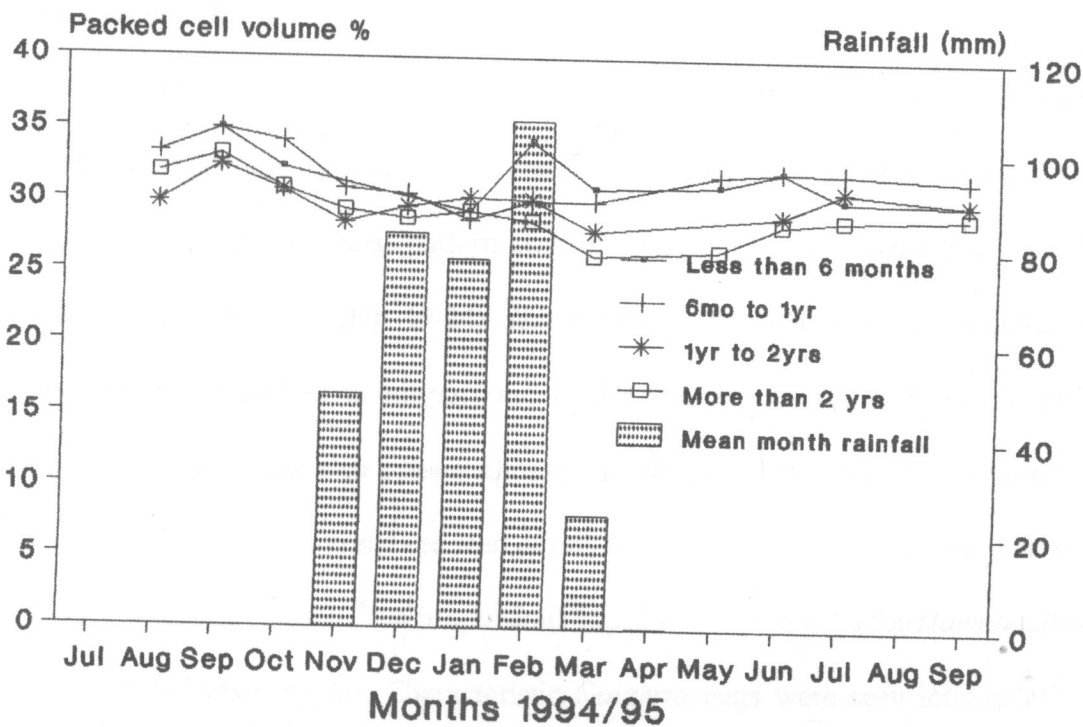


Figure 17. Mean monthly packed cell volumes (PCVs) for farmed goats in Chipembi, according to age groups.

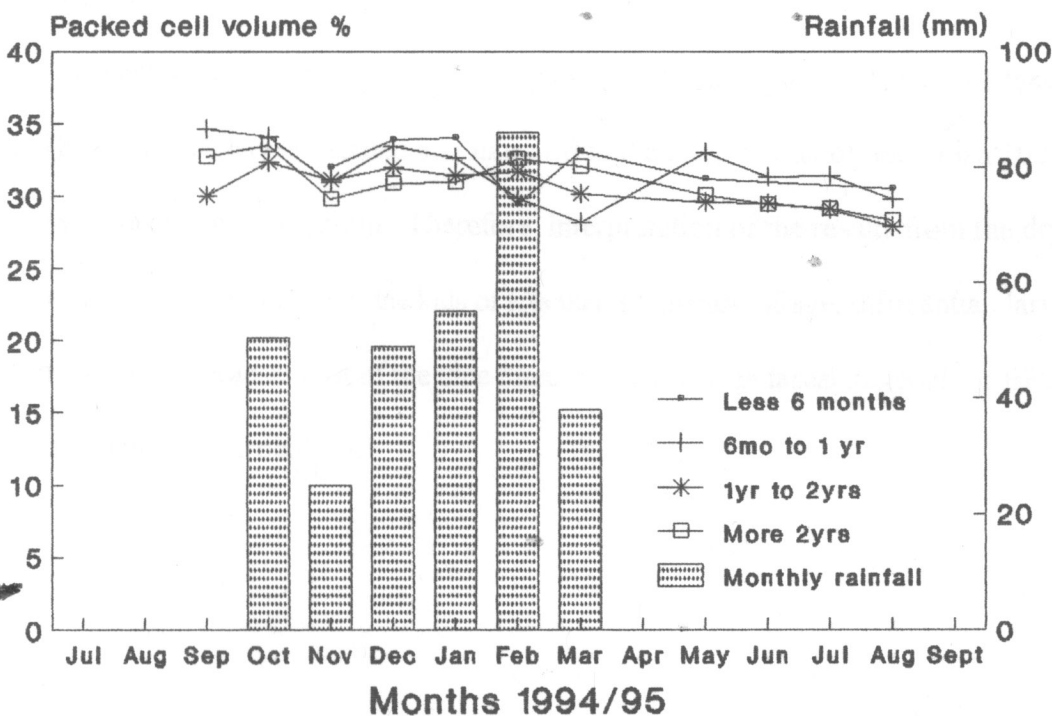


Figure 18. Mean monthly packed cell volumes (PCVs) for farmed goats in Shibuyunji, according to age groups.

