THE COMPARATIVE EFFICACY OF LEVAMISOLE AND FENBENDAZOLE IN THE TREATMENT OF EWES BEFORE LAMBING

by

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F O R F R A N K

another experience

and

happiness shared

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SUMMARY

This project was undertaken to ascertain the effects of two anthelmintics, levamisole and fenbendazole, when given to ewes six weeks before lambing. The investigation involved three flocks of sheep of different breeds, Suffolk, crossbred Suffolk and Cheviot; which lambed in January, April and March respectively. Faecal egg counts of the ewes were recorded regularly between November 1976 and July 1977. Nematode species were identified by the measurement of egg dimensions and the observation of development when incubated for seven days at 4·5°C. Serum pepsinogen values were used as a further measure of the nematode infection.

In all three flocks, both drugs suppressed nematode egg excretion for several weeks. Although treatment had a significant effect in individual ewes in depressing the rise in the faecal egg count associated with lambing and significantly delayed the rise in the January lambing ewes and in a housed section of the April lambing ewes, it did not significantly depress total egg output in any flock over the period of the rise.

The rise in the January flock was post-parturient, whereas a peri-parturient rise occurred in both the later lambing flocks. This may indicate that maturation of inhibited Ostertagia species was of greater importance in

the January flock: that their rise was higher lends further support to this theory.

The failure of either anthelmintic to effectively suppress the rise was attributed largely to reinfection in the January flock and to the inability of the drug to remove inhibited larvae in the other two flocks. This was supported by findings in ewes housed soon after dosing.

Eggs of Ostertagia spp. predominated in all flocks during the rise; this reflects the ability of this genus to survive over winter both on pasture and as inhibited larvae in the sheep.

Sixteen lambs born into the January flock and 533 lambs from the March lambing flock were weighed to measure any increase in live-weight gain which may be due to pre-lambing treatment of the ewes. No significant differences were found.

It was therefore concluded that there was no production benefit gained by the pre-lambing dosing of the ewes with either fenbendazole or levamisole when they were returned to contaminated pasture.

INTRODUCTION

Production constraints due to gastro-intestinal helminths in sheep occur throughout the world. Losses include death due to primary parasitism and lowered returns because of unthriftiness, lowered conception rate, decreased milk yield and poor fleece growth.

The use of anthelmintics as therapeutic agents is widespread but their application in prophylaxis is not so well understood.

This dissertation describes and compares the effect of two anthelmintics, fenbendazole and levamisole, given to ewes six weeks prior to lambing, a regime which has been reported to enhance the growth rate of lambs (MacKay, 1972). Faecal nematode egg counts of ewes and lambs were used together with some serum pepsinogen values to assess the helminth burdens in the sheep. Live-weight gains of lambs were used as a further indication of the value of pre-lambing treatment of ewes.

Two trials were carried out at Easter Bush Farm, Midlothian, with two small flocks of different breeds and reared under different systems of management. A third, larger trial took place at Low Middleton Farm, Northumbria.

REVIEW OF THE LITERATURE

Ovine parasitic gastro-enteritis is a disease syndrome resulting from a mixed infection with a number of trichostrongylid nematodes (Reid, 1973). However, the expression "parasitic gastro-enteritis" was felt to be too broad to be of any real value (Dunn, 1969), since it should also embrace such parasitic diseases as coccidiosis and paramphistomiasis, conditions with widely differing aetiological agents, epidemiologies, and clinical and pathological appearances. Dunn therefore suggested a more meaningful term, "trichostrongylidosis", which could be applied to the syndrome in the absence of a dominant nematode parasite. The condition would be referred to as "oesophagostomiasis" or "ostertagiasis", etc., when a dominant species was involved.

The disease is primarily one of lambs during their first grazing season, but it may also be observed in adult sheep during the winter months. Sheep are reared under widely divergent conditions throughout the world and it is a mark of the adaptability of the nematodes that they too survive under such wide ecological and climatic conditions (Levine, 1963).

The generic composition of the trichostrongylid infection varies with the geographical locality. Until recently, the main factor influencing the relative distribution of species was their bionomic requirements for

pre-parasitic development (Levine, 1963; Gibson & Everett, 1967; Dunn, 1969) but the increased usage of modern anthelmintics has begun to be effective. For example, Haemonchus contortus is diminishing in importance in temperate climates chiefly because of the efficacy of most anthelmintics against this species (Dunn, 1969). Although it must be realised that the survival of Haemonchus in temperate areas at all bears great tribute to the efficacy of fecundity: "fecundity overcomes adversity" (Sewell, 1976).

In the past, the problem of gastro-intestinal parasitism was most severe and widespread in those countries where flock malnutrition exacerbated the debilitating effects of infection (Blood & Henderson, 1974). More recently, the emphasis has shifted to areas of intensive agricultural production, where increased stock density has resulted in greater pasture contamination thus increasing helminthological challenge (Wilson, Morgan, Parnell & Rayski, 1953; Crofton, 1955; Dunn, 1969). MacKay (1972) notes that this phenomenon is becoming more important on marginal land where present economic trends demand increased farm output.

Control of parasitic disease must involve a compromise in management if the full potential of sheep production in terms of protein for human consumption, wool for industry and financial return for farmers is to be realised (Gordon,

1973). There is no shortage of husbandry techniques and new anthelmintics to combat the problem but there is a need to evaluate the various control programmes in relation to costs and practicability.

SPECIES OF GASTRO-INTESTINAL NEMATODES CAUSING DISEASE

Crofton (1963) stated that as many as fifty species of nematodes have been recognised from the alimentary canal of sheep. Many of these species are not of great significance in that they are of limited geographical distribution, or have only been recorded on rare occasions; further the pathological significance of many species is thought to be small or has yet to be scientifically assessed. Reid (1973) summarised the major nematodes isolated from the alimentary tracts of British sheep: in the abomasum, Haemonchus contortus, Ostertagia circumcincta, O. trifurcata and Trichostrongylus axei; in the small intestine, T. vitrinus, T. colubriformis, Cooperia curticei, Nematodirus filicollis, N. spathiger, N. battus, Bunostomum trigonocephalum and Strongyloides papillosus; and in the large intestine, Oesophagostomum venulosum, Chabertia ovina and Trichuris ovis.

Research has been largely concentrated on those gastro-intestinal helminths of major economic importance which Connan (1974) records as N. battus, Ostertagia spp.,

H. contortus and T. vitrinus. In Britain, disease due to Ostertagia spp. is frequent and widespread whereas the others are important pathogens only under certain defined husbandry conditions or in limited climatic regions.

In addition to the frequency with which any species of gastro-intestinal nematode is observed, its importance is related to its feeding habits. Thus, H. contortus and the hookworm, B. trigonocephalum suck blood both in fourth larval stage (L_4) and as adults. Anticoagulant secreted by the buccal capsule increases blood loss and a severe haemorrhagic anaemia may ensue (Jubb & Kennedy, 1970). Many of the other trichostrongylids, e.g. Ostertagia spp. and Trichostrongylus spp., are less pathogenic as adults, which feed largely on mucosal cell debris and interstitial fluid, than as larvae. Ostertagia larvae during their development within the gastric glands result in the replacement of parietal cells by rapidly dividing undifferentiated cells. This leads to an increased abomasal pH with consequent loss of proteolytic pepsin activity and to an increase in mucous secretion from the degenerate mucosa (Horak & Clark, 1964). Impaired digestion leads to emaciation and the occurrence of diarrhoea. In addition, the loss of plasma proteins through the damaged mucosa results in hypoalbuminaemia and dehydration. T. axei also burrows deeply

into the abomasal mucosa during its development and produces a similar though less severe catarrhal abomasitis (Jubb & Kennedy, 1970).

Trichostrongyles inhabiting the small intestine provoke a catarrhal enteritis which is manifested clinically as diarrhoea, loss of appetite, weakness and a loss of body weight which can be severe. Of the nematode species parasitising the large intestine, only O. columbianum is mentioned as a frequent cause of disease: the fibrous nodules containing L_4 appear to interfere with intestinal motility, resulting in chronic diarrhoea and debilitation. However, this parasite is common only in tropical and subtropical regions (Dunn, 1969).

METHODS OF ASSESSING BURDENS OF GASTRO-INTESTINAL PARASITES

Before embarking on an epidemiological study or attempting to diagnose a parasitic gastro-enteritis problem, it is important to understand the value and limitations of the methods used. Seven methods are described in the literature.

1. Post-mortem examination:

Worm counts performed accurately soon after death are the most valuable method of assessing quantitatively and qualitatively the worm burden present (Skerman &

Hillard, 1966). Parnell, Rayski, Dunn & Mackintosh (1954b) drew up a "morbidity table" to assist in rating the pathological importance of counts for individual species present: In this:-

	1	B. trigonocephalum
is equivalent to	2	C. ovina
" " "	4	O. venulosum
" " "	10	H. contortus
" " "	60	Ostertagia spp.
" " "	80	Trichostrongylus spp.
" " "	80	C. curticei
" " "	80	N. battus
" " "	80	S. papillosus.

Brunsdon (1966) confirmed the value of regular post-mortem worm counts in determining precisely the relative importance of the various genera participating in the peri- or post-parturient rise in ewes. He also suggests that such examinations should include a complementary search for histotrophic larval stages by means of peptic digests of selected portions of the alimentary tract and thorough examinations for inhibited larval stages in the lumen. This should yield important information relating to the history of the larvae destined to become the adult worms taking part in the peri-parturient rise.

2. Routine faecal egg counts:

Although widely used as a research tool and in epidemiological studies, the technique is not without numerous drawbacks.

It has been recognised that several variable factors affect the relationship between the number of parasites within the host and the numbers of eggs discharged in the faeces. These include (i) seasonal and hourly variations in egg output; (ii) changes in the immunological status of the host (Brunsdon, 1970); (iii) diet, thus Mayhew (1940) studied the effects of diet on the number of eggs shed, and found that a large component of hay in the diet lowered the number of eggs per gram of faeces; (iv) the number of egg-laying females in proportion to the number of males and immature forms (Dunn, 1969); (v) intercurrent disease, which has been found to raise the egg counts for the individual concerned; (vi) the fecundity of the different worm species also varies; Stoll (1929) and Kates (1947) made an estimation of the relative egg laying capacities of the different species; (vii) Parnell (1962) noticed that a decreased faecal output, such as would occur during starvation or when the diet was highly digestable, lead to an increased faecal egg count.

Crofton (1963) recognised that a further difficulty was incurred when there is a change in the species constitution of the worm burden of the ewe. However, the

intelligent use of the McMaster method has been recommended by many workers. Intelligent use requires frequent and regular sampling of all or at least a representative sample of the group.

Lastly, in the diagnosis of disease, it must be remembered that prepatent infections with some parasites, e.g. N. battus, can cause clinical symptoms when egg counts are low (Reid, 1974).

3. Identification of nematode eggs:

Eggs of Nematodirus spp., T. ovis and S. papillosus are easily identified by morphological features (Kates & Shorb, 1943; Cunliffe & Crofton, 1953). Despite various efforts by other workers to differentiate strongyle eggs, Cunliffe & Crofton (1953) concluded that methods to identify individual eggs in a mixed sample on morphological grounds were impracticable. In the same paper, Cunliffe and Crofton described a method devised for species differentiation of strongyle eggs based on statistical differences in measurements of eggs of different species. This idea was adopted and improved by Jackson & Christie (1975). They found that ellipses drawn from length and breadth measurements of each species overlapped in some cases. However, they were largely able to overcome this difficulty by observing that when eggs are incubated at 4·5°C for seven days, only Ostertagia spp. develop to the pre-hatch stage, while Trichostrongylus

spp. develop only to the gastrula stage. Eggs of other species do not show any development during incubation. Plates illustrating this technique are provided by Woodham (1975) and Aklaku (1976).

4. Faecal culture:

The technique of identifying the third stage larvae (L_3) which hatch from eggs after incubating the faeces has been used by several authors to subdivide the results of egg counts. However, it has numerous faults, not least the skill which is needed both to interpret the literature and to apply it (Cunliffe & Crofton, 1953; Dunn, 1969).

5. Pasture sampling:

A knowledge of the level of pasture contamination by infective larvae is relevant to the control of parasitic gastro-enteritis in sheep (Gibson & Everett, 1967). It is an assessment of the parasitological challenge to which young, susceptible sheep are exposed (Brunsdon, 1976). It is also an important exercise aiding the understanding of epidemiology and may be used to indicate major variations in levels of infection with time (Boag & Thomas, 1971). However, the difficulties in measuring absolute numbers are emphasised by the former authors.

Various methods of estimating infective larvae on

pasture have been described (Gibson & Everett, 1976). None is entirely satisfactory. Recovery of the larvae from the sample involves further difficulties, such as cleaning the material of debris without losing the larvae and differentiating infective larvae from free-living larvae (Sewell & Hammond, 1976). A further problem is equating the number of larvae per kilogram of grass with the daily intake of the sheep.

6. Serum pepsinogen estimations:

In experimental studies on sheep infected with high doses of O. circumcincta larvae, Armour, Jarret & Jennings (1966) showed that plasma pepsinogen increased to levels exceeding 3·0 units tyrosine by day 16, before decreasing exponentially. Similarly, in a natural outbreak of Type II ostertagiasis in housed sheep, Reid & Armour (1973) found plasma pepsinogen levels ranging from 1·5 to 5·0 units. These authors considered pepsinogen estimations to provide a useful guide to abomasal damage. Thomas & Waller (1975), working with lambs during their first grazing season recorded correlations between worm counts in slaughtered lambs and serum pepsinogen levels. They suggest that pepsinogen estimations may be a useful diagnostic tool in Type I ostertagiasis, as it is directly related to abomasal damage and is a much earlier indication of worm build up than faecal egg counts.

EPIDEMIOLOGY

Nematode life history

"It is impossible to overstate the importance of a knowledge of helminth life cycles, for in most of them occurs some vulnerable period at which, if we can but recognise it, the parasites can be attacked, and the spread of infection controlled .... and that, after all, is why veterinary and medical parasitology exists as a subject" (Dunn, 1969).

The free-living and parasitic periods of the life cycles of trichostrongyles were summarised by Gordon (1948). The free-living phase takes place outside the sheep and comprises the egg and the first, second and third larval forms. When conditions of warmth and moisture are optimum, the first stage larva leaves the egg after about 24 hours. After feeding for one or two days or even longer, the first stage larvae (L_1) moult into the second stage (L_2), which again feed before undergoing a further moult into the third stage. The L_3 retains the sheath or "skin" of the second stage and has an enhanced capacity to survive under adverse climatic conditions. After being swallowed by the sheep the sheath is lost and the larvae make their way to the preferred part of the alimentary tract, complete the third moult to L_4 and finally the fourth moult to become adults. The prepatent period varies for the different species from

three weeks for those in the abomasum and the small intestine, to four to seven weeks for those in the caecum and large intestine.

Nematodirus spp. deviates from this standard life cycle in that hatching is delayed until the infective L_3 stage is reached, thus acquiring further protection during the most susceptible stages of development.

Larval bionomics

This is the study of the external requirements of the larvae such as the temperature, humidity, nutrition and pH necessary for survival and functional efficiency (Dunn, 1969). Many workers have studied these factors but in attempting to apply, or even interpret research data, several shortcomings should be borne in mind. Firstly, temperature has often been the only climatic component of the bionomic requirements to be measured and the constancy of other factors such as humidity are not known and cannot be assumed. Secondly, observations drawn over short periods of time are not dependable as an epidemiological basis. Noteworthy exceptions to this reservation are the works of Gibson & Everett (1967) and Crofton (1965). Thirdly, in many of the older studies the only biological criterion was survival, development and activity being ignored. In reading such literature, it must be remembered that the optima for growth and

survival may be quite different (Dunn, 1969).

Eggs and infective larvae have the most resistance to climatic extremes. Laboratory work confirms the long suspected ability of eggs of gastro-intestinal nematodes to undergo inhibition of development and to survive for long periods as a result of adverse conditions on the pasture (Crofton, 1963; Silverman & Campbell, 1959). The requirements vary markedly with the species but, in general, the optimum temperature for survival is probably close to 5°C, which is also the lower limit for any development to take place; optimum humidity is 100 per cent, both for development and for survival, 85 per cent humidity is the lower limit for development and 75 per cent for survival.

The temperature range for optimum development is 22° to 26°C (Dunn, 1969). However, even at this temperature, in constant humidity, species variation in development occurs. Thus, under such conditions in the laboratory, H. contortus may reach the infective stage in five days whereas Ostertagia spp., Trichostrongylus spp. and O. venulosum may take double this time (Silverman & Campbell, 1959). Observations made under field conditions are extremely interesting. Harbour, Morgan, Sloan & Rayski (1946) reported that infective larvae can survive Scottish winters in sufficient numbers to cause infestations in sheep. Gibson & Everett (1967) reported a

regular pattern of survival under snow and suggested that conditions of alternate freezing and thawing were more lethal than sustained periods of freezing. They also found that eggs of O. circumcincta were not only able to survive but were even able to develop during winter. Following the work of Taylor (1943) and Crofton (1955, 1957) it was assumed that the common gastro-intestinal nematodes have a short generation interval in spring and summer conditions (Boag & Thomas, 1971). However, there is increasing evidence that this is not so. Silverman & Campbell (1959), Heath & Michel (1969), Boag & Thomas (1971, 1973) indicated that under natural conditions larval development is slow. Dunn (1969) gave the time required for development to the L_3 stage as 13 weeks, while other authors suggest 10 weeks.

Knowledge of the importance of larval bionomics has lead to the development and use of biohythergraphs. These are constructed by plotting and joining monthly mean rainfall and mean maximum temperatures, and used to predict the times at which helminth burdens are likely to reach problem levels (Gordon, 1948). They have since been made and used for many species of gastro-intestinal nematodes throughout the world.

In order to infect sheep, L_3 must be ingested. L_3 are actively mobile so that, in the presence of a thin film of water and in suitable temperatures, they can move

onto and up blades of grass. This movement, however, is entirely random (Crofton, 1954) and the number of larvae which move up is proportional to the number of blades of grass present (Dunn, 1969). The availability of infective larvae also depends on the length of the pasture sward, since Silangwa & Todd (1964) demonstrated that only 59 per cent reached as far as the first 2·5 cm up the stems.

Parasitic ecology

This is concerned with the establishment of infection and the reaction of the host to the arrival and continued presence of the parasites. Crofton (1953) stated that infection by nematodes of any individual sheep is determined by its genetic constitution, age, nutritional status and past exposure to infection.

Inherited resistance

Many workers have made field observations that different breeds of sheep show different responses to the same nematode challenge. Actual scientific data is rare, though Whitlock (1955b) demonstrated a genetically based resistance transmitted by the sire.

Age

Reid (1973) stated that with N. battus infection age resistance appears in lambs at 10 to 12 weeks of age and is high by six months and age resistance is very

important in S. papillosus infection in lambs. However, in relation to most other gastro-intestinal nematodes age resistance per se is now known to be less important than previously thought.

Nutrition

The effects of nutrition on resistance to the parasites themselves must be differentiated from the resistance to the effects of the parasites (Dunn, 1969). Stewart & Gordon (1953) showed that the rate of infection following a standard dose of T. colubriformis was higher in sheep on a low plane of nutrition than those on an adequate or high protein diet.

Post exposure immunity

Much of the seasonal variation and rhythms of parasitism are mediated by the immunity of the host. As far as can be ascertained, antibodies, whether in the serum or in the gastro-intestinal mucosa, are formed as a result of infection with nematode parasites possess physical and chemical properties similar to those produced in response to other immunogens. An increase in such antibodies or of immuno competent cells may result in (i) a reduction in the adult worm population, such as occurs towards the end of the peri-parturient rise (Soulsby, 1965), (ii) a suppression of egg output of existing females (Boag & Thomas, 1973), (iii) an increase in the prepatent period.

Larval inhibition

Larval inhibition or dormancy, the phenomenon of latency in nematode parasites, is best documented in Ostertagia spp. and was first observed in this genus by Sommerville in 1954. Initially it was speculated that such inhibition was due to an acquired immunity (Martin, Thomas & Urquhart, 1957), however, subsequent work showed that inhibited development of O. ostertagi, in cattle, was a seasonal occurrence and independent of acquired immunity (Anderson, Armour, Jennings, Ritchie & Urquhart, 1965). The aetiology of seasonal inhibition has been ascribed to endocrine changes in the host (Connan, 1968), aging of the infective larvae (Armour, 1967) or to inherent developmental changes in the L_3 stages, either genetically or environmentally induced (Armour, Jennings & Urquhart, 1969b). Armour & Bruce (1974) finally confirmed that chilling is the major stimulus to inhibition in temperate climates. Further work by Blitz & Gibbs (1972b) showed that the degree of inhibition occurring in Canada is higher than that which occurs in Britain. It has been shown that accumulations of inhibited larvae in the host coincides with the onset of environmental conditions adverse to the development of the free-living stages of the nematode. Armour (1967) suggested that inhibited larval development is part of an adaptation by the nematode to its environment and is

triggered by climatic changes unfavourable to further development of the free-living stages. It appears that the percentage of a particular population which becomes inhibited is directly proportional to the degree of adversity to which the free-living stages are subject. In this context, Blitz & Gibbs (1972b) have shown a very high percentage of inhibition during the very cold winters in Canada and, in Israel, Shimshony (1974) has attributed the high degree of latency seen in Ostertagia infections in sheep and goats during the dry season, to a desiccatory stimulus.

