THE EFFECT OF HERBAGE SPECIES ON INTERNAL PARASITE DYNAMICS IN SHEEP

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ABSTRACT

A series of experiments was undertaken to determine the effect of different grass species on gastrointestinal nematode parasitism and performance of lambs and the effect of a broader range of herbage species on nematode larval population dynamics. All of the experiments were undertaken at AgResearch Flock House, located in the southern North Island of New Zealand.

In the first of two unreplicated grazing experiments, four grass species browntop (*Agrostis capillaris* cv Muster), tall fescue (*Festuca arundinacea* cv Au Triumph), Yorkshire fog (*Holcus lanatus* cv Massey Basyn) and perennial ryegrass (*Lolium perenne* cv Nui) were compared in single species swards grazed by weaned lambs in each of two years (1991/92 and 1992/93). Swards were grazed to a target sward height of 5 cm by altering stock numbers. On each grass, one third of the lambs were suppressively drenched fortnightly (SD) and two thirds were trigger drenched (TD), when mean faecal egg count on any treatment reached 1500 eggs per gram (epg) in 1991/92 and 1000 epg in 1992/93. In both years, lamb faecal egg counts were higher ($P<0.05$) in lambs which grazed browntop and tall fescue than in lambs which grazed ryegrass or Yorkshire fog. Parasitism, as measured by tracer lamb nematode burdens, was highest in lambs which grazed browntop, lowest

in lambs which grazed ryegrass and Yorkshire fog, and intermediate in lambs which grazed tall fescue ($P<0.05$). In 1991/92, production losses due to parasitism as measured by the difference in liveweight between SD and TD lambs were higher ($P<0.05$) in lambs which grazed browntop, tall fescue or ryegrass than in lambs which grazed Yorkshire fog. This pattern was not repeated in the second year.

In the second grazing trial, undertaken in 1992/93, lambs grazed tall fescue or Yorkshire fog swards to target heights of 3, 5, or 8 cm. On the tall fescue swards, decreasing sward height increased ($P<0.05$) tracer lamb nematode burdens, but this was not observed on the Yorkshire fog swards. Also, on the tall fescue swards, there was a significant ($P<0.05$) production loss associated with parasitism (as measured by liveweight differences between SD and TD lambs), but such a pattern was not observed on the Yorkshire fog swards.

In a comparison of the recovery of *Trichostrongylus colubriformis* larvae from a range of herbages using the modified Baermann technique, greatest numbers were recovered from cocksfoot (*Dactylis glomerata* cv Wana) and chicory (*Chicorum intybus* cv Puna), lowest numbers from prairie grass (*Bromus willdenowii* cv Matua), perennial ryegrass (*Lolium perenne* cv Nui), and Yorkshire fog (*Holcus lanatus* cv Massey Basyn), and intermediate numbers from browntop (*Agrostis capillaris* cv Muster), tall fescue (*Festuca arundinacea* cv Au Triumph), and white clover (*Trifolium repens* cv Huia) ($P<0.05$). There was a greater than two-fold difference in the number of larvae recovered between chicory, which had the highest number of larvae recovered from it, and prairie grass, which had the lowest.

In a series of experiments undertaken outdoors, faeces containing known numbers of *Ostertagia circumcincta* and *Trichostrongylus colubriformis* eggs were deposited on mini-swards of a range of herbage species, browntop, chicory, cocksfoot, tall fescue, lucerne (*Medicago sativa* cv Otaio), ryegrass, prairie grass, white clover, and Yorkshire fog. Larvae were recovered from four strata (0-2.5, 2.5-5, 5-7.5, and >7.5 cm above the soil surface) at 2, 4, 6, 8, 11 and 14 weeks after the faeces was deposited on the herbage. These "contaminations" were carried out four times in 1992/93 and 1993/94.

Larval development success, defined as the maximum number of larvae recovered on herbage after contamination, differed significantly ($P<0.05$) between herbage species, being greatest on Yorkshire fog and ryegrass, least on white clover and lucerne and intermediate on the other herbages. The proportion of larvae recovered from the bottom stratum, an inverse measure of the ability of the larvae to migrate vertically, differed ($P<0.05$) between herbages. It was greatest on Yorkshire fog and prairie grass, least on white clover, ryegrass and browntop with the other herbages intermediate. Larval survival, as estimated by the decline in larval numbers on the herbage, did not differ (P>0.05) between herbages.

Two experiments to compare larval development success and migration were done in a glasshouse with mini-swards established in 20 cm diameter plant pots. Four grass species, ryegrass, tall fescue, Yorkshire fog, and browntop were compared. Faeces containing known numbers of *Ostertagia circumcincta* and *Trichostrongylus colubriformis* eggs were deposited on swards after cutting to one cm, and the larvae recovered from the four strata (0 - 2.5 cm, 2.5 - 5 cm, 5 - 7.5 cm and >7.5 cm) 4 weeks later.

Larval development success did not differ (P>0.05) between grasses. However, the vertical migration patterns were similar to those observed in the outdoor larval dynamics experiments, with larvae concentrated in the bottom stratum of Yorkshire fog but more evenly spread over the four strata in the other grasses.

The results from these trials show that, under New Zealand conditions, pasture species can have marked effects on larval development success and larval migration on herbage. This translated into differences in lamb parasitism between grass species. Combining the results from the studies in this thesis with other published results suggests that differences in lamb parasitism between herbage species may vary depending on whether a continuous or discontinuous grazing strategy is used.

The studies also demonstrate that on Yorkshire fog swards production losses due to parasitism were lower than for other grasses. It is suggested that parasite levels in lambs which grazed this species were restricted either by physical means through restricted larval migration on herbage or through biochemical means by limiting larval establishment in the gastrointestinal tract of grazing lambs.

This thesis is dedicated to Michael and Rebecca Niezen

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CHAPTER 1. INTRODUCTION

In temperate pastoral ecosystems such as the sheep production systems in most regions of New Zealand, gastrointestinal nematode parasitism has long been considered one of the major animal health problems and one of the largest constraints to sheep production (Tetley 1934, Brunsdon 1988, Vlassoff and McKenna 1994). It was estimated that in 1988, one third of total sheep production in New Zealand (= $946M) was attributable to anthelmintic-based control of nematode infection (Brunsdon 1988).

Of the 29 species of gastrointestinal nematodes of sheep recorded in New Zealand, a sub-group of nine trichostrongylid species are recognised as most important in causing disease and loss of production (Vlassoff and McKenna 1994). These are: *Haemonchus contortus*, *Ostertagia circumcincta*, *O. trifurcata*, *Trichostrongylus axei*, *T. colubriformis*, *T. vitrinus*, *Cooperia curticei*, *Nematodirus filicollis*, and *N. spathiger*. Two of these nine species, *T. colubriformis* and *O. circumcincta* are considered the most common species in temperate regions (Levine and Todd 1975), where most of New Zealand's sheep production takes place. While this may be true in very general terms, there are some notable exceptions. *H. contortus* can have a serious effect on lamb production in the warmer regions of the North Island, while *Nematodirus spp.* can impact on it in the southern regions of the South Island.

For all of the common gastrointestinal nematodes, the basic life cycle is similar. Nematode eggs are passed in the faeces of infected hosts. In the faeces the eggs develop through four stages of embryonation before hatching, and then three larval stages. In the first and second stages of larval development, the larvae feed on bacteria and other micro-organisms. As the larvae develop from the second into the third stage, moulting is incomplete so that the third stage larvae remain in the second stage cuticle retaining it as a sheath. In the third stage, larvae are non-feeding, surviving on stored metabolites. Under most conditions, it is in this stage that the larvae migrate from the faeces on to herbage or into the soil. Under exceptional circumstances, first and second stage larvae have been reported to migrate from the faeces (Silverman and Campbell 1959, Crofton 1963), but this is a rare occurrence (Crofton 1963). The exception to this life-cycle is *Nematodirus*, as larvae develop to the infective stage within the egg.

Once on the herbage, the larvae must be ingested by grazing sheep to develop further. Once ingested, in response to chemical stimuli, they exsheath and enter the gland crypts of either the abomasum or the proximal small intestine depending on nematode species. Over several days, the third stage larvae develop into fourth stage larvae deep in the mucosal crypts. After eight to ten days, the fourth stage larvae moult to form immature adults which become sexually active over the next seven to ten days. After copulating with males, the females begin to produce fertile eggs which pass out in the host's faeces. The infection is then patent and the life-cycle is completed (Crofton 1963).

In New Zealand there is a definite seasonal pattern to the level of larval contamination on herbage. Larval numbers decline through the winter, but increase in the months following lambing in spring as there is an increased nematode egg output from lactating ewes (Brunsdon 1970). Larval contamination may then decline over the summer period if conditions are too dry for larval development, survival and/or migration on to the herbage. The level of larval contamination on herbage increases in the autumn due to a combination of factors: the large number of eggs being passed by lambs; warm, moist conditions, which are conducive to larval development and migration; and declining herbage mass in the pastures. The numbers then decline through the late autumn and winter and increase again in the spring. This pattern has been observed on farms widely distributed throughout New Zealand (Brunsdon 1963, Tetley and Langford 1965, Vlassoff 1973b).

The most common method of gastrointestinal nematode control on sheep farms consists of the regular use of broad spectrum anthelmintics (Kettle *et al.* 1981, Kettle *et al.* 1982, Brunsdon *et al.* 1983, Vlassoff and McKenna 1994). While it is difficult to forecast future trends, it is widely accepted that anthelmintic usage needs to be reduced, because of the increasing prevalence of anthelmintic resistance, consumer pressure to reduce or eliminate residue levels in animal products, and as the general concept of agricultural sustainability takes hold. Alternatives to regular anthelmintic usage are presently being investigated. These include genetic selection of sheep which are resistant to or resilient to gastrointestinal nematode parasites (Bisset *et al.* 1992, Bisset *et al.*

1994), developing vaccines to enhance the immune response to gastrointestinal nematodes (Smith and Smith 1993), ways of reducing development or accelerated mortality of eggs or larvae of gastrointestinal nematodes in the faeces or on the herbage through either bacterial, viral, fungal or invertebrate activity (Waller 1992), and farm management practices which will enhance animal performance through improved nutrition and/or reduced ingestion of larvae (Thomson and Power 1991, MacKay 1994).

Presently, many day to day grazing management decisions are based on feed quality and quantity with little consideration of parasite control through grazing management. Stocking rates in sheep systems in New Zealand range from 5 - 15 stock units per hectare (su/ha), but vary with location and are closely related to the herbage growth potential of the region. Much of the sheep production on the steeper terrain is on pastures which consist of low fertility grass species such as browntop (*Agrostis capillaris*) or Yorkshire fog (*Holcus lanatus*) (Field and Roux 1993) while on flatter terrain, where pasture renewal is feasible, improved pastures consist mainly of perennial ryegrass (*Lolium perenne*), tall fescue (*Festuca arundinacea*), or cocksfoot (*Dactylis glomerata*) and white clover (*Trifolium repens*).

Thus far there has not been a concerted effort to determine the effects of herbage species on larval dynamics in the sward, lamb parasitism and parasitised lamb performance. If large effects exist, then plant breeding programmes aimed at producing plants which will reduce parasitism in lambs may be feasible. Furthermore, farmers in the future may have to incorporate parasitological information with the agronomic characteristics of the species when deciding which pasture species to establish.

They may also be able to adjust their grazing managements to accommodate differences in larval population dynamics on different herbage species.

The studies reported in this thesis concentrate on the effects of pasture herbage species on nematode larval population dynamics and parasitised lamb production. Results are reported of two field grazing studies, and two controlled plot and pot studies designed to investigate specific aspects of larval population dynamics.

CHAPTER 2. LITERATURE REVIEW

2.1. INTRODUCTION

There are a large number of factors in the host, the nematode, and the environment which will determine the type, timing, duration and severity of gastrointestinal nematode infection in lambs. The combination of these factors leads to a complex series of interactions between the host, the parasite, and the environment. The most lucid summary of these interactions has been provided by Brunsdon (1982). Changes in pasture species composition could affect all aspects of the free-living larval stage of the life-cycle and may also impact on host resistance. The literature available on the subject is reviewed below.

2.2. THE EFFECT OF HERBAGE SPECIES ON ANIMAL PARASITISM - GENERAL RESULTS

There is a small body of literature on pasture species - parasite interactions in relation to sheep and cattle. The most relevant work relating to sheep has been undertaken in New Zealand and has shown that lambs which grazed chicory or lucerne had lower gastrointestinal nematode burdens than lambs which grazed either ryegrass, cocksfoot or tall fescue (Scales *et al.* 1995). Also, the production losses due to parasitism were markedly lower when lambs grazed pure swards of chicory than when they grazed any of the other four species. However, it was not possible to determine whether the results were due to differences in larval development, survival or migration, or within-host effects related to nutritional factors. Cattle grazing trials in the USA have shown that renovated fescue paddocks (regular fescue swards disked and seeded with 30 kg/ha of rescue grass (*Bromus catharticus*) and 20 kg/ha of crimson clover) resulted in lower cattle parasite burdens than fescue, temporary winter forage mixture (rye, oats and ryegrass) or ryegrass paddocks (Ciordia *et al.* 1962a). That this may be due to components in the forage affecting parasitism is suggested by the observation that adding maize grain to the diet also reduced worm burdens (Ciordia *et al.* 1962a) which is consistent with earlier results (Vegors *et al.* 1955). In a tropical environment, pangola grass (*Digitaria decumbens*) was reported to result in higher calf gastrointestinal nematode parasite burdens than a range of other tropical grasses and legumes (Guimares *et al.* 1982) but the observation was not explained. In Australia, Donald *et al.* (1979) compared cattle grazing either phalaris (*Phalaris tuberosa*) or lucerne (*Medicago sativa*), which had a similar level of initial contamination, at three stocking rates (L, M, H) and three anthelmintic regimes (none, autumn only, suppressive). Few *O. ostertagi* were found in calves slaughtered from all lucerne treatments or in anthelmintic treated cattle grazing phalaris. It was concluded that the sward factors were not responsible for the differences observed thereby suggesting a within-animal effect. In a study in South Africa, there was a suggestion that pasture species composition changes may have affected the species of parasitic nematodes present, since *Dictyocaulus filaria* appeared to be confined to kikuyu grass paddocks and was never found in grass/legume or all legume swards (Reinecke *et al.* 1989).

Possible influences that pasture species may have on parasitism in grazing ruminants can be considered under two broad categories, effects on the free-living larval stages and effects operating within the host. The population dynamics and availability of free-living stages of gastrointestinal nematode parasites involves a complex interrelationship between larval development from egg to infective larvae, and survival and migration on herbage and in soil. Evidence on the effects of pasture species on the development, migration and survival of gastrointestinal nematode larvae on the herbage and in the soil are reviewed next.

2.2.1. Description Of Common Pasture Species In New Zealand

The studies reported in this thesis will compare several grass species in grazing trials and a broader range of grasses, legumes and one herb in experiments comparing larval population dynamics. These grasses differ markedly in the morphological characteristics of their blade, sheath, ligule, and auricles while the legumes and the herb also differ in their morphology. Brief descriptions of the plants used and accompanying photographs are provided below.

Browntop (*Agrostis capillaris*)

A glabrous, usually rhizomatous, dark green to bluish-green grass. Blades are short (1-15 cm long) and narrow (1-5 mm wide). On the upper surface of the blade, ribs are slight to moderate with rounded tops. The lower surface is dull to slightly glossy and the keel is absent or very indistinct. The sheath is rounded, usually smooth. The ligules are short (0.5-2 mm long), usually invisible in side view and usually shorter than broad. They are translucent and vary from whitish to slightly greenish but are sometimes brownish. Auricles are absent (Lambrechtsen 1981).

Browntop forms dense swards and is widespread in lower fertility hill country soils (Levy 1970).

Cocksfoot (*Dactylis glomerata* L.)

A glabrous, tall, erect, greyish to bluish green, strongly tufted grass. The blades are strongly folded, are 10-45 cm long and 2-14 mm wide and rough near the pointed tip. Older blades are harsh. On the upper surface, ribs are absent or indistinctly rectangular. The lower surface is dull and the keel is sharp and prominent and continues along the sheath. The sheath is strongly compressed, both in the upper part and at the base, is rarely pubescent, and very sharply keeled with cross veins absent. The ligules are long (2-12 mm), membranous and often somewhat ragged along the edge. Auricles are absent (Lambrechtsen 1981).

Cocksfoot is currently being promoted as a relatively drought-tolerant species and one which persists well in lower fertility conditions (Barker *et al.* 1993). It forms an open sward similar to tall fescue (Levy 1970).

Chicory (*Chicorum intybus*)

A perennial rosette herb. The stems are erect, branched above and finely ribbed, with short crisped hairs or glabrous. The leaves have crisped hairs with one midrib on the under surface and is cilioate on the margin. Rosette and lower stem leaves are petiolate or oblanceolate, simple and toothed. The upper leaves are sessile, becoming less lobed, distantly toothed and smaller than the lower leaves. The florets are few and usually blue. (Anon. 1988). Chicory is a drought tolerant species which is capable of high dry matter production in the summer months (Fraser *et al.* 1988).

Tall fescue (*Festuca arundinacea* Schreb.)

A tall, erect, fairly harsh, green to dark green, often strongly tufted grass with bristly hairs along the blade base margin. The plant is otherwise glabrous. The blades are 10-60 cm long and 3-12 mm wide and are flat. On the upper surface the ribs are moderate, somewhat variable in height, width and distance apart. The lower surface is glossy and the keel is indistinct. The sheath is either smooth or rough, often with indistinct cross veins. The base of the sheath is often brownish-purple. The ligules are up to 2 mm long, membranous, firm greenish, but not visible from the side view. The auricles are stout, often brownish and covered with stiff 0.5-1 mm hairs (Lambrechtsen 1981).

Tall fescue is currently being promoted as a more drought tolerant species than ryegrass (Milne *et al.* 1993). It forms an open sward which encourages white clover growth (Levy 1970).

Lucerne (*Medicago sativa*)

A deep rooted erect legume, 0.3 to 0.9 m tall. Hairiness is variable. The leaves are 2-5 cm long, compound, trifoliate with the central leaflet on a longer stalk than the two lateral leaflets. The leaflets are 1-3 cm long, oval to obovate in shape, with mucronate tips. The stipules are slightly serrated. The flowers are purple to bluish-white, approximately 0.8 cm long in racemes of up to 5 cm long (Horn and Hill 1987)

Lucerne is grown in New Zealand as a specialist crop which can produce large quantities of high quality feed (Langer 1990).

Prairie grass (*Bromus willdenowii* Vahl)

A very tall, harsh, slightly hairy green to bluish-green grass. The blades are 30-50 cm long and 6-14 mm wide and are soft to harsh, especially older blades. The tips are often rough. The upper surface of the blade has very short hairs in distinct rows, but the lower half of the blade is sometimes hairless. The ribs are slight or absent. The margins are rough. The lower surface of the blade is dull to slightly glossy, with fewer hairs than on the upper surface. The keel is usually distinct. The sheath is usually densely soft-hairy with hairs up to 2 mm long. It is slightly compressed, distinctly keeled, often with cross veins between the main veins. The ligules are up to 6 mm long, membranous, white, and often split along the margin. Auricles are absent (Lambrechtsen 1981).

Prairie grass is a tufted plant which forms an open sward (Levy 1970).

Perennial Ryegrass (*Lolium perenne* L.)

A bright to dark green, moderately ribbed, glabrous grass. The blades are 3-20 cm long and 2-6 mm wide. On the upper surface of the blades, the ribs are regular, with the central one lower than the others. The lower surface of the blade is very glossy, smooth and the keel rounded to fairly sharp. The base of the sheath is reddish to purplish, while the inner sheath is pale green and smooth. The ligules are up to 2 mm long, membranous, light green and indistinct in very small tillers. The auricle are small and shrivel at their tips (Lambrechtsen 1981).

Ryegrass forms the backbone of the New Zealand pastoral industry and is the most common grass species planted. It is a tufted plant and forms an open sward (Levy 1970).

White clover (*Trifolium repens*)

A prostrate, glabrous legume. Stems to 0.6 m long, rooting at the nodes. Leaves are trifoliate while the leaflets are orbicular to oval. The stipules are small and inconspicuous. Flowers are white in globose inflorescences. Inflorescences are borne on long peduncles (Horn and Hill 1987).

White clover is the most common legume grown in New Zealand pastures. It is stoloniferous and forms a loose turf (Levy 1970).

Yorkshire fog (*Holcus lanatus* L.)

A very soft, velvety hairy, greyish green to green, usually tufted grass. The leaves are 4-20 cm long and 3-10 mm wide. On the upper surface, the ribs are moderate, but their shape is often irregular. The surface is densely covered with short hairs (1 mm or less) and longer ones (up to 2 mm) in more than one row per rib. The lower surface is dull and densely pubescent with hairs 1 mm or less. The sheath has reddish or purplish veins on a white background and is densely pubescent with hairs 1 mm or less in length. The ligules are 1-4 mm long, membranous, hairy and coarsely serrated. Auricles are absent (Lambrechtsen 1981).

Yorkshire fog can form dense swards. It is often found growing in lower fertility, moist conditions (Levy 1970).

2.3. DEVELOPMENT OF LARVAE

The rate of development of gastrointestinal nematode eggs within the faeces varies between nematode species and is dependent on moisture, oxygen and temperature (Rossanigo and Gruner 1995), which in turn, are influenced by the physical nature of the faecal mass. If moisture content is too high, lack of oxygen will limit unembryonated egg development in cattle faeces (possibly sheep faeces as well) and as moisture declines cattle faecal decomposition is slowed but larval development will generally proceed (Murwira *et al.* 1990). While this has been shown for cattle faeces it is assumed that a similar relationship exists for sheep faeces.

In common with almost all poikilotherms, the rate of nematode activity varies with temperature, broadly increasing logarithmically with increase in temperature over the range 5^0C to 40^0C (Croll 1970). The relationship between temperature and development has been well documented for *H. contortus* (Silverman and Campbell 1959, Levine and Todd 1975, Gibson and Everett 1976, Coyne and Smith 1992) *O. circumcincta* (Young *et al.* 1980, Pandy *et al.* 1989, Pandy *et al.* 1993), *T. colubriformis* (Levine and Todd 1975) and *T. vitrinus* (Beveridge *et al.* 1989). If temperature of the faeces is too high (>40° C), mortality of *T. colubriformis* larvae will reach 100% and if it is too low (<4^0 C) development will cease (Beveridge *et al.* 1989). This is similar for all of the common nematode parasite species (Callinan 1978a, Callinan 1978b, Callinan 1979, Young and Anderson 1981).

Most of the studies measuring the rate and success of larval development have either been undertaken indoors in controlled environments at constant temperatures (Pandy *et al.* 1989) or outdoors with a single herbage and nematode species (Gibson and Everett 1972, Rose and Small 1985, Besier and Dunsmore 1993a) where larval recoveries are then related to a range of climatic factors such as temperature, rainfall, relative humidity and sunlight intensity. Both approaches have limitations.

Indoor studies usually show high larval recoveries, up to 100% of eggs used, while outdoor studies generally show recoveries from herbage of less than 5%, usually around 1% (Levine *et al.* 1974, Besier and Dunsmore 1993a, Moss and Vlassoff 1993). Outdoor environments have marked diurnal temperature fluctuations but the impact of varying temperature on larval development is poorly understood. Salih and Grainger (1982) found that fluctuations in temperature accelerated *O. circumcincta* larval development compared to larvae which developed at a similar mean ambient temperature. While Smith *et al.* (1986) reported that *O. ostertagi* larvae took twice as long to develop in the field under fluctuating temperature as in laboratory conditions at the same mean constant temperature, they explained this observation in terms of differences in partial pressure of oxygen in whole and reconstituted faeces. While the two trials were not directly comparable, the contrasting results may suggest that the effect of varying temperature differs between these two nematode species. This agrees with results from experiments involving free-living and plant parasitic nematodes, showing that some species develop more rapidly at fluctuating temperatures than constant temperatures, while other develop more slowly (Croll 1970). Furthermore, not only can the development rate of larvae be altered by constant or fluctuating temperature conditions, but so can the ultimate size which the larvae attain. Third stage larvae of *O. circumcincta* were smaller (648 *vs* 790 μm) when they were cultured outdoors instead of indoors (Gibson and Everett 1972). However, there is no evidence to suggest that this phenomenon is common to all species of gastrointestinal nematode. Also the smaller size may be due factors other than temperature as the larvae recovered from outdoors were placed on herbage plots and were subject to factors other than temperature fluctuations as well. The impact of larval size on survival, migration and establishment success in the host has not been determined.

Michel (1976) has criticised the procedure of relating macroclimatic meteorological parameters to larval development. Essentially the meteorological variables which are generally monitored, (ambient temperature, rainfall, relative humidity and intensity of sunlight), do not measure the conditions to which the larvae are exposed in the faeces or in the sward. This has been recently demonstrated in New Zealand where the temperature which was reached in a faecal mass during a sunny day was far greater than the ambient temperature (Familton and McAnulty 1995).

2.3.1. Faeces And Its Effects On Larval Development

There are other factors which indirectly affect larval development in sheep faeces. The nature of the faeces, either in pelleted, soft or liquid form may have a large impact on the rate of development and the degree of development success. The form of sheep faeces may impact on the rate of cooling of the faeces from 40^0 C when it is voided until ambient temperature is reached (Crofton 1963), which in turn may affect the rate of larval development. With pelleted sheep faeces, pellets may fall to the base of the sward and development success may be higher because they are protected from solar radiation and extremes in temperature. Also, pellets are of such a size and moisture content that development of the eggs inside them is not restricted by lack of oxygen. In sheep faeces with a higher moisture content, which are not pelleted but are still formed, larval development in the outer part of the faecal mass should proceed, but larval development deep within the mass may be reduced by lack of oxygen as occurs in cattle faeces (Anderson *et al.* 1983). As such faeces are generally deposited in a large mass on top of the sward, the mass is exposed to the extremes of temperature and ultraviolet radiation which increase the mortality of eggs and larvae close to the surface of the faeces. In diarrhoeic faeces, sprayed thinly on herbage or on soil, the development success in dry conditions is poor as rapid desiccation of the eggs and direct exposure to extremes in temperature and ultraviolet radiation will be greater than with a large faecal mass or within faecal pellets (Shorb 1943). However, in warm, moist conditions the development success of eggs in loose faeces may be high (Shorb 1943).

Cattle faeces and sheep faeces are potential reservoirs of larvae which continue to migrate from the faecal mass (Gibson and Everett 1972, Barger *et al.* 1984). It would seem plausible to suggest that more rapid disappearance of faeces should result in fewer larvae on herbage (Andersen *et al.* 1970). This assumes that rapid faecal disappearance results in destruction and not dispersal of nematode eggs and/or larvae. Although the development of larvae to the infective stage can occur within four days under ideal conditions, under more typical New Zealand field conditions two to three weeks is more common (Charleston 1982). Faeces disappear within 14 - 17 days in hill country conditions in New Zealand during all seasons except summer (Rowarth *et al.* 1985), so that it is possible that larval development may actually be a race against faecal disappearance. Ideally, if faeces could be removed before larvae begin to migrate from it, little contamination should occur. In fact, Christie (1963) concluded that faecal decomposition can be more rapid than the development of gastrointestinal nematode larvae. Factors known to affect cattle faeces disappearance and invertebrate colonisation of the pat are chemical and physical composition, moisture content, weight, surface area and organic matter content (Barth 1993). It is likely that the same factors affect the disappearance of sheep faeces. As loose cattle faeces disappear more rapidly than formed cattle faeces (Weeda 1967), it is possible that a similar pattern would be observed for sheep faeces. Also, the process by which the faeces disappear may depend on their moisture content. The disappearance of liquid faeces may be more directly related to rainfall, being washed into the soil by rain, while the disappearance of pelleted and soft faeces may be the result of decomposition or be the target of invertebrate activity, or both. While this has been suggested by Crofton (1963), little appears to have been published on the subject.

Invertebrates, especially earthworms, have been implicated in faecal disappearance. Christie (1963) concluded that earthworms were the most spectacular agents of faecal disappearance, as rapid disappearance coincided with large numbers of earthworm casts. In Western Australia, there was rapid faecal disappearance from June to August which was attributed to heavy rainfall destroying the faecal pellets (Besier and Dunsmore 1993a). This period also coincides with the time of maximal earthworm activity in New Zealand and the regions of Australia which receive winter precipitation (Sharpley and Syers 1977). While earthworm destruction of faeces may reduce the survival of gastrointestinal nematodes, earthworms have been shown to increase the dispersal of *O. ostertagi* larvae (Gronvold 1979), and *Lumbricus terrestris* increased dispersion of the entomopathogenic nematode *Steinernema carocapsae* (Shapiro *et al.* 1993).

2.3.2. Effect Of Herbage Species On Sward Microclimate

One of the most obvious ways in which the development, survival and migration of larvae could be altered by plant species is by changing the sward microclimate. The common grass species used in the New Zealand pastoral industry differ in morphological features (Lambrechtsen 1981, Horn and Hill 1987; see 2.2.1.). Monospecific swards of perennial grasses range in morphology from erect species with definite gaps between the tufts where bare ground is exposed, (eg. perennial ryegrass (*Lolium perenne*)or tall fescue (*Festuca arundinacea*)) to more prostrate grasses with a well defined herbage mat which leave little bare ground exposed (eg. browntop (*Agrostis capillaris*) or Yorkshire fog (*Holcus lanatus*)(Levy 1970). Whether these factors affect the sward microclimate is unknown as this is an area poorly studied in field crops and pastures (Monteith 1973). Yet climatic conditions within swards can differ markedly from ambient conditions recorded at 1 metre above ground level; minimum daily temperature is higher, maximum daily temperature is lower, and overall mean daily temperature is lower (Peacock 1975). These differences are not constant as Peacock (1975) reported a greater divergence between ambient temperature and temperature at the soil surface on a bright sunny day than on a dull cloudy day. These differences may be amplified at the site of larval development (Crofton 1963) since there are large differences between ambient temperature and temperature in the faecal mass (Familton and McAnulty 1995).

While the measurements of Peacock (1975) were taken within a single species sward (ryegrass), little comparative work has been undertaken between swards of contrasting morphology. It has been shown that the percentage of incident radiation of wavelength 450 - 1000 nm reaching ground level is greater on monospecific browntop or tall fescue swards than either monospecific ryegrass or white clover swards (Scott *et al.* 1968). If the amount of incident radiation which reaches the soil surface differs, then it is likely that temperature and relative humidity would also differ between the swards of various pasture species. Air movement patterns are also markedly different between tall fescue and white clover swards (Scott 1978) with greater air movement near the soil surface in the tall fescue than the white clover sward. Relative humidity and temperature are lower in swards with greater air movement. Thus the potential for micro-climate differences between swards does exist and this may affect larval development and migration.

Differences in sward microclimate may have a direct impact on larval development through temperature differences but there may also be indirect effects. For example, if pasture species alter soil moisture content this could alter larval development and survival as soil moisture content was found to be the second most important factor after temperature affecting development and survival of *H. contortus* and *T. colubriformis* larvae on pasture (Levine and Todd 1975).

2.3.4. Effect Of Herbage Species On The Development Of Gastrointestinal Nematode Larvae

In New Zealand, grass-based swards (ryegrass/white clover, prairie grass/white clover) had higher populations of mixed nematode infections than lucerne or chicory/white clover swards (Moss and Vlassoff 1993) after having similar numbers of eggs in lamb faeces deposited on them. Similarly higher larval recoveries from grass species than from legume species was reported by Furman (1944). However, the differences occurred only in the winter, while in the summer larval recovery was greater on the white clover. Both these studies measured larval recovery at one point in time, which does not differentiate between possible effects on larval development or larval survival. Also, no attempt was made to relate the differing recoveries to differences in sward microclimates or differential rates of faecal disappearance.

Whether differing pasture species accelerate or slow faecal disappearance is so far unknown. Swards of differing herbage species may alter the flora and fauna which cause its decomposition and disappearance. Coprophagous fungi are one of the initial colonisers of faeces (Bell 1983), and initiate faecal decomposition, but it is not known whether they are affected by pasture species. It was recently suggested that total numbers of earthworms and the species composition of earthworm populations may vary markedly between different herbage species (Springett *et al.* 1995). This could be important as earthworms have long been implicated in accelerating faecal disappearance (Christie 1963). Springett *et al.* (1995) compared specialist crops of sulla (*Hedysarum coronarium*), *Lotus pedunculatus*, *L. corniculatus*, a monospecific sward of white clover and a mixed ryegrass/white clover sward. Total earthworm biomass, particularly for *Aporrectodea caliginosa*, was far greater under the pure white clover sward than under any other herbage species. Furthermore, total earthworm biomass correlated well (R^2=0.82) with the growth rate of earthworms which were fed the same herbages. Studies comparing the perennial grass species commonly found in New Zealand pastures have yet to be undertaken.

2.3.5. Effects Of Ingested Plant Compounds On Larval Development In The Faeces

Faecal moisture content, which will affect larval development (Crofton 1963), may be altered by the herbage species being consumed (Niezen *et al.* 1993) or by the presence of endophytes in the herbage (Fletcher and Sutherland 1993). Few direct studies have been undertaken on the effect of ingested plants on larval development in faeces. Adding maize grain (corn) to calf diets reduced recovery of *T. axei* and *T. colubriformis* larvae from faeces, and similar effects were found if the grain was added directly to the faeces (Ciordia and Bizzell 1963). It is known that the grass species consumed by cattle affects oviposition and development of the face fly (*Musca autumnalis* DeGeer) (Dougherty and Knapp 1994), with reduced oviposition in faeces from cattle fed endophyte-infected fescue compared to endophyte-free controls. The endophyte also reduced the number of eggs laid and larval weights. These differences could not be explained by faecal moisture, nitrogen content or pH.

2.4. SURVIVAL OF LARVAE

Laboratory studies have shown that while the development of larvae is greatest under warm conditions, their survival is greatest under cooler conditions (Todd *et al.* 1976, Boag and Thomas 1985). It is generally accepted that the increased larval activity observed under warmer conditions leads to a more rapid depletion of metabolic reserves (Crofton 1948).

The "true" survival of larvae on herbage can be confounded by the possible flux of larvae between the herbage and the soil. If the soil acts as a reservoir of larvae and larvae migrate from the soil onto the herbage, this will prolong the apparent survival of larvae on the latter. The literature on the role of soil as a reservoir of larvae is contradictory. Some studies have concluded that the soil is not a reservoir (Andersen *et al.* 1970, Rose and Small 1985), while others (Callinan and Westcott 1986) reported that eight times as many larvae migrated into the soil as on to the herbage. These authors reported that larvae did not migrate from the soil back on to the herbage but the trial only lasted 96 hours. The results are in contrast to those with larvae of *O. ostertagi* which were found to migrate into the soil and subsequently onto herbage (Krececk and Murrell 1988). Soil type was not reported in these papers and differences in soil type may account for some of the contradictory findings.

The ability of larvae to migrate vertically on the herbage may also affect survival. If larvae have the ability to migrate to the upper stratum of the sward more readily, then their survival may be reduced as humidity is lower in the upper levels (Crofton 1963).

2.4.1. Effect Of Herbage Species On Nematode Larval Survival

Besier and Dunsmore (1993b) indicated that *H. contortus* larvae survived longer on kikuyu grass (*Pennisitum clandestinum*) due to its "greenness", than on dry, brown, pasture plots. Knapp (1964) placed larvae directly at the base of swards of various herbages and reported that lambs which grazed ryegrass or velvetgrass (*Holcus lanatus*) had lower levels of *H. contortus* than those which grazed white clover (*Trifolium repens*) swards which had received similar levels of contamination. These results are confounded by the possibility of different numbers of larvae migrating into the soil on swards of different herbage species, differential vertical migration and ingestive behaviour by grazing lambs, and the possibility of differing levels of larval establishment within the lambs grazing swards of different herbage species.

2.5. MIGRATION OF LARVAE

Once larvae have developed to the third stage, they migrate from the faeces into the soil or onto the herbage. While Crofton (1954) concluded that under laboratory conditions larval migration is random, Croll (1970) concluded that larval distribution, and hence migration, was not. Free-living, plant parasitic and animal parasitic nematodes have shown evidence of responses to physical and chemical stimuli. (Croll 1970). However, these indications of "behaviour" vary between species and generalisations cannot be made.

For larvae to migrate on to the herbage a surface moisture film is necessary (Crofton 1963, Krececk *et al.* 1990). Larvae use the surface tension of the moisture film to migrate (Croll 1970). Too much moisture on the leaf surface (> 0.15 ml/cm^2 leaf surface) will impede the migration of larvae of most common species of gastrointestinal nematode larvae (Rogers 1940). Anything less than this amount has differential effects on different species of gastrointestinal nematodes. *H. contortus* larvae for example, require less moisture on the leaf surface to migrate than *O. circumcincta* larvae (Rogers 1940).

The migration of *T. colubriformis* larvae is temperature-related, being most rapid in water-saturated soil at 20^0 C (Wallace and Doncaster 1964). This is probably similar for the larvae from other species as well. On grass leaves, migration can be rapid, with larvae reaching the top of blades of grass in 45 minutes when the temperature averaged 24 - 26^0 C. Unfortunately, the height of the grass was not reported. Larvae also have the ability to migrate down the herbage (Rogers 1940), possibly to retreat from drying water films (Crofton 1954) or in a response to changing light conditions (Crofton 1963).

2.5.1. Effect Of Herbage Species On Larval Migration

If larvae are to be ingested by the grazing animal, they must migrate to the grazing zone on the herbage. The morphological features which differentiate herbage species (see 2.9) may affect the vertical and horizontal migration of larvae from the faecal pellet to the grazing zone. There appear to have been no studies to determine whether moisture films vary between grasses in terms of thickness or duration after wetting, either by rainfall or condensation (D. Scott pers comm). Silangwa and Todd (1964), reported that larvae of *H. contortus*, *C. oncophora* and *T. colubriformis* migrated farther within a given time on tall fescue than smooth brome grass. This difference was greater when relative humidity was higher. No reason for the greater movement was suggested. Similarly, Crofton (1948) reported that larvae migrated farther on *Festuca* spp than on *Carex vulgaris*. Yet on both these species most (>90%) of the larvae were found in the bottom 2 cm of the sward. By contrast, larvae were found evenly distributed vertically over the stems and leaves of "clover", presumably white clover (Crofton 1948). No measurement of relative humidity was made. More *T. colubriformis* migrated onto subterranean clover than onto ryegrass at low relative humidity; at high humidity there was no difference in total numbers recovered, but more larvae were found on the clover leaves than stems (Knapp 1963). While the greater migration on clover at low atmospheric humidity may suggest that a greater level of humidity may be maintained within a white clover sward due to the plant morphology, this remains to be demonstrated. While recovery of *T. colubriformis* varied with relative humidity, more *H. contortus* larvae were recovered from clover than ryegrass at both levels of relative humidity (Knapp 1963) suggesting differing responses of the two species to humidity differences.

When faeces were placed at the base of prairie grass/white clover, ryegrass/white clover, chicory/white clover or lucerne swards and larvae collected seven weeks later, a greater proportion of the total larvae recovered were 26-75 mm above ground level than 0-26 mm above ground level, with a gradual decline in the vertical ranges thereafter (Moss and Vlassoff 1993) indicating that in these swards most larvae reside near the base of the sward. The exception was lucerne, where the greatest proportion of larvae were recovered >125 mm above the soil surface, indicating a differential rate of larval migration between herbage species.

Tarshis (1958) observed that under greenhouse conditions, horizontal migration of cattle nematode larvae (primarily *C. punctata*, but also some *T. axei, O. ostertagi* and *H. contortus*) was most rapid on tall fescue (*Festuca arundinacea*), least rapid on oats (*Avena sativa*) and intermediate on crimson clover (*Trifolium incarnatum*) plots. On outdoor plots, migration was greater on crimson clover, than on tall fescue and oats, which were similar. Overall, there was far greater horizontal migration on the glasshouse plots than on outdoor plots, up to 16 inches (41 cm) in 24 hours in the glasshouse, but only a maximum of 6 - 8 inches (15-20 cm) on outdoor plots. Gruner and Sauve (1982) reported that most larvae are found within 10 cm of cattle faecal pats, but gave no indication as to what herbage species were involved. As cattle will avoid grazing near faecal pats, horizontal migration may, in some circumstances, be as important as vertical migration in determining the number of larvae which are ingested, particularly if the larvae can migrate out of the area of grazing avoidance around faecal deposits (Forbes and Hodgson 1985).

2.6. EFFECT OF HERBAGE SPECIES ON LAMB GRAZING BEHAVIOUR AND INGESTION OF LARVAE

The number of larvae ingested by a grazing ruminant will be a function of larval density on herbage, total herbage intake (g DM) and grazing behaviour on herbages of differing morphology. Grazing behaviour has been shown to affect larval ingestion. Goats which grazed grass/clover swards together with sheep, ingested more grass and dead matter, and also ingested more nematode larvae than sheep (Jallow *et al.* 1994). Even if larval migration is similar on different herbage species, the ingestion of larvae could vary with differing grazing patterns.

The density of larvae on herbage (larvae/kg DM) is a function of the larval numbers and the herbage mass and it does not necessarily follow that larval intakes are directly related to absolute larval numbers. For example, greater numbers of larvae were found in the base of pangola grass swards, but when corrected for herbage dry matter, there was no difference in larval density between the 0-7 cm and above 7 cm strata above the soil surface (Aumont and Gruner 1989).

Large differences in bite-depth of sheep grazing grasses of widely contrasting morphology have been observed, with little relationship between mean sward bulk density and ingestion parameters (bite depth, bite area, bite volume, bite weight), but a strong positive relationship between sward height and these parameters (Burlison *et al.* 1991). The relationship between these ingestive parameters and larval ingestion is unknown. However, differences in total herbage dry matter intake of sheep between swards of different bulk density only occurred when herbage dry matter availability was less than 1 tonne per hectare (Black and Kenny 1984). As herbage availability is generally greater than 1 tonne/ha under New Zealand conditions, herbage dry matter intake of lambs should not be restricted by plant species. Differences between grass species in the number of larvae ingested would probably be due to differences in the development, survival and migration of larvae.

There has been little work done to determine whether the ingestive behaviour of lambs, as measured by the above parameters, changes in the presence of contaminated herbage, although it is recognised that cattle (Gruner and Sauve 1982), and to a lesser extent sheep, avoid grazing near faecal pats which are areas that have the highest levels of larval contamination (Gronvold 1979, Gruner and Sauve 1982, Forbes and Hodgson 1985).

2.7. EFFECT OF HERBAGE SPECIES ON PARASITISM IN LAMBS - NUTRITIONAL FACTORS

The close relationship between nutrition and gastrointestinal nematode parasitism in lambs has long been the subject of scientific study and has been reviewed on several occasions (Gibson 1965, Sykes 1983, Sykes 1994). The effects of parasites on digestion are small, with evidence for only a 0.01 to 0.02 unit change in energy or dry matter digestibility (Sykes and Coop 1976, Sykes and Coop 1977, Sykes *et al.* 1979, Coop *et al.* 1982, Sykes *et al.* 1988). Studies have also shown no effect on protein digestion *per se* (Bown *et al.* 1991). However, parasite infection causes loss of plasma protein and stimulates additional mucus secretion (Armour *et al.* 1966, Dargie 1975) and increased cell proliferation and sloughing into the alimentary tract (Dargie 1975, Coop *et al.* 1979, Symons and Jones 1983) and impairment of post-absorptive protein metabolism (Symons and Jones 1975). While some of the protein may be reabsorbed (Rowe *et al.* 1988), the consequence is an induced protein deficiency (Bown *et al.* 1991).

The increase in cell turnover in the gastrointestinal tract caused by nematode parasitism increases the maintenance requirement for protein and energy (Sykes 1983). This increased maintenance requirement, combined with a reduction in food intake (Sykes and Coop 1976, Sykes and Coop 1977, Sykes *et al.* 1988), results in a reduction in efficiency of nutrient utilisation (Sykes 1994). While all infections reduce food intake, the general pattern is that the reduction in efficiency of nutrient utilisation is greater in intestinal than abomasal infections (Sykes 1994).

An improved plane of nutrition can affect lamb parasitism and lamb performance. Lambs on a higher plane of nutrition have been shown to be more "resistant" to gastrointestinal nematodes, having lower rates of larval establishment (Brunsdon 1964, Abbott *et al.* 1985), lower gastrointestinal nematode burdens and faecal egg counts. There is experimental evidence indicating that adequate protein nutrition is more important than energy nutrition in enabling lambs to resist nematode infection (Bown *et al.* 1991).

If the absolute production loss (g liveweight gain/day) due to parasitism is constant for any given nematode burden across a range of nutritional planes, then an overall increase in animal performance, due to enhanced nutrition, will mean a proportionally smaller reduction in animal performance due to such a burden. This was suggested in the findings of Scales *et al.* (1995), who reported that liveweight gain differences between parasitised and non-parasitised treatments were similar at high and low herbage allowances, but as liveweight gain was greater in lambs on the high herbage allowance, the loss due to parasitism was proportionally less.

Thus far, studies on the effects of plane of nutrition on lamb parasitism have relied on changing the plane of nutrition through supplemental protein, using concentrate feeds (van Houtert *et al.* 1995), abomasal infusion of protein (Bown *et al.* 1991) or differing quantities of a similar ration (Roberts and Adams 1990). Little work has been undertaken to compare the effects of plant species of differing chemical composition and nutritive value on parasitised lamb growth. Yet studies with parasite-free lambs has shown large differences in growth rates (Ullyatt 1970).

Long-term grazing trials which compared parasitism on different herbage species could not determine whether the differences were due to differences in larval development, migration or survival, or within-host effects related to nutritional factors (Donald *et al.* 1979, Scales *et al.* 1995). Short intensive grazing trials which eliminated nematode reinfection as a variable have shown substantial differences in parasitised lamb production and established nematode burdens due to the plant species being grazed (Niezen *et al.* 1994, Robertson *et al.* 1995, Niezen *et al.* 1995). Thus far the studies have concentrated on condensed tannin (CT)-containing legumes. The only published work on the effect of plant compounds on larval establishment was by Tetley (1953) who found lower establishment of *H. contortus* in parasite naive lambs fed white clover than fed red clover or cocksfoot (*Dactylis glomerata*). He concluded that the effect was due to the cyanogenetic glucoside lotaustralin, but offered no evidence to support his conclusion.

2.8. LITERATURE REVIEW - SUMMARY

Grazing trials provide strong indications that herbage species can have a marked effect on parasitism, but effects on larval development, survival, and migration on the sward have not been adequately examined. The limited published information suggests that herbage species can affect larval development or survival and migration. However the picture is far from clear. Herbage species vary widely in their morphological features which may affect larval development, survival and migration, which may affect parasitism in grazing lambs. Thus far the reasons for the differing larval movement on the herbage has not been explored to any extent. Herbage species also vary in nutritive value and the ingestive behaviour of lambs varies between different herbages. A further complicating factor may be that different nematode species respond differently to differing conditions.

CHAPTER 3. THE EFFECT OF FOUR GRASS SPECIES ON LAMB PARASITISM AND GROWTH.

3.1 INTRODUCTION

A recent study has shown that pasture species can affect lamb parasitism and growth (Scales *et al.* 1995). Similarly, studies using cattle have indicated that both parasitism and liveweight gain may be markedly affected by pasture species (Ciordia *et al.* 1962a). Comparison of larval dynamics on herbage has indicated that larval development can differ between grass species (Furman 1944), as can larval migration (Silangwa and Todd 1964), further suggesting that parasitism could be affected by grass species. All these factors suggested that a comparison of grass species for lamb parasitism and growth was warranted.

This chapter describes an evaluation of four common New Zealand grass species on gastrointestinal nematode parasitism and lamb growth over two grazing seasons.

3.2 MATERIALS AND METHODS

3.2.1 Management of Pastures

In the autumn of 1991 (March), four species of grass of differing morphology, browntop (*Agrostis capillaris* cv Muster), Yorkshire fog (*Holcus lanatus* cv. Massey Basyn), tall fescue (*Festuca arundinacea* cv. Au Triumph) and perennial ryegrass (*Lolium perenne* cv. Grasslands Nui) were established as clover-free swards on plots of 1.0 ha, except for the ryegrass, which was established on a 0.6 ha plot. The plots were unreplicated subdivisions distributed at random of a single flat paddock of a uniform Kairanga sandy loam soil which had previously been maintained as a perennial ryegrass/white clover sward under uniform grazing management. Prior to the establishment of the grass swards, a crop of barley was grown on the paddock.

Each plot received a standard annual fertiliser dressing in the spring of 150 kg/ha of sulphur-enriched superphosphate. Pure grass swards were maintained by spraying with 2-4-D (® BASF) and dicamba (Banvel ® Sandoz Agro. Inc.) to control broadleaf weeds and white clover. Nitrogen fertiliser was applied monthly at 50 kg urea/ha which approximates to the amount of N fixed by clover in this environment (Steele 1982).

The following spring, the swards were grazed by adult cattle, or by ewe hoggets which had been dosed with slow-release albendazole capsules (Extender 100 ® Nufarm, Auckland NZ) to minimise the number of sheep gastrointestinal nematode larvae on the pastures. Grazing was intermittent and was solely to control herbage growth. Just prior to the start of the trial, the pastures were grazed by ewes with a low worm burden (mean FEC 250 epg in 1991/92 year and 400 epg in 1992/93 year) to provide each paddock with an even, light contamination with gastrointestinal nematode eggs. Each paddock was grazed successively with the same mob of ewes at the equivalent of 94 ewes/ha for 24 hours.

During the trial, the objective was to maintain swards as close as possible to 5 cm height by adjusting stocking rates. At this height dry matter intake of grazing lambs is probably not restricted by herbage availability (Parsons 1984, Maxwell and Treacher 1986). Lambs were added or removed in multiples of three to maintain a 2:1 ratio of trigger-drenched (TD) to suppressively drenched (SD) lambs (see 3.2.3)

3.2.2. Pasture Measurements

Pasture heights were measured twice per week, using a Hill Farming Research Organisation (HFRO) swardstick (Barthram 1986) with a minimum of 25 measurements per sward. Pasture dry matter mass was measured monthly. Hand plucks of herbage, for counts of third stage nematode larvae (L_3's), were taken every second week in 1991/92 and weekly in 1992/93 by the zigzag traverse method (Taylor 1939) and the larvae separated from the herbage using a modified Baermann procedure (Vlassoff 1973b). The extraction procedure is described in detail in Chapter 5.

Hourly temperature and daily precipitation readings were taken from a weather station which was located within 1 km of the trial site.

3.2.2.1. Herbage Analysis

In the 1991/92 year, measurements of *in vitro* herbage digestibility and nitrogen content were made from hand plucks of pasture which were intended to represent ingested herbage. In the 1992/93 year, *in vitro* herbage digestibility and nitrogen content were estimated on the extrusa of 5 oesophageal fistulated wethers. The animals were allowed 24 hours to adjust to the grass species. Bungs were then removed from the fistulae and the animals were allowed to graze for 30 minutes

Figure 3.1. Timetable of events on the grazing trial comparing lamb parasitism and growth on monospecific swards of browntop, tall fescue, Yorkshire fog and ryegrass grazed to target height of 5 cm. 1991/92.

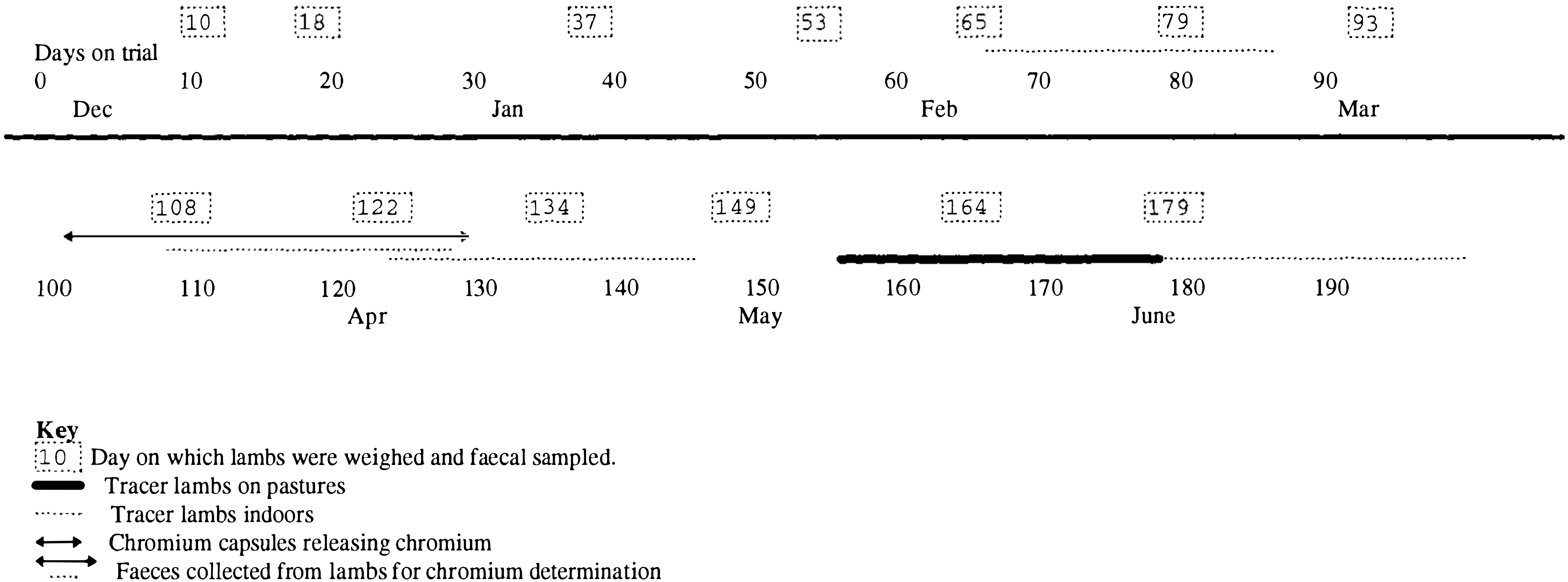
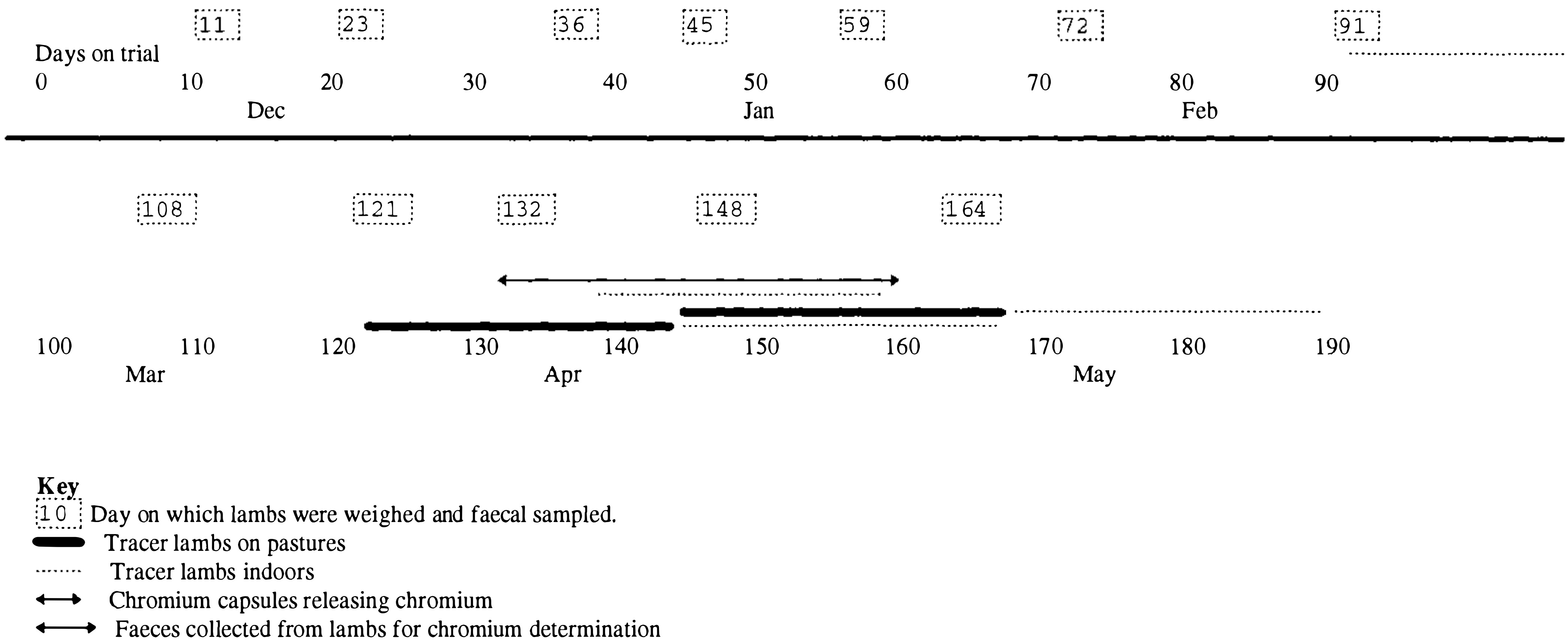


Figure 3.2. Timetable of events on the grazing trial comparing lamb parasitism and growth on monospecific swards of browntop, tall fescue, Yorkshire fog and ryegrass grazed to target height of 5 cm. 1992/93.



under constant supervision to ensure that if they started to ruminate, the collection bags were rapidly removed. Samples were then frozen for further analysis. Herbage digestibility was determined by the method of Tilley and Terry (1963), while nitrogen content was determined by the Kjeldahl method (method 7.016 Association of Analytical Chemists 1980).

3.2.3. Animals

Timetables for the animal measurements for 1991/92 and 1992/93 are provided in Figures 3.1 and 3.2 respectively. Recently-weaned Romney ram lambs sourced from Flock House farms in 1991/92 and purchased from another farm in 1992/93 were randomised to treatments based on liveweight, drenched with ivermectin (Ivomec ® Merck Sharp and Dohme) and then grazed on the trial swards for 184 days in 1991/92 (November 28 1991 until 30 May 1992) and 164 days in 1992/93 (November 11, 1992 until 25 April 1993). Lambs were weighed and faecal sampled fortnightly. Faecal egg counts (FEC; eggs/gram faeces) were undertaken using a modified McMaster technique in which 1 egg counted represented 50 epg. On each grass species, one third of the lambs were suppressively drenched (SD) fortnightly with ivermectin while two thirds were "trigger drenched" (TD) when mean FEC reached 1500 eggs per gram of fresh faeces (epg) on any treatment in 1991/92, but 1000 epg in 1992/93 because of welfare concerns for lambs which grazed browntop (see 3.3.4). The same subset of lambs was trigger drenched or suppressively drenched through the duration of the trial. All anthelmintic treatments were given at 1.5 times the recommended dose rate. At each sampling, faecal consistency was scored from 1 to 5, 1 being liquid and 5 being hard pellets. In 1991/92, after eight days on the trial, the lambs were removed and shorn, resulting in a drop in lamb liveweight (Appendix 3.1).

3.2.3.1. Tracer Lambs

At intervals (see Figs. 3.1 and 3.2), lambs which had been reared indoors free of nematode infection (tracer lambs) were grazed on the swards for 3 weeks, then housed for a further 3 weeks to allow ingested larvae to mature. The lambs were then slaughtered and the abomasa and intestines removed to determine total worm burdens. The organs were washed thoroughly to remove all the digesta and from the washings, 5% aliquots were taken for adult worm identification and counting, and for counting of fourth stage larvae (L_4's). In 1991/92, tracer lambs were released on January 14, March 10 and May 4, with three lambs per sward per period. In 1992/93, tracer lambs were released on January 20, March 18 and April 14, with 4 lambs per grass species per period. These dates coincided with a mid-summer, late-summer/early-autumn and late autumn grazing. No tracer lambs were released onto the ryegrass sward on April 14 as that treatment had been terminated.

3.2.3.2. Herbage Intake Measurements

In both years, at one point during the trial, lambs were given slow-release chromium sesquioxide capsules (Captec Chrome ® Fernz Corp) to measure faecal output and to calculate organic matter intake (OMI) following the methods of Parker *et al.* (1989). In both years, the faeces were pooled over three sets 3 consecutive sample days and analysed for chromium content following the procedure of Williams *et al.* (1962).

Daily faecal organic matter output (FO; g OM/d)) was determined from the formula:

$$FO(g\ OM/d) = \frac{RR\ (mg\ Cr/d)*OM\%}{((Adj\ aa(mg\ Cr/g\ DM)-BC)*CF)*100}$$

Where: RR is the expected average daily release rate of Cr_2O_3 from the controlled release capsule,

Adj aa(mg Cr/g DM) is the atomic absorption reading adjusted to 1 g dried faeces,

BC is the correction for background Cr, which was determined from faeces from lambs which did not have capsules in them,

CF is the recovery correction factor for the CR assay.

OM% is the OM content of the faeces

Then organic matter intake (OMI) is:

$$OMI = \frac{FO}{(1-OMD)}$$

Where OMD is the organic matter digestibility. For this exercise it was assumed that internal nematode burdens did not have an effect on herbage OMD (Sykes 1994)

In 1991/92, capsules were administered on March 8 (day 100) to 12 lambs grazing each herbage species (seven randomly selected trigger drenched and five randomly selected suppressively drenched lambs). Faecal samples for chromium determination were taken *per rectum* on March 15, 18, 21, 23, 25, 27, 30, April 1 and 3. In the 1992/93 year, capsules were administered on 23 March, to 12 lambs grazing each herbage type (seven randomly selected trigger drenched and five randomly selected suppressively drenched lambs). Faecal samples were taken on March 30 and 31 and April 1, 5, 7,8, 12, 15, and 16.

3.2.4. Statistical Procedures

Species plots were unreplicated, and effects were evaluated by analysis of variance using general linear models (GLM ® Statistical Analysis Systems (SAS)) in a completely randomised design with individual animals as the experimental units. The implications of this procedure are considered in Section 3.4. Comparisons were made of least squares means of lamb liveweights, using initial weight as a covariate, lamb FEC, pasture larval densities (L_3/kg herbage DM), pasture larval populations (L_3/ha), pasture herbage mass (kg DM/ha), tracer lamb nematode burdens, lamb faecal output (g DM/day), and estimated lamb OMI (g DM/day), transforming when necessary to normalise data as determined by the random scatter pattern observed when residual *vs* predicted values were plotted. Thus lamb FEC were square-root transformed and tracer lamb nematode burdens were $\log_{10}$ transformed to normalise data prior to analysis.

3.3 RESULTS

3.3.1 Pastures

3.3.1.1. Pasture Heights

In 1991/92, pasture heights were maintained within the 4-6 cm range after the first month (Table 3.1). Yorkshire fog and ryegrass then tended to be slightly below the target height, browntop slightly above and fescue height slowly declined over the duration of the trial. In 1992/93, it took two months to achieve the desired pasture height due to the rapid growing conditions. Browntop maintained a greater sward height than the other grasses throughout the trial. However, due to the poorer physical condition of the lambs on browntop compared with the other grasses, it was decided that no more lambs could be added to the treatment.

3.3.1.2. Pasture Composition

The swards of tall fescue and browntop averaged 50% target species, 30% dead matter and 20% other species, which was usually Yorkshire fog. The sward of Yorkshire fog had very low levels of other herbage species (5%) but higher levels of dead matter (40%, Table 3.2). In both years dead material accumulated on the top of the browntop and Yorkshire fog swards (Plates 3.1 and 3.3), but not on the tall fescue or ryegrass swards (Plates 3.2 and 3.4). In 1992/93, the ryegrass treatment was terminated 1 month early so that the ryegrass sward could be renewed, as an unacceptable level of Yorkshire fog (40% of dry matter) had established in it.

Table 3.1. Monthly average pasture heights (cm) for swards of browntop, tall fescue, Yorkshire fog, and ryegrass continuously grazed by lambs to a target height of 5 cm. 1991/92 and 1992/93 years.

	Month						
	November	December	January	February	March	April	May
1991/92 Year							
Browntop	ND[1]	7.4	5.2	5.8	5.8	5.6	5.1
Tall Fescue	ND	12.0	4.9	6.5	5.5	4.6	4.2
Yorkshire fog	ND	7.7	4.2	4.6	3.8	4.2	4.2
Ryegrass	ND	8.4	4.3	4.3	4.2	4.5	4.0
1992/93 Year							
Browntop	8.7	7.8	6.7	5.9	5.9	6.0	ND
Tall Fescue	7.6	6.4	5.6	4.9	4.9	4.3	ND
Yorkshire Fog	10.3	7.9	6.1	5.1	5.1	4.8	ND
Ryegrass	7.4	7.1	5.6	4.8	4.7	ND	ND

[1] ND - not determined

Table 3.2. Botanical composition % by weight on a dry matter basis (target species (T(%)), other species (O(%)} and dead matter (D(%))} of browntop, tall fescue, Yorkshire fog and ryegrass swards grazed to a target height of 5 cm. Both years.

	1991/92						1992/93					
	Beginning			End			Beginning			End		
	T	O	D	T	O	D	T	O	D	T	O	D
Browntop	67	9	24	53	17	30	51	19	30	49	21	30
Tall fescue	66	12	22	37	15	48	49	17	34	59	19	22
Yorkshire fog	46	0	54	54	4	42	54	5	41	54	4	42
Ryegrass	47	15	38	31	47	22	38	42	20	ND[1]	ND	ND

[1] ND - not determined.

Plate 3.1. Lambs grazing browntop. Note the amount of dead material on the top of the sward. Lambs grazing the tall fescue sward are in the background.

Plate 3.2. Lambs grazing tall fescue. The level of dagginess varied markedly between animals.

Plate 3.3. Lambs grazing Yorkshire fog. Note the dead material on the sward surface, similar to browntop.

Plate 3.4. Lambs grazing ryegrass. Three of the animals are extremely daggy. The Yorkshire fog sward is in the top, righthand corner.

3.3.1.3. Herbage Nitrogen Content and Digestibility

In both years there was no significant herbage effect on nitrogen content or organic matter digestibility (OMD) (Table 3.3). However, there was a consistent pattern in that nitrogen content was greater and OMD lower in the Yorkshire fog.

3.3.1.4. Herbage Mass and Stocking Rate

Herbage DM mass and stocking rates (su/ha) are shown in Table 3.4. As the trial progressed during 1991/92 and throughout 1992/93, there were higher herbage DM masses on the browntop and Yorkshire fog than ryegrass and tall fescue swards. Higher stocking rates were required each year on the browntop and tall fescue than on ryegrass or Yorkshire fog swards to maintain sward height close to the 5 cm target. However, if stocking rate is measured as lamb mass/ha (Table 3.5), there was relatively little difference between three of the grasses in 1991/92; the exception being tall fescue, on which it increased until March and then declined rapidly. In 1992/93, the stocking rate (lamb mass/ha) required to maintain sward heights increased on all treatments until February, when tall fescue, Yorkshire fog and ryegrass plateaued. An increase in stocking rate was required until March to maintain pasture height of browntop. Herbage allowance as measured as the mass of herbage DM available per kg lamb liveweight (Table 3.5) indicated that there was a greater mass of browntop and Yorkshire fog for each kg of lamb liveweight than for tall fescue or ryegrass. This was consistent over both years.

Table 3.3. Herbage nitrogen content (%) and organic matter digestibility (%) of browntop, tall fescue, Yorkshire fog and ryegrass when grazed to a target height of 5 cm. Both years.

	Nitrogen (%)	OMD (%)
1991/92		
Browntop	2.62	61.8
Tall fescue	2.37	61.4
Yorkshire fog	3.07	52.6
Ryegrass	2.33	63.9
Pooled SE	0.320	2.95
Herbage effect (P<)	0.77	0.46
1992/93		
Browntop	2.83	52.8
Tall fescue	2.86	56.8
Yorkshire fog	3.00	47.9
Ryegrass	ND	ND[1]
Pooled SE	0.077	3.62
Herbage effect (P<)	0.73	0.17

[1] ND - not determined

Table 3.4. Herbage mass (DM) (kg DM/ha) and lamb stocking rate (SR) (su[1]/ha) on swards of browntop, tall fescue, Yorkshire fog or ryegrass when continuously stocked to maintain a sward surface height of 5 cm. Both years.

Treatment	November		December		January		February		March		April		May	
	DM	SR	DM	SR	DM	SR	DM	SR	DM	SR	DM	SR	DM	SR
1991/92														
Browntop	ND[2]	ND	3020[a][3]	23.2	3060[ab]	24.3	3770[a]	22.4	2980[a]	23.2	4790[a]	22.1	5863[a]	22.1
Tall Fescue	ND	ND	3170[a]	26.4	3440[a]	27.9	2370[b]	31.2	2330[a]	31.8	2230[b]	16.8	1779[b]	17.4
Yorkshire fog	ND	ND	2790[a]	20.1	2120[ab]	21.6	2790[ab]	18.3	2340[a]	19.7	3190[b]	19.5	5209[ab]	12.6
Ryegrass	ND	ND	2820[a]	21.5	1880[b]	25.0	2450[b]	18.0	1990[a]	18.0	2500[b]	14.5	1780[b]	16.0
Pooled SE	ND	ND	338.7		310.4		271.0		283.0		252.1		160.3	
1992/93														
Browntop	5440[a]	24.0	5350[a]	24.0	6810[a]	28.1	7130[a]	31.1	7110[a]	30.0	5860[a]	27.8	ND	ND
Tall fescue	3460[b]	24.6	2400[c]	23.6	2940[c]	28.5	3090[c]	27.9	3940[c]	27.2	1780[b]	27.0	ND	ND
Yorkshire fog	4280[ab]	23.4	3750[b]	23.4	4580[b]	25.2	5700[ab]	24.4	5980[b]	22.8	5210[ab]	21.6	ND	ND
Ryegrass	3390[a]	24.0	2960[c]	22.7	2740[c]	24.0	5010[b]	23.0	4750[c]	22.0	1780[b]	ND	ND	ND
Pooled SE	290.7		144.3		204.4		376.7		227.9		160.3		ND	ND

[1] 1 lamb is equivalent to .6 su.
[2] ND - not determined
[3] Values in columns with differing superscripts differ significantly $P < .05$

Table 3.5. Stocking rates (SR; kg lamb/ha) and adjusted herbage allowance (DM/SR; kg herbage DM/kg lamb liveweight) over the duration of the trial in which lambs grazed swards to a target height of 5 cm. 1991/92 and 1992/93.

	Month													
	November		December		January		February		March		April		May	
1991/92	SR	DM/SR	SR	DM/SR	SR	DM/SR	SR	DM/SR	SR	DM/SR	SR	DM/SR	SR	DM/SR
Browntop	ND[1]	ND	1140	2.64	1180	2.59	1050	3.59	1130	2.64	1120	4.28	1140	5.14
Tall fescue	ND	ND	1210	2.62	1180	2.92	1360	1.74	1480	1.57	790	2.82	860	2.07
Yorkshire fog	ND	ND	1010	2.76	1040	2.04	880	3.17	960	2.44	1020	3.13	720	7.24
Ryegrass	ND	ND	1040	2.71	1200	1.57	890	2.75	960	2.07	870	2.87	1060	1.68
1992/93														
Browntop	852	6.39	870	6.15	1020	6.68	1220	5.84	1440	4.94	1380	4.25	ND	ND
Tall fescue	873	3.96	840	2.86	1060	2.77	1230	2.51	1180	3.34	1220	1.46	ND	ND
Yorkshire fog	831	5.15	900	4.17	980	4.67	1150	4.96	1070	5.59	1060	4.92	ND	ND
Ryegrass	852	3.98	880	3.36	970	2.83	1210	4.14	1160	4.10	1180	1.51	ND	ND

[1] ND - not determined

3.3.1.5. Herbage Larval Density and Population

In 1991/92, herbage larval densities (L_3/kg dry herbage) (Table 3.6) were lowest on the Yorkshire fog until March and variable on the other grasses. In April and May, larval densities increased dramatically on browntop. In 1992/93, numbers of larvae tended to be higher earlier in the season on all grasses except tall fescue, but appeared, on browntop at least, to be declining after February (Table 3.6). Overall, larval density was higher in 1992/93, particularly on browntop and Yorkshire fog in the January to March period.

In both years, the greatest populations of larvae (L_3/ha) (Table 3.7) were reported on browntop, in 1991/92 in May and in 1992/93 in February, after which they declined. On the other grasses, populations were variable, tending to increase in April and May in 1991/92. In 1992/93, populations were lowest on tall fescue. In 1992/93, there were far greater larval populations during the December to March period than in 1991/92 on all grasses except tall fescue.

3.3.2 Lamb Growth

3.3.2.1. 1991/92

Final liveweights, adjusted to a common initial weight for 1991/92 and 1992/93 for suppressively (SD) and trigger drenched (TD) lambs are shown in Table 3.8. In 1991/92, SD lambs which grazed ryegrass were significantly heavier ($P<0.05$) than SD lambs which grazed the other 3 grasses, which did not differ ($P>0.05$). Trigger drenched (TD) lambs which grazed ryegrass were

Table 3.6. Mean larval density (L_3/kg DM herbage) on swards grazed by lambs to a target height of 5 cm. Mean of two estimates in 1991/92 and four estimates in 1992/93.

	Month						
	November	December	January	February	March	April	May
1991/92							
Browntop	ND[1]	1520	3000	3570	4430	13450	19710
Tall Fescue	ND	2330	3670	5590	1200	3410	8310
Yorkshire fog	ND	1160	2280	980	2290	7700	9330
Ryegrass	ND	1200	9020	5020	1420	6160	8400
1992/93							
Browntop	720	390	11020	14670	7950	5460	ND
Tall Fescue	0	670	1260	3460	4220	17090	ND
Yorkshire fog	510	2000	10000	9720	7300	11690	ND
Ryegrass	1090	6550	8390	8610	4590	ND	ND
Pooled SE (1992/93)	1224	1299	1230	1298	1161	1731	ND
Herbage effect (P<) (1992/93)	NS[2]	0.05	0.05	0.01	0.05	0.05	ND

[1] ND - not determined
[2] NS - not significant (P>0.05).

Table 3.7. Mean larval population (L_3 X 10^6/ha) on swards which were grazed by lambs to a target height of 5 cm. Mean of two estimates in 1991/92 and four estimates in 1992/93.

	Month						
	November	December	January	February	March	April	May
1991/92							
Browntop	ND[1]	4.6	9.2	13.4	13.2	64.4	115.6
Tall Fescue	ND	7.4	12.6	13.3	2.8	7.6	14.8
Yorkshire fog	ND	3.2	4.8	2.7	5.4	24.6	48.6
Ryegrass	ND	3.4	17.0	12.3	2.8	15.4	15.0
1992/93							
Browntop	3.9	20.7	75.0	104.6	56.5	32.0	ND
Tall Fescue	0	1.6	3.7	10.7	16.6	30.4	ND
Yorkshire Fog	2.2	7.5	46.0	55.4	43.6	60.9	ND
Ryegrass	3.7	19.4	23.0	43.1	21.8	ND	ND
Pooled SE (1992/93)	0.61	3.82	12.26	12.73	5.73	14.28	ND
Herbage Effect (P<) (1992/93)	0.27	0.10	0.09	0.03	0.007	0.75	ND

[1] ND - not determined.