4.6 Larval culture

From the differential larval counts it can be seen that *Haemonchus* and *Trichostrongylus* are the most prevalent genera of gastrointestinal nematodes in goats in the study areas (Fig. 19-24). A consistent seasonal pattern was evident for *H. contortus* and *Trichostrongylus* irrespective of age group (Fig. 19-24). *H. contortus* was present in the faecal cultures throughout the year but increases in proportion in the wet season and reduced in the dry season. *Trichostrongylus* was also present throughout the year but unlike *H. contortus* it was more abundant in the dry season and reduced during the rainy season to reach very low levels towards the end of the rainy season. The proportion ranged from 25 to 92% for *Haemonchus*, and 6% to 75% for *Trichostrongylus*. Characteristic *Gaigeria* eggs were seen infrequently from faecal samples during the rainy season from December to March. Larvae for other species were observed infrequently, (0-3% for *Strongyloides*, 0-1% for *Cooperia*, 0-12 %for *Oesophagostomum*, and 0-2% for *Bunostomum*) therefore seasonal patterns could not be described. However, during the dry season very few eggs were present in the faeces of the goats. Thus, very few larvae hatched and more often than not, a total of less than 100 infective larvae were counted per age group. Therefore, interpretation of the results from the dry season should be taken with caution. For the kids of less than six months of age, differential larval counts could not be done because most of the time there was not enough faecal material for EPG determination let alone for coproculture.

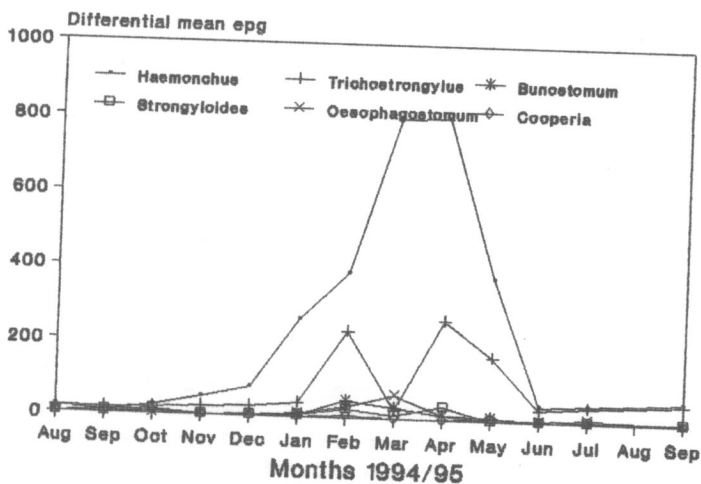


Figure 19. Differential mean epg for goats in Chipembi aged between six months and one year.

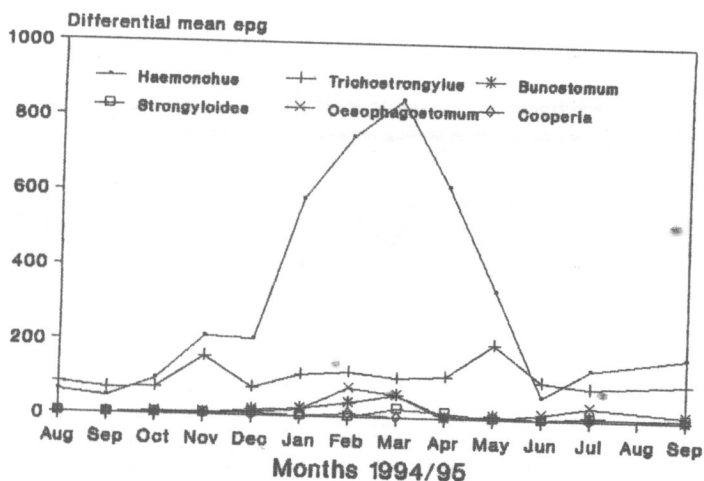


Figure 20. Differential mean epg for goats in Chipembi aged between one year and two years.