During the period of latency, it is thought that the metabolic activity of the larvae is reduced (Armour et al, 1969b), their condition being akin to that of diapause in insects. The term hypobiosis has been suggested by Gordon (1970) to describe these metabolically inactive larvae. Inhibition has also been observed in infections with H. contortus (Gibbs, 1964), and C. ovina (Connan, 1974).

Sources of infection for lambs

There are two principle sources of the initial infection for the young lamb, (i) the residual population of overwintered larvae, (ii) larvae derived from eggs deposited by the ewes during the post-parturient rise in egg counts (Brunsdon, 1976). Several workers state the latter to be of greater relative importance (Crofton,

1958; Brunsdon, 1966; Arundel & Ford, 1969), especially as there is a high mortality of surviving overwintered L_3 occurring annually in Britain in May and June.

The peri-parturient rise

This phenomenon is known to occur in pigs (Connan, 1967) and sheep. Much confusion exists over the best term to use - and its definition. "Post-parturient" describes the rise - both in absolute numbers of adult worms and in strongyle egg output - as it is most commonly but not invariably seen. Sometimes the rise starts before lambing, when it is described as "peri-parturient". Crofton (1958) observed a rise in autumn lambing ewes which confirms the association with lambing. This contradicts a third term, "spring rise", which is still used by some authors, although it is now recognised that this rise, which is observed in rams, wethers and maiden ewes in spring, is a separate but closely allied phenomenon. The spring rise which usually occurs in April or May results from an increased susceptibility to new infection (Morgan, Parnell & Rayski, 1951) due to decreased parasitic challenge during winter, sometimes combined with poor nutritional status. Maturation of inhibited larvae and increased fecundity of the existing worm burden (Taylor, 1935; Spedding & Brown, 1955) are other contributing factors. Parturient ewes do not usually show a spring rise, since their immunity has been

increased during the parturient rise which is usually terminated by a "self-cure" reaction.

The aetiology of the rise associated with parturition in the ewes has been discussed at length by various workers. Morgan et al (1951) studied the parturient rise in hill ewes. They concluded that the malnutrition from which hill sheep commonly suffer in the late winter was important, together with the stress associated with lambing (Paver, Parnell & Morgan, 1955). Other workers (Taylor, 1935; Spedding & Brown, 1956) attributed the increase in worm egg counts to an increase in fecundity of the worms already present in the ewe. Naerland (1952) and Field, Brambell & Campbell (1960) suggested that the increase in numbers of adult worms in the gastro-intestinal tract and the rise in egg counts was due to the maturation of larvae held dormant in the tissues during winter. This has since been shown to be of major importance to the rise by many workers.

The origin of the stimulus which results in the maturation of dormant larvae is not precisely known, but the immunity of the host may be involved. Soulsby (1957), by interpreting reduced levels of serologically demonstrable antibodies indicated a decrease in flock immunity during the peri-parturient rise and suggested that this apparent depression of immune status was due to lack of antigenic stimulus following a decrease in L_3 intake during autumn

and winter. However, the observation made by Connan (1958), namely, that autumn lambing ewes exhibit a peri-parturient rise, and work by Brunsdon (1966) does not support this theory.

Many workers including Soulsby (1957) and Crofton (1954) associated the stress of parturition with the decrease in immunity: This theory was later excluded by Crofton (1963).

It was observed that the behaviour of dormant larvae was similar in castrated male sheep and pregnant ewes.

Studies of the influence of host hormones on the host-parasite relationship by Connan (1967) showed a very close association between the post-parturient rise in sows and lactation. This move was reviewed by Dunsmore (1965).

Further work by Connan (1968b) revived the theory that the rise resulted from an increase in fecundity of all species of existing worms, but though Brunsdon (1970) supported this in part he went further to suggest that the rise attributable to different species was of different form and timing.

Finally, workers in Glasgow (Armour & Bruce, 1974; Armour, 1977) supported by Blitz & Gibbs (1972b) in Canada, suggested that the duration of inhibition of nematode larvae is of a fixed and predetermined length equivalent to the period of adverse conditions. This

probably applies to inhibited larvae which later contribute to the spring rise but cannot explain the rise which is associated with parturition whenever it occurs.

Both the spring rise and the parturient rise are terminated in Britain by a relatively sudden loss of infection. Soulsby (1957) noted a very high antibody level at this time, which he held to indicate a marked and sustained immune response characteristic of the "self-cure" mechanism.

Brunsdon (1976) stated that neither the residual population of overwintered larvae, nor larvae derived from the parturient rise in egg counts of their dams was likely to result in significant levels of parasitism before weaning at approximately 12 weeks. He further stated that in the post-weaning period, untreated lambs are exposed to a further source of infection derived from pasture contamination from their own worm burdens. This may well be the case on contaminated pasture and especially in the relatively warm spring climate of New Zealand, but on clean pasture Boag & Thomas (1971) stated that the first wave of heavy infection in the lambs arose directly from the ewes' egg output with no intervening period of multiplication in the lambs.

A summary may be quoted from the work of Crofton (1963), "The peri-parturient rise is the final expression of a series of biological events concerned with the

transmission of infection from one generation of host to another".

ECONOMICS OF PARASITIC GASTRO-ENTERITIS:

DISEASE AND LOSSES

There are over 1,000 million sheep in the world and 26 million of the total are in Britain. As long ago as 1937, the British Veterinary Association conducted a survey on animal mortality caused by the ten major diseases of sheep in Britain. The total loss was estimated to be in excess of £1 million; deaths due to parasitic gastro-enteritis were estimated to cost £348,000 or 33 per cent of total loss. "Invisible" losses, due to decreased wool and meat production, were estimated to be even higher than this (Morgan *et al*, 1952).

Economic losses from disease in sheep, measured in terms of mortality alone are lower nowadays, the situation having much improved over the years (MacKay, 1972). However, losses from internal parasitism at sub-clinical levels still remain and may be considered to be paramount in terms of interference with appetite (Spedding, 1954; Gordon, 1958; Thomas & Bainbridge, 1967), reduction in growth potential of young animals (Nunns, Rawes & Shearer, 1965; Brunsdon, 1966; Leaning, Cairns, McKenzie & Hunter, 1970), reduction of wool production and quality (Brunsdon, 1974; Leaning *et al*, 1970), decrease in milk yield (Southcott, 1971), and decrease in the number of

live lambs born (Murray, Leaning & Martin, 1971).

The above considerations, together with the increased intensification of the sheep industry, mean that prevention of infestation even at a low level has even been said to be the sine qua non of sound husbandry (MacKay, 1972).

CONTROL

In view of the economic effects of gastro-intestinal parasitism already discussed there is a need for effective parasite control. From this stems the importance of an accurate understanding of the epidemiological pattern of the disease, which is necessary to formulate efficient control measures (Thomas & Boag, 1973). The highly efficient anthelmintics available to todays farmer have lured him into a false sense of security: it must be realised that anthelmintics are not the complete answer, they should be used judiciously alongside good standards of flock and pasture management to obtain best results (MacKay, 1972) in terms of profitability in both the short and long term.

Control by management

Control of parasitic diseases almost inevitably involves a compromise in husbandry. Thus, several methods seek to provide adequately spelled pasture, either by destocking for several months, depending on

climatic conditions, or by alternate grazing with another animal which does not readily become infected. For these methods there is a need for adequate subdivision of pasture so that movement of grazing animals will not be detrimental to pasture or stock and where alternative grazing is desirable, there must be proper proportions of the different species of host available (Donald & Waller, 1973).

In the past, pasture spelling for a period of two or three months was advised on the assumption that free-living stages on the pasture were short-lived. However, recent work has disproved this hypothesis (Ciordia, Bizzel, Baird, McCampbell & White, 1964; Donald, 1967). Donald (1967) in Australia, found no significant decrease in pasture contamination eight weeks after the removal of the sheep, which suggests that effective spelling would take too long for efficient use of grassland.

Alternate rotational grazing with cattle as a means of providing safer pastures for both sheep and cattle has been investigated in Australia by Southcott & Barger (1975). They found, from controlled experiments, that grazing sheep pastures with cattle for six, 12 or 24 weeks resulted in large reductions in numbers of H. contortus and T. colubriformis. Numbers of O. circumcincta were reduced after 12 and 24 weeks of grazing by cattle, but N. spathiger and N. filicollis

were only reduced in numbers after alternate grazing for 24 weeks. They found little evidence of transmission of cattle parasites to sheep, whilst transmission of sheep parasites to cattle was more common. Their conclusion was that alternation of sheep and cattle could be an effective method for preparing parasitologically safer pastures for both species. They suggested that more information is required on the optimal timing of sequential stocking, both in relation to the life-cycles of the nematodes and to the managerial and agronomic restraints imposed on a whole farm system. In Britain, the organisation of such a system may be aided by the work of Silverman & Campbell (1959), Gibson & Everett (1967) and Boag & Thomas (1970), who all showed that the appearance of infective larvae on pasture, from eggs shed in faeces, takes considerably longer than the minimum development period stated by Crofton (1955, 1957). Thus in rotation grazing lambs may be able to safely graze on previously clean pasture for three to four weeks in a British spring or summer (Boag & Thomas, 1973).

Creep grazing, which allows lambs to graze separately from ewes, has been in use for many years. If it is succeeded by a system after weaning whereby lambs graze clean pasture, it is of value (Dunn, 1969).

Early weaning and movement to clean pasture was found to be effective by Levine, Schaeffler & Szanto (1960).

This was supported by Brunsdon (1976), who observed that significant levels of parasitism are unlikely to occur in lambs before 12 weeks of age and suggested that weaning and movement to clean pasture at this age is likely to be effective in controlling parasitic gastro-enteritis. Dunn (1969) points out that if early weaned lambs are not to lose condition, very good keep must be available for them.

Sheep on a good nutritional plane are able to develop better resistance against infection with gastro-intestinal nematodes (Stewart & Gordon, 1953) and also better able to resist the ill-effects of parasitism (Dunn, 1969). This was recognised many years ago, by Frazer (1945) who said, "My considered advice is to look after the sheep and the sheep will look after the worms". Unfortunately, this advice is insufficient because of the increase in stocking rate that has occurred since 1945.

Control: anthelmintics

Prophylactic dosing has been the subject of much criticism of late and there is no doubt that, in the past, much of it has been empirical and economically wasteful (Dunn, 1969). However, in the light of recent epidemiological knowledge, and with highly efficient preparations, the strategic use of anthelmintics has much to recommend it.

Gibson (1966) tested some of the more important

anthelmintics used in sheep.

Tetramisole, a water soluble crystalline hydrochloride of 2, 3, 5, 6, tetrahydro-6-phenyl imidazo (2,1-b), (Thienpont, Vanparys, Raeymackers, Vandenberk, Demoen, Allewijn, Marsboom, Niemegeers, Schellekens & Janssen, 1966), has given outstanding results in the field (Walley, 1966). A review of the literature by MacKay (1972), confirmed that at a level of 15 mg per kg, at least 96 per cent of adults and 26 per cent of larvae of the genera Haemonchus, Ostertagia, Trichostrongylus (abomasal and intestinal species), Nematodirus, Cooperia, Bunostomum, Chabertia, Oesophagostomum and Dictyocaulus were removed. Levamisole is the active L isomer of tetramisole and 7·5 mg per kg has the same activity as 15 mg per kg of tetramisole.

Fenbendazole, (methyl 5-(phenylthio)-2-benzimidazole-carbamate), is one of the most recent anthelmintics to be introduced to the market.

Given at the dose level of 5 mg per kg of body weight it was reported to be 99 to 100 per cent efficacious against adult forms of the genera Haemonchus, Ostertagia, Trichostrongylus, Cooperia, Oesophagostomum, Nematodirus, Chabertia and Dictyocaulus (Kirsch & Duwel, 1975; Kelly, Whitlock, Hogarth-Scott & Mears, 1975; Ross, 1975). Very similar results followed treatment of natural infections in American sheep (Kennedy & Todd, 1975). The

anthelmintic has also been tested in Iran on sheep which had natural infections. The egg laying capacity of all the species involved, which included Marshallagia marshalli, was stopped (Eslami & Anwar, 1976). The only exception to the extremely high efficiency of this drug against adult nematodes was that described by Kelly et al (1975). Contrary to the findings of Ross (1975), he found that at 5 mg per kg only 93 per cent of adult T. colubriformis were removed when post-mortem worm counts were compared with pre-dosing burdens. However, it was observed that the worms appeared incapable of egg-laying, since faecal egg counts were zero. The most probable explanation was that the T. colubriformis in the study was tolerant to the benzimidazole group of drugs (Kelly et al, 1975). Kirsch & Duwel (1975) and Ross (1975) reported that efficacy against three to 10 day old infections with H. contortus, N. battus, T. colubriformis, O. circumcincta and N. filicollis was > 99 per cent in sheep given 5 mg per kg. These results are especially good, since larvae aged between three and 10 days are moulting and, in addition, larvae of Ostertagia spp. are in the stomach glands, - stages which are most resistant to attack by anthelmintics (Gibson & Parfitt, 1975; Kirsch & Duwel, 1975).

Ostertagia spp. are the main parasites contributing to the peri-parturient rise in Great Britain (Morgan &

Sloan, 1947; Morgan et al, 1951; Wilson et al, 1953; Parnell et al, 1954b; Boag & Thomas, 1970) and it is now widely accepted that they arise from the maturation of early fourth stage larvae (EL_4) inhibited in the gastric mucosa. Hence, an anthelmintic which was able to remove inhibited larvae would be of great practical value (Duncan, Armour, Bairden, Jennings & Urquhart, 1976). It is thought that the insusceptibility of these dormant larvae to anthelmintics may be a result of their low metabolic activity (Armour, Bairden & Reid, 1975).

Armour et al (1975), showed that thiabendazole (Thibenzole, Merck, Sharp and Dohme) used at the recommended dose rate was 100, 99·8 and 81·8 per cent efficient against EL_4 in sheep dosed in November, January and March respectively. From these results, they concluded that the susceptibility of inhibited larvae to anthelmintic treatment varies according to their stage of dormancy.

The efficacy of levamisole against inhibited O. circumcincta has been studied by Reid, Duncan & Bairden (1976). Seventeen hill ewes, on two farms, were dosed seven weeks before the expected peak lambing period; after treatment the ewes were retained on concrete for eight days before being slaughtered. Examination of both abomasal contents and mucosal lining revealed that 97 per cent of EL_4 had been removed compared to the burdens found in the undosed control ewes. Apart from the ability of

this drug to remove the source of the peri-parturient rise, the authors claimed that "sheep treated in late autumn or early winter, when inhibition is already established and then moved to clean pasture, aftermath, cash crops, or indeed housed, will have a negligible worm burden".

McKenna (1974) showed that levamisole has a high activity against inhibited H. contortus larvae in sheep. Armour (1977) found that neither levamisole nor thiabendazole was effective against inhibited Ostertagia larvae in cattle. He suggested that inhibition of O. ostertagi in cattle may be "deeper" than that of O. circumcincta, possibly as an aid to species survival since O. ostertagi is unable to develop on pasture between October and March, whereas O. circumcincta is able to develop, albeit slowly, throughout the winter months. Further, overwintered eggs and L_3 of O. circumcincta do not survive on pasture beyond June. Alternatively, Armour suggested that the difference may be related to the fact that the abomasal glands in cattle are deeper than those of sheep and hence O. ostertagi may be better protected than O. circumcincta. Armour claimed to have substantiated these theories in unpublished work showing that the effectiveness of both thiabendazole and levamisole against EL_4 in cattle increases at higher dosage rates. The experimental findings of Anderson & Dobson (1975) support those of

Armour. They suggested that since recommended dose rates were based on therapeutic criteria, they may need to be increased for use in strategic control schemes for helminthosis.

Fenbendazole has been shown to successfully remove inhibited stages of O. ostertagi in cattle (Duncan, Armour, Bairden, Jennings & Urquhart, 1976). It may also prove to be the most effective drug for controlling the peri-parturient rise in sheep.

The strategic use of anthelmintics for the prevention of parasitic gastro-enteritis in lambs has been investigated by many workers (Arundel, 1971; Donnelly, McKinney & Morely, 1972; Boag & Thomas, 1973; Brunsdon, 1974; Anderson & Dobson, 1975; and others). Several workers, (Arundel, 1969; Boag & Thomas, 1973; Anderson & Dobson, 1975), recommend two different dosing regimes, depending on whether clean pasture is available or not. If clean pasture is available, many authors suggest a pre-lambing treatment aimed at eliminating inhibited Ostertagia spp., after which ewes are moved to parasitologically clean pasture, on which lambs may be reared without loss of production due to parasitism (Tetley, 1959). Boag & Thomas (1973) showed that faecal egg counts of lambs reared on clean pasture with dosed ewes and left there after weaning never rose above 200 e.p.g., which was noted in September, and the pasture larval count

never rose above 75 per kg of herbage. This finding contrasted with faecal egg counts of 2,000 per gram recorded in September from lambs left on the pasture which had also been grazed by undosed ewes. Lambs from dosed ewes which were themselves dosed at weaning had a higher burden than those which had not received anthelmintic treatment. Boag and Thomas suggested that dosing at weaning might have interfered with the development of an immune reaction.

Arundel (1971) working under similar conditions confirmed the work of Boag & Thomas (1973). Leaning et al (1970), in New Zealand, showed a significant increase ($P < 0{\cdot}05$) in live weights at 100 days of lambs from ewes treated two weeks and four weeks prior to lambing with thiabendazole, compared to those from ewes treated once at two weeks before lambing. This was attributed to increased thrift and milk production of treated ewes. Similar results were obtained by Nunns et al (1965) and Angelovski, Iliev & Golosin (1973). Where this dosing regime cannot be supported by a move to clean pastures results are disappointing and inconsistant (Lewis & Stauber, 1969; Arundel, 1971; Brunsdon, 1974). This has lead Arundel (1971) to state that prevention of reinfection is therefore the key to successful suppression of the peri-parturient rise.

Post-lambing treatment may be used instead of pre-lambing dosing; however, this has the disadvantage that, due to the spread of lambing, some ewes will pass a considerable number of eggs before treatment. This defect is emphasised by the work of Dunsmore (1965) and Brunsdon (1966; 1970), who found that the peri-parturient rise started about four weeks before lambing. This will not only contaminate the pasture for future stock but may also infect the lambs (Arundel, 1971). It may be especially important where the lamb crop includes large numbers of twin lambs since Southcott (1971) showed that twin lambs eat proportionately more grass and less milk than single lambs and are thereby exposed to greater risks of infection, and Spedding, Brown & Large (1963) showed that lambs reared as singles have fewer worms at slaughter than those reared as twins, even when they have grazed the same pasture. Arundel (1971) suggested that post-lambing treatment is most effective when lambing occurs over a short period.

Connan (1968a) recommended that if reinfection of the ewes after drenching was inevitable, treatment to control the peri-parturient rise should either be delayed as long as possible or repeated at intervals.

Where strategic dosing of ewes is not possible, strategic or tactical dosing of lambs is necessary. Once again it has been shown that if dosing at weaning is not

followed by a move to clean pasture, then repeat dosing at four week intervals is necessary (Kates, Colglazier, Enzie, Lindahl & Samuelson, 1974). Further, it was shown that if repeat drenching was not performed, it was more beneficial, in terms of live weight gain, to move the lambs at weaning to clean pasture, without drenching (Brunsdon, 1976).

It seems that the efficiency of the modern anthelmintic has only to be supported by a high standard of flock and pasture management before losses due to clinical and sub-clinical parasitic gastro-enteritis become a thing of the past.

MATERIALS AND METHODS

TRIAL LOCATIONS

Three trials were conducted on different properties. Two took place on Easter Bush Farm, Roslin, Midlothian, at the Veterinary Field Station of the Royal (Dick) School of Veterinary Studies, University of Edinburgh. This farm consists of approximately 80 hectares at an average altitude of 200 metres above sea-level. The farm is in an exposed situation at the foot of the Pentland Hills, about 12 km south of Edinburgh.

The third trial took place on Low Middleton Farm, the property of Mr. H. MacDonald. This farm consists of 100 hectares of lowland pasture at Belford on the northern coast of Northumbria.

ANIMALS

The responses to treatment of three flocks of sheep were monitored during the trials.

Flock I consisted of 12 Suffolk ewes due to lamb in January 1977. These had been previously selected from a larger flock by the Department of Animal Health to lamb outside on the pastures of Easter Bush Farm. These animals were observed between November 12th, 1976 and the end of April 1977.

Flock II consisted of 33 crossbred Suffolk ewes. This flock was due to lamb outside during April 1977 and also belonged to Easter Bush Farm. This trial commenced on March 1st, 1977, and terminated on July 13th, 1977.

Flock III consisted of 309 halfbred ewes. They were due to lamb during April 1977 in the paddocks of Low Middleton Farm. These ewes were observed during the period between January 29th, 1977 and June 30th, 1977.

PASTURE AND FLOCK MANAGEMENT

On both farms, it was attempted to integrate the trials into the routine flock management. On Easter Bush Farm, there was a full-time shepherd responsible for the sheep. This was not the case at Low Middleton Farm.

Flock I

These sheep were maintained at pasture. However, it was necessary to feed supplementary hay from mid-autumn because of shortage of grazing. From early December, concentrates in the form of sheep protein concentrate pellets (Scottish Agricultural Industries, S.A.I.), mixed in the ratio of 1:5 with bruised oats were given, 100 g per ewe, increasing to one kg per head at lambing. Heavy snow fell in January and lay for six weeks. As this coincided with lambing it was necessary

to house the flock during most of this period. This necessitated splitting up the ewes according to expected lambing dates, for ease of management. Extremely severe spring weather conditions led to ewes and lambs being managed individually, according to available facilities. Lambing percentage was 140. The live-weight gain of lambs was uneven, due to outbreaks of Escherichia coli scour and later orf, which affected most of the lambs from the age of four to 12 weeks

Pasture management was according to Table I.