Table 3.8. Final liveweights (kg) of suppressively drenched (SD) and trigger-drenched (TD) lambs grazed on monospecific swards of browntop, tall fescue, Yorkshire fog or ryegrass to a target height of 5 cm. Both years. In 1992/93, final liveweights are given for day 148, not 164, so that ryegrass was included.

Treatment	SD[1]	TD	SD-TD	%age of SD	SD vs TD
1991/92					
Browntop	35.3[a]	28.8[a]	6.5	18.0	**[2]
Tall Fescue	35.4[a]	27.7[a]	7.7	21.8	**
Yorkshire Fog	36.0[a]	33.2[b]	2.8	7.7	NS[3]
Ryegrass	43.6[b]	38.5[c]	5.1	11.7	**
Pooled SE	.973	.973			
1992/93					
Browntop	28.2[a]	25.9[a]	2.3	8.2	*
Tall fescue	26.4[a]	28.2[b]	-1.8	+6.8	NS
Yorkshire fog	29.1[a]	26.4[ab]	2.7	9.3	*
Ryegrass	33.7[b]	31.6[c]	2.1	6.2	NS
Pooled SE	1.10	1.10			

[1] Values in columns with differing superscripts differ P<0.05.
[2] ** P<0.01, * P<0.05
[3] NS - not significant P>0.05

significantly heavier (P<0.05) than TD lambs which grazed Yorkshire fog. These in turn, were significantly heavier (P<0.05) than TD lambs which grazed tall fescue and browntop which did not differ. Group mean liveweights at each weighing for 1991/92 are given in Appendix 3.1. Only after 60 days on the trial did SD lambs which grazed ryegrass have greater liveweight gains than SD lambs which grazed the other grasses. A similar pattern is evident for the TD lambs. TD lambs which grazed Yorkshire fog became heavier than TD lambs which grazed tall fescue only after 100 days on the trial. When SD lambs are compared with their TD counterparts within grass treatments, SD lambs were heavier (P<0.05) than TD lambs on ryegrass, tall fescue and browntop, but not Yorkshire fog.

The proportion of lambs which had a liveweight greater than 32 kg, a minimum weight for slaughtering, was greater throughout the trial for SD than TD lambs on all four grass treatments (Appendix 3.3). Within the SD lambs, the proportion was greatest on the browntop and ryegrass and least on the tall fescue and Yorkshire fog. For TD lambs, the proportion was greatest for the ryegrass, intermediate for the browntop and Yorkshire fog and lowest for the tall fescue.

3.3.2.2. 1992/93

In 1992/93, SD lambs which grazed ryegrass were again significantly (P<0.05) heavier than SD lambs which grazed the other grasses, which did not differ (Table 3.8). TD lambs which grazed ryegrass were heavier (P<0.05) than lambs which grazed fescue, which were heavier (P<0.05) than lambs which grazed browntop. TD lambs which grazed Yorkshire fog were intermediate between those which grazed tall fescue and browntop. SD lambs were significantly (P<0.05) heavier than their TD counterparts when grazed on browntop and Yorkshire fog, but not tall fescue or ryegrass. Liveweight profiles are provided in Appendix 3.2. Both TD and SD lambs which grazed ryegrass gained weight rapidly between days 25 and 80, after which growth slowed and was similar to lambs which grazed Yorkshire fog and browntop. SD lambs which grazed tall fescue were 2-4 kg lighter than SD lambs which grazed Yorkshire fog and browntop throughout most of the trial. In the last month they gained more weight and achieved the same final liveweight as SD lambs which grazed browntop and Yorkshire fog. TD lambs which grazed Yorkshire fog and browntop gained little weight between days 60 and 120 and then lost weight over the last 30 days of the trial. SD lambs which grazed ryegrass had a greater proportion of animals heavier than 32 kg than SD lambs which grazed the other grasses. In the last 40 days of the trial, liveweights of SD lambs which grazed Yorkshire fog declined so that there was a drop from 40% to 0% of lambs which were greater than 32 kg liveweight (Appendix 3.3). The reason for this is unclear, but it did not occur in the TD treatment where the proportion which attained 32 kg was low anyway.

3.3.3. Faecal Egg Counts

TD lambs were drenched on four occasions in both years, on days 53, 93, 134, and 179 in 1991/92 and on days 45, 91, 132 and 164 in 1992/93. In both years, TD lambs which grazed tall fescue and browntop had the highest FEC (Tables 3.9 and 3.10) with a significant ($P<0.05$) herbage effect at all four FEC peaks in 1991/92 and at two of the four FEC peaks in 1992/93. At the third FEC peak in the 1992/93 season, lambs were drenched before the trigger level of 1000 epg was reached. This was to avoid the rapid rise in FEC's experienced in the previous peak and because of the poor

Table 3.9. Mean faecal egg count (FEC) (eggs/gram fresh faeces (epg)) (arithmetic means and means of square-root transformed data) of trigger drenched lambs which grazed swards to a target height of 5 cm. 1991/92. FEC trigger level 1500 epg.

Arithmetic means	Days After Trial Start												
	10	18	37	53*	65	79	93*	108	122	134*	149	164	179*
Browntop	0	260	1060	1740	0	1200	1910	0	800	2830	0	580	1350
Tall Fescue	10	370	1240	1490	10	950	1890	10	1430	3270	0	920	1620
Yorkshire Fog	0	90	230	780	0	270	910	10	630	1300	10	420	525
Ryegrass	0	150	650	1250	0	370	680	0	340	610	0	110	410
Square-root transformed means													
Browntop	0	14.6	30.2	40.4	0.4	29.4	39.3	0	25.1	49.6	0	18.0	30.4
Tall Fescue	0.7	16.2	33.2	38.4	0.5	28.0	41.8	1.2	35.9	53.1	0.5	26.5	34.2
Yorkshire fog	0	7.3	13.4	27.1	0	11.5	26.7	0.6	22.0	33.1	0	13.0	12.6
Ryegrass	0	8.7	24.4	35.2	0	16.9	34.6	0	19.6	28.3	0	6.9	11.0
Pooled SE	0.43	2.77	3.46	2.97	0.51	4.67	5.05	0.77	4.31	5.49	0.36	4.26	5.50
Herbage Effect	0.28	0.004	0.0001	0.0001	0.67	0.001	0.04	0.49	0.02	0.002	0.57	0.01	0.008

* All lambs drenched with ivermectin at 1.5 time recommended dose rate.

Table 3.10. Mean faecal egg count (FEC) (eggs/gram fresh faeces (epg)) (arithmetic means and means of square-root transformed data) of trigger drenched lambs which grazed swards to a target height of 5 cm. 1992/93. FEC trigger level 1000 epg.

	Days After Trial Start											
Arithmetic Means	11	23	36	45*	59	72	91*	108	121	132*	148	164*
Browntop	0	0	120	1370	0	610	2140	0	ND	750	0	970
Tall Fescue	0	0	90	1020	0	440	3110	0	ND	500	2	1440
Yorkshire Fog	0	0	30	770	0	230	800	0	ND	430	0	900
Ryegrass	0	0	20	430	0	170	590	0	ND	290	0	ND
Square-root transformed												
Browntop	0	1.1	10.7	37.0	0.3	24.6	46.3	0.3	ND	27.3	0	31.1
Tall Fescue	0	0	9.7	31.9	0	21.1	55.8	0.3	ND	22.4	1.5	37.9
Yorkshire fog	0	1.4	5.1	27.7	0.5	15.1	28.3	0.6	ND	20.7	0.3	30.1
Ryegrass	0	0	4.6	20.7	0	13.2	24.3	0	ND	17.1	0.5	ND
Pooled SE	ND	0.84	2.35	5.80	0.50	4.87	8.82	0.49	ND	4.40	0.58	10.23
Herbage Effect	ND	0.17	0.007	0.06	0.44	0.05	0.0006	0.69	ND	0.12	0.04	0.42

* All lambs were drenched with ivermectin at 1.5 times the recommended dose rate.

physical condition of some of the lambs grazing browntop. SD lambs had FEC's near zero on all occasions in both years (data not shown)

3.3.4. Mortalities

A large number of mortalities occurred in TD lambs which grazed browntop in both seasons and in lambs which grazed tall fescue in 1992/93 (Table 3.11). In 1991/92 the trigger level for drenching was set at 1500 epg and this was adhered to, except for the third FEC peak (Table 3.9) where a rapid rise in faecal egg counts occurred. It was at this time that the majority of mortalities occurred. The decision was made to reduce the FEC trigger level to 1000 epg in 1992/93, in order to prevent a similar situation. However, in the second FEC peak of that year (Table 3.10) mean egg counts rose from approximately 400 - 600 epg to between 2000 and 3000 epg on the tall fescue and browntop in a fortnight. Lamb mortalities occurred soon after this peak was reached and the decision was made, on animal welfare grounds, to drench prior to the trigger level of 1000 epg being attained. This may explain the absence of a herbage effect at this time. Due to logistical and time constraints, none of the lambs were necropsied to determine the exact cause of death.

3.3.5. Tracer Lamb Worm Burdens

Tracer lamb worm burdens are summarised by years with the details of each period in Appendices 3.4 to 3.15. Although there were variations between periods in the number of nematodes recovered, pooling over periods summarised the patterns effectively. The exception was in tracers which grazed ryegrass, which tended to have higher worm burdens relative to tall fescue in those periods in which the overall nematode recovery was low, periods 1 and 2 in 1991/92 and period 1 in 1992/93.

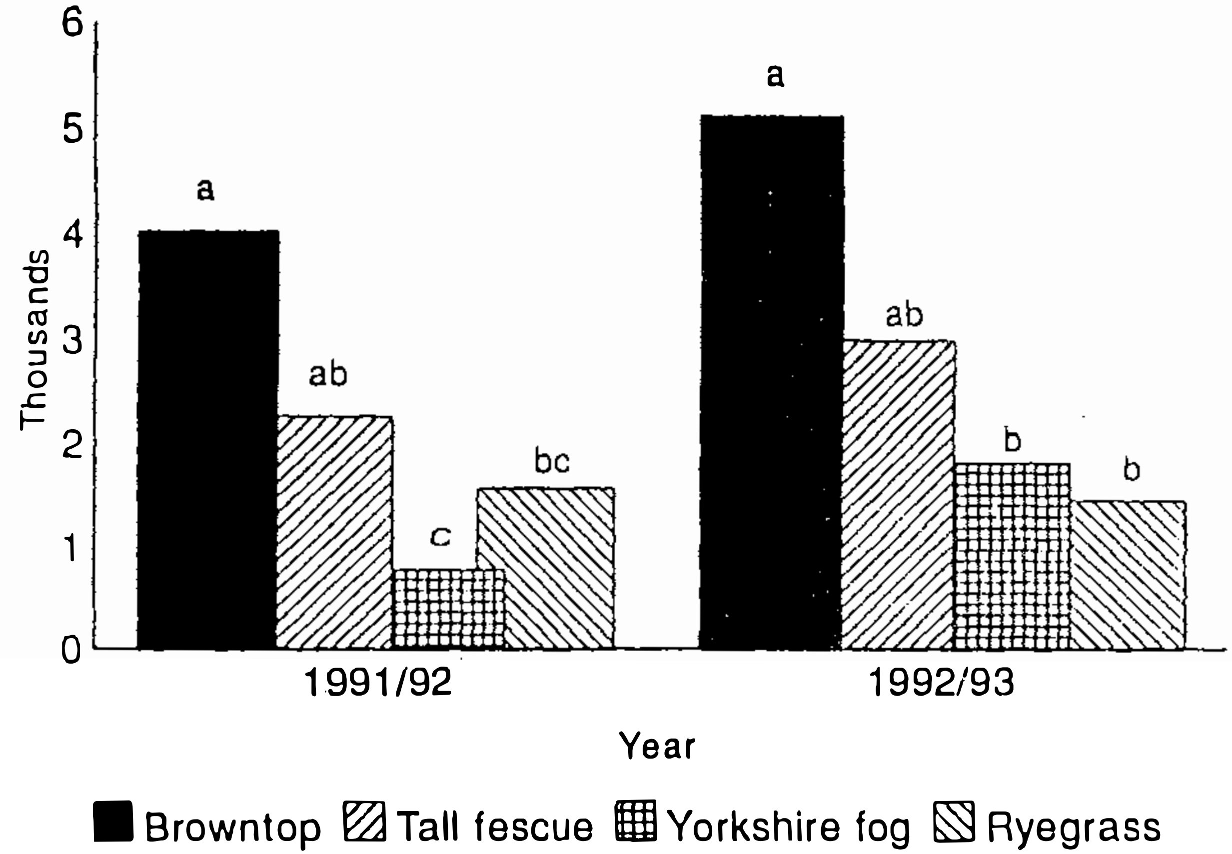
Table 3.11. Number of mortalities in lambs which were either suppressively drenched fortnightly (SD) or trigger drenched (TD) and grazed swards of browntop, tall fescue, Yorkshire fog and ryegrass in both years.

	1991/92		1992/93	
	SD	TD	SD	TD
Browntop	0	9	1	10
Tall fescue	3	3	1	9
Yorkshire fog	0	2	0	5
Ryegrass	0	0	1	1

Mean worm burdens of tracer lambs showed an almost identical pattern between grasses in both years. Those which grazed browntop had the highest total burdens (Fig 3.3), those which grazed ryegrass and Yorkshire fog had the lowest and did not differ significantly and those which grazed tall fescue were intermediate.

Identical patterns of relative numbers of abomasal and intestinal worm burdens between grasses were evident in 1991/92 (Tables 3.12 and 3.13). In 1992/93, the pattern between grasses was similar to 1991/92 but there were fewer abomasal worms and relatively more intestinal worms in 1992/93 compared with 1991/92, particularly in tracer lambs which grazed browntop (Tables 3.14 and 3.15).

Figure 3.3. Mean worm burdens (back transformed $\log_{10}(n+1)$ transformation) of tracer lambs pooled for 3 periods in 1991/92 (3 lambs/grass/period) and 3 periods in 1992/93 (4 lambs/grass/period) when grazing browntop, tall fescue, Yorkshire fog or ryegrass swards to target heights of 5cm.



1991/92 herbage effect P<.009
1992/93 herbage effect P<.006

3.3.5.1. 1991/92

In 1991/92, when results of the tracer lamb worm burdens were pooled over 3 periods, there was no significant (P>0.05) grass species effect on the abomasal parasites *Haemonchus* or *Trichostrongylus* (Table 3.12), but tracer lambs which grazed ryegrass and Yorkshire fog had significantly (P<0.05) lower *Ostertagia* numbers (Table 3.12) than those which grazed tall fescue, with browntop intermediate. Total abomasal burdens were greatest in tracer lambs which grazed browntop, lowest in lambs which grazed Yorkshire fog and intermediate in lambs which grazed tall fescue and ryegrass (Table 3.12). There was no significant grass species effect on the intestinal genera *Cooperia* or *Nematodirus* (Table 3.13), but significantly (P<0.05) lower numbers of *Trichostrongylus* adults and fourth stage larvae in lambs which grazed Yorkshire fog compared to those which grazed browntop and tall fescue. Lambs which grazed ryegrass were intermediate. Total intestinal burdens were greatest in lambs which grazed browntop, lowest in lambs which grazed Yorkshire fog and intermediate in lambs which grazed tall fescue and ryegrass (Table 3.13). A detailed analysis of tracer lamb worm burdens for each grazing period is provided in Appendices 3.4 to 3.9. In terms of any temporal pattern, tracer lamb nematode burdens were substantially higher in the second period (March 10-31; days 102-123) than in the other two periods (Appendices 3.4 - 3.9).

3.3.5.2. 1992/93

In the 1992/93 season there was also no effect of grass species on the abomasal genera *Haemonchus* or *Trichostrongylus* (Table 3.14) but an almost significant (P<0.06) effect on

Table 3.12 Mean abomasal nematode burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Pooled for 3 periods in 1991/92. (3 lambs/grass/period) .

	Abomasum			
	Haemonchus	*Ostertagia*	*Trichostrongylus*	Total
Browntop	1.80^{a1} (188)	2.18^{ab} (239)	2.09^{ab} (151)	3.38^{a} (579)
Tall fescue	2.18^{a} (207)	2.43^{a} (375)	2.28^{a} (317)	3.14^{ab} (900)
Yorkshire fog	1.98^{a} (122)	1.67^{b} (80)	1.60^{b} (49)	2.58^{c} (251)
Ryegrass	2.12^{a} (181)	1.75^{b} (110)	1.98^{ab} (277)	2.77^{bc} (567)
Pooled SEM	.185	.205	.105	0.130
Herbage effect	NS[2]	P<.05	NS	P<0.002

1/ Columns with differing superscripts differ P<.05
2/ NS - not significant P>.10

Table 3.13. Mean intestinal nematode burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Pooled for 3 periods in 1991/92. (3 lambs/grass/period).

	Intestine				
	Cooperia	*Nematodirus*	*Trichostrongylus*	L_4	Total
Browntop	1.49^{a1} (74)	2.66^{a} (659)	3.19^{a} (2424)	2.04^{a} (291)	3.34^{a} (3449)
Tall fescue	1.40^{a} (47)	2.21^{ab} (376)	2.89^{ab} (871)	1.39^{ab} (70)	3.08^{ab} (1364)
Yorkshire fog	$.629^{b}$ (8)	2.34^{ab} (266)	2.26^{c} (253)	$.447^{b}$ (8)	2.69^{c} (534)
Ryegrass	$.965^{ab}$ (44)	1.73^{b} (180)	2.41^{bc} (769)	$.606^{b}$ (21)	2.59^{bc} (1014)
Pooled SE	.261	.257	.206	.270	.204
Herbage effect	NS[2]	NS	P<0.02	P<0.002	P<.08

1/ Columns with differing superscripts differ P<.05
2/ NS - not significant P>.10

Ostertagia numbers, which were lowest in tracer lambs which grazed ryegrass, highest in those which grazed browntop and intermediate in lambs which grazed tall fescue and Yorkshire fog. Total abomasal burdens were significantly ($P<0.05$) lower in lambs which grazed ryegrass than browntop, with tall fescue and Yorkshire fog intermediate (Table 3.14). There was a significant ($P<0.05$) herbage effect on the 3 main genera of intestinal nematodes (Table 3.15). Levels of *Cooperia* were highest in tracer lambs which grazed ryegrass, lowest in those which grazed Yorkshire fog and intermediate in the other two groups. Levels of *Nematodirus* were similar in tracer lambs which grazed all grasses with the exception of Yorkshire fog, where levels were significantly ($P<0.05$) lower. Levels of *Trichostrongylus* were highest in tracer lambs which grazed browntop, lowest in those which grazed Yorkshire fog and ryegrass. These differences accounted for most of the differences in total intestinal burdens, which were significantly higher in lambs which grazed browntop than Yorkshire fog or ryegrass, with tall fescue intermediate (Table 3.15). There was no herbage effect on the ratio of male to female nematodes for any nematode species.

A complete listing of nematode burdens for all 3 periods is provided in Appendices 3.10 to 3.15. Tracer lamb nematode burdens were lower in the first tracer lamb period (January 20 - February 10; days 70 - 91) than in the other two periods, which did not differ.

3.3.6 Lamb Faecal Output and Organic Matter Intake

Daily lamb faecal output (g OM/day) as measured by chromium dilution, and organic matter intake (OMI) showed significant herbage and drenching effects in 1991/92 but not 1992/93 (Table 3.16). In 1991/92, SD lambs which grazed browntop showed extraordinarily high levels of faecal output

Table 3.14. Mean abomasal worm burdens (log_{10} (n+1) transformed; with corresponding arithmetic means in parentheses) and male to female ratio (M:F) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Pooled for 3 periods in 1992/93. (4 lambs/ grass/period).

	Haemonchus		*Ostertagia*		*Trichostrongylus*		Abomasum total
	n	M:F	n	M:F	n	M:F	n
Browntop	1.18^{a1} (122)	.876	2.81^{a} (911)	.72	2.03^{a} (259)	.68	2.97^{a} (1292)
Tall fescue	1.50^{a} (126)	1.032	2.49^{ab} (400)	.61	1.97^{a} (150)	.50	2.74^{ab} (676)
Yorkshire fog	1.28^{a} (46)	.868	2.60^{ab} (575)	.94	1.86^{a} (147)	.87	2.72^{ab} (768)
Ryegrass	1.43^{a} (45)	1.25	2.28^{b} (261)	1.47	1.77^{a} (126)	.51	2.51^{b} (432)
Pooled SEM	.065	ND[3]	.134	.234	.222	.182	.130
Herbage effect	NS[2]	ND	P<.06	P<.08	NS	NS	NS

1/ Columns with differing superscripts differ P<.05.
2/ NS - not significant P>.10.
3/ ND - not done due to insufficient numbers.

Table 3.15. Mean intestinal worm burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) and male to female ratio (M:F) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Pooled for 3 periods in 1992/93. (4 lambs/grass/period).

	Cooperia		*Nematodirus*		*Trichostrongylus*		Intestine total
	n	M:F	n	M:F	n	M:F	n
Browntop	2.13[ab1] (292)	.94	1.60[a] (94)	1.186	3.43[ab] (3445)	1.28	3.65[a] (3831)
Tall fescue	1.52[bc] (85)	1.67	1.82[a] (215)	1.13	3.12[a] (2029)	.77	3.36[ab] (2329)
Yorkshire fog	1.14[c] (32)	.80	0.77[b] (15)	.88	2.87[b] (1023)	.73	3.16[b] (1070)
Ryegrass	2.28[a] (319)	1.52	1.99[a] (153)	.768	2.87[b] (1139)	.85	3.15[b] (1041)
Pooled SEM	.263	.492	.273	ND[3]	.135	.323	.109
Herbage effect	P<.01	NS[2]	P<.01	ND	P<.02	NS	P<.006

1/ Columns with differing superscripts differ P<.05.
2/ NS - not significant P>.10.
3/ ND - not determined due to insufficient numbers

and this was consistent for all lambs in the group. In 1992/93, values on the same treatment were lower and similar to the other grass species. The values for 1992/93 are lower than in 1991/92, but the reason for this is unknown and should not invalidate comparisons between treatments. In 1991/92, TD lambs had significantly lower adjusted OMI than SD lambs which grazed browntop and Yorkshire fog swards, but not tall fescue or ryegrass swards. In 1992/93, there were no significant herbage or drenching effects on adjusted OMI.

A complete listing of lamb faecal outputs and calculated lamb OMI and OMI adjusted for metabolic BW for each of the three periods is given in Appendices 3.16 and 3.17.

3.3.7 Faecal Consistency

For the first 100 days of the trial in 1991/92 and for all of 1992/93, average faecal consistency scores were generally higher in TD lambs which grazed browntop and tall fescue (Appendix 3.18) than in lambs which grazed ryegrass or Yorkshire fog. After day 100 in 1991/92, the faecal consistency score became variable between grasses. There was no difference in faecal consistency between SD lambs which grazed the different grass species (data not shown).

Table 3.16. Mean faecal output (FO; g OM/day) and calculated organic matter intake (OMI g DM/day) from lambs which were suppressively drenched fortnightly (SD) or trigger drenched (TD) while grazing swards to a target height of 5 cm. Both years.

	FO (g OM/day)	OMI (g DM/day)	OMI (g DM/LW $^{0.75}$ /day)
1991/92			
Browntop SD	614	1780	133
TD	413	1020	81
Tall Fescue SD	249	650	50
TD	239	650	53
Yorkshire Fog SD	377	810	64
TD	255	530	43
Ryegrass SD	335	940	66
TD	362	1060	79
Pooled SE	38.3	125.7	10.4
Herbage Effect (P<)	0.0001	0.001	0.01
Drench Effect	0.002	0.001	0.05
1992/93 Year			
Browntop SD	300	640	50
TD	250	540	46
Tall Fescue SD	280	650	56
TD	260	610	50
Yorkshire Fog SD	260	500	39
TD	290	560	47
Ryegrass SD	ND[1]	ND	ND
TD	ND	ND	ND
Pooled SE	19.2	49.2	1.83
Herbage Effect (P<)	0.67	0.81	0.15
Drench Effect	0.35	0.19	0.54

[1] ND - not determined

3.4 DISCUSSION

3.4.1. Procedures

The results of this grazing trial, while indicative, must be interpreted with caution. While it seems likely that the differences were largely a result of grass species differences, the lack of replication means that the contribution of inter-paddock differences due to other factors cannot be assessed. However, all swards were adjacent to one another, were on a similar, uniform soil type and had similar grazing histories. Furthermore, the fact that significant differences in TD lamb FEC were consistently observed over both years and were first observed 18 and 36 days after the start of the trials in 1991/92 and 1992/93 respectively, following similar levels of initial contamination, is suggestive of an inherent grass species effect on the larval populations which developed. There would have been too little time for the egg counts to be significantly affected by larvae derived from the trial lambs themselves. This issue will be discussed further in Chapter 4.

The experiment was carried out under continuous stocking management, despite the general emphasis on rotational grazing management in New Zealand pastoral systems, in order to minimise the influence of short-term sward changes or management fluctuations on larval population dynamics, and thus to provide a firmer basis for understanding the potential impact of grass species characteristics on gastrointestinal parasite infection in lambs. A similar argument was used by Hodgson (1985) to support the use of continuous (steady state) management in developing understanding of the ecophysiology of pasture plants. Grazing was regulated to maintain constant sward height rather than constant herbage mass because the former variable can be more readily measured and maintained on a regular basis. However, it is apparent from the results (Table 3.4.) that there were substantial differences in herbage mass between swards at the same sward height. Variation in either herbage mass or sward height may affect several stages of the life-cycle of nematode parasites; these matters are considered further in Chapters 6 and 7.

The sward heights were maintained at reasonably similar levels between the grass species in both years. When the swards were taller than the target heights, particularly in the first two months of 1992/93, (Table 3.1) heights were similar across all species. Despite differences in herbage mass, at a constant sward height of 5 cm, dry matter intake of grazing lambs was probably not restricted by herbage availability (Parsons 1984, Maxwell and Treacher 1986). Any differences in larval uptake were therefore attributable to the effects of grass species characteristics on lamb ingestive behaviour and/or larval population dynamics.

In both years, the herbage mass (kg DM/ha; Table 3.4) was greatest on the browntop and Yorkshire fog swards. This is consistent with the observed features of the swards in that browntop and Yorkshire fog formed dense canopies while the swards of ryegrass and tall fescue were more open with fewer leaves per unit area. Denser swards may benefit the development success of larvae by offering an environment more sheltered from climatic extremes (Crofton 1963), but they also have a direct bearing on larval density (L_3 per kg herbage dry matter) in that, given similar total larval populations on swards of similar heights, denser swards will have a lower larval density.

3.4.2. Parasite parameters

Larval populations showed a similar pattern across grass species in both years (Table 3.7). As the trial progressed, the greatest larval population (L_3x10^6/ha) was on browntop and the lowest on tall fescue, with ryegrass and Yorkshire fog intermediate. An indication of development success can be derived by comparing larval populations with the numbers of eggs deposited, a function of FEC (Tables 3.9 and 3.10), faecal output per animal (Table 3.16), and stocking rate (Table 3.4). Total egg deposition by lambs on tall fescue and browntop was, on average, about double that deposited on ryegrass or Yorkshire fog swards. This was due to generally higher stocking rates on tall fescue and browntop (Table 3.4) and higher FEC of TD lambs which grazed browntop and tall fescue (Tables 3.9 and 3.10). Faecal output did not differ markedly between TD lambs which grazed the various grasses (Table 3.16). Despite this, larval populations as measured by pasture sampling, were lowest on tall fescue, particularly in March - May 1992 and through all of 1992/93 (Table 3.7). Indeed, the large contrast in larval populations between tall fescue and browntop swards indicates that larval development or survival differed between grass species. However, in field studies it is difficult to differentiate between larval development and survival. Larval population dynamics will be discussed in more detail in Chapters 6 and 7.

Patterns of variation in larval density and tracer lamb nematode burdens were similar over time within grass swards and to a lesser extent between swards within periods. The lowest tracer lamb nematode burdens were observed in the January sampling in both years (Appendices 3.4 to 3.15), and this coincided with the lowest larval density on herbage (Table 3.6). As the larval densities rose during the trial, so did nematode burdens. The major deviation from this pattern occurred in March

1991/92 (Period 2) when larval density was similar to or lower than in the other periods of tracer lamb grazing, but nematode burdens were disproportionately high compared to the other two periods. The high rainfall in this month (99 mm; Appendix 3.19) may have contributed to the high nematode burdens in lambs by facilitating translation of infective larvae onto the herbage for short periods of time which were not detected by fortnightly sampling.

Relationships between herbage larval density and tracer lamb nematode burdens are examined further in Table 3.20, which shows estimates of larval density and tracer lamb worm burdens averaged over each year, and the ratio of these averages. While caution is necessary in interpreting the outcome of calculations of this kind, there was a high degree of consistency of the ratio within grasses, between years. These results suggest that a smaller proportion of infective larvae became established in tracer lambs which grazed ryegrass and Yorkshire fog than browntop and tall fescue.

It is conceivable that the contrasts shown in Table 3.20 were a consequence of between species differences in the process of larval sampling by hand plucking and extraction. For example, there may be differences in the extraction efficiency of larvae from different herbages. This will be addressed in Chapter 5 but, for the present discussion, it can be assumed that the species contrasts shown in Table 3.20 were not an aberration of the sampling technique. Additionally, sampling once per week may not adequately estimate larval availability due to diurnal variation in larval density on

Table 3.20. Average larval density, average total tracer lamb worm burden and the ratio of worm burden to larval density.

	Average larval density (L_3/kg DM) [1]	Average total worm burden (abomasum and intestine) [2]	Ratio
1991/92			
Browntop	8832	4028	0.46
Tall fescue	4436	2264	0.51
Yorkshire fog	4516	785	0.17
Ryegrass	6004	1581	0.26
1992/93			
Browntop	9775	5123	0.52
Tall fescue	6508	3005	0.46
Yorkshire fog	9678	1838	0.19
Ryegrass	7530	1473	0.20

[1] From Table 3.6. Averages were taken over the months in which tracer lambs were grazing.
[2] Total abomasal and intestinal worm burdens from tracer lambs (From Fig. 3.3).

herbage (Rees 1950) and variation in larval density due to climatic conditions may bias estimates for different herbages. However, these explanations seem unlikely as Waller *et al.* (1981) reported a close relationship between larval density on the sward and tracer lamb nematode burdens.

Differences in the ratio of tracer lamb nematode burdens to herbage larval density between different grass species may reflect differences in larval vertical migration, lamb ingestive behaviour and larval establishment rates across grass species. Larval migration has been shown to differ between different grass species (Silangwa and Todd 1964), as has sheep ingestive behaviour (Burlison *et al.* 1991). Differences in larval establishment between grass species have not been reported, but have been observed in a comparison between *Lotus pedunculatus* and ryegrass, where the plants were of widely contrasting nutritive value (Niezen unpublished data). However, it seems unlikely that larval establishment would vary between lambs grazing different grass species of similar nutritive value, as in the present case (Table 3.3), to the extent observed in the nematode burdens. It is concluded that differences in the balance between larval density on herbage and nematode burdens in lambs were most likely to be due to differences in larval vertical migration or to differences in lamb ingestive behaviour between the grass species.

Tracer lamb worm burdens and FEC of TD lambs followed a similar pattern in that the swards in which TD lambs had the lowest FEC (Yorkshire fog and ryegrass) had the lowest tracer lamb worm burdens. TD lambs which grazed browntop and tall fescue had the highest FEC, but the tracer lambs which grazed browntop had approximately double the worm burdens of those which grazed tall fescue. In both years, numbers of *Haemonchus* spp., which have a higher fecundity than other common gastrointestinal nematodes (Crofton 1963), did not differ significantly between lambs which grazed the tall fescue (Appendices 3.4 to 3.15) and lambs which grazed the other grasses, precluding differences in numbers of this genus as a reason for the disparity between the TD lamb FEC and tracer lamb nematode burdens. It is possible that worm fecundity was reduced in TD lambs which grazed browntop swards, possibly due to a density dependent mechanism which suppressed egg output (Waller *et al.* 1981, Barger 1986), though it is also possible that plant biochemical compounds might have influenced nematode fecundity. Unfortunately, the female nematodes recovered from the tracer lambs were not retained to count the number of eggs per female.

3.4.3 Effect of stocking rate on lamb parasitism

At first sight it might appear that stocking rate, measured as lambs/ha (Table 3.4), or lamb mass/ha (Table 3.5), is correlated with lamb parasitism as measured by tracer lamb worm burden (Fig 3.3) or TD lamb FEC (Tables 3.9 and 3.10). Such a conclusion would agree with the results of some previous studies (see Bransby 1993). By contrast, Michel (1969) argued that, while artificial manipulation of stocking rate may lead to differences in parasitism, adjustments in stocking rate to meet differences in pasture productivity will be irrelevant to the severity of parasitism in grazing stock. For the study reported here, comparing stocking rate between grass treatments on a per hectare basis may be an over-simplification because of differences in herbage mass measured between the treatments (Table 3.4). A more appropriate measurement is required of the relationship between egg contamination on the sward, the dilution of the contamination due to differing herbage mass between grass species, and resulting parasitism in grazing lambs. A measurement which accommodates differences in stocking density and herbage mass per unit area is herbage allowance, defined as herbage mass per unit lamb mass (kg herbage DM per kg lamb liveweight; Table 3.5). Using this measurement, there is no readily discernible relationship between herbage allowance and lamb parasitism. For example, tracer lamb worm burdens and TD lamb FEC were far lower in lambs which grazed ryegrass than in lambs which grazed browntop, yet herbage allowance was greater (ie stocking rate was lower relative to herbage mass) on browntop than ryegrass. Despite this greater herbage allowance and hence dilution of larvae on browntop than on any other grass species, tracer lamb worm burdens and TD lamb FEC were highest in lambs which grazed browntop.

A further indication that grass species was likely to have a greater effect than stocking rate on lamb parasitism is further suggested by the fact that significant differences between grass species were observed at the first FEC peak in both years (53 and 45 days after the trial started in 1991/92 and 1992/93 respectively; Tables 3.9 and 3.10), at which time differences in rates of reinfection due to differing stocking rates (or herbage allowance) would have had a minimal confounding effect.

Differences in TD lamb FEC and tracer lamb worm burdens persisted through both years, despite variations in stocking rate within and between treatments needed to maintain constant sward height, suggesting a strong inherent grass effect which was not related to herbage DM mass and stocking rate. However, because of the lack of replication of this trial, no definitive conclusion can be reached. The relationship between stocking rate and parasitism will be discussed further in Chapter 4 (pages 129 - 130).

3.4.4. Parasitism and growth

One of the main findings of this trial is that individual grass species can confer specific advantages which appear to counter the effects of even moderate parasite burdens. There was a clear benefit of ryegrass pasture in maintaining higher lamb growth than on the other grass swards. In both years the TD lambs which grazed ryegrass were heavier than SD lambs which grazed the other grasses. The reasons for this can not be explained simply by the nutritive value of the grass (Table 3.3), lamb OMI (Table 3.16), or levels of parasitism, which were similar to those of Yorkshire fog (Appendices 3.4 to 3.15). The results may reflect a combination of all these factors, as ryegrass had slightly greater OMD than Yorkshire fog, and TD lambs which grazed ryegrass had slightly greater OMI than TD lambs which grazed Yorkshire fog. Ryegrass had similar OMD to browntop and tall fescue, and TD lambs which grazed ryegrass had similar OMI to TD lambs which grazed browntop and higher OMI than TD lambs which grazed tall fescue. However, parasitism, as measured by tracer lamb worm burden or TD lamb FEC, was higher in lambs which grazed browntop or tall fescue than in those which grazed ryegrass. Thus the lamb performance advantage of ryegrass over Yorkshire fog may be due to nutritional factors, while the advantage over browntop and tall fescue may be due to reduced parasitism.

The measure of production losses for parasite infection used in the trial reported in this Chapter underestimates the productive losses due to parasitism as production of SD lambs which graze a pasture with TD lambs will be depressed by the larval challenge emanating from eggs passed by TD lambs. Similarly, the production of TD lambs will be increased because of the reduced larval challenge when they share a pasture with SD lambs. In 1991/92, lamb growth reductions due to parasitism were greatest on the tall fescue and browntop swards (Table 3.8), which coincided with the increased parasitism observed on these two grasses (Tables 3.9 and 3.10, Fig 3.3). In 1992/93, growth reductions due to parasitism were similar to, or lower than those in 1991/92 on all grasses, despite FEC's and tracer lamb worm burdens being comparable to those observed in 1991/92. This was highlighted in the difference between years on tall fescue. In 1991/92, the final liveweight advantage of SD over TD lambs was greatest in tall fescue (7.7 kg; Table 3.8), whereas in 1992/93, TD lambs which grazed tall fescue ended the trial 6.8 kg heavier than SD lambs. The lighter initial weight of the lambs in 1992/93 than in 1991/92 (Appendices 3.1 and 3.2) may have reduced the ability of SD lambs to gain weight while exposed to a larval challenge. SD lamb performance was checked early in the trial (Appendix 3.3) and the lambs appeared not to have subsequently recovered. In both years, lamb mortalities (Table 3.11) were confined to the lightest TD lambs and this resulted in an upward bias of the final liveweight of the TD group. This may explain why on tall fescue, TD lambs were heavier than SD lambs at the end of the trial in 1992/93. A similar pattern was also observed on browntop, where the lighter TD lambs were the ones which died. On the ryegrass swards too few lambs died to indicate whether mortality was related to liveweight, while on Yorkshire fog the mortalities were across all liveweights. That the mortalities on all grasses were generally limited to TD lambs suggests a major effect of gastrointestinal nematodes.

In lambs which grazed ryegrass and browntop, losses in liveweight gain due to parasitism were lower in 1992/93 than in 1991/92 (Table 3.8), while on Yorkshire fog swards, the contrast in lamb performance observed between SD and TD lambs (Table 3.8) was small in both years.

Reduced OMI in TD lambs relative to their SD counterparts was only evident on browntop in both years and on Yorkshire fog in 1991/92 (Table 3.16). The lack of any marked evidence of parasite-induced anorexia is in agreement with other reported results for grazing trials (Holder 1964, Southcott *et al.* 1967, Scales *et al.* 1995), but is in contrast to the consistent reports of anorexia associated with gastrointestinal parasitism in indoor trials (Sykes 1994). Intake estimates in the grazing trial reported here are dependent on extrapolations from *in vitro* OMD estimates. While Sykes (1994) concluded that parasitism only reduced dry matter digestibility (DMD) by 1 - 2 percentage points, these estimates were obtained from indoor trials and results may differ in grazing trials. The high OMI in SD lambs which grazed browntop in 1991/92 is a phenomenon which cannot be readily explained. All the lambs in this treatment group recorded chromium in the faeces, precluding the possibility that the chromic oxide capsules were not functional or regurgitated. The possibility of the capsule release rate interacting with grass species cannot be excluded, as differences associated with feed type have been reported (Parker *et al.* 1989, Luginbuhl *et al.* 1994), but an effect of this magnitude would be most unusual.

3.4.5. Summary

Lamb parasitism and growth were compared on four grasses, browntop, tall fescue, Yorkshire fog and ryegrass maintained at sward heights of approximately 5 cm. Lambs which grazed browntop and tall fescue had higher FEC than lambs which grazed ryegrass or Yorkshire fog. Tracer lamb nematode burdens were highest in lambs which grazed browntop, lowest in lambs which grazed ryegrass and Yorkshire fog and intermediate in lambs which grazed tall fescue. Superficially there appeared to be a direct relationship between stocking rate (lamb mass/ha) and lamb parasitism as measured by tracer lamb worm burden or TD lamb FEC. However, more detailed examination indicated that the effects were more likely to reflect differences in larval migration and/or lamb ingestive behaviour.

Weight gain was always greatest in lambs which grazed ryegrass, with TD lambs on this species having higher final liveweights than SD lambs which grazed the other grasses, except for, Yorkshire fog in 1991/92 and tall fescue and ryegrass in 1992/93. when SD lambs finished the trial significantly heavier than TD lambs

Larval populations, particularly in 1992/93, were highest on the browntop sward, lowest on the tall fescue sward and intermediate on the Yorkshire fog and ryegrass swards. There was no clear evidence that total larval populations (L_3/ha) were related to stocking rate (lambs/ha). The ratio of tracer lamb worm burden to herbage larval density was greatest in both years for browntop and tall fescue and lowest for Yorkshire fog and ryegrass.

The appeared to be little evidence of parasite induced anorexia in either year, with the exception of browntop in both years and Yorkshire fog in 1991/92.

CHAPTER 4

THE EFFECTS OF TALL FESCUE (*Festuca arundinacea cv* GRASSLANDS ROA) OR YORKSHIRE FOG (*Holcus lanatus cv* MASSEY BASYN) GRAZED AT THREE SWARD HEIGHTS ON LAMB PARASITISM AND GROWTH.

4.1 INTRODUCTION

Growth rates for cattle and sheep have been measured at differing stocking rates (Hansen *et al.* 1989) and sward heights (Penning *et al.* 1991). Trials such as these have been undertaken without the consideration of internal parasitism or they have attempted to exclude internal parasites by regular drenching (Penning *et al.* 1991). While some studies suggest an increasing level of parasitism with increasing stocking rate and decreasing sward height (Ciordia *et al.* 1962b, Tetley and Langford 1965, Jagusch *et al.* 1980), others suggest no such relationship (Holder 1964, Downey 1969, Southcott *et al.* 1970). No work has been reported which has compared lamb parasitism and growth on different herbage species at a range of sward heights. There has been a suggestion that more erect grass species may reduce larval ingestion and parasitism (Jagusch *et al.* 1980), but no evidence has been produced. The objective in this trial was to compare lamb production and parasite parameters on two grasses of contrasting morphology, tall fescue (*Festuca arundinacea* cv Grasslands Roa) and Yorkshire fog (*Holcus lanatus* cv Massey Basyn) at three sward heights. The choice of these two grasses was based on the results of the 1991/92 experiment reported in Chapter 3. Lambs which grazed tall fescue had higher FEC and nematode burdens than lambs which grazed Yorkshire fog. Also decreases in lamb growth due to gastrointestinal parasitism were greater on tall fescue than Yorkshire fog. Tall fescue has a more erect morphology, with smooth leaves, while Yorkshire fog has a more prostrate morphology with a denser sward and hairy leaves (Levy 1970).

4.2 MATERIALS AND METHODS

4.2.1 Pasture Management

The experiment reported in this Chapter was a refinement of that reported in Chapter 3 as two of the grass species which gave contrasting results in Chapter 3 were compared at three sward heights: 3 cm, at which OMI should have been restricted, 5 cm, at which OMI should not have been restricted, and 8 cm at which OMI was definitely not restricted (Parsons 1984, Maxwell and Treacher 1986)

Swards of the two species were established in autumn 1992, on 3 randomly allocated 0.8 ha plots for each species on land which had previously been one paddock and which was planted in barley prior to establishing the plots. All plots were on a uniform Kairanga sandy loam and received a standard fertiliser dressing of 150 kg/ha of sulphur-enriched superphosphate the following spring. Pure grass swards were maintained by spraying with 2-4-D (® BASF) and dicamba (Banvel ® Sandoz Agro. Inc.) to control broadleaf weeds and white clover. Nitrogen fertiliser was applied monthly at 50 kg urea/ha (25 kg N/ha) which approximates the amount of N fixed by clover in this environment (Steel 1982). All pastures were maintained at 3, 5 or 8 cm target heights by adjusting stocking rates.

In the spring, the swards were grazed to control herbage growth, by adult cattle, or by ewe hoggets which were dosed with slow release albendazole capsules (Extender 100 ® Nufarm Auckland, New Zealand), to minimise the contamination of pastures with nematode larvae. Just prior to the start of the trial, each pasture was successively grazed for 24 hours by 200 ewes with a low worm burden (average FEC 400 epg) to provide each paddock with an even contamination of gastrointestinal nematode eggs.

In mid-January the tall fescue 8 cm and 5 cm swards were topped at 8 cm to remove excess growth and the cuttings were baled for hay.

As with the trial described in Chapter 3, it was intended to repeat the experiment over two years. However, due to extremely dry conditions in 1993/94, which caused large areas of Yorkshire fog to die, the trial was terminated 45 days after it began. Instead the trial was repeated in 1994/95, but is not reported here due to time constraints.

4.2.2. Pasture Measurements

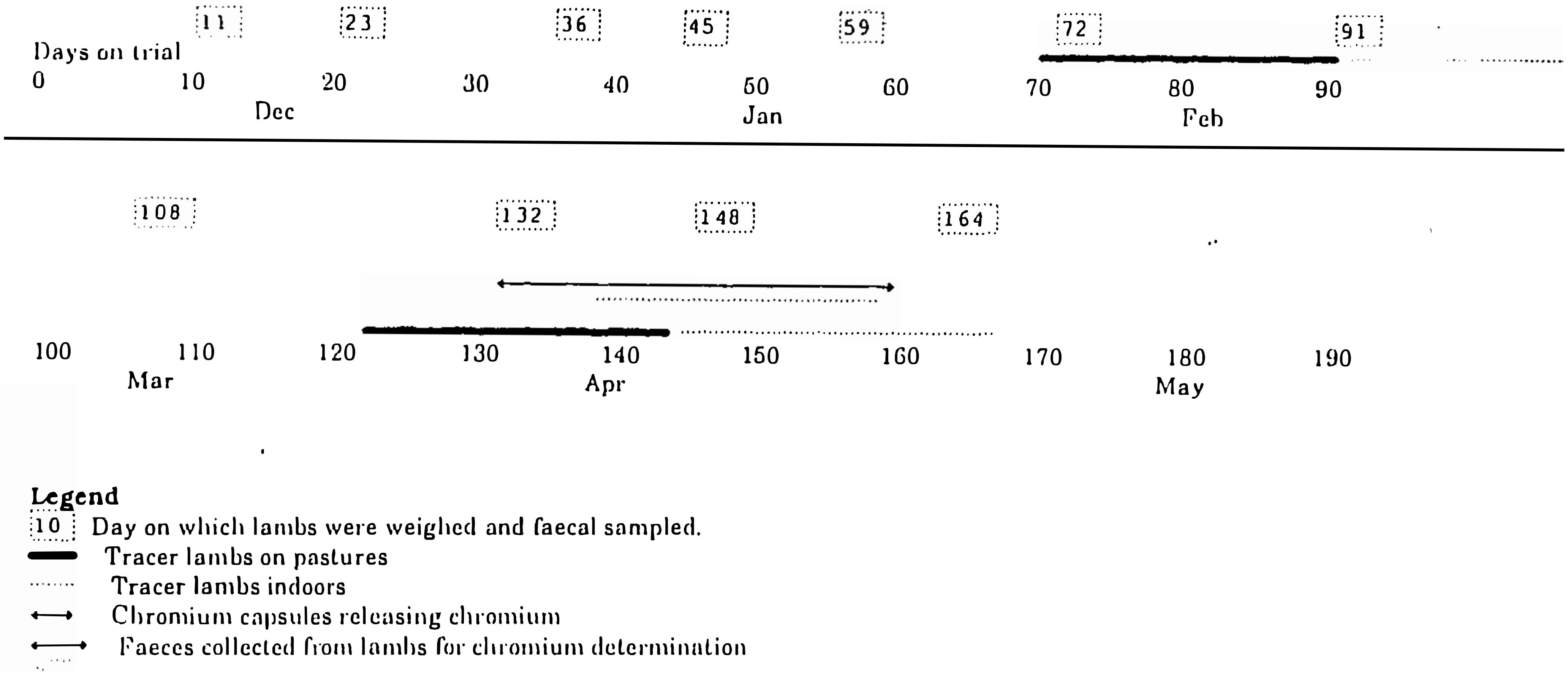
Pasture heights were measured twice per week, using a Hill Farming Research Organisation (HFRO) sward stick (Barthram 1986) with a minimum of 25 readings per sward per measurement, and pasture standing dry matter (kg DM/ha) estimated monthly. Herbage plucks, for determination of density of third stage gastrointestinal nematode larvae (L_3's/kg DM) and larval population (L_3/ha), were taken weekly as described in Chapter 3. The larvae were separated from the herbage using a modified Baermann procedure (Vlassoff 1973b). The procedure is described in Chapter 5.

Daily average temperature and daily precipitation readings were taken from a weather station located within 1 km of the trial site.

4.2.3 Animals

Recently-weaned Romney wether lambs were restrictively randomised to treatment groups based on liveweight. They were drenched with ivermectin (Ivomec ® Merck Sharp and Dohme) at the start of the trial and then grazed on the trial swards for 165 days (November 13 1992 until 26 April 1993) (Fig 4.1). Lambs were weighed and faecal sampled fortnightly. Faecal egg counts (FEC) were carried out using a modified McMaster technique in which one egg counted represented 50 eggs per gram fresh faeces (epg). On each grass species, one third of the lambs were suppressively drenched (SD) fortnightly with ivermectin while two thirds were "trigger drenched" (TD) when the mean FEC reached 1000 epg in any group. Lambs were added or removed in multiples of three to maintain a 2:1 ratio of TD to SD lambs. At all times the anthelmintic was administered at 1.5 times the recommended dose rate. At the time of sampling, faeces were scored for consistency from 1 to 5, 1 being liquid, and 5 being hard pellets.

Figure 4.1. Timetable of events on the grazing trial comparing lamb parasitism and growth on monospecific swards of tall fescue and Yorkshire fog grazed to target heights of 3, 5 or 8 cm.



4.2.3.1. Tracer Lambs

On two occasions, starting January 20 and March 18, which coincided with a mid-summer and a late-summer/early-autumn grazing, lambs which had been reared indoors free of nematode infection (tracer lambs), grazed the swards for 3 weeks and then were housed for a further 3 weeks to allow ingested larvae to mature (Fig 4.1). The lambs were then slaughtered and total worm counts carried out.

4.2.3.2. Faecal Output and Herbage Intake

On 23 March, 12 lambs grazing each herbage type (7 randomly selected trigger drenched and 5 randomly selected suppressively drenched) were dosed with chromium sesquioxide capsules (Fig 4.1) (Captec Chrome ® Fernz Corp) to measure faecal output and calculate OMI (Parker *et al.* 1989; see 3.2.3.2). Samples were taken on March 30 and 31 and April 1, 5, 7, 8, 12, 15, and 16. Faeces were pooled over 3 sample days and analysed for chromium content following the procedure of Williams *et al.* (1962). Extrusa were collected from 5 oesophageally fistulated wethers during this time. The animals were allowed 24 hours to adjust to the grass species. Bungs were then removed from the fistulae and the animals were allowed to graze for 30 minutes under constant supervision. If they started to ruminate, the collection bags were rapidly removed. Extrusa were analysed for nitrogen content using the Kjeldahl method and for dry matter and organic matter digestibility (OMD) using the method described by Tilley and Terry (1963).

4.2.4. Statistical Analysis

Grass species plots at each height were unreplicated and effects were evaluated with individual animals as the experimental units. The limitations of this procedure are considered in Section 4.4. Least-square means of lamb liveweight at each weighing, lamb FEC, pasture larval densities (L_3/kg DM), pasture larval populations (L_3/ha), pasture herbage mass (kg DM/ha), tracer lamb nematode burdens, lamb faecal output (g DM/day), and estimated OMI (g DM/day) were compared by analysis of variance using general linear models (GLM ® Statistical Analysis Systems (SAS)). FEC were square-root transformed and tracer lamb nematode burdens were $\log_{10}$ transformed to normalise data prior to analysis. The reasons for the tranformations were similar to those given in Chapter 3 (3.2.4)

4.3 RESULTS

4.3.1 Pastures

4.3.1.1. Pasture Height

Target pasture heights were not achieved at 3 cm and 5 cm (Table 4.1) until late January and mid-February respectively because insufficient lambs were available to cope with the rapid pasture growth conditions, but the 8 cm target was relatively easily maintained by late December. The tall fescue 8 and 5 cm treatments were cut for hay in late January to remove excess growth. On the 8 cm swards, some patchy grazing occurred, particularly in the tall fescue. All other swards were evenly grazed. The swards are illustrated in Plates 4.1 to 4.5.

In December and January, at all sward heights, herbage mass tended to be slightly higher on the tall fescue than Yorkshire fog swards, while from February to the end of April, herbage dry mass at all heights was higher on the Yorkshire fog swards (Table 4.1).

4.3.1.2. Pasture Composition

Herbage composition is shown in Table 4.2. At the beginning of the trial there was a large amount of *Poa annua* present in the tall fescue swards, but this largely disappeared after the trial started under pressure of grazing. However, as the trial progressed, a spread of Yorkshire fog into the tall fescue swards was observed, particularly in the 3 cm and 5 cm swards. This accounts for most of the "other species" found in the tall fescue swards.

Table 4.1. Monthly average heights (cm) and herbage dry matter mass (DM, kg DM/ha) for monospecific swards of tall fescue and Yorkshire fog which were continuously grazed by sheep to target heights of 3, 5, or 8 cm.

	November		December		January		February		March		April	
Tall Fescue	Height	DM	Height	DM	Height	DM	Height	DM	Height	DM	Height	DM
Tall Fescue												
3 cm	9.2	ND[1]	7.9	2660	5.5	2960	3.5	2550	2.9	1900	2.7	2270
5 cm	7.8	ND	8.9	2830	6.8	3100	4.8	2700	4.3	2080	5.0	1250
8 cm	9.3	ND	10.5	2490	8.4	3030	7.7	2780	8.4	3500	9.2	4330
Yorkshire Fog												
3 cm	7.7	ND	7.1	2590	5.1	3140	3.5	3490	2.9	2480	2.7	3050
5 cm	9.9	ND	9.9	2020	7.9	2730	5.6	4750	5.2	3160	4.9	4160
8 cm	5.7	ND	7.0	2040	7.9	1960	7.7	3490	8.6	4660	8.5	4460
Polled SE		ND		187		217		248		316		288
Herbage effect (P<)		ND		0.01		0.03		0.0001		0.002		0.0001

[1] ND - Not determined

Table 4.2. Botanical composition of tall fescue and Yorkshire fog swards grazed to constant heights of 3, 5 and 8 cm at the beginning (25/11/92) and end (26/4/93) of the grazing period.

	Beginning			End		
3 cm	T	O	D	T	O	D
Tall Fescue	45	54	1	29	49	22
Yorkshire Fog	81	7	12	85	8	37
5 cm						
Tall Fescue	40	50	10	35	49	16
Yorkshire Fog	94	4	2	62	4	34
8 cm						
Tall Fescue	69	22	9	56	31	13
Yorkshire Fog	66	10	24	66	2	32

Target species (T(%)), other species (0(%)) and dead matter (D(%))

Table 4.3. Herbage nitrogen content (N, %), dry matter digestibility (DMD, %) and organic matter digestibility (OMD, %) of tall fescue and Yorkshire fog when grazed to a constant height of 3, 5 and 8 cm.

	(N)%	DMD(%)	OMD(%)
Tall fescue 3 cm	3.46	64.4	68.0
Tall fescue 5 cm	3.91	67.9	70.9
Tall Fescue 8 cm	3.46	66.3	69.6
Yorkshire fog 3 cm	2.66	63.2	64.3
Yorkshire fog 5 cm	3.22	58.9	58.7
Yorkshire fog 8 cm	3.56	68.2	70.8
Pooled SE	.139	2.71	3.48
Herbage effect	P<.0001	NS[1]	P<.05
Height effect	P<.0001	NS	NS
Herbage x height	P<.0001	P<.06	P<.08

[1] NS - Not significant (P>0.10)

Plate 4.1. Tall fescue 8 cm on the right and tall fescue 5 cm on the left of the fence.

Plate 4.2. Tall fescue 5 cm on the right and Yorkshire fog 8 cm on the left of the fence.

Plate 4.3. Yorkshire fog 8 cm on the right and tall fescue 3 cm on the left of the fence.

Plate 4.4. Tall fescue 3 cm on the right and Yorkshire fog 3 cm on the left of the fence.

Plate 4.5. Yorkshire fog 3 cm on the right and Yorkshire fog 5 cm on the left of the fence.

4.3.1.3. Herbage Nitrogen Content and Organic Matter Digestibility

Herbage N(%) levels were significantly higher in the tall fescue than Yorkshire fog swards (Table 4.3). Herbage N levels increased with sward height on Yorkshire fog but not on tall fescue. Tall fescue swards had significantly higher OMD values than Yorkshire fog swards (Table 4.3), the value for Yorkshire fog at the 5 cm sward height was particularly low compared with the other swards in this trial.

4.3.1.4. Herbage Larval Density and Total Population

Larval density on herbage (L_3/kg herbage DM) increased over time (Table 4.4) with a tendency to be higher in the 3 and 5 cm swards than the 8 cm swards, particularly in the January to March period. After February, larval density declined markedly on the Yorkshire fog 3 cm sward but stayed very high on the corresponding tall fescue sward. On the tall fescue 5 cm sward larval density increased throughout the trial, and a similar pattern was observed on the Yorkshire fog 5 cm sward, except in April when larval density declined. Larval densities on the 8 cm swards showed a more variable pattern. On the tall fescue 8 cm sward, larval density increased until January, declined slightly in February, increased in March and declined slightly in April. On the Yorkshire fog 8 cm sward, larval density increased dramatically in December, declined until February, and then increased until April.

Table 4.4. Mean larval density (larvae/kg herbage DM) and estimated total larval population (L_3 x 10^6/ha) on monospecific swards of tall fescue or Yorkshire fog which was grazed by lambs to a target height of 3, 5, or 8 cm.

	November		December		January		February		March		April	
	L_3/kg DM	L_3/ha	L_3/kg DM	L_3/ha	L_3/kg DM	L_3/ha	L_3/kg DM	L_3/ha	L_3/kg DM	L_3/ha	L_3/kg DM	L_3/ha
Tall Fescue												
3 cm	50	0.2	520	1.6	3500	9.7	11130	24.9	14350	32.2	12450	21.9
5 cm	420	1.0	3000	7.4	3890	12.5	4310	11.4	15040	32.5	21520	32.8
8 cm	390	0.8	350	0.7	2020	5.7	1030	3.5	4760	20.9	3260	13.5
Yorkshire Fog												
3 cm	520	1.5	3520	9.9	7890	25.5	12080	43.3	4570	11.8	2740	8.2
5 cm	50	0.1	400	1.0	1800	5.0	2710	9.9	5550	14.5	3920	19.6
8 cm	0	0	6970	14.4	1620	2.7	600	2.2	3030	19.2	16530	71.7
Pooled SE	212	0.77	1390	5.8	1733	3.1	2812	14.9	3342	21.9	3031	28.0
Herbage effect (P<)	0.33	0.90	0.06	0.36	0.66	0.51	0.88	0.81	0.02	0.04	0.13	0.001
Height effect (P<)	0.96	0.86	0.34	0.57	0.10	0.15	0.003	0.006	0.19	0.55	0.37	0.001

From February until April, larval density on tall fescue at any sward height was similar to, or higher than for the corresponding Yorkshire fog sward, the exception being the 8 cm Yorkshire fog sward in April, which was higher than its tall fescue counterpart.

Total larval populations (L_3/ha) over time (Table 4.4) followed a similar pattern to larval densities. Whilst total larval populations from February to April tended to be higher on the tall fescue than the Yorkshire fog swards, there were two exceptions, the 3 cm swards in February, and the 8 cm swards in April, when larval populations were greater on the Yorkshire fog swards

4.3.2 Animal Data

4.3.2.1. Stocking Rate

Stocking rates increased substantially in January (Table 4.5) on all treatments except Yorkshire fog 8 cm as more lambs were introduced to maintain or reduce sward height. From February onwards, stocking rates required to maintain the swards at the target heights were greater on Yorkshire fog than tall fescue.

By the end of the trial, stocking rates (su/ha) were about 40% higher on the Yorkshire fog 3 cm and 8 cm treatments and 20% higher on the 5 cm treatment than on the corresponding tall fescue treatments. Total lamb mass per hectare (kg/ha) was greater (Table 4.5) for Yorkshire fog than tall fescue at all heights, particularly at 3 cm.

Table 4.5. Lamb stocking rate (su[1]/ha (SR) and kg lamb/ha (kg/ha) on monospecific swards of tall fescue and Yorkshire fog which were grazed to target heights of 3, 5, or 8 cm.

	November		December		January		February		March		April	
	SR	kg/ha	SR	kg/ha	SR	kg/ha	SR	kg/ha	SR	kg/ha	SR	kg/ha
Tall Fescue												
3 cm	30	850	27.8	840	40.1	1050	36.0	1280	33.8	1190	31.5	830
5 cm	22.5	650	21.5	650	28.5	860	28.1	1060	21.0	820	19.5	743
8 cm	14.3	410	13.7	460	16.9	560	11.3	530	10.3	470	10.5	490
Yorkshire Fog												
3 cm	30	860	29.3	860	41.6	1190	42.8	1530	45.8	1530	44.3	1360
5 cm	22.5	650	20.5	620	27.4	1100	33.4	1200	24.0	890	23.3	780
8 cm	15.0	400	15.0	510	16.9	530	14.3	630	15.0	600	15.0	620

[1] 1 lamb is equivalent to 0.6 su.

Table 4.6. Final liveweights, adjusted for common initial weight, of suppressively drenched or trigger drenched lambs grazing Yorkshire fog or tall fescue swards to a constant height of 3, 5 or 8 cm.

Treatment	Suppressively Drenched	Trigger Drenched	Contrast of Suppressive *vs* Trigger Drenched
3 cm			
Tall fescue	27.8	24.8	P<.04[1]
Yorkshire fog	24.6	22.3	NS[2]
Contrast of tall fescue vs Yorkshire fog	P<.04	P<.03	
5 cm			
Tall fescue	32.7	26.4	P<.0004
Yorkshire fog	24.9	25.5	NS
Contrast of tall fescue vs Yorkshire fog	P<.0001	NS	
8 cm			
Tall fescue	40.8	33.0	P<.002
Yorkshire fog	29.1	31.5	NS
Contrast of tall fescue vs Yorkshire fog	P<.0001	NS	

1. Pooled SE for drench and herbage effects 1.91.
2. NS - not significant P>.05
3. Height effect P<0.0001, Herbage effect P<0.0001, Herbage x height P<0.12, Drench effect P<0.0002, Drench x herbage P<0.0001.

4.3.2.2. Liveweights

On both grasses, final liveweights adjusted for initial weight of SD and TD lambs increased with increasing sward height (Table 4.6). Final liveweights, were greater for suppressively drenched lambs (SD) at all three tall fescue sward heights than on the corresponding Yorkshire fog swards (Table 4.6). However, only TD lambs which grazed tall fescue at 3 cm were significantly heavier than their Yorkshire fog counterparts. At all three heights of tall fescue, SD lambs were heavier than TD lambs (P<0.05) but this was not so on Yorkshire fog. In fact, on the 5 cm and 8 cm Yorkshire fog treatments the TD lambs ended the trial slightly heavier than the SD lambs, although this was not statistically significant.

The mean lamb liveweights at each weighing are provided in Appendix 4.1. Lambs which grazed tall fescue at 8 cm and 5 cm continued to gain weight from day 72 until the end of the trial while both SD and TD lambs which grazed at 3 cm only maintained their weight. Conversely, both SD and TD lambs which grazed Yorkshire fog at 8 and 5 cm maintained their weight while at 3 cm they lost weight from day 72 onwards. The differences in lamb liveweights were apparent in the condition of the lambs (Plates 4.6 to 4.11).

The proportions of lambs heavier than 32 kg liveweight, a minimum slaughter weight for the industry, are recorded in Appendix 4.2. At the 3 cm sward height, few lambs on either tall fescue or Yorkshire fog attained this weight. At 5 cm, 75% of the SD lambs which grazed tall fescue attained

Plate 4.6. Lambs grazing the 8 cm tall fescue sward.

Plate 4.7. Lambs grazing the 5 cm tall fescue sward.

Plate 4.8. Lambs grazing the 3 cm tall fescue sward.

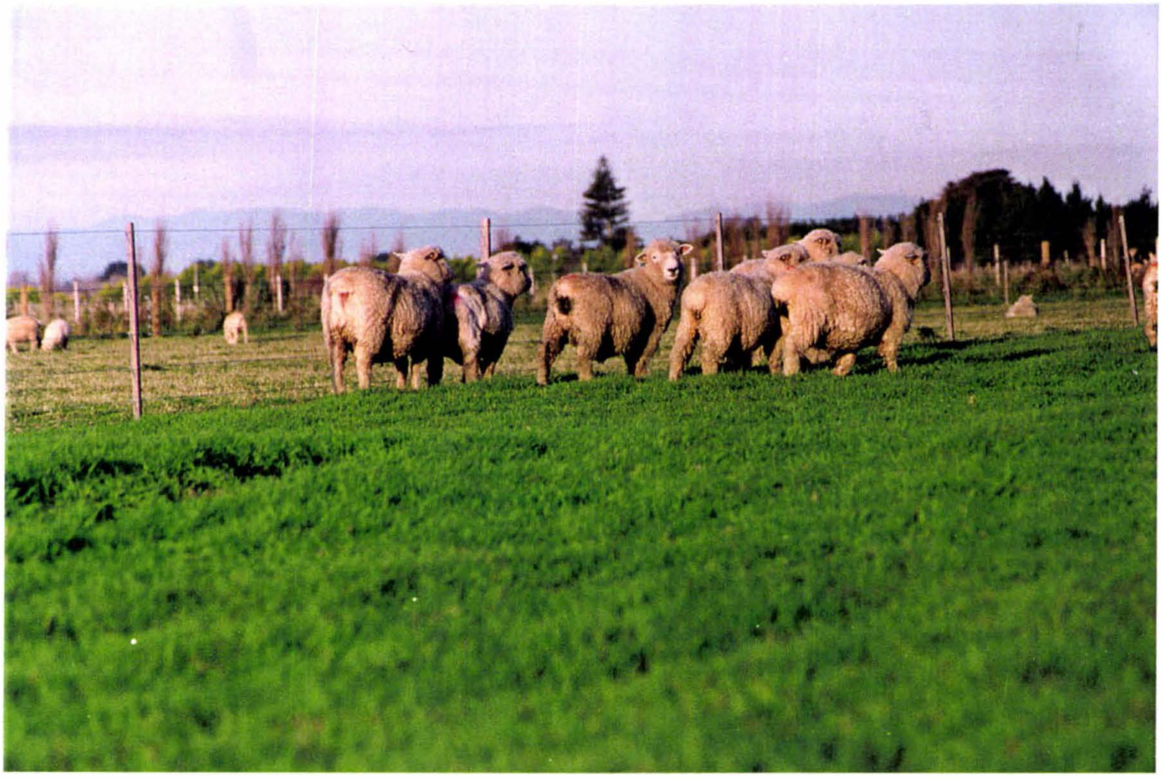


Plate 4.9. Lambs grazing the 8 cm Yorkshire fog sward.

Plate 4.10. Lambs grazing the 5 cm Yorkshire fog sward.

Plate 4.11. Lambs grazing the 3 cm Yorkshire fog sward.

32 kg liveweight by the end of the trial but only 11% on the 5 cm Yorkshire fog. On the 8 cm swards, all SD lambs grazing tall fescue attained 32 kg while only approximately half of the TD lambs in both tall fescue or Yorkshire fog and only 20-30% of SD lambs grazing Yorkshire fog did so. These figures are only approximations as lamb liveweights and the proportion heavier than 32 kg declined from the second-last to the last weighing.

4.3.2.3. Faecal Egg Counts

Trigger drenched lambs were drenched on 3 occasions during the trial, on days 59, 121, and 148, when at least one of the treatments attained a mean FEC of 1000 epg. At the second FEC peak, lambs which grazed Yorkshire fog had overall significantly lower FEC's than lambs which grazed tall fescue (Table 4.7). However, individual contrasts between groups which grazed Yorkshire fog and tall fescue at the three heights were not significant ($P>0.05$). At the first and second FEC peak there was an almost significant ($P<0.10$) sward height effect on FEC in both Yorkshire fog and tall fescue treatments, lambs which grazed the 8 cm sward having the lowest FEC and lambs which grazed the 3 cm swards the highest.

4.3.2.4. Tracer Lamb Nematode Burdens

Tracer lamb nematode burdens showed a similar pattern over both periods (Appendices 4.4 to 4.7). When pooled over both periods (days 70-90 and days 110-130), tracer lamb worm burdens were significantly higher on the tall fescue than Yorkshire fog ($P<0.009$) (Fig 4.2). Total worm burdens

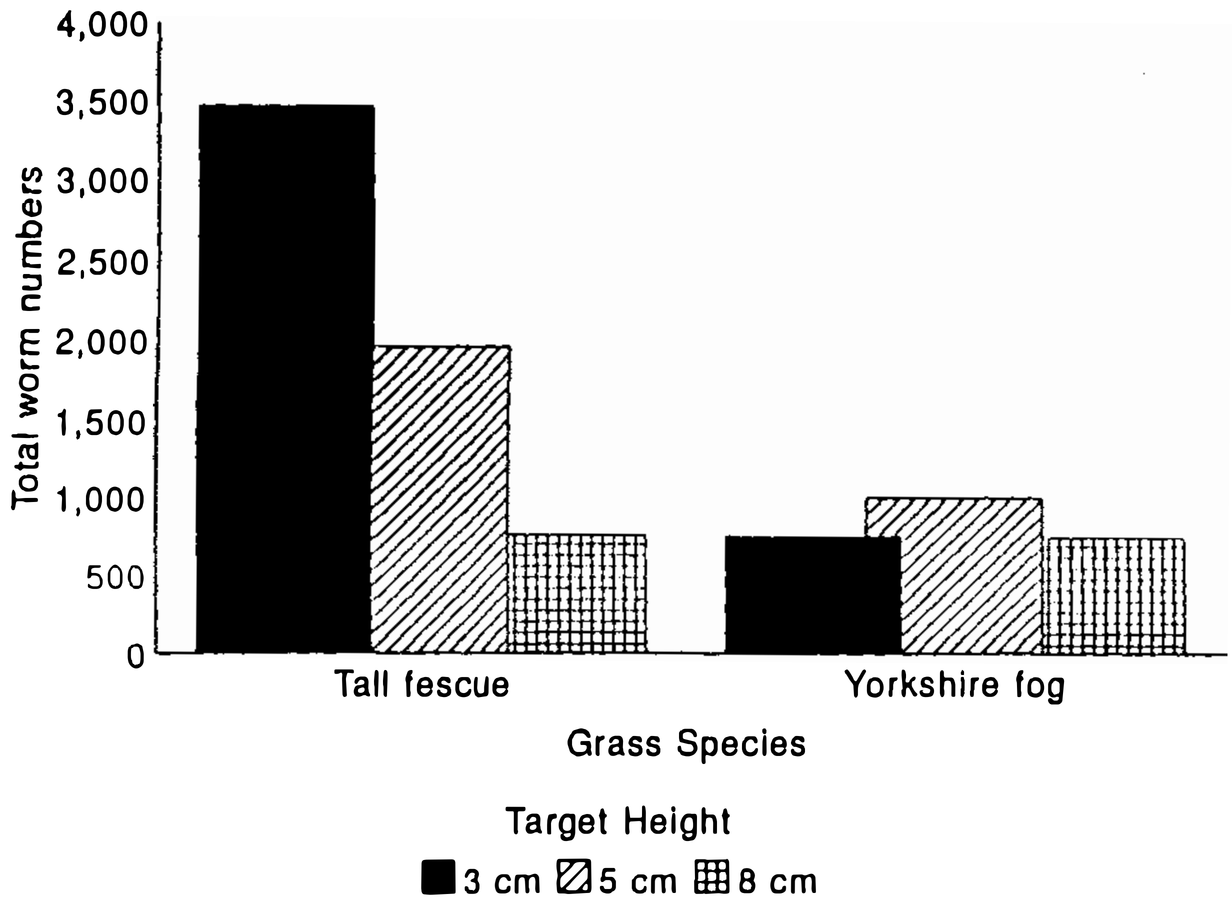
Table 4.7. Mean faecal egg counts (FEC) (eggs per gram fresh faeces (epg))(arithmetic means and means of square root transformed data) of trigger drenched lambs which grazed monospecific swards of tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm. FEC trigger level 1000 epg.

Days on trial	11	23	36	45	59*	72	91	108*	132	148*	164
Arithmetic Means											
Tall Fescue											
3 cm	0	11	375	1240	1381	12	1039	2074	3	1203	5
5 cm	0	46	219	369	1200	24	584	1352	0	590	3
8 cm	0	14	200	405	675	14	377	1059	0	1394	20
Yorkshire Fog											
3 cm	0	16	204	875	1018	6	775	2133	1	1388	2
5 cm	0	0	103	311	431	2	115	918	0	924	3
8 cm	0	8	82	242	585	23	223	640	12	745	25
Square-root transformed means											
Tall Fescue											
3 cm	0	1.05	16.8	31.7	33.5	1.4	29.0	41.6	0.44	31.6	0.76
5 cm	0	1.82	13.2	15.2	32.1	2.4	22.6	29.5	0	20.7	0.4
8 cm	0	1.11	12.0	17.1	21.9	1.9	16.8	31.2	0	34.5	2.0
Yorkshire Fog											
3 cm	0	1.1	11.3	25.7	30.8	0.7	26.1	42.8	0.2	35.1	0.2
5 cm	0	0.0	7.9	15.3	17.9	0.3	8.5	28.0	0	28.5	0.4
8 cm	0	1.2	6.6	11.7	19.5	2.2	12.9	23.6	1.6	25.3	1.7
Pooled SE	ND[1]	1.60	3.87	6.25	6.33	1.62	5.20	8.17	0.81	6.87	1.49
Herbage effect (P<)	ND	0.40	0.001	0.33	0.26	0.21	0.01	0.03	0.07	0.79	0.70
Height effect (P<)	ND	0.81	0.09	0.06	0.009	0.34	0.001	0.08	0.93	0.65	0.001
Herbage x height effect (P<)	ND	0.83	0.50	0.81	0.19	0.56	0.11	0.43	0.44	0.32	0.62

* Lambs were treated with anthelmintic at this time.

[1] ND -not determined

Figure 4.2. Mean total worm burdens (back-transformed $\log_{10}$ transformation) from tracer lambs which grazed monospecific swards of tall fescue or Yorkshire fog to target heights of 3, 5 or 8 cm. Pooled for 2 periods.



Herbage P<0.009, Height P<0.05, Herbage X height NS.

increased as tall fescue sward height decreased but this pattern was not observed on the Yorkshire fog swards (Fig. 4.2). Abomasal worm burdens, pooled over 2 periods, did not differ between lambs which grazed tall fescue and Yorkshire fog ($P>0.05$) (Table 4.8). However, as with total worm burdens, abomasal worm burdens increased in lambs which grazed tall fescue as sward height decreased. This relationship was not present on the Yorkshire fog swards.

Most of the abomasal worm burdens in both periods consisted of *Ostertagia* with low numbers of *Haemonchus* and *Trichostrongylus* (Appendix 4.4; 4.6).