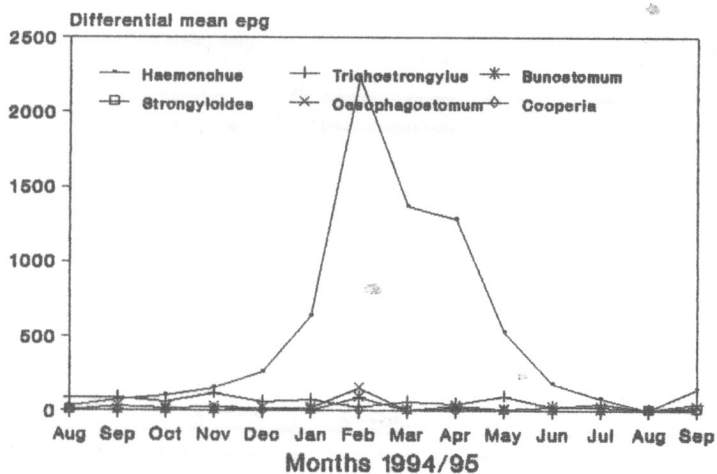


Figure 21. Differential mean epg for goats in Chipembi aged more than two years.

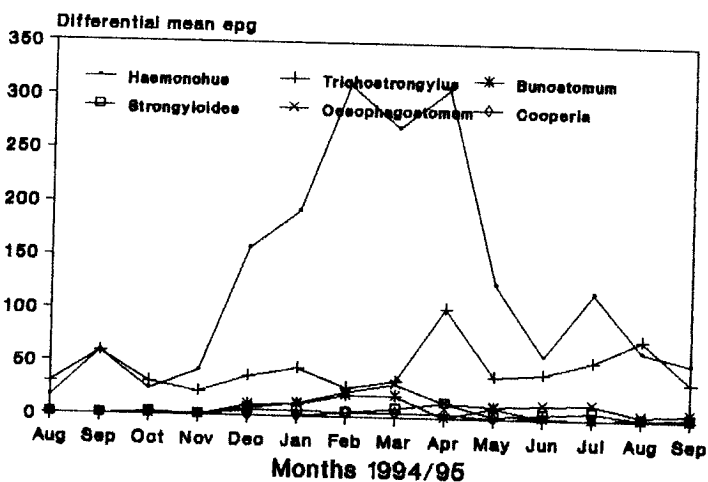


Figure 22. Differential mean epg for goats in Shibuyunji aged between six months and one year.

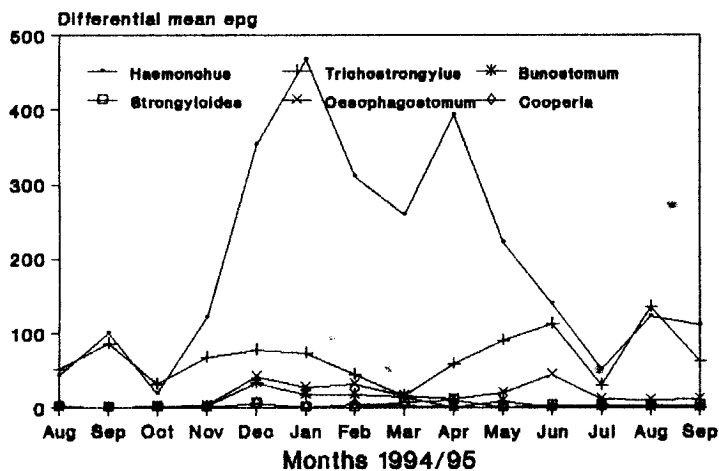


Figure 23. Differential mean epg for goats in Shibuyunji aged between one year and two years.

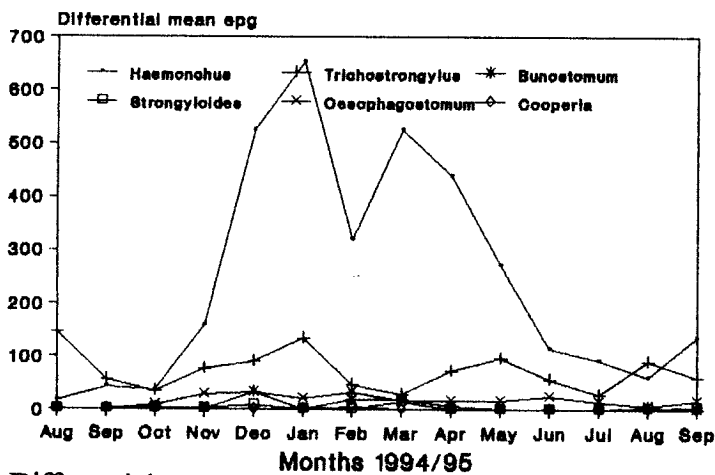


Figure 24. Differential mean epg for goats in Shibuyunji aged more than two years.

4.7 Clinical Observations

The majority of infected animals showed no signs attributable to severe gastrointestinal nematode infection. Some study animals died during the study period but no postmortem examinations were performed. However, some of the deaths were attributed, by the owners, to traumatic injuries. Signs of moderate emaciation and weight loss were evident in a few of the study animals but could not be attributed solely to Helminthosis.

