DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS

CSG 15

Research and Development

Final Project Report

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Project title	Control of internal parasites in organic livestock without the use of pharmaceutical anthelmintics
DEFRA project code	**OFO185**
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Executive summary (maximum 2 sides A4)

Organic systems seek to reduce reliance on external inputs, and develop sustainable methods of production which balance output with high standards of animal welfare. The standards for organic production emphasise preventive control strategies based on grazing management, appropriate breeding and good nutrition. The ultimate goal is to eliminate dependence on anti-parasitic drugs, however this is rarely achieved in practice. The overall objective of this research was to develop organic farming systems, which do not rely on pharmaceutical control of roundworm parasites. Focussing on management and nutrition, the approach was to combine on-farm epidemiological studies, with replicated experiments, in order to develop and demonstrate better systems of control applicable to UK organic farms. The project was a collaborative study involving ADAS, Institute of Rural Science (IRS), Moredun Research Institute (MRI) and Scottish Agriculture Colleges (SAC).

Epidemiology: Five commercial organic farms, reflecting a range of production systems (specialist hill sheep, upland beef and sheep, lowland specialist sheep, specialist dairying, and lowland mixed arable / livestock) were selected for detailed epidemiological study. The aim was to assess the level and pattern of parasite challenge, critical points for disease control, and the degree of success achieved with current management practices. The study combined the use of standard epidemiological techniques, with close collaboration of the researchers, participating farmers and their veterinary advisers. Comprehensive epidemiological data were collected over two contrasting seasons (2002 and 2003). Without recourse to routine anthelmintic, control was generally underpinned by grazing management, within the constraints of land/crop resources and diversity of enterprises available for each farm. Generally, ewes were not drenched apart from the specialist sheep flock, where anthelmintic was given on veterinary advice to reduce pasture contamination at lambing. Nematodirus was a particular problem early in the season on two (specialist sheep, and upland beef and sheep) of the four sheep farms studied. Apart from the extensively managed flock, specific groups of animals in the other three flocks were drenched in both years. Nevertheless, the overall amount of anthelmintic used was substantially less than levels typically used in conventionally managed flocks. In young dairy-stock, stomach worms appeared to be well controlled, the result of frequent movement and integration of grazing and conservation.

A separate study comparing growth rate, faecal egg output and blood pepsinogen levels taken in paired drenched and undrenched cattle, across four herds, did not indicate a high risk of winter parasitism in organically managed animals. Potentially, , the most significant parasite problem found in cattle was lungworm (Dictyocaulus viviparous).

Role of nutrition: Previous studies, using tightly controlled nutritional protocols and a known parasite challenge, developed a nutritional hypothesis for understanding nutritional influences on the host response to parasites. A replicated experiment was set up to test whether this framework could be extended to organically managed ewes carrying a mixed naturally-acquired infection. After lambing, ewes were allocated to one of two treatments - grazing a ryegrass/white clover sward with or without a concentrate supplement (0.6 kg /day GMO-free soyabean meal). Total daily energy and metabolisable protein intake in supplemented animals was calculated to be 128% and 188% respectively, relative to control animals. Up until lambing, mean parasite faecal egg count (FEC) varied between 200 and 300 e.p.g. After lambing, this level was maintained for the control ewes, until weeks 4-6 of lactation, when a clear rise in FEC was evident. In contrast, the supplemented ewes did not show any increase in FEC ($P<0.01$). In a further experiment ewes were managed to achieve two target body condition scores (High - CS 3; or Low - CS 2) at lambing. After lambing, ewes from both treatments were supplemented with 0.9 kg per day fresh weight of home-mixed organic concentrate, until sward height reached 5 cm. Significant treatment differences in ewe live weight and body condition score, established by lambing, were maintained during early lactation. Faecal egg output followed a typical pattern, increasing during peak lactation, but there was no significant effect of treatment. The results suggest that maternal body reserves are less critical to the loss of host immunity during early lactation than current nutritional status. Conversely, good nutrition in early lactation can at least to some degree ameliorate the potential impact of reduced body condition on faecal egg output.

Novel crops: A series of experiments were undertaken to determine the potential of several novel crops for parasite control. Two experiments were undertaken at IRS to investigate the effect of novel cropping on parasite burdens in weaned lambs. Of the four sward types studied (chicory; chicory with Lotus; perennial ryegrass and Lotus; perennial ryegrass and white clover), chicory showed the greatest potential in terms of agronomic performance, improved trace element status, and ability to reduce FEC in lambs. However, there was no significant effect on total worm burden determined post mortem. A further study at SAC compared the effect of chicory or ryegrass/white clover swards on parasite burden in suckling lambs. Lambs grew more quickly on chicory, and tended to have lower FEC, but total worm burden was not reduced. A major limitation of many novel crops is their tendency for poor establishment and persistency, and it is difficult to see how the specific use of these crops for parasite control could be widely recommended to UK organic farmers at the present time.

Parasite pasture ecology: Nematode larvae populations have also been shown to differ between herbage species, potentially due to differences in crop morphology or microclimate beneath the sward (which may affect larval development and survival, or the number of coprophagous or nematophagous organisms at soil level). Several small plot and pot experiments were undertaken to assess the effect of crop type on larval survival, rates of faecal degradation, and soil dwelling invertebrates. The work identified several interacting factors, but insufficient information is currently available to make specific recommendations on the effect of pasture ecology for parasite control.

Overall, the results from this study indicate that with sufficient diversity of cropping and stocking, it is possible to virtually eliminate anthelmintic usage. However, many farms still face significant difficulties, particularly those systems dominated by sheep. The extent to which control can be achieved by management alone, depends on the farming system, with the greatest opportunity for control in the more mixed, or very extensive production systems. Many of the issues faced by the organic sector are increasingly relevant to conventional farmers where anthelmintic resistance is becoming increasingly prevalent. More integrated strategies are required, not only for organic producers, but also to prolong the life of drenches currently used in conventional farming. Practical recommendations have been derived from this research, and promoted to organic and conventional farmers, based around key messages of system planning, parasite monitoring and maintaining biosecurity.

Scientific report (maximum 20 sides A4)

1.0 Introduction

Organic systems seek to reduce reliance on external inputs, and develop sustainable methods of production which balance output with high standards of animal welfare. Internal parasites are a potentially serious threat to the health, welfare and productivity of organically managed livestock (Keatinge, 1996). The standards for organic production emphasise preventive control strategies based on grazing management, appropriate breeding and good nutrition. The ultimate goal is to eliminate dependence on anti-parasitic drugs, however this is rarely achieved in practice (Roderick & Hovi, 1999). There is scope for potential conflicts between consumer expectations of organic livestock production, animal performance in the face of parasite challenge, and animal health and welfare. Meeting the day to day management requirements of organically produced livestock, demands a high standard of husbandry and decision making skill. Better information is required on the overall level of challenge faced by organic livestock, the extent to which internal parasites can be controlled through management, and the potential for alternative approaches which could be more widely adopted in the UK.

2.0 Experimental objectives

The overall objective of this project was to develop organic farming systems, which do not rely on pharmaceutical control of roundworm parasites. Over the last 10-15 years, epidemiological studies have increasingly been directed towards assessing the development of anthelmintic resistant parasites in conventional farming systems. There has been little or no fundamental epidemiology carried out in organic farming systems. The beneficial effect of nutrition (Holmes, 1993), the use of novel crops (Niezen *et al.*, 1998) and the greater use of biological control (Thamsborg *et al.*, 1999) are recognised potential options for parasite control, particularly in sheep. More specifically, the importance of protein nutrition for the maintenance of host immunity to nematode infection has been described by Coop & Kyriazakis (1999). However, less clear is the extent to which some of these strategies can be deployed, ideally in combination, to deliver effective parasite control on UK organic farms.

Focussing on management and nutrition, this project aimed to further develop control strategies, which could support and increase the flexibility of clean grazing systems for sheep and cattle. The approach was to combine on-farm epidemiological studies, with replicated experiments, in order to develop and demonstrate better systems of control applicable to UK organic farms. The project was a collaborative study involving ADAS, Institute of Rural Science (IRS), Moredun Research Institute (MRI) and Scottish Agriculture Colleges (SAC).

The specific objectives of the research were to:-

- study the epidemiology of parasitic gastro-enteritis (PGE) on selected 'focus' farms, representing a range of organic systems.
- quantify the effect of dietary manipulation and novel crops on the development of PGE in organic sheep systems
- evaluate the role of crop type and pasture larval ecology on the development of PGE
- assess the incidence and likely risk of Type II *Ostertagia* in organic cattle
- develop the application of alternative approaches on 'focus' farms, under best management practice
- ensure effective technology transfer

With the agreement of the Sponsor and the Project Steering Group, amendments were made to the original CSG7, taking account of unforeseen delays due to the outbreak of Foot and Mouth Disease in 2001. These included an extension to the period of fieldwork to September 04, to account for the completion of a postponed grazing study at SAC. The original level of funding was increased by £29,287 to cover the additional cost (over 9 months) of a technician supporting the epidemiological studies at Moredun Research Institute.