Intestinal worm burdens were significantly higher in lambs which grazed tall fescue than Yorkshire fog ($P<0.0009$); Table 4.9). This was due to large differences at the 3 cm and 5 cm sward heights. As with abomasal worm burdens, intestinal worm burdens increased in lambs which grazed tall fescue swards as sward height decreased, but this pattern was again not evident in the Yorkshire fog treatments.

Intestinal worm counts were similar for periods 1 and 2 for all three Yorkshire fog sward heights but on the tall fescue 5 and 8 cm swards increased four and 10 fold respectively between periods 1 and 2 (Appendices 4.5 and 4.7). In period 2, the numbers of the three major intestinal worm genera, *Cooperia*, *Nematodirus* and *Trichostrongylus* were all significantly lower ($P<0.01$) in tracer lambs which grazed the Yorkshire fog than in those which grazed tall fescue.

Table 4.8. Mean abomasal nematode burdens ($\log_{10}(n+1)$ transformed; (n)) and the male to female ratio of nematodes recovered (M:F) from tracer lambs with grazed monospecific swards of either tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm. Pooled for both periods. Arithmetic means are shown in parentheses.

	Haemonchus			*Ostertagia*			*Trichostrongylus*			Abomasum total	
	n		M:F	n		M:F	n		M:F	n	
Tall fescue											
3 cm	1.11	(59)	.43	2.75	(577)	.94	1.95	(92)	1.22	2.85	(839)
5 cm	.373	(4)	ND[1]	2.49	(298)	.90	1.72	(68)	.71	2.59	(421)
8 cm	.970	(15)	ND	2.34	(244)	1.42	1.04	(15)	0	2.40	(346)
Yorkshire fog											
3 cm	1.13	(35)	2.33	2.43	(389)	.85	1.88	(161)	.67	2.57	(544)
5 cm	.717	(6)	ND	2.62	(620)	1.19	1.25	(48)	1.10	2.69	(657)
8 cm	1.14	(44)	.89	2.45	(268)	.76	1.35	(35)	.33	2.54	(399)
Pooled SE	.423		ND	.167		.324	.307		.394	.167	
Herbage effect (P<)	NS[2]		ND	NS		NS	NS		NS	NS	
Height effect (P<)	NS		ND	NS		NS	0.02		NS	NS	
Herbage x height effect(P<)	NS		ND	NS		NS	NS		NS	NS	

[1] ND - not determined due to insufficient numbers
[2] NS - not significant (P>0.10)

Table 4.9. Mean intestinal nematode burdens ($\log_{10}$ (n+1) transformed: (n) and the male to female ratio of nematodes recovered (M:F) from tracer lambs which grazed monospecific swards of either tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm. Pooled for both periods. Arithmetic means are shown in parentheses.

	Cooperia			*Nematodirus*			*Trichostrongylus.*			Intestine total	
	n		M:F	n		M:F	n		M:F	n	
Tall fescue											
3 cm	1.87	(192)	.62	2.32	(207)	.73	3.35	(2189)	.82	3.41	(2588)
5 cm	2.04	(114)	.76	1.99	(128)	.67	3.11	(1286)	.99	3.18	(1528)
8 cm	1.52	(40)	.55	1.50	(41)	1.16	2.57	(389)	1.34	2.67	(470)
Yorkshire fog											
3 cm	1.23	(43)	.55	1.16	(34)	.56	2.48	(289)	.72	2.56	(366)
5 cm	1.42	(67)	.33	1.55	(61)	1.00	2.63	(394)	.76	2.72	(522)
8 cm	1.03	(20)	.70	1.57	(54)	1.78	2.49	(306)	.66	2.58	(380)
Pooled SE	.373		.345	.286		.442	.225		.259	.215	
Herbage effect (P<)	0.02		NS	0.005		NS	0.001		NS	0.0009	
Height effect (P<)	NS		NS	NS		NS	0.05		NS	0.05	
Herbage x height effect(P<)	NS		NS	0.02		NS	0.07		NS	0.07	

[1] ND - not determined due to insufficient numbers
[2] NS - not significant (P>0.10)

4.3.2.5. Faecal Output and Calculated Organic Matter Intake

Faecal output and OMI were greater in lambs which grazed tall fescue swards than in lambs which grazed Yorkshire fog swards ($P<0.02$) (Table 4.10). Also, as sward height increased, faecal output increased in SD and TD lambs which grazed tall fescue and TD lambs which grazed Yorkshire fog, but not in the SD lambs which grazed Yorkshire fog swards. A listing of faecal output, OMI, and OMI adjusted to $LW^{0.75}$, by period, is provided in Appendix 4.8. Within tall fescue treatments SD lambs tended to have higher faecal output than TD lambs, while no such effect was observed in the Yorkshire fog treatments. However, when OMI was adjusted to a common metabolic weight ($LW^{0.75}$) overall effect of grass or sward height was not significant (Table 4.10).

4.3.2.6. Faecal Consistency

In the early stages of the trial (up to day 59; Appendix 4.9), the mean faecal consistency score in TD lambs was similar or greater on tall fescue than on Yorkshire fog swards. From days 45 to 108 no consistent differences were observed. From day 108 to the end of the trial, mean faecal consistency scores were markedly higher in lambs which grazed Yorkshire fog 3 cm and 5 cm swards than tall fescue at the corresponding heights. In the 8 cm sward, mean

Table 4.10. Average calculated faecal output (FO; g OM/day), organic matter intake (OMI; g/day) and organic matter intake adjusted to a common metabolic body weight ($LW^{0.75}$) of lambs which were either suppressively drenched fortnightly (SD) or trigger drenched when any treatment reach 1000 eggs per gram (TD). Lambs grazed monospecific swards of tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm.

		FO (g OM/day)	OMI (g/day)	OMI ($LW^{0.75}$)/day)
Tall fescue				
3 cm	SD	250	780	65
	TD	240	740	65
5 cm	SD	300	1020	76
	TD	270	920	76
8 cm	SD	380	1240	85
	TD	330	1090	78
Yorkshire fog				
3 cm	SD	220	620	54
	TD	200	550	50
5 cm	SD	250	600	51
	TD	260	630	52
8 cm	SD	200	670	53
	TD	210	710	51
Pooled SE		40.2	273.9	13.15
Herbage effect (P<)		0.0001	0.02	0.39
Height effect (P<)		0.03	0.15	0.51
Herbage x height effect (P<)		0.0002	0.03	0.39

faecal consistency scores were generally higher in lambs which grazed Yorkshire fog than tall fescue with day 148 being the exception.

4.4 DISCUSSION

4.4.1. Introduction

The selection of Yorkshire fog and tall fescue for comparison in this experiment was based on preliminary results (FEC and lamb liveweights) of the grazing trial in 1991/92 reported in Chapter 3. At the time of the decision on which grass species had to be sown, lambs grazing tall fescue had higher FEC and greater differences in liveweight between SD and TD groups than did lambs grazing Yorkshire fog. In retrospect, the choice was appropriate as consistent differences between Yorkshire fog and tall fescue in TD lamb FEC and tracer lamb worm burdens were observed over both years of that trial. For the grazing trial reported in this Chapter, a more digestible and palatable cultivar of tall fescue (Roa) was sown than the cultivar Au Triumph which was used in the grazing trial reported in Chapter 3 and in the larval population dynamics studies reported in Chapters 5, 6, and 7.

The three sward heights were chosen to cover the range from substantial restriction of herbage intake to unrestricted intake, based on the results of Parsons (1984) and Maxwell and Treacher (1986). As in the experiment reported in Chapter 3, this trial was not replicated. The implications to

One of the major problems in this trial was the inability to control herbage growth during the early stages. This was due to the excellent growing conditions experienced during the season and an inability to obtain lambs as quickly as required. However, the comparisons between grass species and grazing heights are still valid for two reasons:

1/ Stocking rates, as measured in lambs/ha or lamb mass/ha did not differ greatly between the tall fescue and Yorkshire fog swards of similar target height during the early part of the trial, the period when the swards were well above target height. Thus the levels of egg contamination deposited on the swards during this period would have been similar.

2/ Sward height on both species declined in a similar pattern over time, ensuring that the effects of variation in height would have remained similar across tall fescue and Yorkshire fog swards.

Furthermore, tracer lambs and oesophageal fistulated wethers were not used, nor were chromium capsules inserted into lambs, until the swards were grazed to the desired height.

In mid-January the tall fescue 8 cm and 5 cm swards were topped at 8 cm to remove excess growth and the cuttings were baled for hay. Inevitably, this would have removed some nematode larvae although the impact of this on sward infectivity is unknown. Nevertheless, parasitism, as estimated by TD lamb FEC was higher on the tall fescue 5 cm sward than on the Yorkshire fog 5 cm sward during the first 90 days of the trial (Table 4.7) while tracer lamb worm burdens were higher on the tall fescue 5 cm sward than the Yorkshire fog 5 cm sward in the second period. This suggests that by TD lamb FEC was higher on the tall fescue 5 cm sward than on the Yorkshire fog 5 cm sward during the first 90 days of the trial (Table 4.7) while tracer lamb worm burdens were higher on the tall fescue 5 cm sward than the Yorkshire fog 5 cm sward in the second period. This suggests that the level of parasitism in lambs which grazed tall fescue would have been greater still if the excess grass had not been removed. The topping procedure may be one of the reasons why the differences in FEC between lambs which grazed tall fescue and Yorkshire fog was not as great as reported as reported in Chapter 3.

There was a proliferation of Yorkshire fog into the tall fescue swards, particularly the 3 and 5 cm swards (Table 4.2). The effects of this proliferation would have been to some extent reduced by the lambs appearing to select tall fescue in preference to Yorkshire fog. Yet, the Yorkshire fog was consumed to some degree and this may have reduced the differences in lamb parasitism and performance between the herbage treatments.

4.4.2. Effect of Sward Height on Liveweight Gain

The increase in growth in both SD and TD lambs on both grasses as sward height increased and stocking rate decreased, is in agreement with other published results for sheep (Jagusch *et al.* 1980, Chestnutt 1992) and cattle (Ciordia *et al.* 1962b, Hansen *et al.* 1989). The major difference between grasses in lamb performance in response to increased in sward height occurred in the SD rather than the TD lambs. SD lambs which grazed the 8 cm tall fescue sward were 13 kg heavier than those which grazed the 3 cm sward, whereas SD lambs which grazed the Yorkshire fog 8 cm sward were only 4.9 kg heavier than those which grazed the 3 cm sward (Table 4.6). By contrast, final liveweights of TD lambs differed by 8.2 and 9.2 kg between the 8 and 3 cm sward heights for the tall fescue and Yorkshire fog swards respectively. This suggests that the results of lamb performance comparisons on different pasture species grazed to a range of sward heights using suppressively drenched animals may not be valid when lambs are parasitised because the production loss differences between SD and TD lambs were not consistent between grass species. As in the trial reported in Chapter 3, differences in SD and TD lamb performance probably underestimate the true production losses due to parasitism (see 3.4.4).

One of the consequences of the difference in growth between the SD and TD lambs was that for the last 60 days of the trial SD lambs made up a greater proportion of the total lamb mass grazing the tall fescue swards. These were net removers of larvae from the swards compared to TD lambs, which were net contributors (Appendix 4.3). This would have reduced the larval contamination on the tall fescue sward, but the magnitude of the effect is unknown.

4.4.3. Lamb Organic Matter Intake (OMI)

Herbage OMI was far lower in lambs which grazed Yorkshire fog than in lambs which grazed tall fescue (Table 4.10). Also, OMI in lambs which grazed tall fescue increased as sward height increased but this pattern was not observed in lambs which grazed Yorkshire fog, where estimated OMI at all heights were consistently below those of lambs which grazed tall fescue to 3 cm. Herbage OMI would normally be expected to be severely restricted at this height (Parsons 1984, Maxwell and Treacher 1986). However, these contrasts in OMI were largely a function of bodyweight as there was only a non-significant difference in organic matter intakes between grasses when adjusted to a common metabolic body weight (Table 4.10).

Montossi *et al.* (1994) found no behavioural constraints to the ingestion of Yorkshire fog compared to ryegrass, but lower OMI for Yorkshire fog than ryegrass was attributed to the slightly lower OMD for the Yorkshire fog. In the current trial, SD lambs which grazed Yorkshire fog had lower adjusted OMI than lambs which grazed tall fescue swards. Differences in OMI were reflected in differences in lamb performance between grass species at the time, as SD lambs which were grazing tall fescue were gaining weight, while their counterparts grazing Yorkshire fog were not (Fig. 4.1, Appendix 4.1).

The lack of appreciable differences in herbage intake between SD and TD lambs for both Yorkshire fog and tall fescue swards suggests that parasite induced anorexia was not evident. These results are similar to those obtained in the experiment described in Chapter 3. However, they are to some extent dependent upon assumptions about the application of *in vitro* to *in vivo* estimates of forage digestibility. Low levels of condensed tannin (CT) or tannin-like compounds have been detected in both Yorkshire fog (Montossi *et al.* 1994) and tall fescue (F. Liu unpublished) and it is known that CT may reduce *in vitro* digestibility (Jones and Mangan 1977). Further work is required to determine the exact nature of the compounds and whether these compounds will reduce *in vitro* digestibility estimates. Furthermore, extrapolation to field conditions involves assumptions about the effects of parasitism, level of feed intake or plant biochemistry on digestive efficiency. These aspects are considered in more detail in Chapter 8.

4.4.4. Stocking Rate and Animal Production

As sward height decreased, lamb growth decreased on both grasses, as did the proportion of lambs which attained 32 kg, a nominal weight taken to indicate suitability for slaughter. But total lamb production (kg lamb/ha) increased as sward height decreased as a consequence of increasing stocking rate (Table 4.5). This agrees with previously published reports for sheep (Chestnutt 1992) and cattle (Hansen *et al.* 1989).

In a normal farming situation, individual lamb growth could have a major impact on parasite epidemiology. If lambs are removed from the unit at a predetermined weight as is usual, (in this hypothetical instance, 32 kg), then their contamination of the swards also stops. If they are replaced with older stock or cattle then the pasture contamination may rapidly decline. The higher growth rates in the SD lambs which grazed the tall fescue, meant that a greater proportion would have been removed from the unit earlier than from the Yorkshire fog treatments (Appendix 4.2).

4.4.5. Stocking Rate and Parasitism

In this trial, two comparisons of stocking rate effects on parasitism can be made. There were differences in the stocking rate between tall fescue and Yorkshire fog to maintain stipulated heights, and there was a difference in stocking rate within each grass species required to maintain sward height contrasts. These comparisons are discussed in more detail below.

Lamb stocking rates on tall fescue and Yorkshire fog were similar for the first half of the trial and then increased on Yorkshire fog relative to tall fescue swards during the second half (Table 4.5). A higher stocking rate later in the trial would have had less effect on parasitism. Apart from any effects which ambient temperature and precipitation may have had on larval development and survival, higher stocking rates early in the trial would have resulted in increased total egg deposition on the sward which should have translated into increased larval availability while the trial was still underway. In the later stages of the trial, there was less chance of the larvae developing, or of the infection becoming patent before the trial terminated.

The temporal pattern of larval density (L_3/kg dry herbage, Table 4.4) is similar to that demonstrated by Vlassoff (1973b). That is, there was a rise in larval density in the autumn (March to May). However, larval density on the swards in the trial of Vlassoff (1973b) were far higher (4000 to 18000 larvae/kg herbage or 20000 to 90000 larvae/kg dry herbage) than observed in this trial (maximum of 21000 larvae/kg dry herbage).

Within each grass species stocking rate increased as the sward height decreased. Four possible ways in which stocking rate can affect parasitism have been suggested by Bransby (1993) and these are considered in the context of this trial:

1/ At a low average sward height resulting from high stocking rates, animals graze closer to the ground and therefore ingest more larvae: While this may be true, it is based on the assumption that the greatest density of larvae occur in the lower horizons of the sward. This will be discussed in Chapter 6.

2/ As sward height decreases and nutrient intake decreases with increasing stocking rate, plane of nutrition decreases: In this trial, chemical analysis of ingesta from OF wethers indicated only minor reductions in herbage N content and OMD as sward height declined. These differences were small compared to the differences in N content and OMD between the grass species. As sward height decreased, lamb OMI decreased in lambs which grazed tall fescue, but not in lambs which grazed Yorkshire fog.

3/ As stocking rate increases, faecal deposition increases and animals will graze closer to deposited faeces where larval contamination is greatest: This is more relevant for cattle than for sheep, as sheep do not avoid faeces to the same extent as cattle (Forbes and Hodgson 1985).

4/ A higher stocking rate results in an increasing level of contamination being deposited on a decreasing herbage mass: For example, if standing herbage DM mass and lamb stocking rate are averaged over the duration of the trial then, as a crude calculation, on the 3 cm swards 1 stock unit (su) would, on average, have spread its faecal contamination over 44.6 and 48.5 kg of herbage dry matter on the tall fescue and Yorkshire fog swards respectively.

On the 8 cm swards, 1 stock unit would have spread its faecal contamination over 155.2 and 131.3 kg herbage dry matter on the tall fescue and Yorkshire fog swards respectively. These estimates involve variation in stocking rate and herbage mass only and do not allow for variation in faecal output or FEC. As FEC was always lower on both grass species in lambs which grazed the 8 cm swards, then the contrast in contamination deposited (eggs/kg dry herbage) between the 8 cm than 3 cm swards would have been even greater than the above figures suggest.

There has been a suggestion in the literature that larval survival decreases with decreasing sward height. Southcott *et al.* (1970), attributed this to the microclimate on short swards being more hostile. The results from this trial (Table 4.4) reinforce those findings. Shorter swards, which had greater levels of egg deposition on a lower herbage dry mass, did not have consistently elevated levels of herbage larval density or a greater total larval population. The exception was during February when larval density and total population were far greater on the 3 cm than the 8 cm swards of both grass species. The high rainfall in late January (Appendix 3.19) may have been a contributing factor.

It was concluded in Chapter 3 that the differences in stocking rate required to maintain similar sward height across a range of grass species had little effect on lamb parasitism. However, the conclusion was tentative due to the lack of replication. In the study reported in this Chapter, despite larger differences in lamb stocking rate (kg/ha) to maintain sward heights at 3, 5 or 8 cm than in stocking rate to maintain grasses at 5 cm in the trial reported in Chapter 3, the differences in tracer lamb worm burdens due to stocking rate were lower in the trial reported in this Chapter than in the trial reported in Chapter 3 (Figs. 3.3 and 4.2). This will be examined further in Chapter 8.

4.4.6. TD Lamb Faecal Egg Counts and Tracer Lamb Worm Burdens

Faecal egg counts in TD lambs which grazed Yorkshire fog decreased as sward height increased, but tracer lamb worm burdens did not. Thus the tracer lamb worm burdens did not reflect TD lamb FEC, in accord with the results of the study reported in Chapter 3. The reason for the decrease in TD lamb FEC with increasing sward height is difficult to explain. It cannot be readily explained in terms of faecal output, which was broadly similar over the sward height range tested (Table 4.10). The possibility that shorter swards may be more conducive to transmission of worm species of higher fecundity such as *Haemonchus contortus* (Crofton 1963) is not borne out by the results of the tracer lambs (Appendices 4.4 and 4.6). The inconsistency may simply reflect differences in parasitological history between the two groups of lambs as the TD lambs were constantly exposed to larval challenge, whereas the tracer lambs were only exposed to larvae during the period when they grazed the pastures. A previous exposure to larvae will reduce the establishment of incoming larvae (Barger 1986).

The reason for the large contrast between tall fescue and Yorkshire fog in tracer lamb worm burdens and TD lamb FEC may be explained if female nematodes of any given species are more fecund when the overall worm burden is lower (Southcott *et al.* 1970). Such density dependent mechanisms have been described (Waller *et al.* 1981; Barger, 1986; Smith, 1988) and may explain why the tracer lambs on the Yorkshire fog had much lower worm burdens but the TD lambs had less noticeable reductions in FEC compared to their counterparts on tall fescue.

4.4.7. Larval Ingestion and Establishment

The exercise comparing the ratio of tracer lamb worm burdens to larval density as done in 3.4.2. and summarised in Table 3.20., suggests an interaction between the effects of grass species and sward height upon larval ingestion or establishment between tall fescue and Yorkshire fog in the current experiment (Table 4.11).

Table 4.11. Average larval density, average total tracer lamb worm burden and the ratio of worm burden to larval density.

	Average larval density (L_3/kg DM)[1]	Average total worm burden[2]	Ratio
Tall fescue 3 cm	10358	3427	0.33
Tall fescue 5 cm	11190	1949	0.17
Tall fescue 8 cm	2768	816	0.30
Yorkshire fog 3 cm	6820	910	0.13
Yorkshire fog 5 cm	3495	1179	0.34
Yorkshire fog 8 cm	5445	780	0.14

[1] From Table 4.4. Averages were taken over the months in which tracer lambs were grazing.
[2] Total abomasal and intestinal worm burdens. (From Fig. 4.2.)

The comparison between results for the 3 and 8 cm swards between tall fescue and Yorkshire fog show a similar, but less marked contrast in the ratio of tracer lamb worm burdens to herbage larval density than that observed in the trial reported in Chapter 3 (Table 3.20), while at 5 cm the ratio was lower on tall fescue than Yorkshire fog. The difference between the trial reported in Chapter 3 and the trial reported here is attributed to differences in herbage larval density rather than tracer lamb worm burdens (Tables 3.20 and 4.11) and is highlighted by the anomalous results for the 5 cm swards, where larval density on tall fescue was higher at 5 cm than at 3 cm and 8 cm while on Yorkshire fog larval density was lower at 5 cm than at 3 cm and 8 cm. The differing results between the trial reported here and that reported in Chapter 3 will be discussed in more detail in Chapter 8.

4.4.8. Properties of Yorkshire Fog

Yorkshire fog has some properties which must be explored further. The most notable findings in this trial are the differences in tracer lamb worm burdens between lambs which grazed Yorkshire fog and tall fescue, particularly at 3 cm and 5 cm sward heights (Figure 4.2, Tables 4.8 and 4.9). This was more marked for intestinal than abomasal nematodes, but any effect on abomasal nematodes may have been masked by their low numbers in both treatments. The other notable finding was the low liveweight differential between SD and TD lambs which grazed Yorkshire fog, despite large differences between the groups which grazed tall fescue. These observations are in agreement with those reported in Chapter 3.

From the results of this trial it is difficult to determine the cause of the contrast in tracer lamb worm burdens between tall fescue and Yorkshire fog. The ratio of tracer lamb worm burden to herbage larval density (Table 4.11), suggests that on the 3 and 8 cm swards, a similar pattern to that observed in Chapter 3 existed (Table 3.20) in that the ratio of tracer lamb worm burden to herbage larval density was lower for Yorkshire fog than tall fescue. This suggests that either larval ingestion or larval establishment in tracer lambs grazing Yorkshire fog was lower than in lambs grazing tall fescue. However, on the 5 cm sward in animals grazing Yorkshire fog the lower tracer lamb worm burden appeared to be directly related to lower larval density on the herbage.

Whilst the low liveweight differential between SD and TD on the 3 cm and 5 cm Yorkshire fog swards compared with tall fescue (Table 4.6) could be explained by the lower levels of parasitism as measured by tracer lamb worm burdens, this explanation cannot be used to explain the differences in liveweight differential observed on the 8 cm swards as the tracer lamb worm burdens were similar on both grasses. This suggests that a factor other than parasitism was having an effect, but there is no clear indication of what this might be.

4.4.9. Faecal Consistency

The reason for the differences in faecal consistency (Appendix 4.9) is unknown at this stage. While looser faeces is often associated with gastrointestinal nematodes (Larsen *et al.* 1994), grass species can also affect consistency, as was shown in this trial. However, little is known about the physiological mechanisms involved in looser faeces in lambs (Larsen *et al.* 1994, Waghorn 1995)

4.5. SUMMARY

Lamb parasitism and performance were compared on two grasses, tall fescue and Yorkshire fog, grazed at the sward heights of 3, 5 or 8 cm. Lamb parasitism, as measured by lamb FEC and tracer lamb worm burdens, was greater in lambs which grazed tall fescue than in lambs which grazed

Yorkshire fog. The differences were greater at the 3 cm and 5 cm sward heights than the 8 cm sward height.

Final liveweights were greatest in the SD lambs which grazed tall fescue, and were greater at all heights than TD lambs which grazed the same sward. There were no significant liveweight differences between SD and TD lambs which grazed Yorkshire fog. As sward height increased, final liveweights also increased on both grass species.

Pasture larval populations increased over time to a greater extent on the tall fescue swards than the Yorkshire fog swards.

Parasite induced anorexia was not evident in lambs which grazed either tall fescue or Yorkshire fog swards.

This study has shown that results for lamb parasitism and stocking rate determined for one grass species may not be transferable to another and that while individual SD lamb performance was greater on tall fescue, Yorkshire fog appears to hold some promise as a grass species which limits the level of parasitism in lambs and the production losses specifically due to parasitism.

CHAPTER 5.

THE RECOVERY OF TRICHOSTRONGYLID LARVAE FROM A RANGE OF HERBAGES

5.1 INTRODUCTION

The accurate estimation of the numbers of gastrointestinal nematode larvae on herbage in pots, plots and pasture requires a reliable method for their recovery. Various procedures and refinements of them have been described for this purpose (Donald 1967, Heath and Major 1968, Lancaster 1970, Waller *et al* 1981, Chiejina 1982, Couvillion 1993). Most of the procedures involve soaking or washing herbage in water, with or without the addition of surfactants, followed by concentration of the larvae for counting. In several of these methods, including the one used in this study (see 5.2), the washings are filtered and the activity of the larvae used to free them from obscuring debris by means of a modified Baermann procedure (Vlassoff 1973b)

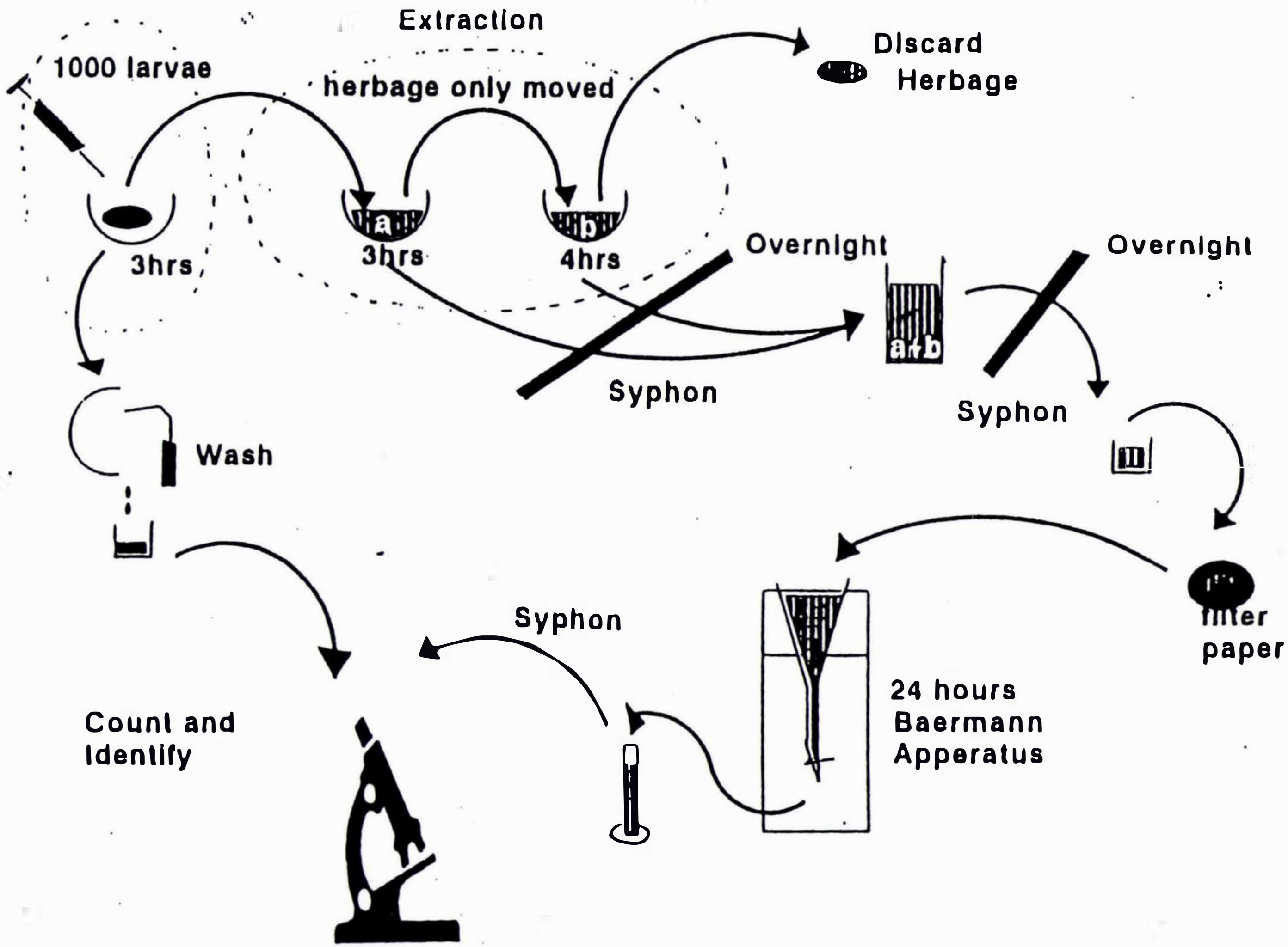
Although the effects of various modifications of procedures on larval recovery rates have been investigated, it appears that no work has been undertaken to determine whether the recovery of larvae varies between different herbages. Yet differences in leaf and stem surface morphology may alter the adherence of larvae to the herbage and thereby alter larval recovery rates. Furthermore, it is possible that compounds in plants released during processing could affect larval activity, which might reduce the number of larvae recovered, as the Baermann extraction process used in many laboratories (Vlassoff 1973b, Williams and Bilkovich 1973, Couvillion 1993) is dependent on larval activity. Since Chapters 6 and 7 will examine larval dynamics on a variety of herbages, it was clearly necessary to compare the efficiency with which larvae could be recovered from them. The experiment to investigate this is the subject of this chapter.

5.2 MATERIALS AND METHODS

Larval extraction rates were compared between browntop (*Agrostis capillaris* cv Muster), chicory (*Chicorium intybus*, cv Grasslands Puna), prairie grass (*Bromus willdenowii*, cv Grasslands Matua), cocksfoot (*Dactylis glomerata*, cv Grasslands Kara), ryegrass (*Lolium perenne*, cv Grasslands Nui), Yorkshire fog (*Holcus lanatus*, cv Massey Basyn), tall fescue (*Festuca arundinacea*, cv Au Triumph) and white clover (*Trifolium repens*, cv Grasslands Huia). Herbage was harvested from plots established for other purposes (see Chapter 6), but which had not been grazed since they were established 6 months previously. Before that, the area was pasture for water buffalo (*Bubalus bubalis*).

Equal amounts of herbage (≈50g wet weight, 15 samples per herbage) were cut into 2.5 cm lengths and wetted with 3 ml of water containing 1000 ± 45 (mean ± standard error) *Trichostrongylus colubriformis* larvae. The water and herbage were then mixed to try to ensure that larvae were distributed throughout the herbage and as little free water as possible remained in the bottom of the container. After 2 hours, the herbage was removed and subjected to the larval extraction process which was based on the method of Vlassoff (1973b). The procedure is summarised in Fig. 5.1. The

Figure 5.1. A schematic diagram of the procedure involved in the contamination of herbage and subsequent removal of larvae.



herbages were soaked, first for 3 hours and then for another 4 hours in two separate volumes of 4 litres of water to which 0.5 ml non-ionic detergent (Teepol) was added. The washings were concentrated to 50 ml by 3-step sedimentation, with each step lasting 24 hours. The supernatant was removed by siphoning and the larvae were extracted from the sediment in a Baermann funnel apparatus (Taylor 1939) using 20 cm glass funnels, 20 mesh/cm sieves and Whatmans No. 1 filter paper. After filling the funnels with water to which 0.5 ml of detergent was also added, the concentrated sediments were gently layered on to the filter paper which was carefully inverted onto the submerged sieve mesh. One collection of larvae in 100 ml was taken from the funnels after 24 hours and the volume siphoned down to 40 ml 24 hours later. After thorough mixing, a 1 ml subsample was taken and the larvae counted. The containers used for the initial 2 hour soaking were rinsed and the larvae were also recovered by the Baermann method and counted. All the water used was non-chlorinated.

Least square means for the numbers of larvae recovered from herbages and washings were compared by analysis of variance using General Linear Models (GLM® Statistical Analysis Systems (SAS)).

5.3. RESULTS AND DISCUSSION

Cocksfoot and chicory gave the highest rates of recovery of approximately 50%, white clover, tall fescue, browntop, Yorkshire fog and ryegrass rates of 30-40%, and prairie grass approximately 25% (Table 5.1). Although there was a three-fold difference in the numbers of larvae recovered from the containers for the different herbages, the numbers recovered from the containers relative to the numbers recovered from herbage were small, less than 10% of the total larvae recovered.

In preliminary experiments on the recovery of larvae in the assay without herbage, the recovery averaged 70% (data not shown). This is slightly lower than reported by others (Todd *et al.* 1970, Chiejina 1982). The fate of the remaining 30% is unknown. They could have been lost in the

Table 5.1. Numbers of larvae recovered from herbages and from the residual water in the plastic containers when 1000 *T. colubriformis* larvae were added to 50g fresh herbage cut into 2.5 cm lengths. Each value is the mean of 15 samples.

Herbage	Larvae recovered from herbage	Larvae recovered from containers	Total Larvae recovered
Prairie grass	249[a]	24	273
Ryegrass	299[ab]	47	346
Yorkshire fog	321[ab]	21	342
Browntop	368[bc]	31	399
Tall fescue	369[bc]	25	404
White clover	381[bc]	40	421
Cocksfoot	476[cd]	49	525
Chicory	519[cd]	64	583
Pooled SE	22.5	5.9	ND[1]
Herbage Effect (P<)	0.0001	0.0001	ND

[1] ND - not determined.

Values in columns with different superscripts differ (P<0.05).

syphoning, or remained on the filter paper or on the sides of the funnel. Todd *et al.* (1970) reported markedly different recovery rates according to the diameter of the funnel used, ranging from 83% with 7 cm funnels to 27% with 30 cm funnels. Presumably, the reason for these differences was that the narrower funnels had steeper sides, but the authors made no comment on this. Henriksen (1965) compared the recovery of *Dictyocaulus* first stage larvae in the standard Baermann funnel procedure with recovery in steeper-sided vessels and showed a much higher recovery with the latter. In the experiments described here, 20 cm diameter funnels were used and the 70% recovery obtained compares favourably with the 50% recovery reported by Todd *et al.* (1970) using funnels of this size. However, it seems likely that at least some of the larvae which were not accounted for were trapped on the sides of the funnels.

The reason more of the larvae were not recovered is unknown. Chiejina (1982) reported that the recovery efficiency decreased from 80 to 60% as larval density on the herbage increased from 10/100g to 200/100g herbage but offered no explanation for this effect. In this experiment, the initial larval density was 2000/100g herbage and this may account for the lower larval recovery to some extent. The larvae which were not recovered were probably still adhering to the herbage, as few larvae were found in the water in the bottom of the mixing containers

Mean recovery rates of larvae from the hirsute species, prairie grass, Yorkshire fog, and tall fescue tended to be lower than from the glabrous species, browntop, tall fescue, white clover, and cocksfoot (313 *vs* 409; pooled SE 22.5). While this was so, ryegrass, also a glabrous species, had the second lowest number of larvae recovered from it. The numbers of larvae recovered from the containers also tended to be lower for the hirsute than glabrous species (23 *vs* 46; pooled SE 5.9). These results suggest that some of the larvae on the hirsute species were still adhering to herbage after 7 hours of soaking.

The reason for the high recovery rate from chicory may be related to the different morphological features of this plant. Chicory leaves were the broadest of any of the leaves of the species evaluated.

The recovery of larvae from the narrower leaved species (browntop and ryegrass) tended to be lower than from non-grass species, while the recovery from the broader leaved grasses (prairie grass, tall fescue and cocksfoot) was more variable. This suggests that the physical nature of the herbage may have affected the dissociation of larvae. Since most of the herbage sank to the bottom of the container, it is unlikely that larvae were trapped underneath the finer species. Yorkshire fog was the only species which floated and thus might have expected to yield a greater recovery of larvae, which it did not.

Another possibility is that the larvae were immobilised or killed by compounds within some of the herbages. As the herbage was cut into 2.5 cm lengths, with a small amount of moisture added, these compounds would have been far more concentrated than under conventional extractions where greater volumes of water are used.

The greater than two-fold difference in the number of larvae recovered between the herbage species (Table 5.1) indicates that any comparison of larval dynamics between herbage species should include an investigation of differences in larval recovery between the species.

CHAPTER 6.

EFFECT OF PLANT SPECIES ON THE DEVELOPMENT, SURVIVAL AND VERTICAL MIGRATION OF LARVAE OF GASTROINTESTINAL NEMATODES WHICH PARASITISE SHEEP

6.1. INTRODUCTION

A recent study has reported that lambs which grazed swards of different herbage species acquired differing levels of gastrointestinal nematode infection (Scales *et al.* 1995). In that experiment, the higher levels of parasitism in lambs which grazed grass species compared with lambs which grazed chicory was consistent with evidence that larger numbers of larvae were recovered from grass swards than from chicory swards after equal contamination with nematode eggs (Moss and Vlassoff 1993). This suggests that differences in levels of parasitism in lambs grazing different herbage species can result from differences in larval dynamics on the different swards.

Levels of gastrointestinal parasitism in cattle have been observed to differ with the type of pasture grazed but no measure of larval dynamics on the sward was made in the trial, although this was suggested as the probable cause of the observed differences (Ciordia *et al.* 1962a).

Recent data have suggested that plant species may affect gastrointestinal nematode establishment and/or survival (Niezen *et al.* 1994, Niezen *et al.* 1995), it is possible that herbages could also affect larval development, survival and/or migration in the sward.

It has long been recognised that the conditions in swards play an important role in the complex relationships between sheep hosts and their parasites (Crofton 1963, Brunsdon 1982). As plants have different growth patterns and widely contrasting morphology (Lambrechtsen 1981), it is likely that this could alter the sward microclimate, and so cause direct effects on larval development and survival or indirect effects through modifying the number of organisms which colonise or consume faeces or consume gastrointestinal nematode eggs or larvae.

Of the studies which have compared larval development and survival on swards of different herbage species, one has suggested an interaction between herbage species and weather for *O. circumcincta* development and/or survival (Furman 1944). In this study it was reported that greater numbers of *O. circumcincta* larvae were recovered from swards of ryegrass than swards of white clover or alfalfa (lucerne) in the winter, but in the summer similar numbers were recovered from all herbage species. In contrast, Knapp (1964) concluded that greater numbers of *Haemonchus contortus* larvae survived over winter on white and subterranean clover than on ryegrass or velvet grass (Yorkshire fog) which suggests that the survival of larvae of different nematode species on different herbage species may differ. However, Knapp (1964) placed larvae at the base of swards in autumn and measured nematode burdens in tracer lambs which grazed the swards the following spring, a process which would be likely to confound differences in true larval survival on the herbage, the number of larvae which migrated into the soil, the vertical migration of the larvae on the herbage, the ingestive behaviour of the grazing lambs and larval establishment and survival within the lamb. No comparisons of herbage species in relation to larval development or survival have been found.

In comparisons using sheep gastrointestinal nematodes, Crofton (1948) found that larvae were more evenly distributed on clover (presumably white clover) than on fescue or *Carex* spp. The vertical migration of third stage larvae of some gastrointestinal nematodes infecting cattle (*H. placei*, *C. oncophora* and *T. colubriformis*) was greater on tall fescue than on smooth brome grass (Silangwa and Todd 1964). The results of these studies suggests that differences in larval migration do exist between herbage species, but there have been few studies to determine the reasons for such differences.

Whilst it is known that the larvae require a moisture film to migrate on herbage, and that vertical migration can be rapid (Rogers 1940), whether there are differences in the characteristics of moisture films and in the rate and extent of larval migration on different pasture species remain largely unknown. Wallace (1959) reported that the external morphology of the plant leaf influenced the existence and thickness of water films, but whether such differences alter larval migration was not studied. To what extent differences in larval migration on different herbage species result in differences in levels of parasitism in grazing animals also remains unknown.

The experiments reported here compare the development, survival and migration of *Ostertagia* and *Trichostrongylus* larvae on swards of a range of herbage species commonly used in pastures in New Zealand.

6.2. MATERIALS AND METHODS

6.2.1. Herbage Species

A series of 8 "contaminations" of a range of herbages with sheep faeces containing known numbers of gastrointestinal nematode eggs were carried out in 1992/93 and 1993/94 (4 per year) to compare development, survival and migration of nematode larvae on herbage species of differing morphology in different seasons. Four plots (each 3 x 2 metres) of monospecific swards of each of the following were established in a randomised block design on prepared seed-beds in October 1991: browntop (*Agrostis capillaris* cv Grasslands Muster), tall fescue (*Festuca arundinacea* cv Au Triumph), Yorkshire fog (*Holcus lanatus* cv Massey Basyn), perennial ryegrass (*Lolium perenne* cv Grasslands Nui), cocksfoot (*Dactylis glomerata* cv Grasslands Kara), prairie grass (*Bromus wildenowii* cv Grasslands Matua), lucerne (*Medicago sativa* cv Grasslands Otaio), white clover (*Trifolium repens* cv Grasslands Huia), chicory (*Chicorium intybus* cv Grasslands Puna). In October 1993, a mixed sward of ryegrass/white clover (cv Nui and Huia respectively) was also sown. The land had previously been pasture and grazed only by water buffalo for the preceding year. Sowing rates of the herbages are shown in Table 6.1. They approximated to commercial sowing rates. Seed was broadcast on the plots by hand on a windless day.

All grass and chicory plots received 4 dressings of the equivalent to 50 kg N/ha throughout the year and all plots received one dressing of superphosphate annually equivalent to 100 kg/ha.

Table 6.1. Sowing rates (g/plot and kg/ha) and 1000 seed weight (g) of herbage species used to compare the dynamics of *Trichostrongylus colubriformis* and *Ostertagia circumcincta* larvae.

Herbage Species	Sowing rate (g seed/plot)	Sowing rate (kg seed/ha)	1000 Seed Weight (g)[1]
Browntop	15	10	0.1
Yorkshire fog	24	16	0.3
Ryegrass	60	40	2.0
Tall fescue	76	50	2.6
Lucerne	24	16	2.0
Chicory	12	8	1.2
Cocksfoot	30	20	0.9
White clover	15	10	0.7
Prairie grass	120	80	11.5

[1] from Charlton (1991).

In order to minimise unwanted plant species, plots of chicory, lucerne, and white clover were sprayed with fluazifop-P-butyl (Fusilade® Imperial Chemical Industries plc, England), all the grass plots were sprayed with 2-4-D plus dicamba (Banvine® Dow Elanco New Zealand), and the ryegrass/white clover plots were sprayed with MCPA (MCPA ® Dow Elanco NZ) in the spring in both years prior to the first contamination. All herbicides were applied at the manufacturers' recommended rates. In spite of these precautions, unsown species did develop in some plots. Consequently, at the time the faeces was deposited, all the swards were subjectively evaluated for weed infestation and plant density. If weed infestation was considered too great or plant density not representative of field conditions, the herbage species was not used in that contamination. In Contamination 2 in 1992/93 and Contamination 1 in 1993/94, chicory was not included in the herbage comparisons because of the high level of plant mortality after mowing (see 6.2.2.) and a resulting invasion by weeds. Lucerne and prairie grass were not included in Contamination 1 in 1993/94 because of weed contamination. Similarly, at the time of cutting the herbage, if individual sub-plots were judged to contain too high a level of non-target species, the sub-plot was not used in the analysis.

6.2.2. Contamination Management

Prior to the faeces being deposited on the plots, all the herbages were cut with a lawnmower with the blade set to a height of 4 cm and the excess herbage removed. Plots were then subdivided into thirty six, 30 x 30 cm subplots and each subplot was contaminated with sheep faeces containing approximately 30,000 (1992/93) or 50,000 (1993/94) *T. colubriformis* and/or *O. circumcincta* eggs in faeces. The quantity of faeces varied between contaminations depending on the FEC of the donor lambs. A summary of the weights of faeces and numbers of eggs deposited for 1992/93 and 1993/94 is provided in Tables 6.2 and 6.3 respectively. The faeces were mixed and placed in the centre of the sub-plot.

The contaminations were undertaken in late spring, early summer, mid-late summer and autumn in both years (Tables 6.2 and 6.3).

6.2.3. Herbage Collection

For each herbage species, six sub-plots were cut at 2, 4, 6, 8, 11 and 14 weeks after contamination. Prior to cutting, sward height was measured in each sub-plot (7 measurements) using an HFRO sward-stick (Barthram 1986). Any remaining faeces were also removed. Herbage was cut by grasping it in small handfuls and cutting as close as possible to ground level. It was then cut from the bottom up into 4 vertical strata, 0-2.5 cm and 2.5-5 cm, 5-7.5 cm and 7.5+ cm above the soil surface and placed in labelled receptacles. Any litter remaining on the soil surface was added to the material from the lowest stratum.

Herbage was harvested consistently between 9 and 10:30 AM to minimise any potential effect of diurnal movement of larvae (Rees 1950).

In 1992/93, the herbage was allowed to grow for the entire 14 weeks. In 1993/94, after the fourth cut, at week 8, any remaining faeces were removed from the sub-plots to be cut on weeks 11 or 14, and the herbage was mown to 4 cm height (pre-contamination height) to simulate a grazing. The

Table 6.2. Contamination number, date of contamination and number of *Trichostrongylus colubriformis* and *Ostertagia circumcincta* eggs applied to each of 36 subplots of each herbage species in each contamination. 1992/93.

		1992/93			
Contamination		1	2	3	4
Date		8/12/92	1/2/93	17/3/93	21/4/93
T. colubriformis					
	Eggs	14900	27900	31100	23100
	Faecal mass (fresh)	14.0	26.0	9.8	14.0
O. circumcincta					
	Eggs	14700	2000	-	8100
	Faecal mass (fresh)	14.0	10.0	0	14.0
Total					
	Eggs	29600	29900	31100	31200
	Faeces (fresh)	28.0	36.0	9.8	28.0

Table 6.3. Contamination number, date of contamination and number of *Trichostrongylus colubriformis* and *Ostertagia circumcincta* eggs applied to each of 36 subplots of each herbage in each contamination. 1993/94.

		1993/94			
Contamination		1	2	3	4
Date		16/10/93	5/1/94	7/3/94	7/5/94
T. colubriformis					
	Eggs	50000	32000	34100	26000
	Faecal mass (fresh)	45.5	7.0	22.0	18.0
O. circumcincta					
	Eggs	-	15700	8700	17500
	Faecal mass (fresh)	0	10.0	18.0	25.0
Total					
	Eggs	50000	47700	42800	43500
	Faecal mass (fresh)	45.5	17.0	40.0	43.0

clippings were removed and the faeces were then redeposited at the centre of the appropriate sub-plot.

6.2.4. Extraction of Larvae

Larvae were recovered from the herbage as described in Chapter 5. Briefly, the herbage was weighed, soaked in 4 l water in a bucket for 4 hours and then in another 4 l water for a further 3 hours. It was then removed and DM mass determined. Herbage washings were concentrated by sedimentation. The supernatant was siphoned off and larvae extracted in Baermann funnels for 24 hours. Because of the large number of samples generated, only 1 count (of a 2.5% aliquot) per sample was made. Ensheathed larvae were identified as either *Trichostrongylus* or *Ostertagia* based on size and morphological characteristics. Unensheathed larvae (either free-living nematodes or first or second stage larvae) were also counted in 1993/94.

At the time the herbage was cut, any remaining faeces were removed from the subplots and weighed. A subsample (2 g) was dried for 24 hours to estimate DM mass. The remainder of the faeces were placed on a Baermann funnel to recover larvae remaining in the faecal mass.

6.2.5. Collection of Faeces for Contamination

Faeces were obtained from 6 Romney ram lambs in 1992/93 and 8 Romney ram lambs in 1993/94. The lambs were reared worm-free and were given a single dose of either 15,000 *T. colubriformis* or *O. circumcincta* infective larvae. They were fed a mixture of chaffed meadow hay and lucerne pellets (Pelleted Lucerne ® Taupo Lucerne, Taupo NZ.). Once the infection was patent, faeces were collected in bags attached to harnesses. The faeces were removed from the bags twice daily, a sample taken to determine faecal egg count (FEC), and the remainder stored in separate buckets for each day of collection and parasite species at 10^{0} C for no longer than 3 days to minimise egg development (Pandy *et al.* 1989). If enough eggs had not been collected by the third day, the faeces were discarded. Once the required numbers of eggs were collected to contaminate all the sub-plots, the faeces containing the eggs of each parasite species were thoroughly mixed over days of collection and six sub-samples taken to determine mean FEC. The amount of faeces to be deposited on each sub-plot was then calculated. For both species of nematode, faeces were weighed and placed in individual pottles. All faeces were weighed to within 0.2 g of the required weights and the weights were recorded. The faeces were then placed on the sub-plots. An extra six samples were weighed and dried immediately to determine initial faecal DM mass deposited.

There were a few instances when the procedure had to be varied from the above because of low egg output by the donor lambs. In Contamination 3 in 1992/93 and Contamination 1 in 1993/94, only *Trichostrongylus* eggs were placed on the sub-plots because sufficient *Ostertagia* eggs were not available. In Contamination 3 in 1993/94, faeces were collected for 5 days.

The initial aim was to have equal numbers of *O. circumcincta* and *T. colubriformis* eggs applied to each sward type in each contamination. This proved difficult because the numbers of eggs shed by lambs infected with *O. circumcincta* were generally much lower than by lambs infected with *T.*

colubriformis. To provide equal numbers of eggs of both species, larger amounts of faeces would have been required than could have realistically placed on the sub-plots. Instead, the numbers of eggs of each nematode species deposited on each sub-plot in each contamination were kept constant but did vary between contaminations.

6.2.6. Climate Data

Daily rainfall and screen temperatures were recorded at the site in both seasons using a Campbell CR21 micrologger equipped with a CSI Model 101 Thermistor probe (Campbell Scientific Inc USA). In 1993/94, temperatures at the base of a representative set of the swards were recorded using either a Campbell CR21 micrologger equipped with CSI Model 101 Thermistor probes or a Squirrel 1250 series memory logger equipped with DM Thermistor Type S probes (Grant Instruments (Cambridge) Ltd, UK). In Contamination 1, temperature probes were inserted in tall fescue, ryegrass and white clover swards at soil level for the first 5 weeks after faeces were deposited on the herbage. In Contaminations 2, 3 and 4, temperature probes were inserted for the first 5 weeks at the base of the swards of all the herbage species. However, all the data from Contamination 2 was lost through a computer software malfunction. Temperature readings from both screen and sward probes were taken every 20 minutes and averaged over three hours to provide eight daily temperature readings.

6.2.7. Statistical Analysis

Least squares means of sward height, and fresh and dry herbage mass, numbers of larvae and larval density (larvae per kilogram herbage DM) were compared at each cut at each height in each contamination by analysis of variance using General Linear Models (®SAS GLM). When larval numbers for each herbage at each cut were plotted over time after each contamination, it was obvious that, despite large differences in the number of larvae recovered at each cut, greater numbers of larvae were consistently recovered from certain herbages than from others. Given the great variability in the numbers of larvae recovered in different contaminations, it was decided that the most appropriate way of comparing herbages was by rank analysis (SAS RANK). Herbages were ranked from lowest to highest according to the numbers of third stage larvae recovered and comparisons of least squares means of rank values made with respect to the numbers and the densities of larvae (larvae/kg dry herbage) measured at each cut by analysis of variance using GLM. A similar ranking analysis was undertaken of the maximum numbers of larvae recovered after contamination.

"Larval development success" in each contamination was defined as the maximum number of larvae recovered from herbage after the faeces were deposited on the herbages, independent of time after contamination. Least squares means of actual numbers and rank values were compared by analysis of variance using GLM.

"Larval survival" for each contamination was defined as the proportion of the maximum number of larvae recovered which were recovered at the end of the 14 weeks, divided by the number of days since the peak. The defining equation was (larvae at week 14/ maximum no. of larvae recovered)/ (no. of days). Least squares means of actual numbers and ranking values were compared by analysis of variance using GLM.

"Larval migration" was inversely defined as the proportion of larvae on the herbage which were recovered from the bottom stratum (0 - 2.5 cm, a measure of the inability of the larvae to migrate) of herbage. Least squares means of actual proportions and rank values were compared by analysis of variance using GLM. Rank values were from 1 (lowest proportion) to 8 (highest proportion) of larvae in the bottom stratum.

The proportion of dry faeces remaining was compared between herbages using SAS GLM. Data were initially arcsine transformed but the results were similar to untransformed data, indicating that there was no advantage from transformation. Least squares means of the proportion of faeces remaining were also ranked and the ranking values analysed by analysis of variance using GLM.

When daily temperature data were plotted over time, they showed that daily maximum screen and sward temperatures occurred consistently in the 1200 - 1500 hour interval and that daily minimum screen and sward temperatures occurred consistently in the 0300 - 0600 hour interval with little variation. The easiest way to compare herbages was to compare the difference between screen temperature and sward temperature for the herbage species at these times. The differences between sward and screen maximum and minimum temperatures were determined for each herbage species and least squares means compared by analysis of variance using GLM.

6.3 RESULTS

6.3.1. Numbers of Larvae Recovered - Ranking Analysis By Herbage Species

The results of ranking analysis of herbages for combined numbers of *Ostertagia* and *Trichostrongylus* larvae recovered is shown in Table 6.4. In both years there was a highly significant herbage effect on the numbers of larvae recovered. In 1992/93, greatest numbers were recovered from browntop, cocksfoot, ryegrass and Yorkshire fog, lowest from white clover with the other herbages intermediate. In 1993/94, highest numbers were recovered from Yorkshire fog and ryegrass, lowest numbers from white clover, chicory and lucerne and intermediate from the other herbages.

The ranking values were generally consistent within herbage species for both nematode species in both years (Table 6.4) in that those herbages which ranked high for one gastrointestinal nematode species ranked high for the other gastrointestinal nematode species as well. The most notable exception was cocksfoot, which ranked relatively higher for *Ostertagia* than *Trichostrongylus* larvae recovered. There was little variation in the ranking analyses between years. The most notable exception was browntop, which ranked markedly higher in 1992/93 than in 1993/94, while tall fescue ranked somewhat higher in 1993/94 than in 1992/93.

Table 6.4. Mean ranking values of total numbers of *Ostertagia* spp. and *Trichostrongylus* spp. third stage larvae recovered from swards of herbages contaminated with faeces containing a known number of eggs. Both years. Ranking value of 1 = lowest number of larvae recovered, 9 = highest.

Herbage	1992/93			1993/94			Combined for both years
	Ostertagia	*Trichostrongylus*	Combined	*Ostertagia*	*Trichostrongylus*	Combined	
Browntop	5.65	5.41	5.56	4.56	3.75	4.00	4.78
Cocksfoot	5.45	5.13	5.43	6.06	4.48	4.81	5.12
Chicory	ND[1]	ND	ND	2.65	4.09	3.47	ND
Tall fescue	4.55	4.43	4.38	5.64	4 56	4.96	4.67
Lucerne	4.10	4.68	4.42	4.33	4.22	3.81	4.12
Prairie grass	4.44	4.55	4.42	4.92	5.59	4.83	4.63
Ryegrass	5.34	5.25	5.48	5.67	5.29	5.63	5.56
Ryegrass/white clover	ND	ND	ND	5.16	4.91	4.45	ND
White clover	4.38	4.09	4.01	4.08	3.48	3.42	3.72
Yorkshire fog	4.99	5.45	5.43	6.28	6.06	6.08	5.76
Pooled SE	0.253	0.277	0.291	0.295	0.312	0.303	0.276
Herbage effect (P<)	0.0001	0.0001	0.0001	0.009	0.02	0.009	0.0001

[1] ND - not determined.

Mean rank values (Table 6.4) were consistent with mean numbers of larvae recovered (Appendix 6.1). However, the herbage effect was not significant for numbers of *Trichostrongylus* larvae recovered in 1992/93, but was in 1993/94 and was for *Ostertagia* in both years. Overall there was a two-fold and three-fold difference in the combined numbers of *Ostertagia* and *Trichostrongylus* larvae recovered between herbage species in 1992/93 and 1993/94 respectively (Appendix 6.1). A summary of the numbers of larvae recovered from each stratum for each herbage at each collection date in each contamination is provided in Appendices 6.2 to 6.49. In addition, a summary of larval recoveries over time in each contamination, pooled over herbages, with corresponding weekly mean temperatures and weekly precipitation is shown in Appendices 6.50 to 6.57.

6.3.2. Development Success

The numbers of larvae recovered from the herbage over the 14 weeks after contamination is a measurement of larval development and larval survival. In this trial, herbages were compared for larval development in two ways: first, a herbage comparison of maximum numbers of larvae recovered, independent of time after contamination, was used as an indicator of the larval development success; and second, the time taken until maximum numbers of larvae were recovered from the herbage was compared to see if the rate of larval development differed between herbages. At the time of recovery of maximum larval numbers, usually 2-4 weeks after contamination, herbage effects on larval survival should have been minimal.

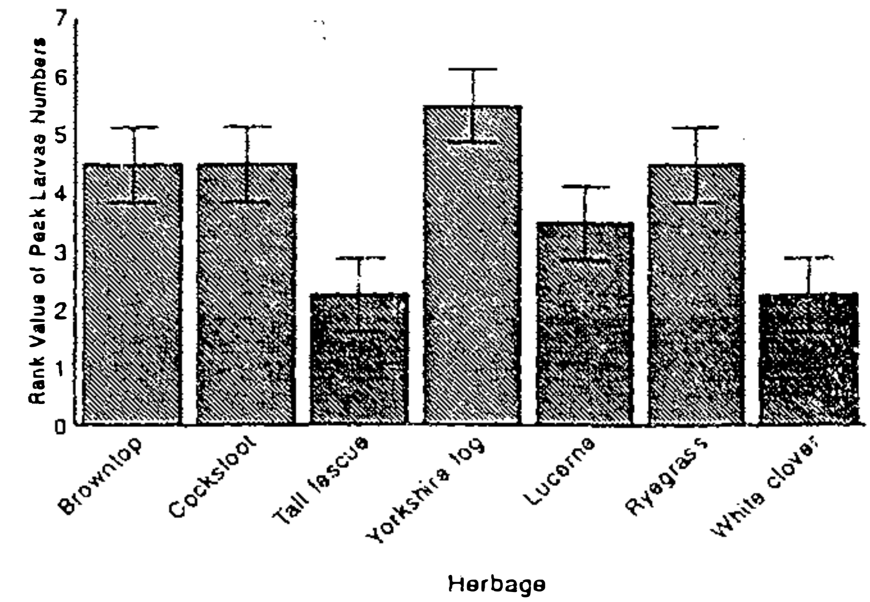
6.3.2.1. Effect of Herbage Species on Maximum Number of Larvae Recovered

A significant ($P<0.0004$, Fig 6.1) herbage effect was observed on the ranking values of the maximum numbers of combined *Ostertagia* and *Trichostrongylus* larvae recovered independent of time after contamination. The two species of nematodes were combined as there was no difference between them. Larval numbers were greatest for Yorkshire fog, intermediate for ryegrass, cocksfoot, browntop and lucerne and lowest for tall fescue and white clover. The ranking values for maximum numbers of larvae recovered agree closely with the mean ranking values of the numbers of larvae recovered at all points in time as described in 6.3.1.

6.3.2.2. Rate of Larval Development

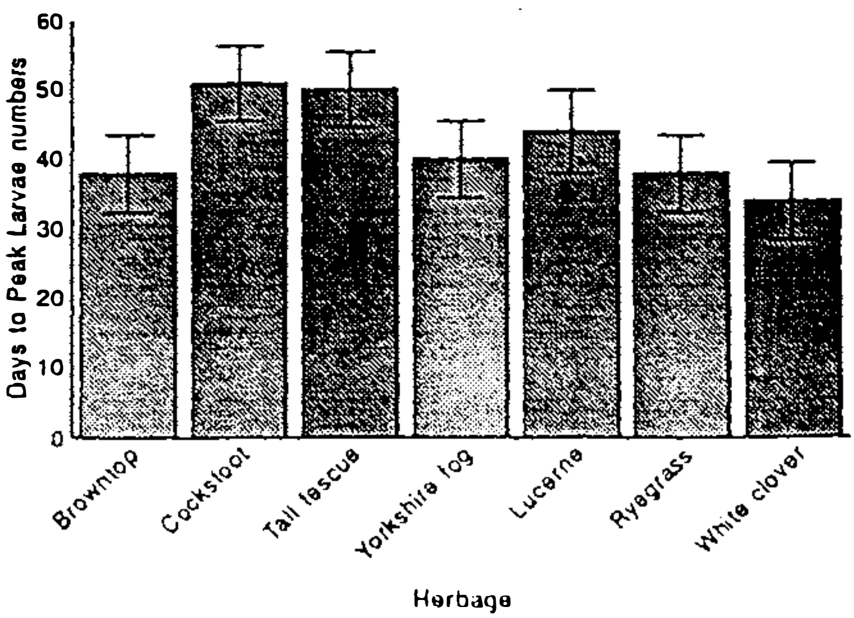
The rate of larval development did not differ significantly between herbage species ($P<0.24$) (Fig 6.2) although there was some suggestion that maximum numbers of larvae were attained earlier on white clover than on cocksfoot and tall fescue. However, there was no relationship between the time required to attain maximum numbers of larvae and the numbers of larvae recovered ($r^2 = 0.13$). This may be due to the large differences between contaminations in the time taken until maximum numbers of larvae were recovered. The time ranged from 30 days in Contamination 1 in 1992/93 to 52 days in Contamination 3 in 1992/93 (Appendices 6.50 to 6.57). Contamination 2 in 1993/94 was excluded from this analysis as there were two distinct peaks, 14 days and 98 days after the faeces were deposited on the herbage, with few larvae recovered in the intervening weeks. A mean from such a pattern would be biologically meaningless.

Figure 6.1. Ranking of maximum numbers of *Trichostrongylus* and *Ostertagia* larvae recovered. Pooled over contaminations, nematode species and years. Rank value of 1 equals the lowest number of larvae recovered



Model P=0.004

Figure 6.2. Days to peak larval numbers on herbages contaminated with eggs in lamb faeces. Pooled over contaminations, nematode species and years.



Model NS P=0.24

6.3.3. Survival of Larvae

In 1992/93, there was a suggestion of a herbage effect on the average ranking values of the rate of decline (survival) of *Ostertagia* and *Trichostrongylus* ($P<0.08$ and $P<0.16$ respectively; Table 6.5). For *Ostertagia*, survival was lowest on the prairie grass, white clover, chicory and tall fescue and greatest on cocksfoot, with all the other herbages intermediate. For *Trichostrongylus*, survival was lowest on the white clover and tall fescue and greatest on the lucerne and cocksfoot. In 1993/94, there was no significant herbage effect (Table 6.5) on the ranking values of survival of *Ostertagia* or *Trichostrongylus* larvae. The ranking values coincide well with the rate of decline of larval numbers which are shown in Appendix 6.58, which also suggests little effect of herbages on larval survival.

6.3.4. Larval Migration - Herbage Species Effects

The vertical migration of larvae in this trial is measured by the proportion of the total number of larvae on the herbage which were in the bottom stratum. Because of significant contamination effects on the proportion of larvae recovered from the bottom stratum, ranking analysis was undertaken and indicated a highly significant herbage effect for both species of nematode except for *Ostertagia* in 1992/93 (Table 6.6). Ranking values were generally greatest for Yorkshire fog (ie the

Table 6.5. Average ranking value of *Ostertagia* and *Trichostrongylus* larval survival on monospecific swards of herbages contaminated with faeces containing a known number of eggs. Lowest ranking value indicate lowest estimate of survival.

	1992/93			1993/94			
	Ostertagia	*Trichostrongylus*	Combined	*Ostertagia*	*Trichostrongylus*	Combined	Combined for both years
Browntop	4.0	5.1	4.8	3.5	4.8	3.8	3.3
Cocksfoot	7.4	6.3	7.0	4.5	5.2	4.2	5.5
Chicory	2.8	3.5	3.7	ND	ND	ND	5.5
Tall fescue	2.8	2.8	2.3	5.5	5.8	6.5	5.0
Lucerne	3.6	7.1	6.8	5.5	3.5	5.1	7.8
Prairie grass	1.9	4.4	4.3	6.0	4.5	4.1	5.0
Ryegrass	4.7	5.1	4.3	6.0	4.5	5.2	4.8
Ryegrass/white clover	ND[1]	ND	ND	5.0	5.5	5.6	7.3
White clover	2.5	2.4	2.6	0.5	4.2	4.5	5.3
Yorkshire fog	5.0	3.3	4.3	4.0	2.5	2.2	3.3
Pooled SE	0.17	0.31	0.32	0.46	0.39	0.37	0.36
Herbage effect	0.08	0.16	0.16	0.91	0.91	0.72	0.56
Contamination effect	0.16	0.95	0.96	0.55	0.56	0.60	0.96

[1] ND - not determined

Table 6.6. Average proportion of the total *Ostertagia* and *Trichostrongylus* third stage larvae recovered from swards of herbages which were recovered from the bottom stratum (0-2.5 cm). Ranking values.

Herbage	1992/93			1993/94			
	Ostertagia	*Trichostrongylus*	Combined	*Ostertagia*	*Trichostrongylus*	Combined	Combined for both years
Browntop	4.5	4.5	4.3	3.5	4.2	3.9	4.1
Cocksfoot	5.7	5.4	5.5	4.5	4.0	3.8	4.6
Tall fescue	3.8	4.2	4.3	4.8	4.9	4.9	4.6
Lucerne	4.2	4.2	4.6	3.4	ND	ND	4.3
Prairie grass	4.7	4.9	4.6	6.4	ND	ND	5.3
Ryegrass	4.4	4.0	4.0	5.3	3.9	4.1	4.1
Ryegrass/white clover	ND[1]	ND	ND	5.3	ND	ND	ND
White clover	3.8	3.3	3.3	4.9	3.2	4.1	3.7
Yorkshire fog	4.8	5.5	5.5	6.4	5.6	6.1	5.8
Pooled SE	0.27	0.26	0.28	0.27	0.23	0.27	0.27
Herbage effect (P<)	0.14	0.0008	0.002	0.0003	0.0001	0.005	0.0001
Contamination effect (P<)	0.99	0.99	0.99	0.97	0.03	0.02	0.11

[1] ND - not determined.

greatest proportion of larvae were in the bottom stratum), intermediate for prairie grass, cocksfoot, tall fescue, browntop, and ryegrass and was lowest for white clover. The actual proportions of total larvae recovered in each season and averaged over 8 contaminations, are shown in Appendix 6.59. The proportions of total larvae recovered in the 0-2.5 stratum were lowest in white clover, ryegrass, tall fescue and browntop, intermediate for cocksfoot, lucerne and prairie grass fog and highest for Yorkshire fog. This pattern was similar in both seasons for both species of nematode.

6.3.4.1. Larvae in Vertical Strata - Herbage Species Effects

Herbage ranking values of larval numbers in each stratum, indicated significant herbage effects in the lowest stratum in both years (as indicated in section 6.3.4.) but not in the top stratum for *Ostertagia* and *Trichostrongylus* either separately or combined (Tables 6.7 and 6.8). In 1992/93, there were significant herbage effects in the 2.5-5 cm and 5-7.5 cm strata with both species of nematode, but not in 1993/94 where herbage differences only approached significance for *Ostertagia.* Within each herbage species, there appeared to be little effect of nematode species on the ranking values in each stratum (Tables 6.7 and 6.8).

Within herbage species, in both years ranking values were lower in the upper stratum than in other strata for Yorkshire fog (proportionally fewer larvae migrated above 2.5 cm). For the other herbage species, there was either little change in the ranking values between strata (cocksfoot, tall fescue

Table 6.7. Average ranking value of *Ostertagia* and *Trichostrongylus* third stage larvae recovered from each of four vertical strata (0-2.5 cm, 2.5-5 cm, 5-7.5 cm 7.5$^+$ cm) of swards of herbages contaminated with faeces containing a known number of eggs. 1992/93.

Herbage	*Ostertagia*				*Trichostrongylus*				Combined			
	0-2.5	2.5 -5	5-7.5	7.5$^+$	0.2.5	2.5-5	5-7.5	7.5$^+$	0-2.5	2.5-5	5-7.5	7.5$^+$
Browntop	5.6	6.0	5.9	5.4	5.2	5.8	6.0	4.7	5.4	6.0	6.0	4.9
Cocksfoot	6.2	5.2	5.0	4.7	5.9	5.2	4.4	5.0	6.6	5.5	4.8	4.9
Tall fescue	4.3	4.3	4.6	4.8	4.1	3.9	4.7	5.0	4.0	3.7	4.8	5.0
Lucerne	4.1	4.1	4.1	4.7	4.7	4.3	4.5	5.2	4.4	4.0	4.3	4.9
Prairie grass	4.8	4.5	4.6	4.1	4.8	4.6	4.2	4.6	4.6	4.6	4.1	4.4
Ryegrass	5.3	4.8	5.5	5.4	4.7	5.4	5.7	5.3	5.0	5.4	5.9	5.7
White clover	3.8	4.8	4.3	4.9	3.7	4.4	4.1	4.2	3.4	4.5	4.0	4.1
Yorkshire fog	5.5	5.4	4.5	4.4	6.4	5.9	4.9	4.7	6.5	5.8	4.9	4.5
Pooled SE	0.29	0.20	0.19	0.22	0.25	0.24	0.23	0.22	0.28	0.25	0.25	0.23
Herbage effect (P<)	0.0003	0.03	0.03	0.59	0.0001	0.002	0.003	0.54	0.0001	0.0001	0.003	0.19

Table 6.8. Average ranking value of *Ostertagia* and *Trichostrongylus* third stage larvae recovered from each of four vertical strata (0-2.5 cm, 2.5-5 cm, 5-7.5 cm 7.5^{+} cm) of swards of herbages contaminated with faeces containing a known number of eggs. 1993/94.

Herbage	*Ostertagia*				*Trichostrongylus*				Combined			
	0-2.5	2.5 -5	5-7.5	7.5^{+}	0-2.5	2.5-5	5-7.5	7.5^{+}	0-2.5	2.5-5	5-7.5	7.5^{+}
Browntop	4.2	5.8	5.8	4.4	4.3	4.9	4.7	4.1	4.3	5.2	5.0	3.9
Cocksfoot	5.4	6.5	5.3	5.9	4.3	5.4	4.5	4.8	4.5	5.6	4.6	4.9
Tall fescue	5.6	5.5	6.3	5.0	5.5	5.0	5.0	4.7	5.4	4.5	5.1	5.0
Lucerne	4.0	5.4	5.9	5.5	4.6	3.9	4.9	4.5	4.2	4.0	5.4	4.5
Prairie grass	6.2	4.6	6.0	5.2	6.3	4.4	5.5	5.5	5.9	3.9	5.3	5.0
Ryegrass	5.9	5.8	5.6	5.3	4.8	5.3	5.5	6.1	5.0	5.6	5.1	5.8
Rye/white clover	5.9	4.4	4.5	6.6	5.1	4.7	4.4	4.9	5.1	4.2	4.2	5.4
White clover	4.1	4.9	4.7	4.9	3.0	4.3	4.4	4.3	3.1	4.3	4.5	4.5
Yorkshire fog	7.1	6.3	4.2	5.3	6.7	5.5	5.0	5.0	7.0	5.8	4.7	5.0
Pooled SE	0.29	0.31	0.30	0.29	0.28	0.29	0.29	0.29	0.28	0.29	0.29	0.29
Herbage effect (P<)	0.0003	0.16	0.10	0.20	0.0001	0.34	0.67	0.12	0.0001	0.04	0.79	0.25

and lucerne) or the changes were not consistent between years (prairie grass, ryegrass, white clover and browntop) .

6.3.5. Faecal Disappearance

6.3.5.1. Contamination Effects

There was wide variation in the rate of faecal DM disappearance between contaminations. However, in general, faeces disappeared most rapidly in the spring, late summer and autumn (Contaminations 1, 3 and 4 in both years) with most disappearing within 4 weeks. In the summer contaminations (Contamination 2), most of the faeces remained on the sward (40% and 80% of the faeces in 1992/93 and 1993/94 respectively) for the full 14 weeks of the experiment. The faecal disappearance rate by contamination, pooled over herbages is summarised in Appendices 6.50 to 6.57.

6.3.5.2. Herbage Species Effect

Despite large differences between contaminations, it appeared that there were some consistent herbage effects on faecal disappearances between contaminations. Ranking analysis of faeces remaining, pooled over years and weeks after contamination in which faeces was present, indicated that faecal disappearance was slowest on the Yorkshire fog swards, intermediate on cocksfoot, tall fescue, lucerne, prairie grass and ryegrass swards and was most rapid from the browntop and white clover swards (Table 6.9).

Within contaminations, faecal DM disappearance was more rapid in the white clover sward than in other herbages, especially after Contaminations 1 and 4 in 1993/94 and Contamination 1 in 1992/93. Conversely ryegrass (Contamination 2 in 1992/93, Contamination 1 and 4 in 1993/94) was associated with slower faecal disappearance than occurred within the other herbages (Appendices 6.62 to 6.69).

6.3.5.3. Larvae in Faeces

Ranking analysis of larvae in faeces, pooled over contaminations and weeks after contaminations in which faeces were recovered showed no significant herbage effect (Table 6.9). There was a positive correlation between herbages of numbers in larvae recovered from faeces and the amount of faeces recovered ($r^2 = 0.56$). In most contaminations, except Contamination 2 (summer) in both years, there was a rapid rise in third stage larvae recovered from faeces at week 2 and then a rapid decline to 0 by weeks 4 or 6, which coincided with the disappearance of faeces (Appendices 6.50 - 6.57). In Contamination 2 in both seasons, when some faeces remained *in situ* for the 14 week period of the trial, larvae were recovered from the faeces over the entire period. A summary of numbers of third stage larvae recovered from faeces from each herbage following each contamination is provided in Appendices 6.2 to 6.49. Generally, maximum numbers of larvae

Table 6.9. Average ranking values of faeces remaining on plots after contamination and on number of larvae in the faeces. Both years. Lowest ranking value indicates lowest amount of faeces remaining and lowest number of larvae in faeces.

Herbage	Faeces Remaining	Larvae in faeces
Browntop	3.4	4.1
Cocksfoot	5.6	4.3
Chicory	ND[1]	ND
Tall fescue	5.8	5.5
Lucerne	4.5	ND
Prairie grass	5.8	4.5
Ryegrass	6.0	5.0
Ryegrass/white clover	ND	ND
White clover	3.2	2.9
Yorkshire fog	6.9	5.7
Pooled SE	0.26	0.23
Herbage effect (P<)	0.0008	0.11
Herbage X contamination effect (P<)	0.02	0.02

[1] ND - not determined

were recovered from the faeces 2 weeks earlier than maximum numbers of larvae were recovered from herbage.