4.8 Tracers

During the study three(3) and two(2) tracer goats in the months of September and October respectively died while on site in Chipembi. No postmortem examinations were carried out due to poor communication links and distance. Further, two(2) more tracers died in August due to grain overload after letting themselves into a granary. One other tracer died during the month of June 1995 after getting stuck in the railings of the pens. Post mortem was carried out on the last goat but it revealed nothing significant as the animal was in a moderate state of decomposition. Identification was made on the sexually mature worms according to Soulsby (1982).

A total of 57 tracers were necropsied and examined. Worm burdens were nil during the dry months of June to August 1995 (Table 5, Fig. 25). *H. contortus* was the most predominant worm found in tracer goats with a maximum mean monthly worm uptake of 495 adults in January 1995. The worm burden pattern for *H. contortus* followed the rainfall pattern with an increase in the burden in December 1994, followed by a steady decline thereafter (Fig. 25). There was an increase in the *Trichostrongylus* worm burden during the rainy season. However, unlike with *H. contortus*, there was no peak and mean monthly worm burdens fluctuated between 2 and 19 adult worms. *O. columbianum* was first seen in tracers in November 1994 and the number of worms

increased to reach a peak monthly mean of 64 in May 1995, one month after the last seasonal rains. Only very few *Trichuris* adult worms were found, starting in February the month with the highest precipitation, and peaking after the last rains in April. Only one *Bunostomum* adult worm each was observed in the months of March and April 1995. After artificial digestion of the abomasal mucosae immature early L₄ larvae of *H. Contortus* were only found during the month of December and May and represented 5 and 8 percent respectively of the monthly total abomasal adult worms.

Table 5. Mean monthly worm burdens of tracer goats in Chipembi 1994/95.

MONTH of grazing	Number of Tracers examined	<i>Haemonchus</i> Mean (range)	<i>Trichostrongylus</i> Mean (range)	<i>Oesophagostomum</i> Mean (range)	<i>Trichuris</i> Mean (range)
September	2	0 (0)	0 (0)	0 (0)	0 (0)
October	3	3 (0-10)	7 (0-20)	0 ()	0 ()
November	3	3 (0-10)	2 (0-5)	1 (0-5)	0 ()
December	5	11 (0-25)	7 (0-20)	1 (0-1)	0 ()
January	5	495 (5-1900)	19 (0-55)	1 (0-3)	0 ()
February	6	268 (10-1085)	8 (0-25)	11 (0-114)	0 ()
March	6	147 (20-800)	12 (0-40)	21 (5-160)	1 (0-7)
April	6	54 (0-100)	10 (0-50)	46 (10-120)	1 (0-9)
May	6	27 (0-90)	4 (0-10)	64 (0-168)	14 (1-25)
June	5	0 ()	0 ()	0 ()	1 (0-5)
July	6	0 ()	0 ()	0 ()	0 ()
August	4	0 ()	0 ()	0 ()	0 ()