The work supports Defra policy to improve animal welfare, reduce chemical inputs in food production and promote more sustainable systems of livestock production.

3. Epidemiological studies (ADAS/MRI)

3.1 Materials and Methods

With assistance from the Soil Association, five commercial organic farms, reflecting a range of production systems (hill sheep, upland beef and sheep, lowland specialist sheep, specialist dairying, and lowland mixed arable/livestock) were selected for detailed epidemiological study. The intention was to select farms with a more mature organic system, i.e. from sector body records already operating at a low level of anthelmintic input. The farms had no prior history of potentially system-limiting parasites, such as liver fluke (*Fasciola hepatica*) or lungworm (*Dictyocaulus viviparous*) in cattle. The overall aim of the epidemiological studies was to assess the level and pattern of parasite challenge, critical points for disease control in each system, and the degree of success achieved with current management practices.

The study combined the use of standard epidemiological techniques, with close collaboration of the researchers, participating farmers and their veterinary advisers. Sentinel groups representing typical stock and management practices for each farm were identified. Few parasitological data are available for 2001 due to restrictions imposed by Foot and Mouth Disease. Comprehensive epidemiological data (including faecal egg output, pasture larval counts, and total worm burdens) were collected over the 2002 and 2003 grazing seasons. Information on total worm burdens were obtained by slaughtering a sample of permanent lambs (animals which had grazed within the sentinel group since birth) and tracer animals (lambs reared indoors without exposure to parasites, followed by a brief grazing period during which parasite larvae were ingested without the influence of acquired host resistance). Epidemiological measurements were supported by management, veterinary, meteorological and animal performance data.

3.2 Results

The five case study farms were not necessarily representative of organic livestock farming in the UK, but provided an insight into the population dynamics of gastrointestinal nematodes across a range of organic farming systems (Table 1).

Table 1 Epidemiological studies – farm type

Farm Profile	**Hill sheep**	**Upland Beef & Sheep**	**Lowland Specialist Sheep**	**Lowland mixed**	**Dairy**
Farm size (ha)	**1414**	**349**	**911**	**750**	**264**
Enterprises	Sheep (Cattle)	Sheep Cattle	Sheep Beef (Arable)	Sheep Arable Beef	Dairy (Arable)
Sheep: Cattle ratio	**90:10**	**58:42**	**74:36**	**30:70**	**0:100**
Stocking rate (LU/ha)	**0.16**	**0.8**	**1.1**	**1.1**	**1.4**

Very consistent results and trends were observed over two contrasting seasons. Ewes showed a typical peri-parturient rise in faecal egg output around lambing, which subsequently declined to low levels by weaning. Pasture larval counts showed considerable variation, but in addition to the other parameters measured, were a useful additional surveillance tool for *Nematodirus.*

Sheep on the organic farms carried a broader range of gastrointestinal nematodes than would be found on many conventional farms using short interval chemoprophylaxis. On most conventional farms regular routine anthelmintic treatments discriminate heavily against species with extended pre-patent periods, and those whose epidemiology is heavily reliant on adult longevity. On all four sheep farms, *Teladorsagia* was the predominant gastrointestinal nematode, both in terms of eggs passed onto pasture, and as total worm burden data confirm, was the principal genus implicated in the challenge from pasture. *Haemonchus* was more prevalent than expected, consistent with the view that milder winters may be enabling *Haemonchus* to over-winter in greater numbers on the pasture, rather than within infected animals. Based on total worm counts in permanent lambs, calculated midsummer 60-day larval recruitment rates (larvae per day) were 150, 127, 130 and 103 for the hill sheep, lowland specialist sheep, upland sheep and beef, and mixed lowland systems respectively.

Without recourse to routine anthelmintic, control was generally achieved by grazing management, within the constraints of land/crop resources and diversity of enterprises available for each farm. All farms had reduced anthelmintic use since conversion. Table 2 gives an overview of sheep performance data and anthelmintic inputs for 2003, with comparable data for 2002 shown in brackets.

Table 2 Sheep performance and parasite burdens

		Extensive Hill	Upland beef and sheep	Lowland mixed	Lowland specialist sheep
No. of routine drenches	Ewes	0(0)	0(0)	0(1)	2(2)
	Lambs	0(0)	2(2)	1(1)	2(2)
Lamb live weight (kg)	Weaning	33 (29)	34(32)	32 (27)	30 (32)
Mean ewe FEC (e.p.g.)	Lambing + 4wks	522 (486)	171 (153)	504 (373)	505 (797)
	Weaning	279 (212)	25 (35)	117 (252)	183 (55)
Mean lamb FEC (e.p.g.)	Lambing + 8wks	2 (4)	233 (1030)	791 (1457)	505 (759)
	Lambing + 12wks	670 (783)	*2 (*77)	*12 (690)	301 (*126)
	Weaning	575 (451)	81 (*29)	699 (*129)	189 (272)

(* lambs drenched previously)

Generally, ewes were not drenched apart from the specialist sheep flock, where anthelmintic was given on veterinary advice to reduce pasture contamination at lambing. *Nematodirus* was a particular problem early in the season on two (specialist sheep, and upland beef and sheep) of the four sheep farms studied resulting in the treatment of young lambs in consecutive seasons. Apart from the extensively managed flock, specific groups of animals were drenched each year in the other three flocks. Nevertheless, the overall anthelmintic input was substantially less than that used in conventionally managed flocks (Frank Jackson, personal communication), which typically average 2.8 drenches per ewe and 3.1 drenches per lamb annually. For each system, a brief summary of parasite epidemiology is given below.

3.2.1 Extensive hill system

On the extensively managed hill farm, parasite burden in lambs was at acceptable levels, at least up to the point of weaning. The main issues for growing lambs were the extent to which parasite burden built up on inbye fields, and subsequently, the potential challenge after weaning. Traditionally this problem is avoided by the sale of stores. However, in ewes there was a marked rise in ewe peri-parturient faecal egg output, with peak counts in excess of 500 e.p.g. But unlike the other farms studied, there was less evidence of the re-acquisition of immunity later in the season, as FEC remained relatively high in both the ewes and hoggs later in the grazing season. The underlying reason for this failure to re-acquire resistance or, in the case of the ewe replacement stock, to express an adequate resistance against worms in their second grazing season, is not clear. The effect could be genetically linked, i.e. stock that are genetically more susceptible to worms, or could be related to some factor which influences the acquisition or maintenance of immunity, such as poor nutrition, trace or macro-element deficiencies. Following the difficult winter of 2001/02, for example, it was felt necessary to drench all ewes and lambs approximately 6 weeks after lambing (at marking) to improve body condition and maintain the health of the flock. Faecal egg count (FEC) in ewe lambs reached their maxima in the early winter months and in the second grazing season averaged over 1000 e.p.g. in October, when *Cooperia* was the predominant species recovered from sentinel stock.

3.2.2 Upland beef and sheep system

On the upland beef and sheep farm, ewes had the lowest peri-parturient increases in faecal egg counts of any of the farms studied, averaging less than 200 e.p.g. and 50 e.p.g. in 2002 and 2003 respectively. Pasture management and a nutritional approach, in which peri-parturient ewes were given high priority, were used in order to maintain relatively low pasture populations. Pastures grazed by sheep in the spring were subsequently used for conservation, or grazed by cattle.

During the summer months the sheep were moved to extensive upland pasture. The farm also had the lowest average total worm burden in tracer lambs (5,258), 50% and 30% that of the specialist sheep farm and mixed lowland farm respectively. The mean burden carried by permanent stock was 4,965, contrasting with 21,756 and 24,000 respectively, for the other two flocks above.

The worm burden data provides evidence that lambs were capable of some population regulation. In both years, burdens carried by permanent stock were less than might be expected from the tracer accumulation rates. This was particularly the case for *Teladorsagia*, which formed a lower proportion of the total population in lambs slaughtered in November 2002 and October 2003 than in those killed earlier in the season.

3.2.3 Lowland mixed livestock and arable system

The mixed lowland farm initially showed the best prospects of eliminating anthelmintic. Prior to the study, no routine anthelmintic was used in ewes or lambs, and individual treatments were typically 5-6 treatments per 100 lambs on an annual basis. Some years previously, lambing date had been put back to late April/early May to avoid the main N*ematodirus* period. No anthelmintic was used during 2001. This low level of input was possible due to a good mix of enterprises (beef, sheep, arable, pigs), modest stocking rates (approximately 7 ewes/ha), alternate grazing of cattle and sheep, a sequence of crops for autumn (rape/mustard) and winter use (undersown clover), and the continuing refinement of a system based on closed flocks/herds.