6.3.7. Larval Density - Introduction

Grazing animal feed intake is generally measured on a dry matter (DM) basis. Thus, the most appropriate measure of the potential availability of infective larvae to the grazing animal is the density of larvae/kg dry herbage. This is a function of the number of larvae recovered and herbage mass. Herbage mass, averaged over the four contaminations in each year is provided in Appendices 6.70 and 6.71, with a summary of fresh and dried herbage mass in each stratum at each point in time provided in Appendices 6.72 to 6.119.

Maximum larval density on herbage after contamination was generally at the same time or within 2 weeks of maximum larval recovery (Appendices 6.50 to 6.57). The slight differences in time taken to attain maximum densities and larval recoveries probably reflected differences in climatic conditions affecting the ability of larvae to migrate on to the herbage, and differences in herbage growth patterns between contaminations.

6.3.7.1. Ranking Analysis of Herbage Species Effects, Pooled Over Contaminations and Strata

As with larval numbers, there were significant ($P<0.001$) herbage effects in both years for ranking values of relative densities of *Ostertagia* and *Trichostrongylus* (Table 6.10). Combined over both years, larval densities were greatest for ryegrass, Yorkshire fog and cocksfoot, lowest for browntop and white clover and intermediate for all other herbage species (Table 6.10). The ranking values between herbages are similar in pattern to the average larval densities (Appendix 6.120).

The herbages generally ranked similarly (within 2 rank placings) for both *Ostertagia* and *Trichostrongylus* larval density, with the exception of lucerne and white clover in 1992/93 and cocksfoot and prairie grass in 1993/94 (Table 6.10). The ranking values of combined larval density (*Ostertagia* and *Trichostrongylus*) for browntop and cocksfoot decreased from 1992/93 to 1993/94 while the relative ranking of prairie grass increased from 1992/93 to 1993/94 due to an increased ranking for *Trichostrongylus* density.

6.3.7.2. Larval Density in Vertical Strata - Herbage Species Effects

There were significant herbage effects on the densities of combined *Ostertagia* and *Trichostrongylus* larvae in all strata in both years (Tables 6.11 and 6.12). For each nematode

Table 6.10. Mean ranking values of density of *Ostertagia* and *Trichostrongylus* third stage larvae (L_3/kg herbage DM) recovered from swards of herbages contaminated with faeces containing a known number of eggs. Both years. Ranking value of 1 = lowest density of larvae, 9 = highest.

Herbage	1992/93			1993/94			Combined for both years
	Ostertagia	*Trichostrongylus*	Combined	*Ostertagia*	*Trichostrongylus*	Combined	
Browntop	6.11	5.23	5.06	2.67	2.85	2.90	3.98
Cocksfoot	6.05	5.54	5.88	5.86	4.23	4.31	5.09
Tall fescue	3.99	4.29	4.23	5.72	4.46	4.73	4.48
Lucerne	3.22	4.61	4.37	5.75	5.77	5.21	4.84
Prairie grass	4.14	4.04	4.02	5.52	6.68	5.86	4.84
Ryegrass	6.27	6.13	6.25	6.69	5.71	5.94	6.09
Rye/white clover	ND[1]	ND	ND	5.97	5.57	5.66	5.87
White clover	4.36	3.81	4.04	5.17	4.08	4.23	4.14
Yorkshire fog	5.05	5.67	5.77	5.17	5.33	5.52	5.65
Pooled SE	0.309	0.350	0.349	0.369	0.290	0.296	0.308
Herbage effect (P<)	0.0003	0.009	0.003	0.0004	0.0001	0.0004	0.0003

[1] ND - not determined

species, significant herbage effects were observed in the lower stratum but not the topmost (7.5^+) except for *Trichostrongylus* in 1993/94 (Table 6.12). Herbage effects on larval density in the middle strata were inconsistent in both years.

In 1992/93, in the lowest stratum, larval density of both species of nematode were greatest for Yorkshire fog and cocksfoot while in the upper strata they were generally greatest for browntop and ryegrass. Over all strata, larval densities were lowest for white clover. Tall fescue had low larval densities in the bottom three strata, but tended to be higher in the top stratum. For lucerne, the ranking value for *Ostertagia* larval density was markedly lower than for *Trichostrongylus* larval density in the lowest 3 strata (Table 6.11). On all other herbages, no pattern emerged.

In 1993/94, larval density in the bottom stratum, combined for both nematode species, was lowest for browntop and white clover and greatest for Yorkshire fog with the other herbages intermediate (Table 6.12). In the top stratum, larval density was greatest in the browntop, lowest in the tall fescue, ryegrass and Yorkshire fog and intermediate in the other herbages.

6.3.8. Temperature in Swards of Different Herbages Species

In all contaminations, except Contamination 4 in 1993/94, average weekly ambient temperatures were consistently above 10^0 C which is above the minimum daily average temperature required for larval development in field conditions (Vlassoff 1973a). A summary, by contamination, of average weekly temperatures and weekly precipitation is provided in Appendices 6.50 to 6.57.

Table 6.11. Average ranking value of *Ostertagia* and *Trichostrongylus* third stage larval density from each of four vertical strata (0-2.5 cm, 2.5-5 cm, 5-7.5 cm 7.5$^+$ cm) of swards of herbages contaminated with faeces containing a known number of eggs. 1992/93.

Herbage	*Ostertagia*				*Trichostrongylus*				Combined			
	0-2.5	2.5 -5	5-7.5	7.5$^+$	0-2.5	2.5-5	5-7.5	7.5$^+$	0-2.5	2.5-5	5-7.5	7.5$^+$
Browntop	4.8	5.4	5.9	5.3	4.0	4.6	5.4	4.8	3.9	4.5	5.5	5.2
Cocksfoot	6.2	5.1	5.0	4.6	5.8	5.3	4.6	4.8	6.3	5.6	4.8	4.6
Tall fescue	4.3	4.3	4.6	4.6	4.0	3.9	4.5	5.0	3.8	3.7	4.6	4.9
Lucerne	4.0	4.1	4.2	4.7	5.5	5.1	5.2	4.6	5.3	4.9	4.9	4.4
Prairie grass	5.3	4.7	4.6	3.9	5.1	4.6	4.3	4.4	5.0	4.8	4.0	4.2
Ryegrass	5.3	4.6	5.5	5.3	4.6	5.0	5.7	5.7	4.8	5.0	5.8	6.2
White clover	4.1	4.9	4.2	4.7	3.6	4.6	4.1	4.4	3.6	4.8	4.0	4.4
Yorkshire fog	5.5	5.7	4.5	4.9	6.3	5.8	4.9	4.6	6.5	5.9	4.9	4.5
Pooled SE	0.23	0.22	0.19	0.23	0.23	0.25	0.23	0.22	0.24	0.26	0.25	0.22
Herbage effect (P<)	0.006	0.17	0.06	0.61	0.0001	0.08	0.05	0.54	0.0001	0.02	0.02	0.005

Table 6.12. Average ranking value of *Ostertagia* and *Trichostrongylus* third stage larval density from each of four vertical strata (0-2.5 cm, 2.5-5 cm, 5-7.5 cm 7.5^{+} cm) of swards of herbages contaminated with faeces containing a known number of eggs. 1993/94.

Herbage	*Ostertagia*				*Trichostrongylus*				Combined			
	0-2.5	2.5 -5	5-7.5	7.5^{+}	0.2.5	2.5-5	5-7.5	7.5^{+}	0-2.5	2.5-5	5-7.5	7.5^{+}
Browntop	2.6	5.3	7.4	6.0	2.8	4.4	5.3	5.6	2.6	4.6	6.5	6.3
Cocksfoot	4.6	6.3	5.6	5.8	3.8	5.2	4.7	5.3	4.1	5.6	4.9	5.3
Tall fescue	5.1	5.1	6.2	4.8	5.2	4.7	5.0	4.3	4.9	4.4	5.1	4.4
Lucerne	5.9	6.6	5.8	4.2	ND[1]	ND	ND	ND	ND	ND	ND	ND
Prairie grass	6.5	4.9	5.3	4.6	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	6.5	5.8	5.1	4.6	5.2	5.4	5.0	5.1	5.4	5.5	4.8	4.6
Rye/white clover	6.0	4.7	3.9	5.8	ND	ND	ND	ND	ND	ND	ND	ND
White clover	5.4	5.0	4.3	6.1	3.4	4.1	4.2	4.9	3.9	4.1	4.2	5.0
Yorkshire fog	5.3	5.7	4.4	5.3	5.5	5.6	5.6	4.0	5.7	5.7	5.5	4.9
Pooled SE	0.28	0.30	0.27	0.29	0.24	0.27	0.27	0.25	0.25	0.27	0.25	0.25
Herbage effect (P<)	0.0001	0.24	0.0002	0.22	0.0001	0.28	0.30	0.01	0.0001	0.06	0.0001	0.002

[1] ND - not determined.

Condensing the information on sward temperatures over the first 5 weeks after contamination in the 1993/94 year to the average difference between maximum and minimum temperature at the base of the sward and screen temperatures, shows that there were significant herbage effects (Table 6.13). However, in Contaminations 3 and 4, over time, the max/min sward temperature either converged towards the screen reading, or the differences between the sward base and the screen readings remained relatively constant. This varied with contamination and herbage species. A summary of herbage differences between sward and screen in max/min temperatures for Contaminations 1, 3, and 4 in 1993/94 is provided in Appendices 6.123 to 6.128. Although minimum temperatures differed relatively little from screen temperatures, the maximum temperatures, with the exception of chicory, were substantially higher, ranging up to 14^{0}C higher especially in Contamination 3 (Appendices 6.123 to 6.128).

6.4 DISCUSSION

6.4.1. Introduction

In the series of contaminations, the results were analysed by ranking analysis, which removed significant contamination effects, and showed that herbage species can significantly affect the numbers of larvae which develop to the third stage, and the vertical migration of third stage larvae, but appear to have little effect on the survival of larvae. Numbers of larvae recovered were consistently greater from browntop, ryegrass and Yorkshire fog, lower from chicory, lucerne and white clover and intermediate from cocksfoot, tall fescue, and prairie grass. These results are

Table 6.13. Difference between sward base and screen temperatures for herbages at 1500 hours (maximum) and 0600 hours (minimum) in average values over 5 weeks after contamination (See appendices 6.123 to 6.128 for more details) 1993/94.

	Contamination 1		Contamination 3		Contamination 4	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Browntop	ND[1]	ND	6.6	-0.2	2.6	-1.2
Cocksfoot	ND	ND	9.3	-0.8	0.4	-0.7
Chicory	ND	ND	0.3	3.7	3.4	-0.7
Tall fescue	6.9	1.9	7.3	0.0	2.7	-1.0
Lucerne	ND	ND	4.9	0.2	-0.6	-0.3
Prairie grass	ND	ND	8.8	-0.5	3.6	-1.1
Ryegrass	6.7	0.4	8.8	-0.9	2.7	-1.1
Ryegrass/white clover	ND	ND	11.3	-1.0	2.8	-1.1
White clover	5.8	1.3	6.5	-0.2	2.4	-1.1
Yorkshire fog	ND	ND	6.8	0.8	1.3	-0.6
Pooled SE	1.21	0.51	0.38	0.16	0.12	0.10
Herbage effect (P<)	0.15	0.0001	0.0001	0.0001	0.0001	0.0001

similar to those of Moss and Vlassoff (1993) who recovered greater numbers of larvae from prairie grass and ryegrass swards than from chicory or lucerne swards. In their experiment, however, the ryegrass and prairie grass swards were not monospecific but were grass/clover mixtures with 60 and 35% white clover content (DM basis) respectively. In light of the results reported here, with some of the lowest recoveries of larvae from the pure white clover swards, the differences reported by Moss and Vlassoff (1993) might have been greater if monospecific swards had been used.

Although the experiments were not designed to determine specific mechanisms by which the differences in larval development and vertical migration may occur, associated measurements can provide indications of the factors which may alter the development and vertical migration of the larvae, and these will be discussed. These factors are summarised in Figure 6.3. First, however, the pattern of larval recovery in each contamination will be discussed.

6.4.2 Temporal Patterns Between Contaminations

In Contaminations 1, 3, and 4 in 1992/93 and Contaminations 1 and 4 in 1993/94, the general pattern of larval recovery over time was similar, in terms of the time elapsed until maximum numbers of larvae were recovered from the herbage, to that reported by others working with gastrointestinal nematodes of sheep (Gibson and Everett 1967, Gibson and Everett 1972) and with *C. oncophora* from cattle (Hertzberg *et al.* 1992). All of these studies were undertaken outdoors in a temperate climate and are thus directly comparable to the results reported here.

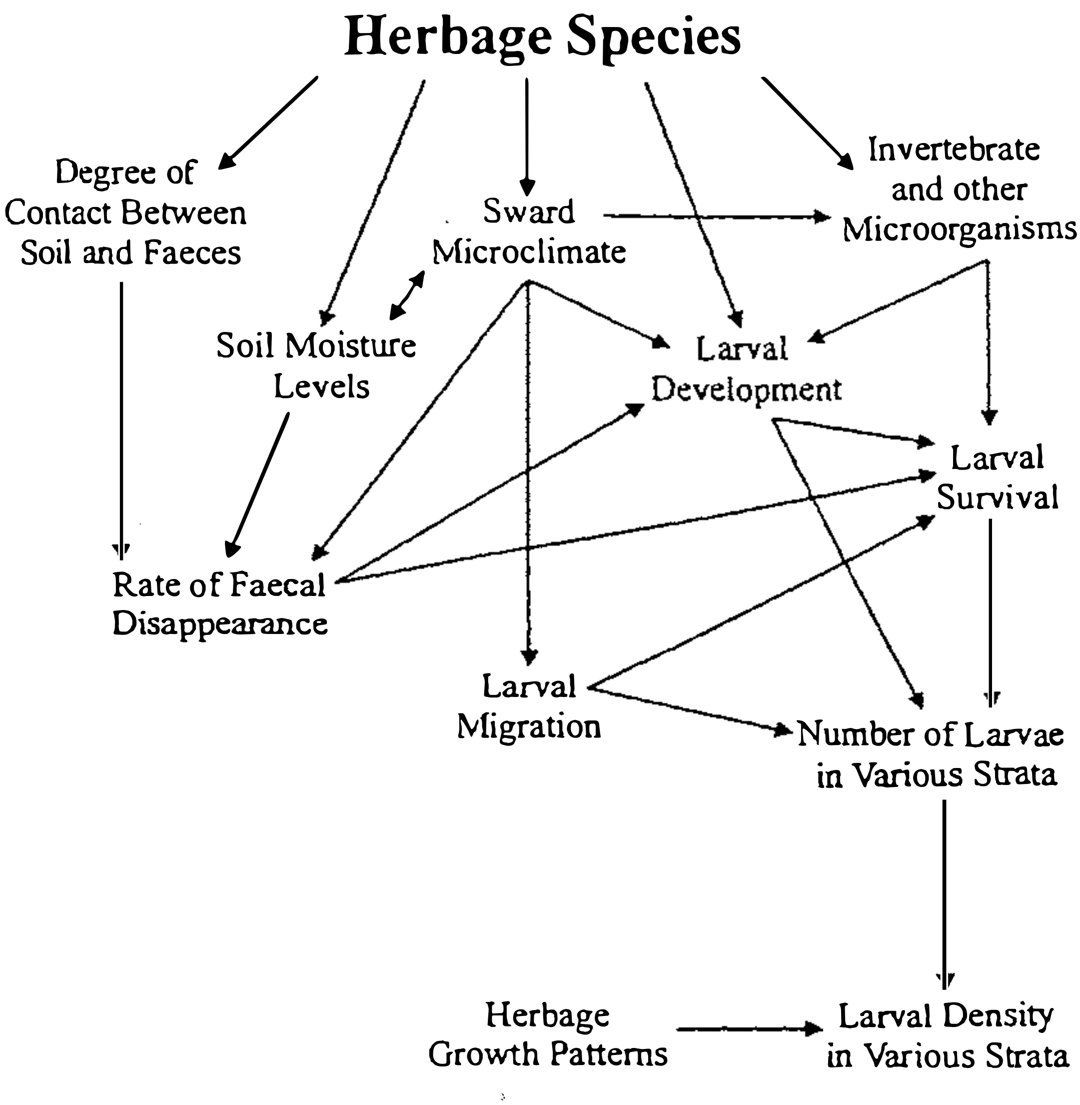


Figure 6.3. Schematic representation of the factors influencing larval development and vertical migration for different herbage species.

In both years, the most intriguing results were from the summer contaminations (Contamination 2) in that development of larvae appeared to be delayed by 4 weeks compared with spring and autumn contaminations in 1992/93, while in 1993/94 maximum numbers of larvae were recovered at weeks 2 and 14, with very few recovered in the interim. The reasons for the different results in the summer are likely to be the dry conditions experienced in both of these contaminations, as a result of which, faeces remained on the swards for the duration of the experiment (14 weeks) in both years. As larvae were always present in faeces (Appendices 6.50 to 6.57), in this series of trials the faeces acted as a reservoir of larvae which migrated from them when the conditions were appropriate as occurs with cattle faeces (Barger *et al.* 1984).

Contamination 3 in 1993/94 was remarkable for the very large numbers of third stage larvae recovered from the herbage. There are two likely contributing factors. 1) This contamination was put out on 7 March, and coincided with 30 mm of rain in the following two days (Appendix 6.56) and moderate (17^0C) average daily screen temperatures. These conditions would have been extremely conducive to larval development and migration. 2) In the preparation of the contamination, faeces were collected over a 5 day period, instead of 2 - 3 days, because of inadequate numbers of eggs being produced by the donors. As a result, over 80% of the eggs had hatched by the time the faeces were deposited on the plots. Even so, there was still a delay of 6 weeks before maximum numbers of larvae were recovered from the herbage. Development from first stage to third stage larvae was relatively rapid and by weeks 2 and 4 there were already large numbers of third stage larvae in the faeces (Appendices 6.38 and 6.39). Migration of most larvae onto the herbage occurred 1 - 2 weeks after larvae had developed to the third stage in the faeces.

6.4.3. Herbage Species Effects on Number of Larvae Recovered

The wide variation between contaminations in time to maximum larval recovery and maximum larval density meant that herbage species effects, pooled over contaminations, were underestimated. Comparisons of herbage species within and between contaminations by ranking analysis removed highly significant contamination effects on larval numbers and larval density (Tables 6.1 and 6.10).

Significant ($P<0.05$) herbage effects were observed on the ranking value (relative numbers) of larvae recovered (Table 6.1). The data indicate that either the development success (numbers of eggs which developed into third stage larvae which then migrated on to the herbage) differed between herbages or the rate of survival of larvae differed, or both. These alternatives will be discussed. It should be noted that the differentiation between larval development and survival in these experiments was artificial and less precise than when compared in experiments undertaken indoors as reported by Boag and Thomas (1985), Smith *et al.* (1986), Pandy *et al.* (1989), and Pandy *et al.* (1993).

6.4.3.1. Development of Larvae

In this series of experiments, it was decided that the best parameter for comparison of larval development success between herbage species would be the maximum number of third stage larvae recovered from the herbage at any time after faeces were deposited on the swards. This is a product of the numbers of eggs which develop into third stage larvae, an element of larval survival of third stage larvae, migration into the soil of larvae which may migrate on to herbage later, and the translation of the larvae from faeces or soil on to the herbage. This measure would tend to underestimate actual development success since it would not include those larvae which remained in the faeces and those which migrated into the soil and were not recovered within the timeframe of the trial.

Variations in larval development are likely to be caused by differences in sward micro-climate, as measured by sward temperature fluctuations, availability of moisture, differences in the rate of faecal disappearance, colonisation of the faeces by predators and pathogens, and possibly the degree of soil contact of the faeces (Fig 6.3).

The maximum numbers of larvae recovered from herbage independent of time showed a highly significant ($P<0.004$, Fig 6.1) herbage ranking effect indicating that the development success of larvae, as defined above, differed between herbage species. As the development of larvae occurs mainly in the faeces (Crofton 1963), it would appear that two possible factors were affecting larval development; 1/ the microclimate of the sward and 2/ the rate of faecal disappearance and the associated colonisation of the faeces by microorganisms. These are discussed below.

6.4.3.2. Sward Microclimate

Most of the studies on the relationship between temperature and larval development have been undertaken at constant temperatures (Ciordia and Bizzell 1963, Pandy *et al.* 1989, Pandy *et al.* 1993). While such information is essential for the basic understanding of the ecology of free living larvae of gastrointestinal nematodes, further work is needed to accurately predict larval development in swards of different herbage species in outdoor conditions where there are wide diurnal variations in the ambient temperature, sward base temperature and in the faeces on the sward. The differences in sward microclimate will play an important role in the development success of larvae.

In Contaminations 3 and 4 in 1993/94, sward maximum and minimum temperatures varied significantly (P<0.0001) between herbages species (Table 6.13). Differences in average maximum sward temperature between herbages were greater than differences in minimum sward temperature in Contaminations 3 and 4 but not Contamination 1 (Table 6.13). The difference in maximum temperatures is likely to have a greater effect on larval development success since the relationship of temperature to rate larval of development is logarithmic (Croll 1970). It has been shown that the development of *T. colubriformis* and *C. oncophora* larvae are more closely related to daily maximum than daily mean or minimum temperature (Ahluwalia 1970, Andersen *et al.* 1970). It is likely that this is also true for the development rates of *O. circumcincta* and other gastrointestinal nematode species but this appears not to have been specifically investigated.

Not only did the average maximum sward temperature differ markedly between herbage species (Table 6.13) but there was a pronounced difference in the pattern over time of average weekly maximum sward temperature, particularly in Contamination 3 (Appendices 6.125 and 6.126). For instance, amongst the grass species, the average weekly maximum sward temperature for cocksfoot was 14.5°C warmer than the screen temperature in the first week after contamination (Appendix 6.126), but this difference declined to 7.1°C by week 5. By contrast, tall fescue averaged 7.9°C above screen temperature in the first week after contamination and the difference stayed at about this level for the next 4 weeks. Differences in average maximum sward temperature occurred between the non-grass species as well. The weekly average maximum sward temperature of lucerne converged to screen temperature over the 5 weeks after contamination while the weekly average sward temperature of chicory was always similar to the weekly average maximum screen temperature for the 5 weeks after contamination (Appendix 6.126). The differences in temperature patterns may be explicable in terms of the regrowth of the herbages. For instance, cocksfoot was much shorter that tall fescue two weeks after contamination, but was of similar height by six weeks (Appendix 6.135). As the grass grew, the maximum temperature declined. Similarly, lucerne grew taller than chicory in the 6 weeks after contamination, which explains why the maximum temperature on the lucerne declined, but not on the chicory.

However, the temperature pattern between herbage species observed in Contamination 3 was not observed in Contamination 4 (Appendices 6.125 to 6.128) where maximum sward temperature of all herbages converged to the screen temperature. The major difference between contaminations was that they were undertaken at different times of the year, hence the angle of solar radiation would have been lower in Contamination 4. This may have reduced the difference between screen maximum temperature and maximum temperature at the base of the sward (Table 6.13).

The temperature differences reported between herbages as great as 9^0C in Contamination 3, would alter the rate of larval development. There has been only one study which has compared the development of larvae at constant and fluctuating temperatures. It was concluded that fluctuating temperature slowed the development of *O. circumcincta* larvae even though the average temperature was the same as the constant temperature treatment (Salih and Grainger 1982).

While large differences between sward maximum temperature and screen maximum temperature would have accelerated the rate of larval development relative to predictions from screen temperature, if the higher sward temperature went beyond optimal temperature, they may have reduced larval development success rate, with higher temperatures being potentially lethal. Also, sward temperature differences are, at best, only an indication of the differences in temperature to be expected in the faecal mass, which is where the development of larvae occurs. Temperatures within faecal pellets exposed to direct sunlight can be far higher than ambient air temperature. For example, Familton and McAnulty (1995) recorded temperatures in faeces of 55^0 C while air temperature was 17^0 C, a difference much greater than the differences between sward temperature and ambient or screen temperature reported here. The observations reported by Familton and McAnulty (1995) were recorded just after the summer solstice, when the solar radiation would be close to perpendicular, thereby maximising the amount of solar radiation absorbed by the faeces and the surrounding soil, and minimising any shading effect of herbage. Nevertheless, at 55^0 C the mortality of any larvae in the faeces would have been high.

No measurements of sward relative humidity were undertaken. Humidity may not be as important for larval development as temperature as there is usually enough moisture in the faeces of sheep to enable development of *T. colubriformis* eggs at least to the embryonated stage where they are relatively resistant to desiccation (Andersen and Levine 1968, Waller and Donald 1970). Development resumes when further moisture becomes available. This may have accounted for the delayed development of larvae in Contamination 2 in both seasons.

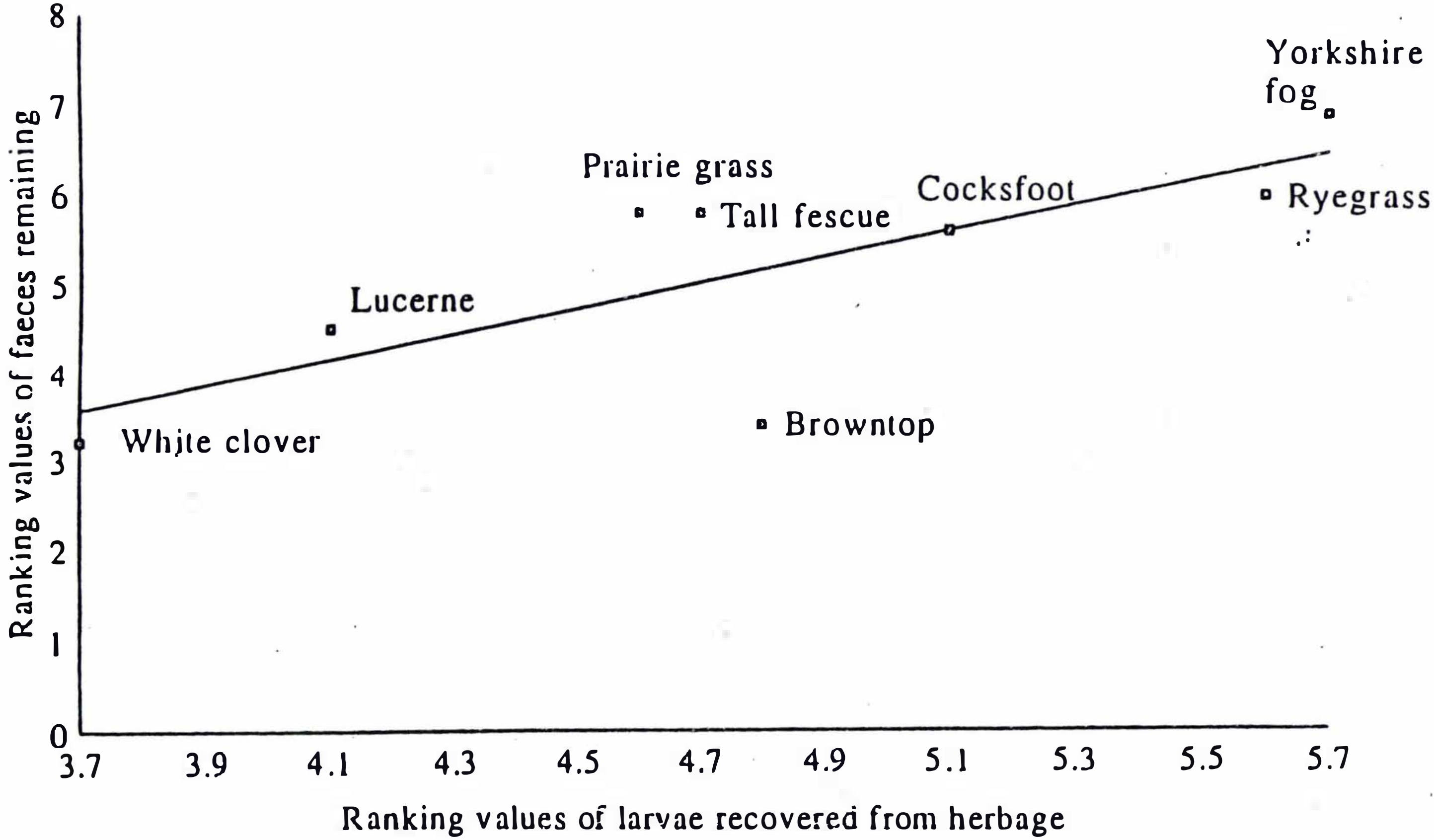
6.4.3.3. Faecal disappearance

The slower disappearance of faeces in the summer than in the spring, autumn and winter is in agreement with other observations of faecal disappearance in New Zealand (Rowarth *et al.* 1985), Western Australia (Besier and Dunsmore 1993a) and in the northern hemisphere (Christie 1963, Levine and Anderson 1973). In New Zealand, increased rate of faecal disappearance in autumn coincides with increased rainfall and greater earthworm activity (Sharpley and Syers 1977, Rowarth *et al.* 1985). However, the relative importance of the various biological organisms and processes which affect faecal disappearance is not fully understood.

From the herbages where the faeces disappeared more rapidly, there was a correspondingly lower number of larvae recovered from herbage (Fig 6.4). These larvae either died or were washed into the soil. Unfortunately, only relatively crude comparisons of faecal disappearance between herbage species were possible as, usually, only one or two measurements of faecal dry matter disappearance could be made before most of the faeces had disappeared (Appendices 6.62 to 6.69). In the extreme case of Contamination 3 in 1992/93, all the faeces had disappeared within 2 weeks (Appendix 6.52) and no estimate of herbage effect on rate of disappearance could be made. In this contamination in particular, it appears that the development of larvae was a race against faecal disappearance because larvae took two to three weeks to develop to the infective stage in Contaminations 2 in 1992/93 and Contaminations 1, 2 and 3 in 1993/94. (Appendices 6.51, 6.54, 6.55 and 6.56).

While there appear to be no previous comparisons of the rate of faecal disappearance in swards of different herbage species, it has been found in New Zealand that the rate of faecal disappearance varies between locations on the same farm. This was related to topography, faeces disappearing more rapidly from flat "camp" locations than from hillsides (Rowarth *et al.* 1985). These are areas where sheep camp and deposit more faeces. They are more fertile and likely to support greater earthworm numbers. Christie (1963), working in Scotland, concluded that earthworms were the most spectacular agents of faecal disintegration. Reports on the disappearance of cattle faecal pats also suggests earthworm involvement (Martin and Hendrie 1979, Gronvold 1987). On the other hand, Besier and Dunsmore (1993a) suggested that, in Western Australia, physical destruction by rainfall is the primary agent of faecal disappearance. In the experiments reported here, the difference in faecal disappearance between herbages appeared to be related to the number of earthworm casts observed at the time of cutting the herbage. There are greater populations of earthworms under pure white clover swards than under grass swards and far greater earthworm activity, as measured

Figure 6.4. Correlation of ranking values for faeces remaining and ranking value for number of larvae recovered from eight herbage species. Meaned within species over years, contaminations and weeks after contamination. The outlying point is browntop.



$r^2 = 0.58$

by the number of earthworm casts (Keogh 1995). This would help to explain the more rapid faecal disappearance from the white clover swards.

There may be an interaction between faecal disappearance and moisture levels in the soil. Earthworm activity is related to soil moisture content (Sharpley and Syers 1977) and it is likely that other invertebrate activity may also be related to soil or faecal moisture content. Also, softening of the faecal pellets by moisture is likely to make them more readily ingested by earthworms or other invertebrates. In Contamination 2 in both seasons when faecal disappearance was slow, the only faeces which did disappear was that which remained in contact with the soil and retained some moisture. Pellets which dried out and hardened appeared devoid of any invertebrate activity. This was particularly apparent on most of the grass swards. If moisture content is important in determining faecal disappearance, then another possible factor in the more rapid disappearance from white clover swards may be the shading effect of the herbage helping to retain moisture in faeces and soil and making the environment more attractive to earthworms and other invertebrates. Similarly, on the browntop swards, the dense foliage enclosed the faecal pellets and the moisture in them was retained. This may have led to the relatively rapid disappearance of the faeces from this sward (Table 6.9).

The importance of the rate of faecal disappearance on larval development success on the herbage is predicated on the assumption that more rapid faecal disappearance results in greater larval mortality and ultimately lowers the numbers of larvae which migrate onto herbage. Results from these experiments indicate that faeces can be a reservoir of larvae beyond the initial development phase, as there was a positive correlation between the amount of faeces remaining and the number of larvae recovered from the faeces ($r^2 = 0.56$, $P<0.05$), and larvae were recovered from the faeces for as long as faeces were present in the sward, at least 14 weeks. Also, particularly for white clover, the number of larvae recovered was lowest and the rate of faecal disappearance most rapid. However, the relation is not a simple one. The impact of rate of faecal disappearance varies for species of gastrointestinal nematode. For instance, *T. colubriformis* and *H. contortus* third stage larvae survive poorly in faeces relative to *O. circumcincta* (Gibson and Everett 1967, Gibson and Everett 1976). Thus, if faecal disappearance is accelerated, it may have a greater impact on numbers of *O. circumcincta* larvae than on numbers of *T. colubriformis*.

The role of faeces as a reservoir of larvae of cattle parasites has been well established (Anderson *et al.* 1983, Barger *et al.* 1984). Two studies have shown that fewer larvae are recovered when there is more rapid disintegration of faeces by dung beetle activity (Bryan and Kerr 1989) and earthworms (Young and Anderson 1981). However, if invertebrates do not cause faecal disappearance but only scattering of the faeces, then gastrointestinal nematode larval development may be enhanced because more oxygen may reach the developing eggs (Young *et al.* 1980), particularly during periods when climatic conditions are conducive to larval development.

While data on the disappearance of cattle faeces and the relationship to the survival of gastrointestinal nematodes may not be directly applicable to the disappearance of sheep faeces, the importance of invertebrates in the disappearance of cattle faeces strengthens the argument that invertebrates are important agents in the disappearance of sheep faeces. Also, the possibility that accelerated rates of faecal disappearance may affect some species of gastrointestinal nematodes more than others suggests that the situation in the field is highly complex. Indeed, it may not be the disappearance of faeces which causes the reduction in the number of larvae but that larval pathogens and predators colonise the faeces via the agents of faecal disappearance. Earthworms have been shown to assist in the dispersal of both beneficial and harmful microorganisms (Doube *et al.* 1993, Shapiro *et al.* 1993) and it is possible that they may assist the colonisation of faeces by nematopathogenic nematodes, nematophagous fungi, and other microorganisms. The species of nematophagous fungi which colonise faeces varies between herbage species (Hay *et al.* 1995) and, as different species of fungi have differing levels of predacious behaviour (Waller and Faedo 1993), variation in rates of success of larval development in the faeces could be affected by the species of nematophagous fungi which colonise the faeces.

6.4.3.4. Degree of Faeces Contact with Soil

The degree of contact of faeces with soil may have a significant effect on numbers of larvae which complete development to the infective stage and subsequently become available on herbage. When herbages were cut and faeces containing eggs placed on the cut swards, it was noted that the level of soil contact with faeces varied markedly between herbage species. When swards consisted of species which form discrete plants, such as lucerne, chicory, tall fescue and ryegrass, most of the faeces were in direct contact with the soil surface, in contrast with the prostrate grasses, browntop and Yorkshire fog where there was little, or no soil contact. Assuming that much of the migration of larvae follows a random pattern (Crofton 1954), then it is highly likely that on those swards in which the faeces came into contact with the soil, more larvae would have migrated into the soil compared to those swards where there was little or no contact.

The degree of soil contact may partially explain why with non-grass species, where the faeces had greater levels of soil contact, the lowest numbers of larvae were recovered from the herbage, while grasses such as browntop and Yorkshire fog, where the faeces had little contact with the soil, had the highest numbers of larvae recovered from herbage. Although the degree of ground contact was not measured directly, there appeared to be a negative relationship between the degree of soil contact and the standing herbage mass at week 2, as little herbage growth took place in the first two weeks (Appendices 6.70 and 6.71). When dry herbage mass at week 2 was correlated with the average numbers of larvae recovered from herbage, coefficients of 0.46 and 0.78 were calculated for 1992/93 and 1993/94 respectively, suggesting that decreasing contact with the soil increased the number of larvae which were ultimately recovered from the sward. Numbers of larvae recovered from herbage may be related to the herbage density as well. On swards on which there was a large herbage mass at week 2 there was simply more herbage for the larvae to migrate onto compared with swards which had little herbage mass.

Previous studies have shown that large numbers of larvae can migrate into the soil (Kauzal 1941, Rees 1950, Callinan 1978 a & b, Callinan 1979, and Callinan and Westcott 1986). However, the implications for gastrointestinal nematode epidemiology are not fully understood. Results from experiments using grass grown in pots in a glass house suggest that there is little migration of larvae from the soil onto herbage (Callinan and Westcott 1986). However, this may vary between nematode species, herbage species and soil type. Also, the short time-frame used by Callinan and Westcott (1986) (72 hours) may have been insufficient to determine temporal patterns adequately.

It is possible that a large number of the larvae which migrate into the soil may be killed by nematophagous fungi (Pandy 1973) or other agents.

6.4.4. Survival of Larvae

Given the variation in the numbers of larvae developing in each contamination, the most appropriate measure of survival of larvae was the ratio of larvae recovered at the end of the trial to the maximum number of larvae recovered at any time after the faeces were deposited divided by the time interval (days). By this measure, there was no significant herbage effect on larval survival. Once larvae have migrated on to the herbage, presumably they are less at risk from pathogens and predators and the death rate would be due primarily to desiccation or the exhaustion of metabolic reserves (Crofton 1963). Measurement of larval survival was compromised by the possibility that significant numbers of larvae migrated into the soil and may have subsequently migrated from it onto the herbage. This was not measured.

The results do not agree with the observation of better survival of *H. contortus* larvae on non-grass than grass species (Knapp 1964). However, since larvae of *H. contortus* have a lower survival rate than *Trichostrongylus* or *Ostertagia* larvae at any given temperature (Boag and Thomas 1985) they may be more affected by differences in sward conditions than either *Trichostrongylus* or *Ostertagia* larvae.

Environmental temperature and humidity have been shown to affect the survival of larvae of gastrointestinal nematodes in several studies (Andersen *et al.* 1970, Levine and Andersen 1973, Todd *et al.* 1976, Boag and Thomas 1985). By the time that maximum numbers of larvae were recovered on the herbage, and the measurement of larval survival initiated, 4 - 6 weeks after contamination, herbage regrowth was well advanced and the differences in sward maximum temperature between herbages tended to be less than when swards were recently cut (Appendices 6.123 to 6.128). As there were no differences in larval survival, but differences in larval migration (see 6.3.4.), then the causes of larval mortality on swards need to be considered. On some species of herbage, a greater proportion of larvae were recovered from the upper strata of the sward (Table 6.6), where the relative humidity is lower and the chances of desiccation greater (Crofton 1963), but the survival of larvae on such swards was similar to those in which larvae were concentrated at the base of the sward. Desiccation is associated with hot and dry conditions, and the two factors are difficult to separate in an uncontrolled environment. In tropical conditions, where conditions are warm and moist, larvae still only survive for short periods of time (40-50 days)(Banks *et al.* 1990, Aumont *et al.* 1992), suggesting that temperature may be the more important factor. Under most New Zealand conditions, the relative humidity in the sward is high (P. Newton pers comm) and might be expected to be high enough to limit mortality from desiccation; in these conditions temperature-related exhaustion of metabolic reserves is probably the major cause of mortality of third stage larvae.

As survival of larvae was unaffected by herbage species, the different levels of larval numbers on different herbage species was determined solely by the developmental success of the larvae. Thus the sward characteristics which influence the development success of larvae are likely to be of particular importance.

The herbage harvest undertaken after week 8 in 1993/94 had little impact on the survival of third stage larvae (Appendices 6.54 and 6.57). Only in Contamination 3 was there a large decline in the numbers of third stage larvae after the harvest (Appendix 6.56), but the decline observed was similar in magnitude to that observed in Contamination 2 in 1992/93 (Appendix 6.51) when no harvest was taken, suggesting that removing the herbage was not responsible. Furthermore, in terms of density of larvae, no effect whatsoever was observed (Appendices 6.41 and 6.42), even though the harvest reduced the sward to a height of 4 cm, which corresponded to an intense grazing.

6.4.5. Migration of Larvae

In both years, significant ($P<0.05$) herbage differences in rank values of the proportion of larvae in the bottom stratum of herbage were observed (Table 6.6). This agrees with the conclusion of Silangwa and Todd (1964) that larvae can migrate further on some grass species than others. One of the best illustrations of the difference in the vertical distribution profile is between larval numbers on Yorkshire fog and prairie grass and ryegrass, lucerne and white clover. In both years, Yorkshire fog and prairie grass had the greatest numbers of larvae of both species of nematodes in the bottom stratum, but on the ryegrass, white clover and lucerne swards they were far more evenly distributed across all four strata (Tables 6.7 and 6.8).

Larvae use the surface tension of moisture films on leaves to migrate vertically (Croll 1970). On the leaf surface of plants, however, there are two types of moisture accumulation, the large discrete drops formed by guttation or by rainfall and a less visible thin film of moisture formed by condensation or rain (Monteith 1963). On Yorkshire fog, the moisture film produced by dew differs markedly from that produced by guttation, with individual droplets of greater size produced by the latter (Hughes and Brimblecombe 1994). Also, drops formed through guttation form at the tips of the leaves, whereas dew is formed over the entire surface.

It was frequently observed that there was greater moisture accumulation over the night-time period on some herbage species than others. This was attributed to either dew or guttation. At the time of cutting, species such as tall fescue and cocksfoot felt dry, with little or no moisture apparent on the leaves, while Yorkshire fog, in particular, was very wet with relatively large volumes of moisture present. A similar pattern was observed in the grazing trials (Chapters 3 and 4), where, on mornings of heavy dew accumulation, the volume of condensation appeared to be greater on the Yorkshire fog swards than on the other grasses. The mechanism by which dew is formed is well-known, the amount which develops depending on atmospheric relative humidity and temperature (Monteith 1963). Less is understood about guttation. The amounts produced may vary with herbage species and may be similar to or greater than that from dew (Hughes and Brimblecombe 1994). The greater apparent volume of moisture on Yorkshire fog may also reflect the presence of large numbers of trichomes on the leaves and stems which may trap the moisture.

It is interesting, therefore, that Yorkshire fog was the grass which had the lowest level of vertical migration of all the herbages (Table 6.6) despite the fact that it was one of the grasses from which the highest numbers of larvae were recovered. This suggests that in some way larval migration was impeded, but the mechanisms involved are unknown. It is possible that either too much moisture was produced, hindering larval migration (Kauzal 1941), or the amount of visible moisture on the leaf surface has little to do with the ability of the larvae to migrate vertically. The large numbers of trichomes on the leaves of Yorkshire fog may physically interfere with larval migration or may affect the position of moisture films or condensation droplets on the leaf surface.

Differences between herbage species in distribution of moisture on leaves have been observed previously. Moisture on *Poa* spp. was found to be restricted to the base of the stems, whereas on clover, the moisture was present on all but the upper leaves of the plant (Crofton 1963). Two possibilities could account for this: differing amounts of moisture (either through condensation or guttation) formed on the different herbages, or similar amounts of moisture formed but ran down the smooth leafed *Poa* spp. If moisture runs down the smooth leafed species, it is possible that larvae may also be washed down to the base of the sward, reducing the infectivity of the swards. Further studies are needed on the relationship between leaf morphology, the nature of the moisture films and the vertical migration of gastrointestinal nematode larvae before any firm conclusions can be made on what effect varying levels of moisture may have on larval migration.

That the surface morphology of grass stems and leaves may influence larval migration was indirectly suggested by Crofton (1954) who reported that the migration of larvae was greater in narrow glass channels than wide ones, but these findings have not been related to larval migration on herbage. Yorkshire fog leaves are striated while ryegrass and tall fescue are not (Lambrechtsen 1981), which suggests that smooth leaves and stems may be more conducive to larval migration.

There are no comparisons of vertical migration between species of gastrointestinal nematode which parasitise sheep, and comparisons of the horizontal migration of species which parasitise cattle have drawn inconclusive results. One study showed that while relatively greater numbers of *C. oncophora* larvae migrated from faeces than of *O. ostertagi* or *Oesophagostomum radiatum*, horizontal migration was similar (Goldberg 1970), while in another study *O. ostertagi* larvae migrated further (laterally) from the faeces than *C. oncophora* (Gruner and Sauve 1982). The reason for the discrepancy could be related to climatic conditions or a possible interaction between herbage species and nematode species. The series of experiments reported here found little evidence of differential larval migration between *Ostertagia* and *Trichostrongylus* larvae on the same herbage indicating that conditions on the leaf surface have the same impact, at least on the two genera studied.

6.4.6. Larval Numbers and Larval Density

In terms of larval ingestion by grazing lambs, larval density, which is a function of larval numbers and herbage mass, is the most appropriate measure of pasture infectivity. The temporal pattern of larval numbers recovered and larval density varied only slightly between contaminations (Appendices 6.50 to 6.57). Also, the patterns of larval numbers and larval density did not differ greatly between herbage species (Appendices 6.2 to 6.49). However, although greater numbers of larvae were recovered from the bottom stratum than from the top stratum, larval density was either similar across all strata (1992/93, Appendix 6.137), or greater in the top stratum (1993/94 Appendix 6.138). A higher density of larvae was also reported in the upper strata than in the bottom strata in a previous study (Moss and Vlassoff 1993).

The large difference in larval density in the top strata between the 1992/93 and 1993/94 data is directly related to the amount of herbage present. The proportion of the total number of larvae recovered from the top strata was 23.9% in 1992/93 and 11.5 % in 1993/94 (Appendix 6.137) indicating that there was less vertical migration in the second year. However, because of slow herbage growth caused by dry conditions and the removal of herbage at week 8, the larval density in the upper strata was greater in 1993/94 than 1992/93 (Appendix 6.138).

6.4.7. Difference Between Gastrointestinal Nematode Species

The major difference observed between the gastrointestinal nematode species was in the fluctuation in numbers over time, particularly in 1993/94. While the numbers of *Trichostrongylus* declined significantly ($P<0.01$, Appendix 6.139) between weeks 8 and 11, no significant ($P>0.05$) decline in the numbers of *Ostertagia* was observed. This suggests that *Ostertagia* were more resilient to changes in environmental conditions than *Trichostrongylus* larvae. The other reported comparison between *O. circumcincta* and *T. colubriformis,* a synthesis of larval development and survival, did not find any evidence of differential survival between the two species (Gibson and Everett 1972). However, there are reports of greater survival of *T. colubriformis* larvae than *H. contortus* larvae (Levine *et al.* 1974, Aumont and Gruner 1989) and of differences between *T. colubriformis*, *T. rugatus* and *T. vitrinus* (Beveridge *et al.* 1989).

6.4.8. Summary.

The dynamics of *Trichostrongylus* and *Ostertagia* larvae were compared on a range of herbages over four contaminations in each of two years.

There were differences in the numbers of larvae recovered from different herbage species and in the larval density on the herbage. These were due to differences in larval development success and not to larval survival.

There were herbage differences in the vertical migration of larvae, with migration greatest on white clover, browntop, ryegrass and lucerne and least on Yorkshire fog.

There were greater numbers of larvae recovered from the bottom stratum of all herbages but there was a similar or greater density of larvae (L_3/kg DM) in the top stratum.

CHAPTER 7.

THE EFFECT OF FOUR GRASS SPECIES ON LARVAL RECOVERY FROM HERBAGE AND SOIL

7.1 INTRODUCTION

While the results from the experiments reported in Chapter 6 showed that larval development and vertical migration differed between herbage species, one of the problems was the variability in the numbers of larvae recovered between contaminations. Also, there was no estimate of the numbers of larvae which migrated into the soil under the various herbage species plots.

Differences in plant morphology and sward structure may have a large influence on the degree of contact which the deposited faeces has with the soil and the number of larvae which migrate into the soil. However, there have been no studies to determine whether the grass species onto which the faeces is deposited will influence the number of larvae which migrate onto the herbage or into the soil.

An experiment was carried out to investigate this by comparing the numbers of larvae recovered from soil and herbage, and the location of the larvae on the herbage under relatively controlled conditions in a glasshouse. The grasses compared were tall fescue, browntop, Yorkshire fog and ryegrass, the grasses used in the grazing trial described in Chapter 3.

7.2 MATERIALS AND METHODS

7.2.1. Treatments

Two "contaminations" of single grass species grown in pots were undertaken. For each contamination, 10 replicate pots (20 cm diameter) of swards of browntop (*Agrostis capillaris* cv Grasslands Muster), tall fescue (*Festuca arundinacea* cv Au Triumph), Yorkshire fog (*Holcus lanatus* cv Massey Basyn), and perennial ryegrass (*Lolium perenne* cv Grasslands Nui), were established on October 12, 1992 using commercial, sterilised potting mix (Midland No. 2). Sowing rates (Table 7.1) varied with the grass species due to differences in seed size to achieve similar seed numbers per pot. Seed was spread on to the soil by hand. Herbage growth was cut monthly to 3 cm height from the time of sowing until the experiment started.

The pots were placed in a glasshouse in which the maximum temperature was restricted to 25^0 C by control of ventilation and mist cooling (C. Bell pers. comm.). Minimum temperature was not regulated. All the pots were mist sprayed for 30 minutes every 24 hours which was equivalent to 10 mm of precipitation daily.

Prior to the faeces being deposited on 14 March and 30 May 1993, all the grasses were cut to a height of one cm. Pots were then contaminated by placing sheep faeces containing approximately 30,000 *T. colubriformis* and/or *O. circumcincta* eggs in faeces (Table 7.2) in the centre of each pot. Collection of the faeces to measure dry matter disappearance, and extraction of herbage in four strata and the top five cm of soil for larval counting was undertaken 28 days later.

Table 7.1. Mean sowing rates (g/pot) and 1000 seed weight (g) of herbages species used to compare the development and vertical migration of *Trichostrongylus colubriformis* and *Ostertagia circumcincta* larvae.

Herbage Species	Sowing rate (g seed/pot)	1000 Seed Weight (g)[1]
Browntop	0.006	0.1
Yorkshire fog	0.015	0.3
Ryegrass	0.120	2.0
Tall fescue	0.150	2.6

[1] from Charlton (1991).

Table 7.2. Date of contamination, faecal mass (g) and estimated mean numbers of *Trichostrongylus colubriformis* and *Ostertagia circumcincta* eggs applied to each of 10 pots of each herbage species in each contamination.

Contamination	March	May
Date	14/3/93	30/4/93
T. colubriformis		
Eggs	31100	23100
Faecal mass (fresh)	9.8	14.0
O. circumcincta		
Eggs	-	8100
Faecal mass (fresh)	0	14.0
Total		
Eggs	31100	31200
Faeces (fresh)	9.8	28.0

7.2.2. Collection of Faeces for Contamination

The collection of the faeces for the contaminations is described in Chapter 6 (6.2.5). The two contaminations reported here coincided with Contaminations 3 and 4 in 1992/93 of the field plot study.

Faeces were obtained from 6 Romney ram lambs, reared worm-free indoors and infected with a single dose of either 15,000 *T. colubriformis* or *O. circumcincta* larvae. Lambs were fed a mixture of chaffed meadow hay and lucerne pellets (Pelleted lucerne; Taupo Lucerne). Once the infection had become patent, faeces were collected for 24 hours in bags attached to the lambs. The faeces, which remained pelleted throughout, were removed from the bags twice daily. Faeces containing the eggs of each parasite species was thoroughly mixed and six sub-samples taken to determine the average FEC. The amount of faeces to be deposited on each pot was then determined. For each parasite species, faeces were weighed and placed in individual pottles. All faeces were weighed to within 0.2 g (1% variation) of the required weights and the weights were recorded. The faeces containing the two species were then mixed together and placed on the cut stubble. An additional six samples were weighed and dried immediately to determine initial faecal DM mass deposited.

In the March contamination, only *T. colubriformis* eggs were available because the *O. circumcincta* infection did not become patent in the donor lambs.

7.2.3. Herbage Collection

The faeces remaining after 28 days were removed, dried and weighed. Clumps of tillers were then cut with scissors at ground level. These herbage samples were then cut into 4 strata (0-2.5 cm, 2.5-5 cm, 5-7.5 cm and 7.5^{+} cm above the soil surface) and weighed fresh. Any dead herbage remaining on the soil surface was added to the 0-2.5 cm stratum. The top five cm of soil was also removed from the pot.

7.2.4. Extraction of Larvae

Larvae were recovered from the herbage as described in Chapter 5. For the recovery from soil, one cm layer of soil was placed directly onto enough Baermann funnels to extract the larvae from all the soil. The soil was placed on the sieves lined with tissues and immersed in water for 24 hours for larval extraction.

7.2.5. Statistical Analysis

Fresh herbage mass, numbers of larvae and larval density (larvae per kilogram herbage DM) were compared at each stratum in both contaminations. The numbers of larvae recovered from the soil and faecal disappearance (% DM disappearance) were compared between grass species. For all analyses least squares means were compared by analysis of variance using General Linear Models (®SAS GLM).

Preliminary analysis of faecal disappearance showed no advantage from arcsine transformation of the data.

7.3. RESULTS

Grass growth was substantially greater in the March contamination than in May with the result that total herbage mass in the latter was only 68, 50, 45 and 56% of the March mass for browntop, tall fescue, Yorkshire fog, and ryegrass respectively (Table 7.3). The greater growth in the March experiment is reflected in the relatively large herbage mass in the 7.5^{+} cm stratum in all grasses, although that for browntop was significantly lower than for the other grasses. In both contaminations, the herbage mass in the two lower strata did not differ between grasses. In the May experiment particularly, there was a substantial decline in herbage mass 5-7.5 cm above the soil, and again significant differences between grasses at 7.5^{+} cm.

In the March contamination, total fresh herbage mass was significantly lower on the browntop than on the other three grasses (Table 7.3.), while in the May experiment total herbage mass did not differ significantly across species, although total fresh herbage mass for browntop was again the lower than for the other grasses.

Table 7.3. Mean fresh herbage mass (g/pot) from four strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm above the soil surface) and total herbage mass from grasses grown in pots in a glasshouse. Each measurement is the mean of 10 pots.

	March					May				
	0-2.5	2.5-5	5-7.5	7.5^{+}	Total Mass	0-2.5	2.5-5	5-7.5	7.5^{+}	Total Mass
Browntop	29.9	20.9	17.6	45.5	113.9	38.2	19.7	9.9	9.5	77.3
Tall fescue	37.0	26.2	23.8	98.8	185.8	42.7	20.8	9.4	20.4	93.3
Yorkshire fog	34.9	26.7	24.7	109.6	195.9	46.2	22.2	9.8	11.0	89.2
Ryegrass	36.9	27.0	24.1	104.3	192.3	40.8	23.4	11.7	31.5	107.4
Pooled SE	4.1	2.4	2.1	12.7	19.5	4.3	2.1	1.1	2.8	9.1
Herbage Effect (P<)	0.53	0.20	0.07	0.003	0.02	0.58	0.60	0.39	0.0001	0.13

The total numbers of larvae recovered were about five times greater after the May contamination than after that in March (Table 7.4.). There was no significant (P>0.05) herbage effect on the total numbers of larvae recovered or the numbers recovered from each stratum, in either contamination. There was a consistent pattern in both contaminations in that the greatest proportion of total larvae recovered from the lowest stratum occurred on Yorkshire fog, while the lowest proportion occurred on tall fescue and browntop in March and tall fescue and ryegrass in May. The lowest proportion of total larvae recovered from the top stratum occurred on the Yorkshire fog and ryegrass in the March and from the Yorkshire fog and browntop in May. The highest proportion recovered in the top stratum occurred on the tall fescue and browntop in the March contamination and from tall fescue and ryegrass in May. However none of the differences were significant (P>0.05) due to the high level of variation within each grass species.

Larval density (L_3/kg fresh herbage; Table 7.5) was greater in the May contamination than in March because of the greater numbers of larvae recovered and the lower herbage growth in the former. There was no significant (P>0.05) grass species effect on the larval density in any of the strata.

Table 7.4. Mean numbers of larvae and percentage of total larvae recovered from four strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm above the soil surface) and total number of larvae recovered from grasses grown in pots in a glasshouse. Each measurement is the mean of 10 pots.

	March					May				
	0-2.5	2.5-5	5-7.5	7.5$^+$	Total Number	0-2.5	2.5-5	5-7.5	7.5$^+$	Total Number
Browntop	164 (68.3)	44 (18.3)	20 (8.30)	12 (5.0)	240	755 (57.8)	464 (35.5)	60 (4.6)	27 (2.1)	1306
Tall fescue	120 (67.4)	40 (22.5)	8 (4.5)	10 (5.6)	178	462 (34.6)	744 (55.8)	56 (4.2)	72 (5.4)	1334
Yorkshire fog	188 (81.0)	28 (12.1)	8 (3.4)	8 (3.4)	232	696 (67.8)	268 (26.1)	48 (4.7)	15 (1.5)	1027
Ryegrass	132 (76.7)	12 (7.0)	24 (14.0)	4 (2.3)	172	402 (44.7)	385 (42.8)	52 (5.8)	61 (6.8)	900
Pooled SE	63.9	18.8	7.2	6.8	75.3	161.9	151.5	26.5	31.3	249.3
Herbage Effect (P<)	0.87	0.60	0.25	0.85	0.90	0.38	0.14	0.99	0.53	0.48

Table 7.5. Mean density of larvae recovered (larvae/kg fresh herbage) from four strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm above the soil surface) and average density of larvae recovered from grasses grown in pots in a glasshouse. Each measurement is the mean of 10 pots.

	March					May				
	0-2.5	2.5-5	5-7.5	7.5$^+$	Average Density	0-2.5	2.5-5	5-7.5	7.5$^+$	Average Density
Browntop	5540	1947	1012	1259	2269	19597	23710	6554	4557	15608
Tall fescue	3032	1614	377	102	1476	10094	32289	5550	4585	14129
Yorkshire fog	8619	1304	277	93	1756	14394	12516	3631	1468	11323
Ryegrass	3646	494	853	54	886	11426	15138	4522	1461	9136
Pooled SE	3006	772	311	660	595.5	3734	6408	2231	1395	2563.6
Herbage Effect (P<)	0.55	0.57	0.24	0.47	0.18	0.36	0.13	0.78	0.20	0.39

Faecal disappearance (Table 7.6.) did not differ significantly (P>0.05) between grass species in either contamination. In the May contamination, more faeces disappeared than in March (90 *vs* 75-85%) even though the faecal mass applied in May was far greater (Table 7.2). In the second contamination, the faeces were colonised by the larvae of the moth *Opogna omoscopa*. The numbers of larvae recovered from the soil were greater in the May contamination than in the March one, as would be expected given the higher total numbers which developed. In both contaminations, the mean numbers of larvae recovered from soil were lower for the ryegrass treatment than from the other grass species but the differences were not significant (P>0.05; Table 7.6). The proportion of total larvae recovered from soil was least from ryegrass in the March contamination and lowest from ryegrass and tall fescue in May. Overall, the numbers of larvae recovered from the soil represented from 37-63% of all larvae recovered.

7.4 DISCUSSION

This study showed that a large proportion (37-63%) of the total numbers of larvae could be recovered from the soil, but it was not possible to distinguish between larvae in the soil and those on the soil surface (Table 7.6). Recovery of larvae was only made from the top 5 cm of soil. Future studies should extract larvae from a greater depth of soil; and it is then possible that an even greater number will be recovered because the larvae have the ability to migrate at least 15 cm

Table 7.6. Faecal disappearance and numbers of larvae recovered from the top 5 cm of soil (values in parentheses are the percentage of total larvae recovered (soil and herbage)) from grasses grown in pots in a glasshouse. Each measurement is the mean of 10 pots.

	March		May	
	Faecal Disappearance (%)	Larvae in Soil	Faecal Disappearance (%)	Larvae in Soil
Browntop	74.5	303 (56.2)	93.2	901 (44.0)
Tall fescue	79.6	300 (63.0)	91.2	788 (37.8)
Yorkshire fog	81.2	201 (48.2)	91.4	905 (46.8)
Ryegrass	84.6	134 (43.8)	91.4	512 (39.6)
Pooled SE	4.65	14.6	1.10	220.8
Herbage Effect (P<)	0.46	0.17	0.47	0.52

into the soil (Krecek and Murrell 1988). That relatively large numbers of larvae could be recovered from the soil, taken together with evidence of the re-emergence of larvae from soil as observed by Krececk and Murrell (1988) and possibly observed in Contamination 2 in 1993/94 described in Chapter 6 (Appendix 6.55) suggests that the soil can at certain times act as a reservoir of larvae, from which they can re-emerge on to herbage when the conditions are right. In the New Zealand context, whether they can re-emerge from the soil and, if so, the conditions which are most conducive to emergence should be investigated.

The proportion of the total larval population recovered from the soil was far less than reported by Callinan and Westcott (1986) who recovered eight times as many larvae from the soil as from the herbage. However, they applied the third stage larvae in water directly to the soil surface at the base of the sward. With the larvae in immediate, direct contact with the soil, the probability of them migrating directly into the soil must be far greater than after placing faeces containing eggs on freshly cut swards.

This experiment and that of Callinan and Westcott (1986), both carried out indoors using sterilised soil, showed substantial numbers of larvae in the soil. By contrast, field studies on unsterilised soil (Andersen *et al.* 1970, Rose and Small 1985). showed that the soil was not a significant reservoir of larvae (<5% of total numbers). Sterilisation of the soil will remove predators or pathogens of the larvae, for example, nematophagous fungi (Pandey 1973, Waller 1992). Under field conditions, soil may be less of a potential reservoir of larvae than suggested by pot experiments.

Rowarth *et al* (1985) found that sheep faeces in New Zealand disappeared in 14-17 days in the autumn months, whereas in the current experiment some faeces were still remaining after 28 days, even though conditions were continuously moist. In the experiment reported here, there was greater disappearance of faeces in May despite a greater mass being applied. This was largely attributable to the activity of the larvae of the moth *Opogna omoscopa*, which caused the destruction of the pellets and dispersal of the faeces. As a result, after 28 days it was difficult to separate the faeces from the soil and to properly estimate the rate of faecal disappearance. However, due to the warm, moist conditions in the glasshouse, this should have had little impact on the development or survival of the larvae. There is no suggestion that the moth larvae are predators of gastrointestinal nematode larvae. That more larvae were recovered in the May contamination may have been due to the faecal dispersion exposing more eggs to oxygen levels required for development than would be the case in water-saturated faecal pellets. The other possibility is that as the weather was warmer in the March contamination (Appendices 6.51 and 6.53) which would have resulted in overall warmer conditions in the glasshouse, many of the larvae may have died by 28 days having exhausted their stored metabolites. Conversely the cooler conditions in May could have slowed the development of the larvae and increased survival. As only one sampling after contamination was undertaken, this could not be tested.

The differences in the proportions of total larvae in the lowest and highest strata, particularly between the tall fescue and the Yorkshire fog, suggest that vertical migration may be greater on tall fescue than on Yorkshire fog. This agrees with the results described in Chapter 6 where vertical migration was also greater on tall fescue than Yorkshire fog. Differential vertical migration on different grass species has been reported for larvae of the nematode species which infect cattle (Silangwa and Todd 1964). In that experiment, larvae migrated farther on tall fescue than smooth brome grass. The reason for the increased migration on tall fescue as reported in that experiment and observed in the current experiment is unknown. It is possible that the striations in the leaf of tall fescue (Lambrechtsen 1981) are of a width which facilitates larval migration (Crofton 1954) or that the trichomes present on the Yorkshire fog either physically impede larval migration, or indirectly slow migration by affecting the formation and extent of water films which may reduce larval migration. More intensive, controlled studies are required to investigate this.

In this study there were no significant grass effects on larval density (Table 7.5). The most interesting feature of these results was that larval density on all grasses declined in the upper strata in contrast to the results of Chapter 6 where, in the corresponding contamination, cut at the same time, larval density was similar across all strata or increased in the upper strata (Appendices 6.15 and 6.21). It is possible that the daily spraying may have washed the larvae down the herbage, increasing the larval density in the bottom stratum.

CHAPTER 8

GENERAL DISCUSSION

8.1. INTRODUCTION

The studies reported in this thesis show that herbage species can affect nematode burdens in grazing lambs (Chapters 3 and 4), the recovery of larvae from herbage (Chapter 5), and successful development and migration of larvae on to herbage (Chapter 6). The reductions in growth of lambs attributable to parasitism varied between grass species, with production losses least in lambs which grazed swards of Yorkshire fog compared to other grass swards (Chapters 3 and 4). In terms of the parasite-environment relationships summarised in Figure 8.1, virtually all the interrelationships of the nematode lifecycle were shown to be affected by pasture species. As well, herbage species may affect larval ingestion through changes in ingestive behaviour of lambs and larval establishment in lambs.

In the experiments reported in this thesis, a range of techniques was used to evaluate lamb parasitism and the development, survival and migration of nematode larvae. The validity of these techniques and the conclusions which can be drawn from them are assessed briefly before considering the experimental results in more detail.

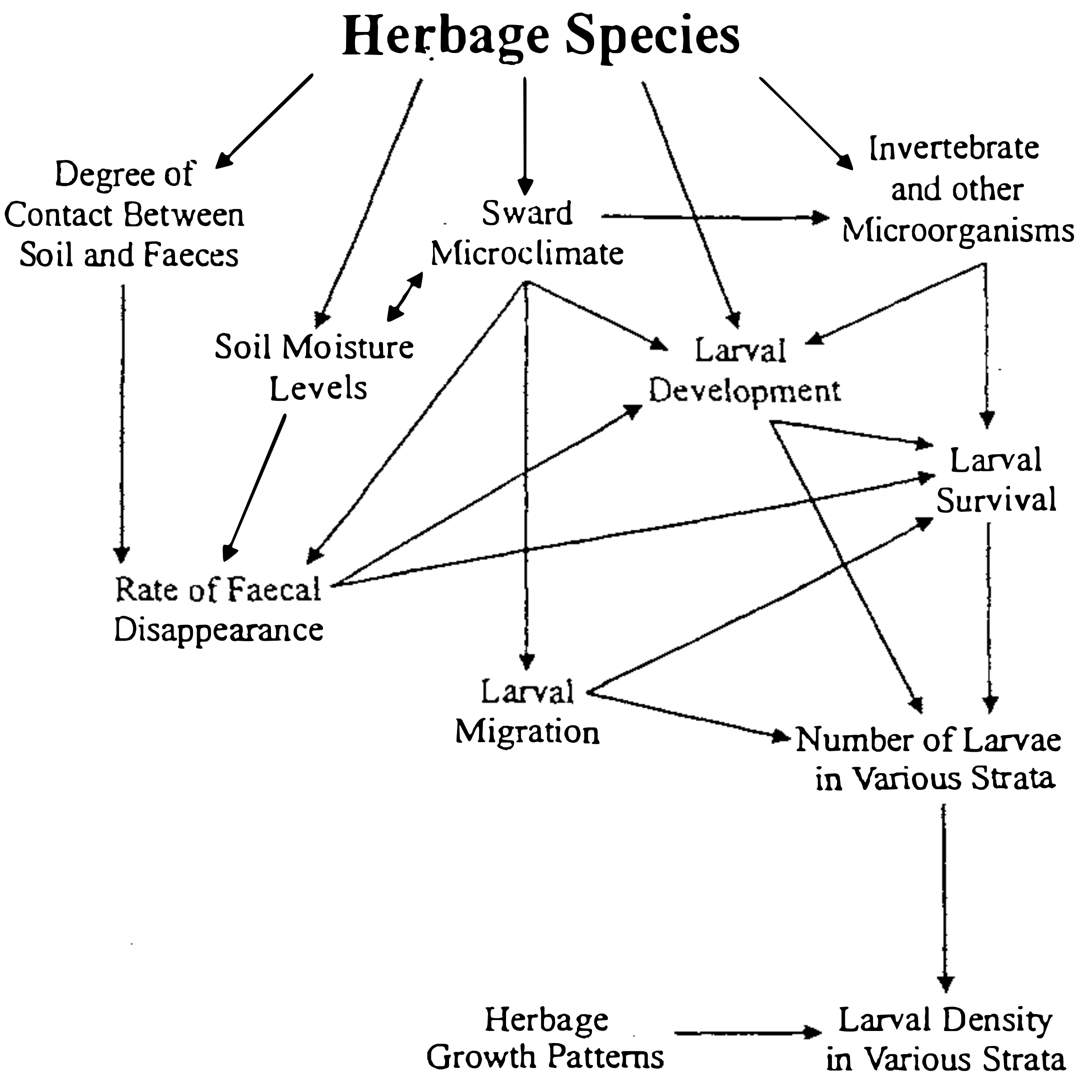


Figure 8.1. Diagrammatic representation of parasite-environment interactions. As in Figure 6.3.

8.2. EXPERIMENTAL TECHNIQUES

8.2.1. General

The grazing trials were not replicated and the results of the trials reported in Chapters 3 and 4 individually have to be treated with some caution. However, the consistent differences in tracer lamb worm burdens observed between years in the experiment reported in Chapter 3, the consistently lower tracer lamb worm burdens from Yorkshire fog swards than tall fescue swards observed in the experiment reported in Chapter 4, and the consistency in lamb parasitism between tall fescue and Yorkshire fog observed in both trials, strongly suggest an inherent grass effect. These results are reinforced by the fact that in both trials treatments were randomised on adjacent plots which had been parts of larger paddocks before the trials started, were on similar soil types and had not had any larval contamination in the previous year.

While the findings of the studies reported in Chapters 3 and 4 individually are not definitive, taken as a whole, they provide reasonable evidence that herbage species can have a marked effect on parasitism independent of stocking rate. If the results of the tracer lamb worm burdens from the trials reported in Chapters 3 and 4 are pooled over space and time, there are 5 replicates (paddock within year) of Yorkshire fog and tall fescue and two replicates of browntop and ryegrass, which can be analysed in an unbalanced design. The herbage effect on tracer lamb worm burdens then becomes highly significant ($P<0.002$, Table 8.1). The exercise can be extended further by specifically focussing on Yorkshire fog and tall fescue for which 5 replicates exist. Tracer lambs which grazed tall fescue had double the total worm burdens of tracer lambs which grazed

Yorkshire fog (2292 vs 1098 P<0.03). Thus over a wide range of stocking rates, Yorkshire fog resulted in tracer lamb worm burdens only half of those measured on tall fescue. Stocking rate was higher on the tall fescue than Yorkshire fog in the trial reported in Chapter 3, while in the trial reported in Chapter 4 stocking rate was slightly higher on the Yorkshire fog than tall fescue at all three sward heights. This comparison provides further evidence that grass species can have a significant effect on tracer lamb worm burdens and is consistent over and within years. While such an exercise could also be used to compare lamb performance between grasses, the varying levels of lamb mortalities between grass treatments would make overall comparison more difficult.

Table 8.1. Average tracer lamb worm burden and average herbage allowance (kg DM/kg lamb liveweight) for grasses used in the trial reported in Chapter 3 and Chapter 4.

Grass	Number of replicates (paddocks within years)	Tracer lamb worm burden	Herbage allowance
Browntop	2	4576[a2]	4.6
Tall fescue	5	2292[b]	3.4
Yorkshire fog	5	1098[c]	4.0
Ryegrass	2	1528[b]	2.8
Pooled SE		246.9	ND[1]
Herbage effect		0.002	ND

[1] ND - not determined

[2.] Values with differing superscripts differ (P<0.05).

One of the issues raised in the discussion of Chapter 3 was the possibility that the different stocking rates between grass species may have confounded the results. Although there was a general pattern in the trial reported in Chapter 4 of increasing FEC with decreasing sward height and increasing stocking rate, the increases in egg count between the 5 cm and 3 cm swards for both tall fescue and Yorkshire fog were small (Table 4.7) compared to the large differences in stocking rate between these swards (Table 4.5). In the comparison of four grass species, the differences in stocking rate were much smaller (Table 3.4), but the differences in TD lamb FEC were much larger (Tables 3.9 and 3.10). Furthermore, the tracer lamb worm burdens in lambs which grazed browntop (Fig 3.3.) were greater than in those which grazed either tall fescue or Yorkshire fog to 3 cm in the same year (Chapter 4) (Fig 4.2), despite higher stocking rates and lower sward heights on the latter two species.

Comparison between pooled mean values for tracer lamb worm burdens and herbage allowance (kg herbage/kg lamb mass) (Table 8.1.) shows a consistent relationship between these variables. There is detailed discussion of the relationships between stocking rate or herbage allowance and lamb parasitism in sections 3.4.3. and 4.4.5.. The exercise here highlights the parasite problem associated with browntop, which resulted in significantly ($P<0.05$) higher tracer lamb worm burdens in those which grazed browntop than in those which grazed the other grasses, despite the fact that the herbage allowance on browntop was the most generous of all the grasses (Table 8.1).

It is therefore concluded that the differences in stocking rates between herbage species in order to maintain swards at 5 cm height had only a minor impact on the level of parasitism in lambs, in agreement with the conclusion reached by Michel (1969). Whilst it has been assumed that increasing stocking rate increases parasitism (Bransby 1993), a lack of direct relationship between levels of parasitism and stocking rate has been observed previously. Holder (1964), Southcott *et al.*

(1970) and Scales *et al.* (1995) all found little difference in lamb parasitism associated with increased stocking rate, though Downey (1969) showed that burdens of *T. colubriformis*, but not *O. circumcincta*, increased in a direct relationship to increased stocking rate.

The measure of production losses for parasite infection used in the grazing trials underestimates the productive losses due to parasitism because production of SD lambs which graze a pasture with TD lambs will be depressed by the larval challenge emanating from eggs passed by TD lambs. Similarly, the production of TD lambs will be increased because of the reduced larval challenge when they share a pasture with SD lambs. However, the relative production losses between treatments should provide an indication of the potential production losses as measured by the difference in performance of parasite-free and parasitised lambs.

In the field studies, levels of parasitism were compared by lamb FEC and tracer lamb worm burdens. Faecal egg counts are a function of total adult worm burden, worm species composition of the burden, the fecundity of the given species at the time of sampling and the faecal output of the animal. The FEC thus provides an estimate of the current adult worm burden but does not account for any larvae which may have been ingested in the previous 2-3 weeks. There was no evidence of differences between grass species in OMI adjusted for metabolic body weight (Table 3.16) nor were there differences between grass species in nematode species composition in tracer lamb worm burden (Appendices 3.4 to 3.15). In the studies reported here, FEC provided a useful index of infection as demonstrated by comparisons with tracer lamb worm burdens.

Tracer lamb worm burdens were used as a second measure of available parasite infestation. These animals provide a synthesis of larval density on ingested herbage and establishment rate in the host. They only measure parasite infestation on herbage for the period of time the animals are grazing. It is assumed that tracer lambs have the same ingestive behaviour as resident lambs which have been grazing the swards for longer periods of time.