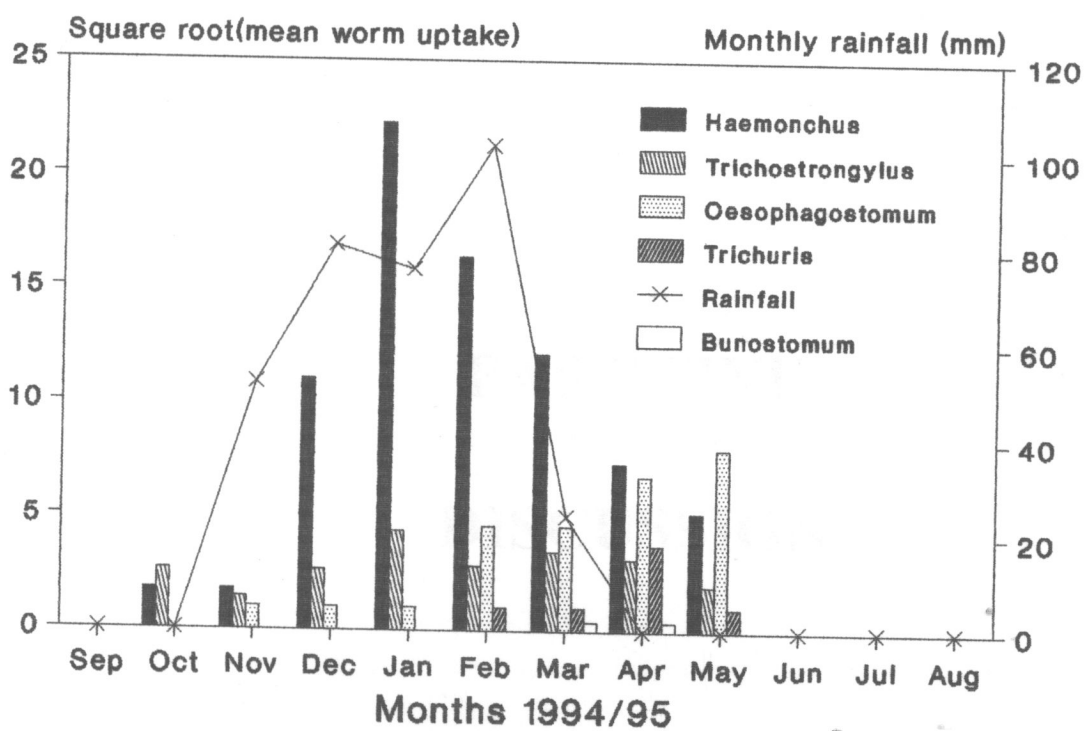


Figure 25. Mean monthly worm burdens of tracers from Chipembi.

PART FIVE

DISCUSSION

This study indicates a distinct seasonal pattern in gastrointestinal nematode faecal egg excretion in field infections in the traditional grasslands of Zambia. This agrees with the findings of Nakazawa *et al.* (1989) in a study carried out in goats in the Luangwa district of Zambia. Season was the most important factor influencing the strongyle egg output. Excretion during the rainy season was highest, followed by the post rainy season and lastly by the dry season as indicated by mean faecal egg counts and the percentage of animals excreting more than 200 EPG. It was only during the dry season that differences related to age were very significant ($P < 0.05$), especially between the animals less than six months and the other age groups, with the older animals excreting more eggs in their faeces. This is in agreement with the findings of Jacquet *et al.* (1995) in goats in the dry areas of southern Mauritania but quite unexpected in comparison to findings in sheep where lambs had significantly higher faecal egg counts than adult sheep.

The mean total egg counts for both areas rose in November/December 1994 due to an increased *H. contortus* egg-output and reached a peak in January/February 1995 (Figs. 5 and 6). This is demonstrated by the increase in the *H. contortus* larvae from an average of 68% in October 1994 to 92 % in February 1995. The declining trend of the EPGs which was observed mid-rainy season can be attributed to self-cure phenomenon due to increased acquired immunity, as described in sheep in the semi-arid areas of Kenya (Allonby and Urquhart, 1973) and or better nutrition which enhanced the animal's immunity. These two factors would lead to expulsion of adult worms and also suppress the parasites egg laying capacity (Connan, 1974 cited by Connor *et al.*, 1990). Houtert *et al.* (1995), in a study with sheep conclude that supplementary feeding with proteins substantially reduced the production losses attributable to infection with *T. colubriformis* and was associated with enhanced expulsion of the parasite burden.

The aforementioned rise in mean total faecal egg counts in November and mean total worm counts in December with the onset of the rainy season was similar to that described for sheep by Njau (1987) and Swan (1970), Viljoen, 1964; Allonby and Urquhart, 1975; Horak, 1978).

The epidemiological pattern observed in the two study areas is essentially attributable to one factor: the presence of larvae on pasture during the warm wet rainy season. During this season there is sufficient moisture and suitable temperatures for the development of the pre-parasitic stages of all worms. Asanji (1988) also recorded a wet season peak in faecal egg counts and attributed it to two factors: termination of arrested larval development at the end of the dry season and augmentation by larvae newly acquired from vegetation since during this time the climatic conditions were conducive for larval development. The low EPGs recorded in the dry season could be associated with the self-cure phenomenon (Connor *et al.*, 1990) and or the absence of re-infection (Vercruysse, 1983). The fall in EPGs could also indicate a decline in the worm burden due to sheer mortality of ageing worms. There was a consistent decline in the mean EPG's for all age groups beginning from March into the dry season. After the end of the rainy season temperature and moisture conditions are very unconducive to larval development and survival on vegetation (Okon and Enyenihi, 1977), and any new larval intake could only be from pastures surrounding water bodies (ponds, rivers, lakes, watering points or wells) where the conditions are more favourable for larval survival. The extremely small size and low initial moisture content of the faecal pellets of goats predispose them to very rapid drying during hot dry weather and therefore make them a much less suitable environment for the development and survival of free-living stages than the much larger bovine dung pad, which generally has a much higher moisture content (Chienjina *et al.*, 1989). It is conceivable that some L₃ could develop and survive inside ovine and caprine faecal pellets during the dry season on shaded pasture with

adequate grass cover, especially if there was some precipitation during the period of deposition. This would account for the few animals that acquired infections during the dry season. Chienjina *et al.*, (1989) concluded that pastures used exclusively by sheep and/or goats in the derived savanna may be considered free of L₃ larvae one month after the end of the rains up to the end of the dry season. A small rise in mean EPGs was observed in mature goats in the late dry season of 1994 and 1995 distinctly so in Shibuyunji. A similar brief, dry-season rise in nematode EPG in the absence of detectable larvae on pasture was also observed by Njau (1987) in Tanzanian sheep. Vercruysse (1983) also noticed a similar rise in EPGs one to two months before the onset of the rainy season in Senegal. Southcott *et al.* and Mitchell (1972, 1974 both cited by Njau, 1987) associated this phenomenon with loss of host immunity due to stress with the result that the fecundity of the female *H. contortus* worms increases or arrested larvae become able to continue their development. It could be attributed to the simultaneous maturation of inhibited larvae due to stress of the harsh weather conditions and malnutrition, since larval uptake and infections during the dry season can be precluded.