Flock II

The crossbred ewes were run at pasture, with access to turnips and hay during the winter and early spring. These ewes were managed as a unit together with a larger flock of Cheviots. Supplementary feed was given as for Flock I. Ewes were grouped in various lambing paddocks according to expected lambing date. Indoor accommodation was used as necessary. Lambing percentage was 185 and lamb growth was good.

Grazing management is detailed in Table II.

Flock III

These ewes were outwintered on pasture with access to turnips from mid-January. Supplementary rations consisting of crushed oats and barley, sugar beet, concentrate nuts (S.A.I.) and fish meal were provided for eight

TABLE I.

FLOCK I: PADDOCK MANAGEMENT

Paddock	Hectares	Grazing History	Grazing by Flock I
A_I	4·5	Summer '76, dairy herd. Autumn '76, small group of rams. Permanent pasture.	October '76 to housing in January '77
B_I	1·5	Used irregularly for small groups of sheep and/or cattle. Permanent pasture.	Ewes with newborn lambs, first two weeks in February '77
C_I	4·4	Used for fattening Suffolk lambs for the last three years. Summer '76, cut for silage, then grazed by dairy herd until November. Permanent pasture.	Grazed February '77 until end of trial, together with another 20 Suffolk ewes and lambs

TABLE II.

FLOCK II: PADDOCK MANAGEMENT

Paddock	Hectares	Grazing History	Grazing by Flock II
A_{II}	3·1 grass plus 3·0 turnips	Second year rye grass. Summer '76, cut twice for hay. Autumn '76, grazed with cattle.	October '76 until March/April '77. Grazed together with 80 Cheviot ewes and 10 hoggs
B_{II}	3·3	Used for lambing during spring of 1974, 5 and 6. Used for fattening lambs during autumn '76, and for ewes until January '77. Rested January until April. Permanent pasture.	During lambing, beginning of April until second week in May, together with Cheviot flock
C_{II}	5·8	Grazed by cattle and horses during '76. Used for tupping in November. Rested until May '77. Permanent pasture.	Early May, until termination of trial, together with Cheviot ewes and lambs

weeks prior to lambing. Ewes were lambed in three groups, each of seven days duration from March 15th.

The first group was housed overnight during its lambing period. Following lambing, ewes were individually penned for 12 to 24 hours, before being turned out in two separate groups - those with singles and those with twins. All third lambs were removed and bottle-fed. Supplementary feeding continued to be given only to those ewes with twins. This system was repeated with ewes lambing during the second and third seven-day periods. These groups of sheep continued to be managed independently right up to weaning. Lambing percentage was 184 - higher than anticipated. Lambs grew well and were expected to be sold fat at 45 to 55 kg from the end of June.

FAECAL SAMPLING

Faecal samples were collected fortnightly from each ewe (per rectum) in the Easter Bush flocks during the period of the trials. Samples were likewise taken from a representative sample of the Low Middleton flock at strategic intervals during the experiment. All lambs born into flocks I and II were sampled at approximately 10 weeks of age. All ewes and lambs sampled could be individually recognised. Each sample was placed into a labelled, airtight plastic container and held at $4^{\circ}C$

until immediately prior to examination in the laboratory.

QUANTITATIVE AND QUALITATIVE FAECAL ANALYSIS

A. QUANTITATIVE

Faecal nematode egg counts were estimated by the Modified McMaster Method (Whitlock, 1948) to determine the number of eggs per gram of faeces, and to make a preliminary identification of those species which are morphologically distinct. If this method resulted in a count of less than 200 strongyle type eggs per gram, the more sensitive Saturated Salt Flotation Technique (Sewell & Hammond, 1976) was performed.

These methods were used routinely for the examination of faecal samples from each animal throughout the trials. Each egg seen was recorded, according to its morphology under one of two headings: (1) Strongyle type. (2) Nematodirus spp. In Flock I, eggs of Strongyloides papillosus and coccidial oocysts were also recorded. Mean egg counts for each group were calculated from individual results and recorded graphically each fortnight.

B. QUALITATIVE

On each sampling occasion, an equal amount of faeces from each ewe within each group was pooled to give a total amount of approximately 10 grams. The method followed for recovery of the eggs was that described by

Aklaku (1976) except that it was found that if the centrifugation of the resuspended sediment in saturated salt was increased from two minutes at 2,000 rpm to 15 minutes at 3,000 rpm, the final suspension of eggs was cleaner, enabling more accurate measurement and assessment of development. The criteria for identification of the strongyle eggs were described by Aklaku (1976). The method was based on that originally described by Jackson & Christie (1975). Eggs were incubated for seven days at 4·5°C, then measured: species were recognised by their dimensions and stage of development.

On two separate occasions the validity of the method was checked using the procedure of larval identification. Faecal cultures and recovery of infective larvae were carried out according to the method described by Sewell & Hammond (1976). Larval identification was carried out using the criteria selected by Myers (1975) from the extensive but confused literature created by other investigators.

HERBAGE SAMPLING

This was performed to assess the level of reinfection by strongyle third stage (L_3) larvae occurring in each flock of ewes after dosing. Five hundred grams of grass was collected from the paddock grazed by each flock during the period between dosing and lambing. The N-shaped

collection routine developed by Lancaster (1970) was utilised. Recovery and distinction between infective L_3 larvae and free-living larvae were performed according to the method described by Sewell & Hammond (1976), with minor alterations.

SERUM PEPSINOGEN ASSAYS

Fifteen ml samples of blood were collected into labelled vacutainers (Becton - Dickinson) from each of four ewes in the three treatment groups of Flock II. The same ewes were sampled on six occasions between March 1st and July 13th, 1977. The blood was allowed to clot, at room temperature, for 24 hours. Each clot was gently loosened with a clean wooden spatula and the vacutainer centrifuged at 1,500 rpm for three minutes to sediment the clot. Serum was removed into plastic containers, each labelled with the ewe's number and date of sampling. Serum was stored at -20°C until pepsinogen estimations were performed. The method used was that described by Sewell & Hammond (1976). Absorbance was measured using a spectrophotometer (Unicam, S.P. 1800) at a wavelength of 750 nm. A standard graph was prepared using solutions of tyrosine of known concentrations. This was used to estimate the concentration of tyrosine in the serum samples in μmols per ml. A factor of 3472 was used to convert the units of pepsinogen into International Units (I.U.).

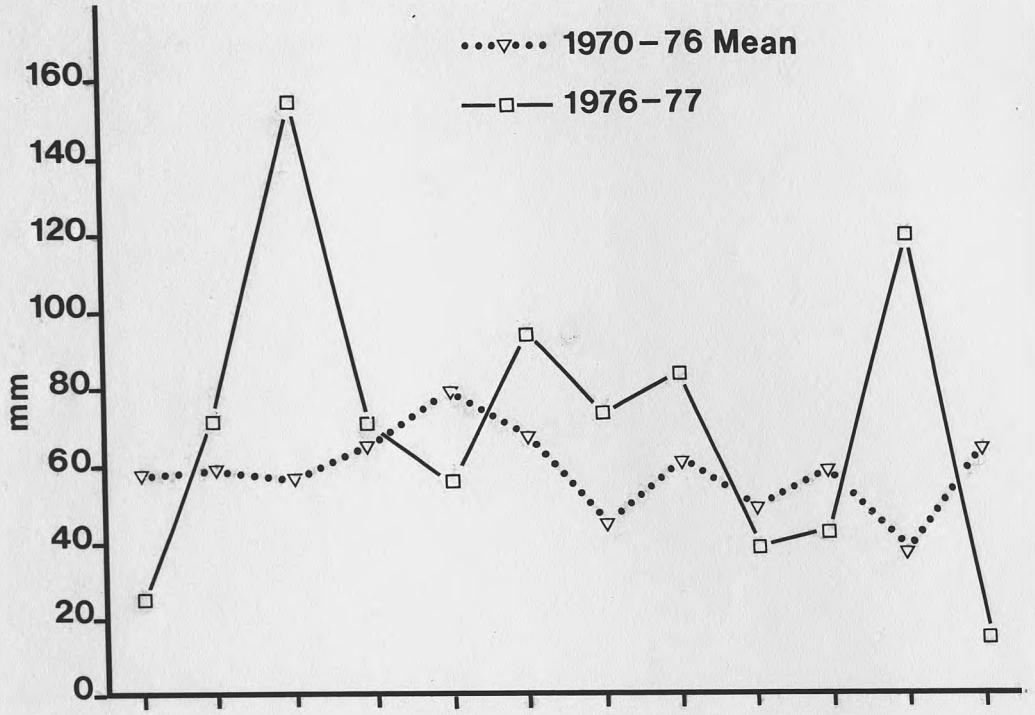
STATISTICAL ANALYSIS

Statistical analysis was performed on results when sufficient information was available. Because of high variance, associated with faecal egg count data, a square root transformation was used wherever statistical tests involving an assessment of normality were applied.

METEOROLOGICAL DATA

This was obtained from the School of Agriculture, University of Edinburgh, which is situated 0·5 km from Easter Bush Farm. Monthly mean temperatures - recorded daily at 10 a.m. -, monthly mean grass temperatures and monthly mean rainfall data is shown in Figures 13 and 14.

TOTAL MONTHLY RAINFALL



MONTHLY TEMPERATURES

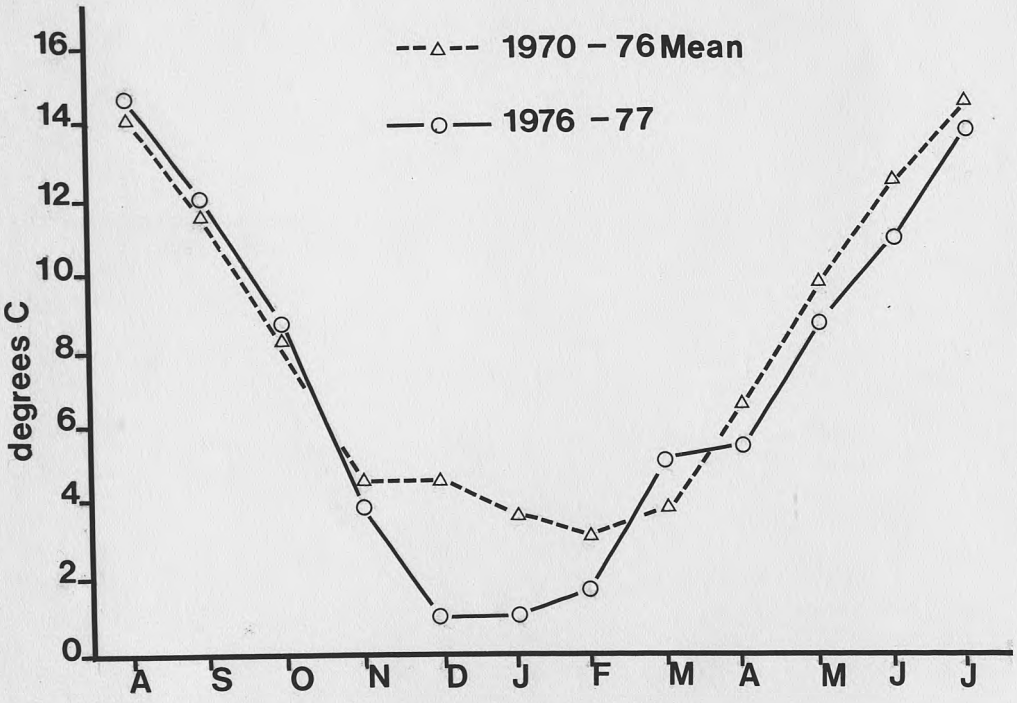


Figure 13

MEAN MONTHLY GRASS MINIMUM

TEMPERATURES

---△--- 1959-75 Mean

—□— 1976-77

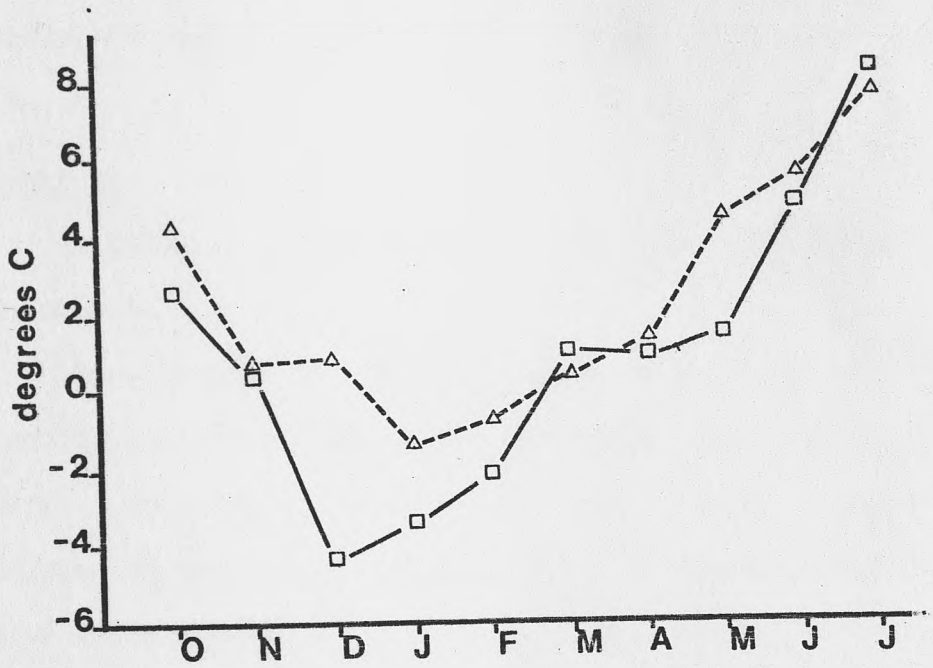


Figure 14

EXPERIMENTS AND RESULTS

FLOCK I. EXPERIMENTAL DESIGN

On November 26th, 1976, twelve Suffolk ewes were allocated into two treatment groups using tables of random numbers.

Group IF.

Six ewes, each of which received 15 ml of Fenbendazole (Panacur, Hoechst U.K. Limited) by mouth on that day.

Group IC.

Six ewes, none of which received anthelmintic treatment.

Faecal samples were collected from the ewes at fortnightly intervals from November 12th, until April 29th. Lambing commenced on January 4th. Lambs were weighed at birth and at two-weekly intervals until they were approximately 14 weeks of age. Faecal samples were taken from the rectum of each lamb at the age of about 10 weeks.

FLOCK I. RESULTS

A. Strongyle-type egg counts

A comparison of the mean faecal egg counts for groups IF and IC is given in Figure 1 which also shows the period over which each group lambed. This is

FLOCK I MEAN STRONGYLE EGG COUNTS

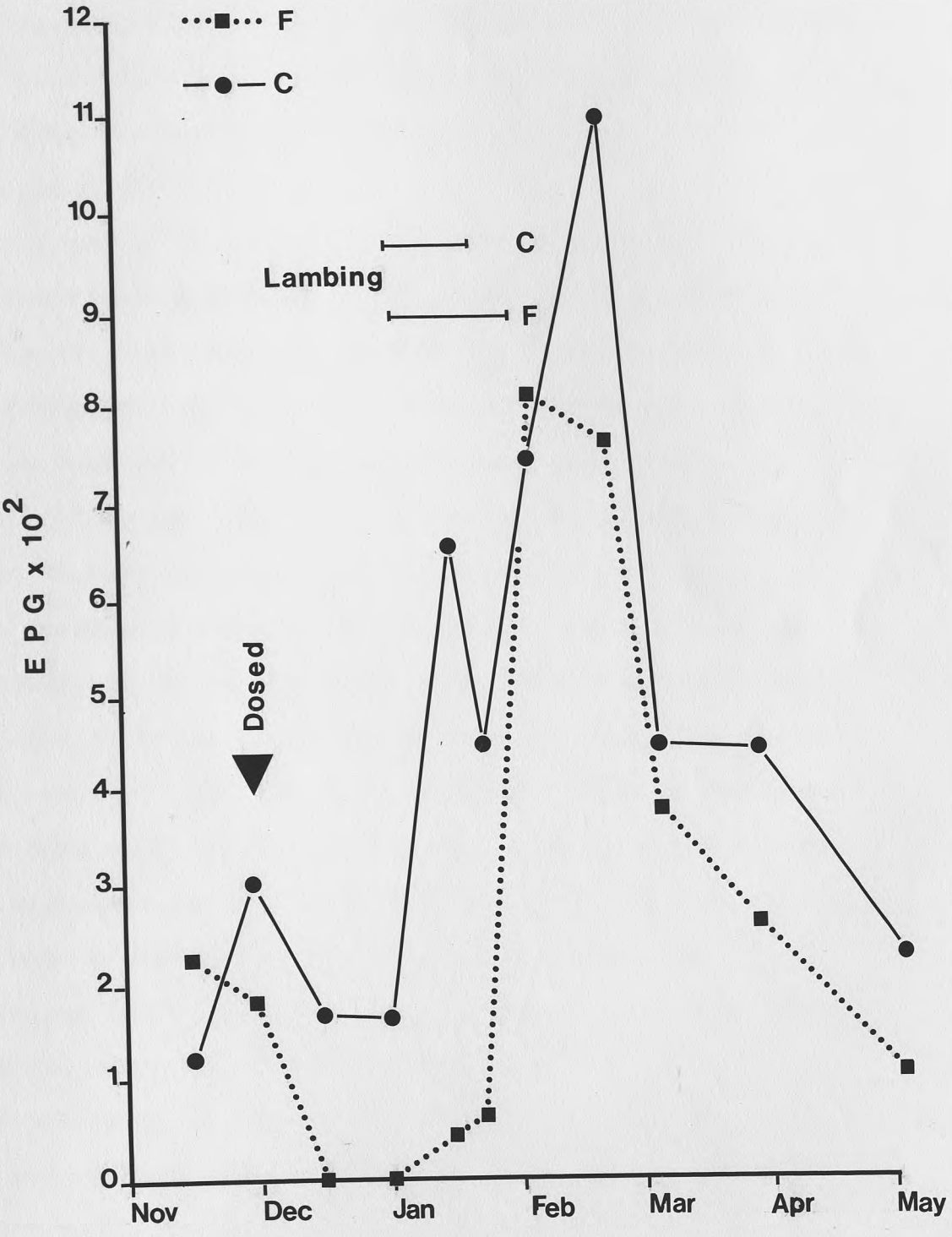


Figure 1

indicated with a horizontal line labelled with the appropriate letter. This method is used throughout the dissertation. Table I (Appendix) shows the faecal egg count for each ewe in the flock. The median lambing date was January 12th for group IC and January 16th for group IF.

Prior to dosing, the faecal egg counts of all ewes in the flock were low. Egg counts for each ewe in group IF, a fortnight after dosing, were negligible and they remained at low, but gradually increasing levels for a further 10 weeks, until three weeks after the median lambing date. The group mean egg count then rose steeply to a peak of 776 eggs per gram (e.p.g.). The start of this rise in individual ewes ranged from six days to 20 days post partum, with a median interval of 11 days between lambing and the start of the rise. The start of the rise was calculated from graphs drawn for each ewe, using the figures in Table I (Appendix). It was taken as starting from the day when the egg count rose to greater than 200 per cent of the value on the previous sampling date, except when the previous count was nil when the first positive count was used. The post-parturient rise in egg counts extended for between 30 and 92 days with a median of 39 days. The end of the post-parturient rise was calculated separately for each ewe. It was taken as being the return to within

150 per cent of the mean of the faecal egg counts before dosing, or in the undosed ewes, the mean of the egg counts before the rise started. Two ewes, H59 and A16, had egg counts which never rose above 250 and were judged not to show a post-parturient rise.

The mean strongyle egg count of the undosed group remained low until January 14th, two days after the median lambing date, when it rose to 650 e.p.g. Figure 1 shows that the rise for group IC was composed of two peaks separated by a period of five weeks. Inspection of the data in Table I (Appendix) suggests that the egg count of one ewe, J12, on January 14th and 21st is largely responsible for this phenomenon. The largest mean egg count recorded was 1,100 e.p.g. on February 18th, 25 days after the median lambing date. The start of the rise in individual ewes ranged from five days prior to lambing to 20 days after lambing with a median of six days. The median extent of the rise was 57 days with a range in individual ewes from 39 to 99 days.

An adult ewe excretes about 2,000 grams of faeces each day (Woodham, 1975). Using this figure and egg counts from individual ewes, an estimate of the total excretion of eggs during the period of the post-parturient rise was made. The mean figure for an undosed ewe was 97×10^6, while that calculated for a

dosed ewe was 54×10^6 eggs.

A summary of data is given in Table III.

TABLE III.

FLOCK I: A COMPARISON OF THE POST-PARTURIENT RISE OBSERVED IN DOSED AND UNDOSED EWES

	Dosed	Undosed
Median date of lambing	16/1	12/1
Time of onset, days after lambing	11	6
Duration in days	39	57
Peak egg count, e.p.g.	776	1,100
Onset of rise to peak, in days	30	28

B. Variation in nematode species

(i) Egg differentiation

Table II (Appendix) and Figures 2, 3, 4, 5 and 6 show the calculated faecal egg counts for each species of nematodes encountered during the trial.

Ostertagia spp.

Figure 2 shows that after treatment with fenbendazole, Ostertagia spp. eggs were not observed in the faeces for four and a half weeks. It also illustrates the important contribution this genus made to the post-parturient rise in both treated and untreated ewes.