In 2002, the clean grazing system broke down for the sentinel group of animals, thought to be due to the inadvertent contamination of grazing by rams the previous year. Ewes and lambs required drenching in July.

In the two years of the study this system produced the highest average tracer and permanent stock burdens of any of the case study farms. The data from 2003 provides marked evidence of resilience (the ability to maintain productivity under challenge) in the flock of Lleyn sheep. In August 2003 tracers accumulated more than 1,400 worms per grazing day and permanent stock carried an average burden of over 44,000 worms. Examination of the worm burden data also provides some evidence that by the end of the grazing season the sheep had some capacity to regulate their worm burdens. The average worm burden of the permanent stock killed at the end of October was about one quarter of that recorded in animals killed in August. The obvious resilience in this flock may either be an inherent characteristic of the breed or may have arisen through inadvertent selection, as this flock is a closed flock which has for many years used minimal amounts of anthelmintic. Under these circumstances resilient animals, which perform well under challenge, would be expected to be selected as replacements ahead of less resilient animals.

3.2.4 Lowland specialist sheep system

On the specialist lowland sheep farm, *Nematodirus* was a recognised problem from the outset of the study, and resulted in a significant number of deaths during 2000 (before the epidemiological study began). Lambing date, a high ratio of sheep to cattle, and little or no clean grazing were clear predisposing factors.

In terms of strongyle worms (excluding *Nematodirus*), there was a marked peri-parturient rise in faecal egg count in the spring with average peak egg counts in excess of 400 e.p.g. in March (2002) and April (2003). The pattern of infection in the lambs was similar in both seasons in that lamb egg counts reached their maxima in the late summer/ early autumn months. In both years, average maximum lamb egg counts were relatively high, in excess of 1500 e.p.g., however these counts did not trigger drenching since the animals had no clinical signs such as weight loss, scouring or general ill thrift. This finding again suggests that resilience may play an important role at certain times.

Since there were few management options for the control of *Nematodirus battus*, such as the use of non-susceptible hosts or cropping/conservation to break the cycle, mob samples were used to trigger drenching of lambs, in an attempt to reduce contamination to levels which would reduce problems the following season. Derogation was sought from the organic sector body to treat lambs twice during the spring in order to try to break the cycle. The system of monitoring weekly during the high risk period with a rapid turn round of the mob sample within 24 hours of receipt worked reasonably well, but lambs required drenching twice each year during the early summer.

An expansion in the size of suckler herd, and the provision for more alternate grazing by sheep and cattle, was designed to improve parasite control. However, the provision of a one year break from sheep on some of the land, was not sufficient to break the cycle, and there were indications that young cattle were acting as a 'biological bridge' to carry infection over to the third grazing season after sheep. However, with limitations on the proportion of arable cropping and cattle grazing available, more radical, longer-term options, such as changing lambing date, may be necessary to give sufficient long-term control.

3.2.5 Organic dairy system

With careful grazing management and frequent movement of stock, faecal egg counts in young dairy-bred stock were low in both grazing seasons, only one mean count exceeding 100 e.p.g. Spring-born animals were given priority for the cleanest pastures available and, with one exception in July 2002, tended to have lower faecal egg counts than their autumn-born counterparts. The predominant genus recorded in the cattle samples was *Ostertagia,* with some *Cooperia* also present. Given the rotational grazing system, pasture samples were collected from the field currently being grazed by permanent stock. Pasture larval counts were generally very low **-** only 3 out of 11 samples taken in 2002 had positive counts with a maximum recorded count of 5,493 third stage larvae (L_3) per kilo of dry herbage**.** In 2003, 5 of the 10 samples were positive, but the maximum count was only 566 L_3 per kilo of dry herbage. In 2002, there was also some evidence of low grade lungworm infections in faecal samples taken from calves at housing, subsequently confirmed by an ELIZA test on supporting blood samples.

4.0 Effect of dietary manipulation

4.1 Direct effect of tannins (ADAS)

Studies have shown that ‘novel’ forages such as chicory and *Lotus* sp. have the potential to influence the nematode burden in sheep, and/or are associated with improved growth rates in animals which have high faecal egg counts. A number of potential mechanisms are suggested; effects on the survival and/or migration of infective free-living larvae in the sward (Moss and Vlassoff, 1993), effects of tannin content (Waghorn *et al*., 1995) on the parasite and/or effect on fecundity, enhanced mineral/trace element status; or from tannins binding with dietary protein and rendering it less degradable in the rumen.

A number of experiments have tried to segregate direct and indirect effects of tanniferous crops, using a known source of condensed tannin (e.g. Quebracho) delivered as an in-feed additive or directly as a drench (Athanasiadou *et al*, 2000). The objective of this experiment was to determine the effect of condensed tannins on the parasite burden of lactating organically managed ewes carrying a mixed, naturally acquired infection.

4.1.1 Materials and Methods

The experiment was a randomised block design, using 48 twin-bearing pure-bred Scottish Blackface ewes from the organic unit at Redesdale. After lambing, ewes were blocked (paired) on the basis of flock of origin, lambing date, parity, body weight and condition score at lambing. One of each pair was drenched with Quebracho (Quebracho ATO powder; Roy Dickson Wilson Ltd) given as a drench at a concentration of 8% w/w estimated food dry matter intake, for three consecutive days, prior to turnout to pasture. Originally it had been intended to repeat the treatment as a single drench given at fortnightly intervals for six weeks after turnout. However, on advice from the Named Veterinary Surgeon, drenching was stopped after the initial drenching period (see results below). The intensity of sampling was also reduced accordingly. Assessments were made of ewe live weight, condition score, faecal egg output and blood metabolites, at lambing, three and six weeks after lambing. At pasture, ewes grazed one of 4 paddocks. Drenched and undrenched ewes grazed separately, to allow for any potential effects of tannin treatment on pasture contamination. Two days after the initial drenching period had been completed, 16 ewes (8 from each treatment) were taken to the Moredun Research Institute for total worm counts *post mortem.*

4.1.2 Results

During the initial 3-day period of tannin treatment adverse effects unexpectedly occurred, to varying levels, in 16 out of 24 ewes drenched. Animals tended to scour profusely for three to five days after treatment, producing loose brown coloured faeces. Other symptoms varied from reduced feed intake, raised body temperature and general depression, to total loss of appetite, salivation, and increased water consumption. There were also indirect effects on the lambs, including reduced maternal instinct, and increased incidence of watery mouth and joint ill. Two ewes developed systemic effects 10 days after treatment, and were taken for *post mortem* examination. Both animals lost up to 20 kg in live weight in the two weeks following treatment. From histopathology, the clinical diagnosis for both ewes indicated sub-acute necrotising nephropathy and mild sub-acute hepatopathy. Severe kidney damage was evident in high blood urea (92.1 mmol/l , expected range 2.6 - 6.6) and elevated creatinine levels. Evidence of significant tubular epithelial damage was also consistent with exposure to a nephrotoxin.

Subsequent analysis of blood samples taken before tannin drenching, and analysed for a range of liver enzymes, did not indicate any predisposing reduction in liver function in the animals most affected. One possible explanation for the adverse reaction experienced, is that the impact of the tannin drench may have accentuated in animals which have a high metabolic rate, and at a time when appetite (and hence dilution effect on the tannin drench) is also reduced.

Tannin drenching did not significantly reduce ewe faecal egg output, or total worm burdens. Lamb growth rate from birth to six weeks was significantly lower ($P< 0.05$) in the tannin-treated group, probably due to a residual effect of reduced feed intake on milk production.

4.2 Effect of nutrition on peri-parturient rise in lactating ewes (ADAS)

A significant proportion of organic producers seek derogation to use a single anthelmintic drench in order to suppress faecal egg output in the period around lambing. This approach is only acceptable to the organic sector bodies as a short-term measure, and as part of an agreed disease reduction plan. Furthermore, depending on the type of anthelmintic used, the reduction in parasite burden following drenching may be relatively short lived, especially if animals continue to graze on contaminated pasture. The peri-parturient rise (PPR) in faecal egg output, a consequence of changes in host immunity to parasites, is therefore expected to be an important factor in the epidemiology of gastro-enteritis in organically managed sheep.

There is an increasing body of evidence that nutrition, particularly protein, can affect host immunity to parasites in the critical period around lambing (Houdijk *et al*., 2001). The majority of this evidence has been obtained at research centres with housed sheep, under well-controlled conditions, using specifically defined nutritional protocols, and known type and level of parasite infection. The objective of this experiment was to test whether this hypothesis for understanding nutritional influences on the host response to parasites, could be extended to practical organic farming and with a mixed naturally-acquired infection.