Levine (1963) considered 50mm or more of rainfall and 15-37°C mean monthly temperature as optimum conditions for the pasture transmission of *Haemonchus* and 50mm or more rainfall and only 6-20°C, as optimum for transmission of *Trichostrongylus*. Fraser *et al.* (1991) also notes that 50mm monthly rainfall is the critical minimum for the development of the free-living stages of *Haemonchus* spp. As illustrated by the bioclimatographs for Shibuyunji and Chipembi (Figs. 5 and 6) during the study period, the critical rainfall requirement for larval development and survival was only fulfilled during the months of October 1994, January and February 1995 for Shibuyunji and December 1994, January and February 1995 for Chipembi. The mean monthly temperature with a minimal 11°C (July 1995) provided temperatures favourable for development of the free living stages at all times during the year.

The total seasonal rainfall of 355.8mm and 303.5mm for Chipembi and Shibuyunji respectively were very low. In normal years 800-1000 mm are usually recorded for both sites. Egg counts, worm burdens, and tracer larval intake might have been higher in a year with normal quantity of rain. Clinical signs characteristic of severe gastrointestinal nematode infections would probably have been observed.

The use of faecal egg counts as an ante-mortem means of diagnosing naturally-acquired gastrointestinal nematode infections of domestic livestock has been practised for many years (Vercruysse, 1983). Faecal egg output sometimes varies and does not necessarily correlate with worm burdens because of the population dynamics of these parasites (Fraser *et al.*, 1991; Leggoe, 1991; Stear *et al.*, 1995). However, Robert and Swan (1981) and Fakae (1990b) found a strong correlation between the strongyle worm burden and EPG on ovine haemonchosis. Leggoe (1991), in Australia found that the correlation between egg counts and total worm counts was weaker during the wet months than during the drier months. This would tend to re-emphasize the value of the faecal egg count as a quick and reliable method for assessing and monitoring trends in worm burdens of small ruminants under field conditions (Fakae, 1990b). The discrepancy between EPG and worm burden as seen in an individual animal (Allonby and Urquhart, 1975) is likely to be reduced when egg counts of a large number of animals are available (Roberts and Swan, 1981).

Monthwise figures of percentage of larvae on differential larval count show that a marked seasonal pattern was followed by *Haemonchus* and *Trichostrongylus* spp. only. A peak was recorded from December 1994 to February 1995 and June to July respectively. These results concur with the findings of Nakazawa *et al.* (1989). *H. contortus* and *Trichostrongylus* emerged as the most prevalent species. These results are in agreement with the findings of Grant (1981), Specht (1982), Craig (1986) and Vercruysse (1983) who studied nematode parasites of small ruminants in Zimbabwe, Mozambique, southern United States of America and Senegal

respectively. *Cooperia* spp larvae were only seen from faecal cultures infrequently contributing only 1% of the total mean monthly larval count. This would agree with the assertion by Bisset(1980, cited by Fakae, 1990) that *Cooperia* spp. are better adapted to sheep. *Cooperia* spp. are predominantly parasites of cattle (Boomker *et al.*,1994), thus the low infrequent infection seen in the goats was probably acquired from cattle and may be regarded as accidental.

There is a discernible seasonal trend in the proportion of goats carrying strongyle eggs at both sites with all goats sampled from shedding strongyle eggs by mid-rainy season. There is then less animals shedding strongyle eggs during the dry season.

Regarding the age/faecal egg count relationship (Figs. 5 and 6), the faecal egg counts for the adult animals were unexpectedly high. Goats of more than two years old exhibited egg counts significantly ($P<0.05$) higher than all of the other younger age groups. The constantly high egg output observed in the goats seems to support the reported hypothesis that goats do not develop high levels of host resistance (Pomroy and Charleston, 1989), as do sheep and cattle (Rahman, 1992). However, Al-Quaisy *et al.*(1987), in an experimental *H. contortus* infection carried out in Iraq however, demonstrated that the percentage of adult worm recovery in goats was less than in sheep indicating that goats are more resistant to haemonchosis than sheep. The study however, demonstrated that goats had a higher recovery of the mucosal phase of the larvae than sheep, indicating a degree of immunity which prevented maturation of the same. A lack of challenge during the prolonged dry season combined with insufficient nutrition could be responsible for the lack of protective immunity at the start of the following rainy season (Njau, 1987; Kaufmann and Pfister, 1990). The adult goats therefore, may constitute a major source of pasture contamination. The study would thus indicate that no infection of young animals occurs during the dry season when conditions do not favour the development of infective larvae. Suckling kids are less exposed to a contaminated pasture during the rainy season as evident in the very low