FLOCK I MEAN STRONGYLE EGG COUNTS

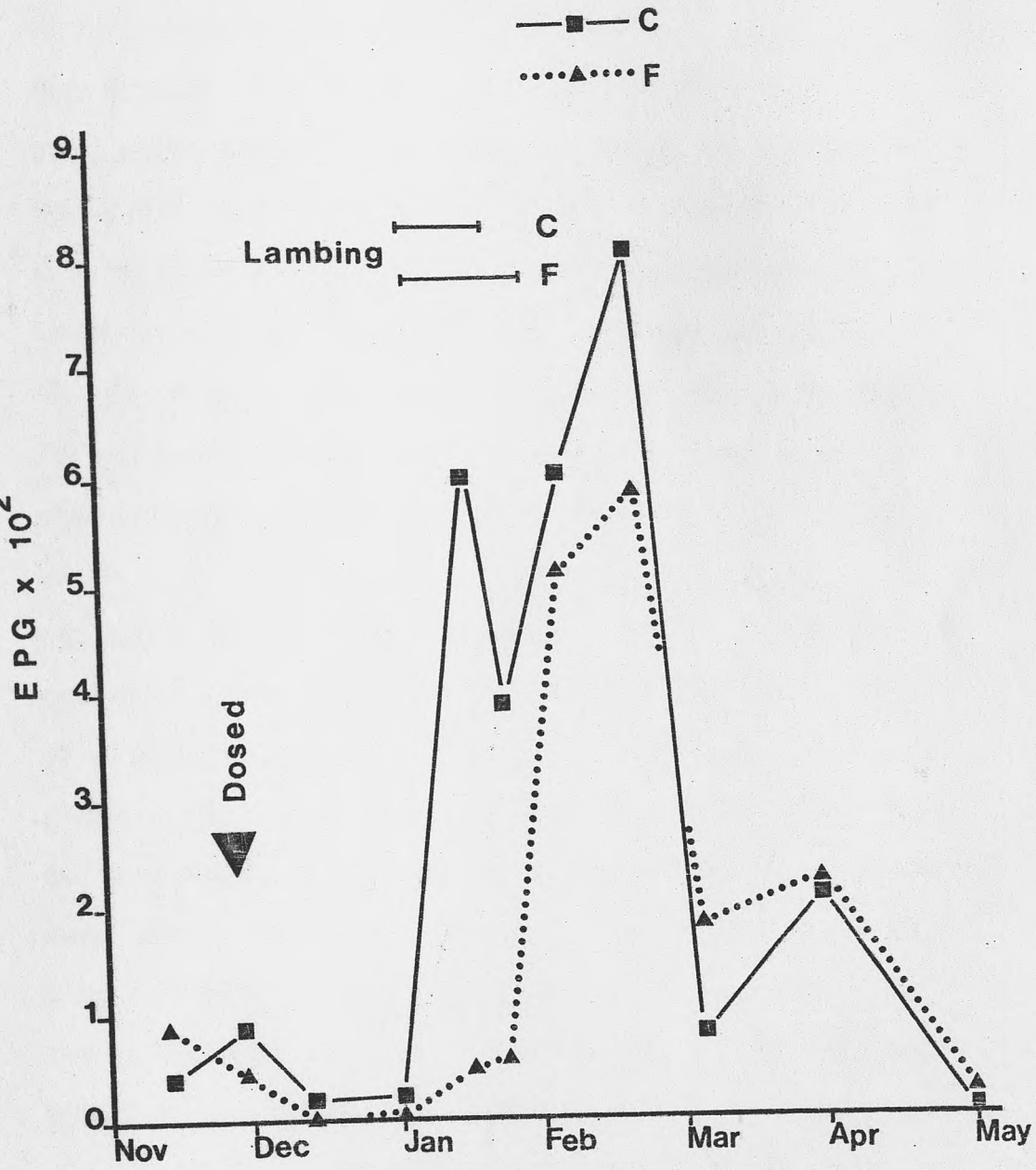


Figure 2

Before the onset of the rise, Ostertagia spp. eggs were present in each ewe in very small numbers - 30 e.p.g. - approximately 20 per cent of the ewes' egg output.

Throughout the remainder of this dissertation, such percentages when used are given in brackets immediately after the egg count. The start of the post-parturient rise also coincided with an increase in the proportion of Ostertagia eggs. At the peak of the rise Ostertagia spp. contributed 74 per cent of the total egg output from the undosed ewes and 66 per cent of that from the dosed ewes. In the undosed ewes, Ostertagia spp. constituted an estimated 82 per cent of all the eggs excreted during the rise. This figure was lower at about 70 per cent for the dosed ewes. The numbers of eggs of Ostertagia spp. decreased more quickly than did the total egg output, so that one week after the termination of the rise, the proportion of eggs of Ostertagia spp. in the faeces of the dosed ewes was 49 per cent and in the undosed ewes, 15 per cent. These figures had dropped to seven and two per cent respectively by the end of the trial. Nevertheless, in both groups, the pattern of the counts for this species generally corresponded to the pattern of the mean egg counts

for each group.

Trichostrongylus axei

The faecal egg counts calculated for this species are shown in Figure 3. After treatment with fenbendazole, no eggs were seen for seven weeks. In the undosed ewes, counts averaged about 10 e.p.g. (36). The peak mean count for this species was 99 e.p.g. (22) recorded on March 4th, two weeks after the peak mean egg count. The peak mean count in the dosed sheep was also delayed relative to the maximum mean egg output during the rise. The drop in T. axei egg output corresponded in each group to the cessation of the post-parturient rise. Unlike Ostertagia, the counts then rose again to 40 (18) and 55 (49) e.p.g. in the undosed and dosed ewes respectively.

Chabertia ovina

The numbers of eggs excreted by this species are illustrated in Figure 4. After treatment with fenbendazole, no eggs were observed for six weeks, while the mean count for the undosed group rose to 50 e.p.g. (33). The rise in mean total egg production in dosed and undosed groups preceded the maximum mean excretion of C. ovina eggs by four weeks and three weeks respectively. After the post-

FLOCK I MEAN FAECAL EGG COUNTS

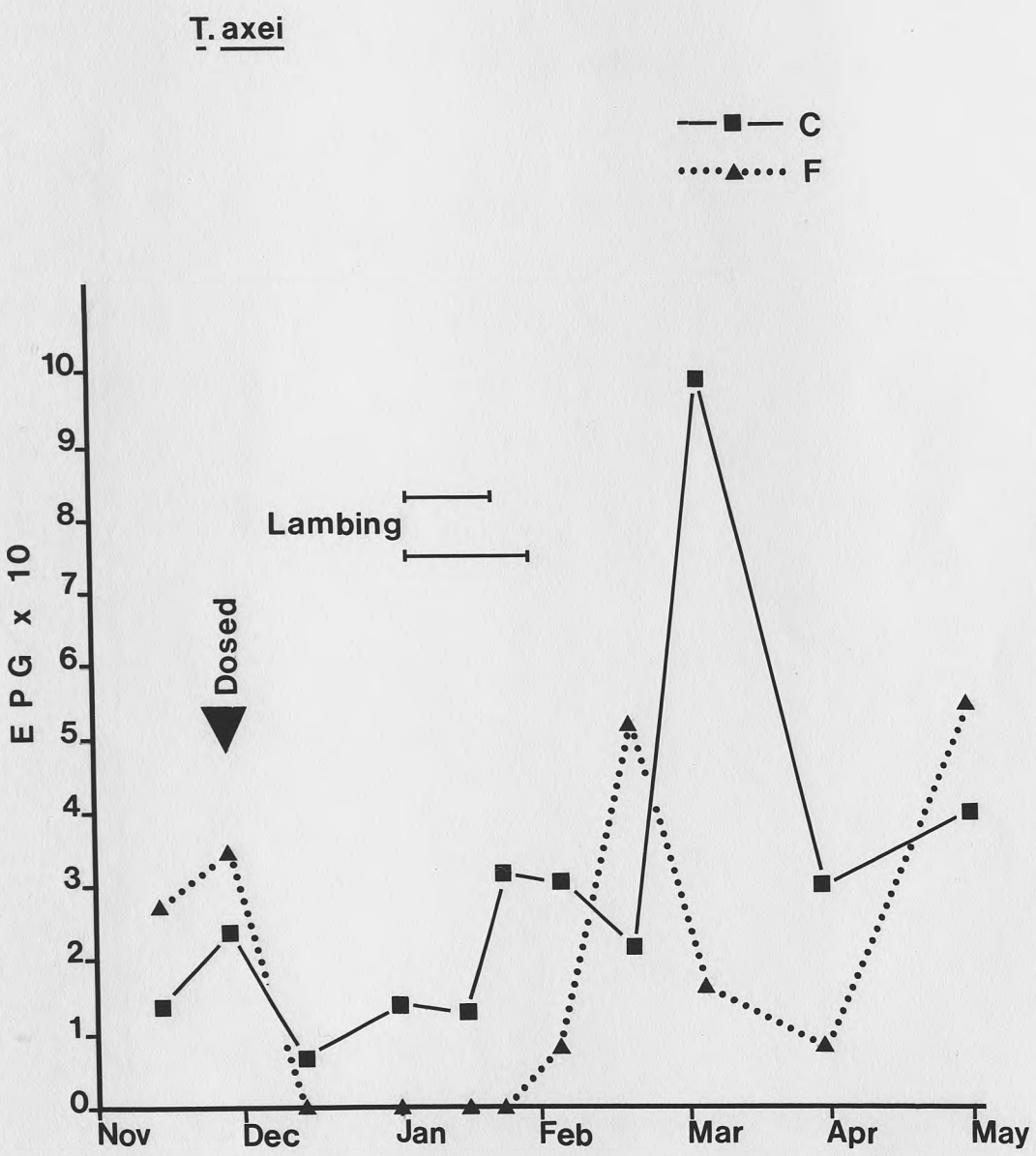


Figure 3

FLOCK I MEAN FAECAL EGG COUNTS

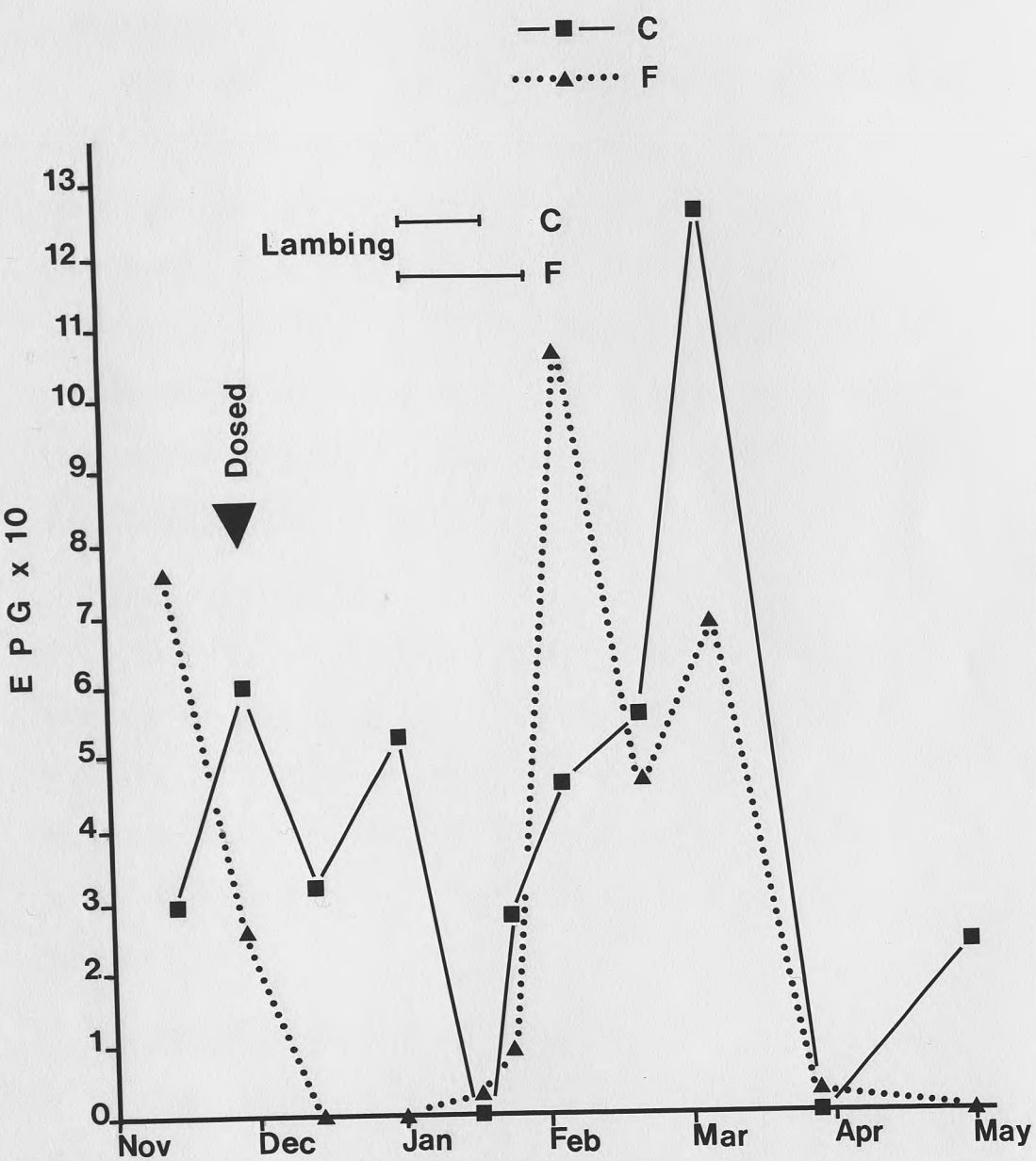


Figure 4

parturient rise had finished, egg production by C. ovina remained very low.

Oesophagostomum venulosum

The frequency with which eggs of this species were observed is shown in Figure 5. No eggs of this species were seen for six weeks following treatment, after which counts returned to pre-treatment levels. This contrasted sharply with the marked, though delayed, increase observed in the undosed sheep. Maximum excretion of eggs of O. venulosum was 182 e.p.g. (40).

Cooperia curticei

The fluctuations of egg output by this species are shown in Figure 6. The general picture is similar to that observed for the previous species:- no rise was observed in the dosed group whereas a peak of 97 e.p.g. (9) was observed in the undosed group.

Trichostrongylus colubriformis

Egg production by this species is also shown in Figure 6. No eggs were observed for seven weeks after treatment. Two peaks occurred in the dosed ewes' output, however, the first may be due to the egg output of one ewe, J12. Following the termination of the rise in the dosed group, egg

FLOCK I MEAN FAECAL EGG COUNTS

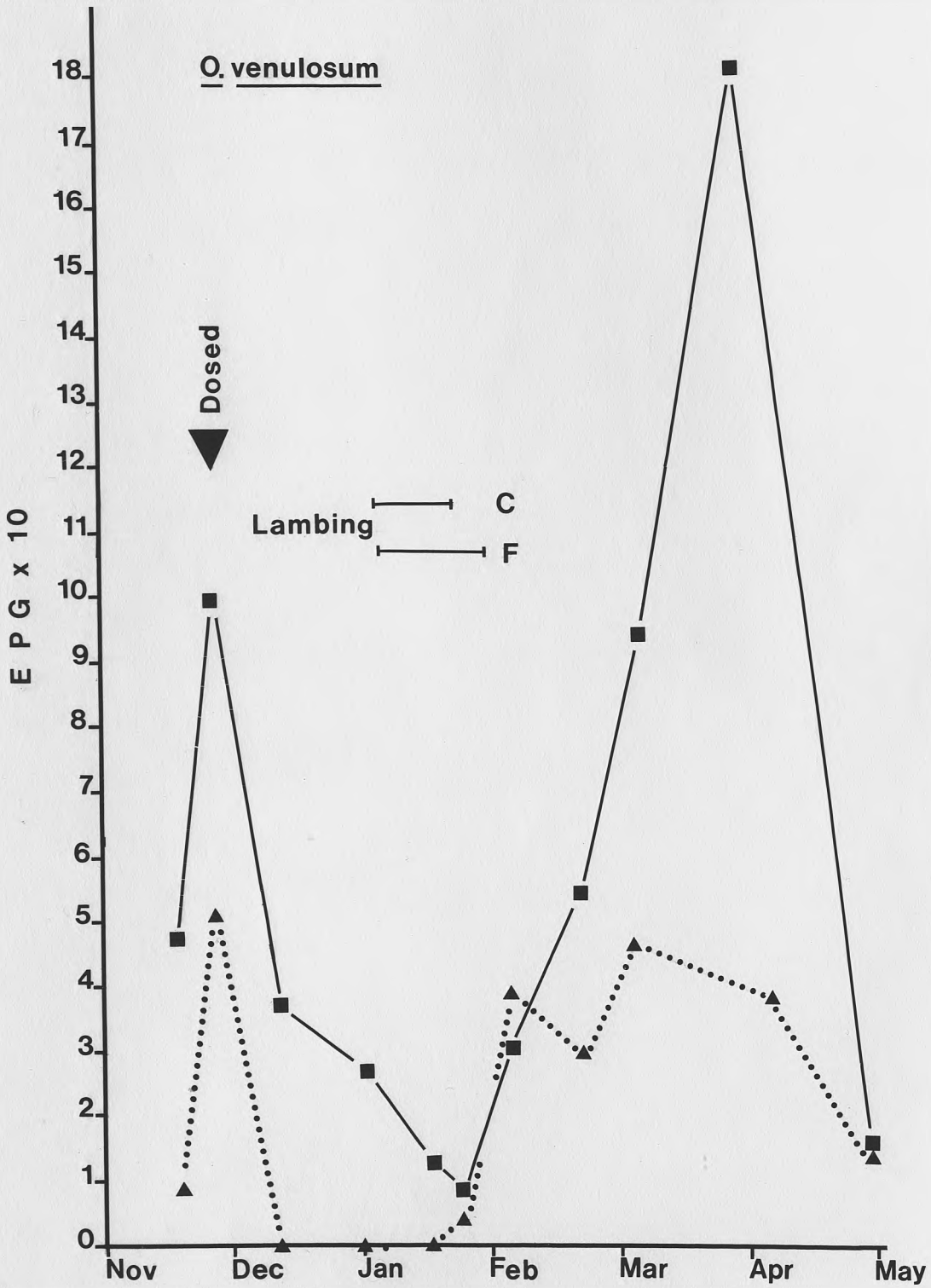


Figure 5

FLOCK I MEAN FAECAL EGG COUNTS

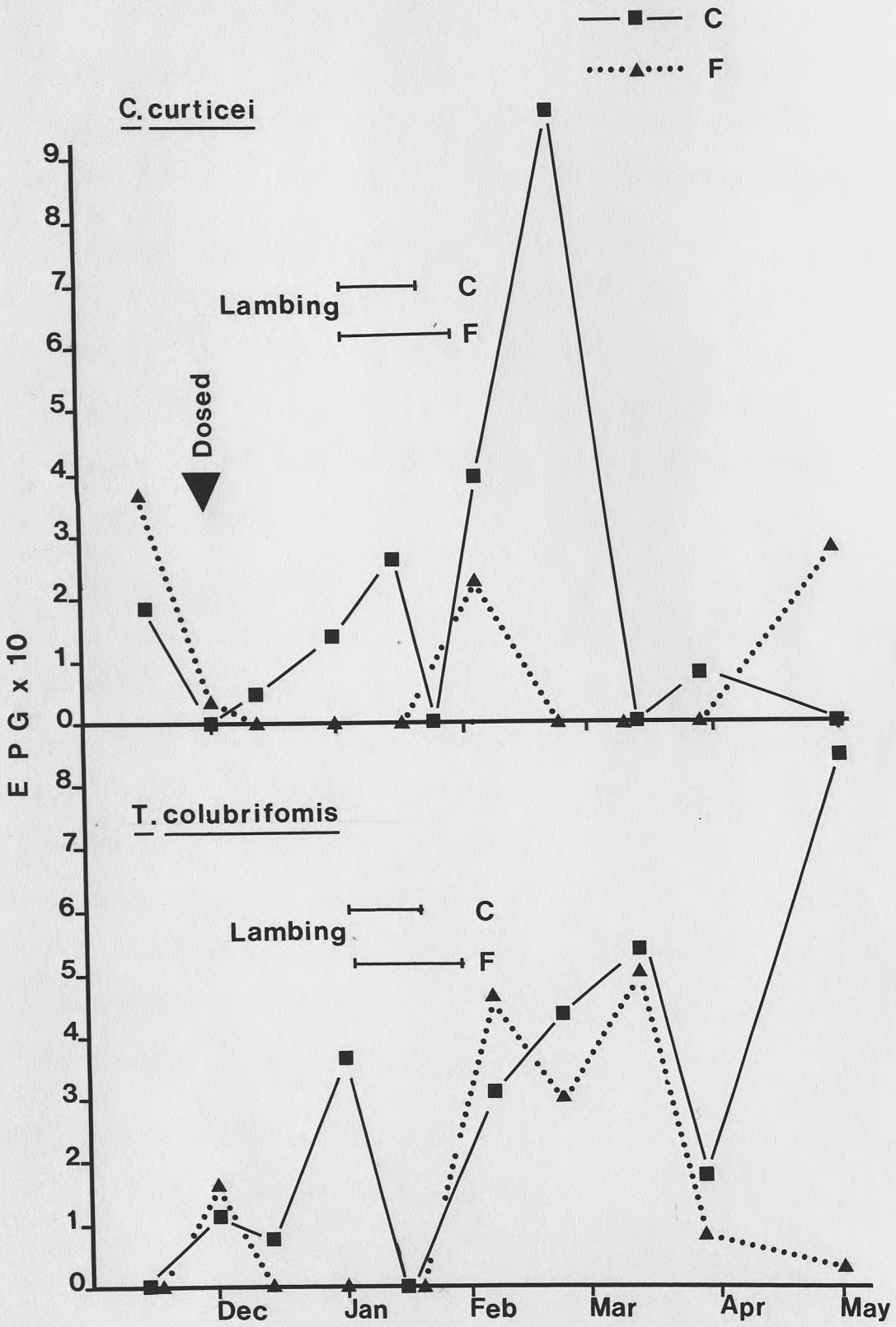


Figure 6

counts fell to very low levels. However, in the undosed group, they rose to attain a higher level of 85 e.p.g. (39) than at any time during the rise.