4.2.2 Materials and Methods

The experiment was a randomised block design, with two treatments, three replicates (paddocks), and 8 ewes per replicate (2 x 3 x 8 = 48 ewes). Purebred, twin-bearing, Scottish Blackface ewes were managed during late pregnancy to achieve a body condition score of 2 – 2¼ at lambing. After lambing, ewes were paired on the basis of lambing date, body condition score, flock of origin, FEC and live weight. One of each pair was randomly allocated to one of two treatments:

- *Control*: Grazing alone, plus *ad lib* mineral supplement
- *Supplement:* Grazing, *ad lib* mineral, and 0.6 kg /day GMO-free soyabean meal (CP 44%; source HiPeak Feeds)

Ewes and lambs were turned out onto a ryegrass/white clover pasture, in six experimental paddocks (each 0.45 ha), to provide a peak stocking rate of approximately 18 ewes per hectare. The aim was to provide a sward height of 4-6cm, as recommended for commercial sheep production. Ewe live weight, body condition score, faecal egg output were determined weekly. The proportions of parasite eggs by species were determined by coproculture of a bulked sub-sample of faeces. Ultrasonic measurements were taken to assess muscle and fat depth over the loin on 4 occasions corresponding to approximately 2, 4, 6 and 8 weeks after lambing. Blood samples were taken weekly for determination of a range of blood metabolites. Lamb live weight was recorded at weekly intervals until approximately 8 weeks of age.

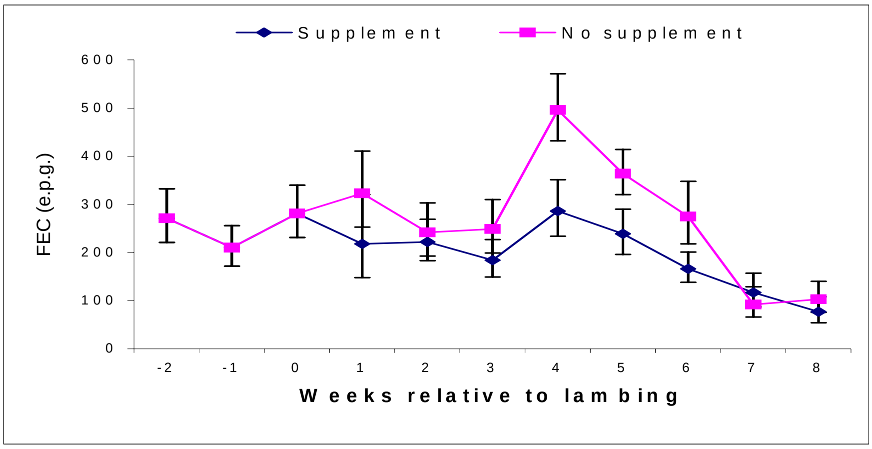
An N-alkane technique was used in a sample of ewes (5 animals per plot; 15 per treatment) four weeks after lambing to estimate total herbage intake, botanical composition of the herbage consumed, total daily faecal output and total diet digestibility.

4.2.2 Results

Concentrate supplementation significantly (P<0.001) increased ewe live weight during early lactation. Supplemented ewes had consistently higher mean body condition scores from the first week of lactation, but differences were not statistically significant (P=0.091). Levels of backfat were low across both treatments, and differences were not statistically significant. Statistically significant treatment differences (P<0.01) were observed in muscle depth. Beta-hydroxybutyrate (BHB) levels were similar for both treatments, and well below levels which would indicate extensive mobilisation of body fat. Lambs from supplemented ewes were 0.35 kg heavier at 8 weeks, and tended to have a higher daily live weight gain (P=0.10).

The FEC data are presented in Figure 1, as backtransformed means, together with 95% confidence limits. Up until lambing, mean FEC varied between 200 and 300 e.p.g. After lambing, this level was maintained for the control ewes, until a clear rise during weeks 4-6 of lactation. In contrast, the supplemented ewes did not show this rise in FEC (P<0.01). However, based on repeated measures analysis, statistically there was no overall effect of treatment throughout the entire experiment (P=0.25).

Figure 1. The effect of supplementation on ewe faecal egg count (FEC)



Data are not available on the distribution of parasite species according to treatment. For the experiment as a whole, the proportions of parasite eggs by species for *Teladorsagia spp*., *Trichostrongylus spp* and *Chabertia* sp. respectively, altered from 78:6:16 at lambing to 7:47:46 by the eighth week of lactation. Mean strongyle counts in the control paddocks increased rapidly after week four of the experiment, relative to supplemented group (Table 3). The number of *Nematodirus* larvae recorded was similar for both groups.

Table 3. Pasture larval counts (larvae/kg/DM)

Week of experiment	Other strongyles		Nematodirus	
	Control	Supplementation	Control	Supplementation
1	90	156	44	33
2	0	257	249	131
3	256	221	604	561
4	43	700	343	705
5	697	380	694	398
6	1499	1235	2147	1686
7	5259	3577	0	0
8	7606	2899	61	0

Sward height was within the target range over the first 6 weeks of the experiment, averaging 4.4 cm across both treatments. From the results of N-alkane analysis, no significant treatment differences were seen in estimated herbage dry matter intake. Total dry matter intake was significantly higher (P<0.05) in the supplemented group (2.71 vs. 2.16 kg), due directly to the input of concentrates. From the results of N-alkane analysis, calculated total daily output of faeces was similar for both groups (0.63 kg DM), but estimated total dry matter digestibility was significantly higher (P<0.001) in supplemented animals (766 vs. 703 g/kg). Based on estimated herbage intake, total daily energy and metabolisable protein intakes in supplemented ewes were calculated to be 128% and 188% respectively relative to control animals.

The result indicates that faecal egg output can be manipulated by nutrition, at least during the period of peak lactation. Although the observed effect of protein supplementation on FEC is in the direction expected, the differences between supplemented and unsupplemented groups are less than those found in previous experiments using housed sheep and a controlled challenge, usually involving only one or two parasite species.

The fact that control ewes were not able to consume more herbage, or select differentially from the sward, may indicate that their overall nutrition was limited by the grazing available. However, as measured by differences in lamb growth rate, the control group still performed relatively well. The provision of 0.6 kg soyabean meal per day to the supplemented group was a significant addition, at the upper end of what might be considered acceptable for commercial practice. However, the return in extra lamb growth to approximately 8 weeks of age, was limited. The nutritional theory speculates that, if lactation performance is not severely penalised, additional supplementation would not result in clearly improved host response to gastrointestinal parasites (Coop and Kyriazakis, 1999).

4.3 Effect of body condition at lambing on the PPR in ewes (ADAS)

If nutritional state can affect host immunity to parasites, it might also be expected that maternal body reserves could affect the potential availability of nutrients for metabolism by the host animal. In support of the previous experiment (4.2), the objective of this experiment was to assess the effect of ewe body condition at lambing, on animal performance parameters and the post-parturient rise in ewe faecal egg output.

4.3.1 Materials and methods

Forty-two, twin-bearing, multiparous Scottish Blackface ewes were managed to achieve two target body condition scores (High - CS 3; or Low - CS 2) at lambing. After lambing, ewes from both groups were paired on the basis of lambing date, body condition score and live weight. Each pair was randomly allocated to one of three grazing plots, each sub-divided into two 0.45 ha paddocks. For each treatment, three groups of ewes (n=7) and their twin lambs were grazed separately (16 ewes/ha) on one of six paddocks available. For both treatments, ewes were supplemented with 0.9 kg per day fresh weight of home-mixed organic concentrate, until sward height reached 5 cm. Similar parasitological, animal performance and feed intake data were collected as in the previous experiment.

4.3.2 Results

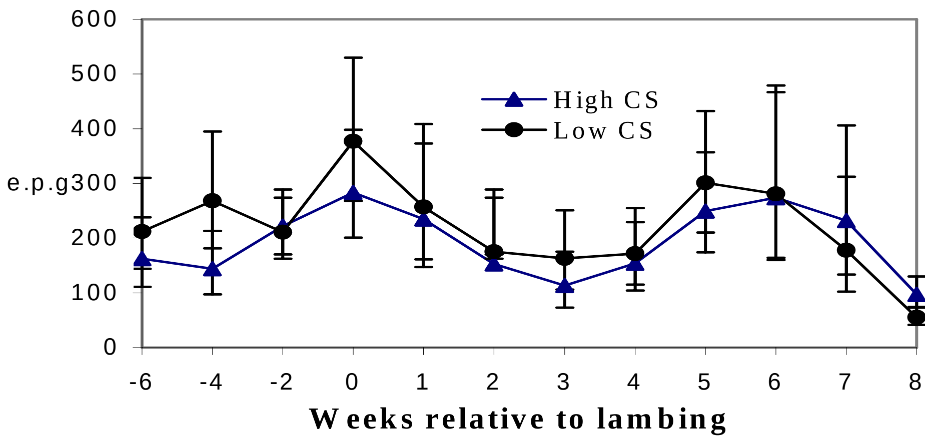
Following dietary manipulation during mid- and late lactation, significant treatment differences in ewe live weight and body condition score (CS) were established by lambing, and maintained during early lactation (Table 4). From ultrasound scanning data, High CS ewes had significantly greater backfat (P< 0.05) and muscle (P< 0.01) depth during early lactation. There was no significant treatment effect on ewe blood BHB levels.