EPGs observed in the very young kids probably as a result of a diet consisting mainly of milk and only a limited amount of grazing from vegetation contaminated with infective larvae. Fagibemi and Dipeolu (1982) demonstrated that strongyle eggs were found in faeces of small ruminants of 3 months of age and older and lowest infection rates were found in 3-6 month old kids and lambs. The relatively higher infection of strongyles in older animals, contradicts the findings of many previous studies in the sub-region (Lovelace *et al.*, 1989) and Asanji (1987) in Sierra Leone. The higher prevalence and mean EPG in older goats compared to young ones however, agree with the findings of Anene *et al.* (1994) in Nigeria who found a significantly ($P < 0.05$) higher strongyle infection and mean EPG in adults than in young animals, and Jacquet *et al.* (1992) in Mauritania. In contrast to both situations, Maingi *et al.* (1993) in Kenya reported that the prevalence of strongyle infection and mean faecal egg counts for kids (<6 months), immatures (6-12 months) and adults (> 12 months) did not vary significantly between the three age groups. With the aforementioned, it should be noted that faecal egg counts in age groups below one year may not represent the susceptibility of these animals because the samples includes a considerable proportion of animals weaned at the end, or even after, the rains when no third stage larvae are present on the pasture as demonstrated by the zero larvae pick up by tracers (Fig.25).

In several areas other than Zambia, hypobiosis of trichostrongylids in ruminants has been reported by a number of investigators (Gibbs, 1982). Many explanations for this phenomenon have been proposed, but most plausible seem to be those associated with ecological factors. Armour (1980) suggested that arrested development of larvae is a part of an adaptation of these nematodes to their environment triggered by climatic conditions unfavourable to further development of the free-living stages. This adaptation occurs in the tropics and subtropical areas when climate deviates to extreme heat and dryness (Hart, 1964; Ogunsusi and Eysker, 1979; Williams *et al.*, 1983; Altaif and Issa, 1983). Early fourth-stage larvae were only found in the

months of December and May. After each grazing period the tracers were housed, kept free from further exposure to helminth infestation, for three weeks which was sufficiently long for all L₃ acquired from pasture to develop into adult worms. Thus all immature stages of *H. contortus* recovered at necropsy in December 1994 and May 1995 had definitely undergone hypobiosis. The factors responsible for hypobiosis were not clearly defined but the phenomenon was associated with increasing levels of rainfall and absence of any environmental moisture. Another factor often associated with hypobiosis is density dependence which is a regulatory mechanism exerted by some nematodes on the structure of their populations under conditions of high infective dose (Michel, 1970 cited by Ikeme *et al.*, 1987). This could explain the occurrence of hypobiotic larvae in December when environmental conditions were very favourable for the development and activity of *H. contortus*. Although pepsin-HCl digestion of the mucosa, as used in the present study, is the most commonly used technique for the recovery of hypobiotic larvae, Gasbarre (1987, cited by Pandey 1994) demonstrated that when abomasal mucosae were incubated in buffered physiological saline for 24 hours, the total yield of the hypobiotic larvae of the bovine abomasal worm *Ostertagia ostertagi* was three times higher than when acid-pepsin was used. A similar technique was recommended by the World Association for the Advancement of Veterinary Parasitology, W.A.A.V.P. (Powers *et al.*, 1982). However this technique has not been evaluated for *H. contortus* infections of small ruminants. Thus if the same is true it would indicate that the results on the number of L₄ recovered would be underestimated. The recovery of only a few 4th-stage larvae from the abomasal mucosae digestion of tracers during the months of December 1994 and May 1995 should not suggest that arrested development does not occur to any significant degree in goats in Zambia. This is because at the time of the year (after the rainy season) when hypobiosis is expected to occur in naturally grazing ruminants in this part of the world, the tracer goats did not pick up any infective larvae from pasture. This problem could have

been overcome by having some tracer goats grazing the pastures for overlapping periods of up to three months each prior to necropsy.

The mean packed cell volumes did not change much during the entire study period and were clustered around 30% for all age groups. This is higher than normal range of packed cell volume in goats of 23 to 28.7% (Jain, 1986) but conform to the values obtained by Smith *et al.* (1986) in Nigerian dwarf goats. Thus, there was a very poor correlation between the faecal egg counts and the packed cell volume. This could be attributed to the relatively low mean eggs for all age groups and would tend to agree with the findings of Albers *et al.* (1990) that the correlation between faecal egg counts and haematological parameters tended to be higher when responses in haematological parameters were more pronounced. Smith *et al.* (1986), in Nigeria, also found that there is no definite relationship between haematocrit and parasite infestation when parasitism is low-level and subclinical. This could be ascribed to the activation of the erythropoietic system of the hosts leading to adequate compensation of the low level blood loss. This would therefore infer that a strong correlation between the two parameters would be more likely found in heavily parasitized animals.