Trichostrongylus vitrinus

Egg production of T. vitrinus is not shown graphically. No eggs were observed for seven weeks after dosing and the contribution of this species to the post-parturient rise in both groups was very small.

Haemonchus contortus

Egg production of this species is not shown graphically since eggs of this nematode were observed irregularly and in small numbers during the trial. Treatment resulted in no eggs being recorded for 11 weeks; however neither was the control group found to excrete eggs of this species for 10 weeks at a similar time. However, on the last sampling date, the undosed ewes were observed to excrete a mean of 35 e.p.g. (16).

(ii) Larval differentiation

This method was used only once. Samples collected from group IC on January 21st were examined to confirm the observed sudden increase in Ostertagia eggs which had dominated egg production by all other species in the previous sampling.

Eighty-nine of the 100 larvae examined were Ostertagia spp., the remainder being of various species, which were not further identified. The percentage of Ostertagia eggs calculated from the process of egg differentiation was 85 per cent on the same sample.

C. Strongyloides papillosus

Figure 7 shows the egg counts for this species during the trial. Contrary to the post-parturient rise in egg counts of strongyle species, egg counts of S. papillosus fell during the same period. Fenbendazole appeared to have no effect on egg production by this species.

D. Coccidial oocysts

These were present at low levels in ewes in both groups throughout the trial. Counts never rose above 1,000 per gram of faeces and declined before lambing.

E. Herbage larvae estimation

Grass collected from paddock A_I on January 11th indicated a low level of pasture contamination by infective larvae. The figure was estimated to be 40 per kg of grass.

F. Egg counts from lambs

The mean faecal strongyle egg count at about 10 weeks

FLOCK I MEAN FAECAL EGG COUNTS

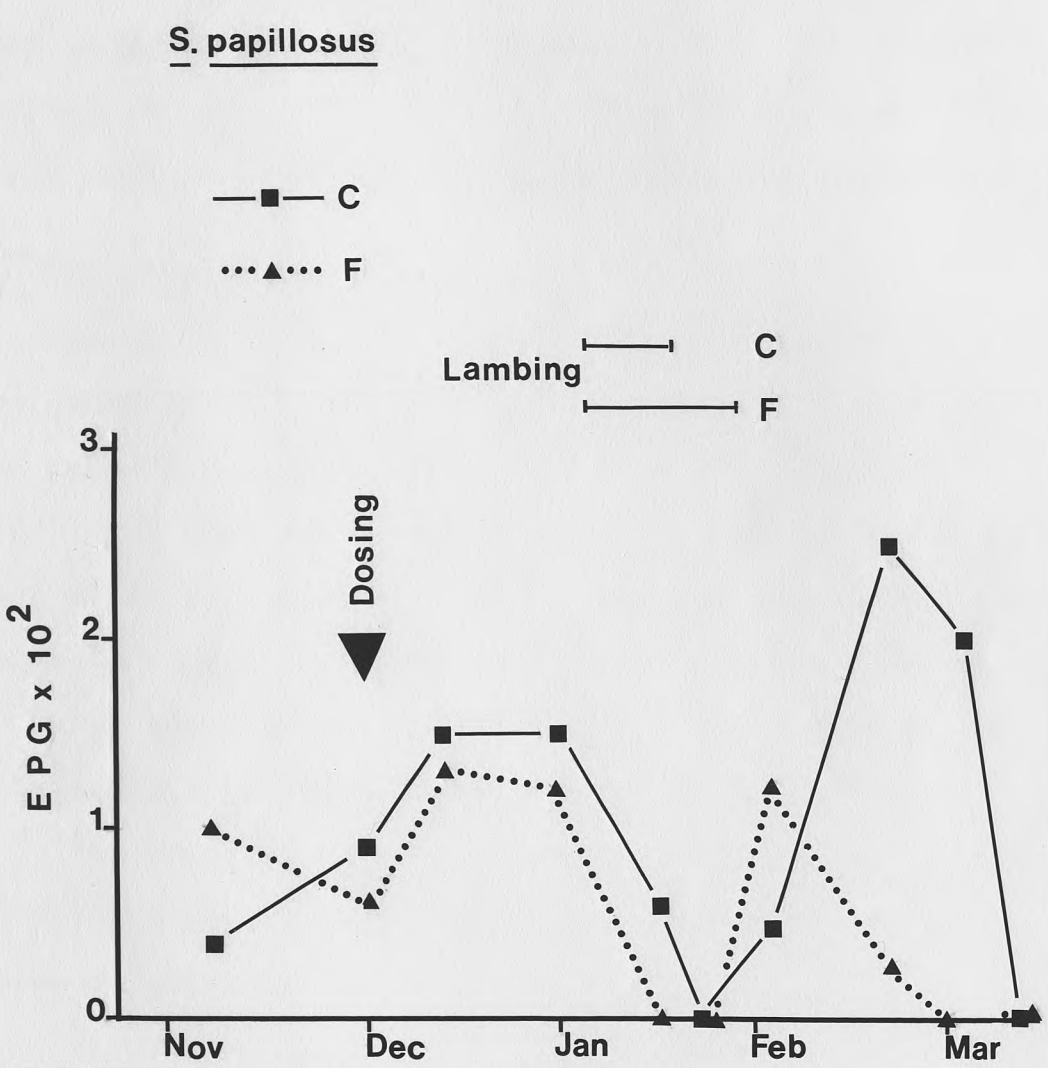


Figure 7

of age was 475 e.p.g. Nine lambs of the 14 sampled had eggs of Nematodirus battus in their faeces with counts varying from 50 to 850 e.p.g. (mean, 470 e.p.g.). Very large numbers of coccidial oocysts were also observed.

G. The live-weight of the lambs

Table IV shows the live-weight of lambs from group IC and group IF at birth and at approximately 56 days of age. The table also shows that five of the six undosed ewes had single lambs (one lamb of the only set of twins was dead at birth), whereas five of the six dosed ewes gave birth to twins. As lambing took place over a period of 22 days, the weight of each lamb at 56 days was extrapolated from its weight before and after this age.

The mean weight gain of the lambs between birth and 56 days of age was 17·3 kg for group IC and 13·8 kg for those in group IF.

FLOCK II. EXPERIMENTAL DESIGN

The trial commenced on March 1st, 1977 when the 33 ewes were randomly divided into the following three groups.

Group IIF.

Eleven ewes, each of which was dosed orally with 15 ml of fenbendazole on March 1st.

Group IIL.

Eleven ewes, each of which was injected with six ml of

TABLE IV.

FLOCK I: LIVE-WEIGHT OF LAMBS AT BIRTH AND AT 56 DAYS OF AGE

Lamb No.	Birth weight (kg)	Weight at 56 days (kg)	Weight gain (kg)
LAMBS FROM EWES IN GROUP C			
3	dead at birth		
4	4·0	13·4	11·4
14	5·0	19·6	14·6
15	6·1	26·0	19·9
25	5·3	25·0	19·7
28	7·1	28·2	21·1
29	6·1	23·1	17·0
Mean weight gain			17·3
LAMBS FROM EWES IN GROUP F			
1	5·0	15·8	10·8
2	4·2	17·6	13·4
11	4·0	14·1	10·1
12	4·2	18·6	14·4
23	3·2	14·8	11·6
24	3·3	17·0	13·7
40	4·1	20·4	16·3
41	4·2	14·4	10·2
42	5·1	26·0	20·9
48	4·0	20·8	16·8
49	dead at birth		
Mean weight gain			13·8

levamisole (Nemicide, I.C.I.) subcutaneously on March 1st.

Group IIC.

Eleven ewes, each of which acted as undosed controls. Two of these ewes were subsequently found to be barren and therefore their egg counts were not included in any calculations for the group.

Commencing on March 1st, faecal samples were taken from each ewe every fortnight until June 19th, and then again on July 13th. Faecal samples were taken from the lambs when they were approximately 10 weeks old.

INVESTIGATION INTO REINFECTION OF EWES

On March 15th, nine ewes, three from each of groups IIC, IIF and IIL were selected on the following criteria:-

Firstly, on the basis of age, ewes born in the same season, 1975, were chosen, since it was presumed they would have similar immunity against gastro-intestinal parasites: secondly, the nine ewes were expected to lamb within a short period, in order to reduce managemental problems and to enable more relevant comparisons to be made regarding observations on the post-parturient rise.

These ewes were housed from March 15th in order to assess the effect of reinfection following anthelmintic treatment. The ewes were managed as one group, were

bedded on straw and fed an adequate diet of hay and concentrate pellets (S.A.I.) mixed in a ratio of 1:5 with bruised oats.

They lambed indoors and were sampled at intervals of a fortnight or less until they were returned to pasture on June 19th.

SERUM PEPSINOGEN STUDY

It was decided to take samples of blood from a population of ewes at fortnightly intervals during the course of the trial in order to study the serum pepsinogen values of ewes receiving either fenbendazole or levamisole relative to the untreated controls.

For this purpose four ewes from each of the three groups, IIC, IIF and IIL, were chosen, using tables of random numbers. Two ewes, L35 from group IIL and L125 from group IIF were in the housed group, the other 10 ewes were managed outside: K35, M174 and M138 from group IIF; H80, K83 and H81 from group IIL, and L59, M76, H30 and L161 were from group IIC.

FLOCK II. RESULTS

A. Strongyle-type egg counts

Figures 8 and 9, and Tables III and IV (Appendix), show the mean faecal egg counts for each of the three treatment groups in the outdoor and indoor ewes

FLOCK II MEAN STRONGYLE EGG COUNTS

Ewes at pasture

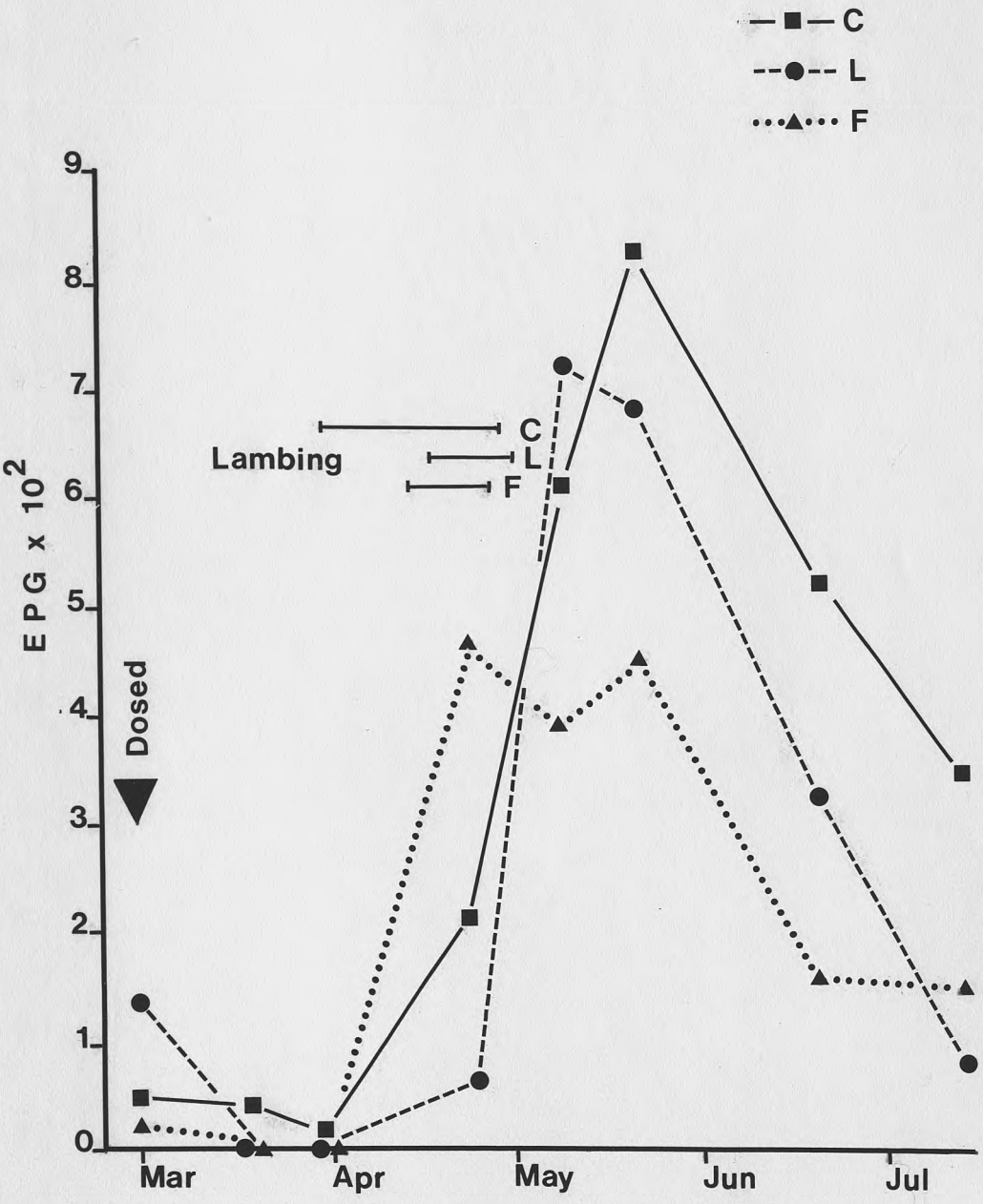


Figure 8

FLOCK II MEAN STRONGYLE EGG COUNTS

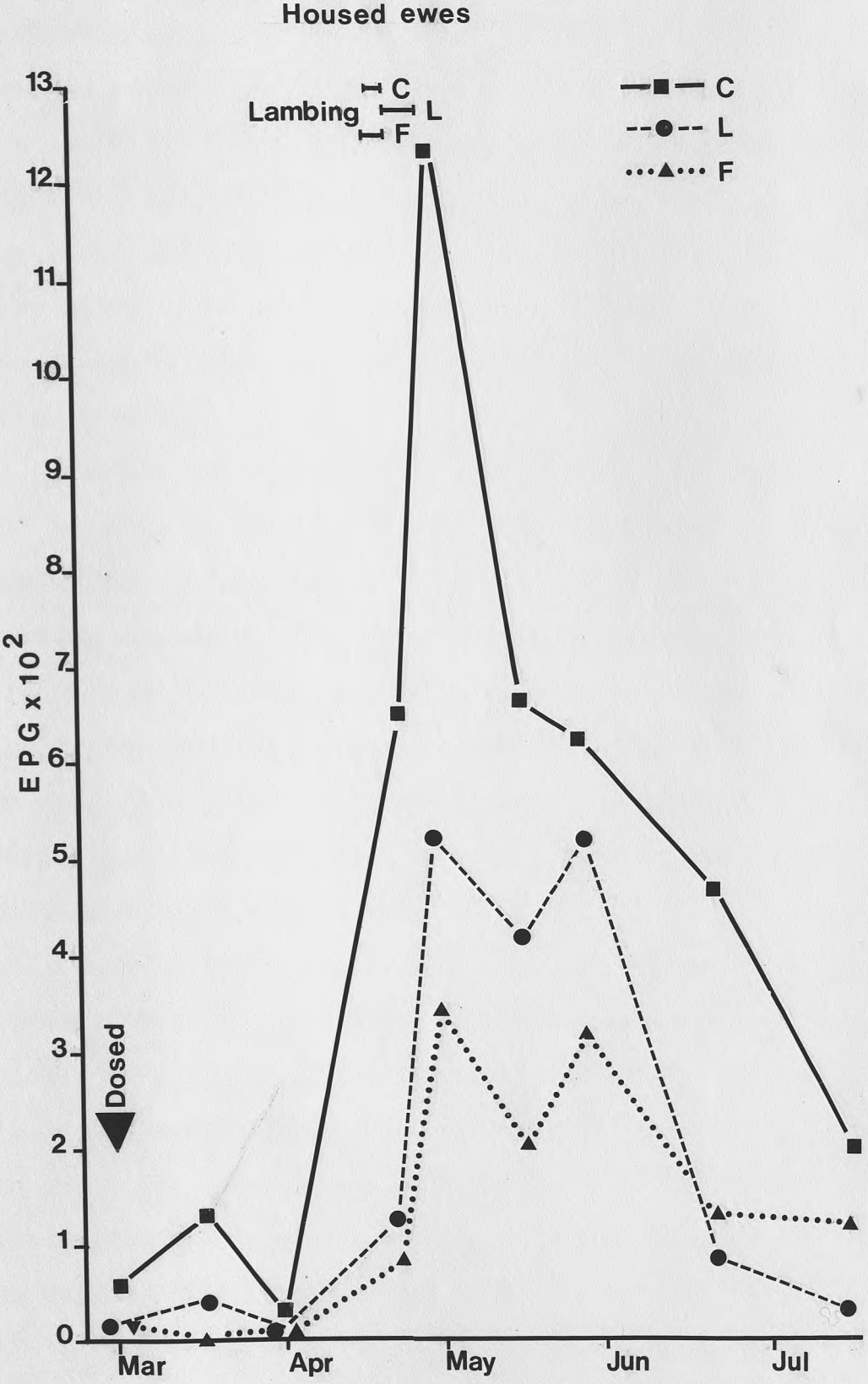


Figure 9

respectively. Median lambing dates for the outdoor ewes in groups IIC, F and L were April 22nd (range April 9th to 28th), April 23rd (range April 18th to May 1st) and April 19th (range April 9th to 24th). Median lambing dates for the housed ewes in groups IIC, F and L were April 18th (range April 16th to 19th), April 18th (range April 17th to 23rd) and April 21st (range April 18th to 26th).

From a low count, dosing with both fenbendazole and levamisole further reduced the egg output to almost negligible levels for four weeks. In both indoor and outdoor undosed ewes, the rise in egg production preceded with the median lambing dates by about 17 days. This is in contrast with flock I, when the rise began a median of nine days after lambing. Data concerning the peri-parturient rise is summarised in Table V, outdoor ewes, and Table VI, indoor ewes.

In both the indoor and outdoor ewes the rise terminated first in those ewes which had received anthelmintics: this was especially marked in the housed ewes. It was calculated for the ewes at pasture that an animal in group IIC produced a mean count of 12×10^6 eggs during the peri-parturient rise, and for groups IIL and F at pasture were 8×10^6 and 4×10^6 eggs. Figures for the housed ewes were 14×10^6, 6×10^6 and 3×10^6 eggs respectively.

TABLE V.

FLOCK II: OUTSIDE EWES. A COMPARISON OF THE POST-PARTURIENT RISE OBSERVED IN GROUPS C, F AND L.

	Group IIC	Group IIF	Group IIL
Median lambing date, April	22	23	19
Date of onset of rise, April	2	5	5
Approximate duration of rise in days (projected from Figure 8)	134	94	79
Onset of rise to peak, days	46	19	30
Peak mean egg count	820	465	726

TABLE VI.

FLOCK II: HOUSED EWES. A COMPARISON OF THE POST-PARTURIENT RISE OBSERVED IN GROUPS C, F AND L.

	Group IIC	Group IIF	Group IIL
Median lambing date, April	18	18	21
Date of onset of rise, April	3	24	21
Approximate duration of rise in days (projected from Figure 9)	120	61	64
Onset of rise to peak, days	32	11	15
Peak mean egg count	1233	338	550

B. Variation in nematode species

Egg differentiation

Pooled samples from both ewes at pasture and those which were housed were subjected to analysis and Table V, and Figures 10 and 11 show the results obtained.

Ostertagia spp.

Figure 10 shows that after treatment with either fenbendazole or levamisole, eggs were not recorded from the faeces of groups IIF and IIL for a period of four weeks. As with flock I, Ostertagia spp. were the main contributors to the peri-parturient rise in all three groups. The pattern of Ostertagia egg production in group IIC was similar to group IC. Fenbendazole also produced similar effects in groups IF and IIF. Maximum egg production by Ostertagia spp. in groups IIC, IIF and IIL was 340 (78), 133 (37) and 226 (34) e.p.g. In contrast to flock I, therefore, Ostertagia spp. were only the dominant egg producers in group IIC: T. colubriformis was the major egg layer in groups IIF and IIL.