Table 4. Changes in ewe body condition score, live weight and muscle depth.

Week	Body condition score (median)			Ewe live weight (kg)			Muscle depth (mm)		
relative to lambing	High CS	Low CS	*Level sign.*	High CS	Low CS	s.e.d.	High CS	Low CS	s.e.d.
L – 2	2.75	2.00	***	67.2	60.9	1.38	23.1	22.2	0.80
L	3.00	2.00	***	59.9	55.9	0.99	N/A	N/A	N/A
L+ 2	2.88	2.13	***	60.6	55.6	1.43	23.2	20.9	0.78
L + 4	2.75	2.00	***	61.1	56.4	1.96	24.0	20.9	0.84
L + 6	2.63	2.13	***	61.3	56.7	2.03	24.1	21.2	0.92
L + 8	2.62	2.37	***	58.3	54.3	1.96	24.3	21.1	0.96

Faecal egg output followed a temporal pattern typical of the PPR in lactating ewes, but there was no significant effect of treatment (Fig. 2). Although mean litter weights at eight weeks of age were 1.0 kg heavier for High CS ewes, overall differences in lamb live weight were not statistically significant.

Figure 2. FEC in ewes at two levels of body condition score



The results suggest that either maternal body reserves are less important to the expression of PPR than current nutritional status or, within this experiment, the level of post-lambing feeding imposed on mature Scottish Blackface ewes was not sufficiently challenging to allow any potential effects of body condition to be expressed. Provided it is adequate, concurrent level of nutrition is likely to have a greater impact on the PPR than ewe body condition score at lambing. Conversely, good nutrition in early lactation can, at least to some degree, ameliorate the potential impact of reduced body condition on faecal egg output.

4.4 The effect of novel cropping on parasite burden in weaned lambs (IRS)

Two experiments were undertaken in consecutive years (2001 and 2002) to investigate the effect of novel cropping on parasite burdens in weaned lambs.

4.4.1 Materials and methods

In the first year, four sward types (chicory; chicory with *Lotus*; perennial ryegrass and *Lotus*; perennial ryegrass and white clover) were selected for evaluation on the basis of potential agronomic performance (Section 5). The trial design consisted of eight 0.55 ha grazing plots, consisting of two replicates of each forage combination. Each plot was grazed for an eight week experimental period by six 6-month old Lleyn male castrate lambs, and for the first four weeks by an additional five female Lleyn lambs to control sward height**.** On the advice of the Named Veterinary Surgeon, lambs were drenched with anthelmintic two weeks after the start of the trial. This decision was based on the *post mortem* results of one male lamb (euthanised due to respiratory distress), which reported 24,000 e.p.g. trichostrongylid eggs and 700 e.p.g. *Nematodirus battus*. This changed the focus of the trial from looking at the effect of the forages on established parasites to purely their effect on re-infection.

In terms of parameters measured, weekly assessments were made of live weight, condition score, dag score, FEC and faecal consistency score (FCS). Blood samples (serum & plasma) were collected from all male lambs before the trial (week 0), in the middle (week 5) and at the end of the trial (week 8). On completion of the trial a proportion of the lambs from each forage group were slaughtered and total worm counts performed separately for the abomasum, small intestine, and large intestine. Pasture larval counts were performed weekly on each of the plots from early September to the end of October, fortnightly until Christmas, and then monthly until April. Botanical composition was assessed using two exclusion cages per 0.55 ha plot at the start of the trial. On completion of the trial period, a strip of forage (0.3 m by 1 m) was cut to ground level from under each cage. Each sample was separated into sown forage and weeds, and fresh and dry weights were determined.

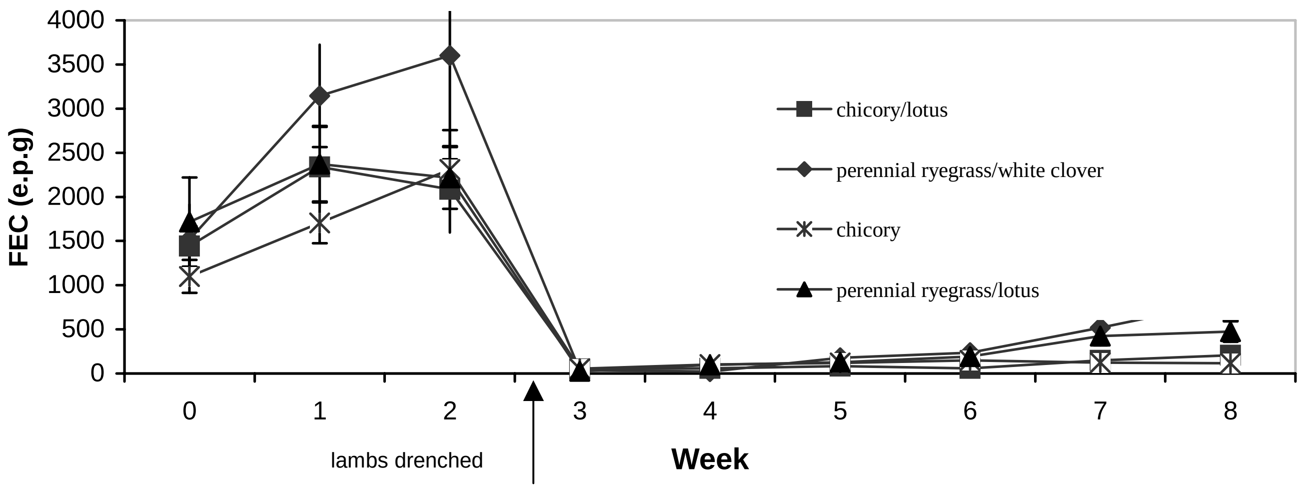
In 2002 (Year 2), the effect of crop type on overwintering larvae and subsequent reinfection rates was assessed, using two replicates each of chicory or perennial ryegrass/white clover (PRG/WC) swards. Instead of measuring pasture larvae, tracer lambs were used on two occasions over four-week grazing periods. The permanent male lambs (6 per 0.55 ha plot) were drenched and housed for two weeks before the experiment began. Similar parasitological measurements were made as in Year 1. At the end of the experiment, the permanent lambs were also slaughtered, and material recovered for total worm counts.

4.4.2 Results

Year 1

Mean faecal egg counts ranged from approximately 2000 – 3500 e.p.g. by week two of the experiment, and subsequently fell sharply in response to anthelmintic treatment (Fig 3).

Figure 3. Mean FEC in lambs grazing perennial ryegrass/white clover or chicory swards



All lambs gained live weight and condition satisfactorily throughout the experiment, with chicory recording the highest live weight gains. Faecal counts were significantly lower in lambs grazing chicory-based swards during the last two weeks of the experiment (*P*< 0.05). No significant treatment differences were obtained in total worm burdens (*P* = 0.345).

Year 2

The chicory-grazed permanent lambs had significantly higher live weights over the last eight weeks of the trial *(P* < 0.05) compared to those grazing perennial ryegrass and white clover. Faecal egg counts were also significantly lower over the final three weeks of the grazing trial (*P* < 0.05), although there was no significant difference in the faecal samples taken at slaughter. For tracer lambs, there was no significant effect of crop type on FEC taken at slaughter.

No overall significant difference was observed between forages in total worm counts in the permanent lambs (Table 5). For the first batch of tracer lambs (grazed to week 4), total worm count was significantly lower in the chicory-grazed lambs (*P* = 0.045). However, when the three sections of the gastro-intestinal tract were considered separately this difference only occurred in the small intestine (*P* = 0.032). No significant differences in total worm count were observed in the second batch of tracer lambs (grazed to week 8).