In the grazing experiment reported in Chapter 3, there was a consistent ratio between tracer lamb worm burden and larval density on the sward within grass species, but this ratio varied substantially between grass species (Table 3.20). A similar, though somewhat less marked pattern was observed in the experiment described in Chapter 4 (Table 4.11) on the 3 cm and 8 cm swards only. This suggests that either larval migration varied or larval establishment in tracer lambs differed between the trials reported in Chapters 3 and 4. This will be discussed in 8.3.3.

The FEC of TD lambs reflected relative worm burdens in tracer lambs between grass species remarkably well, particularly in the experiments described in Chapter 3. The only poor relationship was between tall fescue and browntop (Chapter 3), where TD lamb FEC and tracer lamb worm burdens did not match closely (Tables 3.9 and 3.10 and Figure 3.3). In the experiment described in Chapter 4 there was a poorer relationship between TD lamb FEC and tracer lamb worm burden in that on the tall fescue large differences in tracer lamb worm burdens were not reflected in large differences in TD lamb FEC. The reason for this is unknown.

In the grazing experiments reported in Chapters 3 and 4, lamb organic matter intake (OMI) was measured by the chromium dilution technique. No consistent effect of parasitism on OMI, as measured by the difference in OMI between SD and TD lambs, was observed. This is in contrast to most indoor feeding trials, where reduced OMI in parasitised lambs is commonly observed. Most trials in which anorexia has been reported have involved lambs fed pelleted feed (Sykes and Coop 1976, Sykes and Coop 1977, Steel *et al.* 1980, Steel *et al.* 1982), though the effect was also observed in one indoor feeding trial where fresh herbage was fed (Sykes *et al.* 1988). There are three major differences between indoor and outdoor trials. Firstly, the indoor trials provide more direct, precise measurements of OMI, whilst the measurements in outdoor trials are indirect and prone to greater error. Secondly, in the indoor trials, the control animals remain uninfected while in the grazing experiments reported in this thesis they faced a larval challenge even though they were treated with anthelmintic fortnightly. It is possible that larval challenge may reduce OMI and digestive efficiency although reports from indoor feeding trials do not support such a suggestion (Sykes 1994). If digestive efficiency was reduced by larval challenge, the effect would not have been identified in the standard *in vitro* analysis of samples from oesophageally fistulated sheep. Thirdly, the TD lambs were also treated with anthelmintic at approximately six-weekly intervals. However, in both experiments, the period of measurement of OMI was timed to coincide with the three weeks prior to anthelmintic treatment.

8.3. PARASITE POPULATION DYNAMICS

8.3.1. Larval Development and Survival.

It is important to reassess the results of the field studies (Chapters 3 and 4) in terms of the experiments on larval dynamics (Chapters 5, 6 and 7). Before this is done, however, a re-examination of the information generated in Chapters 5, 6 and 7 is necessary.

The larval dynamics studies were based on the recovery of larvae using a modified Baermann technique. There are weaknesses in the use of this technique, especially for comparing larval dynamics between herbage species, since it was found that there were different recovery rates between herbage species (Table 5.1). Further studies are needed to determine the reasons for differential recoveries and the fate of the larvae which were not recovered.

The larval numbers reported in Chapters 6 and 7 were not adjusted for the differential recoveries of *Trichostrongylus* larvae from herbage species reported in Chapter 5, which invites the question as to what effect such an adjustment would have. For this exercise, the recovery rates for *Ostertagia* larvae from the herbage species were assumed to be similar to those of *Trichostrongylus* larvae. Adjusted numbers of larvae recovered from herbages in each year in the experiment reported in Chapter 6, pooled over contaminations and strata, are shown in Table 8.2. These re-analyses increased the differences in herbage effects on larvae recovered, with a greater than four-fold difference in the number recovered between white clover (which had the lowest numbers recovered) and Yorkshire fog (which had the highest number), but did not alter the rankings significantly (Appendix 8.1 and Table 6.1). Adjusted recoveries for the grasses compared in Chapter 7 (Table 8.3) were less different than those compared in Chapter 6 because, in the former case, there was little difference in the recovery rates of larvae from the four grass species used (Table 5.1). While the adjusted recoveries did alter the absolute differences between the herbages, the relative values were essentially unaffected (see Tables 8.2 and 7.4). Because of this, the unadjusted values will be used for simplicity in the comparison of the results between Chapters 6 and 7. However, the potential importance of differential larval recovery to the investigation of plant species effects cannot be over-emphasised.

8.3.2. Larval Migration and Distribution

The fundamental difference between the grazing trials and the larval dynamics study was that the grazing trial was under a continuous stocking management regime, while the larval dynamics experiments were under conditions more akin to a rotational stocking regime (ie intermittent defoliation) where herbage grows for a period and is removed in a short space of time. Such differences will affect lamb ingestive behaviour (Cosgrove and Mitchell 1995) and the aspects of larval dynamics which determine larval ingestion (see 8.3.3.). If parasitism is directly related to development success of larvae, then lambs which grazed Yorkshire fog and ryegrass should have exhibited the greatest levels of parasitism (Table 8.2). However, these were the grass species on which the lambs had the lowest levels of parasitism as measured by TD lamb FEC (Table 3.10) and tracer lamb worm burdens (Figure 3.3). Conversely, tall fescue, which had the lowest

Table 8.2. Average number of *Ostertagia* and *Trichostrongylus* third stage larvae (larvae per plot) recovered from swards contaminated with faeces containing a known number of eggs. As shown in Appendix 6.1 (in parentheses) but adjusted for the rate of recovery from Table 5.1.*

Herbage	1992/93			1993/94		
	Ostertagia	*Trichostrongylus*	Combined	*Ostertagia*	*Trichostrongylus*	Combined
Browntop	87.7 (32.3)	216.6 (79.7)	304.3 (112.0)	280.2 (103.1)	1238.6 (455.8)	1518.8 (558.9)
Cocksfoot	57.3 (27.3)	134.9 (64.2)	192.2 (91.5)	250.6 (119.3)	640.1 (304.7)	890.7 (424.0)
Tall fescue	30.9 (11.4)	136.3 (50.3)	167.2 (61.7)	271.3 (100.1)	743.1 (274.2)	1014.4 (374.4)
Prairie grass	49.4 (12.3)	193.2 (48.1)	242.6 (60.4)	408.8 (101.8)	1062.7 (264.6)	1471.5 (366.4)
Ryegrass	91.6 (27.4)	208.7 (62.4)	300.3 (89.8)	432.8 (129.4)	1220.4 (364.9)	1653.0 (494.3)
White clover	32.2 (12.3)	129.7 (49.2)	161.9 (61.5)	184.8 (70.4)	397.6 (151.5)	582.4 (221.9)
Yorkshire fog	72.6 (23.3)	266.7 (85.6)	339.3 (108.9)	486.9 (156.3)	1810.8 (583.6)	2297.7 (739.9)
Pooled SE	7.02	31.8	34.0	26.8	141.6	152.8
Herbage effect (P<)	0.03	0.16	0.07	0.002	0.0005	0.0001
Contamination effect (P<)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Herbage X Contamination (P<)	0.74	0.002	0.70	0.51	0.0001	0.0001

*For actual number of eggs in Contaminations see Chapter 6, Table 6.2 and 6.3.

Table 8.3. Average numbers of *Ostertagia* and *Trichostrongylus* third stage larvae recovered (larvae per pot) from herbages grown in a glasshouse contaminated with faeces containing a known number of eggs. As shown in Table 7.4 (in parentheses) but adjusted for the rate of recovery from Table 5.1.*

	March	May
Browntop	641 (240)	3120 (1306)
Tall fescue	477 (178)	3512 (1334)
Yorkshire fog	673 (232)	3202 (1027)
Ryegrass	575 (172)	2609 (900)
Pooled SE	201.9	668.4
Herbage effect (P<)	0.69	0.42

*For actual number of eggs in Contaminations see Chapter 7, Table 7.2.

larval development success of the grasses used in the grazing experiments (Table 8.2), and might have been expected to result in the lowest parasitism in lambs, was also the grass on which the highest TD lamb FECs and second highest tracer worm burdens were observed (Table 3.10 and Figure 3.3).

It has been shown that overall larval numbers on the herbage as assessed by herbage plucks may not necessarily reflect what the grazing lamb acquires (Table 3.20). Larval migration differed between grass species (Table 6.6), as did herbage dry matter production (Appendices 6.70 to 6.119). affecting larval density in the various strata. A more appropriate estimator of larval availability to the grazing animal than overall larval numbers is the larval density in the grazing stratum. Lambs generally graze the top of the sward (Clark 1993, Cosgrove and Mitchell 1995). Thus the best approximation to the grazing zone from the larval dynamics experiments is provided by the top stratum (>7.5 cm stratum), particularly with continuous stocking (Clark 1993). If the larval density in the top stratum, a function of larval development success, herbage growth, and migration of larvae, is compared to the average density over all strata, then a relative "herbage infectivity" index can be determined which can be applied to the larval densities measured in the swards in the grazing experiments.

The average larval density in the top stratum was greater than the average larval density over all strata (Appendices 6.121 and 6.122), being 6.7, 1.7, 1.2, and 1.2 times greater in the top stratum on browntop, tall fescue, ryegrass and Yorkshire fog respectively (see 8.3.5). The larval densities of the top stratum of the swards used in the grazing trial described in Chapter 3, when corrected as discussed in Section 8.3, resulted in very high estimates of larval density in the top stratum and potentially high levels of larval intake particularly on browntop and may have contributed to the higher levels of parasitism observed in lambs which grazed it (see 8.3.3). On this basis, the tracer lamb nematode burdens would have been expected to be far higher than were observed, because the establishment rate of ingested larvae appears to be close to 50% in lambs which have not been previously infected (Niezen, Charleston and Waghorn unpublished data). The tracer lamb worm burdens in the field trials reported in this thesis seemed low when compared to results of Brunsdon (1970) and Scales *et al.* (1995), but are similar to worm burdens recovered in tracer lambs in other trials (Brunsdon 1963, Tetley 1959). Waller *et al.* (1981) concluded that worm burdens in tracer lambs under high larval challenge underestimated larval contamination on the sward. These authors used larval density measurements over the entire sward, and the results reported in Chapter 6 indicate that contamination in the upper, grazed stratum would have been even further underestimated. Unfortunately, no information was provided on the sward composition or the sward height in that experiment.

8.3.3. Larval Ingestion and Establishment

In the experiment described in Chapter 7, larval development success was observed to be lower on tall fescue than most other grasses (Appendix 6.1), which resulted in lower larval populations on tall fescue (Table 3.6) but, because of the greater migration of larvae on tall fescue, density in the top stratum was little different from ryegrass and Yorkshire fog. In the grazing experiment described in Chapter 3, on browntop not only were larval populations high (Table 3.6), but the ability of larvae to migrate resulted in very high densities in the top stratum (Table 8.4). Of the grasses compared in Chapters 3 and 4, there was a strong positive association between larval density in the top stratum and average tracer lamb worm burden.

In Chapters 3 and 4, the ratio of larval density to tracer lamb nematode burdens was compared between treatments (3.4.2 and 4.4.7). However, the larval density measured in the grazing trials was measured over the entire herbage, not just in the top stratum, which is the grazing zone in a continuously stocked situation (Clark 1993). The relationship between larval density in the top stratum and over the entire herbage can be calculated as larval density over the entire herbage was measured in the trial reported in Chapter 6 (Appendix 6.120), as was larval density in four strata (Appendices 6.121 and 6.122). When larval density in the top stratum is divided by average larval density over all strata, the resulting ratio can be multiplied against the larval density (over all strata) measured in the swards in the grazing trials to obtain an estimate of larval density in the grazing zone. The ratio of larval density in the grazing zone to tracer lamb worm burden is then an estimate of larval establishment in tracer lambs (Table 8.4). In the trial reported in Chapter 3, estimated larval establishment in lambs which grazed browntop was consistently low over both years, intermediate but slightly more variable on ryegrass and Yorkshire fog and consistently highest on tall fescue (Table 8.4). The differences in the establishment ratio appear to be inversely related to the larval challenge which is consistent with previous studies done indoors (see Barger 1986).

Both SD and TD lambs which grazed the 5 cm Roa tall fescue swards in 1992/93 (Chapter 4) had higher growth rates than SD and TD lambs which grazed the 5 cm Au Triumph tall fescue swards (Chapter 3) in the same year (Appendices 3.2 and 4.1). This probably reflects the higher N content and OMD of Roa than Au Triumph (Table 3.3 and 4.3). It is possible that the better nutritional status of lambs grazing Roa than Au Triumph helped to limit larval establishment in tracer lambs (Bown *et al.* 1991). Further studies are required to confirm these estimates and to determine mechanisms involved. However, in both trials, worm burdens were consistently lower in tracer lambs which grazed Yorkshire fog than tall fescue and the ratio differences observed between the two trials were primarily due to differences in larval density on the herbage rather than tracer lamb worm burdens.

8.3.4. Differences Between Larval Dynamics Indoors and Outdoors

The results of the larval dynamics studies undertaken outdoors (Chapter 6) and in the glass house (Chapter 7) can be compared in two ways. Firstly, a direct comparison of the results of the corresponding contaminations can be made and secondly, a more general comparison can be made of the results of all the outdoor contaminations with the results of the two experiments done in the glasshouse.

Table 8.4. Average larval density in surface stratum, average total tracer lamb worm burden and the ratio of worm burden to larval density.

	Average larval density (L_3/kg DM x 10^2)[1]	Average total worm burden[2]	Adjusted ratio
Chapter 3			
1991/92			
Browntop	592	4028	0.07
Tall fescue	75	2264	0.30
Yorkshire fog	54	785	0.14
Ryegrass	72	1581	0.22
1992/93			
Browntop	655	5123	0.08
Tall fescue	110	3005	0.27
Yorkshire fog	116	1838	0.16
Ryegrass	90	1473	0.16
Chapter 4			
1992/93			
Tall fescue 3 cm	176	3273	0.19
Tall fescue 5 cm	190	1943	0.10
Tall fescue 8 cm	47	816	0.17
Yorkshire fog 3 cm	85	1555	0.18
Yorkshire fog 5 cm	44	1418	0.32
Yorkshire fog 8 cm	68	780	0.11

[1] From Tables 3.6 and 4.4. Averages were taken over the months in which tracer lambs were grazing and adjusted for increased larval density in the top stratum (see 8.3.5).
[2] Total abomasal and intestinal worm burdens.

In the direct comparison between corresponding contaminations, the numbers of larvae recovered were greater in the glasshouse than outdoors in the corresponding cuts (Table 7.4 and Appendices 6.15 and 6.21), but larval distribution in the strata was approximately similar, with greater numbers of larvae recovered from the lower strata than the upper strata. Faecal disappearance was more rapid outdoors than indoors in the March contamination (Table 7.6 and Appendix 6.64), but was more variable in the May contamination, being more rapid outdoors for tall fescue and ryegrass but slower on browntop and Yorkshire fog (Table 7.6 and Appendix 6.65).

The reason for the lower numbers of larvae recovered outdoors was probably not related to more extremes of temperature, as the range of temperatures outdoors was compatible with larval development (Appendices 6.52 and 6.53). As discussed earlier, the sterile soil used in the glasshouse experiments may have contributed to greater numbers of larvae being recovered. It may also have been the reason for the slower rate of faecal disappearance. It is interesting to note that in the May contamination, faecal disappearance was slower outdoors on browntop and Yorkshire fog, the two grasses which form dense swards and on which faeces was not in direct contact with the soil surface.

In more general terms, under glasshouse conditions there were no significant differences in the numbers of larvae recovered from four grass species, in contrast to the results from outdoors where significant effects were observed for a wide range of herbages (Appendix 6.1). In the latter study, fewest larvae were recovered from tall fescue, intermediate numbers from browntop and ryegrass and the greatest numbers from Yorkshire fog (Appendix 6.1). In particular, there was about a two-fold difference in the numbers of larvae recovered between Yorkshire fog and tall fescue ($P<0.05$; Appendix 6.1). This indicates that indoor trials as undertaken here, with sterile soil without any invertebrates or microorganisms present, do not adequately estimate the difference in larval development success compared with outdoor trials.

Whilst the glasshouse experiments were not a reliable predictor of relative larval development success between herbage species, the patterns of larval migration observed in the outdoor and indoor experiments were similar. In both experiments vertical migration was more restricted on the

Yorkshire fog than on other herbages (Tables 6.7 and 7.1). The contrast was particularly great between Yorkshire fog and tall fescue in both experiments. Thus, even under the moist conditions experienced in the glasshouse, vertical distribution of larvae varied between grass species, suggesting that some innate characteristic of stem or leaf surface morphology had a significant bearing on the ability of larvae to migrate upwards.

8.3.5. Relationships Between the Larval Population Dynamics Studies and Grazing Trials

If the differences in larval population dynamics observed in the outdoor plot experiments (Chapter 6) could be related to the levels of lamb parasitism described in Chapters 3 and 4, then a rapid appraisal of the "parasite potential" of pastures could be based on small, relatively inexpensive larval dynamics trials.

From the data in Chapter 6, the average larval density in the top stratum was 6.7, 1.7, 1.2 and 1.2 times greater than the average density over all strata for the browntop, tall fescue, ryegrass and Yorkshire fog respectively (Appendices 6.120, 6.121 and 6.122, Table 8.4). Values of top-stratum larval densities for the different grasses agree more closely with the differences in tracer lamb worm burdens and lamb FEC's between the different grass species (Fig 3.3 and Tables 3.9 and 3.10) than values for larval development success, average number of larvae recovered, or overall larval density. The exception was the tall fescue, which had similar larval density in the top stratum to Yorkshire fog and ryegrass, but far higher TD lamb FEC and tracer lamb worm burdens possibly due to a higher establishment rate (see Table 8.4). Under a continuous stocking regime, a combination of larval vertical migration and herbage growth pattern are the most important factors likely to influence parasitism in lambs. Any grass which impedes vertical migration of larvae should result in lower levels of parasitism. Thus it is suggested that the higher levels of parasitism observed in lambs which grazed browntop was due to the far higher larval density in the top stratum of the sward than in the other grass species, reflecting limited impedance to vertical migration. It is concluded that the method described above could provide a preliminary appraisal of the "parasite potential" of swards which are grazed under a continuous socking management regime.

8.3.6. Differences Between Continuous and Discontinuous Stocking Management

The literature on the value of rotational *vs* continuous stocking for control of gastrointestinal nematode parasitism is equivocal. Under temperate conditions, Roe *et al.* (1959) and Gibson and Everett (1968) concluded that there was little difference between such grazing management systems, while Ross *et al.* (1937) and Lindahl *et al.* (1963) claimed advantages for rotational over continuous stocking. It is difficult to draw clear conclusions from these results as different rotation lengths were used in areas of differing climatic conditions. With a more comprehensive understanding of larval population dynamics, rotational grazing to minimise parasitism can be highly effective. This has been demonstrated in tropical conditions (Banks *et al.* 1990, Barger *et al.* 1994) and has been achieved by taking advantage of the short survival time of larvae on the swards, due to the high ambient temperature, and using grazing intervals which are longer than the survival time of most of the larvae.

On a continuously stocked sward, Clark (1993) concluded that the probability of a leaf being defoliated increased with a higher vertical position within the sward canopy. Thus, in a situation of continuous stocking, for larvae to be ingested they must migrate into the grazing zone. It has been concluded that the ability of larvae to concentrate in the grazing zone relates to parasitism in lambs (8.3.2.). On discontinuously stocked swards animals consume most of the plant, particularly at low herbage allowances (Scales *et al.* 1995), thereby reducing the effects of differences in larval migration. Instead, the development success of the larvae rather than their vertical migration will become the most important factor which determines larval ingestion in lambs.

Confirmation of this hypothesis comes from the results reported by Scales *et al.* (1995), in which lamb worm burdens, particularly in the second year when the trial was not affected by drought, were greatest on ryegrass, intermediate on tall fescue and cocksfoot and lowest on lucerne and chicory. The lamb worm burdens correlate better (r^2=0.82 at the low herbage allowance and r^2=0.70 on the high herbage allowance) with the total recoveries of combined *Ostertagia* and *Trichostrongylus* larvae on the various herbages in the current studies in 1993/94 (Appendix 6.1) than with measurements of migration (Table 6.6, Appendix 6.59) or relative density of larvae in the grazing zone (Appendices 6.120, 6.121, and 6.122). This strongly suggests that under a discontinuous stocking regime worm burdens in lambs are more related to the development success of the larvae than to the ability to migrate on herbage.

8.4. PARASITISM AND LAMB PRODUCTION

There was a clear difference between plant species in lamb production as measured by individual growth rates. Most notably, in both grazing studies lamb liveweight gains were greater on ryegrass than on any of the other swards. The trigger drenched (TD) lambs which grazed ryegrass were generally heavier than the suppressively drenched (SD) lambs on the other grasses. The reasons for this can not be explained simply by the nutritive value of the grass (Table 3.3), lamb OMI (Table 3.16), or levels of parasitism, which were similar to those of Yorkshire fog (Appendices 3.4 to 3.15) but by a combination of all these factors which varies with the grass species being compared (see 3.4.4).

In both grazing trials reported in this thesis (Chapters 3 and 4) there was no evidence of a reduction in herbage organic matter intake (OMI) due to parasitism, in agreement with other grazing trials (Holder 1964, Southcott *et al.* 1970, Scales *et al.* 1995), but in contrast to indoor feeding trials. While this may due to differences in measurement techniques used (see 8.2.), it highlights the need to be extremely cautious about extrapolating results obtained indoors to grazing trials.

The combination of high FEC, high lamb nematode burdens, and the high incidence of mortalities in lambs indicates that browntop is extremely conducive to gastrointestinal parasitism in lambs. This could have a substantial impact on the New Zealand sheep industry as a large proportion of hill country pastures are browntop dominant (Field and Roux 1992). It may be that the first step towards reducing gastrointestinal parasitism on such farms would be to replace browntop with a grass species such as ryegrass or Yorkshire fog which is associated with lower parasitism in lambs. While ryegrass demonstrated superior individual lamb performance, it is generally only a minor constituent of pastures in the hill country of New Zealand (Field and Roux 1993) as it does not persist well in low fertility conditions (Barker *et al.* 1993). The results from the grazing experiments indicate a marked reduction in parasitism, an increase in growth and a reduction in mortality in lambs grazing Yorkshire fog compared with those grazing browntop, particularly under continuously stocked conditions. Though the relatively high nutrient requirements of ryegrass may limit its potential for replacing browntop in hill country, Yorkshire fog does not suffer the same limitations (Levy 1970). In view of the accumulating evidence of its potential for providing some biological control of internal parasite infection, either by physical means through restricting larval vertical migration or by biochemical restriction of larval establishment in lambs, use of Yorkshire fog in these conditions deserves further study.

8.5. CONCLUSIONS

The field study reported in Chapter 3 demonstrated the benefits of ryegrass and Yorkshire fog in reducing lamb parasitism. This was attributable to the lower larval density in the upper sward structure which is subject to grazing. In Yorkshire fog this appeared to be a consequence of the larvae being less able to migrate up the herbage, while in the ryegrass it was explicable by the greater herbage mass in the grazing zone. Lamb performance was greater on ryegrass than on any other grass, but this advantage cannot be easily explained in terms of parasite burden, herbage OMI or the nutritive value of herbage ingested. Small advantages in all of these variables may explain the improved performance.

The slight differences in stocking rate between grasses compared in Chapter 3 had little impact on lamb parasitism. In Chapter 4, there were greater differences in lamb stocking rate than in the trial reported in Chapter 3 but smaller differences in lamb parasitism than observed in Chapter 3. Thus the large differences in lamb parasitism observed in Chapter 3, as measured by TD lamb FEC and tracer lambs worm burdens, were caused by the grass species which the lambs grazed.

The reduction in lamb OMI, often observed in parasitised lambs used in indoor trials, was not observed in the field studies reported in Chapters 3 and 4. The reasons for this are discussed.

Larval population dynamics between grass species were compared in a glasshouse and outdoors. It is concluded that glasshouse studies do not approximate outdoor studies for estimating larval development, but do so for estimating larval vertical migration.

Under continuous stocking management, plant species effects on parasitism were best defined in terms of the larval density in the top stratum of the sward rather than mean larval density over all strata. Conversely, under conditions akin to discontinuous stocking, larval development success is best related to lamb parasitism and migrating behaviour may be less important. It appears feasible that a relatively simple, inexpensive test can be developed which will predict the "parasite potential" of different pasture species.

In conclusion, the results reported in this thesis demonstrate that pasture species can have a major impact on gastrointestinal nematode larval dynamics and lamb parasitism. It appears entirely feasible that the selection of herbage species might be used as a method of controlling parasitism in lambs, and that plant breeding programmes could be implemented which select for traits, as yet unidentified, which reduce larval development, impede vertical migration of larvae, reduce lamb parasitism and reduce production losses due to parasitism.

REFERENCES

Abbot, E.M.; Parkins, J.J.; Holmes, P.H. 1985: Influence of dietary protein on parasite establishment on finn dorset and scottish blackface lambs given a single moderate infection of *Haemonchus contortus*. Research in Veterinary Science *38*: 6-13.

Ahluwalia, J.S. 1970. Studies on *Cooperia curticei* (Ransom 1907) a nematode parasite of sheep. PhD thesis. Massey University, Palmerston North, New Zealand.

Andersen, F.L., Levine, N.D. 1968. Effect of desiccation on the survival of the free-living stages of *Trichostrongylus colubriformis*. The Journal of Parasitology 54: 117-128.

Andersen, F.L., Levine, N.D., Boatman, P.A. 1970. Survival of third-stage *Trichostrongylus colubriformis* larvae on pasture. The Journal of Parasitology 56: 209-232.

Anderson, N., Donald, A.D., Waller, P.J. 1983. Epidemiology and control of parasitic gastroenteritis of cattle in the temperate climatic zone. *In* The Epidemiology and Control of Gastrointestinal Parasites of Cattle in Australia. Eds N. Anderson and P.J. Waller. Commonwealth Scientific and Industrial Research Organisation. pp 47-63.

Armour, J., Jarrett, W.F.H., Jennings, F.W. 1966. Experimental *Ostertagia circumcincta* infections in sheep. Development and pathogenesis of a single infection. American Journal of Veterinary Research 27: 1267-1278.

Association of Official Analytical Chemists. 1980. Official Methods of Analysis of the Association of Official Chemists. 13th Edition. A.O.A.C. Inc., Arlington, Virginia 22209, U.S.A.

Aumont, G., Gruner, L. 1989. Population evolution of the free-living stage of goat gastrointestinal nematodes on herbage under tropical conditions in Guadeloupe (French West Indies). International Journal for Parasitology 19: 539-546.

Aumont, G., Gauthier, D., Gruner, L., Matheron, G. 1992. Dynamics of the free-living populations of gastrointestinal trichostrongyles of cattle in a natural grazing system in Guadeloupe (French West Indies). Preventative Veterinary Medicine 12: 245-258.

Banks, D.J.D., Singh, R., Barger, I.A., Pratap, B., LeJambre, L.F. 1990. Development and survival of infective larvae of *Haemonchus contortus* and *Trichostrongylus colubriformis* on pasture in a tropical environment. International Journal for Parasitology 20: 155-160.

Barger, I.A. 1986. Population regulation in Trichostrongylids of ruminants. Parasitology - Quo Vadit?. Proceedings of the Sixth International Congress of Parasitology. pp 531-540.

Barger, I.A., Lewis, R.J., Brown, G.F. 1984. Survival of infective larvae of nematode parasites of cattle during drought. Veterinary Parasitology 14: 143-152.

Barger, I.A., Siale, K., Banks, D.J.D., LeJambre, L.F. 1994. Rotational grazing for control of gastrointestinal nematodes of goats in a wet tropical environment. Veterinary Parasitology 53: 109-116.

Barker, D.J., Lambert, M.G., Dymock, N., Gray, Y.S. 1993. Introduction, production and persistence of five grass species in dry hill country 5. Central Wairarapa, North Island, New Zealand. New Zealand Journal of Agricultural Research 36: 29-39.

Barth, D. 1993. Importance of methodology in the interpretation of factors affecting degradation of dung. Veterinary Parasitology 48: 99-108.

Barthram, G.T. 1986. Experimental techniques: the HFRO sward stick. In `Biennial Report 1984-85'. pp. 29-30. (Hill Farming Research Organisation: Penicuik.)

Bell, A. 1983. Dung Fungi: An Illustrated Guide to Coprophilous Fungi in New Zealand. 88 pp. Victoria University Press, Wellington.

Besier, R.B., Dunsmore, J.D. 1993a. The ecology of *Haemonchus contortus* in a winter rainfall region in Australia: the development of eggs to infective larvae. Veterinary Parasitology 45: 275-292.

Besier, R.B., Dunsmore, J.D. 1993b. The ecology of *Haemonchus contortus* in a winter rainfall region in Australia: the survival of infective larvae on pasture. Veterinary Parasitology 45: 293-306.

Beveridge, I., Pullman, A.L., Martin, R.R., Barelds, A. 1989. Effects of temperature and relative humidity on development and survival of the free-living stages of *Trichostrongylus colubriformis*, *T. rugatus* and *T. vitrinus*. Veterinary Parasitology 33: 143-153.

Bisset, S.A., Vlassoff, A., Morris, C.A., Southey, B.R., Baker, R.L., Parker, A.G.H. 1992. Heritability and genetic correlations among faecal egg counts and productivity traits in Romney sheep. New Zealand Journal of Agricultural Research. 35: 51-58.

Bisset, S.A., Morris, C.A., Squire, D.R., Hickey, S.M. and Wheeler, M. 1994. Genetics of resilience to nematode parasites in Romney sheep. New Zealand Journal of Agricultural Research *37*: 521-534.

Black, J. L., Kenny, P.A. 1984. Factors affecting diet selection by sheep. II Height and density of pasture. Australian Journal of Agricultural Research 35: 565-578.

Boag, B., Thomas, R.J. 1985. The effect of temperature on the survival of infective larvae of nematodes. The Journal of Parasitology 71: 383-384.

Bown, M.D.; Poppi, D.P.; Sykes, A.R. 1991: The effect of post-ruminal infusion of protein or energy on the pathophysiology of *Trichostrongylus colubriformis* and body composition of lambs. Australian Journal of Agricultural Research 42: 253-267.

Bransby, D.I. 1993. Effects of grazing management practices on parasite load and weight gain of beef cattle. Veterinary Parasitology 46: 215-221.

Brunsdon, R.V. 1963. The seasonal availability to grazing sheep of infective Trichostrongyle larvae on pasture. New Zealand Veterinary Journal 11: 86-89.

Brunsdon, R.V. 1964. The effect of nutrition on the establishment and persistence of the Trichostrongyle infestation. New Zealand Veterinary Journal 12: 108-111.

Brunsdon, R.V. 1970. The spring-rise phenomenon: seasonal changes in the worm burdens of breeding ewes and in the availability of pasture infection. New Zealand Veterinary Journal 18: 47-54.

Brunsdon R.V. 1982. Host/parasite interrelationships in Trichostrongylid infections. In: Control of Internal Parasites of Sheep. Ed. A.D. Ross. pp 21-24.

Brunsdon, R.V. 1988. The economic impact of nematode infection in sheep: implications for future research and control. New Zealand Society for Parasitology Inc. Miscellaneous Publication No. 1. A.C.G. Heath (Ed). pp 4-16.

Brunsdon, R.V., Kissling, R., Hosking, B.C. 1983. A survey of anthelmintic usage for sheep: time for a change? New Zealand Veterinary Journal 31: 24-29.

Bryan, R.P., Kerr, J.D. 1989. Factors affecting the survival and migration of free-living stages of pastrointestinal nematode parasites of cattle in central Queensland. Veterinary Parasitology 30: 315-326.

Burlison, A.J., Hodgson, J., Illius, A.W. 1991. Sward canopy structure and the bite dimensions and bite weight of grazing sheep. Grass and Forage Science 46: 29-38.

Callinan, A.P.L. 1978a. The ecology of the free-living stages of *Ostertagia circumcincta*. International Journal for Parasitology 8: 233-237.

Callinan, A.P.L. 1978b. The ecology of the free-living stages of *Trichostrongylus axei*. International Journal for Parasitology 8: 453-456.

Callinan, A.P.L. 1979. The ecology of the free-living stages of *Trichostrongylus vitrinus*. International Journal for Parasitology 9: 133-136.

Callinan, A.P.L., Westcott, J.M. 1986. Vertical distribution of trichostrongylid larvae on herbage and in soil. International Journal for Parasitology 16: 241-244.

Charleston, W.A.G. 1982. An introduction to gastrointestinal nematode parasites of sheep and cattle in New Zealand. In: Control of Internal Parasites of Sheep. Ed. A.D. Ross. pp 5-10.

Charlton, J.F.L. 1991. Some basic concepts of pasture seed mixes for New Zealand farms. Proceedings of the New Zealand Grasslands Association 53: 37-40.

Chestnutt, D.M.B. 1992. Effect of sward surface height on the performance of ewes and lambs continuously grazed on grass/clover and nitrogen-fertilized grass swards. Grass and Forage Science 47: 70-80.

Chiejina, S.N. 1982. Evaluation of a modified Baermann apparatus for the recovery of infective trichostrongylid larvae from herbage samples. Journal of Helminthology 56: 105-109.

Christie, M.G. 1963. The disintegration of sheep dung and the pre-parasitic stages of trichostrongylids. Journal of Comparative Pathology 73:416-423.

Ciordia, H., Bizzell, W.E., Baird, P.M., McCampbell, H.C., Vegors, H.H., Sell, O.E. 1962a. The influence of pasture type and supplemental grain feeding on numbers of gastrointestinal nematodes in beef yearlings. American Journal of Veterinary Research 23: 1001-1005.

Ciordia, H., Bizzell, W.E., Vegors, H.H., Baird, D.M., McCampbell, H.C., Sell, O.E. 1962b. The effect of three grazing intensities of winter temporary pasture on internal parasitism of beef-type yearling cattle. American Journal of Veterinary Research 23: 15-20.

Ciordia, H., Bizzell, W.E. 1963. Effect of a grain diet on development of some cattle nematode larvae. The Journal of Parasitology 49 (5): 44 (Abstract 104).

Clark, H. 1993. Influence of sward characteristics on the diet selected by grazing sheep in perennial ryegrass swards maintained at two sward heights. Proceedings of the XVII International Grassland Congress. pp 456.

Coop, R.L., Angus, K.W., Sykes, A.R. 1979. Chronic infection with *Trichostrongylus vitrinus* in sheep. Pathological changes in the small intestine. Research in Veterinary Science 26: 363-371.

Coop, R.L., Sykes, A.R., Angus, K.W. 1982. The effect of three levels of intake of *Ostertagia circumcincta* larvae on growth rate, food intake and body composition of growing lambs. Journal of Agricultural Science, Cambridge 98: 247-255.

Cosgrove, G.P., Mitchell, R.J. 1995. Effect of sward type on intake parameters during progressive defoliation by lambs. Annales de Zootechnie 44: 249 (abstract).

Couvillion, C.E. 1993. Estimation of the numbers of trichostrongylid larvae on pastures. Veterinary Parasitology 46: 197-203.

Coyne, M.J., Smith, G. 1992. The development and mortality of the free-living stages of *Haemonchus contortus* in laboratory culture. International Journal for Parasitology 22: 641-650.

Crofton, H.D. 1948. The vertical distribution of infective larvae of *Trichostrongylus retortaeformis* in relation to their habitat. Parasitology 39: 17-25.

Crofton, H.D. 1954. The vertical migration of infective larvae of strongyloid nematodes. Journal of Helminthology 28: 35-52.

Crofton, H.D. 1963. Nematode parasite population in sheep and on pasture. Technical Communication No. 35 of the Commonwealth Bureau of Helminthology. Commonwealth Agricultural Bureaux, England. 104 pp.

Croll, N.A. 1970. The behaviour of nematodes. Edward Arnold Ltd, London. 117 pp.

Dargie, J.D. 1975. Applications of radioisotope techniques to the study of red cell and plasma protein metabolism in helminth diseases of sheep. In Pathogenic processes in parasitic infections (eds. A.E.R. Taylor and R. Muller). Blackwell Scientific, Oxford. pp 1-26.

Donald, A.D. 1967. Populations of strongyloid infective larvae in pastures after sheep are removed from grazing. Australian Veterinary Journal 43: 122-128.

Donald, A.D., Axelsen, A., Morley, F.H.W., Waller P.J., Donnelly, J.R. 1979. Growth of cattle on phalaris and lucerne pastures II. Helminth parasite populations and effects of anthelmintic treatment. Veterinary Parasitology 5: 205-222.

Doube, B.M., Stephens, P.M., Davoren, C.W., Ryder, M.H. 1993. Interactions between earthworms, beneficial soil microorganisms and root pathogens. Applied Soil Ecology 1: 3-10.

Dougherty, C.T., Knapp, F.W. 1994. Oviposition and development of face flies in dung from cattle on herbage and supplemented herbage diets. Veterinary Parasitology 55: 115-127.

Downey, N.E. 1969. Grazing management in relation to Trichostrongylid infestation in lambs 2. Level of infestation associated with increased stocking rate and its effects on the host. Irish Journal of Agricultural Research 8: 375-395.

Familton, A., McAnulty, R. 1995. The epidemiology of gastrointestinal parasites of sheep - back to basics. Proceedings of the 24th Seminar of the Sheep and Beef Cattle Society. Publication No. 165. Foundation for Continuing Education of the New Zealand Veterinary Association.

Field, T., Roux, M. 1993. Pasture types and farming enterprises in New Zealand. Proceedings of the XVII International Grasslands Congress. 341-342.

Fletcher, L.R., Sutherland, B.L. 1993: Grazing ryegrass/endophyte associations and their effect on animal health and performance. pp 115-120 *in*: Proceedings of the Second International Symposium on Accremonium/grass Interactions: Plenary papers. Hume, D.E.; Latch, G.C.M.; Easton, H.S. *ed.* AgResearch, Grasslands Research Centre, Private Bag, Palmerston North, New Zealand.

Forbes, T.D.A., Hodgson, J. 1985. The reaction of grazing sheep and cattle to the presence of dung from the same or other species. Grass and Forage Science 40: 177-182.

Fraser, T.J., Cosgrove, G.P., Thomas, W.J., Steven, D.R., Hickey, M.J. 1988. Performance of 'Grasslands Puna' chicory. Proceedings of the New Zealand Grassland Association 49: 193-196.

Furman, D.P. 1944. Effects of environment upon the free-living stages of *Ostertagia circumcincta* (Stadelmann) Trichostrongylidae: II. Field experiments. American Journal of Veterinary Research 5: 147-153.

Gibson, T.E. 1965. Helminthiasis in sheep. The Veterinary Record 77:1034-1040.

Gibson, T.E., Everett, G. 1967. The ecology of the free-living stages of *Trichostrongylus colubriformis*. Parasitology 57: 533-547.

Gibson, T.E., Everett, G. 1968. A comparison of set stocking and rotational grazing for the control of Trichostrongylosis in sheep. British Veterinary Journal 124: 287-298.

Gibson, T.E., Everett, G. 1972. The ecology of the free-living stages of *Ostertagia circumcincta*. Parasitology 64: 451-460.

Gibson, T.E., Everett, G. 1976. The ecology of the free-living stages of *Haemonchus contortus*. British Veterinary Journal 132: 50-59.

Goldberg, A. 1970 Development, migration, and survival on pasture of gastrointestinal nematodes of cattle: summer contamination. Proceedings of the Helminthological Society of Washington 37: 166-169.

Gronvold, J. 1979. On the possible role of earthworms in the transmission of *Ostertagia ostertagi* third-stage larvae from feces to soil. The Journal of Parasitology 65: 831-832.

Gronvold, J. 1987. Field experiment on the ability of earthworms (Lumbricidae) to reduce the transmission of infective larvae of *Cooperia oncophora* (Trichostrongylidae) from cow pats to grass. Journal of Parasitology 73: 1133-1137.

Gruner, L., Sauve, C. 1982. The distribution of trichostrongyle infective larvae on pasture an grazing behaviour in calves. Veterinary Parasitology 11: 203-213.

Guimares, M.P., Costa, H.M.D.A., Lima. W.S., Leite, C.R. 1982. The effect of different types of pastures on helminthic infection of cows and calves. Arq. Esc. Vet. UFMG, Belo horizonte 34: 77-81.

Hansen, J.W., Zajac, A.M., Eversole, D.E., Gerken, Jr., H.J. 1989. The effect of stocking rate and parasite control on the performance of replacement beef heifers on pasture. Veterinary Parasitology 34: 103-115.

Hay, F.S., Niezen, J.H., Miller, C. 1995. Infestation of sheep dung by nematophagous fungi on plots of different pasture species. Novel Approaches to the Control of Helminth Parasites of Livestock, Armidale. (abstract)

Heath, D.D., Major, G.W. 1968. A technique for the recovery of strongyle larvae from masticated herbage. Journal of Helmintholgy 42: 299-304.

Henriksen, S.A. 1965. En forbedret teknik ved undersogelse for lungeormelarver I faeces. Nordisk Veterinary Medicine 17: 446-454.

Hertzberg, H., Schneider, T., Lopmeier, F.J., Stoye, M. 1992. The influence of weather and egg contamination on the development of third-stage larvae of *Cooperia oncophora* on pasture. International Journal for Parasitology 22: 719-730.

Hodgson, J., 1985. The significance of sward characteristics in the management of temperate sown pastures. Proceedings of the Fifteenth International Grassland Congress. Kyoto, Japan. pp 63-66.

Holder, J.M. 1964. The effect of Trichostrongylosis on pasture intake of sheep. Australian Journal of Agricultural Research 15: 408-416.

Horn, P.E., Hill, G.D. 1987. What legume is that? A guide to the identification of legumes of the sub-family Papilionoideae. Lincoln College Centre for Resource Management, Special Publication No. 5. 103 pp.

Hughes, R.N., Brimblecombe, P. 1994. Dew and guttation: formation and environmental significance. Agricultural and Forest Meteorology 67: 173-190.

Jagusch, K.T.; Rattray, P.V.; Vlassoff, A. 1980: Effects of level of nutrition and drenching strategy on pasture utilization during autumn by set - stocked hoggets infected with gastro - intestinal nematodes. Proceedings of the New Zealand Society of Animal Production 40: 12-17.

Jallow, O.A., McGregor, B.A., Anderson, N., Holmes, J.H.G. 1994. Intake of trichostrongylid larvae by goats and sheep grazing together. Australian Veterinary Journal 71: 361-364.

Jones, W.T., Mangan, J.L. 1977. Complexes of the condensed tannins of sainfoin (*Onobrychis viciifolia* Scop.) with fraction 1 leaf protein and with submaxillary mucoprotein and their reversal with polyethylene glycol and pH. Journal of the Science of Food and Agriculture 28: 126-136.

Kauzal, G.P. 1941. Examination of grass and soil to determine the population of infective larval nematodes on pastures. Australian Veterinary Journal 17: 181-184.

Keogh, R. 1995. Report to the New Zealand Meat Research and Development Council (MRDC) on project No. 91DS19/1.4. 37 pp.

Kettle, P.R., Vlassoff, A., Lukies, J.M., Ayling, J.M., McMurtry, L.W. 1981. A survey of nematode control measures used by sheep farmers and of anthelmintic resistance on their farms Part 1. North Island and the Nelson region of the South Island. New Zealand Veterinary Journal 29: 81-83.

Kettle, P.R.; Vlassoff, A.; Ayling, J.M.; McMurtry, L.W.; Smith, S.J.; Watson, A.J. 1982: A survey of nematode control measures used by sheep farmers and of anthelmintic resistance on their farms Part 2: South Island excluding the Nelson region. New Zealand Veterinary Journal *30*: 89-81.

Knapp, S.E. 1963. Effect of humidity on vertical migration of third-stage trichostrongyloids on different types of forage. The Journal of Parasitology 49 (5): 44 (Abstract 103).

Knapp, S.E. 1964: Relationship of different species of forage to the survival and infectivity of *Haemonchus contortus* in lambs. Journal of parasitology 50: 144-148.

Krecek, R.C., Murrell, K.D. 1988. Observations on the ability of larval *Ostertagia ostertagi* to migrate through pasture soil. Proceedings of the Helminthological Society, Washington 55: 24-27.

Krecek, R.C., Murrell, K.D., Douglass, L.W. 1990. Effects of microclimatic variables on the availability and movement of third-stage larvae of *Ostertagia ostertagi* on herbage. Onderstepoort Journal of Veterinary Research 57: 133-135.

Lambrechtsen, N.C. 1981. What grass is that? Aguide to identification of some introduced grasses in New Zealand by vegetative characters. New Zealand Department of Scientific and Industrial Research Information Series No. 87. 136pp.

Lancaster, M.B. 1970. The recovery of infective nematode larvae from herbage samples. Journal of Helminthology 44: 219-230.

Langer, R.H.M. 1990. Pastures their ecology and management. Oxford University Press. 499 pp.

Larsen, J.W.A., Anderson, N., Vizard, A.L., Anderson, G.A., Hoste, H. 1994. Diarrhoea in Merino ewes during winter: association with trichostrongylid larvae. Australian Veterinary Journal. 71: 365-372.

Levine, N.D., Andersen, F.L. 1973. Development and survival of *Trichostrongylus colubriformis* on pasture. The Journal of Parasitology 59: 147-165.

Levine, N.D., Todd, K.S., Boatman, P.A. 1974. Development and survival of *Haemonchus contortus* on pasture. American Journal of Veterinary Research 35: 1413-1422.

Levine, N.D., Todd, K.S. Jr. 1975. Micrometeorological factors involved in the development and sueval of free-living stages of the sheep nematodes *Haemonchus contortus* and *Trichostrongylus colubriformis*. A review. International Journal of Biometeorology 19: 174-183.

Levy, E.B. 1970. Grasslands of New Zealand. A.R. Shearer, Government Printer Wellington, New Zealand. 373pp.

Lindahl, I.L., Kates, K.C., Turner, J.H., Enzie, F.D., Whitmore, G.E. 1963. Effect of management systems on the growth of lambs and development of internal parasitism. I. Dry lot vs two pasture rotation systems. The Journal of Parasitology 49: 209-217.

Luginbuhl, J.M., Pond, K.R., Burns, J.C., Fisher, D.S. 1994. Evaluation of the Captec controlled-release chromic oxide capsule for faecal output determination in sheep. Journal of Animal Science 72: 1375-1380.

Mackay, A. 1994. Non-chemical mixed livestock systems. Annual Report on Contract No. C10 323 to the Foundation for Research Science and Technology. 104pp.

Martin, N. A., Hendrie, J. 1979. Lumbricid earthworms and cattle dung in New Zealand pastures. Proceeding of the Second Australasian Conference on the Role of Invertebrates on Nutient Cycling and Energy Flow. T.K. Crosby and R.P. Pottinger (eds). pp 1-10.

Maxwell, T.J. and Treacher, T.T. 1986. Decision rules for grazing management. In: Efficient sheep production from grass. J.E. Pollott (ed.). British Grassland Society Occasional Symposium No. 21: 67-78.

Michel, J.F. 1969. The epidemiology and control of some nematode infections of grazing animals. Advances in Parasitology 7: 211-282.

Michel, J.F. 1976. The epidemiology and control of some nematode infections in grazing animals. Advances in Parasitology 14: 355-397.

Milne, G.A., Molony, S.C., Smith, D.R. 1993. Demonstration of dryland species on 90 east coast North Island farms. Proceedings of the New Zealand Grassland Association 55: 39-44.

Monteith, J.L. 1963. Dew: facts and fallacies. In: The Water Relations of Plants. A.J. Rutter and F.H. Whitehead (Eds). pp 37-56.

Monteith, J.L., 1973. Principles of Environmental Physics. Edward Arnold Ltd. London.

Montossi, F.M., Hu, Y., Hodgson, J., Morris, S.T. 1994. Herbage intake, ingestive behaviour and diet selection in sheep grazing *Holcus lanatus* and perennial ryegrass swards. Proceedings of the New Zealand Society of Animal Production 54: 71-74.

Moss, R.A.; Vlassoff, A. 1993: Effect of herbage species on gastro-intestinal roundworm populations and their distribution. New Zealand Journal of Agricultural Research 36: 371-375.

Murwira, H.K., Kirchman, H., Swift, M.J. 1990. The effect of moisture on the decomposition rate of cattle manure. Plant and Soil. 122: 197-199.

Niezen, J.H.; Waghorn, T.S.; Waghorn, G.C.; Charleston, W.A.G. 1993: Internal parasites and lamb production - a role for plants containing condensed tannins? Proceedings of the New Zealand Society of Animal Production 53: 235-238.

Niezen, J.H., Waghorn, T.S., Raufaut, K., Robertson, H.A., McFarlane, R.G. 1994. Lamb weight gain and faecal egg count when grazing one of seven herbages and dosed with larvae for six weeks. Proceedings of the New Zealand Society of Animal Production 54: 15-18.

Niezen, J., Waghorn, T.S., Charleston, W.A.G., Waghorn, G.C. 1995. Growth and gastrointestinal nematode parasitism in lambs grazing lucerne (*Medicago sativa*) or sulla (*Hedysarum coronarium*) which contains condensed tannins. Journal of Agricultural Science, Cambridge 125: 281-289.

Pandy, V.S. 1973. Predatory activity of nematode trapping fungi against the larvae of *Trichostrongylus axei* and *Ostertagia ostertagi*: A possible method of biological control. Journal of Helminthology 47: 35-48.

Pandy, V.S., Chaer, A., Dakkak, A. 1989. Effect of temperature on the development of the free-living stages of *Ostertagia circumcincta*. Veterinary Parasitology 32: 193-197.

Pandy, V.S., Chaer, A., Dakkak, A. 1993. Effect of temperature and relative humidity on survival of eggs and infective larvae of *Ostertagia circumcincta*. Veterinary Parasitology 49: 219-227.

Parker, W.J., McCutcheon, S.N., Carr, D.H. 1989. Effect of herbage type and level of intake on the release of chromic oxide from intraruminal controlled release capsules in sheep. New Zealand Journal of Agricultural Research 32: 537-546.

Parsons, A.J. 1984. Guidelines for management of continuously grazed swards. Grass Farmer, British Grassland Society, Hurley 17: 5-9.

Peacock, J.M. 1975. Temperature and leaf growth in *Lolium perenne* I. The thermal microclimate: its measurement and relation to crop growth. Journal of Applied Ecology 12: 99-114.

Penning, P.D., Parsons, A.J., Orr, R.J., Treacher, T.T. 1991. Intake and behaviour responses by sheep to changes in sward characteristics under continuous stocking. Grass and Forage Science 46: 15-28.

Rees, G. 1950. Observations on the vertical migrations of the third-stage larva of *Haemonchus contortus* (Rud.) on experimental plots of *Lolium perenne* S24, in relation to meteorological and micrometeorological factors. Parasitology 40: 127-143.

Reinecke, R.K., Kirkpatrick, R., Kriel, A.M.D., Frank, F. 1989. Availability of infective larvae of parasitic nematodes of sheep grazing on kikuyu (*Pennisetum clandestinum*) pastures in the winter rainfall area. Onderstepoort Journal of Veterinary Research 56: 223-234.

Roberts, J.A., Adams, D.B. 1990. The effect of level of nutrition on the development of resistance to *Haemonchus contortus* in sheep. Australian Veterinary Journal 67: 89-91.

Robertson, H.A., Niezen, J.H., Waghorn, G.C., Charleston, W.A.G., Jinlong, M. 1995. The effect of six herbages on liveweight gain, wool growth and faecal egg count of parasitised ewe lambs. Proceedings of the New Zealand Society of Animal Production 55:199-201.

Roe, R., Southcott, W.H., Turner, H.N. 1959. Grazing management of native pasture in the New England region of New South Wales I. Pasture and sheep production with special reference to systems of grazing and internal parasites. Australian Journal of Agricultural Research 10: 530.

Rogers, W.P. 1940. The effects of environmental conditions on the accessibility of third stage trichostrongyle larvae to grazing animals. Parasitology 32: 208-225.

Rose, J.H., Small, A.J. 1985. The distribution of the infective larvae of sheep gastro-intestinal nematodes in soil and on herbage and the vertical migration of *Trichostrongylus vitrinus* larvae through the soil. Journal of Helminthology 59: 127-135.

Ross, I.C., Chamberlin, W.E., Turner, H.N. 1937. The influence of improvements of pastures and rotational grazing on parasitism, body weight and fleece production in cross-bred sheep in Tasmania. Journal of the Council of Scientific and Industrial Research, Australia 10: 313-326.

Rossangio, C.E., Gruner, L. 1995. Moisture and temperature requirements in faeces for the development of free-living stages of gastrointestinal nematodes of sheep, cattle and deer. Journal of Helminthology 69: 357-362.

Rowarth, J.S., Gillingham, A.G., Tillman, R.W., Syers, J.K. 1985. Release of phosphorus from sheep faeces on grazed, hill country pastures. New Zealand Journal of Agricultural Research 28: 497-504.

Rowe, J.B., Nolan, J.V., Chaneet, G. De, Teleni, E., Holmes, P.H. 1988. The effect of haemonchosis and blood loss into the abomasum on digestion in sheep. British Journal of Nutrition 59: 125-139.

Salih, N.E. Grainger, J.N.R. 1982. The effect of constant and changing temperatures on the development of eggs and larvae of *Ostertagia circumcincta*. Journal of Thermal Biology 7: 35-38.

Scales, G.H., Knight, T.L., Saville, D.J. 1995. Effect of herbage species and feeding level on internal parasites and production performance of grazing lambs. New Zealand Journal of Agricultural Research 38: 237-247.

Scott, D. 1978. Air movements within six vegetations. New Zealand Journal of Agricultural Research 21: 651-654.

Scott, D., Menalda, P.H., Brougham, R.W. 1968. Spectral analysis of radiation transmitted and reflected by different vegetations. New Zealand Journal of Botany 6: 427-449.

Shapiro, D.I., Berry, E.C., Lewis, L.C. 1993. Interactions between nematodes and earthworms: Enhanced dispersal of *Steinernema carpocapsae*. Journal of Nematology 25: 189-192.

Sharpley, A.N., Syers, J.K. 1977. Seasonal variation in casting activity and in the amounts and release to solution of phosphorus forms in earthworm casts. Soil Biology and Biochemistry 9: 227-231.

Shorb, D. A. 1943. Survival on grass plots of eggs and preinfective larvae of the stomach worm *Haemonchus contortus*. Journal of Agricultural Research 68: 317-324.

Silangwa, S.M., Todd, A.C. 1964. Vertical migration of trichstrongylid larvae on grasses. Journal of Parasitology 50: 278-285.

Silverman, P.H., Campbell, J.A. 1959. Studies on parasitic worms of sheep in Scotland. I. Embryonic and larval development of *Haemonchus contortus* at constant conditions. Parasitology 49: 23-38.

Smith, G., Grenfell, B.T., Anderson, R.M. 1986. The development and mortality of the non-infective free-living stages of *Ostertagia ostertagi* in the field and in laboratory culture. Parasitology 92: 471-482.

Smith, G. 1988. The population biology of the parasitic stages of *Haemonchus contortus*. Parasitology 96: 185-195.

Smith, W. D. Smith, S. K. 1993. Evaluation of aspects of the protection afforded to sheep immunised with a gut membrane protein of *Haemonchus contortus*. Research in Veterinary Science 55: 1-9.

Southcott, W.H., Heath, D.D., Langlands, J.P. 1967. Relationship of nematode infection to efficiency of wool production. Journal of the British Grassland Society 22:117-120.

Southcott, W.H., Langlands, J.P., Heath, D.D. 1970. Stocking intensity and nematode infection of grazing sheep. Proceedings of the XI International Grasslands Congress. pp. 888-890.

Springett, J. A., Gray, R.J., Niezen, J.H. 1995. The effect of different pasture plant species on earthworms. Proceedings of Driven by Nature. G. Cadisch (ed.) (abstract). pp 25.

Statistical Analysis Systems Institute. 1987. SAS/STAT Guide for Personal Computers, Version 6. Cary, NC: SAS Inc.

Steel, J. W., Symons, L. E. A., Jones, W.O. 1980. Effects of level of larval intake on the productivity and physiological and metabolic responses of lambs infected with *Trichostrongylus colubriformis*. Australian Journal of Agricultural Research 31: 821-838.

Steel, J. W., Jones, W. O., Symons, L. E. A. 1982. Effects of a concurrent infection of *Trichostrongylus colubriformis* on the productivity and physiological and metabolic responses of lambs infected with *Ostertagia circumcincta.* Australian Journal of Agricultural Research 33: 131-40.

Steel, K.W. 1982. Nitrogen in Grassland Soils. In "Nitrogen Fertilisers in New Zealand Agriculture". New Zealand Institute of Agricultural Science, Ed. P.B. Lynch. pp 29-45.

Sykes, A.R. 1983. Effects of parasitism on metabolism in sheep. In: Sheep Production (ed. W. Haresign). Butterworths, London. pp 283-295.

Sykes, A.R. 1994. Parasitism and production in farm animals. Animal Production 59: 155-172.

Sykes, A.R., Coop, R.L. 1976. Intake and utilization of food by growing lambs with parasitic damage to the small intestine caused by daily dosing with *Trichostrongylus colubriformis* larvae. Journal of Agricultural Science, Cambridge 86: 507-515.

Sykes, A.R., Coop, R.L. 1977. Intake and utilization of food by growing lambs with abomasal damage caused by daily dosing with *Ostertagia circumcincta* larvae. Journal of Agricultural Science, Cambridge 88: 671-677.

Sykes, A.R., Coop, R.L., Angus, K.W. 1979. Chronic infection with *Trichostrongylus vitrinus* in sheep. Some effects on food utilization, skeletal growth and certain serum constituents. Research in Veterinary Science 26: 372-377.

Sykes, A.R., Poppi, D.P., Elliott, D.C. 1988. Effect of concurrent infection with *Ostertagia circumcincta* and *Trichostrongylus colubriformis* on the performance of growing lambs consuming fresh herbage. Journal of Agricultural Science, Cambridge 110: 531-541.

Symons, L.E.A., Jones, W.O. 1975. Skeletal muscle, liver and wool protein synthesis by sheep infected by the nematode *Trichostrongylus colubriformis.* Australian Journal of Agricultural Research 26: 1063-1072.

Symons, L.E.A., Jones, W.O. 1983. Intestinal protein synthesis in guinea pigs infected with *Trichostrongylus colubriformis.* International Journal of Parasitology 13: 309-312.

Tarshis, I.B. 1958. A preliminary study of lateral migration of infective larvae of some cattle nematodes on experimentally contaminated forage plots. Proceedings of the Helminthological Society 25: 99-106.

Taylor, E.L. 1939. Technique for the estimation of pasture infestation by strongyloid larvae. Parasitology 31: 473-478.

Tetley, J.H. 1934. The nematodes of sheep in the Manawatu district, New Zealand. Journal of Helminthology 12: 183-196.

Tetley, J.H. 1953. Inhibition of populations of *Haemonchus contortus* in sheep fed on white clover (*Trifolium repens*) high in lotaustralin. Nature 171: 311-312.

Tetley, J.H. 1959. The seasonal availability to sheep of infective nematode larvae on pasture. Journal of Helminthology 33: 281-288.

Tetley, J.H., Langford, B.M. 1965. A study of nematode parasitism in hill-country breeding ewes. New Zealand Journal of Agricultural Research 8: 573-584.

Tilley, J.M.A., Terry, R.A. 1963. A two-stage technique for the *in vitro* digestibility of forage crops. Journal of the British Grassland Society 18: 104-111.

Thomson, N.A., Power, M.T. 1991. Effect of grazing management on minimising effects of parasitic nematodes on lamb production. Proceedings of the New Zealand Grassland Association 53: 129-134.

Todd, K.S., Levine, N.D., Anderson, F.L. 1970. An evaluation of the Baermann Technic using infective larvae of *Haemonchus contortus.* Proceedings of the Helminthological Society 37: 57-63.

Todd. K.S. Jr., Levine, N.D., Boatman, P.A. 1976. Effect of temperature on survival of free-living stages of *Haemonchus contortus.* American Journal of Veterinary Research 37: 991-992.

Ulyatt, M.J. 1970. Evaluation of pasture quality under New Zealand conditions. Proceedings of the New Zealand Grassland Association 32: 61-68.

vanHoutert, M.F.J., Barger, I.A., Steel, J.W., Windon, R.G., Emery, D.L. 1995. Effects of dietary protein intake on responses of young sheep to infection with *Trichostrongylus colubriformis.* Veterinary Parasitology 56: 163-180.

Vegors, H.H., Sell, O.E., Baird, D.M., Stewart, T.B. 1955. Internal parasitism of beef yearlings as affected by type of pasture, supplemental corn feeding, and age of calf. Journal of Animal Science 14: 256-267.

Vlassoff, A. 1973a. Biology of the free-living phase of Trichostrongyle nematode parasites of sheep. Proceedings of the New Zealand Society for Parasitology 1: 31-34.

Vlassoff, A. 1973b. Seasonal incidence of infective trichostrongyle larvae on pasture grazed by lambs. New Zealand Journal of Experimental Agriculture 1: 293-301.

Vlassoff, A., McKenna, P.B. 1994. Nematode parasites of economic importance in sheeep in New Zealand. New Zealand Journal of Zoology 21: 1-8.

Waghorn, G.C. 1995. The physiological mechanisms involved in the formation of dags in sheep. Report to Wools of New Zealand. 95 pp.

Wallace, H.R. 1959. The movement of eelworms in water films. Annals of Applied Biology 47: 366-370.

Wallace, H.R., Doncaster, C.C. 1964. A comparative study of the movement of some microphagous, plant-parasitic and animal-parasitic nematodes. Parasitology 54: 313-326.

Waller, P.J. 1992. Prospects for biological control of nematode parasites of ruminants. New Zealand Veterinary Journal 40: 1-3.

Waller, P.J., Donald, A.D. 1970. The response to desiccation of eggs of *Trichostrongylus colubriformis* and *Haemonchus contortus* (Nematoda: Trichostrongylidae). Parasitology 61: 195-204.

Waller, P.J., Dobson, R.J., Donald, A.D., Thomas, R.J. 1981. Populations of strongyloid nematode infective stages in sheep pastures: comparison between direct pasture sampling and tracer lambs as estimators of larval abundance. International Journal for Parasitology 11: 359-367.

Waller, P.J., Faedo, M. 1993. The potential for nematophagous fungi to control the free-living stages of nematode parasites of sheep: screening studies. Veterinary Parasitology 49: 285-297.

Webb, C.J., Sykes, W.R., Garnock-Jones, P.J. 1988. Flora of New Zealand. Volume IV. Naturalised Pteridophytes, Gymnosperms, Dicotyledons. Department of Scientific and Industrial Research. Christchurch, New Zealand.

Weeda, W. C. 1967. The effect of cattle dung patches on pasture growth, botanical composition, and pasture utilisation. New Zealand Journal of Agricultural Research 10: 150-159.

Williams, C.H., David, D.J., Iismaa, O. 1962. The determination of chromic oxide in faeces samples by atomic absorption spectrophotometry. Journal of Agricultural Science 59: 381-385.

Williams, J.C., Bilkovich, F.R. 1973. Distribution of *Ostertagia ostertagi* infective larvae on pasture herbage. American Journal of Veterinary Research 34: 1337-1344.

Young, R.R., Nicholson, R.M., Tweedie, R.L., Schuh, H.J. 1980. Quantitative modelling and prediction of development times of the free-living stages of *Ostertagia circumcincta* under controlled and field conditions. Parasitology 81: 493-505.

Young, R.R., Anderson, N. 1981. The ecology of the free-living stages of *Ostertagia ostertagi* in a winter rainfall region. Australian Journal of Agricultural Research 32: 371-88.

Appendix 3.1. Liveweights of lambs (kg), adjusted to a common initial weight (Day 0) which were either suppressively drenched fortnightly (SD) or trigger drenched when any one treatment reached 1500 eggs per gram faeces (TD), and grazed swards to a target height of 5 cm. 1991/92.

	Days on Trial													
	0	10	18	37	53	65	79	93	108	122	134	145	164	179
Browntop SD	30.7	27.3	30.1	30.4	29.9	29.7	30.0	31.1	31.6	33.1	34.5	34.9	35.3	35.3
TD	30.7	27.3	30.2	29.6	27.9	27.4	27.5	27.7	29.2	29.5	27.9	30.1	29.5	28.8
Tall Fescue SD	30.7	26.2	28.0	26.6	26.8	27.2	29.2	30.1	30.1	31.1	32.0	32.1	34.0	35.4
TD	30.7	26.2	28.3	26.5	24.5	25.2	26.1	26.6	27.8	27.1	26.0	28.6	28.6	27.7
Yorkshire Fog SD	30.7	27.6	31.1	30.7	27.4	28.1	29.3	30.3	29.5	30.7	32.5	33.8	35.2	36.0
TD	30.7	27.3	30.9	30.5	27.2	27.8	29.2	29.3	28.8	30.1	31.5	31.7	33.4	33.2
Ryegrass SD	30.7	27.0	30.0	30.9	30.3	30.8	31.0	34.1	34.5	37.6	39.0	40.4	41.8	43.4
TD	30.7	27.1	30.0	29.5	27.8	29.0	29.9	30.6	32.3	33.4	33.6	36.4	37.3	38.5
Pooled SE	ND[1]	0.53	0.53	0.54	0.65	0.70	0.86	0.77	0.89	0.83	0.93	0.93	0.89	0.98
Herbage Effect	ND	0.03	0.001	0.001	0.001	0.001	0.01	0.001	0.001	0.001	0.001	0.001	0.001	0.001

[1] ND - not determined

Appendix 3.2. Liveweights of lambs (kg), adjusted to a common initial weight (Day 0), which were either supressively drenched fortnightly (SD) or trigger drenched when any one treatment reached 1000 eggs per gram faeces (TD), and grazed swards to a target height of 5 cm. 1992/93.

	Days on Trial											
	0	11	23	36	45	59	72	91	108	132	148	164
Browntop SD	21.3	21.5	22.0	21.3	23.2	25.8	26.8	29.3	29.5	29.4	28.2	29.2
TD	21.3	21.7	22.7	20.6	21.7	23.9	24.1	26.6	26.8	26.6	25.9	24.4
Tall Fescue SD	21.3	21.4	20.9	19.7	22.1	22.8	25.0	25.8	25.1	26.5	26.4	28.3
TD	21.3	21.8	22.1	21.2	24.4	23.8	26.4	26.7	25.8	27.8	28.2	27.8
Yorkshire Fog SD	21.3	23.2	25.8	21.4	24.5	26.6	28.4	29.5	29.5	30.1	29.1	28.7
TD	21.3	22.4	25.0	20.4	23.2	24.2	26.7	26.9	27.4	27.5	26.4	24.6
Ryegrass SD	21.3	23.3	24.8	20.8	24.2	27.6	31.7	32.3	33.1	34.0	33.7	ND
TD	21.3	23.6	25.6	20.7	24.3	27.6	28.3	30.4	31.1	31.5	31.6	ND
Pooled SE	ND[1]	0.83	0.95	0.77	1.12	1.00	1.16	1.14	1.24	1.30	1.18	1.23
Herbage Effect	ND	0.14	0.001	0.77	0.21	0.001	0.0001	0.0001	0.0001	0.0001	0.0001	0.25

[1] ND - Not determined

Appendix 3.3. The proportion (%) of lambs which were either suppressively drenched fortnightly (SD) or trigger drenched (TD) when FECs reached 1500 epg in 1991/92 or 1000 epg in 1992/93 and attained a liveweight of 32 kg. Lambs grazed swards to a target height of 5 cm.

		Days after the start of the trial													
1991/92		0	10	18	37	53	65	79	93	108	122	134	149	164	179
Browntop	SD	20	60	10	50	60	50	60	50	60	60	60	60	70	60
	TD	33	45.8	16.7	45.8	45.8	29.2	20.8	20.8	25	29.2	25	20.8	29.2	29.2
Tall fescue	SD	30	30	20	20	20	20	20	20	20	20	30	30	40	50
	TD	18.2	27.3	4.6	13.6	4.6	4.6	4.6	9.1	4.6	4.6	0	0	13.6	9.1
Yorkshire fog	SD	20	40	20	50	40	20	20	20	20	20	20	40	50	50
	TD	23.8	47.6	23.8	47.6	38.1	19.1	19.1	28.6	33.3	28.6	23.8	19.1	23.8	33.3
Ryegrass	SD	14.3	42.9	28.6	42.9	42.9	42.9	42.9	42.9	57.1	57.1	71.4	71.4	71.4	71.4
	TD	33.3	33.3	16.7	33.3	33.3	8.3	16.7	25	25	33.3	50	41.7	50	50
1992/93		36	45	59	72	91	108	121	132	148	164				
Browntop	SD	0	0	0	7.1	14.3	28.6	28.6	14.3	14.3	21.4				
	TD	0	6.6	7	0	0	3.3	3.3	6.7	10	10				
Tall fescue	SD	0	0	0	0	0	7.7	7.7	7.7	7.7	15.4				
	TD	0	3.6	0	3.6	3.6	7.1	3.6	10.7	10.7	17.9				
Yorkshire fog	SD	0	0	0	8.3	16.7	25	41.7	25	8.3	0				
	TD	0	3.7	0	3.7	3.7	14.8	0	11.1	14.8	7.4				
Ryegrass	SD	0	0	0	12.5	37.5	37.5	50	62.5	50	ND[1]				
	TD	0	6.3	0	6.3	6.3	25	12.5	37.5	37.5	ND				

[1] ND - Not determined

Appendix 3.4. Mean abomasal worm burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 1 in 1991/92. (3 lambs/grass).

	Haemonchus	*Ostertagia*	*Trichostrongylus*	Abomasum total
Browntop	2.65^{a1} (460)	2.34^{a} (220)	1.89^{ab} (80)	3.00^{a} (760)
Tall fescue	2.42^{ab} (287)	2.28^{a} (220)	2.45^{ab} (383)	2.96^{a} (890)
Yorkshire fog	2.12^{b} (157)	1.19^{a} (40)	1.66^{b} (47)	2.41^{b} (217)
Ryegrass	2.47^{ab} (297)	2.18^{a} (180)	2.57^{a} (577)	2.92^{a} (1053)
Pooled SEM	.075	.200	.139	.0625
Herbage effect	NS[2]	NS	P<.10	P<.03

1/ Columns with differing superscripts differ P<.05.
2/ NS - not significant P>.10.

Appendix 3.5. Mean intestinal worm burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 1 in 1991/92. (3 lambs/grass).

	Cooperia	*Nematodirus*	*Trichostrongylus*	L_4	Intestine total
Browntop	.854^{a1} (25)	2.11^{a} (130)	2.52^{a} (360)	1.04^{ab} (10)	2.69^{a} (525)
Tall fescue	1.17^{a} (43)	2.15^{a} (210)	2.62^{a} (450)	1.46^{a} (43)	2.80^{a} (747)
Yorkshire fog	.844^{a} (13)	2.34^{a} (243)	1.89^{b} (77)	.347^{b} (3)	2.51^{a} (337)
Ryegrass	1.34^{a} (67)	2.34^{a} (220)	2.54^{a} (423)	.347^{b} (3)	2.80^{a} (713)
Pooled SEM	.344	.114	.080	.175	.0882
Herbage effect	NS^{2}	NS	P<.03	P<.10	NS

1/ Columns with differing superscripts differ P<.05.
2/ NS - not significant P>.10.

Appendix 3.6. Mean abomasal worm burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 2 in 1991/92. (3 lambs/grass).

	Haemonchus	*Ostertagia*	*Trichostrongylus*	Abomasum total
Browntop	.661^{a1} (10)	1.61^{a} (80)	2.20^{a} (215)	3.59^{a} (305)
Tall fescue	1.68^{ab} (50)	2.51^{a} (547)	2.42^{a} (477)	3.25^{b} (1073)
Yorkshire fog	1.98^{b} (127)	2.16^{a} (153)	1.85^{a} (80)	2.86^{c} (360)
Ryegrass	2.16^{b} (155)	1.85^{a} (95)	2.22^{a} (170)	3.37^{ab} (420)
Pooled SEM	.156	.184	.165	.050
Herbage effect	P<.07	NS^{2}	NS	P<.009

1/ Columns with differing superscripts differ P<.05.

2/ NS - not significant P>.10.

Appendix 3.7. Mean intestinal worm burdens ($\log_{10}(n+1)$ transformed; with corresponding arithmetic means in parentheses) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 2 in 1991/92. (3 lambs/grass).

	Cooperia	*Nematodirus*	*Trichostrongylus*	L_4	Intestine total
Browntop	2.29^{a1} (195)	3.03^{a} (1110)	3.58^{a} (3803)	2.85^{a} (725)	3.76^{a} (5915)
Tall fescue	1.75^{a} (70)	1.80^{a} (397)	3.08^{b} (1202)	1.43^{a} (93)	3.26^{b} (1810)
Yorkshire fog	$.694^{b}$ (7)	2.06^{a} (117)	2.65^{c} (447)	$.497^{b}$ (10)	2.76^{c} (627)
Ryegrass	1.86^{a} (75)	$.893^{a}$ (30)	3.32^{ab} (2089)	1.91^{a} (80)	3.36^{b} (2270)
Pooled SEM	.142	.350	.056	.291	.044
Herbage effect	$P<.03$	NS[2]	$P<.005$	NS	$P<.002$

1/ Columns with differing superscripts differ $P<.05$.
2/ NS - not significant $P>.10$.

Appendix 3.8. Mean abomasal worm burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 3 in 1991/92. (3 lambs/grass).

	Haemonchus	*Ostertagia*	*Trichostrongylus*	Abomasum total
Browntop	1.99^{a1} (127)	2.44^{a} (357)	2.15^{a} (157)	2.61^{ab} (640)
Tall fescue	2.44^{a} (283)	2.49^{a} (360)	1.97^{a} (93)	2.82^{a} (737)
Yorkshire fog	1.85^{a} (83)	1.67^{ab} (47)	1.28^{a} (20)	2.10^{b} (150)
Ryegrass	1.74^{a} (83)	1.25^{b} (50)	1.23^{a} (47)	1.95^{b} (180)
Pooled SEM	.125	.200	.106	.120
Herbage effect	NS[2]	P<.10	NS	P<.06

1/ Columns with differing superscripts differ P<.05.
2/ NS - not significant P>.10.

Appendix 3.9. Mean intestinal worm burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 3 in 1991/92. (3 lambs/grass).

	Cooperia	*Nematodirus*	*Trichostrongylus*	L_4	Intestine total
Browntop	3.38^{a1} (2827)	2.77^{a} (710)	1.36^{a} (27)	2.18^{a} (190)	3.50^{a} (3753)
Tall fescue	2.96^{ab} (913)	2.69^{a} (523)	1.29^{a} (27)	1.29^{ab} (73)	3.18^{ab} (1537)
Yorkshire fog	2.24^{ab} (190)	2.62^{a} (437)	$.347^{b}$ (3)	$.497^{b}$ (10)	2.80^{ab} (640)
Ryegrass	1.66^{b} (237)	1.68^{a} (240)	0^{b} (0)	0^{b} (0)	1.87^{b} (477)
Pooled SEM	.251	.254	.135	.248	.278
Herbage effect	P<.10	NS[2]	P<.008	P<.04	NS

1/ Columns with differing superscripts differ P<.05.
2/ NS - not significant P>.10.