Chabertia ovina

Figure 10 shows the egg production of this species. Treatment with both anthelmintics reduced the observed egg counts to zero for four weeks. The maximum egg counts coincided approximately with the total maximum mean in egg output for each group. Peak egg production

FLOCK II Mean faecal egg count

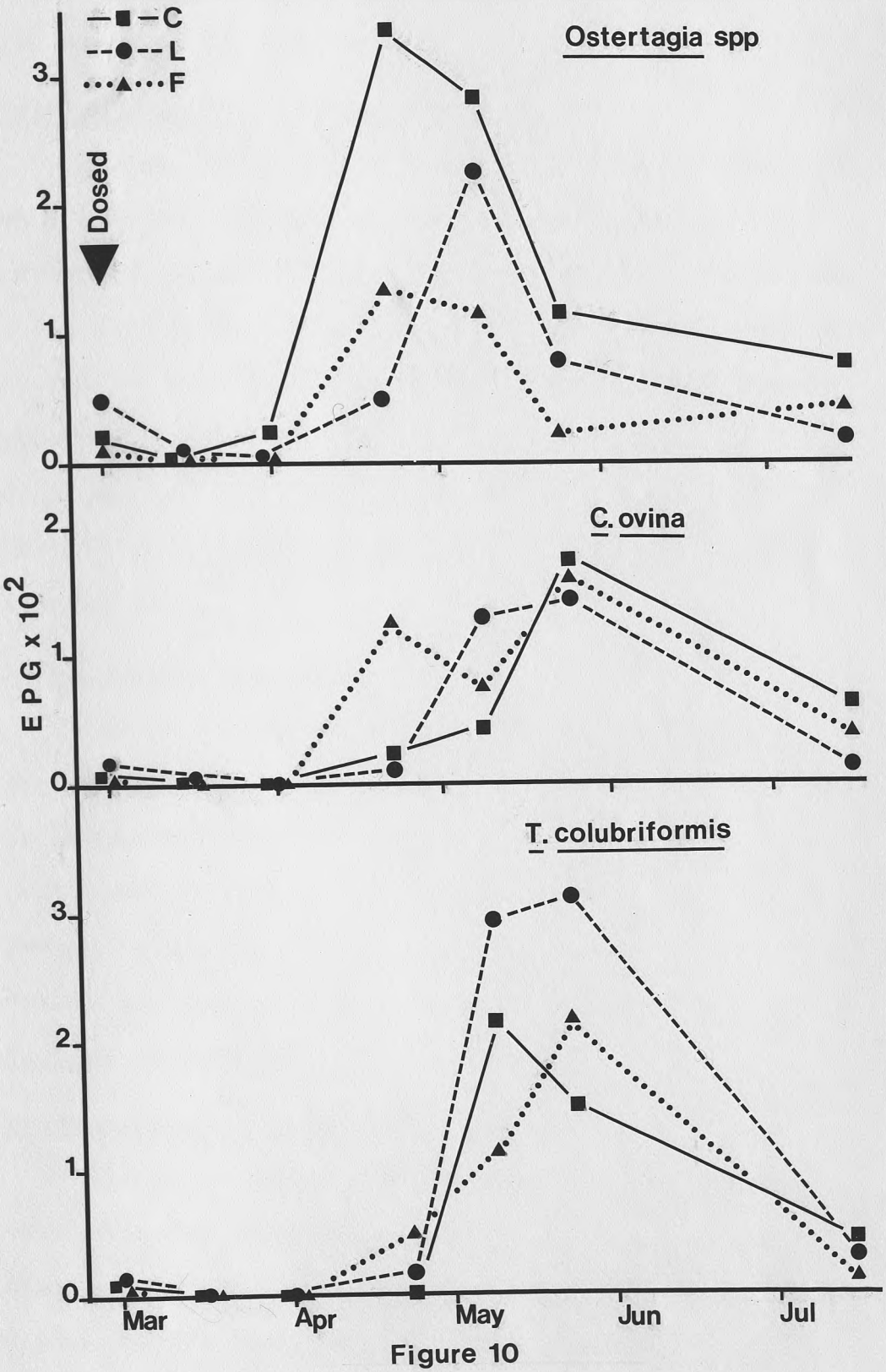


Figure 10

by C. ovina was 175 (28), 165 (40) and 153 (24) e.p.g. for groups IIC, IIF and IIL.

Trichostrongylus colubriformis

Figure 10 shows the steep rise in egg counts of this species which coincided with the peak of the peri-parturient rise in all three groups. Prior to this, both anthelmintics had reduced the observed egg counts to zero for four weeks. The maximum counts recorded for groups IIC, IIF and IIL, were 216 (32), 216 (52) and 307 (48) e.p.g. respectively. These observations differ markedly to those made for flock I (Figure 6).

Trichostrongylus axei

Figure 11 shows that T. axei eggs were not recorded following treatment with either fenbendazole or levamisole for the remainder of the trial. This contrasted with the rise seen in group IIC, which reached a peak of 90 e.p.g. (16). In flock I, fenbendazole did not permanently reduce egg counts due to T. axei (Figure 3).

Oesophagostomum venulosum

Figure 11 shows that no eggs of this species were observed prior to the start of the peri-parturient rise. Egg production was 77 (12), 29 (8) and 51 (3) e.p.g. at its maximum for groups IIC, IIF and IIL.

FLOCK II MEAN FAECAL EGG COUNTS

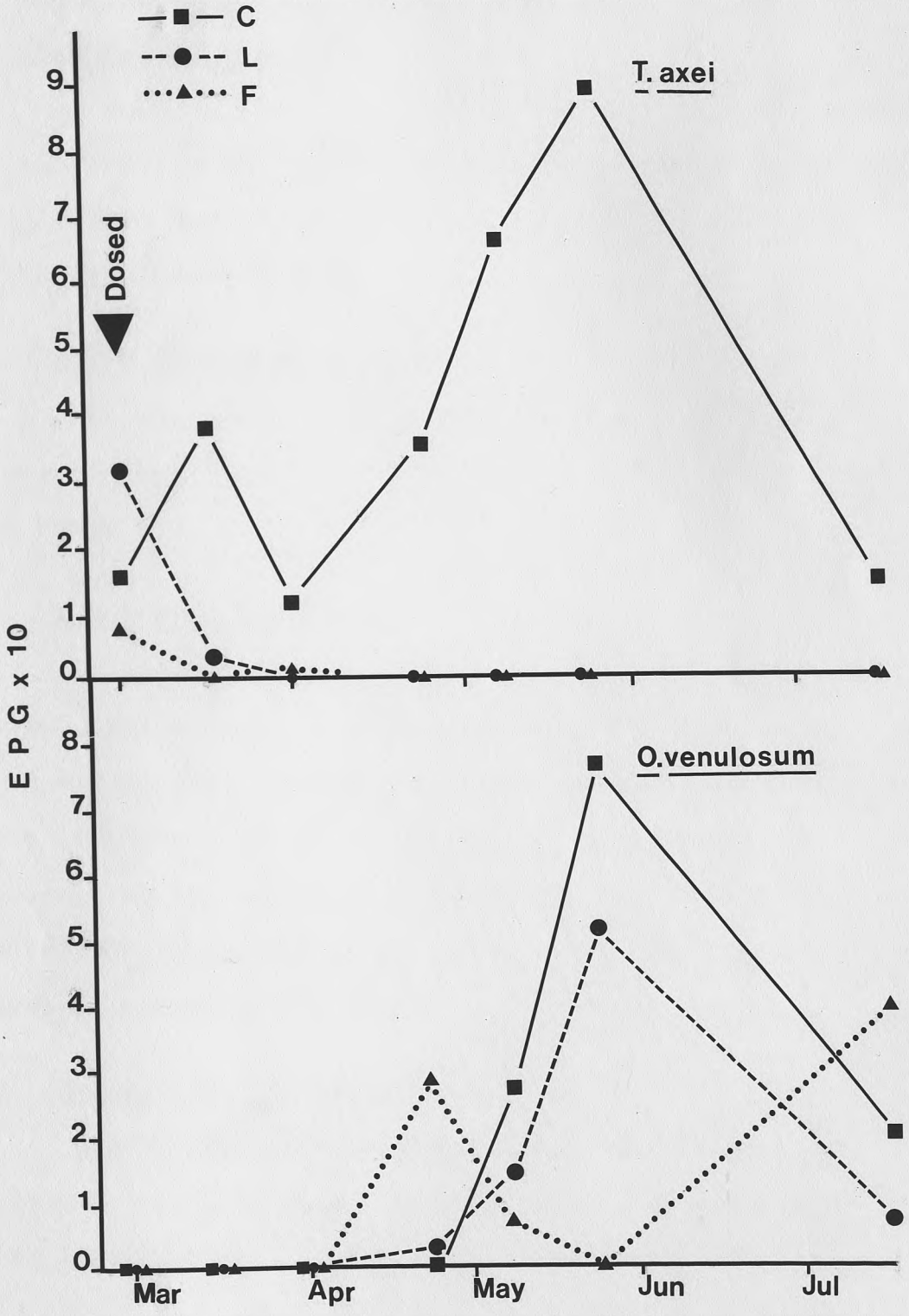


Figure 11

Haemonchus contortus, *Trichostrongylus vitrinus* and *Cooperia curticei*

Table V (Appendix) shows that, at no time during the trial were eggs of these species numerous, neither did they show fluctuations corresponding with the peri-parturient rise.

C. Serum pepsinogen assays

The results of this study are given for individual ewes together with mean egg counts for the same period in Table VII.

D. Egg counts from lambs

It was possible to sample only 40 lambs from the total crop of 60. The mean strongyle egg count was 850 e.p.g. with a range of 100 to 2,200 e.p.g., when the lambs were about 10 weeks old. *N. battus* was present at low levels (50 to 300 e.p.g.) in approximately 50 per cent of the lambs. Coccidial oocysts were observed in all lambs in very large numbers.

E. Herbage larvae estimation

Grass collected on March 28th from paddock A_{II} yielded an estimated 30 infective third stage larvae per kg of grass.

TABLE VII.

FLOCK II: SERUM PEPSINOGEN VALUES (units tyrosine) IN RELATION TO STRONGYLE EGG COUNTS

(bottom figures, e.p.g.)

Group	Sheep No.	Date of lambing	Sampling dates 1/3	16/3	1/4	22/4	15/5	13/7
C	L59	*	0·49 31	0·42 18	0·76 3	0·52 3	1·81 50	0·94 0
C	H30	15/4/77	2·15 NS	2·22 0	1·70 3	1·88 0	3·92 2150	1·94 750
C	L161	28/4/77	0·38 190	0·21 4	NS 24	0·56 9	0·24 750	0·28 600
C	M76	*	1·76 22	NS 1	0·69 10	0·50 31	0·69 14	0·10 50
F	K35	18/4/77	3·19 9	2·26 0	1·08 7	1·84 200	2·40 300	2·39 0
F	L125**	17/4/77	1·58 35	2·12 0	1·22 7	1·94 200	1·70 150	2·12 100
F	M138	29/4/77	0·80 13	0·60 0	0·42 3	1·04 12	1·25 150	1·11 100
F	M174	1/5/77	0·42 1	0·24 4	0·24 7	0·45 54	0·45 18	2·01 0
L	H80	22/4/77	0·38 33	0·50 4	0·41 0	0·45 37	0·21 NS	0·38 100
L	K83	24/4/77	2·78 15	1·63 NS	1·04 0	1·74 40	2·43 105	2·47 250
L	H81	19/4/77	0·35 447	0·66 19	0·56 NS	0·45 35	1·06 1200	0·35 0
L	L35**	21/4/77	0·66 48	0·96 0	1·29 7	1·00 206	0·80 900	0·30 50

* barren

** housed

NS not sampled

FLOCK III. EXPERIMENTAL DESIGN

The ewes were randomly divided into three groups each consisting of 103 ewes and the groups treated as follows.

Group IIIF.

All ewes were dosed and ear-tagged on January 29th, 1977, with 15 ml of fenbendazole orally. Twenty of these ewes were randomly chosen as a representative sample for faecal examination. Each received an individually numbered ear-tag, half of which was coloured red - indicating that the ewe should be sampled for faeces, the other half was blue showing that she had been dosed with fenbendazole. The other 83 ewes in this group received all blue ear-tags and lambs born into the "blue" group were also tagged with blue tags.

Group IIIL.

This group was similarly chosen and dosed with six ml of levamisole subcutaneously. Twenty ewes which were to be sampled for faeces received numbered red and yellow tags. The remaining 83 ewes received double yellow tags and lambs born from these ewes received yellow tags.

Group IIIC.

These ewes were left as undosed controls. Twenty

ewes chosen to be sampled for faeces received all red tags, and the remainder were untagged. Lambs born into this latter group were also untagged.

Faecal samples were taken from the selected ewes on January 29th prior to treatment, on February 26th, to check the efficacy of treatment, and on April 23rd, about five weeks after lambing to observe the content of any post-parturient rise.

All lambs born into the flock excepting those which had lost their ear-tags and those which had been hand-reared were weighed on June 29th.

FLOCK III. RESULTS

A. Strongyle-type egg counts

The results from the three faecal samples are shown in Figure 12 and Table VI (Appendix).

In late January, egg counts were very low and one month after dosing with fenbendazole, the mean egg count for group IIIF was still only 30 e.p.g. - one-fifth of the count observed in the undosed group. Those ewes which had received levamisole also had a lower egg count at this time.

A post-parturient rise occurred in all three treatment groups. It was highest in group IIIC and lowest in group IIIF.

FLOCK III MEAN STRONGYLE EGG COUNTS

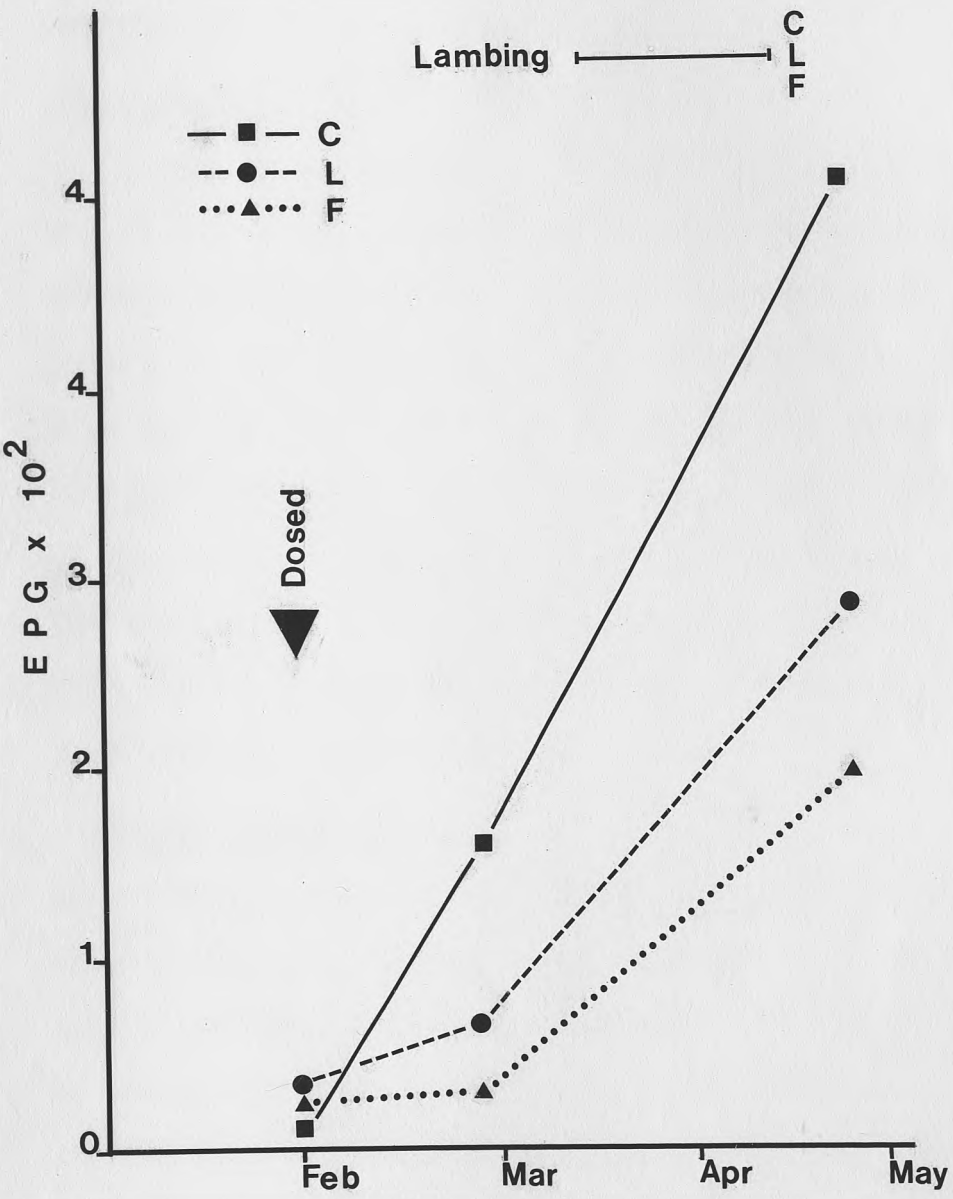


Figure 12

B. Variation in nematode species

(i) Egg differentiation

Table VIII shows the numbers of eggs per gram of faeces recorded for each species of nematode observed in flock III.

Ostertagia spp.

Eggs were present in very small numbers at the start of the trial, however, one month after dosing, Ostertagia spp. were the dominant egg layers in group IIIF and IIIL, producing 73 per cent and 81 per cent of total egg counts respectively. In group IIIC, Ostertagia eggs comprised 41 per cent of the total mean egg production. The contribution to the rise was 30, 34 and 47 per cent of total mean egg production for groups IIIC, IIIF and IIIL respectively.

Trichostrongylus axei

At the start of the trial, this species was responsible for 87, 84 and 84 per cent of the small mean total egg production by all species of nematodes, in groups IIIC, IIIF and IIIL. One month after dosing, egg production was observed to fall to very low levels in groups IIIF and IIIL but remained at 36 (22) e.p.g. in group IIIC. This pattern was maintained at the last sampling.

TABLE VIII.

FLOCK III: ESTIMATED FAECAL EGG COUNT FOR EACH SPECIES OF NEMATODE (e.p.g.)

Nematode species	Sampling dates		
	29/1/77	26/2/77	23/4/77
GROUP C			
T. axei	13	36	26
Ostertagia spp.	1	67	154
T. vitrinus	0	0	103
C. ovina	1	20	62
C. curticei	1	0	0
O. venulosum	1	10	56
T. colubriformis	0	27	112
Total for all species	17	160	513
GROUP F			
T. axei	21	1	4
Ostertagia spp.	1	22	73
T. vitrinus	0	1	31
C. ovina	2	2	23
C. curticei	1	0	0
O. venulosum	1	2	29
T. colubriformis	0	3	50
Total for all species	26	31	210
GROUP L			
T. axei	31	0	0
Ostertagia spp.	1	53	136
T. vitrinus	0	1	40
C. ovina	3	4	40
C. curticei	2	0	0
O. venulosum	1	2	46
T. colubriformis	0	5	26
Total for all species	38	65	288

Trichostrongylus vitrinus

Egg laying by this species increased from low levels before the rise to 20, 15 and 14 per cent of the mean total egg production in groups IIIC, IIIF and IIIL during the post-parturient rise.

Chabertia ovina

Egg laying by this species increased from very low levels prior to the post-parturient rise, to 12, 11 and 14 per cent of the mean total egg production during the rise: counts are for groups IIIC, IIIF and IIIL respectively.

Cooperia curticei

Eggs of this species were only observed and then in very low numbers, at the beginning of the trial.

Oesophagostomum venulosum

Eggs recorded for this species rose from low levels at the start of the trial to represent 11, 14 and 16 per cent of mean egg counts recorded for groups IIIC, IIIF and IIIL respectively.

Trichostrongylus colubriformis

Egg counts followed the pattern already observed for O. venulosum, C. ovina and T. vitrinus. Counts for groups IIIC, IIIF and IIIL on April 23rd were 22, 24 and 9 per cent of total mean egg production respectively.

(ii) Larval differentiation

This technique was performed on samples collected on February 26th. Following incubation of the pooled samples, the first 100 larvae seen in each of groups IIIC, IIIF and IIIL were identified. The percentage of each species present was converted to actual numbers from the mean egg count already recorded for each group and expressed in Table IX.

TABLE IX.

FLOCK III: ESTIMATED FAECAL EGG COUNT FOR EACH SPECIES OF NEMATODE: LARVAL DIFFERENTIATION - FEBRUARY 26th

Nematode species	Percentage of larvae		
	Group C	Group F	Group L
T. axei	36	0	0
Ostertagia spp.	79	30	54
C. ovina	18	0	8
O. venulosum	12	0	0
T. colubriformis	15	0	2
Total for all species	160	30	64

C. Herbage larvae estimation

The pasture grazed by the sheep during the period after dosing was sampled on February 26th and gave an estimated contamination level of 15 infective third stage larvae per kg of grass.

D. The live-weight of lambs

Table X shows the live-weight of lambs on June 29th. Lambs' weights were recorded into one of six groups according to age and status as a twin or single. The bottle-reared third lambs were not weighed. Table X also shows that in general ewes dosed with fenbendazole lambed earlier than those dosed with levamisole: the reverse occurred in flock II. The average overall weight of those lambs whose mothers had remained undosed was 35·1 kg, while that of lambs born from ewes in group IIIF and IIIL was 34·8 kg and 34 kg respectively.

TABLE X.

FLOCK III: LIVE-WEIGHT OF LAMBS AT APPROXIMATELY 14 WEEKS OF AGE

Lamb group	Ewe group	Number of lambs	Mean weight (kg)
Early twins	C	72	33·32
	F	44	35·02
	L	24	33·08
Early singles	C	14	38·00
	F	6	39·80
	L	10	35·40
Second eldest twins	C	54	32·92
	F	22	33·50
	L	10	32·60
Second eldest singles	C	8	41·62
	F	18	38·88
	L	12	36·16
Youngest twins	C	42	32·24
	F	16	29·25
	L	54	31·70
Youngest singles	C	28	32·50
	F	8	32·21
	L	16	34·81

DISCUSSION

EXPERIMENTAL DESIGN

Animals

The proximity of flocks I and II on Easter Bush Farm enabled a frequent and detailed study of the peri-parturient rise which was not possible with the sheep at Low Middleton Farm. It was only possible to take samples from these ewes on three occasions and Figure 12 shows that interpretation of anthelmintic treatment must be based largely on hypotheses, since factual information is limited. An additional sampling during lambing would have given important information about the comparative timing and size of the peri-parturient rise in the three treatment groups. Even in flocks I and II further samplings would have given more detailed information.