Although no transmission of gastrointestinal nematodes was observed in tracer goats in the dry months (Table 5, Fig.25), naturally infected animals in the study areas harboured adult worms of all species as shown by egg counts and differential mean EPGs during the dry months (Figs.19-24). The worms found in these naturally infected animals could have originated from infections acquired in the late rainy season/early dry season or larvae resuming development after a period of hypobiosis (Charles, 1989; Blitz and Gibbs, 1971). This must be an explanation of one method by which the nematode parasites survive the six months (mid-April to mid-October) of continuous dry weather. This agrees with the findings of Ogunsusi and Eysker (1979) in northern Nigeria.

A peak uptake of *Trichuris ovis* worms was found in tracer goats in the early dry season when few other worms were picked up from pasture. *Trichuris ovis* eggs are resistant to extreme weather factors (Blood and Radostitis, 1989) and thus infections are likely to persist on pastures for extended periods. *Trichuris* spp. are of great importance in Australia in times of drought and may survive the summer to infect the next seasons lambs (Blood and Radostitis, 1989). This may be the plausible explanation for the late appearance of adult *Trichuris ovis* worms in tracer goats two months into the dry season when a few other worms were picked up.

The spectrum of gastrointestinal nematode species obtained from the present study is broadly similar to those reported by Nakazawa *et al.* (1989) and Lovelace and colleagues (1989) as being involved in parasitic gastroenteritis in goats in Zambia. The study recorded 8 gastrointestinal nematode species in goats of the two study areas, all of which have been reported in goats of different climatic areas of the world by several workers. Pandey *et al.* (1994) also found a high *Trichostrongylus* spp. worm burden on postmortem worm counts in the dry season in a study in Zimbabwe. However, unlike Pandey *et al.* (1994), this study did not find any *T. axei* on postmortem worm counts of tracer goats. The overall nematode infection rate in adult goats in the present study was found to be between 84% and 100%, which is more than 53.8% that was reported by Islam (1984) for goats in Zambia. The results are however in agreement with the results of Lovelace *et al.* (1989), Nakazawa *et al.* (1989), Muimo (1989) in Zambia and Njau (1987) in Northern Tanzania. From the results it can therefore be concluded that adult goats kept under traditional management are largely infected with gastrointestinal nematodes throughout the year. These results uphold the findings of Pandey *et al.* (1994) in Zimbabwe who found adult gastrointestinal nematodes in goats throughout the year. The results would further tend to indicate that survival of the gastrointestinal strongyles from one rainy season to the next may be associated with inhibition of larval development and long survival of adult worms within the host. The

relative importance of these two phenomena requires further investigation.

No information is currently available on helminth control programmes in the traditionally managed small ruminants in Zambia. The prevention of the adverse effects of gastrointestinal nematodes just before the onset of the favourable season i.e. October, may be most beneficial. A small peak in the eggs was observed just before the end of the dry season and this could be attributed to the maturation of inhibited larvae due to environmental stress, trekking of the animals for food and due to nutritional stress. On the basis of the foregoing results, therefore, control may be achieved by strategic treatment of all animals more than 5 months old just before the onset of the rains with a broad spectrum larvicidal anthelmintic. Adult goats would all need to be treated as the findings of this study indicate that they do not develop sufficient immunity to limit re-infection levels and intensity of infection. This would reduce the contamination and infection pressure on pasture during the forthcoming rainy season. Re-infection after the first anthelmintic treatment before the rains may occur quite rapidly (Zinsstag *et al.*, 1995). This is the major explanation as to why a single treatment may have no beneficial effect. All animals would then again need another treatment about one month after the end of the rainy season. This treatment would be necessary to control the worms acquired during the rainy season. Treatment one month after the end of the rains is advocated for because larvae activity has been shown for at least four weeks after the last rains (Fakae and Chiejina, 1988) and by larval uptake by tracer goats after the rainy season. After this period the risk of the goats to re-infection with gastrointestinal nematodes is greatly reduced and would remain low throughout the dry season. At this time when the grass covering is reduced the animals will tend to browse more (Connor *et al.*, 1990) thus significantly reducing the chance of larval intake (Jacquiet *et al.*, 1992). Appropriate control measures however, should be based on cost-effectiveness to optimise production. With information gathered so far, it is too early to evaluate the significance of the low worm burden as it affects the

production of goats in the traditional sector. This is only possible after studies with adequate controls have been designed and a thorough cost-benefit analysis made. There is therefore a need to study, in detail, the economic impact of subclinical gastrointestinal helminthosis on production in goats.

PART SIX

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