Appendix 3.10. Mean abomasal worm burdens ($\log_{10}$ (n+1) transformed, with corresponding arithmetic means in parentheses) and male to female ratio (M:F) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 1 in 1992/93. (4 lambs/grass).

	Haemonchus		*Ostertagia*		*Trichostrongylus*		Abomasum total
	n	M:F	n	M:F	n	M:F	n
Browntop	.75^{b1} (60)	.81	2.34^{a} (283)	.88	1.83^{a} (113)	.55	2.50^{a} (457)
Tall fescue	2.03^{a} (110)	1.44	2.35^{a} (235)	.51	1.84^{a} (70)	.75	2.61^{a} (415)
Yorkshire fog	1.75^{ab} (90)	1.25	2.60^{a} (733)	.59	1.92^{a} (250)	.53	2.74^{a} (1073)
Ryegrass	1.06^{ab} (20)	3	2.37^{a} (263)	.94	2.17^{a} (188)	.56	2.61^{a} (470)
Pooled SEM	.249	ND[3]	.122	ND	.087	ND	.130
Herbage effect	NS[2]	ND	NS	ND	NS	ND	NS

1/ Columns with differing superscripts differ P<.05.
2/ NS - not significant P>.10.
3/ ND - not determined due to insufficient numbers

Appendix 3.11. Mean intestinal worm burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) and male to female ratio (M:F) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 1 in 1992/93. (4 lambs/grass).

	Cooperia		*Nematodirus*		*Trichostrongylus*		Intestine total
	n	M:F	n	M:F	n	M:F	n
Browntop	1.71[a1] (247)	.72	1.69[ab] (50)	.37	3.34[a] (2617)	.77	3.41[a] (2913)
Tall fescue	1.26[a] (53)	1.33	1.99[a] (105)	1.47	2.69[b] (508)	.561	2.81[bc] (665)
Yorkshire fog	1.64[a] (43)	1.15	1.44[b] (33)	.66	2.36[b] (257)	.64	2.49[c] (333)
Ryegrass	2.48[a] (468)	.99	1.82[ab] (93)	.85	2.93[ab] (1305)	.83	3.09[ab] (1865)
Pooled SEM	.267	ND[3]	.106	ND	.113	ND	.106
Herbage effect	NS[2]	ND	NS	ND	P<.04	ND	P<.03

1/ Columns with differing superscripts differ P<.05.
2/ NS - not significant P>.10.
3/ ND - not determined due to insufficient numbers

Appendix 3.12. Mean abomasal worm burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) and male to female ratio (M:F) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 2 in 1992/93. (4 lambs/grass).

	Haemonchus		*Ostertagia*		*Trichostrongylus*		Abomasum total
	n	M:F	n	M:F	n	M:F	n
Browntop	1.86[a1] (225)	.730	2.97[a] (1092)	.73[a]	2.39[a] (303)	.82[a]	3.16[a] (1620)
Tall fescue	1.29[a] (193)	.833	2.82[ab] (660)	.89[a]	2.04[ab] (233)	.27[a]	3.03[a] (1085)
Yorkshire fog	1.53[a] (45)	.800	2.36[bc] (272)	1.06[a]	1.51[ab] (33)	.75[a]	2.48[b] (350)
Ryegrass	1.79[a] (70)	1.00	2.18[c] (260)	1.54[a]	1.37[b] (65)	.60[a]	2.41[b] (395)
Pooled SEM	.334	ND[3]	.111	.306	.203	.147	.104
Herbage effect	NS[2]	ND	P<.02	NS	NS	NS	P<.02

1/ Columns with differing superscripts differ P<.05.
2/ NS - not significant P>.10.
3/ ND - not determined due to insufficient numbers

Appendix 3.13. Mean intestinal worm burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) and male to female ratio (M:F) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 2 in 1992/93. (4 lambs/grass).

	Cooperia		*Nematodirus*		*Trichostrongylus*		Intestine total
	n	M:F	n	M:F	n	M:F	n
Browntop	2.51^{a1} (360)	1.182	2.21^{a} (163)	1.096	3.52^{a} (3538)	.83	3.58^{a} (4060)
Tall fescue	1.99^{b} (118)	.807	2.57^{a} (433)	1.059	3.28^{ab} (1933)	2.20	3.38^{a} (2483)
Yorkshire fog	1.66^{b} (53)	.500	1.03^{b} (18)	1.33	2.90^{ab} (880)	.80	2.94^{b} (950)
Ryegrass	2.09^{ab} (170)	1.06	2.16^{a} (213)	.730	2.81^{b} (973)	.80	2.96^{b} (1355)
Pooled SEM	.104	ND[3]	.145	ND	.0896	.491	.0886
Herbage effect	P<.02	ND	P<.002	ND	P<.01	NS[2]	P<.02

1/ Columns with differing superscripts differ P<.05.
2/ NS - not significant P>.10.
3/ ND - not determined due to insufficient numbers

Appendix 3.14. Mean abomasal worm burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) and male to female ratio (M:F) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 3 in 1992/93. (4 lambs/grass).

	Haemonchus		*Ostertagia*		*Trichostrongylus*		Abomasum total
	n	M:F	n	M:F	n	M:F	n
Browntop	.716[a1] (47)	3.66	3.10[a] (1297)	.59[a]	1.75[a] (347)	.65	3.18[a] (1690)
Tall fescue	.854[a] (25)	1.50	2.10[b] (210)	.16[a]	2.10[a] (145)	.45	2.43[b] (380)
Yorkshire fog	.687[a] (15)	1.0	2.84[a] (758)	.76[a]	2.16[a] (185)	.72	2.94[ab] (958)
Ryegrass	ND[4]	ND	ND	ND	ND	ND	ND
SEM	.527	ND[3]	.166	.155	.473	ND	.153
Herbage effect	NS[2]	ND	P<.05	NS	NS	ND	P<.09

[1]/ Columns with differing superscripts differ P<.05.
[2]/ NS - not significant P>.10.
[3]/ ND - not determined due to insufficient numbers
[4]/ ND - The ryegrass treatment was terminated prematurely due to Yorkshire fog proliferation into the sward.

Appendix 3.15. Mean intestinal worm burdens ($\log_{10}$ (n+1) transformed; with corresponding arithmetic means in parentheses) and male to female ratio (M:F) from tracer lambs which grazed either browntop, tall fescue, Yorkshire fog or ryegrass paddocks which had been continuously grazed to a constant height of 5 cm. Period 3 in 1992/93. (4 lambs/grass).

	Cooperia		*Nematodirus*		*Trichostrongylus*		Intestine total
	n	M:F	n	M:F	n	M:F	n
Browntop	2.04^{a1} (247)	.41	$.72^{a}$ (47)	13.12	3.40^{a} (4150)	$.69^{a}$	3.51^{a} (4440)
Fescue	1.12^{ab} (85)	.214	0^{a} (0)	0	3.65^{a} (5265)	$.85^{a}$	3.65^{a} (5350)
Yorkshire fog	$.26^{b}$ (3)	0	0^{a} (0)	0	3.21^{a} (1740)	$.73^{a}$	3.21^{a} (1740)
Ryegrass	ND[1]	ND	ND	ND	ND	ND	ND
SEM	.449	ND[3]	.358	ND	.208	.128	.170
Herbage effect	NS[2]	ND	NS	ND	NS	NS	NS

1/ Columns with differing superscripts differ P<.05.
2/ NS - not significant P>.10.
3/ ND - not determined due to insufficient numbers
*/ The ryegrass treatment was terminated prematurely due to Yorkshire fog proliferation into the sward.

Appendix 3.16. Mean calculated faecal output (FO, g OM/day), organinc matter intake (OMI) and OMI adjusted to metabolic bodyweight (g DM/ kg $LW^{0.75}$) from lambs which were suppressively drenched fortnightly or trigger drenched when any one treatment reached 1500 eggs per gram, while grazing browntop, tall fescue, Yorkshire fog or ryegrass swards to a target height of 5 cm. 1991/92.

	Period 1			Period 2			Period 3		
	FO	OMI	OMI ($LW^{0.75}$)	FO	OMI	OMI ($LW^{0.75}$)	FO	OMI	OMI ($LW^{0.75}$)
Browntop									
SD	621.9	1555	117	797.9	1996	150	423.3	1059	80
TD	488.8	1222	95	269.3	673	54	482.0	1205	114
Tall fescue									
SD	258.3	669	52	240.4	623	49	250.2	647	50
TD	280.1	860	71	228.6	704	58	207.0	640	53
Yorkshire fog									
SD	491.7	1180	93	289.8	690	55	348.9	830	66
TD	270.0	650	52	233.6	560	45	261.5	630	51
Ryegrass									
SD	411.2	1090	77	274.9	730	51	318.5	850	60
TD	536.0	1420	105	253.1	670	49	295.7	790	58
Pooled SE	70.15	175	14.6	62.7	137	11.4	75.6	65.0	5.20
Herbage effect (P<)	0.02	0.03	0.13	0.001	0.001	0.0002	0.13	0.001	0.08
Drench effect	0.07	0.41	0.55	0.001	0.001	0.004	0.27	0.001	0.02

Appendix 3.17. Mean calculated faecal output (FO, g OM/day), organinc matter intake (OMI) and OMI adjusted to metabolic bodyweight (g DM/kg LW$^{0.75}$) from lambs which were suppressively drenched fortnightly or trigger drenched when any one treatment reached 1000 eggs per gram, while grazing browntop, tall fescue, or Yorkshire fog swards to a target height of 5 cm. 1992/93.

	Period 1						Period 3		
	FO	OMI	OMI$^{0.75}$	FO	OMI	OMI$^{0.75}$	FO	OMI	OMI$^{0.75}$
Browntop									
SD	308.5	654	52	317.4	672	53	277.7	587	47
TD	285.9	605	52	267.6	568	49	212.5	450	38
Tall fescue									
SD	356.4	824	71	250.9	581	50	234.8	544	47
TD	239.1	553	46	307.3	711	59	239.2	553	46
Yorkshire fog									
SD	297.5	572	45	251.4	482	38	235.2	451	35
TD	314.0	603	47	263.0	505	39	205.4	393	31
Ryegrass									
SD	ND	ND	ND	ND	ND	ND	ND	ND	ND
TD	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pooled SE	53.6	21.9	1.79	41.9	22.4	1.86	25.9	23.5	1.85
Herbage effect	0.97	0.15	0.07	0.52	0.10	0.17	0.43	0.16	0.21
Drench effect	0.23	0.39	0.28	0.82	0.87	0.63	0.07	0.50	0.70

[1] ND - not determined

Appendix 3.18. Average faecal consistency of TD lambs which grazed swards to a target height of 5 cm. At each sampling faeces were scored on a scale of 1 to 5; one being liquid, 5 being hard pellets.

	Days After Start of Trial										
1991/92	37	53[1]	65	79	93[1]	108	122	134[1]	149	164	179[1]
Browntop	3.43	3.84	3.72	3.90	3.71	3.46	3.08	2.36	3.64	ND	3.08
Tall fescue	3.60	3.26	3.32	3.47	3.21	3.93	3.46	2.73	4.07	ND	3.07
Yorkshire fog	3.35	3.63	3.13	3.22	3.06	3.26	3.13	2.91	3.27	3.45	2.91
Ryegrass	2.89	3.11	3.10	3.30	2.57	3.00	3.00	2.50	3.25	3.00	3.63
Pooled SE	0.23	0.28	0.25	0.24	0.24	0.16	0.19	0.21	0.16	0.19	0.20
Herbage Effect	0.10	0.06	0.08	0.002	0.006	0.07	0.83	0.80	0.04	0.06	0.004
1992/93	23	36	45[1]	59	72	91[1]	108	132*	148	164*	
Browntop	3.88	3.10	3.15	3.48	3.65	3.67	3.78	3.63	3.81	2.87	
Tall Fescue	3.91	3.21	3.36	3.54	3.26	3.75	4.00	3.95	4.05	3.05	
Yorkshire fog	3.45	2.75	3.09	2.94	3.08	3.67	3.56	3.76	3.61	2.91	
Ryegrass	3.79	2.93	3.09	2.79	3.29	3.21	3.07	2.77	3.13	ND[1]	
Pooled SE	0.24	0.13	0.18	0.29	0.27	0.31	0.28	0.33	0.29	0.37	
Herbage effect	0.06	0.12	0.02	0.02	0.003	0.09	0.003	0.002	0.10	0.12	

[1] ND - Not determined

[1] All lambs were drenched with ivermectin at 1.5 times the recommended dose rate.

Appendix 3.19. Monthly rainfall (mm) and mean monthly maximum and minimum temperatures (^{0}C) for the months of the grazing period in both years.

Month	Rainfall (mm)	Maximum Temperature (^{0}C)	Minimum Temperature (^{0}C)
1991/92			
December	47.8	20.2	10.6
January	62.4	22.6	11.7
February	121.8	21.9	11.7
March	99.2	19.3	8.9
April	23.2	17.0	4.8
May	39.7	14.2	4.1
June	66.4	13.6	4.1
1992/93			
November	46.3	19.6	9.2
December	166.6	21.0	9.3
January	74.9	21.0	10.8
February	46.6	22.5	9.6
March	70.1	20.8	8.5
April	51.3	19.0	7.6

Appendix 4.1. Average liveweights of lambs which grazed monospecific swards of tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm. Lambs were either suppressively drenched fortnightly or trigger drenched when any one treatment attained a faecal egg count of 1000 eggs per gram faeces.

Treatment		Days After the Start of the Trial											
		0	11	23	36	45	59	72	91	108	132	148	164
Tall fescue													
3 cm	SD	19.0	26.4	20.3	24.0	23.2	26.5	27.6	28.1	27.0	27.7	29.3	27.8
	TD	19.1	26.1	20.0	23.7	24.0	23.8	25.7	26.4	24.5	25.7	26.1	24.8
5 cm	SD	19.5	25.6	19.9	23.2	25.0	26.0	27.7	28.6	30.3	32.0	33.4	32.7
	TD	19.1	25.8	19.4	23.0	23.2	23.7	25.7	26.4	25.4	27.7	28.2	26.4
8 cm	SD	20.5	27.5	21.9	26.6	27.8	28.8	31.9	34.9	36.7	35.8	41.3	40.8
	TD	18.7	26.8	20.5	24.7	25.6	26.2	29.8	32.3	31.4	33.5	33.8	33.0
Yorkshire fog													
3 cm	SD	18.6	25.2	20.0	24.1	25.0	24.8	27.2	27.7	26.0	26.0	26.9	24.6
	TD	19.6	24.2	19.2	23.1	23.3	23.5	25.9	26.4	23.8	24.4	24.9	22.3
5 cm	SD	19.1	24.8	18.5	21.9	23.4	26.5	28.8	27.6	25.8	26.3	27.7	24.9
	TD	19.5	26.5	20.8	25.2	25.2	27.4	30.5	29.1	26.9	28.0	29.4	25.5
8 cm	SD	18.5	24.4	18.8	23.5	25.7	25.0	30.2	30.5	24.9	29.5	31.1	29.1
	TD	19.8	25.5	19.6	25.1	26.3	27.5	31.3	31.9	25.3	33.0	32.9	31.5
Pooled SE		1.05	1.44	1.34	1.45	1.93	1.92	1.79	1.80	2.01	1.89	1.89	1.91
Herbage effect		0.73	0.02	0.09	0.50	0.99	0.94	0.17	0.39	0.001	0.001	0.001	0.001
Height effect		0.79	0.69	0.71	0.07	0.02	0.04	0.001	0.001	0.001	0.001	0.001	0.001
Herbage x height effect		0.90	0.28	0.31	0.48	0.80	0.09	0.08	0.20	0.001	0.51	0.10	0.12

Appendix 4.2. Proportion of suppressively drenched (SD) or trigger drenched (TD) lambs which grazed monospecific swards of tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm and which weighed more than 32 kg. Expressed on a percentage basis.

Treatment		Days After the Start of the Trial											
		0	11	23	36	45	59	72	91	108	132	148	164
Tall fescue													
3 cm	SD	7.7	0	0	0	0	15.4	7.7	23.1	15.4	7.7	15.4	7.7
	TD	0	0	0	0	0	0	0	0	0	0	0	0
5 cm	SD	7.7	0	0	0	0	0	25	25	37.5	50	75	75
	TD	0	0	0	0	0	0	0	0	0	13.3	20	6.7
8 cm	SD	25	0	0	0	25	75	75	25	100	50	100	100
	TD	0	0	0	0	0	22.2	55.6	0	0	55.6	55.6	66.7
Yorkshire fog													
3 cm	SD	0	0	0	0	7.7	7.7	23.1	7.7	7.7	7.7	15.4	7.7
	TD	0	0	0	0	4	4	4	8	4	0	0	0
5 cm	SD	0	0	0	0	11.1	22.2	22.2	22.2	11.1	11.1	11.1	11.1
	TD	23.1	0	0	7.7	15.4	23.1	38.5	30.8	15.4	23.1	30.8	0
8 cm	SD	0	0	0	0	0	16.3	33.3	22.2	16.7	16.7	33.3	16.7
	TD	0	0	7.7	15.4	23.1	46.2	46.2	30.8	23.1	61.5	61.5	38.5

Appendix 4.3. Proportion of suppressively drenched (SD) lamb mass to total mass when grazing monospecific swards of tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm.

Treatment	Days After the Start of the Trial											
	0	11	23	36	45	59	72	91	108	132	148	164
Tall fescue												
3 cm	.349	.374	.355	.362	.326	.404	.349	.360	.392	.387	.376	.402
5 cm	.338	.319	.316	.347	.350	.342	.350	.325	.384	.391	.386	.396
8 cm	.336	.300	.329	.333	.334	.320	.330	.265	.259	.299	.328	.331
Yorkshire fog												
3 cm	.338	.343	.317	.342	.331	.345	.338	.344	.348	.342	.345	.361
5 cm	.329	.307	.309	.303	.317	.350	.321	.345	.329	.330	.331	.349
8 cm	.336	.421	.273	.325	.328	.313	.308	.290	.296	.277	.289	.284

Appendix 4.4. Mean abomasal nematode burdens ($\log_{10}(n+1)$ transformed; (n)) and the male to female ratio of nematodes recovered (M:F) from tracer lambs which grazed monospecific swards of either tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm. Arithmetic means are shown in parentheses. Period 1.

	Haemonchus			*Ostertagia*			*Trichostrongylus*			Abomasum total	
	n		M:F	n		M:F	n		M:F	n	
Tall fescue											
3cm	1.02	(37)	.57	2.62	(500)	.94	1.81	(80)	.50	2.70	(613)
5cm	0	(0)	0	2.40	(250)	.90	1.77	(68)	.69	2.50	(318)
8cm	.260	(3)	0	2.18	(188)	1.42	.59	(8)	0	2.20	(198)
Yorkshire fog											
3cm	1.20	(33)	2.25	2.41	(408)	.85	1.93	(185)	.68	2.57	(625)
5cm	0	(0)	0	2.64	(647)	1.19	1.22	(43)	1.17	2.66	(690)
8cm	.925	(48)	1.11	2.28	(220)	.76	.998	(25)	.67	2.38	(273)
Pooled SE	.366		ND[1]	.182		.324	.335		ND	.192	
Herbage effect (P<)	0.05		ND	NS		NS	NS		ND	NS	
Height effect (P<)	NS[2]		ND	NS		NS	0.03		ND	NS	
Herbage x height effect(P<)	NS		ND	NS		NS	NS		ND	NS	

[1] ND - not determined due to insufficient numbers
[2].NS - not significant (P>0.10)

Appendix 4.5. Mean intestinal nematode burdens ($\log_{10}$ (n+1) transformed; (n)) and the male to female ratio of nematodes recovered (M:F) from tracer lambs which grazed monospecific swards of either tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm. Pooled for both periods. Arithmetic means are shown in parentheses. Period 1.

	Cooperia			*Nematodirus*			*Trichostrongylus*			Intestine total	
	n		M:F	n		M:F	n		M:F	n	
Tall fescue											
3cm	1.63	(210)	.91	2.05	(157)	1.14	3.23	(1886)	.82	3.29	(2253)
5cm	1.79	(78)	.72	1.79	(115)	.64	2.86	(845)	.99	2.94	(1038)
8cm	1.05	(25)	1.00	1.09	(23)	1.25	2.10	(197)	1.34	2.24	(245)
Yorkshire fog											
3cm	1.25	(50)	.67	1.43	(40)	.33	2.63	(1080)	.72	2.74	(1170)
5cm	1.26	(76)	.77	1.51	(33)	2.33	2.64	(631)	.76	2.72	(740)
8cm	.819	(23)	1.25	1.56	(55)	2.14	2.49	(330)	.66	2.58	(408)
Pooled SE	.474		.323	.258		.251	.237		.259	.220	
Herbage effect (P<)	NS[2]		NS	NS		NS	0.05		NS	NS	
Height effect (P<)	NS		NS	NS		NS	NS		NS	0.05	
Herbage x height effect(P<)	NS		NS	NS		NS	NS		NS	NS	

[1] ND - not determined due to insufficient numbers
[2] NS - not significant (P>0.10)

Appendix 4.6. Mean abomasal nematode burdens (log_{10} (n+1) transformed; (n)) and the male to female ratio of nematodes recovered (M:F) from tracer lambs which grazed monospecific swards of either tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm. Pooled for both periods. Arithmetic means are shown in parentheses. Period 2.

	Haemonchus			*Ostertagia*			*Trichostrongylus*			Abomasum total	
	n		M:F	n		M:F	n		M:F	n	
Tall fescue											
3cm	1.18	(81)	.84	2.85	(653)	.93	2.05	(104)	1.05	2.96	(839)
5cm	.746	(8)	1.00	2.59	(346)	.58	1.66	(68)	.61	2.68	(421)
8cm	1.68	(26)	.54	2.50	(299)	1.20	1.50	(21)	1.33	2.61	(346)
Yorkshire fog											
3cm	1.04	(37)	.44	2.45	(370)	.92	1.81	(137)	.48	2.57	(544)
5cm	1.25	(11)	.33	2.61	(593)	1.02	1.34	(53)	.71	2.72	(657)
8cm	1.43	(39)	1.66	2.66	(316)	.92	1.81	(44)	.61	2.75	(398)
Pooled SE	.401		ND[1]	.151		.168	.254		.150	.131	
Herbage effect (P<)	NS[2]		ND	NS		NS	NS		NS	NS	
Height effect (P<)	NS		ND	NS		NS	NS		NS	NS	
Herbage x height effect(P<)	NS		ND	NS		NS	NS		NS	NS	

[1] ND - not determined due to insufficient numbers
[2] NS - not significant (P>0.10)

Appendix 4.7. Mean intestinal nematode burdens ($\log_{10}$ (n+1) transformed; (n)) and the male to female ratio of nematodes recovered (M:F) from tracer lambs which grazed monospecific swards of either tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm. Pooled for both periods. Arithmetic means are shown in parentheses. Period 2.

	Cooperia			*Nematodirus*			*Trichostrongylus*			Intestine total	
	n		M:F	n		M:F	n		M:F	n	
Tall fescue											
3cm	2.06	(173)	1.43	2.52	(257)	1.53	3.44	(2411)	.92	3.51	(2841)
5cm	2.29	(149)	.59	2.19	(140)	.89	3.36	(1820)	.70	3.42	(2109)
8cm	2.00	(65)	.75	1.92	(58)	.76	3.04	(643)	.77	3.11	(865)
Yorkshire fog											
3cm	1.19	(36)	.25	.788	(27)	.50	2.28	(709)	.61	2.33	(771)
5cm	1.53	(57)	.13	1.58	(88)	.86	2.61	(603)	.65	2.71	(749)
8cm	1.30	(39)	1.25	1.58	(53)	.36	2.49	(357)	.88	2.58	(449)
Pooled SE	.239		ND[1]	.290		.187	.154		.144	.157	
Herbage effect (P<)	0.002		ND	0.003		NS	0.0001		NS	0.0001	
Height effect (P<)	NS[2]		ND	NS		NS	NS		NS	NS	
Herbage x height effect(P<)	NS		ND	0.10		NS	NS		NS	NS	

[1] ND - not determined due to insufficient numbers
[2] NS - not significant (P>0.10)

Appendix 4.8. Mean calculated faecal output (FO; g OM/day), organic matter intake (OMI) and organic matter intake adjusted to a common metabolic body weight ($LW^{0.75}$) from lambs which were either suppressively drenched fortnightly (SD) or trigger drenched when mean faecal egg count reached 1000 eggs per gram. Lambs grazed monospecific swards of tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm.

		Period 1			Period 2			Period 3		
		FO	OMI	OMI($LW^{0.75}$)	FO	OMI	OMI($LW^{0.75}$)	FO	OMI	OMI($LW^{0.75}$)
Tall Fescue										
3 cm	SD	247.9	770	63.8	280.7	880	72.9	261.8	820	67.9
	TD	260.2	820	71.9	192.9	600	52.6	261.2	820	71.9
5 cm	SD	330.2	1133	84.2	294.4	1011	75.2	269.1	924	68.7
	TD	258.3	887	73.5	239.5	821	68.0	266.7	916	75.9
8 cm	SD	525.0	1725	117.8	336.2	1106	75.5	350.4	1153	78.8
	TD	361.8	1188	85.3	306.1	1005	72.2	337.6	1105	79.4
Yorkshire fog										
3 cm	SD	244.7	685	59.5	209.0	585	50.8	229.3	641	55.7
	TD	207.9	580	52.8	207.0	579	52.7	191.5	536	48.8
5 cm	SD	253.0	611	52.6	252.8	610	52.5	226.1	547	47.1
	TD	323.1	782	64.3	228.4	553	45.4	233.9	566	46.5
8 cm	SD	216.2	740	58.4	179.9	615	48.6	194.0	664	52.4
	TD	213.6	730	53.0	196.2	671	48.7	208.0	712	51.7
Pooled SE		54.15	162.3	24.3	31.5	82.4	2.10	34.7	577.1	13.05
Herbage effect (P<)		0.0008	0.007	0.94	0.0001	0.0001	0.003	0.0001	0.04	0.23

Appendix 4.9. Average faecal consistency of TD lambs which grazed monospecific swards of tall fescue or Yorkshire fog to target heights of 3, 5, or 8 cm. At each sampling, faeces of lambs was scored for consistency from 1 to 5; 1 being liquid faeces, 5 being pellets.

	Days After Trial Start								
	36	45	59*	72	91	108*	132	148*	164
Tall Fescue									
3cm	3.46	3.05	3.05	2.69	3.43	3.09	3.80	3.38	3.70
5cm	3.73	3.17	3.29	3.30	3.33	3.52	3.52	2.75	3.47
8cm	3.25	3.21	3.47	3.00	3.13	3.08	3.00	2.78	2.90
Yorkshire fog									
3 cm	3.24	3.00	3.00	3.39	3.36	4.00	4.53	4.13	4.45
5cm	3.13	3.25	3.07	3.40	3.19	4.26	4.36	3.83	4.25
8 cm	3.29	3.07	2.79	3.27	ND[1]	3.30	3.23	2.36	3.57
Pooled SE	0.30	0.35	0.37	0.37	0.40	0.43	0.44	0.45	0.42
Herbage effect (P<)	0.0001	0.20	0.001	0.12	.050	0.0003	0.02	0.02	0.0001
Height effect (P<)	0.16	0.85	0.42	0.84	.010	0.03	0.0005	0.0001	0.0009
Herbage x height effect (P<)	0.10	0.56	0.02	0.23	0.03	0.16	0.59	0.02	0.39

* Lambs were treated with anthelmintic at this time

[1] ND - not determined

Appendix 6.1. Average numbers of *Ostertagia* and *Trichostrongylus* third stage larvae recovered from swards of herbages contaminated with faeces containing a known number of eggs. Both years.

Herbage	1992/93			1993/94		
	Ostertagia	*Trichostrongylus*	Combined	*Ostertagia*	*Trichostrongylus*	Combined
Browntop	32.3	79.7	112.0	103.1	455.8	558.9
Cocksfoot	27.3	64.2	91.5	119.3	304.7	424.0
Chicory	7.0	53.5	60.5	39.8	262.7	302.5
Tall fescue	11.4	50.3	61.7	100.1	274.2	374.4
Lucerne	10.6	48.7	59.3	87.2	152.6	239.8
Prairie grass	12.3	48.1	60.4	101.8	264.6	366.4
Ryegrass	27.4	62.4	89.8	129.4	364.9	494.3
Ryegrass/white clover	ND[1]	ND	ND	98.3	252.9	351.2
White clover	12.3	49.2	61.5	70.4	151.5	221.9
Yorkshire fog	23.3	85.6	108.9	156.3	583.6	739.9
Pooled SE	2.62	11.87	12.68	9.99	52.84	56.95
Herbage effect (P<)	0.005	0.83	0.56	0.06	0.02	0.01

[1] ND -not determined.

Appendix 6.2. Third stage larval numbers and other nematodes (Others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 14900 *Trichostrongylus colubriformis* (Trichs) and 14700 *Ostertagia circumcincta* (Ost) eggs. Contamination 1 Week 2 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	0	ND[1]	13.3	419	0	0	0	0	0	0
Cocksfoot	0	91.1	ND	6.7	254	6.7	297	0	0	0	0
Chicory	0	26.5	ND	0	0	0	0	0	0	0	0
Tall fescue	0	106.5	ND	13.3	422	6.7	272	0	0	0	0
Lucerne	0	0	ND	0	0	0	0	0	0	0	0
Prairie grass	0	6.7	ND	13.3	407	0	0	6.7	242	0	0
Ryegrass	0	75.5	ND	13.3	423	6.7	286	0	0	0	0
White clover	0	8.3	ND	13.3	845	6.7	516	6.7	319	0	0
Yorkshire fog	0	47.1	ND	53.3	1935	0	0	0	0	0	0
Pooled SE	NA[2]	10.7	NA••	3.24	118.93	1.36	73.74	0.97	41.37	NA	NA
Herbage effect (P<)	NA	0.30	NA	0.04	0.04	0.75	0.73	0.56	0.56	NA	NA

[1] ND - not determined; [2] NA - not applicable

Appendix 6.3. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 14900 *Trichostrongylus colubriformis* (Trichs) and 14700 *Ostertagia circumcincta* (Osts) eggs. Contamination 1 Week 4 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	13.3	313	20.0	1621	13.3	1491	0	0
Cocksfoot	ND	ND	ND	126.7	10620	66.7	16683	20.0	4349	6.7	1474
Chicory	ND	ND	ND	20	1762	41.5	9262	0	0	60.0	4033
Tall fescue	ND	ND	ND	6.7	537	6.7	1889	0	0	0	0
Lucerne	ND	ND	ND	46.7	56952	13.3	2990	26.7	4854	40.0	2096
Prairie grass	ND	ND	ND	13.3	840	33.3	5851	0	0	6.7	444
Ryegrass	ND	ND	ND	40.0	2660	20.0	4133	20.0	6893	13.3	4443
White clover	ND	ND	ND	13.3	453	0	0	6.7	1108	0	0
Yorkshire fog	ND	NA	ND	271.0	12041	60.0	6788	18.8	3304	8.8	1689
Pooled SE	NA[2]	NA	NA	13.51	859.5	5.66	1295.4	2.93	670.1	3.60	419.8
Herbage effect (P<)	NA	NA	NA	0.005	0.03	0.19	0.22	0.35	0.26	0.007	0.17

[1] ND - not determined
[2] NA - not applicable

Appendix 6.4. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 14900 *Trichostrongylus colubriformis* (Trichs) and 14700 *Ostertagia circumcincta* (Ost) eggs. Contamination 1 Week 6 1992/93.

Herbage				Vertical height (cm)							
		Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	10.7	1068	13.2	148	0	0	0	0
Cocksfoot	ND	ND	ND	118.5	11057	18.0	2627	0	0	0	0
Chicory	ND	ND	ND	7.0	250	50.7	6502	32.3	5850	30.0	518
Tall fescue	ND	ND	ND	86.1	8401	0	0	0	0	8.3	2502
Lucerne	ND	ND	ND	29.2	2375	5.7	8666	0	0	13.3	305
Prairie grass	ND	ND	ND	30.7	4480	18.0	2811	0	0	6.7	526
Ryegrass	ND	ND	ND	106.4	8283	80.9	10867	0	0	6.7	965
White clover	ND	ND	ND	0	0	16.9	1912	0	0	6.7	265
Yorkshire fog	ND	ND	ND	110.9	10850	20.0	2118	0	0	9.3	296
Pooled SE	NA[2]	NA	NA	8.42	727.6	4.52	834.5	1.08	229.0	2.20	260.8
Herbage effect (P<)	NA	NA	NA	0.19	0.15	0.08	0.27	0.001	0.001	0.38	0.68

[1] ND - not determined
[2] NA - not applicable

Appendix 6.5. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 14900 *Trichostrongylus colubriformis* (Trichs) and 14700 *Ostertagia circumcincta* (Ost) eggs. Contamination 1 Week 8 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	20.0	957	0	0	15.3	1343	6.7	579
Cocksfoot	ND	ND	ND	69.9	7151	26.7	3828	0	0	0	0
Chicory	ND	ND	ND	3.3	84	6.7	2983	13.3	2312	13.3	660
Tall fescue	ND	ND	ND	20.0	1783	0	0	0	0	0	0
Lucerne	ND	ND	ND	20.0	4967	8.3	8286	0	0	6.7	54
Prairie grass	ND	ND	ND	33.3	2975	6.7	884	6.7	1494	0	0
Ryegrass	ND	ND	ND	80.0	7448	20.0	2739	20.0	2891	7.2	421
White clover	ND	ND	ND	0	0	6.7	1442	0	0	0	0
Yorkshire fog	ND	ND	ND	26.7	3277	40.0	3415	26.7	3229	6.7	214
Pooled SE	NA[2]	NA	NA	4.85	523.5	4.05	888.6	2.70	419.0	1.56	93.4
Herbage effect (P<)	NA	NA	NA	0.02	0.03	0.43	0.70	0.27	0.50	0.55	0.63

[1]ND - not determined
[2] NA - not applicable

Appendix 6.6. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 14900 *Trichostrongylus colubriformis* (Trichs) and 14700 *Ostertagia circumcincta* (Ost) eggs. Contamination 1 Week 11 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	0	0	1	227	6.7	632	0	0
Cocksfoot	ND	ND	ND	26.7	2333	0	0	6.7	861	0	0
Chicory	ND	ND	ND	20.0	2971	0	0	6.7	1441	0	0
Tall fescue	ND	ND	ND	6.7	639	13.3	2179	0	0	0	0
Lucerne	ND	ND	ND	0	0	0	0	15.0	4072	7.8	1020
Prairie grass	ND	ND	ND	6.7	444	0	0	0	0	0	0
Ryegrass	ND	ND	ND	13.3	1567	0	0	6.7	1595	0	0
White clover	ND	ND	ND	0	0	0	0	0	0	0	0
Yorkshire fog	ND	ND	ND	13.3	1746	26.7	3521	13.3	1329	6.7	153
Pooled SE	NA[2]	NA	NA	3.11	394.65	1.19	186.21	2.11	374.93	0.98	88.28
Herbage effect (P<)	NA	NA	NA	0.55	0.65	0.001	0.001	0.77	0.48	0.51	0.36

[1] ND - not determined
[2] NA - not applicable

Appendix 6.7. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 14900 *Trichostrongylus colubriformis* (Trichs) and 14700 *Ostertagia circumcincta* (Ost) eggs. Contamination 1 Week 14 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	8.9	377	0	0	0	0	13.3	227
Cocksfoot	ND	ND	ND	26.7	1950	0	0	0	0	20.0	478
Chicory	ND	ND	ND	0.4	265	6.5	783	0	0	3.7	61
Tall fescue	ND	ND	ND	0	0	0	0	0	0	0	0
Lucerne	ND	ND	ND	13.3	2836	6.7	1851	0	0	6.7	144
Prairie grass	ND	ND	ND	0	0	0	0	0	0	6.7	175
Ryegrass	ND	ND	ND	8.9	719	12.7	1963	8.0	1062	6.7	636
White clover	ND	ND	ND	0	0	33.3	8408	0	0	0	0
Yorkshire fog	ND	ND	ND	6.7	883	6.7	529	0	0	0	0
Pooled SE	NA[2]	NA	NA	2.62	356.03	3.67	897.87	0.68	90.67	2.14	72.23
Herbage effect (P<)	NA	NA	NA	0.42	0.65	0.61	0.57	0.33	0.48	0.51	0.58

[1] ND - not determined
[2] NA - not applicable

Appendix 6.8. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 27900 *Trichostrongylus colubriformis* (Trichs) and 2000 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 2 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	0	317.2	0	0	0	0	0	0	0	0
Cocksfoot	10.0	10.0	60.0	0	0	0	0	0	0	0	0
Tall fescue	0	0	771.9	0	0	0	0	16	13584.8	0	0
Lucerne	0	0	188.9	20.0	10645	0	0	0	0	0	0
Prairie grass	0	0	1840.5	0	0	0	0	0	0	0	0
Ryegrass	0	10.3	108.7	0	0	0	0	0	0	0	0
White clover	0	21.3	569.3	0	0	6.7	7559.3	0	0	0	0
Yorkshire fog	0	0	55.4	0	0	0	0	0	0	0	0
Pooled SE	1.25	2.82	165.3	2.55	1375.39	0.82	976.07	1.00	1045.5	NA[1]	NA
Herbage effect (P<)	0.46	0.46	0.16	0.48	0.50	0.45	0.49	0.01	0.08	NA	NA

[1] NA - not applicable

Appendix 6.9. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 27900 *Trichostrongylus colubriformis* (Trichs) and 2000 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 4 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	316.8	320.3	0	0	0	0	0	0	0	0
Cocksfoot	0	115.8	106.5	0	0	0	0	0	0	0	0
Tall fescue	35.1	125.6	345.3	0	0	0	0	0	0	0	0
Lucerne	3.1	62.3	306.8	0	0	0	0	106.7	515218	0	0
Prairie grass	17.0	203.9	108.3	0	0	0	0	0	0	0	0
Ryegrass	0	0	365.9	0	0	0	0	0	0	0	0
White clover	40.8	275.9	383.3	0	0	0	0	0	0	0	0
Yorkshire fog	9.5	123.2	519.2	0	0	6.7	4663	0	0	0	0
Pooled SE	4.86	28.0	50.13	NA[1]	NA	0.84	511.92	10.66	62616.09	NA	NA
Herbage effect (P<)	0.24	0.17	0.49	NA	NA	0.46	0.46	0.42	0.42	NA	NA

[1] NA - not applicable

Appendix 6.10. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 27900 *Trichostrongylus colubriformis* (Trichs) and 2000 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 6 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	35.7	422.8	ND[1]	93.3	9189	106.7	18154	286.7	74964	80.0	45186
Cocksfoot	30.2	688.1	ND	100.0	10199	46.7	7469	16.3	2072	60.0	3526
Tall fescue	48.2	1192.3	ND	40.0	5215	33.3	6760	93.3	20204	146.7	22440
Lucerne	38.9	748.3	ND	44.4	13669	52.8	14600	61.6	20512	183.2	11648
Prairie grass	37.2	1079.4	ND	73.3	13263	26.7	3465	40.0	7817	73.3	4132
Ryegrass	26.2	618.0	ND	38.5	4695	106.7	17910	180.0	41497	220.0	43112
White clover	31.8	360.9	ND	66.7	9996	40.0	10098	153.3	37310	431.2	77204
Yorkshire fog	16.1	2624.2	ND	34.6	6938	71.9	15663	27.8	6181	33.5	2560
Pooled SE	9.17	98.29	NA[2]	8.38	1337.20	11.59	2143.33	23.19	5447.30	23.16	4044.56
Herbage effect (P<)	0.99	0.02	NA	0.41	0.69	0.52	0.59	0.13	0.06	0.01	0.001

[1] ND - not determined
[2] NA - not applicable

Appendix 6.11. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 27900 *Trichostrongylus colubriformis* (Trichs) and 2000 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 8 1992/93.

Herbage				Vertical height (cm)							
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	14.8	82.6	ND[1]	353.3	27973	144.8	17301	166.7	32378	198.4	32190
Cocksfoot	80.0	787.2	ND	33.3	4039	86.7	15456	60.0	10282	320.0	11635
Tall fescue	29.6	834.3	ND	120.0	13622	120.0	18868	60.0	10429	146.7	9697
Lucerne	0	197.7	ND	93.3	32984	13.3	6530	72.4	46987	140.0	7355
Prairie grass	15.2	358.5	ND	160.0	27973	94.2	18442	112.4	25218	80.8	6739
Ryegrass	32.9	211.2	ND	26.7	3511	46.7	7002	60.0	11273	80.0	7178
White clover	0	129.4	ND	66.7	15170	86.7	23505	80.0	21740	200.0	17882
Yorkshire fog	0	327.6	ND	566.5	97465	203.6	26765	82.0	17749	46.4	2238
Pooled SE	9.26	86.4	NA[2]	25.40	3866.71	13.90	2285.58	12.83	3510.84	23.86	2050.32
Herbage effect (P<)	0.46	0.41	NA	0.001	0.001	0.09	0.42	0.46	0.24	0.18	0.07

[1] ND - not determined
[2] NA - not applicable

Appendix 6.12. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 27900 *Trichostrongylus colubriformis* (Trichs) and 2000 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 11 1992/93.

Herbage	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	22.0	0	ND[1]	20.0	1482	33.3	2745	26.7	4162	45.9	3115
Cocksfoot	0	5.4	ND	20.0	2148	26.7	3985	20.0	3561	6.7	170
Tall fescue	50.1	83.8	ND	26.7	4275	28.9	4902	33.3	7278	86.7	6448
Lucerne	6.0	25.4	ND	6.7	1777	40.0	14699	13.3	5240	0	0
Prairie grass	0	51.8	ND	13.3	1615	40.0	3629	0	0	20.0	768
Ryegrass	18.5	239.3	ND	6.7	837	21.8	3401	0	0	6.7	377
White clover	0	0	ND	0	0	13.3	2801	12.8	2465	6.7	741
Yorkshire fog	0	30.7	ND	25.9	3385	13.3	3531	20.0	4564	26.7	1007
Pooled SE	3.52	19.37	NA[2]	3.82	488.99	7.06	1472.24	4.54	1021.62	5.98	393.94
Herbage effect (P<)	0.21	0.10	NA	0.61	0.50	0.96	0.52	0.57	0.64	0.02	0.004

Vertical height (cm) spans the 0-2.5, 2.5-5, 5-7.5 and 7.5+ columns.

[1] ND - not determined
[2] NA - not applicable

Appendix 6.13. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 27900 *Trichostrongylus colubriformis* (Trichs) and 2000 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 14 1992/93.

Herbage	Vertical height (cm)									
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	0	ND[1]	33.3	2630	26.7	2278	26.7	2771	26.7	1047
Cocksfoot	0	17.1	ND	40.0	3856	13.3	1722	53.3	7247	13.3	361
Tall fescue	0	16.5	ND	6.7	818	6.7	1091	26.7	3960	30.9	1723
Lucerne	0	0	ND	113.3	32911	13.3	5458	13.3	4852	73.3	3290
Prairie grass	0	0	ND	22.7	2503	20.0	3063	20.0	4038	13.3	468
Ryegrass	0	36.6	ND	6.7	643	20.0	2000	46.7	5413	13.3	564
White clover	0	0	ND	0	0	13.3	3358	0	0	0	0
Yorkshire fog	21.3	0	ND	86.7	11168	15.0	2107	40.0	5333	60.0	1855
Pooled SE	2.67	4.32	NA[2]	9.06	2257.02	3.30	654.4	6.52	943.12	7.81	305.65
Herbage effect (P<)	0.46	0.32	NA	0.04	0.02	0.89	0.82	0.51	0.72	0.28	0.19

[1] ND - not determined
[2] NA - not applicable

Appendix 6.14. Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 31100 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 3 Week 2 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	10.0	ND	10.1	720	0	0	ND	ND	ND	ND
Cocksfoot	ND	ND	ND	13.3	2287	0	0	ND	ND	ND	ND
Chicory	ND	5.7	ND	0	0	0	0	ND	ND	ND	ND
Tall fescue	ND	5.7	ND	0	0	0	0	ND	ND	ND	ND
Lucerne	ND	ND	ND	0	0	0	0	ND	ND	ND	ND
Prairie grass	ND	12.8	ND	11.5	2850	0	0	ND	ND	ND	ND
Ryegrass	ND	0	ND	0	0	0	0	ND	ND	ND	ND
White clover	ND	2.8	ND	13.3	4666	0	0	ND	ND	ND	ND
Yorkshire fog	ND	28.5	ND	0	0	6.7	1197	ND	ND	ND	ND
Pooled SE	NA[2]	4.20	NA	1.93	630.04	0.72	146.94	NA	NA	NA	NA
Herbage effect (P<)	NA	0.79	NA	0.47	0.56	0.52	0.52	NA	NA	NA	NA

[1] ND - not determined
[2] NA - not applicable

Appendix 6.15 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 31100 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 3 Week 4 1992/93.

Herbage	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	33.3	2881	100.0	12083	20.0	6143	0	0
Cocksfoot	ND	ND	ND	6.7	922	6.7	1538	0	0	0	0
Chicory	ND	ND	ND	0	0	4.1	988	11.1	2810	4.8	498
Tall fescue	ND	ND	ND	6.7	780	0	0	0	0	0	0
Lucerne	ND	ND	ND	3.9	1642	6.7	1814	0	0	0	0
Prairie grass	ND	ND	ND	13.3	1627	13.3	2110	6.7	1509	180.0	29811
Ryegrass	ND	ND	ND	23.7	3115	1.6	178	40.9	9407	29.4	4663
White clover	ND	ND	ND	0	0	0	0	0	0	0	0
Yorkshire fog	ND	ND	ND	78.6	8247	86.7	14454	6.7	1729	0	0
Pooled SE	NA[2]	NA	NA	0.49	849.80	11.14	1897.37	4.25	1235.61	17.93	3472.09
Herbage effect (P<)	NA	NA	NA	0.43	0.49	0.35	0.44	0.58	0.62	0.43	0.47

[1] ND - not determined
[2] NA - not applicable

Appendix 6.16 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 31100 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 3 Week 6 1992/93.

Herbage				Vertical height (cm)							
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	17.2	38886	0	0	6.7	6403	0	0
Cocksfoot	ND	ND	ND	13.3	168766	0	0	0	0	20.0	12201
Chicory	ND	ND	ND	0	0	0	0	9.6	87729	0.2	1943
Tall fescue	ND	ND	ND	0	0	0	0	0	0	6.7	16969
Lucerne	ND	ND	ND	0	0	0	0	0	0	0	0
Prairie grass	ND	ND	ND	6.7	54032	0	0	0	0	0	0
Ryegrass	ND	ND	ND	6.7	25496	26.7	17415	0	0	6.7	4629
White clover	ND	ND	ND	0	0	0	0	0	0	0	0
Yorkshire fog	ND	ND	ND	46.7	67828	0	0	0	0	8.2	4705
Pooled SE	NA[2]	NA	NA	2.35	15518.08	1.74	1366.39	0.98	6744.07	2.39	2564.56
Herbage effect (P<)	NA	NA	NA	0.001	0.17	0.03	0.03	0.43	0.18	0.66	0.69

[1] ND - not determined
[2] NA - not applicable

Appendix 6.17 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 31100 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 3 Week 8 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	6.7	492	26.7	3644	20.0	3452	6.7	767
Cocksfoot	ND	ND	ND	20.0	2402	0	0	0	0	0	0
Chicory	ND	ND	ND	6.7	6657	8.8	2464	0	0	0.4	42
Tall fescue	ND	ND	ND	6.7	941	0	0	6.7	1151	0	0
Lucerne	ND	ND	ND	6.7	1817	0	0	0	0	0	0
Prairie grass	ND	ND	ND	0	0	0	0	0	0	0	0
Ryegrass	ND	ND	ND	0	0	6.7	719	13.3	2065	6.7	736
White clover	ND	ND	ND	0	0	53.3	17978	0	0	0.7	77
Yorkshire fog	ND	ND	ND	33.3	4349	13.3	3009	7.0	1517	0	0
Pooled SE	NA[2]	NA	NA	2.85	654.59	5.79	2145.32	2.08	406.14	1.02	131.60
Herbage effect (P<)	NA	NA	NA	0.22	0.32	0.54	0.54	0.35	0.36	0.65	0.65

[1] ND - not determined
[2] NA - not applicable

Appendix 6.18 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 31100 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 3 Week 11 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	5.8	81	33.3	3254	6.7	733	0	0
Cocksfoot	ND	ND	ND	40.0	5043	2.2	0	6.7	1197	0	0
Chicory	ND	ND	ND	8.9	1855	6.7	870	91.3	46318	0	0
Tall fescue	ND	ND	ND	6.7	952	6.7	1101	26.7	4557	0	0
Lucerne	ND	ND	ND	26.7	10718	33.3	24497	33.3	32960	6.7	1331
Prairie grass	ND	ND	ND	0	0	20.0	3879	13.3	2801	0	0
Ryegrass	ND	ND	ND	0	0	13.3	3047	6.7	1649	33.3	2395
White clover	ND	ND	ND	0	0	6.7	2299	6.7	2150	0	0
Yorkshire fog	ND	ND	ND	6.7	1897	33.3	11132	6.7	1850	0	0
Pooled SE	NA[2]	NA	NA	4.29	858.11	4.21	2601.31	7.58	4717.28	1.73	174.31
Herbage effect (P<)	NA	NA	NA	0.48	0.16	0.55	0.58	0.40	0.40	0.002	0.04

[1] ND - not determined
[2] NA - not applicable

Appendix 6.19 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 31100 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 3 Week 14 1992/93.

Herbage					Vertical height (cm)						
		Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	0	0	6.7	658	6.7	728	0	0
Cocksfoot	ND	ND	ND	0	0	13.3	2214	6.7	1247	7.5	259
Chicory	ND	ND	ND	7.1	727	0	0	8.8	1840	1.3	246
Tall fescue	ND	ND	ND	0	0	0	0	60.0	11177	0	0
Lucerne	ND	ND	ND	46.7	12667	0	0	0	0	0	0
Prairie grass	ND	ND	ND	0	0	0	0	0	0	6.7	127
Ryegrass	ND	ND	ND	0	0	0	0	0	0	6.7	1904
White clover	ND	ND	ND	0	0	0	0	6.7	3436	0	0
Yorkshire fog	ND	ND	ND	0	0	0	0	0	0	0	0
Pooled SE	NA[2]	NA	NA	5.05	1370.39	1.08	156.45	6.30	1229.00	1.23	207.26
Herbage effect (P<)	NA	NA	NA	0.54	0.54	0.10	0.06	0.55	0.60	0.68 1.23	0.57

[1] ND - not determined
[2] NA - not applicable

Appendix 6.20 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 23100 *Trichostrongylus colubriformis* (Trichs) and 8100 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 2 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	34.9	68.7	ND[1]	0	0	6.7	965	6.7	6217	0	1910
Cocksfoot	0	0	ND	0	0	0	0	0	0	0	0
Chicory	71.2	18.6	ND	0	0	1.2	76	0	0	0	0
Tall fescue	0	0	ND	0	0	0	0	0	0	0	0
Lucerne	18.1	2.0	ND	0	0	0	0	0	0	ND	ND
Prairie grass	0	0	ND	0	0	0	0	0	0	0	0
Ryegrass	0	0	ND	0	0	6.7	2691	13.3	10262	6.7	9847
White clover	275.8	35.4	ND	0	0	6.7	5742	0	0	ND	ND
Yorkshire fog	0	1.4	ND	0	0	0	0	0	0	ND	ND
Pooled SE	29.77	4.96	NA[2]	NA	NA	1.20	691.03	1.50	1315.95	1.15	1455.20
Herbage effect (P<)	0.38	0.10	NA	NA	NA	0.67	0.63	0.49	0.70	0.52	0.62

[1] ND - not determined
[2] NA - not applicable

Appendix 6.21 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 23100 *Trichostrongylus colubriformis* (Trichs) and 8100 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 4 1992/93.

Herbage	Larvae in Faeces			Vertical height (cm)							
				0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	20.0	885	20.0	3217	26.7	10822	0	0
Cocksfoot	ND	ND	ND	26.7	3253	26.7	6697	6.7	3257	0	0
Chicory	ND	ND	ND	6.7	3151	0	0	0	0	6.7	2193
Tall fescue	ND	ND	ND	13.3	2012	0	0	6.7	1961	20.0	8625
Lucerne	ND	ND	ND	6.7	1274	6.7	3189	0	0	0	0
Prairie grass	ND	ND	ND	13.5	1821	15.4	3608	0	0	0	0
Ryegrass	ND	ND	ND	166.7	24662	0	0	2.0	608	0	0
White clover	ND	ND	ND	20.0	4551	6.7	1688	0	0	0.4	81
Yorkshire fog	ND	ND	ND	0	0	0	0	0	0	0	0
Poole SE	NA[2]	NA	NA	11.96	1926.26	2.37	585.02	2.30	868.60	2.23	837.71
Herbage effect (P<)	NA	NA	NA	0.12	0.20	0.14	0.20	0.25	0.17	0.55	0.50

[1] ND - not determined
[2] NA - not applicable

Appendix 6.22 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 23100 *Trichostrongylus colubriformis* (Trichs) and 8100 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 6 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	66.7	3774	39.1	5717	0	0	6.7	30101
Cocksfoot	ND	ND	ND	20.0	2844	13.3	2932	0	0	0	0
Chicory	ND	ND	ND	8.3	3545	0.2	117	10.3	4954	1.8	4360
Tall fescue	ND	ND	ND	0	0	6.7	1438	6.7	3111	6.7	1731
Lucerne	ND	ND	ND	12.9	1702	0	0	0	0	0	0
Prairie grass	ND	ND	ND	74.8	7092	32.9	8335	0	0	0	0
Ryegrass	ND	ND	ND	73.3	11679	33.3	8020	26.6	8727	0	0
White clover	ND	ND	ND	6.7	873	6.7	1834	0	0	0	0
Yorkshire fog	ND	ND	ND	93.3	5816	13.3	3699	0	0	0	0
Pooled SE	NA[2]	NA	NA	5.80	797.51	3.16	690.83	2.36	877.22	1.02	3328.30
Herbage effect (P<)	NA	NA	NA	0.005	0.10	0.12	0.17	0.24	0.32	0.66	0.59

[1] ND - not determined
[2] NA - not applicable

Appendix 6.23 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 23100 *Trichostrongylus colubriformis* (Trichs) and 8100 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 8 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	13.3	927	33.3	4917	26.6	5866	86.7	33675
Cocksfoot	ND	ND	ND	80.0	14520	86.7	15013	33.3	9049	6.7	991
Chicory	ND	ND	ND	6.7	6996	13.3	4837	6.7	3047	6.7	779
Tall fescue	ND	ND	ND	6.7	899	33.3	7040	0	0	6.7	872
Lucerne	ND	ND	ND	0	0	0	0	0.5	302	0	0
Prairie grass	ND	ND	ND	7.4	515	0	0	16.3	4638	0	0
Ryegrass	ND	ND	ND	33.3	5240	0	0	40.0	10207	6.7	928
White clover	ND	ND	ND	6.7	2192	6.7	2497	6.67	3824	4.2	6561
Yorkshire fog	ND	ND	ND	86.6	9622	0	0	0.3	224	0	0
Pooled SE	NA[2]	NA	NA	5.66	1120.46	4.56	889.37	4.16	1137.37	9.94	3902.86
Herbage effect (P<)	NA	NA	NA	0.01	0.14	0.004	0.02	0.32	0.48	0.64	0.63

[1] ND - not determined
[2] NA - not applicable

Appendix 6.24 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 23100 *Trichostrongylus colubriformis* (Trichs) and 8100 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 11 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	0	0	13.3	1421	6.7	1169	0	0
Cocksfoot	ND	ND	ND	18.1	2920	33.3	6381	6.7	1475	20.0	1438
Chicory	ND	ND	ND	6.7	2221	0	0	0	0	0	0
Tall fescue	ND	ND	ND	6.7	1228	0	0	6.7	1223	6.7	558
Lucerne	ND	ND	ND	4.8	909	0	0	0	0	5.0	426
Prairie grass	ND	ND	ND	6.7	1186	6.7	1719	0	0	0	0
Ryegrass	ND	ND	ND	6.7	1421	0	0	20.0	4945	0	0
White clover	ND	ND	ND	6.7	1168	0	0	0	0	0	0
Yorkshire fog	ND	ND	ND	13.3	1761	6.7	1173	0	0	13.3	1413
Pooled SE	NA[2]	NA	NA	1.92	397.81	2.49	475.07	1.84	414.27	1.34	119.26
Herbage effect (P<)	NA	NA	NA	0.77	0.93	0.11	0.12	0.33	0.23	0.02	0.03

[1] ND - not determined
[2] NA - not applicable

Appendix 6.25 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 23100 *Trichostrongylus colubriformis* (Trichs) and 8100 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 14 1992/93.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	16.2	1096	0	0	0	0	0	0
Cocksfoot	ND	ND	ND	13.3	2254	16.9	2543	13.3	2037	0	0
Chicory	ND	ND	ND	1.0	38	0.3	77	0	0	0.9	75
Tall fescue	ND	ND	ND	0	0	0	0	0	0	0	0
Lucerne	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Prairie grass	ND	ND	ND	0	0	0	0	6.7	1489	6.7	514
Ryegrass	ND	ND	ND	6.7	764	7.0	987	0	0	6.6	302
White clover	ND	ND	ND	7.2	889	0	0	0	0	0	0
Yorkshire fog	ND	ND	ND	13.3	2069	6.7	1028	6.7	1076	0	0
Pooled SE	NA[2]	NA	NA	2.70	395.94	1.80	270.51	2.26	379.41	1.28	80.65
Herbage effect (P<)	NA	NA	NA	0.71	0.74	0.35	0.35	0.75	0.76	0.68	0.68

[1] ND - not determined
[2] NA - not applicable

Appendix 6.26 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 50000 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 1 Week 2 1993/94.

Herbage	Vertical height (cm)									
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	16.3	727.5	6.7	293	13.3	810	0	0	6.7	1776
Cocksfoot	ND	0	575.6	0	0	0	0	0	0	0	0
Tall fescue	ND	21.6	176.1	0	0	0	0	0	0	0	0
Ryegrass	ND	16.5	20.9	0	0	0	0	0	0	0	0
White clover	ND	99.5	722.2	6.7	821	13.3	2323	0	0	73.3	22974
Yorkshire fog	ND	0	726.0	13.3	945	0	0	13.3	2857	13.3	1867
Pooled se	NA[2]	13.69	124.74	3.84	222.78	3.84	498.17	2.72	582.81	14.98	4698.94
Herbage effect (P<)	NA	0.16	0.22	0.58	0.49	0.58	0.52	0.46	0.46	0.50	0.49

[1] ND - not determined
[2] NA - not applicable

Appendix 6.27 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 50000 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 1 Week 4 1993/94.

Herbage				Vertical height (cm)								
		Larvae in Faeces		0-2.5		2.5-5		5-7.5		7.5+		
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	202.5	1508.9	133.3	6895	153.3	16493	26.7	5317	53.3	11112
Cocksfoot	ND	313.2	1096.2	53.3	7084	20.0	4013	20.0	5700	40.8	5170
Tall fescue	ND	83.8	628.5	98.4	8496	89.1	16202	37.1	9771	45.8	5938
Ryegrass	ND	140.4	200.8	220.0	20422	73.3	11834	112.1	22703	26.7	2491
White clover	ND	0	11.8	20.0	2704	13.3	3582	26.7	6773	20.0	4093
Yorkshire fog	ND	258.2	951.4	233.3	24702	33.3	5603	86.7	16291	73.3	5515
Pooled SE	NA[2]	45.92	165.58	21.12	1963.62	18.72	2563.63	14.60	2821.51	11.20	1823.18
Herbage effect (P<)	NA	0.22	0.04	0.008	0.004	0.13	0.32	0.23	0.29	0.63	0.69

[1] ND - not determined
[2] NA - not applicable

Appendix 6.28 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 50000 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 1 Week 6 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	75.8	4219	260.0	25429	233.3	32325	340.0	23158
Cocksfoot	ND	ND	ND	26.6	3763	20.0	3953	73.3	19002	20.0	1533
Tall fescue	ND	ND	ND	43.8	5298	33.6	6467	66.4	15077	102.0	4842
Ryegrass	ND	ND	ND	88.2	9011	73.3	11502	100.0	15764	120.0	9036
White clover	ND	ND	ND	9.8	784	6.7	1512	13.3	3272	6.7	849
Yorkshire fog	ND	ND	ND	40.0	4983	40.0	6304	40.0	9050	33.3	1079
Pooled SE	NA[2]	NA	NA	12.12	1241.60	13.74	1718.63	22.24	3525.01	24.18	1218.23
Herbage effect (P<)	NA	NA	NA	0.35	0.51	0.001	0.001	0.04	0.14	0.001	0.001

[1] ND - not determined
[2] NA - not applicable

Appendix 6.29 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 50000 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 1 Week 8 1993/94.

Herbage	Vertical height (cm)									
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	80.0	4658	61.3	3817	84.5	7312	193.3	5293
Cocksfoot	ND	ND	ND	106.7	10696	113.3	14482	160.0	27338	193.3	5820
Tall fescue	ND	ND	ND	13.3	1224	39.7	5894	33.3	6144	73.3	2731
Ryegrass	ND	ND	ND	6.7	653	13.3	1444	33.3	4513	60.0	2149
White clover	ND	ND	ND	5.3	895	0	0	6.7	1439	20.0	675
Yorkshire fog	ND	ND	ND	60.0	5635	20.0	3197	13.3	3069	53.3	1126
Pooled SE	NA[2]	NA	NA	14.54	1226.76	10.94	1162.11	12.00	1936.82	24.11	694.61
Herbage effect (P<)	NA	NA	NA	0.11	0.07	0.02	0.004	0.002	0.001	0.07	0.08

[1] ND - not determined
[2] NA - not applicable

Appendix 6.30 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 50000 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 1 Week 11 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	0	0	0	0	0	0	6.7	183547
Cocksfoot	ND	ND	ND	0	0	6.7	1712	0	0	0	0
Tall fescue	ND	ND	ND	6.7	883	0	0	0	0	0	0
Ryegrass	ND	ND	ND	6.7	767	6.7	1986	0	0	0	0
White clover	ND	ND	ND	0	0	13.3	2736	0	0	0	0
Yorkshire fog	ND	ND	ND	9.1	797	6.7	2033	0	0	0	0
Pooled SE	NA[2]	NA	NA	2.44	275.73	3.53	862.10	NA	NA	1.33	36709.40
Herbage effect (P<)	NA	NA	NA	0.64	0.67	0.76	0.81	NA	NA	0.44	0.44

[1] ND - not determined
[2] NA - not applicable

Appendix 6.31 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 50000 *Trichostrongylus colubriformis* (Trichs) eggs. Contamination 1 Week 14 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	0	0	0	0	0	0	0	0
Cocksfoot	ND	ND	ND	0	0	0	0	0	0	0	0
Tall fescue	ND	ND	ND	0	0	0	0	0	0	0	0
Ryegrass	ND	ND	ND	0	0	0	0	0	0	0	0
White clover	ND	ND	ND	0	0	0	0	0	0	0	0
Yorkshire fog	ND	ND	ND	0	0	0	0	0	0	0	0
Pooled SE	NA[2]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Herbage effect (P<)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[1] ND - not determined
[2] NA - not applicable

Appendix 6.32 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 32000 *Trichostrongylus colubriformis* (Trichs) and 15700 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 2 1993/94.

Herbage	Vertical height (cm)									
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	0	2192.6	6.7	474	13.3	1180	66.7	33828	20.0	232433
Cocksfoot	0	0	916.1	33.3	4240	20.0	5758	6.7	6318	80.0	72883
Chicory	0	0	240.6	113.3	49002	0	0	33.3	30708	26.7	11748
Tall fescue	0	0	1185.4	46.7	6674	33.3	6314	33.3	10709	80.0	32654
Lucerne	0	0	323.7	26.2	3053	25.6	5337	8.5	3590	21.5	27218
Prairie grass	0	0	2073.9	306.7	36743	26.7	3987	226.7	53664	26.7	14461
Ryegrass	0	0	760.3	253.3	23484	166.7	32515	13.3	6470	53.3	53038
Rye/white clover	0	0	763.4	26.2	3118	225.3	130926	0	0	133.5	80120
White clover	0	0	598.9	40.0	8292	6.7	1328	40.0	50572	40.0	863496
Yorkshire fog	0	0	92.8	153.3	20450	33.3	6415	0	0	133.3	119902
Pooled SE	NA[2]	NA	157.24	31.27	2452.8	16.81	2324.2	16.63	3972.7	15.40	1384.2
Herbage effect (P<)	NA	NA	0.16	0.60	0.51	0.32	0.13	0.30	0.27	0.82	0.16

[1] ND - not determined
[2] NA - not applicable

Appendix 6.33 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 32000 *Trichostrongylus colubriformis* (Trichs) and 15700 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 4 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	0	185.6	0	0	0	0	0	0	6.7	11837
Cocksfoot	0	0	184.6	0	0	6.7	1073	0	0	0	0
Chicory	0	0	413.2	0	0	35.5	8809	0.72	146	0	0
Tall fescue	0	0	223.5	0	0	0	0	0	0	0	0
Lucerne	0	0	238.2	0	0	0	0	6.7	1349	0	0
Prairie grass	0	0	286.3	0	0	0	0	0	0	6.7	858
Ryegrass	0	23.7	53.1	0	0	0	0	0	0	0	0
Rye/white clover	0	0	273.3	0	0	0	0	0	0	6.7	4050
White clover	0	0	171.4	6.7	648	6.7	1202	0	0	0	0
Yorkshire fog	0	0	214.9	6.7	670	6.7	1591	0	0	13.3	3109
Pooled SE	NA[2]	2.04	32.71	0.87	444.8	1.41	996.3	0.60	1164.8	1.53	9396.9
Herbage effect (P<)	NA	0.45	0.80	0.64	0.64	0.11	0.05	0.54	0.54	0.72	0.63

[1] ND - not determined
[2] NA - not applicable

Appendix 6.34 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 32000 *Trichostrongylus colubriformis* (Trichs) and 15700 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 6 1993/94.

Herbage				Vertical height (cm)								
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+		
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	
Browntop	0	0	805.3	0	0	0	0	0	0	0	0	
Cocksfoot	4.3	0	470.8	0	0	0	0	0	0	0	0	
Chicory	0	0	164.1	0	0	0	0	0	0	0	0	
Tall fescue	0	0	230.5	0	0	0	0	0	0	0	0	
Lucerne	0	0	354.8	0	0	0	0	0	0	0	0	
Prairie grass	0	0	417.7	0	0	0	0	0	0	0	0	
Ryegrass	104.4	515.8	359.7	0	0	0	0	0	0	0	0	
Rye/white clover	0	0	415.5	0	0	0	0	0	0	0	0	
White clover	0	0	394.8	0	0	0	0	0	0	0	0	
Yorkshire fog	59.7	74.6	391.4	0	0	0	0	0	0	0	0	
Pooled SE	10.56	41.64	56.12	NA	NA	NA	NA	NA	NA	NA	NA	
Herbage effect (P<)	0.57	0.37	0.73	NA	NA	NA	NA	NA	NA	NA	NA	

[1] ND - not determined
[2] NA - not applicable

Appendix 6.35 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 32000 *Trichostrongylus colubriformis* (Trichs) and 15700 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 8 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	0	168.1	0.6	54	0	0	0	0	0	0
Cocksfoot	0	11.3	496.6	2.0	148	0	0	0	0	0.9	0
Chicory	40.6	19.9	154.2	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	0	0	108.7	0	77	0	0	6.7	3440	7.8	1923
Lucerne	0	0	867.9	0.9	541	0	0	7.5	181	0	0
Prairie grass	0	0	ND	6.7	0	0	0	0	0	0	0
Ryegrass	0	0	395.8	0	454	0	0	0	0	6.7	187
Rye/white clover	0	0	333.5	6.7	0	0	0	0	0	0	0
White clover	0	0	511.5	0	0	0	0	0	0	0	0
Yorkshire fog	80.9	40.5	697.0	0	0	0	0	0	0	0	0
Pooled SE	8.29	3.84	72.66	1.06	256.6	NA	NA	1.06	212.4	1.01	119.3
Herbage effect (P<)	0.54	0.45	0.34	0.72	0.72	NA	NA	0.60	0.56	0.63	0.44

[1] ND - not determined
[2] NA - not applicable

Appendix 6.36 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 32000 *Trichostrongylus colubriformis* (Trichs) and 15700 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 11 1993/94.

Herbage				Vertical height (cm)							
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	33.0	0	38.0	0	0	0	0	0	0	0	0
Cocksfoot	0	0	144.8	0	0	8.0	1578	0	0	0	0
Chicory	0	0	174.1	1.2	126	0	0	0.8	324	0	0
Tall fescue	0	0	113.5	20.4	21130	0	0	0	0	0	0
Lucerne	0	0	165.3	7.9	676	0	0	1.0	298	0	0
Prairie grass	0	0	653.8	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	132.9	105.2	385.6	0.1	10	8.0	1330	0	0	0	0
Rye/white clover	0	0	219.4	0	0	0	0	0	0	0	0
White clover	0	0	60.5	7.9	1126	8.0	2124	7.9	3185	6.7	59577
Yorkshire fog	0	0	408.7	7.9	1654	0	0	0	0	0	0
Pooled SE	11.85	6.28	37.84	2.14	1575.3	1.42	465.1	0.82	434.3	0.75	419.7
Herbage effect (P<)	0.51	0.05	0.08	0.71	0.77	0.74	0.73	0.59	0.42	0.55	0.02

[1] ND - not determined
[2] NA - not applicable

Appendix 6.37 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 32000 *Trichostrongylus colubriformis* (Trichs) and 15700 *Ostertagia circumcincta* (Ost) eggs. Contamination 2 Week 14 1993/94.

Herbage	Vertical height (cm)									
	Larvae in Faeces				0-2.5		2.5-5		5-7.5	7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	109.6	426.0	27.6	1668	0	0	79.7	25402	84.1	0
Cocksfoot	0	30.6	629.3	26.7	1853	59.3	9293	26.7	1807	196.1	656099
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	0	0	299.7	91.6	6509	26.7	4071	26.7	9452	120.0	195019
Lucerne	44.7	47.0	491.2	31.4	3894	156.7	58867	85.3	68850	32.1	0
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	0	0	124.2	19.6	1238	120.0	21353	106.7	48010	186.7	259455
Rye/white clover	0	49.9	1331.7	67.6	4884	40.0	7611	9.6	0	124.1	320264
White clover	0	0	530.0	13.3	1597	193.3	48644	26.7	288626	46.4	131502
Yorkshire fog	0	0	1008.3	66.7	6052	26.7	4737	129.6	73721	113.3	28993
Pooled SE	3.71	9.69	128.4	8.91	2714.4	24.97	4333.5	15.73	4361.2	24.00	30570.52
Herbage effect (P<)	0.21	0.21	0.38	0.41	0.53	0.52	0.36	0.55	0.72	0.76	0.41

[1] ND - not determined
[2] NA - not applicable

Appendix 6.38 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 34100 *Trichostrongylus colubriformis* (Trichs) and 8700 *Ostertagia circumcincta* (Ost) eggs. Contamination 3 Week 2 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	1601.1	2983.7	376.2	1246.7	52588	573.3	61455	220.0	106558	66.7	154776
Cocksfoot	1467.8	5737.2	340.9	846.7	71920	300.0	75530	13.3	10627	6.7	868
Chicory	1459.7	9332.8	111.6	300.3	45204	159.6	74944	15.1	26425	130.2	155995
Tall fescue	1346.4	8017.0	182.9	326.7	33109	273.3	61049	53.3	32733	106.7	168509
Lucerne	955.8	2043.0	602.7	266.7	39866	73.3	29179	73.3	47522	13.3	8546
Prairie grass	1468.8	2391.6	370.4	606.7	73134	237.8	108528	113.3	119565	240.0	160193
Ryegrass	1546.2	3184.6	806.0	593.3	81233	446.7	137381	93.3	103988	13.3	30639
Rye/white clover	719.8	6572.4	261.8	760.0	111012	313.3	124180	0	0	26.7	79832
White clover	1012.8	8190.1	454.8	580.0	106951	146.7	56000	80.0	81509	26.7	240347
Yorkshire fog	1326.8	11016.5	703.6	1572.3	233825	413.3	89197	73.3	72143	0	0
Pooled SE	92.0	467.4	53.30	43.24	5528.92	27.85	8667.97	15.73	8721.40	12.34	15285.26
Herbage effect (P<)	0.69	0.005	0.31	0.001	0.001	0.04	0.40	0.55	0.11	0.01	0.13

[1] ND - not determined
[2] NA - not applicable

Appendix 6.39 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 34100 *Trichostrongylus colubriformis* (Trichs) and 8700 *Ostertagia circumcincta* (Ost) eggs. Contamination 3 Week 4 1993/94.

Herbage	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
					Vertical height (cm)						
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	631.1	2902.0	557.1	1833.3	63374	1613.3	169267	346.7	183860	40.0	27009
Cocksfoot	122.5	1328.5	345.8	400.0	42921	340.0	79906	73.3	34476	40.0	19424
Chicory	137.7	1500.0	753.3	174.5	12304	170.7	28706	103.7	37302	172.7	33730
Tall fescue	172.4	5741.3	397.1	446.7	42928	565.2	101711	80.0	28175	66.7	20863
Lucerne	126.3	2312.0	346.1	620.0	103487	520.0	185836	326.7	159434	187.3	15901
Prairie grass	572.2	4084.0	413.4	1306.7	125995	300.0	71367	115.5	456685	36.0	2352
Ryegrass	0	720.4	181.5	740.0	75580	800.0	173240	220.0	975258	84.0	48529
Rye/white clover	170.0	2419.6	414.7	760.0	83199	246.7	59971	66.7	36089	20.0	17780
White clover	375.0	3337.9	376.9	413.3	60059	333.3	81862	220.0	61833	320.0	149209
Yorkshire fog	832.7	7433.2	1306.8	2866.7	156577	600.0	96756	46.7	19714	73.3	89206
Pooled SE	40.98	306.5	62.96	81.48	6735.94	62.42	9394.11	18.17	10471.63	12.87	9035.52
Herbage effect (P<)	0.004	0.003	0.08	0.001	0.01	0.004	0.03	0.01	0.04	0.001	0.11

[1] ND - not determined
[2] NA - not applicable

Appendix 6.40 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 34100 *Trichostrongylus colubriformis* (Trichs) and 8700 *Ostertagia circumcincta* (ost) eggs. Contamination 3 Week 6 1993/94.