In flock I, the January lambing Suffolks, there are three ewes, A16, D5 and H59, which were studied individually and as part of a larger Suffolk flock in 1975 by Woodham in his epidemiological survey of gastro-intestinal parasitism, and in 1976 by Singh in his evaluation of pre-lambing dosing with levamisole. Two other investigations into the seasonal variation of parasitic nematodes were made by Myers (1974) and Aklaku (1976) who both used the January lambing Suffolk flock, but who did not include data for individual ewes. It was felt that a continuation of the previous studies would be of value both in

comparing the reactions of individual ewes in different years and in providing more data for related ewes under the same system of management.

Flock II, the April lambing crossbred Suffolk ewes, has not formed part of a previous study on gastro-intestinal parasitism. However, the ewes were managed as part of a larger Cheviot flock which formed part of the epidemiological studies conducted by Myers (1974), Woodham (1975) and Aklaku (1976). The former two authors noted that the Cheviot ewes appeared less susceptible to trichostrongylidosis than Suffolk ewes which were managed under the same system. Observations made on Suffolk crossbred ewes may give further evidence relating to this theory of the varying genetic susceptibility to helminth infections of different breeds at Easter Bush Farm. A more direct and informed comparison may also be made of the value of pre-lambing anthelmintic treatment of ewes lambing in January (flock I) and ewes lambing in April (flock II).

Flock III, the Cheviot ewes in Northumbria, was chosen because the large number of ewes available would enable a better statistical analysis of any observed benefits of dosing in an intensively managed lowland flock.

Choice of drugs

Levamisole was chosen as a standard modern anthelmintic

against which to compare a newer less well known drug for three reasons:-

(i) The efficacy of levamisole against adult and immature gastro-intestinal parasites in sheep has been extensively tested and found to be very high (Forsyth, 1966; MacKay, 1972; Boag & Thomas, 1973).

(ii) Its action against inhibited H. contortus larvae (McKenna, 1974) and inhibited O. circumcincta (Reid et al, 1976) was likewise found to be greater than 95 per cent efficient.

(iii) The drug was used on the January lambing Suffolk ewes at Easter Bush Farm by Singh (1976).

Fenbendazole was chosen since, although it has been shown in preliminary investigations to be effective against inhibited O. ostertagi larvae in cattle (Duncan et al, 1976), its efficacy against inhibited larvae in sheep was not known. The present trials were therefore designed to evaluate its performance against inhibited larvae and to measure this in terms of lamb live-weight gains at weaning.

Time of dosing

The value of dosing to prevent pasture contamination due to the peri-parturient rise has been recognised for many years. Murray et al (1971) showed that dosing

prior to tupping followed by a move to clean pasture was economically advantageous. However, the academic year did not allow a study of pre-tupping dosing, and clean pasture was not available. MacKay (1972), working with flocks of Scottish hill ewes, suggested that it was economically advantageous to dose ewes prior to lambing even when the absence of clean pasture made reinfection inevitable. This contradicts Lewis & Stauber (1969), Arundel (1971) and Brunsdon (1974), who all concluded that pre-lambing dosing must be followed by movement to clean pasture if the potential production benefits are to be realised. Since clean pasture was not available - a common situation on sheep farms - it was decided to try to reproduce MacKay's results in lowland flocks.

Techniques of estimating worm-burdens

Post-mortem worm counts are the most reliable method of establishing the numbers and species composition of helminths in sheep. Unfortunately, considerations of economics did not allow serial slaughter of the ewes, neither did it allow slaughter of two or three animals after dosing, when digestion techniques would have enabled a direct evaluation of the efficacy of each drug against inhibited larvae. The disadvantages of McMaster egg counts have been discussed earlier. In this project, two chambers of a McMaster slide were examined and, if the averaged count was less than 150 e.p.g., a salt

flotation was carried out. The ratio of counts using the McMaster technique to counts after salt flotation was usually about 1 to 2:1 but ranged from 10:1 to 0·5:1. The general impression was that above 100 e.p.g. the McMaster technique was more reproducible, while below 100 e.p.g. salt flotations were more sensitive. Consistent results were most difficult to obtain in spring, when the faeces of ewes were very fluid following the flush of grass.

No difficulty was experienced in identifying eggs of Nematodirus spp. or Strongyloides papillosus in routine McMaster examination. It was also found that after incubating faeces at 4°C for six days, the larvated eggs of Ostertagia spp. could be easily recognised. In view of the major importance of Ostertagia spp. both as the dominant parasite responsible for the post-parturient rise (Seghetti & Marsh, 1945; Crofton, 1954) and in causing disease in lambs (Boag & Thomas, 1971, 1972, 1973), this technique could be a valuable diagnostic tool.

Identification of L_3 larvae after culture is the most commonly used method of discriminating between species of strongyle eggs observed in faeces. This technique was only used twice and was found to be tedious, time consuming and subjective. Crofton (1963) recognised that the standard incubation conditions in the laboratory may favour the development of one species above another

and thus it cannot be assumed that the proportions of the different species is the same for the larvae as for the eggs from which they were derived. This may be illustrated using H. contortus as an example; very few, if any, eggs of this species may be expected to survive and develop on pasture in the conditions prevailing during a Scottish spring (Kates, 1950), whereas, in the warmth and humidity of an incubator it might be expected that survival and development of H. contortus would be especially favoured.

The technique of egg identification developed by Christie & Jackson (1975) and used in a modified form during these trials was found to be simpler and less subjective than larval differentiation. However, it was still time consuming and tedious and of value only as a research tool owing to the very strong light source which is necessary for the microscope, and the time involved. Problems were encountered with T. axei in flock III, which did not develop to the gastrula stage as described by Christie & Jackson (1975), Woodham (1975) and Aklaku (1976), although the measurements of the eggs were within the ellipses drawn for the species by Woodham (1975). An explanation could be that the T. axei isolated from flock III (Northumbria) was a local strain with reduced survival in saturated salt or a slower rate of development.

Development of T. axei recovered from sheep at Easter Bush Farm was in line with the observations of Woodham (1975). The modifications suggested by Aklaku were useful but further research is necessary if the technique is to realise its full potential in the field. Modification of the light source, so that an ordinary light microscope may be used, and further information on the effects of low temperature incubation and salt flotation on the viability and development rate of eggs of all gastro-intestinal nematodes is needed.

EFFECTS OF TREATMENT - FLOCK I.

Ewes

Figure 1 shows that, after oral dosing with fenbendazole, the mean egg counts for group IF remained below 100 for 56 days, as it may be assumed that egg counts fall to zero within 24 hours of treatment (Ross, 1975). However, by the 70th day after treatment, four of the six ewes had counts of 200 or above, and three of these had counts in excess of 1,000 e.p.g.

Two ewes, A16 and H59 did not show any post-parturient rise. These findings are very similar to those of Singh (1976). His explanation was that ewes had become reinfected with larvae which had survived the mild winter of 1975 - 6 on the pasture. Figure 14 shows that the winter of 1976 - 7 was considerably colder than

the previous winter and was unlikely to permit larval development. Pasture contamination was found to be low at 40 per kg, and ewes were removed from even this source of reinfection during January due to inclement weather, although larvae ingested during December may have inhibited and, later, matured to contribute to the post-parturient rise. If Singh's theory of reinfection is to be accepted, several observations need to be explained. The first is the time lag of 70 days between dosing and the start of the rise, since the prepatent periods of the species responsible for the rise are usually only 19 to 23 days. The second is that reinfection is a continuous process, yet the amplification in egg counts was about 60-fold in four ewes over a 14 day period. The third is that, prior to treatment, only 20 per cent of the total mean egg count was due to Ostertagia spp. yet on January 14th and January 21st, 96 per cent of total mean egg production was due to Ostertagia spp.

It is possible that larvae picked up from the pasture during December were mostly Ostertagia species, and that these inhibited in the ewes until around parturition when relaxation of ewes' resistance allowed them all to develop at once. An alternative suggestion is that although after anthelmintic treatment new infection rapidly becomes re-established (Sewell, 1976), fenbendazole may have a residual effect on the host, which either

prevents the re-establishment of infection or delays egg production (Tharaldsen, 1977). This theory may receive circumstantial support from observations of Woodham (1975) and Aklaku (1976) who noticed that when housed January lambing Suffolk ewes were put back on to pasture a steep rise in egg counts occurred three weeks later. This would suggest that infective larvae were immediately ingested by the ewes and that they commenced egg laying after a normal prepatent period. Larvae on the pasture at this time of the year, however, would not have received the chill stimulus which induces inhibition.

Unfortunately, the species composition of the pasture contamination was not known but it is likely that Ostertagia spp. predominated, with some Trichostrongylus spp., C. curticei and C. ovina (Soulsby, 1965). This could support the theory that the post-parturient rise was in part due to maturation of Ostertagia larvae that were ingested and inhibited after dosing.

However, these explanations do not seem entirely satisfactory since the post-parturient rise was very large relative to the lightness of pasture contamination, so, an alternative hypothesis, that fenbendazole did not remove inhibited larvae should be considered. Ewes treated with fenbendazole in Norway in autumn and then housed on slatted floors during winter did not show a peri-parturient rise whereas undosed controls did

(Tharaldsen, 1977). However, there is evidence to suggest that anthelmintics are more efficient against inhibited larvae in the early stages of dormancy in autumn than when dormancy is well established in winter or spring (Armour et al, 1975). After the dry months of August and September, October was both cold and very wet, Figure 13. It may be expected that larvae which were trapped within the faecal pellets during the dry summer were suddenly released and exposed to chilling, the stimulus for inhibition within the host (Armour & Bruce, 1974). It may be postulated therefore that the ewes were carrying larger than average burdens of inhibited Ostertagia larvae. The combination of anthelmintic dosing during the "deeper" period of dormancy and an unusually heavy burden may be an alternative explanation for the presence of a post-parturient rise in the treated ewes largely composed of eggs of Ostertagia spp.

Both these hypotheses explain the sudden appearance of large numbers of eggs, since the stimulus for maturation could reasonably be expected to occur over a short period of time. They also explain the preponderance of Ostertagia eggs and why egg laying was delayed relative to the undosed ewes, even taking into account the slightly later lambing period of the former group. Pepsin digest techniques on abomasal mucosae of ewes slaughtered 48 hours after dosing would have clearly indicated the

efficacy of fenbendazole against inhibited larvae.

Prior to the rise, counts of 200 to 300 e.p.g. were consistent with the findings of a number of workers on Scottish sheep during winter. Egg counts of the undosed ewes were significantly higher than those of the dosed ewes on 14th January ($N = 10$, $t = 4{\cdot}62$, $P < 0{\cdot}001$) and on 21st January ($N = 11$, $t = 3{\cdot}54$, $P < 0{\cdot}01$). Although the peak mean count of group IC was higher than group IF, this was not found to be significant ($N = 11$, $t = 1{\cdot}21$, $P > 0{\cdot}05$), neither were the individual peaks of control sheep significantly higher than those of the dosed group ($N = 11$, $t = 0{\cdot}54$, $P > 0{\cdot}05$).

Larvae developing from eggs shed during the peri-parturient rise are a major source of infection to the newly grazing lamb. Although each undosed ewe was estimated to excrete nearly twice as many eggs over the period of the post-parturient rise as a dosed ewe, analysis of the transformed summated data showed that this difference was not significant ($N = 11$, $t = 0{\cdot}97$, $P > 0{\cdot}05$).

Table II (Appendix) and Figure 2 show that Ostertagia spp. was the predominant genus contributing to peri-parturient rise in egg counts in both dosed and undosed ewes. This contrasts with the findings of Singh (1976) who found that Cooperia was the predominant genus in the undosed sheep. This could perhaps be

explained by the climatic differences of 1975 - 6 and 1976 - 7, as, in the latter year, conditions enhanced the likelihood of inhibition of Ostertagia. A marked but delayed rise in numbers of O. venulosum eggs was observed in the undosed sheep, that in the dosed sheep was considerably smaller, Figure 5. As O. venulosum has a low survival rate over winter, this suggests that the rise in the undosed group was due to an increased fecundity of the existing burden, while the small rise in the dosed sheep resulted from larval pick up. The similar picture obtained for C. curticei cannot be likewise explained since this species is reputed to be able to overwinter on pasture (Kates, 1950). The rise in egg production of T. axei and C. ovina was delayed relative to the mean total rise and was consistently higher in the undosed sheep. This agrees with the findings of Woodham (1975) at Easter Bush Farm and Connan (1968b) working in Cambridge.

T. colubriformis did not make an important contribution to the rise in either group IC or group IF, an observation consistent with findings of previous workers at Easter Bush Farm. Eggs of B. trigonocephalum were not detected during any of the three trials although Woodham (1975) and Aklaku (1976) recorded a very low level of parasitism by this species in the ewes at Easter Bush Farm. It was felt that the severe winter weather conditions may have been unsuitable for successful transmission to occur.

H. contortus was present only in very small numbers until late April when a single raised count was recorded for the undosed group. This is consistent with the findings of Woodham (1975) and Singh (1976) from the same flock. H. contortus may overwinter in sheep in a similar manner to Ostertagia spp (Blitz & Gibbs, 1972a, b) which would explain the findings of Morgan et al (1951) and Parnell et al (1954a) who showed that the number of H. contortus eggs in the faeces remain low until about May or June.

Egg production by S. papillosus did not appear to be affected by treatment with fenbendazole (Figure 7) and fell in association with housing and lambing in both groups. The drop in egg production by this species could be associated with the very vulnerable larvae failing to survive the extremely cold months of December and January, Figures 13 and 14. The subsequent increase in egg counts in late January and early February may be associated with the cool, moist and inevitably unhygienic conditions associated with intensively housed ewes.

Five of the six treated ewes gave birth to twins, whereas only one ewe of the undosed group had twins. This had not been anticipated from the lambing histories of the individual ewes. However, it seemed highly unlikely that fenbendazole given six weeks prior to lambing could thus affect the numbers of lambs born. A x^2

test was performed using Yates' correction and the apparent difference was found not to be significant ($x^2 = 3{\cdot}20$, $P > 0{\cdot}05$). This emphasizes the danger associated with drawing conclusions from apparent differences between small samples.

The post-parturient rise in three ewes, D5, A16 and H59 had been previously studied by Woodham (1975) and Singh (1976). In 1975, D5 was housed and the rise was twice as high and of longer duration than in 1977. This is a common finding in housed sheep: it has been suggested that the absence of further challenge from pasture contamination prevents the self-cure reaction. In 1976, D5 was treated with levamisole and lambed at pasture, a post-parturient rise occurred and was attributed to reinfection. The steady decrease in size of the post-parturient rise over the past three years may be related to a build up of immunity in the ewe.

A16, another old ewe, failed to show a rise after treatment in 1977, in 1975 when, again this ewe was housed, the rise was high, peak 590 e.p.g.

H59 did not show a rise in 1977, after being dosed with fenbendazole; this ewe showed a peak count of 400 e.p.g. in 1976 when she was untreated and at pasture.

Further studies of individual ewes over successive years may show that responses to challenge are predictable. If so, in the future, farmers may be able to select lines

of sheep which show increased resistance to helminth challenge.

The live-weight gain of the lambs was used in an attempt to measure the effect of the ewes' worm burdens on their milking capacity. Leaning et al (1970) showed a significant increase in live-weight gain ($P < 0{\cdot}05$), at 100 days, of lambs from ewes dosed prior to lambing and grazed on "spelled pasture" compared to lambs from undosed ewes. They found that much of the live weight advantage was already present at six weeks of age and concluded that the most likely explanation was that the pre-lambing drench had had a direct effect on the thrift of the ewe during lambing and early lactation leading to increased milk production. MacKay (1972) working with hill sheep on contaminated pasture came to a similar conclusion. It was therefore decided to use the live-weight gain achieved at 56 days of age, before extensive grazing commenced, as a measure of the ewes milking capacity. The observed difference between the two groups of lambs in this experiment was not significant ($N = 17$, $t = 1{\cdot}91$, $P > 0{\cdot}05$). However, it is probable that the observed greater live-weight gain of the lambs from the undosed ewes was not related to the treatment regime but resulted from the greater milk intake by the single lambs. This lack of significance indicates again that results from small groups of animals may be misleading.

Faecal samples from the lambs at the age of 10 weeks showed a low level of infection with S. papillosus. Strongyle egg counts varied and it was interesting to note that the three highest counts, 1,300, 1,300 and 8,500 e.p.g. occurred in twin lambs. The difference in the variance of the egg counts between the twin lambs and the single lambs is highly significant ($F_{1,12} = 9{\cdot}33$, $P < 0{\cdot}01$). Spedding et al (1963) first made the observation that lambs reared as singles had fewer worms when slaughtered compared with lambs reared as twins, even when they graze the same pasture. This may well be because twin lambs must graze more and, therefore, pick up more infective larvae, in order to supplement their share of the ewes milk compared to single lambs.

EFFECTS OF TREATMENT - FLOCK II.

Ewes

The ewes of flock II, which were maintained at pasture, differed from flock I in three major ways, (i) breed: flock II was crossbred Suffolk, whereas flock I had been Suffolk, (ii) date of lambing: flock II lambed during April, while flock I had lambed in January, (iii) pasture grazed: flock II grazed clean pasture during autumn and winter, whereas flock I had been grazing lightly contaminated pasture.

Before the ewes were dosed on March 1st, the egg

count was low (Figures 8 and 9), whereas ewes in flock I during this month had high counts associated with the post-parturient rise. This is consistent with the theory that the "trigger" for dormant Ostertagia larvae to re-commence development is somehow connected with lambing, but does not support Armour & Bruce (1974) who stated that the duration of inhibition is of a fixed and predetermined length equivalent to the duration of adverse conditions. If this was so, it might be expected that the peak egg output of the January and April lambing flocks would coincide. However, it is interesting to note that the January lambing ewes had a post-parturient rise in egg counts while the April lambing ewes produced a peri-parturient rise. This phenomenon has been noticed in previous years and was attributed partly to a higher level of reinfection from the pasture in the April lambing ewes (Woodham, 1975). This explanation is not felt to be entirely applicable in 1977, since the ewes were moved in early April to pasture which had been rested for three months, during which time temperatures had been very low (Figures 13 and 14) and eggs deposited by sheep in January (Table II, p. 41) were unlikely to develop into infective larvae before the rise occurred in April. Further, the extremely cold winter of 1976/77 might be expected to be more lethal to infective larvae, than previous milder winters. Perhaps, therefore, larvae

were already maturing from a dormancy of a partially predetermined duration and it was these larvae which contributed to the early part of the peri-parturient rise.

It was interesting to note that neither of the two untreated barren ewes had counts which rose above 50 e.p.g. This suggests that these ewes (i) did not have any inhibited Ostertagia larvae, or (ii) that they were present but did not produce eggs during the trial, or (iii) that they matured in small numbers throughout the winter and never produced a rise in egg counts. It also appears that these ewes were unaffected by any spring increase in larval challenge.

Treatment of the ewes in flock II which remained at pasture depressed mean egg counts below 100 for 32 days in group IIF and 54 days in group IIL. The high count for group IIF on April 22nd was largely due to one ewe, K60, which was one of the first to lamb, on April 18th. This effect of treatment is similar to that in flock I. Treatment of the ewes in flock II, which were housed likewise, depressed egg counts for 32 days in group IIL and 54 days in group IIF. The peak of the peri-parturient rise in group IIC (indoor ewes) was of similar magnitude to that in group IC but lower than that in the ewes of group IIC at pasture.

It is possible that the less heavily contaminated autumn grazing of the April lambing flock was responsible for

the lower peak shown by these ewes relative to the January lambing flock.

Previous workers, Woodham (1975) and Southcott, George & Lewis (1972) found that April lambing ewes had a higher peak of egg production than January ewes. Their explanation was that larvae picked up during spring provided a more important contribution to the population of egg-laying adults than those developed from inhibited larvae in the later lambing ewes compared with the earlier lambing ewes. This may not have been applicable to 1977 because of the extremely cold winter, or alternatively there may have been a similar spring 'pick-up' but fewer overwintering larvae because of the 'clean' autumn pastures.

The difference in the magnitude of the peak in housed ewes and ewes at pasture in flock II, which remained untreated, is difficult to explain: the difference was not significant ($N = 9$, $t = 0{\cdot}92$, $P > 0{\cdot}05$) and it is possible that the housed ewes may have had particularly high counts anyway. If it had been possible to house more ewes, a more meaningful result may have been obtained.

Neither fenbendazole nor levamisole suppressed the rise in indoor or outdoor ewes, although both drugs appeared to be more effective in the housed ewes compared to the ewes at pasture, though the difference was not significant with either drug ($N = 11$, $t = 0{\cdot}05$; $N = 11$,

t = 0·04, respectively, P ▷ 0·05). Singh (1976) made a similar observation for levamisole and it is possible that this difference was due to infective larvae picked up by the outdoor ewes. Unfortunately it was impossible to house the ewes in flock II immediately after dosing, so it was not possible to entirely distinguish between a post-parturient rise from reinfection and one from adults developed from dormant larvae which were not removed by treatment - although the former theory is thought to be more likely. In 1976, Singh had housed six Suffolk ewes in November immediately after treatment with levamisole and the post-parturient rise of individual ewes never rose above 300 e.p.g. (except for one ewe, which showed a sudden anomalous rise from 100 to 1,300 e.p.g. 48 days after lambing). The higher counts in the housed ewes of flock II compared to the housed ewes in Singh's experiment may be explained by (i) dormant larvae that were less susceptible to anthelmintics in spring than in autumn (Armour et al, 1975) and/or reinfection which occurred during the week between dosing and housing; this latter suggestion is unlikely because pasture contamination was very light.