Table 5 Total worm count by location in lambs fed on chicory or ryegrass/white clover swards

		Abomasum	Small Intestine	Large Intestine	Total worm count
Weaned lambs	Chicory	1138 (+/- 454)	3149 (+/- 2198)	164 (+/- 30)	4450 (+/- 2526)
	PRG/WC	1945 (+/- 443)	1985 (+/- 1016)	375 (+/- 87)	4305 (+/- 1153)
Tracers Batch 1	Chicory	1883 (+/- 278)	3007 (+/- 699)	23 (+/- 12)	4913 (+/- 9695)
	PRG/WC	2530 (+/- 491)	5733 (+/- 1077)	37 (+/- 19)	8300 (+/- 1482)
Tracers Batch 2	Chicory	8000 (+/- 2539)	7517 (+/- 1538)	70 (+/- 22)	15587 (+/- 3083)
	PRG/WC	5193 (+/- 972)	4813 (+/- 903)	133 (+/- 75)	10150 (+/- 1485)

Notably, consistent improvements were also observed in the trace element status of lambs grazing novel forages. In 2001**,** significantly increased levels of cobalt (Vit B12) were observed for chicory/*Lotus* ($P < 0.01$), chicory ($P = 0.027$) and PRG/*Lotus* ($P = 0.024$), when compared to PRG/WC. However there was no significant forage effect on albumin ($P = 0.144$) or copper ($P = 0.125$) status. In 2002, lambs grazing chicory had significantly higher serum cobalt levels compared with those grazing PRG/WC ($P < 0.001$). Copper levels were also slightly higher in the chicory lambs, although this was not statistically significant. Differences in serum albumin levels were observed between the two forage treatments, with the chicory-fed performance lambs having significantly higher levels at the end of the trial period ($P = 0.022$).

4.5 Effect of novel cropping on parasite burden in lactating ewes and suckling lambs (SAC)

The grazing studies with lactating ewes at SAC Tulloch were designed to complement the earlier trials at IRS using weaned lambs. The experiment was originally planned to take place over two years 2001 and 2002, but was delayed by 18 months due to the outbreak of FMD and the failure of *Lotus* to establish successfully at Aberdeen. With the agreement of Defra, and based on earlier results at IRS, the experiment was conducted using chicory as the test crop. The first half of the experiment started on clean pasture in April 2003 and was concluded in August 2003. The experiment was repeated during summer 2004 on the same but by then, contaminated, swards. The aim of the experiment was to investigate;

- the potential anthelmintic effect of chicory during the peri-parturient relaxation of immunity (PPRI) in ewes
- whether grazing on chicory can replace anthelmintic drenching of peri-parturient ewes
- the effects of chicory on the uptake and establishment of parasites in unweaned lambs.

4.5.1 Materials and methods

Four 0.8 ha plots were established for each of two forage types (grass/clover or chicory) in spring 2002. The plots had not been previously grazed by sheep, but in 2002 were grazed by growing cattle in order to control pasture growth. Four treatments were imposed:

(i) chicory sward grazed by ewes, that had not been drenched with an anthelmintic;
(ii) chicory sward grazed by ewes, that had been drenched with an anthelmintic;
(iii) grass/clover sward grazed by undrenched ewes
(iv) grass/clover sward grazed by ewes that had been drenched with an anthelmintic.

Fifty-six Shetland x Cheviot twin-rearing ewes (7 ewes x 4 treatments x 2 replicates) were allocated to experimental plots one or two weeks after lambing, based on their strongyle faecal egg counts at lambing (mean FEC 363, se 57.6 e.p.g. of faeces) and their condition score prior to lambing. Half of the ewes were drenched with an anthelmintic (Ivermectin; 0.08 w/v, Oramec, Merial UK) within two days of lambing, whereas the rest remained undrenched.

Sward height was measured fortnightly, and pasture samples collected at two points during the experiment to determine sward composition. Ewes and lambs were weighed every fortnight. Faecal samples were collected weekly from ewes until week 10 of lactation, and fortnightly thereafter. Lamb faecal samples were taken weekly from approximately six weeks after lambing until the end of the experiment. At two points (approx 12 weeks after lambing, and at weaning), a subset (blocked by live weight and by litter) of six lambs per plot was slaughtered for total worm number burden and parasite species determination.

4.5.2 Results (2003)

Lamb growth rate

Mean ewe body condition score prior to lambing was similar (1.65, se 0.16) in all experimental groups**.** After lambing, the condition scores of all ewes progressively increased, with drenched ewes achieving a higher body condition score at weaning (2.6 vs. 2.3, s.e.d. 0.08) compared to undrenched ewes. Ewe live weight at lambing and at weaning was similar in all treatment groups (mean 56.4, se 0.75 kg, and mean 55.2, se 0.71 kg respectively). Undrenched ewes had the same level of live weight gain compared with drenched ewes grazing either on chicory or grass/clover. This was presumably a reflection of the relatively low production penalties that are imposed by parasites on the lactating ewe.

The live weight gain of lambs from turnout until weaning is given in Table 6. The figures include only lambs that were at pasture throughout the experiment (n=8, i.e. 4 pairs of twins).

Table 6. Live weight gain (g/day) of organically reared lambs grazing with their mothers, either on grass/clover or chicory pastures.

Forage	Anthelmintic drench	LWG g/day)
Grass/White clover	-	219
	+	271
Chicory	-	262
	+	268
s.e.d.		10.3
Level of sign.	Sward	***
	Anthelmintic	**
	Interaction (S x A)	**

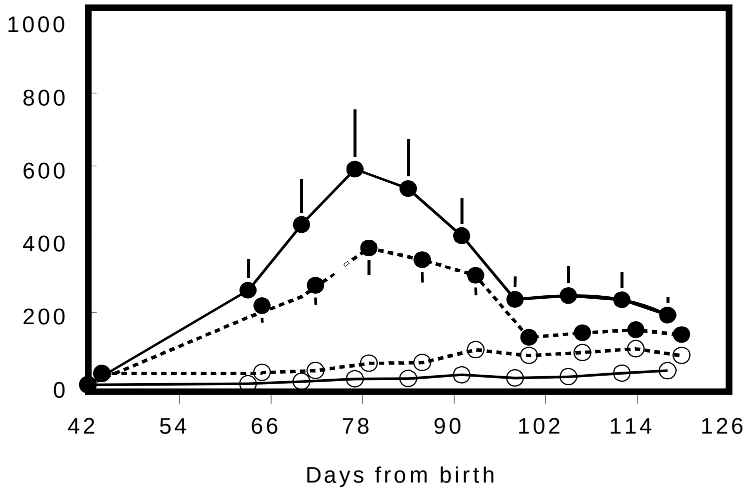
There was a significant (P<0.01) interaction between sward type and drenching treatment on lamb growth rate. This occurred because lambs grazing on ryegrass/white clover, with undrenched mothers, had the lowest growth rates. There was no growth rate effect of drenching on lambs that were grazing chicory. In terms of lamb growth rate, grazing ewes on chicory swards had the same effect as drenching peri-parturient ewes managed on a grass/clover sward.

Faecal egg counts

Faecal egg counts in drenched ewes remained very low (<100 eggs per gram faeces) throughout the experiment. Sward type did not affect the pattern of FEC in undrenched animals, which peaked at approximately week 6 of lactation. By the end of the experiment, these faecal egg outputs were similar to the FEC of drenched ewes.

Sward type significantly reduced FEC throughout the experiment (Fig. 4), in lambs from undrenched ewes (shown as solid circle), compared with those from ewes drenched with anthelmintic (shown as open circle). The FEC of lambs grazing chicory are shown as a dotted line, while the FEC of those grazing on ryegrass/white clover are given as a solid line.

Figure 4. Backtransformed FEC (e.p.g. fresh faeces) of organically reared lambs



For lambs whose dams had not been drenched, faecal egg counts were lower in animals grazing chicory, compared with those grazing ryegrass/white clover. Peak FEC was reached at approximately week 11 of age. FEC of lambs suckling drenched ewes remained very low (<100 eggs per gram faeces) throughout the experiment.

Lamb total worm burdens

The worm burdens of the lambs slaughtered during the first slaughter point (week 12 of age) are given in Table 7. The worm burdens of the lambs slaughtered during the second slaughter point (weaning) were very low and not significantly affected by treatment.

Table 7 Total worm burdens (male, female, immature) in lambs grazing grass/clover or chicory pastures.

	Forage	Anthelmintic	Male	s.e.	Female	s.e.	Immature	s.e.
Abomasum	Grass	-	1492	356	1804	438	462	50
		+	129	60	133	52	79	35
	Chicory	-	1467	345	2066	509	813	180
		+	75	22	104	14	42	17
s.e.d.			353		476		135	
Small Intestine	Grass	-	400	78	533	167	175	48
		+	537	215	641	226	50	18
	Chicory	-	941	267	1320	359	538	180
		+	133	59	138	74	25	12
s.e.d.			252		327		131	

There was a significant effect of ewe drenching on the number of worms recovered from the abomasum of lambs ($P<0.001$) at 12 weeks of age, but there was no effect of sward type on worm numbers. As expected, lambs from drenched ewes carried approximately 5% of the abomasal worm burden of those from undrenched ewes.

Worm speciation

The predominant species of the worms carried in the abomasum was Teladorsagia (Table 8).