Herbage					Vertical height (cm)						
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	218.3	462.5	540.0	36227	1286.7	111532	195.9	57424	66.7	35563
Cocksfoot	259.5	1510.3	2300.7	893.3	73258	733.3	127560	126.7	51607	106.7	512280
Chicory	300.2	4950.0	3884.3	446.7	51998	98.7	43865	86.7	64901	86.7	228404
Tall fescue	311.4	3043.5	2981.8	1133.3	88241	540.0	85180	93.3	30151	186.7	59274
Lucerne	25.5	255.0	989.7	473.3	70965	206.7	98298	140.0	48390	306.7	24400
Prairie grass	217.4	1592.5	780.6	1060.0	110431	260.0	66599	233.3	122755	260.0	48200
Ryegrass	83.6	1738.8	968.4	993.3	103491	753.3	117417	433.3	126882	433.3	76162
Rye/white clover	36.3	971.4	899.2	1020.0	107197	571.4	97129	266.7	79598	180.0	97623
White clover	79.2	68.4	249.7	206.7	37642	153.3	38332	100.0	24293	140.0	467519
Yorkshire fog	151.5	1727.4	1775.0	1253.3	89660	1733.3	266078	1226.7	296141	433.3	106485
Pooled SE	21.63	218.23	211.0	47.61	5922.34	47.16	7842.31	33.51	11363.00	28.59	17571.27
Herbage effect (P<)	0.04	0.003	0.03	0.001	0.14	0.001	0.001	0.001	0.002	0.13	0.59

[1] ND - not determined
[2] NA - not applicable

Appendix 6.41 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 34100 *Trichostrongylus colubriformis* (Trichs) and 8700 *Ostertagia circumcincta* (Ost) eggs. Contamination 3 Week 8 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	0	0	506.7	17220	966.7	85738	366.7	93862	220.0	345665
Cocksfoot	0	291.0	541.6	913.3	64071	980.0	159164	486.7	108374	333.3	156528
Chicory	574.8	1230.9	6140.2	360.0	61137	133.3	36466	120.0	44341	173.3	34430
Tall fescue	294.2	894.5	1570.7	753.3	68978	553.3	91915	273.3	86596	359.4	122034
Lucerne	0	0	173.9	180.0	27196	126.7	29856	133.3	48676	233.3	16350
Prairie grass	30.4	0	489.6	833.3	103806	413.3	114946	340.0	167094	186.7	43681
Ryegrass	33.5	43.8	692.2	546.7	47543	440.0	67568	420.0	941422	633.3	86149
Rye/white clover	206.0	201.6	986.7	433.3	53289	326.7	64327	339.9	84866	513.3	138521
White clover	0	0	0	80.0	12959	106.7	26316	100.0	22602	240.0	38129
Yorkshire fog	95.6	269.2	746.7	693.3	57335	966.7	144672	826.7	172277	613.3	85939
Pooled SE	34.63	60.52	191.07	33.93	3685.74	33.29	6057.51	34.05	8020.82	31.35	14275.87
Herbage effect (P<)	0.05	0.002	0.001	0.001	0.001	0.001	0.001	0.008	0.01	0.03	0.003

[1] ND - not determined
[2] NA - not applicable

Appendix 6.42 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 34100 *Trichostrongylus colubriformis* (Trichs) and 8700 *Ostertagia circumcincta* (Ost) eggs. Contamination 3 Week 11 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	0	0	60.0	2021	86.7	78245	6.67	112011	6.7	ND
Cocksfoot	0	0	0	113.3	10924	120.0	48536	73.3	119256	26.7	340374
Chicory	0	94.0	1115.2	466.7	76691	66.7	282517	40.0	75463	20.0	0
Tall fescue	0	31.3	73.8	193.3	20293	186.7	54850	113.3	617578	20.0	77947
Lucerne	0	0	0	93.3	16014	46.6	53982	13.3	623766	66.7	546514
Prairie grass	0	0	0	326.7	36081	93.3	60793	40.0	128029	21.6	303723
Ryegrass	0	0	96.1	180.0	26837	86.7	52885	113.3	218638	88.9	884466
Rye/white clover	0	0	92.7	186.7	19371	13.3	6425	40.0	55148	106.7	848076
White clover	0	0	0	53.3	10068	106.7	49672	73.3	104286	13.3	221016
Yorkshire fog	0	40.8	154.3	166.7	13199	40.0	15902	53.3	167624	ND[1]	ND
Pooled SE	NA[2]	5.70	26.14	12.10	1860.16	8.61	21554.31	10.37	58910.88	7.62	93755.76
Herbage effect (P<)	NA	0.05	0.001	0.001	0.001	0.03	0.49	0.51	0.60	0.13	0.79

[1] ND - not determined
[2] NA - not applicable

Appendix 6.43 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 34100 *Trichostrongylus colubriformis* (Trichs) and 8700 *Ostertagia circumcincta* (Ost) eggs. Contamination 3 Week 14 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	0	0	12.5	350	40.0	5613	0	0	6.7	54227
Cocksfoot	0	0	0	6.7	670	53.3	19339	26.7	24755	6.7	34743
Chicory	0	83.3	201.3	40.0	10181	20.0	16190	1.3	1208	0	0
Tall fescue	0	0	0	66.7	6866	20.0	5995	13.3	8014	0.6	9322
Lucerne	0	0	0	33.3	5770	0	0	13.3	6926	6.7	35350
Prairie grass	0	0	0	33.3	6404	20.0	9074	0	0	20.0	23715
Ryegrass	0	0	0	53.3	6107	6.7	3439	0	0	6.7	6513
Rye/white clover	0	0	0	60.0	8076	26.6	9658	0	0	6.7	13933
White clover	0	0	0	13.3	1795	0	0	0	0	0	0
Yorkshire fog	0	109.5	0	48.9	2735	6.7	1942	6.7	12825	0	0
Pooled SE	NA[2]	10.16	10.04	5.08	825.4	3.80	1719.84	2.91	2657.62	1.55	4237.85
Herbage effect (P<)	NA	0.31	0.008	0.31	0.36	0.16	0.40	0.67	0.71	0.36	0.86

[1] ND - not determined
[2] NA - not applicable

Appendix 6.44 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 26000 *Trichostrongylus colubriformis* (Trichs) and 17502 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 2 1993/94.

Herbage	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	623.9	704.9	1370.0	6.7	382	0	0	ND	ND	ND	ND
Cocksfoot	508.4	2221.5	2204.9	46.7	6440	26.7	24676	40.0	159320	53.3	476416
Chicory	218.7	716.4	2796.9	1.4	121	6.7	18422	13.3	21219	ND[1]	ND
Tall fescue	792.8	631.3	1193.9	40.0	5262	33.3	19631	53.3	154566	13.3	28075
Lucerne	355.7	736.2	3537.3	34.2	4730	30.7	5892	44.0	203423	8.2	8014
Prairie grass	644.7	1203.7	2126.9	46.7	9287	60.0	189437	13.3	18931	6.7	32497
Ryegrass	981.6	1185.5	2839.8	14.2	2000	46.7	92078	53.3	318526	0	0
Rye/white clover	90.42	1543.0	2635.8	26.7	4600	26.7	22626	26.7	116925	26.7	406428
White clover	48.4	96.8	290.5	13.3	2292	13.3	60184	12.0	29619	ND	ND
Yorkshire fog	1044.7	1330.8	4812.5	26.7	2261	6.7	24020	0	0	ND	ND
Pooled SE	56.89	76.90	193.39	4.10	615.62	5.17	16795.05	4.49	34812.73	4.11	51564.52
Herbage effect (P<)	0.02	0.001	0.005	0.38	0.17	0.47	0.65	0.16	0.71	0.29	0.46

Vertical height (cm) applies to columns 0-2.5 through 7.5+.

[1] ND - not determined
[2] NA - not applicable

Appendix 6.45 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 26000 *Trichostrongylus colubriformis* (Trichs) and 17500 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 4 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	0	0	288.5	18276	43.3	12125	71.5	102893	ND	ND
Cocksfoot	0	0	0	220.0	24141	100.0	48269	0	0	6.7	6868
Chicory	184.1	109.9	512.6	16.4	12826	27.9	19794	49.0	191197	2.2	19353
Tall fescue	17.7	0	0	25.1	6462	7.4	6304	33.8	26448	0	0
Lucerne	935.1	555.1	1811.7	40.0	8058	13.3	6283	6.7	1707	13.3	8872
Prairie grass	272.6	47.7	271.0	66.7	14460	0	0	0	0	26.7	45504
Ryegrass	0	49.5	81.2	33.3	6377	0	0	0	0	8.9	101250
Rye/white clover	0	0	0	161.1	27430	26.7	12999	20.0	44559	33.3	79778
White clover	0	0	0	26.7	4441	33.3	189044	6.7	598427	ND[1]	ND
Yorkshire fog	495.9	121.2	853.8	406.7	26865	46.7	48899	6.7	11538	0	0
Pooled SE	43.23	21.48	95.2	15.49	1487.88	6.15	10172.29	3.41	47679.40	3.53	12101.27
Herbage effect (P<)	0.002	0.001	0.01	0.001	0.03	0.12	0.07	0.48	0.51	0.59	0.74

[1] ND - not determined
[2] NA - not applicable

Appendix 6.46 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 26000 *Trichostrongylus colubriformis* (Trichs) and 17500 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 6 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	0	0	0	46.7	2162	1.1	464	6.7	23063	ND	ND
Cocksfoot	0	0	0	166.7	23240	33.3	17083	0	0	6.7	9934
Chicory	0	0	0	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	0	0	0	120.0	13538	33.3	13769	13.3	10846	6.7	15154
Lucerne	0	44.6	0	49.7	12177	92.4	33584	3.5	2488	10.4	5396
Prairie grass	0	0	0	93.3	25274	13.3	6072	20.0	16044	0	0
Ryegrass	0	0	0	180.0	29050	86.7	31655	0	0	6.7	14026
Rye/white clover	0	0	0	113.3	14852	13.3	3543	20.0	12957	26.7	33182
White clover	0	0	0	93.3	24085	15.5	4118	0	0	0	0
Yorkshire fog	0	0	0	120.0	8071	106.7	34184	0	0	6.7	151060
Pooled SE	NA[2]	3.84	NA	16.59	2754.21	8.46	2576.22	2.40	2446.68	2.01	5197.87
Herbage effect (P<)	NA	0.45	NA	0.71	0.62	0.08	0.08	0.33	0.56	0.16	0.04

[1] ND - not determined
[2] NA - not applicable

Appendix 6.47 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 26000 *Trichostrongylus colubriformis* (Trichs) and 17500 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 8 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	80.0	3997	46.7	13335	6.7	5987	0	0
Cocksfoot	ND	ND	ND	73.3	11734	26.7	10552	26.7	15470	66.7	56655
Chicory	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	ND	ND	ND	153.3	33518	66.7	30979	26.7	20362	6.7	10187
Lucerne	ND	ND	ND	209.9	58563	130.0	67079	25.8	21077	0	0
Prairie grass	ND	ND	ND	214.1	41238	40.0	13530	53.3	37907	0	0
Ryegrass	ND	ND	ND	166.7	28515	40.0	15687	40.0	16247	40.0	77072
Rye/white clover	ND	ND	ND	160.0	21706	53.3	14184	20.0	9502	60.0	57250
White clover	ND	ND	ND	26.7	4234	80.0	17326	13.3	5689	126.7	507979
Yorkshire fog	ND	ND	ND	526.7	36699	140.0	37342	33.3	29625	60.0	148076
Pooled SE	NA[2]	NA	NA	17.57	2375.90	11.16	2716.23	6.61	3710.33	9.20	31885.62
Herbage effect (P<)	NA	NA	NA	0.001	0.006	0.42	0.06	0.90	0.76	0.09	0.04

[1] ND - not determined
[2] NA - not applicable

Appendix 6.48 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 26000 *Trichostrongylus colubriformis* (Trichs) and 17500 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 11 1993/94.

Herbage	Vertical height (cm)										
	Larvae in Faeces				0-2.5		2.5-5		5-7.5		7.5+
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	13.3	620	20.0	9627	6.7	147821	ND	ND
Cocksfoot	ND	ND	ND	73.3	11919	40.0	24679	80.0	427104	0	0
Chicory	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	ND	ND	ND	211.4	32214	13.3	7499	60.0	121158	7.6	44772
Lucerne	ND	ND	ND	20.0	8179	26.7	377147	ND	ND	ND	ND
Prairie grass	ND	ND	ND	53.3	11472	53.3	30293	26.7	57775	6.7	150219
Ryegrass	ND	ND	ND	75.4	8448	77.3	33867	0	0	10.4	44564
Rye/white clover	ND	ND	ND	86.7	12035	6.7	4321	7.7	38004	0	0
White clover	ND	ND	ND	13.3	3351	20.0	16412	13.3	227515	ND	ND
Yorkshire fog	ND	ND	ND	140.0	9870	126.7	65637	26.7	168937	0	0
Pooled SE	NA[2]	NA	NA	10.94	1712.02	6.80	31662.87	6.33	44632.52	1.23	28234.84
Herbage effect (P<)	NA	NA	NA	0.01	0.05	0.01	0.38	0.11	0.59	0.52	0.91

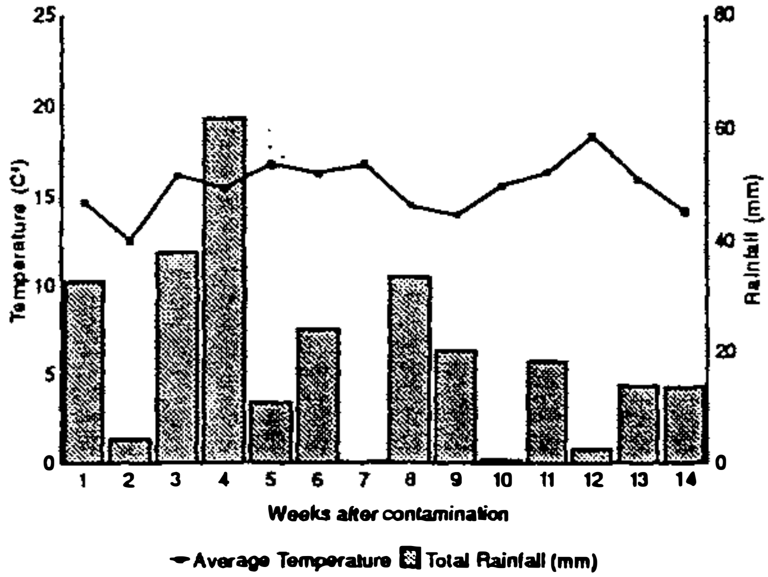
[1] ND - not determined
[2] NA - not applicable

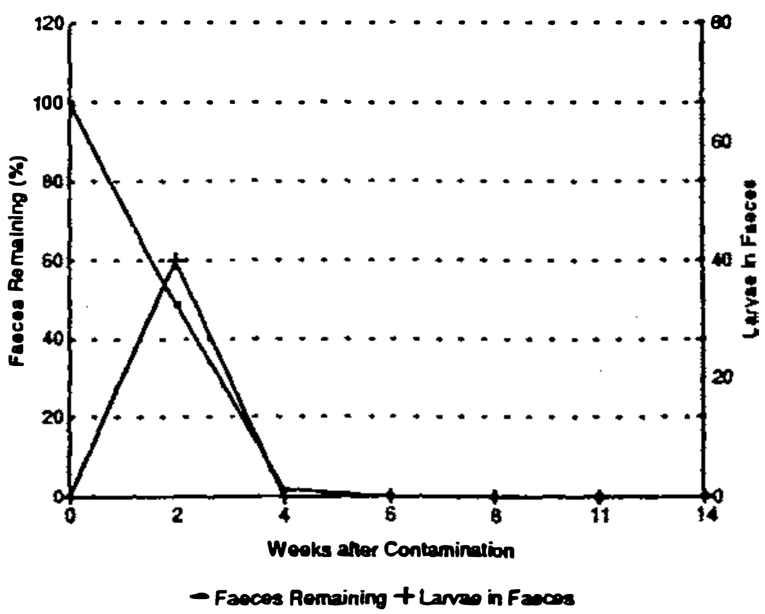
Appendix 6.49 Third stage larval numbers and other nematodes (others) in remaining faeces and third stage larvae in vertical strata (L_3) and larval density (L_3/kg DM herbage) for herbage plots contaminated with 26000 *Trichostrongylus colubriformis* (Trichs) and 17500 *Ostertagia circumcincta* (Ost) eggs. Contamination 4 Week 14 1993/94.

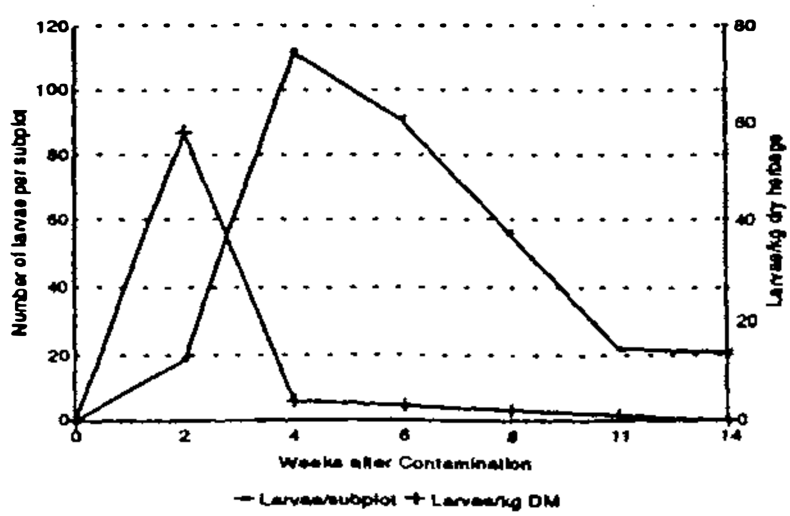
Herbage	Vertical height (cm)										
	Larvae in Faeces			0-2.5		2.5-5		5-7.5		7.5+	
	Ost	Trichs	Others	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM	L_3	L_3/kg DM
Browntop	ND[1]	ND	ND	53.3	2917	53.3	14676	26.7	25228	6.7	85076
Cocksfoot	ND	ND	ND	40.0	4125	26.7	10180	26.7	34531	13.3	51580
Chicory	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	ND	ND	ND	33.3	4896	6.7	2865	20.0	21859	0	0
Lucerne	ND	ND	ND	60.0	13639	13.3	6578	80.0	152597	1.8	34166
Prairie grass	ND	ND	ND	25.5	3355	4.7	5705	4.6	18792	8.8	54628
Ryegrass	ND	ND	ND	113.3	16969	26.7	8321	26.7	21519	53.3	200733
Rye/white clover	ND	ND	ND	6.7	646	20.0	3982	40.0	21150	0	0
White clover	ND	ND	ND	38.4	5067	121.7	25277	61.4	32526	20.7	355967
Yorkshire fog	ND	ND	ND	73.3	5181	62.2	14186	13.3	18983	8.8	149541
Pooled SE	NA[2]	NA	NA	8.13	1355.86	9.25	2215.68	5.70	9493.74	2.21	25564.34
Herbage effect (P<)	NA	NA	NA	0.26	0.21	0.38	0.67	0.20	0.09	0.03	0.35

[1] ND - not determined
[2] NA - not applicable

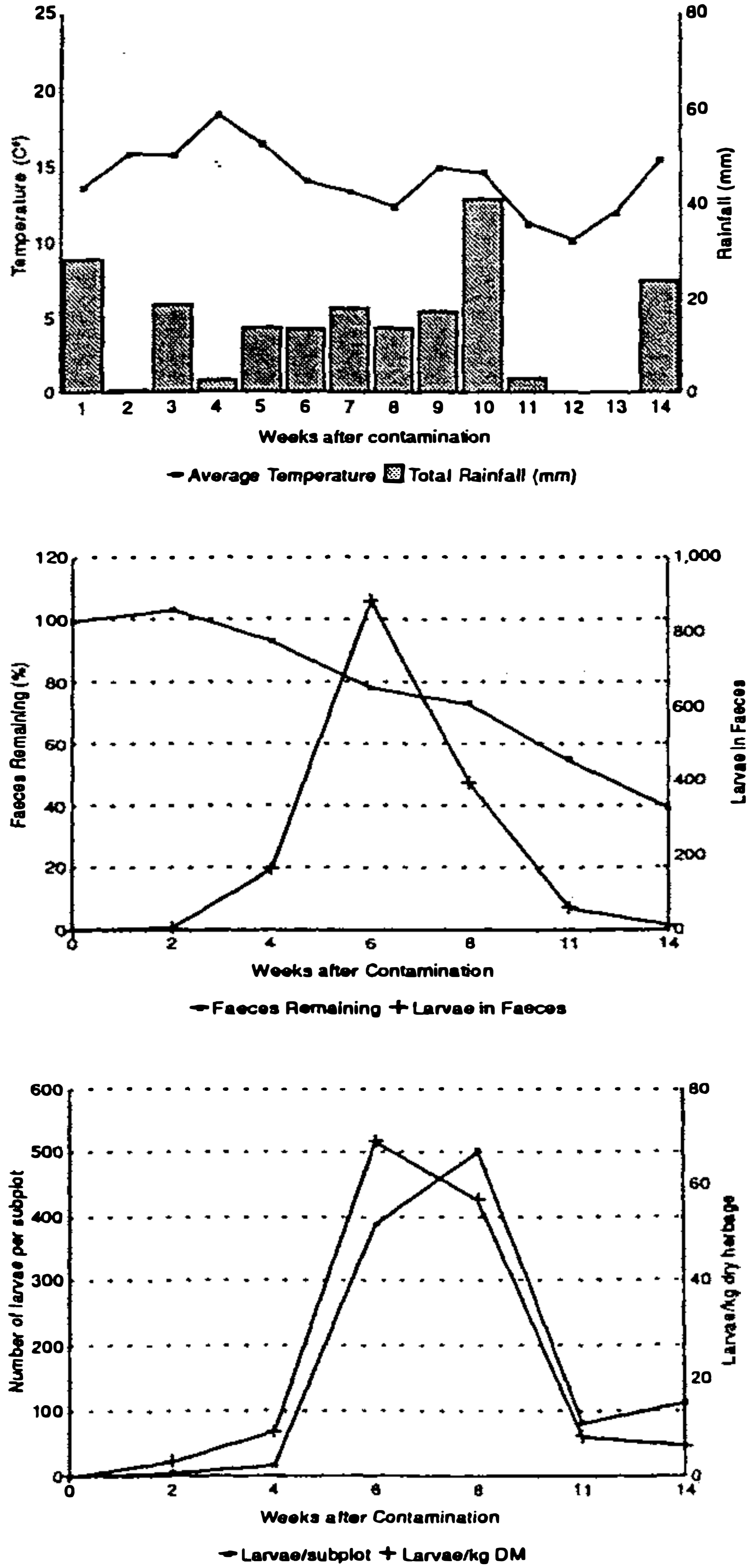
Appendix 6.58. Climatic data, faecal disappearance, average number of larvaein faeces and on herbage and larval density on herbage. Contamination 1, 1992/93 which started on 8/12/92.



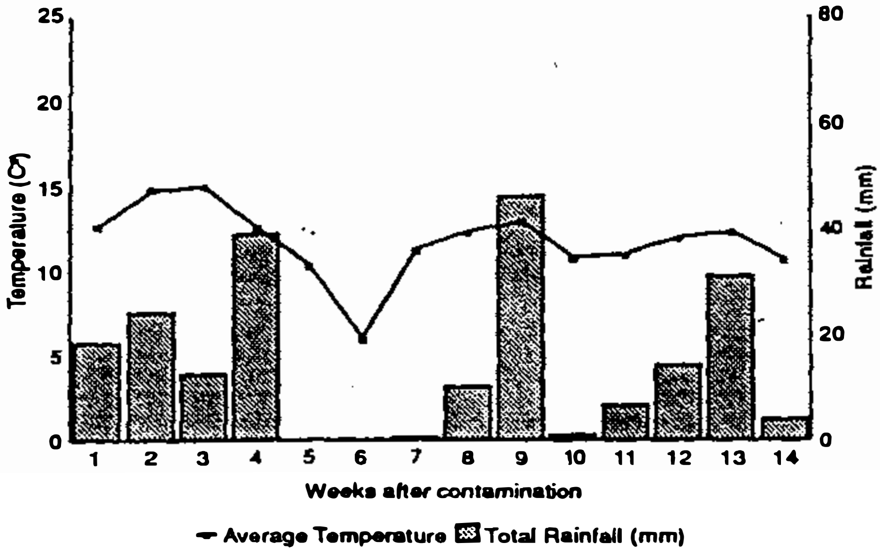


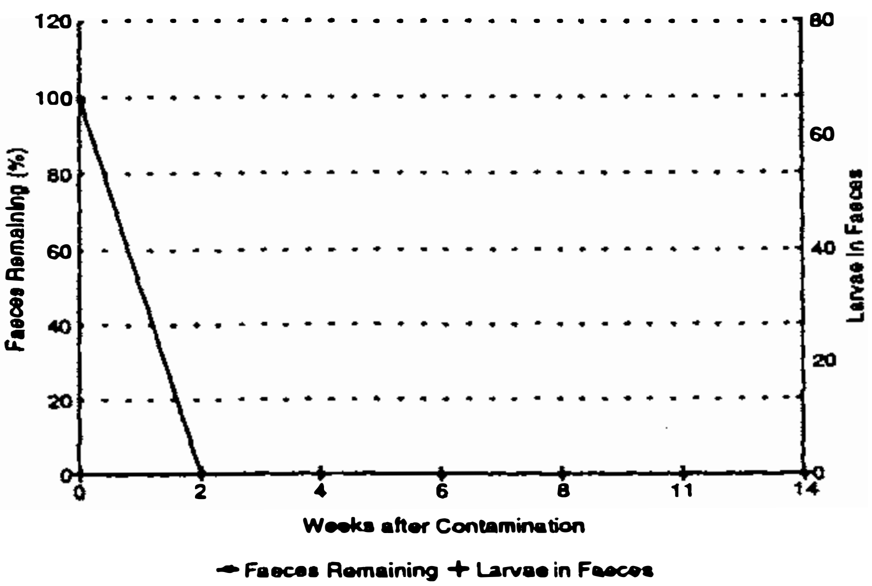


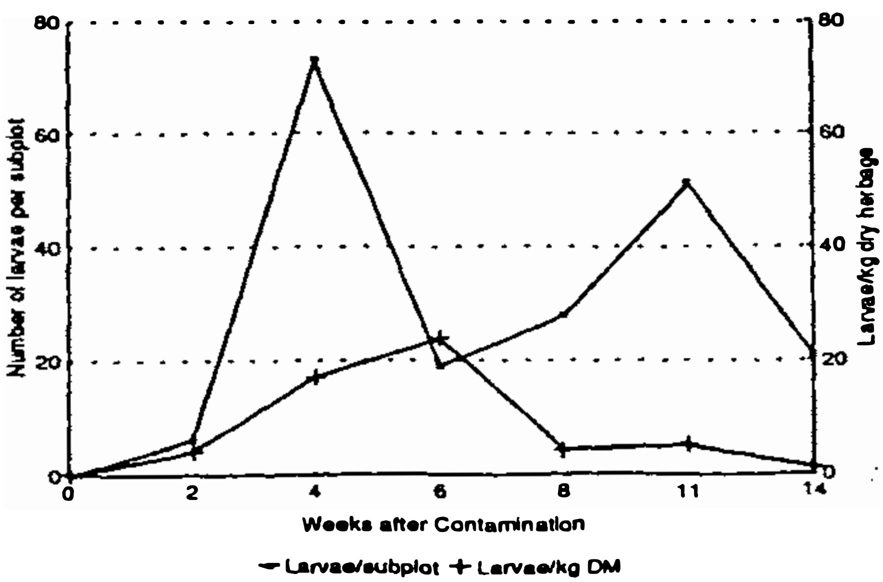
Appendix 6.51. Climatic data, faecal disappearance, average number of larvae in faeces and on herbage and larval density on herbage. Contamination 2, 1992/93 which started on 1/2/93.



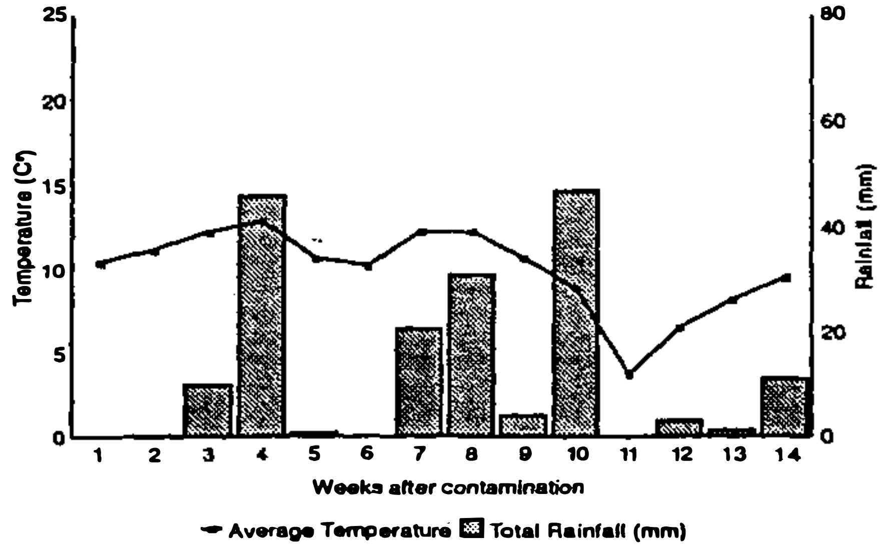
Appendix 6.52. Climatic data, faecal disappearance and average number of larvae in faeces and on herbage and larval density on herbage. Contamination 3, 1992/93 which started on 17/3/93.

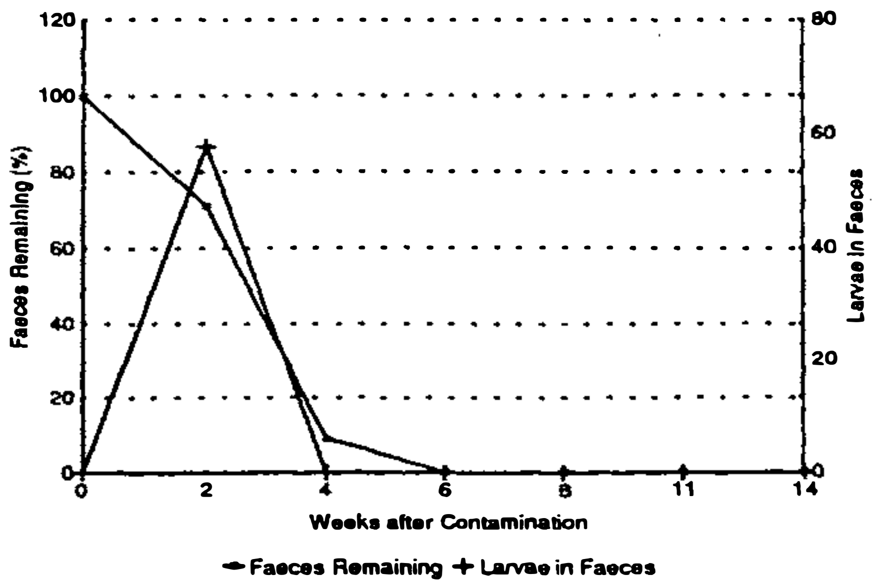


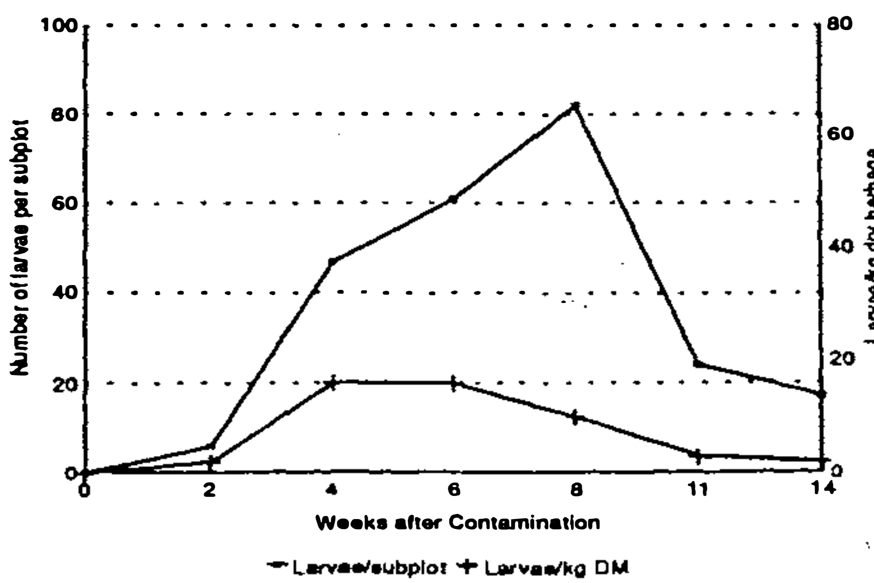




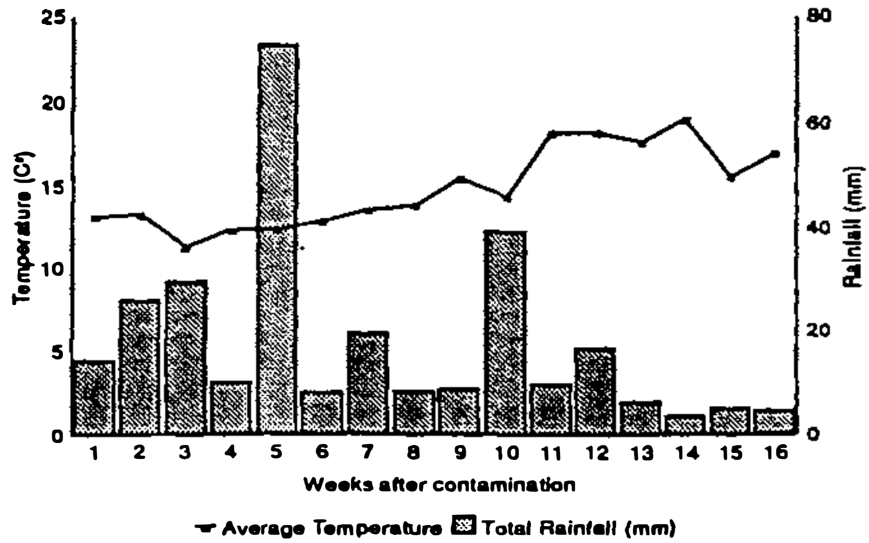
Appendix 6.53. Climatic data, faecal disappearance, average number of larvae in faeces and on herbage, and larval density on herbage. Contamination 4, 1992/93 which started on 21/4/93

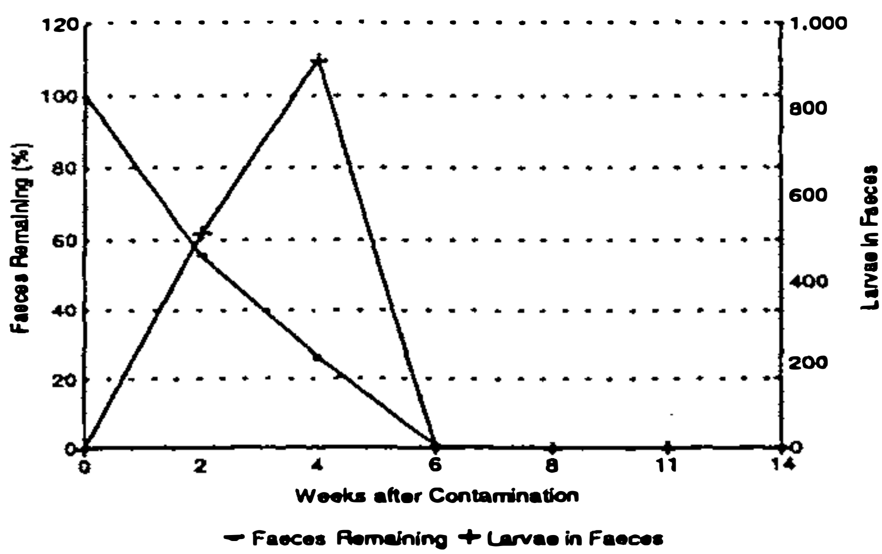


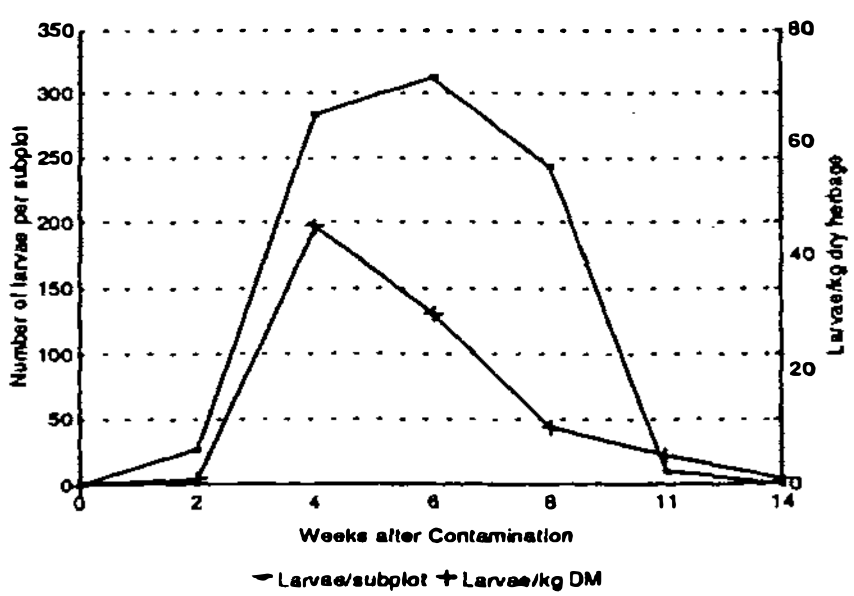




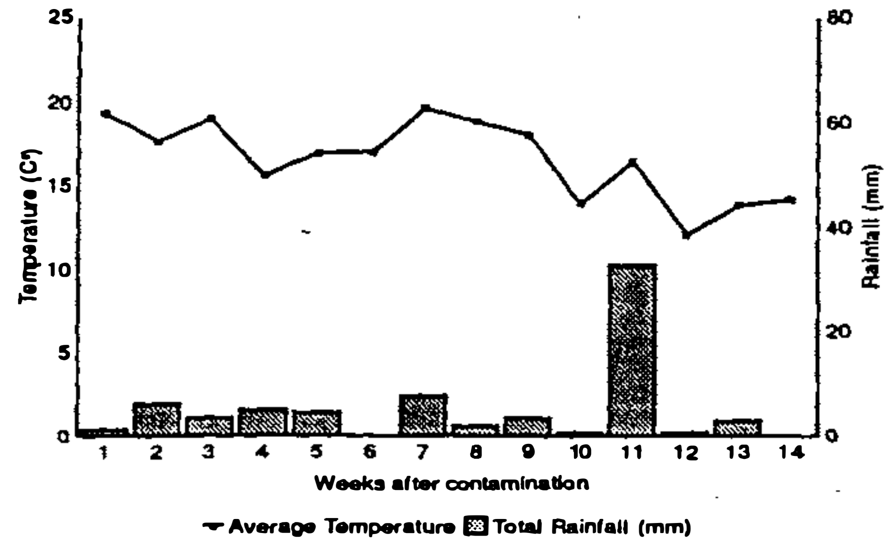
Appendix 6.54. Climatic data, faecal disappearance, average number of larvae in faeces and on herbage and larval density on herbage. Contamination 1 1993/94, which started on 16/10/93.

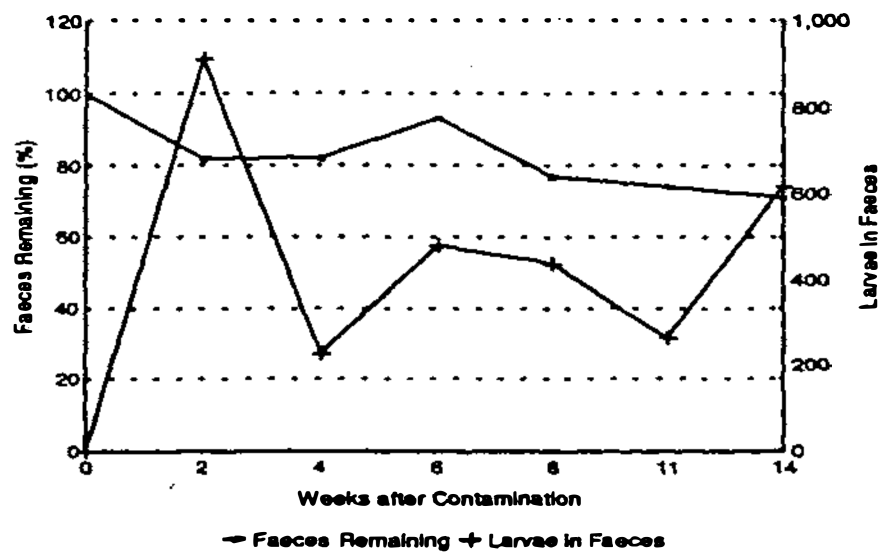


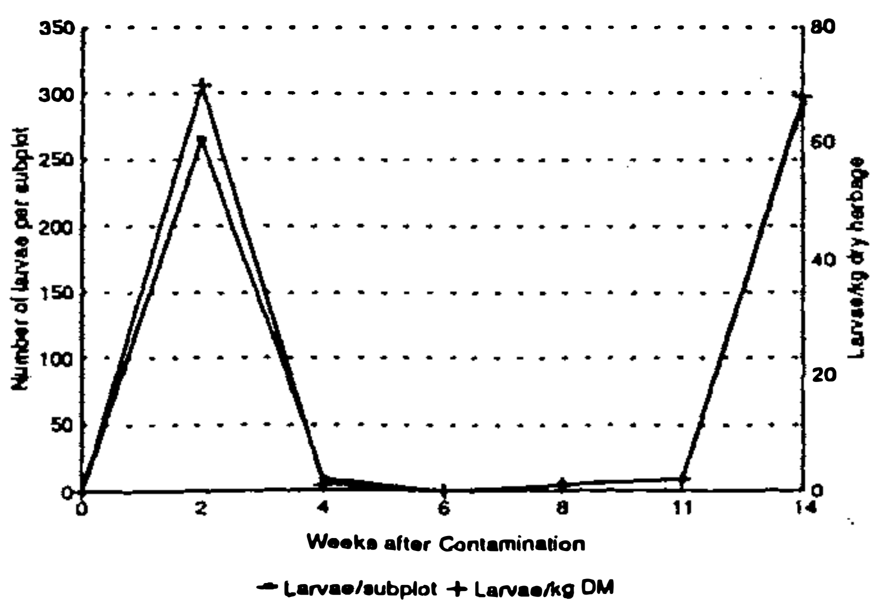




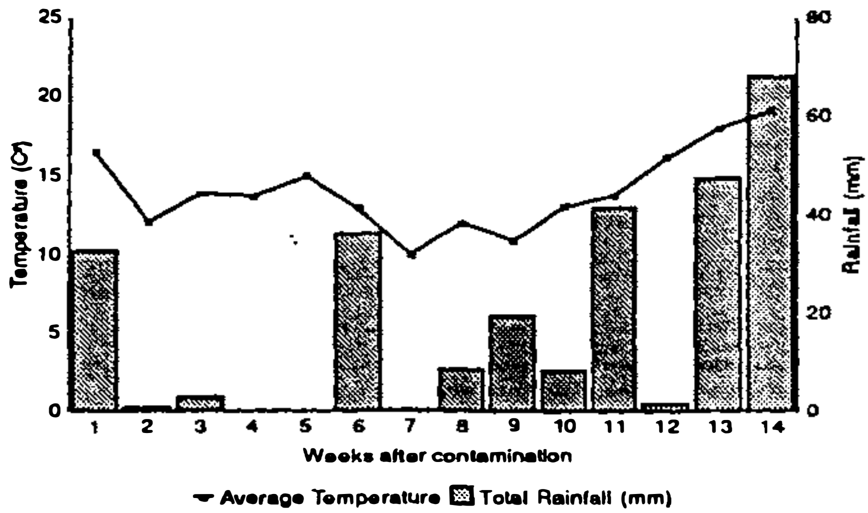
Appendix 6.55. Climatic data, faecal disappearance, average number of larvae in faeces and on herbage and larval density on herbage. Contamination 2, 1993/94 which started on 5/1/94.

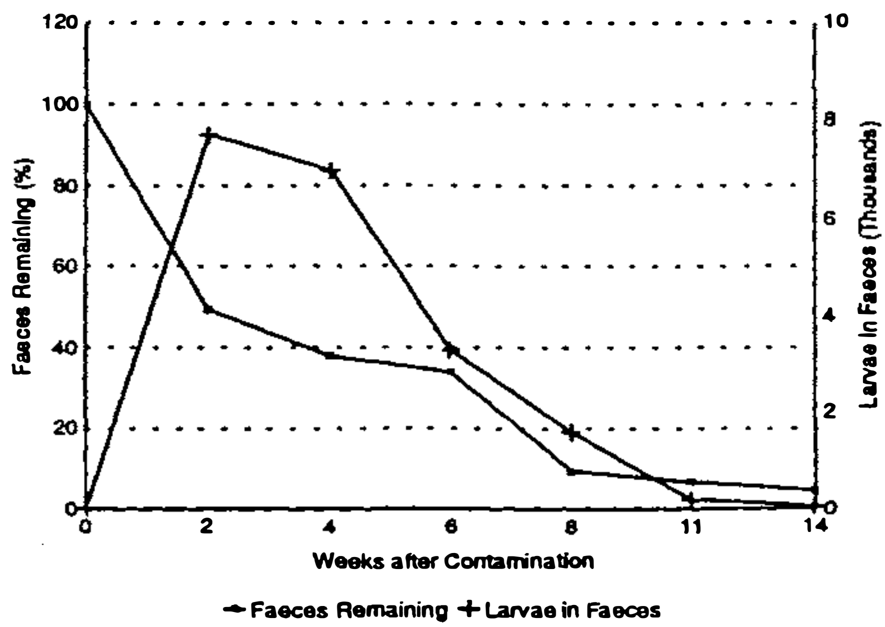


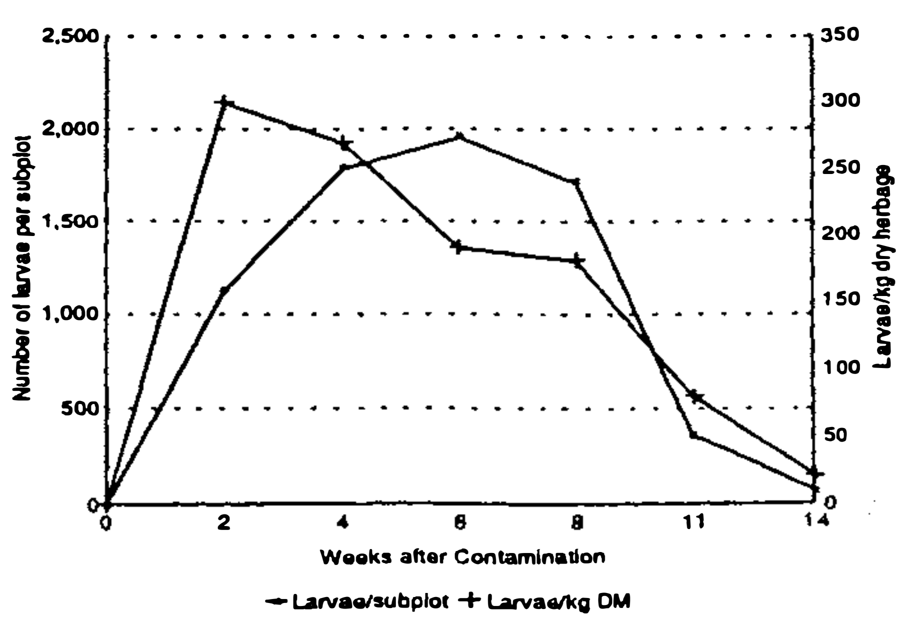




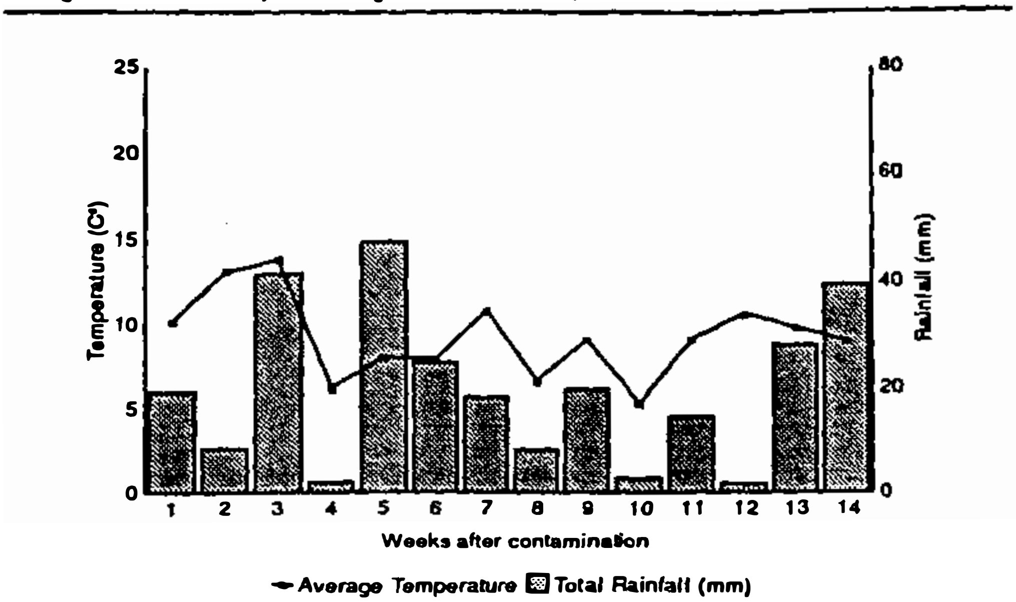
Appendix 6.56. Climatic data, faecal disappearance, average number of larvae in faeces and on herbage, and larval density on herbage. Contamination 3, 1993/94 which started on 7/3/94.

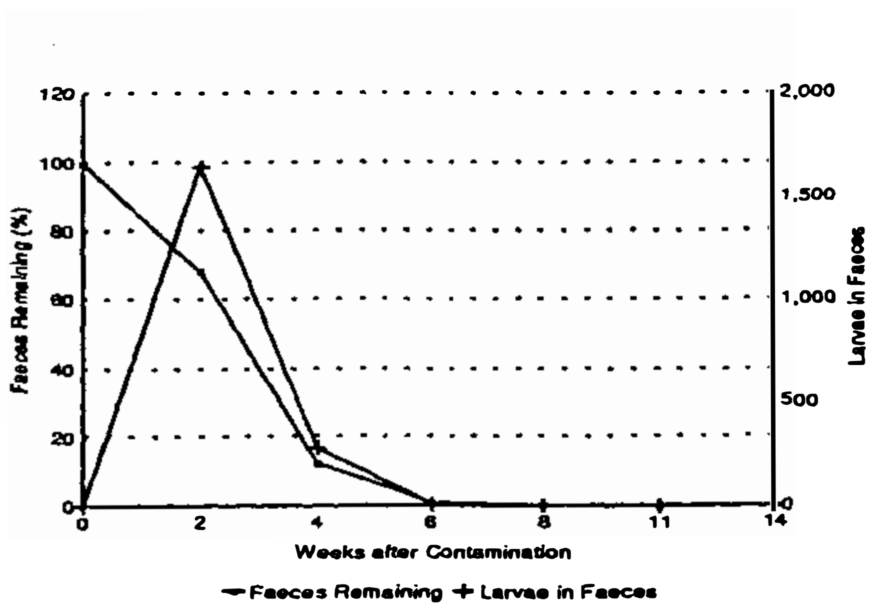


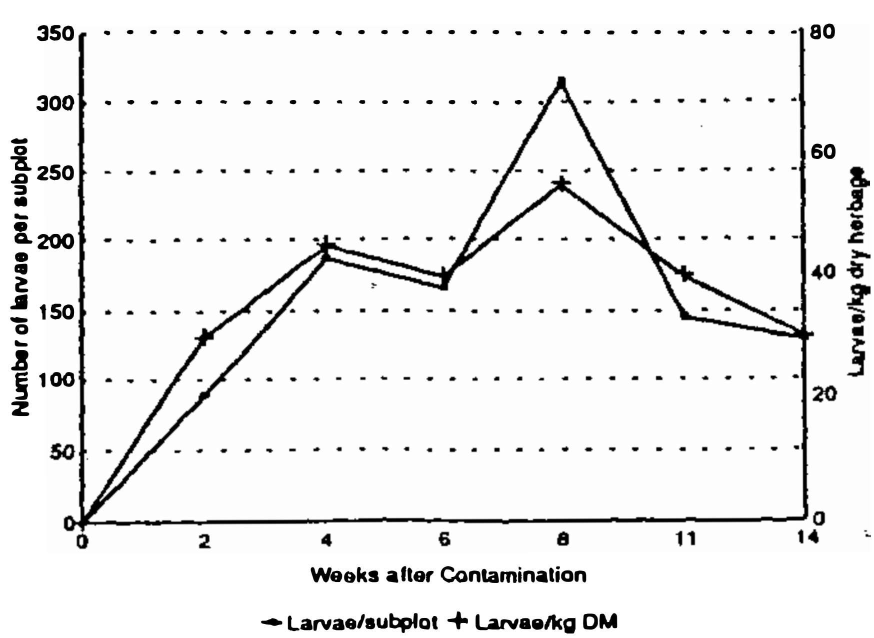




Appendix 6.57. Climatic data, *faecal disappearance*, average number of larvae in faeces and on herbage and larval density on herbage. Contamination 4, 1993/94 which started on 7/5/94.







Appendix 6.58. Real number analysis for larval calculated survival on herbage (X 10^{-3}), defined as ((number at week 14)/maximum number recorded)/time interval (days). Pooled over contaminations.

	1992/93			1993/94			
	Ostertagia	*Trichostrongylus*	Combined	*Ostertagia*	*Trichostrongylus*	Combined	Combined for both years
Browntop	4.8	3.1	3.2	3.6	5.3	2.0	1.8
Cocksfoot	7.5	3.9	10.1	3.5	3.5	1.8	2.5
Chicory	2.4	2.5	2.8	ND[1]	ND	ND	3.2
Tall fescue	1.1	2.0	2.2	4.6	2.7	4.0	2.6
Lucerne	3.2	11.5	13.5	7.6	0.7	2.6	6.3
Prairie grass	1.6	3.1	2.3	4.6	0.9	0.9	2.2
Ryegrass	5.0	3.5	2.6	6.5	2.8	6.2	3.8
Ryegrass/white clover	ND	ND	ND	3.6	1.7	1.2	3.2
White clover	0.7	1.6	0.3	2.8	4.5	7.4	4.2
Yorkshire fog	5.4	1.6	2.9	3.8	0.4	1.5	2.1
Pooled SE	0.36	0.46	0.65	0.41	0.37	0.52	0.47
Herbage effect (P<)	0.40	0.10	0.07	0.88	0.54	0.57	0.82
Contamination effect (P<)	0.009	0.20	0.19	0.04	0.0001	0.0005	0.002

[1] ND - not determined

Appendix 6.59. Average proportion of the total *Ostertagia* and *Trichostrongylus* third stage larvae recovered from swards of which were recovered from the bottom stratum (0-2.5 cm). Expressed on a percent basis.

Herbage	1992/93			1993/94			
	Ostertagia	*Trichostrongylus*	Combined	*Ostertagia*	*Trichostrongylus*	Combined	Combined for both years
Browntop	25.9	30.8	31.9	29.3	29.6	28.7	30.3
Cocksfoot	47.5	42.7	45.2	33.4	21.4	25.3	35.3
Tall fescue	14.3	22.8	27.1	38.1	37.3	41.5	34.3
Lucerne	21.4	28.9	35.3	26.4	ND	ND	35.6
Prairie grass	24.6	32.5	33.9	46.8	ND	ND	41.2
Ryegrass	22.0	23.6	26.2	40.3	25.4	30.5	28.4
White clover	15.5	15.0	20.4	39.0	19.6	30.4	25.4
Yorkshire fog	28.5	38.1	41.5	50.9	41.9	48.7	45.1
Pooled SE	4.70	4.64	4.48	3.10	3.04	3.05	3.81
Herbage effect (P<)	0.22	0.10	0.14	0.10	0.01	0.03	0.06
Contamination effect (P<)	0.02	0.0002	0.0003	0.0001	0.0001	0.0001	0.0001

Appendix 6.60. Average number of *Ostertagia* and *Trichostrongylus* third stage larvae recovered from each of four vertical strata (0-2.5 cm, 2.5-5 cm, 5-7.5 cm 7.5^{+} cm) of swards of herbages contaminated with faeces containing a known number of eggs. 1992/93.

Herbage	*Ostertagia*				*Trichostrongylus*				Combined			
	0-2.5	2.5 -5	5-7.5	7.5^{+}	0.2.5	2.5-5	5-7.5	7.5^{+}	0-2.5	2.5-5	5-7.5	7.5^{+}
Browntop	9.1	8.3	8.3	7.5	25.2	20.8	22.6	14.4	31.4	26.6	27.9	19.1
Cocksfoot	10.3	6.8	5.8	4.7	27.3	15.6	6.8	17.3	34.3	20.4	10.4	20.1
Tall fescue	3.4	2.1	2.1	3.9	11.9	9.4	13.2	17.2	14.4	11.1	14.3	19.4
Lucerne	5.4	0.1	1.0	4.6	14.6	7.2	13.3	17.2	18.3	7.7	13.7	20.0
Prairie grass	6.51	1.6	3.0	1.7	16.1	11.7	7.1	15.8	20.4	13.0	8.8	16.7
Ryegrass	12.5	2.9	7.9	4.3	17.4	15.6	16.2	15.7	26.0	17.8	21.2	18.2
White clover	1.4	4.2	2.1	5.1	7.8	9.8	10.3	24.2	8.9	12.9	11.4	27.2
Yorkshire fog	14.2	4.7	2.5	2.8	55.4	22.9	9.5	6.2	65.1	26.3	10.9	7.7
Pooled SE	2.14	1.30	1.14	1.00	7.14	3.23	3.60	6.14	8.00	3.53	4.14	6.64
Herbage effect (P<)	0.21	0.20	0.07	0.48	0.04	0.19	0.41	0.95	0.02	0.07	0.31	0.94

Appendix 6.61. Average number of *Ostertagia* and *Trichostrongylus* third stage larvae recovered from each of four vertical strata (0-2.5 cm, 2.5-5 cm, 5-7.5 cm 7.5^{+} cm) of swards of herbages contaminated with faeces containing a known number of eggs. 1993/94.

Herbage	*Ostertagia*				*Trichostrongylus*				Combined			
	0-2.5	2.5 -5	5-7.5	7.5^{+}	0.2.5	2.5-5	5-7.5	7.5^{+}	0-2.5	2.5-5	5-7.5	7.5^{+}
Browntop	41.6	38.2	15.5	9.2	178.1	189.6	58.4	36.8	206.7	214.7	69.8	43.4
Cocksfoot	55.2	34.0	15.0	16.3	126.9	101.1	41.1	36.8	163.6	121.9	49.3	47.9
Tall fescue	52.7	24.6	15.4	11.0	120.2	89.7	31.9	39.9	152.5	100.3	38.8	47.3
Lucerne	28.8	27.3	17.7	14.4	57.7	27.7	30.2	38.7	69.4	46.2	44.6	46.5
Prairie grass	60.6	11.8	22.0	8.3	169.70	24.9	36.0	35.5	225.3	36.0	59.7	43.6
Ryegrass	60.1	36.2	20.7	12.7	133.2	109.3	58.0	67.2	170.8	133.2	68.8	73.4
Rye/white clover	52.1	16.6	7.5	25.7	128.16	59.2	34.2	41.9	157.5	68.6	36.8	58.8
White clover	31.9	16.7	11.7	10.3	46.0	44.7	24.4	36.8	68.0	53.2	30.4	44.3
Yorkshire fog	95.7	38.3	7.9	16.0	281.8	155.1	102.5	55.8	347.0	182.1	106.2	67.8
Pooled SE	7.08	4.20	3.16	2.64	32.0	22.35	13.31	9.60	34.49	25.30	14.52	11.10
Herbage effect (P<)	0.04	0.13	0.70	0.35	0.11	0.04	0.31	0.88	0.04	0.06	0.50	0.93

Appendix 6.62. Proportion of faeces which disappeared (%DM basis) from herbages contaminated with faeces containing nematode eggs. Contamination 1 1992/93

	Week 2	Week 4	Week 6	Week 8	Week 11	Week 14
Browntop	64.5	100.0	100.0	100.0	100.0	100.0
Cocksfoot	55.4	100.0	100.0	100.0	100.0	100.0
Chicory	30.4	88.4	100.0	100.0	100.0	100.0
Tall fescue	47.3	100.0	100.0	100.0	100.0	100.0
Lucerne	45.0	99.4	100.0	100.0	100.0	100.0
Prairie grass	43.6	99.1	100.0	100.0	100.0	100.0
Ryegrass	52.0	97.1	100.0	100.0	100.0	100.0
Ryegrass/white clover	ND[1]	ND	ND	ND	ND	ND
White clover	68.9	100.0	100.0	100.0	100.0	100.0
Yorkshire fog	54.3	99.4	100.0	100.0	100.0	100.0
Pooled SE	2.10	0.63	NA[2]	NA	NA	NA
Herbage effect (P<)	0.02	0.005	NA	NA	NA	NA

[1] ND - not determined
[2] NA - not applicable

Appendix 6.63. Proportion of faeces which disappeared (%DM basis) from herbages contaminated with faeces containing nematode eggs. Contamination 2 1992/93

	Week 2	Week 4	Week 6	Week 8	Week 11	Week 14
Browntop	-7.5	4.6	13.6	26.7	64.4	77.3
Cocksfoot	0.7	8.5	13.2	11.8	33.1	47.2
Chicory	ND[1]	ND	ND	ND	ND	ND
Tall fescue	-6.6	5.5	23.0	18.3	49.7	60.6
Lucerne	-3.3	3.9	48.1	76.5	75.2	ND
Prairie grass	-4.9	5.7	21.8	20.8	36.0	63.2
Ryegrass	0.5	3.7	19.1	17.1	24.8	43.0
Ryegrass/white clover	ND[1]	ND	ND	ND	ND	ND
White clover	-1.1	12.6	20.3	33.9	61.3	74.9
Yorkshire fog	-3.3	8.2	10.4	23.8	43.0	72.6
Pooled SE	0.70	0.93	2.37	1.36	2.21	2.31
Herbage effect (P<)	0.09	0.28	0.02	0.0001	0.0008	0.002

[1] ND - not determined

Appendix 6.64. Proportion of faeces which disappeared (%DM basis) from herbages contaminated with faeces containing nematode eggs. Contamination 3 1992/93

	Week 2	Week 4	Week 6	Week 8	Week 11	Week 14
Browntop	100.0	100.0	100.0	100.0	100.0	100.0
Cocksfoot	100.0	100.0	100.0	100.0	100.0	100.0
Chicory	100.0	100.0	100.0	100.0	100.0	100.0
Tall fescue	100.0	100.0	100.0	100.0	100.0	100.0
Lucerne	100.0	100.0	100.0	100.0	100.0	100.0
Prairie grass	100.0	100.0	100.0	100.0	100.0	100.0
Ryegrass	100.0	100.0	100.0	100.0	100.0	100.0
Ryegrass/white clover	ND[1]	ND	ND	ND	ND	ND
White clover	100.0	100.0	100.0	100.0	100.0	100.0
Yorkshire fog	100.0	100.0	100.0	100.0	100.0	100.0
Pooled SE	NA[2]	NA	NA	NA	NA	NA
Herbage effect (P<)	NA	NA	NA	NA	NA	NA

[1] ND - not determined
[2] NA - not applicable

Appendix 6.65. Proportion of faeces which disappeared (%DM basis) from herbages contaminated with faeces containing nematode eggs. Contamination 4 1992/93

	Week 2	Week 4	Week 6	Week 8	Week 11	Week 14
Browntop	15.8	86.4	100.0	100.0	100.0	100.0
Cocksfoot	21.5	90.8	100.0	100.0	100.0	100.0
Chicory	41.1	75.0	100.0	100.0	100.0	100.0
Tall fescue	48.3	99.8	100.0	100.0	100.0	100.0
Lucerne	30.4	100.0	100.0	100.0	100.0	100.0
Prairie grass	32.8	100.0	100.0	100.0	100.0	100.0
Ryegrass	16.7	100.0	100.0	100.0	100.0	100.0
Ryegrass/white clover	ND[1]	ND	ND	ND	ND	ND
White clover	41.2	100.0	100.0	100.0	100.0	100.0
Yorkshire fog	5.0	64.6	100.0	100.0	100.0	100.0
Pooled SE	3.00	1.05	NA[2]	NA	NA	NA
Herbage effect (P<)	0.08	0.0001	NA	NA	NA	NA

[1] ND - not determined
[2] NA - not applicable

Appendix 6.66. Proportion of faeces which disappeared (%DM basis) from herbages contaminated with faeces containing nematode eggs. Contamination 1 1993/94

	Week 2	Week 4	Week 6	Week 8	Week 11	Week 14
Browntop	46.3	70.2	100.0	100.0	100.0	100.0
Cocksfoot	45.0	65.8	100.0	100.0	100.0	100.0
Tall fescue	41.3	75.3	100.0	100.0	100.0	100.0
Ryegrass	35.1	64.6	96.5	100.0	100.0	100.0
White clover	54.0	100.0	100.0	100.0	100.0	100.0
Yorkshire fog	44.7	68.4	100.0	100.0	100.0	100.0
Pooled SE	2.33	2.32	0.46	NA[1]	NA	NA
Herbage effect (P<)	0.17	0.0002	0.08	NA	NA	NA

[1] NA - not applicable

Appendix 6.67. Proportion of faeces which disappeared (%DM basis) from herbages contaminated with faeces containing nematode eggs. Contamination 2 1993/94

	Week 2	Week 4	Week 6	Week 8	Week 11	Week 14
Browntop	15.4	12.3	3.9	19.1	23.6	36.5
Cocksfoot	18.1	17.6	5.1	23.4	25.6	27.4
Chicory	15.7	19.2	9.7	20.7	27.2	ND
Tall fescue	17.6	16.6	4.6	24.8	23.0	26.1
Lucerne	20.1	23.2	27.6	29.0	26.6	32.0
Prairie grass	15.5	16.9	16.1	ND[1]	30.1	ND
Ryegrass	19.0	15.3	4.5	20.8	27.4	26.3
Ryegrass/white clover	19.3	17.7	25.4	22.7	23.4	25.7
White clover	20.7	18.2	5.9	22.5	24.8	27.5
Yorkshire fog	17.7	18.5	12.5	21.8	23.7	29.8
Pooled SE	0.38	0.49	3.21	0.50	0.65	0.94
Herbage effect (P<)	0.09	0.03	0.28	0.009	0.51	0.11

[1] ND - not determined

Appendix 6.68. Proportion of faeces which disappeared (%DM basis) from herbages contaminated with faeces containing nematode eggs. Contamination 3 1993/94

	Week 2	Week 4	Week 6	Week 8	Week 11	Week 14
Browntop	65.3	70.1	77.7	98.8	100.0	100.0
Cocksfoot	56.1	65.8	68.2	91.9	99.7	99.8
Chicory	38.8	45.0	46.2	75.4	62.0	64.2
Tall fescue	35.1	38.2	57.0	89.9	92.1	99.6
Lucerne	44.8	66.4	69.5	92.5	100.0	100.0
Prairie grass	62.5	65.3	64.5	92.0	99.3	100.0
Ryegrass	53.5	78.5	69.2	87.7	95.4	97.4
Ryegrass/white clover	60.4	68.9	73.0	90.2	96.9	98.1
White clover	53.4	67.5	85.5	97.7	100.0	100.0
Yorkshire fog	43.9	53.3	49.0	92.3	88.7	97.6
Pooled SE	1.52	1.47	1.62	1.23	0.77	0.68
Herbage effect (P<)	0.007	0.0001	0.0005	0.07	0.0001	0.0001

Appendix 6.69. Proportion of faeces which disappeared (%DM basis) from herbages contaminated with faeces containing nematode eggs. Contamination 4 1993/94

	Week 2	Week 4	Week 6	Week 8	Week 11	Week 14
Browntop	45.5	100.0	100.0	100.0	100.0	100.0
Cocksfoot	38.2	100.0	100.0	100.0	100.0	100.0
Chicory	3.8	81.9	100.0	100.0	100.0	100.0
Tall fescue	42.0	96.4	100.0	100.0	100.0	100.0
Lucerne	3.7	42.9	95.1	98.8	100.0	100.0
Prairie grass	14.8	82.0	99.2	100.0	100.0	100.0
Ryegrass	27.4	92.6	100.0	100.0	100.0	100.0
Ryegrass/white clover	26.2	99.6	100.0	100.0	100.0	100.0
White clover	95.4	100.0	100.0	100.0	100.0	100.0
Yorkshire fog	29.8	85.1	99.6	100.0	100.0	100.0
Pooled SE	1.27	1.48	0.29	0.10	NA[1]	NA
Herbage effect (P<)	0.0001	0.0001	0.06	0.45	NA	NA

[1] NA - not applicable

Appendix 6.70. Dry mass (g) of herbages after contamination with faeces containing nematode eggs. Summed over strata and averaged over Contaminations. 1992/93.

Herbage	Weeks after contamination					
	2	4	6	8	11	14
Browntop	70	110	107	120	169	194
Cocksfoot	35	78	107	136	163	227
Chicory	6	9	24	25	36	38
Tall fescue	32	80	113	116	115	184
Lucerne	22	37	60	74	76	53
Prairie grass	32	81	93	74	154	185
Ryegrass	45	67	84	107	115	173
White clover	22	44	65	65	72	60
Yorkshire fog	31	47	63	82	114	205
Pooled SE	2.6	2.6	2.6	2.6	2.6	2.6

Appendix 6.71. Dry mass (g) of herbages after contamination with faeces containing nematode eggs. Summed over strata and averaged over Contaminations. 1993/94.