Tharaldsen's ewes (1977), which were housed after autumn treatment with fenbendazole, did not excrete any eggs until being turned out to pasture after lambing the following spring. This may be the ideal method of

preventing the peri-parturient rise and further work may show that autumn treatment combined with movement to clean pastures at that time will be equally successful.

The apparent differences in total egg production during the rise between indoor ewes of groups C and F, C and L; and L and F were not significant, ($N = 6$, $t = 2{\cdot}10$; $N = 6$, $t = 1{\cdot}67$; $N = 6$, $t = 1{\cdot}80$ respectively, $P > 0{\cdot}05$), although C versus (F plus L) was significant ($N = 10$, $t = 3{\cdot}06$, $P < 0{\cdot}05$).

In the outdoor ewes, none of the similar observed differences were significant:-

C versus F ($N = 14$, $t = 1{\cdot}18$, $P > 0{\cdot}05$)

C versus L ($N = 14$, $t = 0{\cdot}93$, $P > 0{\cdot}05$)

L versus F ($N = 16$, $t = 1{\cdot}14$, $P > 0{\cdot}05$)

C versus (L plus F) ($N = 22$, $t = 1{\cdot}20$, $P > 0{\cdot}05$).

The peri-parturient rise of the ewes at pasture continued for longer in each of the three treatment groups than those of the housed ewes (Table V, p. 61). This is contrary to the findings of most workers, who explained the earlier termination of the rise in the pastured sheep in terms of a "self-cure" mechanism as a result of ingestion of large numbers of infective larvae which had developed from eggs deposited during the rise. Housed ewes were removed from this source of challenge and therefore no typical "self-cure" took place (Soulsby, 1965).

The egg counts of each of the three housed treatment groups on April 22nd and April 29th were subjected to 't' tests. The following results were obtained for April 22nd:-

C versus F significant ($N = 6$, $t = 4{\cdot}28$, $P < 0{\cdot}05$)

C versus L significant ($N = 6$, $t = 3{\cdot}73$, $P < 0{\cdot}05$)

L versus F not significant ($N = 6$, $t = 0{\cdot}45$, $P > 0{\cdot}05$)

C versus (L plus F) highly significant ($N = 9$, $t = 4{\cdot}37$, $P < 0{\cdot}01$)

and on April 29th:-

C versus F significant ($N = 6$, $t = 3{\cdot}13$, $P < 0{\cdot}05$)

C versus L significant ($N = 6$, $t = 2{\cdot}80$, $P < 0{\cdot}05$)

L versus F not significant ($N = 6$, $t = 1{\cdot}11$, $P > 0{\cdot}05$)

C versus (L plus F) high significant ($N = 9$, $t = 3{\cdot}64$, $P < 0{\cdot}01$).

In the pastured sheep, there was no delay observed in the start of the peri-parturient rise in the dosed groups relative to the control group (Figure 8).

The above discussions suggest that the degree of contamination of autumn grazing combined with the date of lambing, i.e. January or April, may have had more influence on the dynamics of the rise in flocks I and II than did the difference in breed.

Egg differentiations (Table V, Appendix) were performed on pooled samples from both indoor and outdoor ewes, so it is not known whether the generic composition

of the rise differed in the two management groups. However, it is likely that Ostertagia spp. would have been more dominant in the housed ewes. These sheep were only exposed to reinfection for one week after treatment, so that if inhibited Ostertagia larvae were not removed by dosing they were likely to have made a greater contribution to the peri-parturient rise in these ewes.

Ostertagia eggs were never present as such a large percentage - 33 compared to 95 - of total egg production in flock I, Figure I and Table II (Appendix), as in flock II, Figure 10 and Table V (Appendix). This might be because some maturation of inhibited larvae takes place during winter, well before lambing (Armour et al, 1975). Such continuous loss of inhibited larvae may also explain why the rise in the April lambing flock was smaller than in the January lambing flock.

Similar rises in O. venulosum eggs occurred in groups IIC and IIL; the rise in IIF was very delayed and may be related to increased intake of infective larvae rather than to the peri-parturient rise (Figure 11).

C. curticei eggs were rarely observed in flock II, although they were quite common in flock I, (Figure 6). This is unusual since C. curticei usually becomes more common in spring and summer. However, the severe winter may have taken an unusually heavy toll of infective larvae on the pasture.

T. axei made a contribution to the rise only in group IIC, Figure 11, whereas it was consistently present in both groups of flock I during the post-parturient rise.

C. ovina made a similar contribution to the rise in all treatment groups in both flocks (Figures 10 and 4), which suggests that infective larvae of this species were able to survive the cold winter on pasture.

T. colubriformis made a greater contribution to the rise in all groups in flock II compared to flock I.

As with flock I, eggs of H. contortus and T. vitrinus were infrequently observed and made little or no contribution to the peri-parturient rise.

Lambs

At 10 weeks, lambs of flock II had low egg counts of S. papillosus probably due to early development of acquired resistance.

The strongyle egg counts of lambs of flock II at 10 weeks of age were higher than those of lambs from flock I, with median counts of 750 e.p.g. and 375 e.p.g. respectively. This difference was probably due to the increased availability of infective larvae in May and June compared to February and March. Heath & Michel (1969) showed that lambs acquire strongyle infection from two sources, namely residual larvae from the previous year's grazing, which survived the winter, and from larvae derived from eggs passed during the peri-parturient rise of their dams.

The eggs in the faeces of lambs in flock I were more probably the result of acquiring the larvae which had overwintered on the pasture as the eggs derived from their mothers' post-parturient rise would not have developed. In this respect it would have probably been wiser to give the January lambing flock the cleaner autumn pasture. Many workers have shown that eggs deposited by ewes in spring are not infective for a further eight to 10 weeks. The rise in egg counts of flock II at pasture commenced 12 weeks prior to sampling the lambs, so that, allowing for a prepatent period in the lambs of 19 to 23 days, it seems possible that much of their infection was derived from the peri-parturient rise of their dams.

Serum pepsinogen assays

Serum pepsinogen estimations were carried out in an attempt to study the degree of abomasal damage associated with the development of Ostertagia spp.

Table VII (p. 65) shows the results that were obtained. Ewe numbers L59 and M76 were barren and neither had egg counts which rose above 50 e.p.g. Their plasma pepsinogen values were correspondingly low, below 0·80 units tyrosine. From the literature, pepsinogen levels below about 0·50 units indicate normal abomasal function, which occurs in healthy unparasitised sheep (Anderson, 1972). L161 and H30 had peak pepsinogen values which corresponded with peak egg counts: values

fell from a very low peak of 0·56 units to pre-lambing levels of 0·28 units in L161, and from 3·92 to 1·94 units in H30; the former ewe still had a count of 750 e.p.g. at the end of the trial.

Of the ewes treated with fenbendazole, L125 was subsequently housed; this ewe had consistently high pepsinogen levels of over 1·50 units, yet the egg count never rose above 200 per gram of faeces. Pepsinogen levels of K35 fell from a high level, 3·19 units on May 1st, when she was dosed, to 1·08 units a month later. Levels then rose again, corresponding to the peri-parturient rise in egg counts and remained at 2·40 units after the peri-parturient rise had terminated. The work of Armour et al (1966) suggests that after a single infection serum pepsinogen values return to normal levels 60 days after infection. Unfortunately it is not known whether the peri-parturient rise in these dosed ewes was due to continuous reinfection, when pepsinogen levels could be expected to remain elevated, or to a single wave of larval maturation, when pepsinogen values would be expected to decrease as abomasal lesions healed. M138, also treated with fenbendazole, did not show a peri-parturient rise, although some eggs were recorded on April 22nd, and pepsinogen values correspondingly rose to over 1·00 units and remained high until the end of the trial. Anderson (1973) noticed that mature ewes with

small worm burdens had consistently higher pepsinogen levels than weaner sheep. He suggested that on reinfection mucosal damage is preceded by a hypersensitive state. The findings of Reid & Armour (1975) supported this view and they acknowledged that this situation must influence the conversion efficiency of the ewe owing to the amount of abomasal damage present and that even without overt clinical signs, peptic activity will be reduced.

M174, group IIF, showed no peri-parturient rise and pepsinogen levels were correspondingly low, below 0·50 units until July 13th when they rose steeply to 2·01 units. It is possible that increasing numbers of infective larvae became available in July and led to the development of a hypersensitive abomasal mucosa as discussed above. Faecal samples taken from this ewe in late July might have had egg counts which would have given additional support to this theory.

Of the ewes dosed with levamisole, H80 did not show a peri-parturient rise and pepsinogen values remained low, never exceeding 0·50 units. K83 also did not show a peri-parturient rise and pepsinogen values fell from a pre-dosing value of 2·78 units to 1·04 units four weeks later. The egg counts from this ewe started to rise slowly to 250 e.p.g. recorded at the end of the trial, and pepsinogen values likewise rose to 2·47 units.

However, this also is more likely to be due to a hypersensitivity reaction since Armour et al (1966) showed that this level of serum pepsinogen resulted from a large single dose of 100,000 O. circumcincta, a degree of challenge which was unlikely to be available on the pasture. H81 showed a high peak egg count of 1,200 e.p.g., which fell sharply to 200 e.p.g. three weeks later: pepsinogen levels corresponded to the pattern of egg excretion. L35 was housed and showed a peak egg count of 900 e.p.g. on May 19th, which fell steeply to 50 e.p.g. on July 13th. Pepsinogen values showed a rise, which was delayed with respect to egg counts, the highest value being 2·95 units recorded on July 13th.

It was hoped that the pattern of pepsinogen values would differentiate between a peri-parturient rise due largely to reinfection, and one which resulted from maturation of inhibited larvae which had not been removed by treatment. Thus, pepsinogen values might have been expected to rise slowly where larvae picked up from the pasture resulted in progressive damage to the abomasal lining, or sharply as waves of inhibited larvae resumed development (Armour, 1977). This distinction could not be made and although it is possible that had larger numbers of sheep been sampled, results would have been more meaningful; even this seems improbable.

Although some correlation between strongyle egg

counts and serum pepsinogen values was found, it was not felt to be a useful diagnostic tool for individual animals; Anderson (1972) came to the same conclusion. He pointed out, however, that a useful correlation existed between mean pepsinogen levels of groups of sheep grazing different pastures and the availability of infective larvae. Further investigations may show this to be the case with sheep on Easter Bush Farm.

EFFECTS OF TREATMENT - FLOCK III.

Ewes

The faecal examinations in flock III, Figure 12, were performed to observe the effect of the two drugs without attempting a close study of the progress of the peri-parturient rise, as in flocks I and II. Before treatment, the counts were extremely low, corresponding to a pasture contamination level of 15 infective larvae per kg of herbage. Four weeks later, group IIIF had a mean count of only 30 e.p.g., that of group IIIL was slightly higher at 65 e.p.g., both these values being less than the untreated group.

A change in generic composition of eggs excreted by groups IIIF and IIIL between January 21st and February 26th, Table VIII (p. 69), suggests that either (i) pasture contamination was composed largely of *Ostertagia* larvae, or (ii) post-treatment egg excretion was due to matured

Ostertagia larvae which had survived anthelmintic treatment. This change in the species contribution to total egg counts did not occur in group IIIC but was present, to a lesser extent, one month after treatment in groups IF, IIF and IIL.

The same relative differences in mean egg counts were maintained at the next sampling date, April 23rd. The difference in the variance of the egg counts at this time as between the control and the pooled treated ewes is highly significant ($F_{17,28} = 3{\cdot}93$, $P < 0{\cdot}01$); that between the two treated groups not being significant ($N = 28$, $t = 0{\cdot}23$, $P > 0{\cdot}5$). A possible explanation for this is that some of the control ewes have already self-cured. Tentative support for this hypothesis may be drawn from group IIC, where the mean peak count occurred 46 days after the group rise started: if the peak in group IIIC was similarly timed, then it would have occurred prior to April 23rd.

Table VIII (p. 69) shows that although Ostertagia species dominated egg production in all three groups during the rise, other species, namely T. colubriformis, T. vitrinus, O. venulosum and C. ovina appeared to be present in larger numbers than in the previous two flocks. A possible explanation is that as this flock had been grazing clean pasture since weaning the previous summer, comparatively few Ostertagia spp. were available in the

autumn, so that the burdens of inhibited larvae over-wintering in the ewes were fewer than in flocks I and II. This may also explain why the peak mean egg counts of each group in flock III were lower than the corresponding groups in flocks I and II.

Table XI shows the percentage of ewes in each group of the three flocks which showed a post or peri-parturient rise.

TABLE XI.

Flock	Group	Percentage of ewes showing a P.P.R*
I	C	100
I	F	33
II	C	100
II	F	64
II	L	73
III	C	53
III	F	39
III	L	40

*P.P.R. = peri or post-parturient rise.

A x^2 test showed that treatment with both fenbendazole and levamisole has a significant effect on preventing the post or peri-parturient rise ($x^2 = 5{\cdot}05$, $P < 0{\cdot}05$). However, more studies are needed to determine why some

ewes, irrespective of whether or not they received anthelmintics, show a rise, while others do not.

Lambs

There was no significant difference between the weights, at approximately 14 weeks of age, of the lambs from ewes treated with fenbendazole and those from untreated ewes ($N = 330$, $t = 1{\cdot}30$, $P > 0{\cdot}05$) or lambs from ewes treated with levamisole and those from untreated ewes ($N = 334$, $t = 0{\cdot}73$). However, there appeared to be a significant difference in weights of lambs from ewes treated with fenbendazole and ewes treated with levamisole ($N = 230$, $t = 1{\cdot}93$, $P < 0{\cdot}05$). The most probable explanation of this can be seen from inspection of Table X (p. 73), as ewes dosed with fenbendazole tended to lamb earlier than those dosed with levamisole. This order is the reverse of that which occurred in flocks I and II.

Singh (1976), using small numbers of animals, found that the mean live-weight gain of lambs from dosed ewes was slightly higher than that of untreated ewes under the same management, but he suggested that the effect of treatment may become significant if a much larger number of animals was tested. The results of this present experiment suggest that there is no real benefit to be obtained from dosing low-ground ewes six weeks prior to

lambing if they can be rapidly reinfected from pasture. This is in agreement with the findings of most workers. MacKay (1972), who worked with hill sheep on contaminated pasture, is an exception. However, hill sheep differ from low-ground sheep in that they are often expected not only to survive severe winter weather on extremely poor grazing but also to conceive, gestate and rear a lamb. Even the relatively small gain achieved by removing the potentially damaging helminths by pre-lambing dosing may thus help these ewes over the crucial period of lambing and encourage milk yield. The situation in lowland flocks is less critical, which perhaps explains why the benefits are less, if they exist at all.

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APPENDIX TABLE I.

FLOCK I: STRONGYLE EGG COUNTS FOR EACH EWE (e.p.g.)

Undosed sheep (Group I C)

Ewe No.	Date of lambing	Sampling dates 12/11	26/11	10/12	1/1	14/1	21/1	4/2	18/2	4/3	25/3	29/4
D 5	15/1	0	0	0	0	N.S.	50	50	500	200	150	50
J 9	4/1	200	400	100	200	650	800	850	750	400	*N.S.	50
J 12	9/1	200	400	300	10	1050	400	1400	1400	700	550	400
H 12	14/1	N.S.	400	400	300	550	500	950	1250	550	400	150
D 12	9/1	350	400	200	N.S.	900	800	650	650	650	650	100
F 23	15/1	0	200	0	300	100	200	750	2150	200	550	200
Mean		150	300	116	160	650	450	775	1117	450	450	220

Fenbendazole dosed sheep (Group I F)

A 16	28/1	0	0	0	0	0	7	28	150	N.S.	52	50
H 2	8/1	300	300	0	0	0	9	1058	1000	150	158	N.S.
J 7	13/1	100	100	0	0	25	86	2050	250	950	600	50
F 65	4/1	600	300	0	1	250	246	1250	2350	650	550	300
H 59	18/1	0	0	0	18	0	7	81	250	25	50	50
J 22	18/1	200	400	0	6	2	19	200	600	150	200	50
Mean		233	183	0	4	46	62	776	760	385	268	112

*N.S. = not sampled.

APPENDIX TABLE II.

FLOCK I: ESTIMATED FAECAL EGG COUNTS FOR EACH SPECIES OF NEMATODE (e.p.g.)

Nematode species	Sampling dates										
	12/11	26/11	10/12	1/1	14/1	21/1	4/2	18/2	4/3	26/3	29/4
GROUP C											
Ostertagia spp.	41	84	16	6	598	382	597	814	71	211	4
C. ovina	29	60	32	53	0	27	46	55	126	0	24
O. venulosum	48	100	38	27	13	9	31	55	94	182	16
H. contortus	0	10	10	3	0	0	0	0	0	0	35
T. axei	14	24	7	14	13	32	31	22	99	31	40
T. vitrinus	5	11	2	5	0	0	0	11	4	0	8
T. colubriformis	0	12	6	37	0	0	31	44	54	18	85
C. curticei	19	10	4	14	26	0	39	99	0	8	0
Total for all species	156	311	115	159	650	450	775	1100	448	450	212
GROUP F											
Ostertagia spp.	77	57	0	4	44	49	512	586	188	214	8
C. ovina	75	26	0	0	2	9	116	46	69	0	0
O. venulosum	9	51	0	0	0	4	39	30	46	38	15
H. contortus	0	4	0	0	0	0	0	0	8	0	3
T. axei	27	35	0	0	0	0	8	53	16	8	54
T. vitrinus	9	2	0	0	0	0	31	15	8	0	0
T. colubriformis	0	16	0	0	0	0	47	30	50	8	3
C. curticei	36	2	0	0	0	0	23	0	0	0	28
Total for all species	233	193	0	4	46	62	776	760	385	268	111

APPENDIX TABLE III.

FLOCK II: MEAN (± S.D.) STRONGYLE EGG COUNTS FOR EWES AT PASTURE (e.p.g.)

Sampling dates	GROUP C	GROUP F	GROUP L
1/3	48 ± 86	26 ± 38	138 ± 201
16/3	39 ± 80	1 ± 3	4 ± 6
1/4	23 ± 42	4 ± 3	5 ± 4
22/4	215 ± 439	465 ± 890	64 ± 69
7/5	616 ± 353	390 ± 412	726 ± 838
19/5	820 ± 752	452 ± 514	684 ± 809
24/6	523 ± 452	158 ± 246	330 ± 379
13/7	341 ± 360	150 ± 250	83 ± 103

APPENDIX TABLE IV.

FLOCK II: MEAN (± S.D.) STRONGYLE EGG COUNTS FOR HOUSED EWES

Sampling dates	GROUP C	GROUP F	GROUP L
1/3	63 ± 70	22 ± 14	21 ± 24
16/3	130 ± 148	0 ± 0	34 ± 7
1/4	29 ± 18	2 ± 4	4 ± 3
22/4	650 ± 180	75 ± 109	114 ± 104
29/4	1233 ± 513	338 ± 230	525 ± 173
13/5	666 ± 28	200 ± 0	417 ± 144
19/5	617 ± 35	316 ± 152	520 ± 377
24/6	467 ± 368	130 ± 30	75 ± 100
13/7	200 ± 282	116 ± 76	33 ± 28

APPENDIX TABLE V.

FLOCK II: (POOLED SAMPLES OF OUTDOOR AND INDOOR EWES)

ESTIMATED FAECAL EGG COUNTS FOR EACH SPECIES OF NEMATODE (e.p.g.)

GROUP C

Nematode species	Sampling dates						
	1/3	16/3	1/4	22/4	7/5	19/5	13/7
Ostertagia spp.	25	4	18	326	283	130	78
C. ovina	6	1	0	20	40	175	59
O. venulosum	0	2	0	0	27	77	10
H. contortus	0	0	0	0	13	0	29
T. axei	16	38	12	35	67	90	15
T. vitrinus	1	0	0	0	0	0	10
T. colubriformis	4	2	0	0	216	150	44
C. curticei	1	2	0	0	27	0	0
Total for all species	53	49	30	381	673	622	245

GROUP F

Ostertagia spp.	12	1	2	133	120	17	45
C. ovina	3	0	0	125	75	165	42
O. venulosum	0	0	0	29	7	0	39
H. contortus	0	0	0	0	0	0	0
T. axei	8	0	1	0	0	0	0
T. vitrinus	0	0	0	22	60	17	3
T. colubriformis	2	0	0	50	112	216	11
C. curticei	0	0	0	0	0	0	0
Total for all species	25	1	3	359	374	415	140

GROUP L

Ostertagia spp.	50	7	5	48	226	77	18
C. ovina	13	2	0	12	133	153	13
O. venulosum	0	0	0	3	13	51	7
H. contortus	0	0	0	0	0	26	0
T. axei	34	4	0	0	0	0	0
T. vitrinus	2	0	0	6	0	26	3
T. colubriformis	7	1	0	9	292	307	26
C. curticei	2	0	0	0	0	0	0
Total for all species	108	14	5	78	664	640	67

APPENDIX TABLE VI.

FLOCK III: MEAN (± S.D.) STRONGYLE EGG COUNTS (e.p.g.)

Group	Sampling dates					
	29/1/77		26/2/77		23/4/77	
C	16	20·71	160	213·12	513	832·78
F	25	38·62	30	66·38	210	183·83
L	37	62·76	65	76·52	288	289·59