Table 8. Speciation of total nematode worm counts recovered from the abomasum or small intestine

	Forage	Anthelmintic	*Teladorsagia*	%	*Trichos. spp*	%	*Haemonchus*	%
Abomasum	Grass	-	3286	100	0	0	10	0
		+	262	100	0	0	0	0
	Chicory	-	3514	99	19	1	0	0
		+	179	100	0	0	0	0
Small			***Trichos. spp***	**%**	***Cooperia***	**%**	***Nematodirus***	**%**
Intestine	Grass	-	583	78	71	1	179	21
		+	25	2	0	0	1154	98
	Chicory	-	1667	63	31	2	565	35
		+	0	0	11	16	260	84

The species of worms carried in the small intestine were mixed, mainly Trichostrongylus and Nematodirus. However, the proportion of Trichostrongylus: Nematodirus differed between lambs suckling undrenched and drenched ewes. In the latter, the intestinal worms were predominantly Nematodirus (approximately 0.90), indicating that the main source of these worms was probably the cattle that had grazed on this pasture in the preceding year.

Overall, the results indicate that grazing on chicory had no effect on the peri-parturient rise in ewe faecal egg output. In terms of growth rate, grazing on chicory seemed to confer benefits on the performance of organically reared lambs grazing with their undrenched mothers. This is consistent with the findings of other studies with lambs grazing experimentally on chicory swards. Lambs grazing chicory and suckling undrenched ewes also had significantly lower FEC, but the reduction was not as marked as in the drenched animals. However, the number of worms recovered at approximately 12 weeks of age was not different between swards. This apparently contradictory finding could be accounted for by variations in FEC due to differences in faecal dry matter content, or the fact that animals were slaughtered at a relatively late stage when all animals had started expressing immunity towards parasites. The benefits seen in lamb performance and the observed consistency of the faeces whilst grazing on chicory does not support the former. The large within group variation in worm counts, and the similarity observed in FEC between groups after week 12 support the latter view.

The experiment did not allow for any distinction between potential benefits arising from an effect of plant secondary metabolites contained in chicory, and from a lower parasite intake due to the structure of the chicory sward.

5.0 Novel cropping and pasture ecology (IRS)

Nematode larvae populations have been shown to differ between herbage species. These differences may be due to differences in the growth pattern of the sward and laminae morphology, which may alter the microclimate of the sward, affecting larval development and survival or, indirectly, modify the number of coprophagous or nematophagous organisms at soil level. Alternatively, certain plants may produce chemical compounds that are either unattractive, or toxic to sheep nematodes. In addition, the larval stages of many nematode parasites develop within faeces. Rapid decomposition can expose larvae to climatic extremes and reduce their survival, whereas slow rates of breakdown may impede migration into the sward and subsequent re-infection rates. Therefore, understanding the ecology of the decomposition of faeces is also important in the development of strategic parasite control programmes.

5.1 Materials and methods

5.1.1 Agronomy

In a preliminary study during 2000, the agronomic performance of selected novel forages and forage combinations was assessed at IRS. Forages selected were chicory (*Cichorium intybus*), birdsfoot trefoil (L*otus. corniculatus*), greater birdsfoot trefoil (*L. uliginosus*), sulla (*Hedysarium coronarium*) and white clover (*Trifolium repens*). These were compared with a control sward of perennial ryegrass and white clover control.

Forages selected as potential companion species for birdsfoot trefoil were white clover, perennial ryegrass, timothy and chicory. Overall there were nine forage treatments, plus the control. Two sets of plots were established in June 2000; one to determine the total agronomic performance of forages over the season (i.e. total yield); and, one to examine the effects of mimic grazing by cutting on two dates (at the end August and end of September). Plots were sown, by hand, either as monocultures or in a 50:50 mixture by number of seeds sown.

5.1.2 Larval survival and development

To assess the effect of crop type on larval survival and development, six replicate 1m^2 plots were sown with chicory, chicory/*Lotus corniculatus*, PRG/*Lotus* and PRG/WC. After establishment, each plot was artificially contaminated with 105g of faeces, carrying an estimated 198,000 *Teladorsagia circumcinta* eggs. Forage was harvested weekly for eight weeks from five predetermined 10cm^2 areas and pasture larval counts determined.

5.1.3 Faecal degradation

Faecal breakdown rates were determined using ‘faecal sample strips’ which consisted of small perspex strips, each with ten holes, designed to allow easy assessment of breakdown and some protection from heavy rainfall. These holes were filled with fresh faeces and pegged into the sward in pairs, 5cm apart, at ground level, with the holes parallel to the ground. The number of holes emptied were then scored daily, until all the faeces was removed. Faecal degradation rate was estimated to be the number of days required for all ten holes to be emptied.

Faecal breakdown rates were recorded using a common faecal type (sheep grazing a PRG/WC sward) placed in each of the test forages (2001), and then in 2002, using faeces from each of four test forages placed in a common sward environment (PRG/WC). Estimates of faecal breakdown were undertaken at high density (one pair of strips per 9m^2) and low density (one pair per 1m^2). To complement the faecal degradation assessments, invertebrate sampling was carried out using pitfall trapping.

5.2 Results

5.2.1 Agronomy

Of the forages tested, chicory performed best (Tables 9 and 10), in terms of total dry matter yield, recovery following stimulated grazing, sward height and ability to suppress weeds.

Table 9 Botanical composition (mean % by dry matter) six weeks after sowing on mimic grazing plots

Forage Species (variety and seed rate – kg/ha)	**Sp. sown or *L.corniculatus***	**Other Sp.sown**	Chickweed **(unsown)**	**Other unsown weeds**
Birdsfoot trefoil (Leo, 18kg/ha)	55	-	14	31
Greater birdsfoot trefoil (Maku, 18kg/ha)	60	-	9	31
Chicory (Grasslands Puna, 18 kg/ha)	62	-	17	21
Sulla (cv. Grasslands Aokau, 18 kg/ha)	42	-	21	37
WC (cv. Gwenda, 7.2 kg/ha)	53	-	6	41
Birdsfoot trefoil (13 kg)/chicory (15 kg)	44	32	12	12
Birdsfoot trefoil (13 kg)/WC 6 kg)	43	32	8	18
Birdsfoot trefoil (13 kg)/timothy (Erecta, 3.5 kg)	46	25	8	21
Birdsfoot trefoil (18 kg)/PRG (Tivoli, 18.5)	51	28	10	11

Table 10 Biomass (gDM/m^2) of sown species (or combination of sown species) and weeds

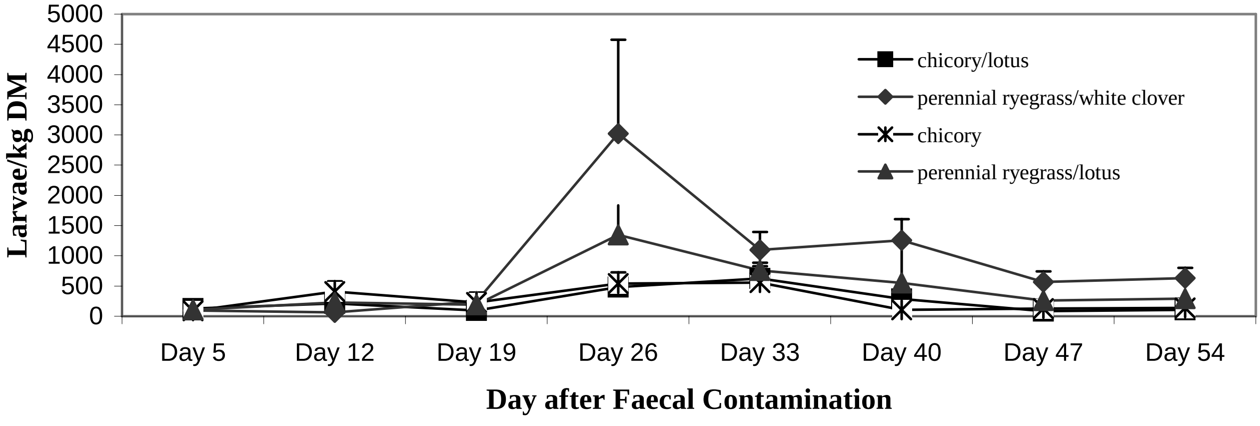
Forage species	13/09/00 Total Yield	18/10/00 Total Yield	29/08/00 Mimic Grazing	28/09/00 Mimic Grazing
Birdsfoot trefoil	78 : 76	323 : 355	121 : 197	21 : 48
Greater birdsfoot trefoil	8 : 72	90 : 402	3 : 34	10 : 110
Chicory	158 : 69	1074 : 214	1223 : 425	155 : 6
Sulla	68 : 95	175 : 497	74 : 98	58 : 101
WC	38 : 74	155 :377	10 : 54	62 : 113
Birdsfoot Trefoil/chicory	5 : 130 : 66	39 : 862 : 131	112 : 609 : 396	7 : 153 : 14
Birdsfoot Trefoil/WC	32 : 22 : 85	156 : 138 : 343	86 : 195 : 142	17 : 63 : 65
Birdsfoot trefoil /timothy	63 : 18 : 87	397 : 144 : 694	119 : 49 : 173	14 : 27 : 63
Birdsfoot trefoil/PRG	46 : 29 : 113	169 : 232 : 499	114 : 57 : 117	11 : 105 : 32
PRG/WC	39 : 14 : 74	539 : 84 : 167	99 : 27 : 70	128 : 58 : 30

Chicory (and possibly perennial ryegrass) were shown to be the best companion species for birdsfoot trefoil in terms of ratio of total dry matter yield of birdsfoot trefoil to dry matter yield of non-sown weed species. Sulla produced a total dry matter yield that was comparable to white clover, but was affected by foliar disease (an unidentified rust) and slug damage during the trial. Birdsfoot trefoil was significantly affected by weed invasion. Despite successful establishment greater birdsfoot trefoil had the worst performance of all the alternative forages, due to its poor competitiveness.