Herbage	Weeks after contamination					
	2	4	6	8	11	14
Browntop	111	110	144	185	106	113
Cocksfoot	59	75	88	119	60	78
Chicory	14	27	17	17	9	7
Tall fescue	69	88	104	102	65	77
Lucerne	35	59	78	64	28	32
Prairie grass	21	29	31	36	21	22
Ryegrass	69	85	102	139	54	75
Ryegrass/white clover	28	47	69	69	39	51
White clover	47	70	78	98	47	62
Yorkshire fog	75	103	132	149	70	95
Pooled SE	1.3	1.3	1.3	1.3	1.3	1.3

Appendix 6.72. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire fog. Contamination 1 1992/93. Week 2.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	60.3	18.5	12.9	3.5	3.5	0.9	0.5	0.1	75.3	34.1
Cocksfoot	30.6	8.1	9.4	2.1	6.6	1.6	6.1	1.7	52.6	15.2
Chicory	6.0	0.8	3.3	0.5	0.8	0.4	0.8	0.1	14.5	2.3
Tall fescue	30.5	9.6	8.7	2.1	6.3	2.2	4.4	0.9	49.8	16.9
Lucerne	13.2	3.1	6.8	1.3	2.5	0.5	0.5	0.1	23.0	5.5
Prairie grass	18.8	6.1	6.3	1.6	4.1	1.1	4.7	1.5	33.9	10.6
Ryegrass	26.1	8.1	8.3	2.0	5.0	1.2	2.8	0.7	41.9	14.9
White clover	45.0	7.1	17.3	2.2	10.1	2.1	3.1	0.8	75.5	30.8
Yorkshire fog	39.1	10.3	18.9	3.9	11.6	2.5	6.3	1.5	71.6	23.7
Pooled SE	0.96	0.26	0.45	0.10	0.29	0.067	0.25	0.055	1.41	0.53
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001

Appendix 6.73. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 1 1992/93. Week 4.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	86.3	39.1	38.0	16.6	25.2	9.4	14.6	4.8	162.4	69.9
Cocksfoot	42.7	13.0	17.2	4.9	15.4	4.3	21.5	4.9	96.7	27.1
Chicory	61.5	9.2	44.0	6.0	38.9	5.2	114.1	19.4	230.6	39.9
Tall fescue	39.4	13.6	12.1	3.7	11.5	3.4	12.5	5.4	75.5	26.1
Lucerne	29.0	6.9	20.9	4.4	21.1	7.2	152.4	27.7	223.4	46.2
Prairie grass	43.2	14.0	22.4	6.3	16.0	4.6	32.8	10.8	114.4	35.7
Ryegrass	37.7	14.3	13.9	4.8	10.1	3.2	10.1	3.8	74.6	26.1
White clover	60.8	35.4	46.5	7.3	36.7	5.6	64.6	6.5	208.6	54.8
Yorkshire fog	68.3	24.7	37.9	12.4	24.8	7.4	27.1	7.0	158.8	51.5
Pooled SE	1.60	0.51	1.14	0.25	1.01	0.21	2.65	0.54	5.39	1.18
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Appendix 6.74. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 1 1992/93. Week 6.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	48.1	22.5	40.9	17.9	30.6	11.3	36.3	12.0	156.4	63.7
Cocksfoot	33.0	10.0	25.5	7.3	21.7	6.1	38.7	8.8	118.8	32.3
Chicory	52.0	8.6	53.9	6.7	45.1	6.0	140.9	27.1	274.5	48.3
Tall fescue	30.7	10.5	22.1	6.9	15.4	4.6	20.2	8.6	88.3	30.7
Lucerne	21.1	5.0	14.9	3.1	17.0	5.8	221.1	40.2	274.1	54.2
Prairie grass	34.0	11.0	26.9	7.6	16.4	4.7	51.0	16.7	128.3	40.1
Ryegrass	33.2	12.1	22.0	7.2	16.0	5.0	23.4	6.9	90.6	31.2
White clover	56.2	32.7	47.1	7.4	44.8	6.9	155.8	15.7	303.9	62.7
Yorkshire fog	31.7	12.3	26.4	8.5	24.0	7.0	54.5	13.7	138.1	41.5
Pooled SE	1.53	0.61	1.79	0.34	1.12	0.23	5.00	0.92	7.99	1.56
Herbage effect (P<)	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Appendix 6.75. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 1 1992/93. Week 8.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	45.3	20.9	37.6	16.4	29.3	10.9	35.9	11.9	148.1	60.1
Cocksfoot	32.6	9.9	25.4	7.3	23.2	6.5	63.0	14.4	144.1	38.1
Chicory	27.6	4.7	27.2	3.8	32.3	4.6	138.5	27.8	225.6	40.9
Tall fescue	32.4	11.2	23.6	7.3	23.6	7.0	36.8	15.7	116.4	41.3
Lucerne	15.9	3.8	15.3	3.2	15.3	5.2	320.3	58.2	366.7	70.4
Prairie grass	33.5	10.8	20.8	5.9	17.2	5.0	91.2	29.9	162.7	51.6
Ryegrass	28.0	10.5	22.9	7.6	19.0	5.9	36.8	12.5	106.6	36.4
White clover	34.7	20.2	32.7	5.1	33.1	5.1	128.8	13.0	229.1	43.4
Yorkshire fog	23.3	8.3	27.2	8.8	29.2	8.5	136.1	34.8	215.8	60.4
Pooled SE	1.00	0.32	0.97	0.25	0.93	0.22	9.73	1.81	11.56	2.27
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.03

Appendix 6.76. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 1 1992/93. Week 11.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	43.8	19.2	38.7	15.6	39.6	13.2	88.8	26.0	210.9	73.9
Cocksfoot	41.1	12.9	32.5	9.2	29.1	8.0	106.4	15.7	209.0	45.9
Chicory	31.1	5.1	25.7	3.5	25.2	3.4	249.4	51.8	331.4	63.9
Tall fescue	30.3	10.1	25.5	7.5	20.0	5.8	52.5	27.7	128.3	51.0
Lucerne	16.5	3.7	16.2	3.1	16.2	7.3	255.6	19.2	304.5	33.2
Prairie grass	27.4	8.7	21.8	5.9	17.9	5.0	112.0	21.8	179.0	41.5
Ryegrass	23.6	8.6	20.8	6.6	16.5	4.8	29.4	9.5	90.3	29.5
White clover	31.6	5.9	24.6	4.1	23.1	3.6	122.8	16.8	202.0	30.4
Yorkshire fog	38.9	11.3	34.6	8.3	36.6	7.8	205.8	36.0	316.0	63.4
Pooled SE	0.93	0.25	0.85	0.22	0.91	0.23	12.29	1.93	14.26	2.34
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.007	0.001

Appendix 6.77. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 1 1992/93. Week 14.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	37.8	18.0	30.9	14.6	30.8	12.6	152.1	56.0	244.8	101.2
Cocksfoot	45.5	13.4	33.9	9.9	30.2	8.7	144.1	44.5	253.8	76.4
Chicory	33.2	6.0	22.9	3.2	22.4	3.3	333.3	64.0	412.0	76.5
Tall fescue	28.0	9.9	22.8	7.5	19.6	6.1	58.3	19.1	128.7	42.6
Lucerne	15.3	3.9	12.1	2.8	11.2	2.6	199.3	57.5	237.9	66.8
Prairie grass	20.6	6.8	17.5	5.1	16.5	4.9	74.4	34.3	128.9	51.2
Ryegrass	23.6	8.7	21.4	7.4	18.5	6.1	56.8	19.1	119.5	41.4
White clover	38.9	38.0	28.0	4.2	25.7	3.9	142.3	9.2	235.0	55.3
Yorkshire fog	21.8	9.3	21.1	8.7	19.3	7.2	149.0	50.0	211.2	75.1
Pooled SE	0.90	0.40	0.77	0.18	0.77	0.17	8.45	1.78	10.05	2.09
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Appendix 6.78. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1992/93. Week 2.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	20.5	5.7	4.2	1.0	0.9	0.2	0.04	0.0	25.7	6.9
Cocksfoot	19.3	4.1	9.6	1.8	3.9	0.8	1.6	0.4	34.4	7.1
Chicory	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	19.9	4.5	11.0	2.3	7.0	1.4	5.1	1.0	42.9	9.3
Lucerne	19.2	3.6	4.2	0.7	0.9	0.2	0.4	0.1	24.8	4.6
Prairie grass	10.0	2.1	4.7	0.9	2.4	0.5	2.0	0.5	19.1	3.9
Ryegrass	24.6	5.6	13.4	2.8	6.0	1.3	2.8	0.6	46.8	10.2
White clover	31.2	4.6	5.3	0.7	0.7	0.1	0	0	32.1	4.7
Yorkshire fog	5.2	1.1	0.3	0.04	0	0	0	0	5.4	1.1
Pooled SE	0.93	0.19	0.47	0.09	0.21	0.04	0.19	0.04	1.32	0.30
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Appendix 6.79. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1992/93. Week 4.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	43.1	12.4	25.3	6.2	10.7	2.6	4.3	1.2	83.4	21.5
Cocksfoot	40.7	8.1	27.9	5.2	19.6	3.9	26.2	6.0	114.3	23.8
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	35.9	8.2	29.0	5.3	22.7	4.0	30.3	6.2	117.9	24.9
Lucerne	38.2	8.3	8.6	1.7	4.3	0.8	8.5	1.6	59.5	11.0
Prairie grass	44.2	9.4	28.2	4.8	22.8	4.1	40.9	9.1	136.1	28.7
Ryegrass	35.2	7.5	24.2	4.2	15.7	3.0	15.6	3.2	90.8	19.4
White clover	33.7	5.4	27.1	3.9	14.0	2.4	7.0	1.3	81.9	12.0
Yorkshire fog	14.9	4.0	9.6	1.8	4.4	0.9	1.8	0.4	30.0	5.8
Pooled SE	1.08	0227	0.75	0.17	0.57	0.13	0.88	0.22	2.74	0.65
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

[1] ND - not determined

Appendix 6.80. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1992/93. Week 6.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	39.2	10.4	27.3	6.2	14.2	3.4	7.7	2.1	88.4	22.6
Cocksfoot	46.4	9.6	34.2	6.2	24.8	4.9	65.0	14.1	170.5	36.0
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	40.6	8.6	33.6	6.7	27.5	5.4	61.8	7.2	163.5	34.0
Lucerne	16.6	2.8	16.2	2.6	14.8	2.5	78.1	18.1	125.7	23.4
Prairie grass	37.5	6.5	33.8	6.3	26.4	5.3	64.9	16.7	162.5	34.7
Ryegrass	39.5	7.9	29.4	5.5	22.0	4.2	25.1	5.0	116.1	24.7
White clover	36.1	5.8	29.6	4.2	27.6	4.1	34.4	6.0	127.6	19.4
Yorkshire fog	34.0	6.4	28.3	5.6	18.2	4.0	19.1	4.2	99.5	19.2
Pooled SE	1.10	0.21	0.87	0.17	0.78	0.16	3.27	0.72	5.03	1.04
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.001	0.002	0.001

[1] ND - not determined

Appendix 6.81. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1992/93. Week 8.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	46.2	12.2	34.2	7.7	23.5	5.2	24.3	6.1	128.2	32.4
Cocksfoot	38.9	8.0	32.2	6.1	27.8	6.2	128.0	28.2	222.3	47.7
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	38.1	9.3	30.7	6.7	27.1	5.6	82.3	17.3	178.2	36.8
Lucerne	17.9	3.2	12.6	2.2	11.9	1.9	125.7	22.3	168.0	31.6
Prairie grass	28.5	6.1	23.5	4.6	20.3	4.2	60.3	14.7	132.5	28.6
Ryegrass	33.7	7.9	30.3	6.4	26.4	5.3	62.8	12.3	153.2	32.2
White clover	28.8	4.0	26.1	3.6	25.1	3.7	64.6	10.6	144.6	22.5
Yorkshire fog	32.7	6.4	31.2	5.0	30.8	4.9	71.5	12.8	166.3	30.6
Pooled SE	0.69	0.15	0.71	0.14	0.70	0.13	4.49	0.83	5.65	1.11
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.001	0.007	0.001

[1] ND - not determined

Appendix 6.82. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1992/93. Week 11.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	42.0	13.0	40.0	10.7	34.5	8.7	69.2	16.8	185.7	46.4
Cocksfoot	34.4	8.3	28.5	6.5	25.1	5.7	147.9	37.0	235.9	50.8
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	26.5	6.8	22.7	5.8	18.8	4.5	49.5	12.0	117.5	24.3
Lucerne	16.9	3.5	13.9	2.7	11.3	2.1	113.1	23.2	155.2	29.0
Prairie grass	35.9	8.3	31.5	7.2	28.0	6.6	147.7	37.0	243.2	53.8
Ryegrass	30.8	8.6	26.7	7.1	22.7	6.0	67.8	15.8	147.9	31.0
White clover	29.0	4.6	28.3	4.4	28.2	4.4	71.1	12.6	156.6	24.4
Yorkshire fog	26.2	5.8	25.1	4.5	24.0	4.0	100.5	17.8	175.8	32.7
Pooled SE	1.14	0.28	0.92	0.21	0.81	0.19	5.11	1.17	7.15	1.51
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.001	0.002	0.001

[1] ND - not determined

Appendix 6.83. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1992/93. Week 14.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	50.3	12.8	47.6	10.8	46.0	10.1	113.3	23.8	257.2	64.2
Cocksfoot	56.5	11.5	45.4	8.2	37.7	6.9	240.7	48.2	380.2	82.0
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	41.9	8.6	36.5	7.4	31.7	6.4	144.3	29.8	254.4	51.9
Lucerne	19.3	3.1	13.1	1.9	12.3	1.8	109.1	17.3	153.7	28.7
Prairie grass	38.2	7.6	34.2	6.0	30.7	5.4	167.2	33.8	270.2	59.9
Ryegrass	46.8	9.5	43.2	8.5	39.4	7.6	124.5	23.5	253.9	53.1
White clover	32.0	4.0	33.2	3.7	29.9	3.7	95.4	13.4	190.5	29.9
Yorkshire fog	47.1	8.4	47.2	7.0	44.1	6.1	279.0	37.7	417.4	78.2
Pooled SE	1.36	0.29	0.99	0.17	1.18	0.20	6.74	1.25	8.56	1.77
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

[1] ND - not determined

Appendix 6.84. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1992/93. Week 2.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	105.5	15.9	49.8	6.6	22.6	2.9	9.2	0.8	187.0	26.2
Cocksfoot	68.9	7.5	30.8	3.1	16.1	1.7	28.8	1.7	144.7	14.0
Chicory	11.6	0.6	9.4	0.4	7.6	0.4	10.9	0.6	39.5	2.0
Tall fescue	59.8	6.6	32.9	3.5	28.7	2.4	40.8	4.8	162.2	17.3
Lucerne	28.6	2.8	21.8	1.6	17.5	1.4	21.7	1.8	89.7	7.6
Prairie grass	42.8	3.8	25.3	2.1	16.2	1.3	20.8	1.6	105.1	8.8
Ryegrass	65.2	7.0	34.1	3.2	24.2	2.3	28.3	3.0	151.7	15.5
White clover	38.3	3.3	26.7	2.0	18.5	1.5	11.6	1.0	95.1	7.7
Yorkshire fog	97.6	9.1	47.4	3.6	23.3	1.6	16.9	1.3	183.7	15.4
Pooled SE	1.50	0.17	1.32	0.12	0.91	0.08	1.55	0.12	4.03	0.38
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.006

Appendix 6.85. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1992/93. Week 4.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	104.2	11.4	59.9	9.5	30.5	4.4	16.6	2.9	211.2	28.1
Cocksfoot	61.5	6.6	37.4	4.8	22.5	3.1	25.2	3.5	146.6	17.9
Chicory	30.1	2.1	32.1	2.0	33.2	2.3	87.2	6.5	182.6	12.3
Tall fescue	64.1	7.6	44.5	6.1	31.7	4.1	63.4	9.4	203.7	27.1
Lucerne	27.6	2.9	25.5	2.4	20.9	2.2	58.4	7.5	132.3	14.7
Prairie grass	62.6	6.0	52.8	4.7	39.1	3.7	70.6	8.2	225.1	22.5
Ryegrass	58.0	7.1	42.2	5.3	29.9	3.7	36.6	5.5	166.7	20.3
White clover	46.2	4.1	47.7	4.2	37.5	3.8	31.9	3.8	163.2	15.9
Yorkshire fog	111.1	7.7	74.0	5.6	44.9	3.9	58.4	7.1	288.3	22.9
Pooled SE	1.99	0.18	1.53	0.14	1.18	0.11	3.35	0.29	7.08	0.63
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.0001

Appendix 6.86. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1992/93. Week 6.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	54.0	10.5	37.9	8.3	25.4	5.0	27.5	6.0	144.7	29.7
Cocksfoot	40.2	6.8	30.7	5.6	24.4	4.2	42.8	8.2	138.2	24.8
Chicory	16.8	1.0	16.2	1.1	17.5	1.2	76.6	6.7	127.1	9.7
Tall fescue	39.6	7.6	32.1	6.4	27.2	4.9	85.7	15.8	184.6	34.6
Lucerne	22.9	2.8	17.2	2.7	15.9	2.2	80.9	12.7	137.0	20.3
Prairie grass	41.7	6.8	33.9	5.4	29.6	4.6	99.6	16.6	204.9	33.4
Ryegrass	42.8	7.0	34.9	6.3	26.9	4.4	38.1	6.5	142.7	24.2
White clover	27.9	3.9	25.7	3.7	22.0	3.2	25.9	4.2	101.4	15.0
Yorkshire fog	45.8	7.4	44.5	5.6	39.9	4.7	135.4	19.2	265.6	36.8
Pooled SE	1.21	0.19	0.79	0.12	0.78	0.11	0.41	0.49	5.55	0.81
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001

Appendix 6.87. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1992/93. Week 8.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	64.6	12.7	45.8	7.6	30.6	5.1	58.1	8.4	183.3	33.9
Cocksfoot	52.8	7.5	40.7	5.5	31.4	5.0	49.2	14.5	203.5	32.5
Chicory	42.8	3.1	40.4	3.0	37.8	2.7	42.5	23.2	387.3	32.4
Tall fescue	40.4	7.8	32.9	6.1	27.8	5.2	40.9	19.2	199.1	38.3
Lucerne	21.0	3.6	17.5	2.6	19.0	2.6	15.6	10.1	156.1	17.7
Prairie grass	47.9	6.4	39.6	4.7	35.8	4.6	61.5	19.7	257.8	35.4
Ryegrass	65.2	10.0	55.1	7.5	43.6	6.2	45.2	13.6	251.0	37.2
White clover	28.8	3.8	26.5	3.3	24.2	3.1	31.4	16.8	152.4	23.3
Yorkshire fog	73.9	8.0	66.5	5.7	59.6	5.2	49.5	28.5	483.5	46.3
Pooled SE	1.49	0.19	1.47	0.14	1.28	0.13	2.03	0.96	12.89	1.31
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002

Appendix 6.88. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1992/93. Week 11.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	58.1	11.7	46.1	9.4	40.8	8.8	68.6	16.1	213.5	46.0
Cocksfoot	49.2	6.6	34.6	5.0	26.8	4.4	105.1	20.2	215.8	36.0
Chicory	42.5	3.1	40.8	2.8	41.9	3.0	335.9	34.0	461.1	43.0
Tall fescue	40.9	6.5	33.2	5.7	29.6	5.3	132.5	24.5	236.1	42.1
Lucerne	15.6	2.9	13.8	2.2	11.0	1.8	71.7	12.0	112.1	18.9
Prairie grass	61.5	7.0	48.2	5.4	41.3	4.9	256.5	36.5	407.5	53.8
Ryegrass	45.2	6.3	33.1	4.9	27.6	4.3	100.6	15.4	206.5	30.9
White clover	31.4	3.4	26.2	2.7	23.0	2.6	66.9	7.7	147.5	16.4
Yorkshire fog	49.5	5.5	43.9	4.0	44.4	3.6	403.3	37.8	541.1	50.9
Pooled SE	2.03	0.19	1.76	0.16	1.78	0.15	15.78	1.65	20.86	2.05
Herbage effect (P<)	0.001	0.001	0.004	0.001	0.003	0.001	0.001	0.001	0.001	0.002

Appendix 6.89. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1992/93. Week 14.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	94.1	16.0	79.3	10.8	64.8	9.5	78.0	13.1	316.1	49.5
Cocksfoot	64.2	7.5	47.0	5.7	38.5	4.9	173.7	25.0	323.4	43.1
Chicory	51.0	3.2	43.2	2.7	44.8	3.1	283.4	22.3	422.3	31.3
Tall fescue	50.9	6.9	45.4	5.9	40.8	5.7	193.5	28.7	330.6	47.2
Lucerne	24.0	3.9	15.1	2.1	12.2	1.8	86.9	12.8	138.2	20.6
Prairie grass	65.8	6.6	49.7	4.3	44.5	4.2	288.8	26.3	448.8	41.5
Ryegrass	51.8	6.2	37.3	4.5	32.8	4.1	95.4	16.4	217.2	31.2
White clover	46.0	4.1	37.8	3.0	33.9	3.0	102.8	9.9	220.6	20.0
Yorkshire fog	105.9	7.4	67.2	4.6	60.5	3.7	401.5	26.5	635.2	42.1
Pooled SE	3.70	0.30	2.28	0.19	2.12	0.17	11.44	1.12	16.23	1.48
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.0002

Appendix 6.90. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1992/93. Week 2.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	72.9	21.0	23.4	5.7	4.9	1.3	0.5	0.1	101.7	28.0
Cocksfoot	39.7	7.6	11.5	2.1	3.2	0.6	2.1	0.2	56.5	10.5
Chicory	15.7	1.3	8.8	0.8	5.1	0.5	3.4	0.4	33.0	2.8
Tall fescue	33.8	6.2	15.3	2.4	5.9	0.9	3.7	0.7	58.7	10.3
Lucerne	25.5	5.8	3.1	0.5	1.0	0.1	0.2	0	29.7	6.4
Prairie grass	41.9	9.5	9.4	1.6	3.0	0.7	2.8	0.4	57.2	12.2
Ryegrass	37.6	8.4	15.5	2.7	6.4	0.9	2.3	0.5	61.7	12.5
White clover	34.7	5.0	8.2	1.3	0.5	0.1	0	0	43.4	6.4
Yorkshire fog	40.5	12.5	6.3	1.6	3.1	0.03	0	0	49.8	14.1
Pooled SE	1.14	0.30	0.72	0.16	0.35	0.05	0.22	0.03	1.50	0.31
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.005	0.001	0.0001

Appendix 6.91. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1992/93. Week 4.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	107.6	22.2	47.0	8.3	12.6	2.5	2.2	0.5	169.4	33.4
Cocksfoot	60.5	8.0	27.4	3.9	12.3	2.2	6.6	1.3	106.8	15.3
Chicory	13.1	1.4	11.7	1.2	9.2	0.9	12.2	1.3	44.0	4.5
Tall fescue	51.8	7.3	27.6	4.4	15.9	2.5	16.6	2.8	111.8	15.1
Lucerne	28.7	4.5	15.1	2.3	4.0	0.6	1.2	0.3	49.0	7.6
Prairie grass	40.3	6.6	21.4	3.2	12.4	1.9	12.5	2.2	86.4	13.6
Ryegrass	44.6	7.1	22.2	3.3	13.6	2.1	10.4	1.8	90.9	14.3
White clover	34.2	4.4	24.4	3.4	11.3	1.8	2.2	0.5	71.5	10.0
Yorkshire fog	61.4	13.8	16.4	2.9	4.3	0.8	1.4	0.3	83.4	17.7
Pooled SE	1.36	0.25	0.82	0.13	0.43	0.06	0.57	0.07	2.44	0.41
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001

Appendix 6.92. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1992/93. Week 6.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	98.4	18.7	47.6	7.9	16.5	3.2	5.0	1.1	167.4	30.8
Cocksfoot	52.3	7.5	29.5	4.5	18.5	2.9	16.0	2.9	116.3	17.7
Chicory	28.3	2.2	27.5	2.0	29.2	2.4	51.1	4.8	136.0	11.5
Tall fescue	49.8	8.5	33.1	5.4	21.5	3.6	26.3	4.8	130.7	22.2
Lucerne	40.3	6.6	20.2	3.0	7.5	1.2	3.1	0.6	71.0	10.3
Prairie grass	46.0	9.1	25.7	3.9	13.3	2.2	13.3	2.3	98.3	17.3
Ryegrass	40.1	6.4	28.1	4.3	19.9	3.1	21.6	3.7	109.6	17.5
White clover	42.5	6.2	28.5	4.0	12.8	2.0	4.2	0.7	88.1	12.9
Yorkshire fog	53.3	16.4	13.0	2.2	3.7	0.7	1.6	0.3	71.7	19.7
Pooled SE	1.22	0.23	0.87	0.13	0.73	0.09	0.87	0.12	2.90	0.44
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001

Appendix 6.93. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5⁺ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1992/93. Week 8.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	108.9	15.1	53.9	7.5	20.9	3.6	7.8	1.5	191.6	27.7
Cocksfoot	89.5	5.4	56.2	5.7	34.0	4.0	36.4	5.1	216.1	20.2
Chicory	30.6	2.2	32.5	2.1	30.6	2.0	62.6	6.1	156.3	12.4
Tall fescue	60.0	6.1	44.5	5.1	31.6	4.0	40.9	6.1	177.0	21.3
Lucerne	40.4	4.7	30.7	3.1	16.3	2.0	14.7	1.7	102.2	11.4
Prairie grass	64.2	7.5	35.6	3.7	25.5	2.5	31.5	3.9	156.8	16.7
Ryegrass	55.0	6.1	42.4	5.0	32.8	3.9	48.4	6.6	178.5	21.5
White clover	37.2	3.7	29.1	3.1	18.0	1.8	10.7	1.6	95.0	10.0
Yorkshire fog	89.0	8.8	35.6	3.0	15.5	1.6	9.9	1.3	150.1	14.7
Pooled SE	1.36	0.15	1.36	0.13	1.01	0.10	2.85	0.30	5.34	0.52
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001

Appendix 6.94. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1992/93. Week 11.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	93.8	17.5	58.6	9.7	30.1	5.8	16.7	3.7	199.2	36.7
Cocksfoot	53.9	6.6	38.6	5.3	30.8	4.5	66.5	11.2	189.9	27.5
Chicory	28.6	2.3	28.4	2.3	29.5	2.4	112.4	10.7	198.9	17.8
Tall fescue	49.7	6.3	43.4	5.9	35.7	5.2	79.7	13.5	208.5	30.9
Lucerne	21.7	3.8	20.6	3.1	17.4	2.6	40.5	6.7	100.2	16.2
Prairie grass	31.4	4.7	25.3	3.7	21.4	3.1	59.2	9.3	137.3	20.7
Ryegrass	39.9	5.6	31.3	4.5	27.2	3.9	57.9	9.2	156.3	23.2
White clover	27.4	3.6	20.8	3.0	13.4	2.0	15.6	2.1	77.2	10.8
Yorkshire fog	63.3	6.9	47.2	4.6	36.7	3.8	68.9	9.4	216.1	24.7
Pooled SE	1.20	0.14	0.98	0.11	0.90	0.10	4.01	0.43	6.51	0.70
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001

Appendix 6.95. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1992/93. Week 14.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	66.4	13.3	50.6	9.5	34.3	7.0	34.0	7.7	185.4	35.9
Cocksfoot	53.4	7.4	42.4	6.4	32.6	5.2	89.5	16.2	217.9	35.2
Chicory	35.3	3.5	30.2	2.9	26.3	2.7	97.5	10.3	189.3	19.5
Tall fescue	45.2	5.8	40.9	5.7	37.9	5.8	144.6	25.3	268.6	42.5
Lucerne	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Prairie grass	35.4	5.6	31.6	5.3	28.5	4.8	116.0	20.3	211.5	36.0
Ryegrass	46.7	7.1	39.5	6.3	34.4	5.5	103.0	16.7	223.6	35.6
White clover	42.5	6.5	31.5	4.3	21.5	3.2	5.3	1.6	100.8	15.5
Yorkshire fog	54.4	6.8	51.5	5.6	48.0	5.2	128.4	16.2	282.2	33.8
Pooled SE	1.64	0.22	1.34	0.19	1.27	0.17	6.12	0.85	8.64	1.35
Herbage effect (P<)	0.002	0.001	0.001	0.001	0.009	0.001	0.003	0.001	0.001	0.02

[1] ND - not determined

Appendix 6.96. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 1 1993/94. Week 2.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	117.5	18.9	70.8	10.4	33.2	4.4	21.5	2.7	243.0	36.4
Cocksfoot	78.8	10.0	37.1	4.8	18.1	2.1	19.7	2.5	150.6	18.9
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	85.5	11.0	43.3	4.7	23.3	2.2	29.6	3.1	181.7	20.9
Lucerne	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	86.3	12.8	37.6	5.0	16.5	1.9	15.4	11.7	155.9	31.4
White clover	81.9	6.7	55.3	4.5	37.1	3.0	38.5	3.8	212.7	18.0
Yorkshire fog	108.0	11.4	76.6	7.5	44.1	4.7	55.1	6.2	283.8	29.7
Pooled SE	4.16	0.53	3.07	0.36	1.68	0.18	2.42	0.28	8.96	1.11
Herbage effect (P<)	0.02	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001

[1] ND - not determined

Appendix 6.97. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 1 1993/94. Week 4.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	62.7	19.2	38.5	9.4	21.2	5.0	16.8	4.3	139.1	37.9
Cocksfoot	29.5	7.9	20.8	4.5	15.2	3.5	31.9	7.8	97.4	23.7
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	40.6	10.3	26.3	5.3	21.0	3.6	44.2	9.8	132.1	29.4
Lucerne	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	44.2	12.1	34.1	7.0	25.8	4.9	44.1	9.1	148.1	33.0
White clover	49.6	7.7	34.1	4.3	30.6	4.1	53.9	8.2	168.2	24.2
Yorkshire fog	35.5	8.9	32.0	6.1	28.2	5.1	63.2	12.1	159.0	32.2
Pooled SE	1.28	0.33	0.85	0.16	0.63	0.11	3.16	0.60	4.46	0.90
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.006	0.001	0.0001

[1] ND - not determined

Appendix 6.98. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5⁺ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 1 1993/94. Week 6.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^+ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	72.8	17.7	49.1	10.5	37.7	7.4	63.8	13.5	223.4	49.0
Cocksfoot	30.8	7.5	23.5	5.2	18.4	4.0	61.6	14.3	134.2	30.9
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	34.9	8.2	25.0	5.4	22.3	4.5	81.3	16.7	163.5	34.8
Lucerne	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	45.4	11.2	36.3	7.3	29.9	5.7	80.8	15.5	192.4	39.7
White clover	55.4	7.7	37.4	4.3	33.6	3.7	91.5	11.8	217.9	27.4
Yorkshire fog	40.	7.6	34.2	5.9	31.9	5.0	162.3	31.0	268.3	49.4
Pooled SE	2.09	0.44	1.34	0.26	1.09	0.19	5.45	1.04	8.76	1.71
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0004

[1] ND - not determined

Appendix 6.99. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 1 1993/94. Week 8.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	40.7	15.7	41.2	12.9	41.5	10.9	160.0	40.5	283.4	80.1
Cocksfoot	33.4	8.7	29.7	7.5	24.9	6.1	104.1	28.5	192.1	50.8
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	31.5	8.7	29.0	7.5	25.3	6.1	126.8	29.0	212.5	51.4
Lucerne	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	38.1	12.6	34.2	10.2	27.7	7.4	111.7	29.4	211.8	59.5
White clover	43.0	7.6	36.2	5.7	34.9	5.1	194.1	29.7	308.1	48.2
Yorkshire fog	37.5	6.6	30.4	6.7	31.7	5.2	295.6	55.6	395.2	74.2
Pooled SE	1.40	0.33	0.82	0.21	1.25	0.25	8.87	1.74	9.80	1.92
Herbage effect (P<)	0.08	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001

[1] ND - not determined

Appendix 6.100. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 1 1993/94. Week 11.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	36.9	12.4	21.9	6.4	6.9	2.1	1.4	0.7	67.2	21.5
Cocksfoot	25.2	6.9	15.3	4.2	8.2	2.0	14.3	3.3	62.9	16.4
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	22.5	6.3	14.9	3.3	11.0	2.4	16.2	3.5	64.6	15.5
Lucerne	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	23.0	7.7	13.0	3.2	6.4	1.5	4.8	1.2	47.3	13.7
White clover	33.0	6.6	24.4	3.8	19.8	3.1	30.2	4.5	107.4	18.0
Yorkshire fog	32.2	10.2	18.6	3.9	10.8	2.0	6.7	1.3	68.3	17.4
Pooled SE	1.32	0.37	0.76	0.17	0.65	0.14	1.12	0.21	2.39	0.61
Herbage effect (P<)	0.003	0.001	0.001	0.001	0.001	0.02	0.001	0.001	0.001	0.004

[1] ND - not determined

Appendix 6.101. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 1 1993/94. Week 14.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	44.5	17.6	26.0	8.7	12.5	3.9	8.1	2.6	91.2	32.7
Cocksfoot	30.3	11.1	20.3	5.8	15.1	4.1	20.8	6.0	86.5	27.0
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	32.2	11.0	26.8	5.6	15.7	3.9	25.7	6.8	100.3	27.3
Lucerne	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	31.7	12.8	18.2	6.0	9.1	3.0	5.0	1.9	63.9	23.7
White clover	35.7	9.9	25.6	6.1	19.7	5.0	14.4	4.5	95.4	25.4
Yorkshire fog	34.0	9.7	40.7	6.8	25.0	5.3	27.2	6.2	127.0	28.0
Pooled SE	0.98	0.33	2.46	0.45	0.72	0.19	1.28	0.35	3.82	0.93
Herbage effect (P<)	0.001	0.001	0.06	0.22	0.001	0.004	0.001	0.001	0.001	0.05

[1] ND - not determined

Appendix 6.102. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^+ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1993/94. Week 2.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^+ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	35.8	16.1	22.0	9.0	6.7	2.6	1.4	0.6	65.9	28.2
Cocksfoot	25.2	7.8	12.4	3.3	5.1	1.4	3.4	0.9	46.1	13.4
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	52.0	10.8	31.5	6.2	13.4	2.7	11.2	2.4	108.1	22.1
Lucerne	39.4	7.2	25.5	4.4	13.7	2.4	12.2	2.2	90.8	16.2
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	26.1	11.0	14.8	5.4	5.2	2.1	2.7	1.1	48.9	19.7
Ryegrass/white clover	27.2	5.9	17.1	3.4	8.7	1.8	7.2	1.5	60.2	12.5
White clover	25.7	6.0	18.5	3.8	7.1	1.4	2.1	0.4	53.4	11.5
Yorkshire fog	33.2	7.2	23.0	4.5	9.7	1.9	5.2	1.3	71.1	14.9
Pooled SE	1.17	0.29	0.87	0.19	0.52	0.11	0.46	0.10	2.65	0.56
Herbage effect (P<)	0.001	0.001	0.001	0.22	0.001	0.04	0.001	0.001	0.001	0.0001

[1] ND - not determined

Appendix 6.103. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1993/94. Week 4.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	38.5	2.2	26.4	11.9	8.2	3.5	1.7	0.8	74.8	17.9
Cocksfoot	28.3	10.2	17.9	5.6	8.8	2.7	9.4	2.6	64.5	21.1
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	57.2	13.2	41.3	8.9	25.4	5.8	34.6	9.0	158.5	37.0
Lucerne	32.5	6.6	28.1	5.0	21.0	3.9	33.5	9.3	115.0	24.8
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	30.1	13.0	20.1	7.6	8.6	2.8	4.8	1.8	63.6	25.1
Ryegrass/white clover	30.3	8.3	26.0	5.8	14.8	3.5	18.5	4.4	89.7	21.3
White clover	30.2	10.2	17.9	5.6	8.8	2.7	7.8	2.6	64.7	21.1
Yorkshire fog	34.5	8.2	31.2	6.6	20.9	4.3	23.4	5.3	110.0	24.4
Pooled SE	0.95	0.25	0.73	0.18	0.61	0.15	1.79	0.48	3.00	0.78
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001

[1] ND - not determined

Appendix 6.104. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1993/94. Week 6.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	38.5	20.1	25.8	12.4	10.7	4.8	4.4	1.8	79.3	39.1
Cocksfoot	26.6	11.6	15.3	5.5	8.3	2.7	10.0	3.4	60.3	23.3
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	44.3	12.8	33.8	9.0	21.7	5.8	30.4	9.8	130.1	37.3
Lucerne	31.9	7.8	24.6	5.3	20.8	4.6	69.6	19.1	146.9	36.8
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	27.6	13.3	15.3	6.3	6.2	2.1	3.8	1.3	52.9	23.0
Ryegrass/white clover	30.6	9.9	23.2	6.6	18.2	4.8	49.7	13.3	121.6	34.6
White clover	24.5	7.5	17.1	4.7	8.8	2.3	15.9	3.5	66.2	18.0
Yorkshire fog	34.1	9.1	28.1	6.9	21.2	5.1	43.2	13.0	126.7	34.0
Pooled SE	0.90	0.31	0.70	0.21	0.63	0.20	2.43	0.67	3.47	0.97
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0001

[1] ND - not determined

Appendix 6.105. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5⁺ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1993/94. Week 8.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^+ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	47.4	22.6	23.0	12.0	8.8	3.9	2.7	1.3	81.9	30.5
Cocksfoot	30.6	7.0	24.3	4.8	21.9	4.2	93.8	20.1	170.6	34.7
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	23.6	8.0	12.6	3.9	7.6	1.4	6.5	2.7	50.2	15.0
Lucerne	39.4	11.8	27.4	8.0	35.9	6.0	23.0	7.9	125.7	30.4
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	25.3	7.2	18.0	4.6	15.9	3.7	105.5	25.4	164.7	38.6
Ryegrass/white clover	27.2	11.3	18.6	7.4	13.2	5.5	44.7	9.3	103.7	31.5
White clover	25.7	8.0	12.7	3.3	4.2	1.0	9.3	2.3	51.8	13.0
Yorkshire fog	33.6	16.0	17.5	7.4	5.9	2.3	2.4	1.1	59.4	23.1
Pooled SE	1.22	0.49	0.51	0.18	2.24	0.41	2.64	0.66	3.81	1.15
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.03	0.08	0.001	0.001	0.001	0.0001

[1] ND - not determined

Appendix 6.106. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1993/94. Week 11.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	48.0	16.2	22.8	10.1	4.5	1.9	0.9	0.4	76.3	28.6
Cocksfoot	40.0	11.7	17.5	6.5	3.8	1.0	0.6	0.3	61.9	19.5
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	51.6	11.3	25.4	8.2	7.6	2.1	3.7	1.1	88.3	22.6
Lucerne	28.4	6.5	17.0	3.8	11.3	1.7	32.4	4.4	89.1	16.3
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	40.5	11.5	20.0	7.1	5.4	1.6	1.7	0.6	67.6	20.7
Ryegrass/white clover	41.3	8.5	25.8	5.8	6.7	1.3	2.7	0.7	76.5	16.3
White clover	31.5	6.6	16.9	4.4	4.1	1.3	1.3	0.4	53.8	12.7
Yorkshire fog	28.9	7.1	18.0	5.0	5.8	1.4	2.2	0.7	54.9	14.2
Pooled SE	1.11	0.30	0.80	0.24	0.57	0.14	2.46	0.35	4.11	0.77
Herbage effect (P<)	0.001	0.001	0.03	0.001	0.05	0.65	0.04	0.10	0.24	0.0003

[1] ND - not determined

Appendix 6.107. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 2 1993/94. Week 14.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	64.6	15.6	29.8	7.0	6.6	2.2	1.6	1.8	102.7	22.7
Cocksfoot	34.8	15.2	14.0	5.2	3.7	1.4	1.5	1.0	54.0	21.4
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	40.2	15.5	20.7	7.0	7.1	2.6	3.6	1.5	71.7	23.6
Lucerne	27.7	8.3	15.3	3.2	8.2	1.8	28.4	6.0	79.6	17.7
Prairie grass	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ryegrass	43.3	18.4	20.0	6.9	5.5	1.9	2.2	0.8	71.0	24.5
Ryegrass/white clover	28.7	13.0	18.3	6.0	8.2	2.3	5.1	1.9	60.3	19.9
White clover	36.1	10.2	14.3	3.7	4.0	1.5	2.8	0.8	57.2	16.2
Yorkshire fog	32.9	12.0	20.6	6.0	9.4	2.2	4.4	1.3	67.3	21.2
Pooled SE	1.10	0.36	0.72	0.22	0.49	0.17	0.71	0.22	2.11	0.90
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.08	0.71	0.001	0.001	0.24	0.36

[1] ND - not determined

Appendix 6.108. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1993/94. Week 2.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	74.3	23.0	26.9	8.5	6.7	2.1	1.8	0.6	109.7	34.2
Cocksfoot	40.2	11.6	12.3	3.6	3.6	1.0	1.3	0.4	57.5	16.6
Chicory	32.4	7.2	11.2	2.5	5.1	1.0	5.3	0.7	54.0	11.4
Tall fescue	32.8	9.4	16.6	4.5	6.1	1.5	4.3	1.1	59.8	16.5
Lucerne	26.5	6.2	14.6	2.5	9.1	1.6	5.6	1.0	55.7	11.4
Prairie grass	31.1	8.5	10.7	2.4	6.1	1.1	6.4	1.3	54.2	13.2
Ryegrass	24.1	7.4	11.6	3.1	4.9	1.0	3.9	0.8	44.5	12.3
Ryegrass/white clover	27.5	7.0	10.1	2.3	3.2	0.6	2.2	0.4	43.0	10.3
White clover	34.6	5.4	16.7	2.7	7.3	1.3	2.2	0.5	60.7	9.7
Yorkshire fog	83.7	7.0	23.0	4.7	3.5	0.8	0.3	0.2	110.6	12.7
Pooled SE	1.10	0.28	0.47	0.12	0.30	0.08	0.29	0.06	1.37	0.29
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.01	0.05	0.003	0.03	0.004	0.0001

Appendix 6.109 7.38. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1993/94. Week 4.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	68.4	26.2	29.5	9.6	7.6	2.4	2.0	0.6	107.6	38.7
Cocksfoot	28.8	9.4	15.5	4.1	6.9	1.6	5.0	1.3	56.2	16.3
Chicory	40.5	11.9	20.9	6.3	12.2	3.0	25.0	3.7	98.6	24.9
Tall fescue	27.9	9.7	17.4	5.3	9.8	2.6	12.4	3.3	67.6	20.8
Lucerne	30.8	6.3	18.4	3.0	13.4	2.1	50.6	9.1	113.2	20.4
Prairie grass	31.7	10.4	18.4	4.3	11.9	2.4	27.3	4.8	89.3	22.0
Ryegrass	31.6	9.4	20.7	4.7	12.9	2.6	15.1	2.8	80.3	19.5
Ryegrass/white clover	32.3	9.1	16.6	3.9	8.1	1.8	5.6	1.4	62.6	16.2
White clover	32.7	6.0	25.0	3.9	21.7	3.6	20.8	3.6	100.2	17.1
Yorkshire fog	63.3	20.6	32.1	6.4	11.9	2.4	5.1	1.0	112.4	30.4
Pooled SE	0.87	0.30	0.50	0.13	0.39	0.09	1.16	0.19	1.81	0.44
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.01	0.001	0.001	0.001	0.0001

Appendix 6.110. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1993/94. Week 6.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	121.7	15.1	49.1	11.8	12.1	3.1	3.3	1.0	186.2	30.9
Cocksfoot	57.2	13.6	24.4	5.6	10.6	2.7	8.2	2.0	100.4	23.8
Chicory	40.1	7.6	25.2	4.2	15.5	2.4	16.5	2.6	97.3	16.9
Tall fescue	42.1	12.8	23.8	6.4	12.4	3.1	14.0	3.5	92.3	25.7
Lucerne	43.5	7.1	20.8	2.4	14.7	3.2	75.9	14.8	154.9	27.4
Prairie grass	40.6	10.0	20.0	4.1	13.4	2.7	29.3	7.4	103.2	24.2
Ryegrass	48.2	11.4	31.7	6.4	21.9	4.1	30.3	5.7	132.1	27.5
Ryegrass/white clover	52.0	10.4	31.1	5.4	17.5	3.3	9.0	1.8	109.6	21.0
White clover	40.3	6.2	31.7	4.4	30.8	4.3	35.5	5.8	138.4	20.7
Yorkshire fog	112.2	16.2	50.1	6.5	26.7	4.3	19.2	3.5	208.2	30.5
Pooled SE	1.44	0.27	0.87	0.16	0.57	0.11	1.60	0.31	2.96	0.59
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.005	0.001	0.001	0.001	0.0005

Appendix 6.111. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1993/94. Week 8.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	85.9	29.9	39.9	11.6	11.7	3.4	2.5	1.1	140.0	46.0
Cocksfoot	51.1	14.0	33.2	8.4	17.2	3.9	10.1	2.3	111.5	28.6
Chicory	32.5	5.7	25.9	3.6	20.4	2.8	34.3	4.6	113.2	16.7
Tall fescue	44.6	12.7	21.4	5.9	11.9	3.3	13.5	4.1	88.7	25.3
Lucerne	36.4	7.1	23.1	3.7	15.3	2.6	78.0	16.1	152.8	29.5
Prairie grass	40.0	10.3	19.3	4.4	11.3	2.5	23.1	6.0	93.7	23.2
Ryegrass	46.3	11.6	31.0	6.8	23.0	4.8	35.9	7.4	136.2	30.5
Ryegrass/white clover	44.2	8.6	27.5	6.0	19.5	4.0	15.5	3.9	106.7	22.6
White clover	35.4	5.9	32.9	4.4	31.1	4.4	50.1	7.5	149.5	22.2
Yorkshire fog	65.0	13.7	43.2	7.0	29.8	5.0	33.3	5.7	171.3	31.4
Pooled SE	1.59	0.46	0.70	0.25	0.49	0.12	1.65	0.32	2.50	0.56
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.0001

Appendix 6.112. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5⁺ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1993/94. Week 11.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	130.7	31.2	22.7	1.3	0.4	0.3	0	0	158.9	32.8
Cocksfoot	63.1	9.6	12.9	2.3	2.9	0.8	0.8	0.4	79.7	13.0
Chicory	37.4	6.5	7.7	1.4	2.6	0.7	0.5	0.2	48.2	8.7
Tall fescue	53.4	12.1	13.2	3.4	1.6	0.3	0.4	0.2	68.5	15.9
Lucerne	31.8	5.7	6.6	1.4	1.6	0.5	0.3	0.2	40.4	7.8
Prairie grass	49.6	10.4	8.3	1.6	2.6	0.7	0.6	0.2	61.0	12.9
Ryegrass	35.9	6.8	9.1	1.8	3.1	0.8	2.0	0.6	50.0	9.9
Ryegrass/white clover	61.5	9.6	13.7	2.3	3.5	0.8	0.9	0.4	79.6	13.0
White clover	54.4	5.6	17.6	2.3	5.7	1.0	0.3	0.2	78.0	9.1
Yorkshire fog	107.0	16.9	12.5	2.1	0.7	0.2	0	0	120.2	19.2
Pooled SE	2.02	0.36	0.61	0.10	0.17	0.04	0.13	0.04	2.49	0.45
Herbage effect (P<)	0.001	0.001	0.001	0.006	0.001	0.003	0.19	0.25	0.001	0.0001

Appendix 6.113. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 3 1993/94. Week 14.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	132.2	27.7	26.3	5.7	3.1	0.8	0.4	0.2	161.9	34.4
Cocksfoot	80.0	11.8	18.9	3.3	4.7	1.1	2.7	0.7	106.3	16.8
Chicory	31.5	4.0	8.4	1.8	3.4	0.5	1.6	0.3	45.0	6.6
Tall fescue	54.6	9.9	19.6	2.7	5.0	1.1	1.4	0.4	80.5	14.0
Lucerne	45.9	6.7	17.7	2.4	10.6	1.5	13.6	1.9	87.8	12.4
Prairie grass	58.0	7.9	17.5	2.5	8.1	1.2	6.4	1.0	90.1	12.6
Ryegrass	51.1	7.7	18.2	3.0	8.8	1.6	6.5	1.0	84.7	13.3
Ryegrass/white clover	57.5	8.4	18.7	2.9	7.9	1.3	4.3	0.8	88.4	13.4
White clover	48.2	5.0	26.7	3.6	14.2	1.9	4.1	0.6	93.2	11.1
Yorkshire fog	152.4	20.9	27.3	3.4	5.7	0.9	1.7	0.3	187.1	25.4
Pooled SE	1.67	0.27	0.73	0.11	0.41	0.06	0.76	0.11	2.62	0.41
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.005	0.07	0.11	0.001	0.0001

Appendix 6.114. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1993/94. Week 2.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	52.4	12.5	0.9	0.1	0	0	0	0	53.3	12.6
Cocksfoot	52.0	8.3	8.3	1.2	4.1	0.4	1.2	0.1	65.6	10.0
Chicory	21.1	3.5	3.0	0.4	0.5	0.1	0	0	24.7	3.9
Tall fescue	38.1	7.6	6.2	1.3	2.3	0.4	1.5	0.2	48.1	9.6
Lucerne	49.4	9.0	13.9	1.5	9.5	0.9	2.9	0.4	75.7	11.7
Prairie grass	36.8	6.0	7.8	0.8	3.6	0.3	2.6	0.1	50.8	7.3
Ryegrass	27.7	4.9	5.9	0.6	2.8	0.2	0.7	0.1	37.1	5.8
Ryegrass/white clover	41.8	5.9	9.6	1.1	2.8	0.4	1.8	0.2	56.0	7.6
White clover	59.0	6.4	9.9	1.0	0.9	0.1	0.1	0	69.9	7.4
Yorkshire fog	105.1	16.9	3.9	0.5	0.5	0.1	0	0	109.5	17.5
Pooled SE	1.64	0.29	0.46	0.05	0.30	0.03	0.17	0.02	2.14	0.34
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.01	0.002	0.001	0.0001

Appendix 6.115. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1993/94. Week 4.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	64.2	15.9	6.8	2.4	0.7	0.4	0	0	71.2	18.6
Cocksfoot	55.0	9.2	12.1	2.4	6.7	1.2	6.1	1.2	80.0	14.0
Chicory	29.1	3.9	13.8	1.6	7.6	0.2	3.9	0.5	54.4	6.1
Tall fescue	24.6	4.1	5.4	1.7	3.5	0.8	2.2	0.5	35.8	7.0
Lucerne	33.1	5.3	20.0	2.0	18.4	2.3	31.5	4.7	103.0	14.3
Prairie grass	27.5	4.2	19.4	1.8	6.3	0.9	3.9	0.5	57.2	7.4
Ryegrass	26.8	4.8	19.0	1.7	4.7	0.8	3.2	0.4	53.7	7.8
Ryegrass/white clover	40.1	6.1	11.5	2.2	5.9	1.0	2.8	0.6	60.3	9.8
White clover	54.8	6.8	4.7	0.9	1.7	0.2	0	0	61.3	7.9
Yorkshire fog	81.1	14.0	18.9	1.9	1.2	0.3	0.2	0.1	101.3	16.3
Pooled SE	1.05	0.17	1.49	0.15	0.43	0.25	1.12	0.17	2.93	0.39
Herbage effect (P<)	0.001	0.001	0.36	0.77	0.001	0.001	0.001	0.001	0.003	0.0001

Appendix 6.116. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1993/94. Week 6.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	126.4	21.9	13.7	2.6	2.0	0.4	0	0	142.1	24.9
Cocksfoot	56.9	6.7	13.6	2.0	6.7	1.0	5.3	0.7	82.5	10.5
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	51.1	7.5	13.9	2.5	6.6	1.2	4.3	0.8	75.9	12.0
Lucerne	42.8	4.5	25.1	2.6	24.3	2.4	60.2	7.1	152.3	16.6
Prairie grass	37.9	3.9	13.2	1.5	6.6	0.7	4.6	0.6	62.3	6.7
Ryegrass	46.7	6.1	20.0	2.9	11.4	1.6	10.0	1.3	88.1	11.9
Ryegrass/white clover	56.9	7.3	22.8	3.2	12.6	1.8	8.2	1.3	100.5	13.6
White clover	73.6	6.5	34.5	3.5	12.8	1.5	1.2	0.2	122.0	11.8
Yorkshire fog	134.6	14.7	21.7	2.8	3.8	0.6	0.3	0.1	160.4	18.1
Pooled SE	1.76	0.26	0.69	0.09	0.49	0.06	1.19	0.14	2.90	0.43
Herbage effect (P<)	0.001	0.001	0.001	0.005	0.001	0.001	0.001	0.001	0.001	0.0001

[1] ND - not determined

Appendix 6.117. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5$^+$ cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1993/94. Week 8.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5$^+$ cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	138.9	24.1	19.7	4.0	2.3	0.5	0.2	0	161.1	28.6
Cocksfoot	60.9	8.3	34.0	3.4	11.7	2.0	9.4	1.8	116.1	15.4
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	39.5	6.0	12.2	2.5	5.3	1.2	3.7	0.9	60.7	10.5
Lucerne	29.0	3.5	16.6	2.4	13.8	2.0	45.3	7.6	104.6	15.4
Prairie grass	58.1	6.4	23.2	2.9	12.2	1.6	10.2	1.5	103.7	12.4
Ryegrass	42.4	5.9	13.8	2.4	6.3	1.2	4.3	0.9	66.8	10.3
Ryegrass/white clover	55.9	7.6	25.0	3.9	12.4	2.0	8.5	1.6	101.8	15.0
White clover	74.4	7.2	38.7	4.6	18.0	2.5	3.8	0.7	134.9	14.9
Yorkshire fog	130.3	15.1	25.8	3.6	5.3	0.9	2.2	0.4	163.7	19.9
Pooled SE	2.26	0.33	1.26	0.14	0.33	0.52	1.11	0.19	3.05	0.51
Herbage effect (P<)	0.001	0.001	0.004	0.06	0.001	0.001	0.001	0.001	0.001	0.0001

[1] ND - not determined

Appendix 6.118. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1993/94. Week 11.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	127.9	20.9	8.9	1.7	1.0	0.1	0	0	137.8	22.7
Cocksfoot	71.4	8.7	10.2	1.6	2.5	0.5	0.8	0.2	85.0	10.9
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	60.0	8.6	12.0	2.1	3.3	0.5	0.9	0.1	76.1	11.3
Lucerne	20.4	3.5	1.4	0.2	0	0	0	0	21.8	3.6
Prairie grass	51.9	6.0	11.4	1.5	3.7	0.6	1.1	0.1	68.1	8.3
Ryegrass	60.9	8.4	13.1	2.0	3.9	0.6	1.4	0.2	79.4	11.3
Ryegrass/white clover	54.2	7.9	9.0	1.5	2.1	0.4	1.1	0	66.4	9.8
White clover	55.6	5.5	11.4	1.5	1.1	0.1	0	0	68.1	7.1
Yorkshire fog	128.5	16.4	15.5	2.0	1.9	0.4	0.6	0.1	146.5	18.8
Pooled SE	1.78	0.27	0.33	0.06	0.13	0.02	0.09	0.11	1.81	0.30
Herbage effect (P<)	0.001	0.001	0.001	0.001	0.001	0.001	0.02	0.02	0.001	0.0001

[1] ND - not determined

Appendix 6.119. Fresh and dry herbage mass (g) in 4 vertical strata (0-2.5, 2.5-5, 5-7.5, and 7.5^{+} cm) and total herbage mass of browntop, cocksfoot, chicory, tall fescue, lucerne, prairie grass, ryegrass, white clover and Yorkshire. Contamination 4 1993/94. Week 14.

	0-2.5 cm		2.5-5 cm		5-7.5 cm		7.5^{+} cm		Total	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Browntop	118.1	19.0	20.9	4.0	2.7	0.5	0.2	0.1	141.9	23.6
Cocksfoot	78.7	9.2	16.6	2.6	4.7	0.8	1.4	0.3	101.4	12.9
Chicory	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tall fescue	57.6	8.1	14.8	2.6	5.2	1.0	1.6	0.5	79.2	12.2
Lucerne	36.6	4.6	17.2	2.3	7.8	1.1	3.8	0.5	65.3	8.5
Prairie grass	69.7	7.6	21.1	2.5	8.2	1.3	5.6	0.7	104.5	12.1
Ryegrass	62.6	7.9	22.4	3.2	8.9	1.4	4.2	0.8	97.9	13.3
Ryegrass/white clover	83.1	10.9	27.7	4.2	10.5	1.8	3.7	0.6	125.0	17.5
White clover	71.4	6.0	39.5	4.6	15.1	2.1	4.8	0.6	130.8	13.4
Yorkshire fog	141.3	15.2	30.1	3.8	6.7	1.0	1.4	0.3	179.5	20.3
Pooled SE	1.99	0.27	0.88	0.13	0.43	0.06	0.30	0.04	2.52	0.38
Herbage effect (P<)	0.001	0.001	0.001	0.02	0.002	0.004	0.04	0.06	0.001	0.0001

[1] ND - not determined

Appendix 6.120. Average density of *Ostertagia* and *Trichostrongylus* third stage larvae (10^3/kg herbage DM) recovered from swards of herbages contaminated with faeces containing a known number of eggs. Both years.

Herbage	1992/93			1993/94			Combined for both years
	Ostertagia	*Trichostrongylus*	Combined	*Ostertagia*	*Trichostrongylus*	Combined	
Browntop	3.8	11.2	13.8	7.7	29.3	35.1	24.4
Cocksfoot	4.6	7.4	10.5	17.6	35.6	48.7	29.6
Tall fescue	1.3	7.2	8.1	17.5	36.0	49.1	28.6
Lucerne	0.8	5.5	6.1	23.3	32.9	52.0	28.7
Prairie grass	2.2	10.8	12.3	18.1	47.2	61.2	36.9
Ryegrass	6.9	11.0	15.7	24.9	59.4	78.0	46.8
Ryegrass/white clover	ND[1]	ND	ND	23.8	57.0	76.6	ND
White clover	1.8	11.1	12.6	17.0	34.8	47.6	30.0
Yorkshire fog	3.5	20.3	22.4	16.2	65.4	77.5	50.0
Pooled SE	0.66	3.15	3.45	2.24	7.17	8.15	9.31
Herbage effect (P<)	0.007	0.46	0.39	0.16	0.28	0.24	0.37

[1] ND - not determined.

Appendix 6.121. Average density of *Ostertagia* and *Trichostrongylus* third stage larvae (10^2kg dry herbage) recovered from each of four vertical strata (0-2.5 cm, 2.5-5 cm, 5-7.5 cm 7.5$^+$ cm) of swards of herbages contaminated with faeces containing a known number of eggs. 1992/93 .

Herbage	*Ostertagia*				*Trichostrongylus*				Combined			
	0-2.5	2.5 -5	5-7.5	7.5$^+$	0-2.5	2.5-5	5-7.5	7.5$^+$	0-2.5	2.5-5	5-7.5	7.5$^+$
Browntop	5.2	3.3	33.6	53.3	8.2	9.7	39.0	62.4	11.7	12.2	60.0	97.4
Cocksfoot	4.1	4.5	7.2	3.7	35.0	22.5	8.8	2.4	37.7	25.8	12.3	4.3
Tall fescue	2.0	1.2	4.6	2.0	5.0	14.3	14.3	7.0	6.2	15.5	16.0	7.8
Lucerne	8.6	0.4	4.8	6.7	23.7	23.4	196.4	0.4	29.3	24.1	198.5	3.7
Prairie grass	3.4	3.1	5.2	0.9	31.4	10.7	51.0	4.6	33.6	13.1	53.0	4.7
Ryegrass	6.2	6.0	30.3	56.5	9.1	17.5	19.1	10.8	13.2	21.8	37.9	47.9
White clover	0.9	8.2	4.3	9.2	7.5	18.9	25.0	12.1	8.0	24.7	26.5	17.6
Yorkshire fog	5.3	6.6	3.6	9.0	56.3	24.9	11.3	2.9	59.7	29.7	12.2	8.2
Pooled SE	1.93	1.81	4.93	13.45	10.76	5.68	39.76	10.14	11.01	5.97	40.23	17.62
Herbage effect (P<)	0.83	0.66	0.05	0.46	0.21	0.83	0.32	0.07	0.21	0.78	0.35	0.11

Appendix 6.122. Average density of *Ostertagia* and *Trichostrongylus* third stage larvae (x10/kg dry herbage) recovered from each of four vertical strata (0-2.5 cm, 2.5-5 cm, 5-7.5 cm 7.5^{+} cm) of swards of herbages contaminated with faeces containing a known number of eggs. 1993/94.

Herbage	*Ostertagia*				*Trichostrongylus*				Combined			
	0-2.5	2.5 -5	5-7.5	7.5^{+}	0.2.5	2.5-5	5-7.5	7.5^{+}	0-2.5	2.5-5	5-7.5	7.5^{+}
Browntop	3.8	43.3	1156.9	3514.0	14.9	94.1	454.8	1936.9	17.8	126.6	1316.4	4445.3
Cocksfoot	9.8	55.4	513.0	1549.4	22.6	98.7	220.7	1577.6	29.9	140.3	605.4	2740.0
Tall fescue	10.0	29.6	834.0	644.8	23.0	82.7	621.4	1113.7	30.4	105.0	1246.9	1597.3
Lucerne	17.9	426.5	257.1	3452.2	42.8	215.9	44.6	2926.6	58.1	630.1	145.4	5995.1
Prairie grass	14.4	46.3	194.6	297.4	43.7	103.3	20.9	732.9	55.6	135.4	61.8	647.2
Ryegrass	15.2	59.3	237.5	789.1	35.7	145.5	406.8	1062.6	47.1	190.0	585.0	1654.4
Rye/white clover	13.8	32.5	109.1	1627.9	38.1	94.1	19.4	267.2	49.2	114.2	50.0	1551.3
White clover	13.0	44.5	272.2	1337.1	22.6	69.4	708.2	999.9	32.3	102.8	912.4	1974.6
Yorkshire fog	12.0	64.4	346.0	623.0	49.4	143.2	2391.1	1385.9	58.4	191.5	2650.6	1855.8
Pooled SE	2.09	61.00	150.10	701.50	5.87	25.35	431.30	620.67	6.68	75.46	454.17	1160.18
Herbage effect (P<)	0.40	0.26	0.19	0.68	0.19	0.45	0.42	0.91	0.12	0.20	0.36	0.79

Appendix 6.123. Difference in daily minimum sward and screen temperature (^{0}C) for herbages. Weekly average for five weeks after faecal deposition, Contamination 1 1993/94.

	Weeks After Contamination				
	1	2	3	4	5
Tall fescue	0.1	1.6	2.5	3.1	1.9
Ryegrass	-1.3	0.2	1.0	1.3	1.1
White clover	-0.3	1.5	2.1	2.1	1.1
Pooled SE	0.26	0.22	0.21	0.24	0.22

Herbage x week $P<0.81$

Appendix 6.124. Difference in daily maximum sward and screen temperature (^{0}C) for herbages. Weekly average for five weeks after faecal deposition, Contamination 1 1993/94.

	Weeks After Contamination				
	1	2	3	4	5
Tall fescue	10.0	8.4	6.2	5.6	4.3
Ryegrass	9.2	7.6	6.1	6.3	4.2
White clover	8.6	6.3	5.4	5.0	3.7
Pooled SE	0.62	0.53	0.53	0.53	0.53

Herbage x week $P<0.09$.

Appendix 6.125. Difference in daily minimum sward and screen temperature (^{0}C) for herbages. Weekly average for five weeks after faecal deposition, Contamination 3 1993/94.

	Weeks After Contamination				
	1	2	3	4	5
Browntop	-0.2	-0.5	0.1	-0.2	0.2
Cocksfoot	-1.5	-1.1	-0.1	-0.8	-0.4
Chicory	6.7	2.7	3.6	2.4	5.2
Tall fescue	-0.5	-0.2	0.6	-0.3	0.1
Lucerne	-1.2	-0.3	0.9	0.5	0.8
Prairie grass	-0.3	-0.7	-0.1	-1.1	-0.3
Ryegrass	-0.7	-0.9	-0.9	-0.8	-0.9
Ryegrass/white clover	-1.3	-1.1	-0.3	-1.5	-0.8
White clover	-1.2	-0.4	0.4	-0.3	0.7
Yorkshire fog	12.0	5.9	7.2	5.1	3.9
Pooled SE	0.22	0.16	0.16	0.16	0.25

Herbage x week P<0.17.

Appendix 6.126. Difference in daily maximum sward and screen temperature (^{0}C) for herbages. Weekly average for five weeks after faecal deposition, Contamination 3 1993/94.

	Weeks After Contamination				
	1	2	3	4	5
Browntop	6.8	5.6	7.7	6.6	6.6
Cocksfoot	14.5	10.3	8.8	6.3	7.1
Chicory	-0.5	0.2	0.3	0.8	0.3
Tall fescue	7.9	6.1	8.5	6.9	8.0
Lucerne	11.5	5.7	4.8	1.4	1.8
Prairie grass	7.6	7.5	11.2	8.5	7.7
Ryegrass	5.5	8.4	10.1	10.1	6.5
Ryegrass/white clover	12.6	9.8	12.3	11.4	10.7
White clover	10.6	6.6	6.6	4.8	4.2
Yorkshire fog	12.0	5.9	7.2	5.1	3.9
Pooled SE	0.49	0.37	0.37	0.37	0.72

Herbage x week P<0.002.

Appendix 6.127. Difference in daily minimum sward and screen temperature (^{0}C) for herbages. Weekly average for five weeks after faecal deposition, Contamination 4 1993/94.

	Weeks After Contamination				
	1	2	3	4	5
Browntop	-1.2	-2.4	-1.4	-0.4	-0.8
Cocksfoot	-0.7	-1.9	-1.4	0.7	-0.2
Chicory	-0.6	-1.7	-1.3	0.8	-0.6
Tall fescue	-0.8	-2.4	-1.5	0.3	-0.6
Lucerne	-0.6	-1.4	-1.1	1.5	0.2
Prairie grass	-1.1	-1.9	-1.3	-0.6	-0.7
Ryegrass	-1.0	-2.0	-1.3	-0.5	-0.7
Ryegrass/white clover	-1.1	-2.1	-1.5	-0.2	-0.7
White clover	-1.4	-1.9	-1.1	-0.5	-0.5
Yorkshire fog	-0.7	-2.2	-1.4	1.2	0.0
Pooled SE	0.17	0.10	0.11	0.11	0.11

Herbage x week P<0.64.

Appendix 6.128. Difference in daily maximum sward and screen temperature (^{0}C) for herbages. Weekly average for five weeks after faecal deposition, Contamination 4 1993/94.

	Weeks After Contamination				
	1	2	3	4	5
Browntop	3.4	2.9	2.6	2.7	1.5
Cocksfoot	2.4	1.0	-0.1	-0.6	-0.8
Chicory	4.5	2.4	3.5	4.6	1.8
Tall fescue	4.3	2.9	2.6	2.3	1.6
Lucerne	1.4	-0.3	-0.5	-1.6	-1.8
Prairie grass	5.2	4.2	2.7	3.8	1.8
Ryegrass	4.3	3.0	2.2	2.7	1.3
Ryegrass/white clover	5.0	3.2	2.0	2.3	1.3
White clover	5.3	2.1	1.4	2.2	0.8
Yorkshire fog	2.2	0.7	1.1	1.8	0.8
Pooled SE	0.17	0.12	0.13	0.13	0.13

Herbage x week P<0.003.

Appendix 6.129. Average height (cm) of herbages after faeces had been deposited. Contamination 1 1992/93.

Herbage	Weeks after contamination					
	2	4	6	8	11	14
Browntop	8.4	13.0	17.4	18.5	18.1	18.1
Cocksfoot	14.0	17.9	25.4	29.4	28.8	37.9
Chicory	2.1	19.0	19.4	24.9	56.6	ND[1]
Tall fescue	10.4	13.5	13.9	19.4	17.9	19.2
Lucerne	3.7	32.0	67.5	75.0	63.5	ND
Prairie grass	8.9	19.5	17.8	21.4	23.4	18.2
Ryegrass	11.0	15.1	15.0	19.9	18.2	ND
White clover	8.8	19.9	21.9	19.7	16.5	ND
Yorkshire fog	10.6	17.6	21.4	25.8	14.3	14.5

[1] ND - not determined

Appendix 6.130. Average height (cm) of herbages after faeces had been deposited. Contamination 2 1992/93.

Herbage	Weeks after contamination					
	2	4	6	8	11	14
Browntop	4.3	10.3	10.4	13.6	18.5	18.7
Cocksfoot	6.4	17.2	25.5	29.6	33.8	30.3
Chicory	1.9	ND[1]	ND	ND	ND	ND
Tall fescue	7.6	13.8	17.0	19.8	19.2	19.9
Lucerne	2.9	9.6	22.5	33.7	34.4	ND
Prairie grass	4.3	18.1	19.3	20.6	32.1	21.9
Ryegrass	8.2	12.6	15.0	19.2	22.4	22.0
White clover	3.9	8.4	13.0	14.8	17.9	15.4
Yorkshire fog	1.4	4.2	6.7	15.6	23.6	21.0

[1] ND - not determined

Appendix 6.131. Average height (cm) of herbages after faeces had been deposited. Contamination 3 1992/93.

Herbage	Weeks after contamination					
	2	4	6	8	11	14
Browntop	7.1	12.0	15.5	15.8	16.1	14.7
Cocksfoot	8.7	14.2	18.2	25.1	32.3	29.7
Chicory	1.4	9.2	12.4	23.2	20.4	12.2
Tall fescue	11.6	16.4	22.3	22.7	22.1	25.6
Lucerne	5.0	19.4	25.9	26.5	22.1	25.8
Prairie grass	5.3	19.3	24.2	29.8	34.7	21.3
Ryegrass	11.2	13.8	16.0	22.2	22.4	24.3
White clover	5.9	11.4	12.1	16.7	14.8	16.6
Yorkshire fog	6.3	19.0	22.8	16.6	16.9	15.9

Appendix 6.132. Average height (cm) of herbages after faeces had been deposited. Contamination 4 1992/93.

Herbage	Weeks after contamination					
	2	4	6	8	11	14
Browntop	5.7	8.7	10.5	10.8	12.3	14.7
Cocksfoot	5.4	9.4	12.9	14.6	20.9	26.5
Chicory	3.6	5.5	11.7	11.5	11.5	12.0
Tall fescue	4.2	11.1	13.0	14.9	28.1	28.1
Lucerne	3.1	5.4	6.6	4.7	12.7	ND[1]
Prairie grass	5.1	10.4	11.2	12.3	18.0	26.7
Ryegrass	7.5	11.6	14.8	16.2	18.1	22.2
White clover	4.8	7.2	5.9	7.5	6.9	ND
Yorkshire fog	3.4	4.9	5.0	7.5	14.9	14.9

[1] ND - not determined.

Appendix 6.133. Average height (cm) of herbages after faeces had been deposited. Contamination 1 1993/94.

Herbage	Weeks after contamination						
	2	4	6	8	After mowing	11	14
Browntop	8.2	11.8	18.4	30.5	5.6	6.3	ND[1]
Cocksfoot	12.7	17.9	23.7	ND	4.7	11.7	ND
Tall fescue	11.9	18.1	20.2	26.9	4.0	10.6	ND
Ryegrass	12.0	18.4	20.9	27.1	3.7	8.4	ND
White clover	10.8	14.0	18.4	18.7	ND	9.9	ND
Yorkshire fog	10.5	17.1	25.7	ND	3.6	6.3	ND

[1] ND - not determined.

Appendix 6.134. Average height (cm) of herbages after faeces had been deposited. Contamination 2 1993/94.

Herbage	Weeks after contamination						
	2	4	6	8	After mowing	11	14
Browntop	5.3	6.3	6.2	6.8	4.1	4.6	5.2
Cocksfoot	9.7	11.2	10.0	9.6	4.1	4.7	5.6
Chicory	4.9	ND[1]	10.9	9.0	2.6	3.0	3.9
Tall fescue	8.6	10.1	7.5	7.1	3.7	4.0	4.3
Lucerne	8.5	20.5	31.7	53.6	3.3	7.0	14.1
Prairie grass	6.6	8.1	6.7	ND	ND	ND	ND
Ryegrass	6.8	7.7	6.5	6.4	3.8	4.2	5.0
Ryegrass/white clover	8.6	10.3	10.1	10.0	4.4	5.9	6.4
White clover	5.3	5.2	4.6	4.2	3.9	4.1	3.5
Yorkshire fog	7.2	9.4	10.4	8.6	3.2	5.2	4.9

[1] ND - not determined.

Appendix 6.135. Average height (cm) of herbages after faeces had been deposited. Contamination 3 1993/94.

Herbage	Weeks after contamination						
	2	4	6	8	After mowing	11	14
Browntop	5.1	7.5	7.9	7.7	ND[1]	4.2	4.5
Cocksfoot	4.5	7.9	8.4	10.4	ND	4.9	5.2
Chicory	3.5	5.7	7.3	9.4	ND	2.1	3.0
Tall fescue	7.1	9.9	8.0	10.3	ND	4.2	4.5
Lucerne	4.7	23.1	26.1	34.6	ND	3.7	5.4
Prairie grass	7.3	13.5	15.8	19.6	ND	4.8	5.3
Ryegrass	5.2	10.8	13.4	15.0	ND	5.7	5.9
Ryegrass/white clover	6.4	8.2	10.2	13.6	ND	5.4	5.7
White clover	6.7	9.8	11.4	15.3	ND	5.1	6.1
Yorkshire fog	5.2	9.2	11.3	12.6	ND	4.1	4.3

[1] ND - not determined

Appendix 6.136. Average height (cm) of herbages after faeces had been deposited. Contamination 4 1993/94.

Herbage	Weeks after contamination					
	2	4	6	8	After mowing	11	14
Browntop	2.8	4.3	4.9	6.1	ND[1]	3.3	4.1
Cocksfoot	5.3	5.2	5.8	8.6	ND	3.3	4.6
Chicory	ND	ND	ND	ND	ND	ND	ND
Tall fescue	4.2	4.7	5.1	4.6	ND	2.9	4.5
Lucerne	2.9	6.9	11.8	6.9	ND	2.3	ND
Prairie grass	3.4	3.4	4.9	7.6	ND	4.4	5.4
Ryegrass	3.1	4.6	5.8	5.3	ND	2.7	5.4
Ryegrass/white clover	4.9	6.2	7.3	8.4	ND	3.8	6.1
White clover	2.9	4.7	6.2	7.3	ND	3.8	7.3
Yorkshire fog	3.2	3.8	4.3	5.5	ND	3.9	5.1

[1] ND - not determined

Appendix 6.137. Average number of *Ostertagia* and *Trichostrongylus* third stage larvae recovered in the four vertical strata (0-2.5 cm, 2.5-5 cm, 5-7.5 cm and 7.5$^+$ cm). Pooled over all herbages, contaminations and times after contaminations.

	Vertical Strata					Height Effect (P<)
	0 - 2.5	2.5 - 5	5 - 7.5	7.5$^+$	Pooled SE	
1992/93						
Ostertagia	8.1	4.3	3.7	3.9	0.87	0.0003
Trichostrongylus	22.0	14.1	12.4	16.0	2.50	0.07
Combined	27.4	17.0	14.8	18.6	2.70	0.02
1993/94						
Ostertagia	51.1	25.1	13.4	12.5	2.90	0.0001
Trichostrongylus	136.2	85.8	33.9	29.9	12.70	0.0001
Combined	183.6	110.0	50.0	44.7	8.42	0.0001
Combined for both years	38.4	23.5	17.8	16.3	2.40	0.0001

Appendix 6.138. Average density of *Ostertagia* and *Trichostrongylus* third stage larvae (10^3/kg dry herbage) recovered in the four vertical strata (0-2.5 cm, 2.5-5 cm, 5-7.5 cm and 7.5^+ cm). Pooled over all herbages, contaminations and times after contaminations.

	Vertical Strata					
	0 - 2.5	2.5 - 5	5 - 7.5	7.5^+	Pooled SE	Height Effect (P<)
1992/93						
Ostertagia	4.9	5.2	10.2	16.1	4.57	0.26
Trichostrongylus	22.0	17.7	45.8	12.7	10.89	0.15
Combined	24.9	20.8	52.3	23.1	11.62	0.19
1993/94						
Ostertagia	1.5	9.1	43.3	147.4	22.64	0.0001
Trichostrongylus	2.8	6.6	56.2	138.0	22.0	0.0001
Combined	4.6	14.7	95.8	256.6	36.4	0.0001
Combined for both years	14.8	17.7	74.1	139.3	25.2	0.0001

Appendix 6.139. Average numbers of *Ostertagia* and *Trichostrongylus* third stage larvae recovered over time from herbage plots contaminated with faeces containing a known number of eggs. Pooled over vertical strata and herbage species. Both years.

	Weeks After Contamination							
	2	4	6	8	11	14	Pooled SE	Time Effect (P<)
1992/93								
Ostertagia	5.2	25.2	30.3	30.8	8.3	17.6	4.3	0.0002
Trichostrongylus	8.4	53.2	113.6	145.2	37.2	28.7	19.0	0.0001
Combined	9.7	64.4	137.0	168.8	43.6	42.3	19.0	0.0001
1993/94								
Ostertagia	130.2	94.2	138.9	118.5	78.6	83.2	18.48	0.09
Trichostrongylus	287.1	513.7	518.8	499.3	33.1	16.0	96.7	0.0001
Combined	384.8	582.1	623.7	587.5	88.8	75.5	104.28	0.0001

Appendix 6.140. Average density of *Ostertagia* and *Trichostrongylus* third stage larvae (10^3/kg dry herbage) recovered from the plots contaminated with faeces containing a known number of eggs. Pooled over vertical strata and herbage species. Both years.

	Weeks After Contamination							
	2	4	6	8	11	14	Pooled SE	Time Effect (P<)
1992/93								
Ostertagia	0.7	4.8	8.3	3.4	0.8	0.7	0.93	0.0001
Trichostrongylus	15.8	7.4	21.7	14.8	2.8	0.7	4.4	0.001
Combined	16.2	9.9	27.9	17.4	3.4	1.3	4.72	0.0001
1993/94								
Ostertagia	32.1	17.8	16.6	15.2	15.4	13.7	3.63	0.004
Trichostrongylus	79.9	75.6	44.9	47.4	11.7	5.5	11.47	0.0001
Combined	105.3	89.3	57.6	59.0	23.5	15.9	13.03	0.0001

Appendix 8.1. Mean, adjusted ranking values of total numbers of *Ostertagia* and *Trichostrongylus* third stage larvae recovered from swards of herbages contaminated with faeces containing a known number of eggs. Ranking value of 1 = lowest number of larvae recovered, 7 = highest.

Herbage	1992/93			1993/94		
	Ostertagia	*Trichostrongylus*	Combined	*Ostertagia*	*Trichostrongylus*	Combined
Browntop	5.0	4.8	4.9	4.1	3.9	3.9
Cocksfoot	4.6	4.3	4.4	4.3	3.6	3.7
Tall fescue	3.9	3.9	3.8	4.5	4.2	4.2
Prairie grass	4.2	4.5	4.4	4.8	ND[1]	ND
Ryegrass	4.7	4.9	5.1	4.8	4.7	4.9
White clover	3.8	3.6	3.4	3.7	3.4	3.3
Yorkshire fog	4.5	5.0	5.0	4.7	4.6	4.7
Pooled SE	0.27	0.27	0.29	0.30	0.28	0.29
Herbage effect (P<)	0.001	0.0001	0.0001	0.002	0.0001	0.0001
Contamination effect (P<)	0.005	0.002	0.002	0.007	0.0001	0.0001
Treatment x Contamination (P<)	0.30	0.0001	0.0001	0.30	0.0001	0.0001