5.2.2 Larval survival and development

Following seeding of test plots using faeces from a single parasite species (*Teladorsagia circumcinta*), significantly higher numbers of larvae (Figure 5) were recovered from the PRG/WC sward during weeks 4-8 ($P<0.05$) and over the trial as a whole ($P<0.001$).

Figure 5. Number of larvae (no. per kg DM) recovered from four crop types



Reduced numbers of larvae recovered from chicory swards is consistent with some earlier studies (Moss and Vlassof, 1993). However, from this experiment it is not possible to determine whether the result is due to altered larval development, larval survival or the migratory ability of larvae on different forages.

5.2.3 Faecal degradation studies

From the small plot data, sward type significantly affected faecal breakdown (P<0.001), with the slowest rate of degradation occurring on chicory and the most rapid on the PRG/WC sward. A similar pattern was observed in the field plots with mean faecal breakdown rates of approximately 6 days for PRG/WC, 8 days in *Lotus*/PRG and chicory/*Lotus*, and 11 days in the chicory sward respectively. Forage type and density of faecal samples were observed to affect faecal breakdown rates. Faeces in chicory plots were slowest to break down (at both densities) and faecal sample strips took longer to empty when set at low density. There were no significant differences in breakdown rates comparing faeces derived from different forage sources placed within a PRG/WC sward. However, faeces derived from chicory swards were observed to degrade significantly faster within chicory swards compared to those derived from PRG/WC.

Significantly lower total invertebrate numbers were recorded in swards containing chicory, with the highest numbers occurring on PRG/WC. This is consistent with the faster rates of faecal breakdown occurring where invertebrate numbers are highest, but with no specific taxonomic group being entirely responsible. Significant interactions occurred between forage and faecal density, and faecal density as used in this experiment would have to be related to real agricultural situations.

Lower invertebrate numbers on chicory may be related to botanical diversity. Field plots containing chicory had significantly (P<0.001) lower numbers of plant species per quadrat compared with PRG/WC. Faecal breakdown rates and invertebrate numbers may also be affected by differences in sward micro-climate.

6.0 Winter parasitism in organically managed cattle (ADAS)

The incidence of winter scours has virtually disappeared from conventional systems, due to the efficacy of modern anthelmintics (Taylor, 1987) against immature stages of the parasite (*Ostertagia ostertagi*). However, information from the organic sector bodies in the UK indicates that a proportion of organic farms still seek derogation to treat cattle with anthelmintic at housing. The basis of this approach is the perceived risk of winter scour (‘Type II Ostertagia’) occurring during the late winter/early spring.

The overall objective of this experiment was to determine the impact of winter parasitism (roundworms) on the health and performance of organically managed cattle. An epidemiological approach was favoured given the unpredictable nature of the disease, and the technical challenge associated with generating conditions predisposing to the condition on a single research site.

6.1 Materials and Methods

Four organic herds (two dairy and two beef) were used for the study undertaken in autumn/winter 2002/03. The experiment was a randomised block, continuous design experiment, with two treatments - drenched and undrenched. Animals (mean age 370 days, mean live weight 289 kg) had completed only one season at grass, and could therefore be expected to carry a parasite burden into the housed period. At the start of the experiment, animals were paired on the basis of previous grazing history, breed, sex, and live weight. One of each pair was then treated with a benzimidazole drench. Individual pairs (n=64) were maintained in common pens, and under the same management regime for the duration of the experiment. Assessments of faecal egg output, blood pepsinogen and live weight were made on four occasions at approximately monthly intervals, until turnout in March/April 2003.

6.2 Results

Faecal egg output was low (less than 120 e.p.g.) throughout the experiment. As expected, drenching significantly reduced FEC (P<0.001). For individual farms, there were no statistically significant treatment differences in daily live weight gain (Table 11).

Table 11 Effect of winter drenching on total daily live weight gain and blood pepsinogen level at turnout

Site	Treatment	Suckler herds		Dairy herds		All herds
		Farm O	Farm R	Farm M	Farm H	combined
Live weight gain (kg/day)	Drench	0.575	1.10	-0.01	0.63	0.65
	No drench	0.426	1.13	0.10	0.63	0.57
	Sign.	NS	NS	NS	N/S	P<0.05
Pepsinogen (IU/l)	Drench	0.431	0.298	0.320	0.982	0.579
	No drench	0.604	0.535	0.690	1.854	1.049
	Sign.	P<0.05	P<0.05	N/S	P<0.001	P<0.001

Three of the four herds had significantly lower blood pepsinogen levels in treated animals, although pepsinogen levels were at all stages within the standard reference range of 0-2 IU/l. Pepsinogen levels at the end of the winter were strongly correlated (0.54) with age of animal (P<0.001), but this overall effect was entirely due to data from one site (Farm H). There was no significant relationship between final pepsinogen level, and overall rate of daily live weight gain, by farm or by treatment group within a farm.

7.0 Develop the application of alternative approaches to parasite control on organic farms

The objective was to determine the extent to which parasites could be controlled on commercial organic farms, identify limiting factors for each representative system, and where possible facilitate development towards better systems of control.

7.1.1 Materials and methods

The results of laboratory analysis from the epidemiological studies reported in Section 3 were returned to the farmer and his veterinary surgeon. At the end of the each grazing season meetings were held with each farmer, and where possible his veterinary surgeon, to review the epidemiological data and plan parasite control strategies for the following season.

7.2 Results

Comprehensive epidemiological data was accumulated for each farm, drawn from a variety of sources – FEC data, animal live weights, pasture larval counts, coproculture, tracer/permanent lamb total worm burden. For reasons of cost, the extent of the information provided was beyond the scope of most commercial farmers. However, the value of building up epidemiological knowledge over time is considerable. This provides information to support a more rounded interpretation of the disease situation on-farm, and can give more confidence as to when an anthelmintic drench is, or is not, required.

Good progress was made in reducing anthelmintic input to ewes, which was eliminated without detrimental effect in the extensive hill and mixed upland beef and sheep systems. The upland beef and sheep system succeeded in substantially reducing ewe FEC during the peri-parturient period, making a conscious decision to improve nutrition before and after lambing. Ewes continued to be drenched on the specialist sheep farm, in an attempt to reduce pasture contamination for lambs later in the season. This approach was recommended by the farm veterinary surgeon, with the agreement of the organic sector body, and was reviewed before the start of each grazing season. Based on faecal samples taken each spring, the clinical advice was to continue to drench ewes. Within the time scale of the project it was difficult to judge whether this approach was having a meaningful impact on the challenge to lambs later in the season, however it is very unlikely that this approach would be acceptable indefinitely to the organic sector body. On the mixed lowland farm, no anthelmintic was given to ewes in 2000 or 2001 **.** However, lean ewes at weaning in 2002 led to anthelmintic treatment of the sentinel group. In this case, it was not possible to determine whether reduced body condition was a symptom or a contributor to parasitic challenge.

Nematodirus was identified as a potentially system-limiting parasite on the specialist sheep farm. Supported by pasture larval counts, drenching lambs twice during the spring was adopted as a pre-emptive strategy over three grazing seasons, to try to reduce the challenge the following spring. This approach was not effective in reducing the medium term challenge from *Nematodirus*. Although cattle were increasingly used to vary the species mix, there was evidence of some carryover of *Nematodirus* by young cattle, to bridge the gap between sheep grazing seasons. Once established, *Nematodirus* is likely to be a persistent threat. To some extent, the potential threat can be estimated each year from temperature data during the winter and spring. Given the potentially devastating effect of the disease on young lambs, there are only two options – the use of anthelmintic in most years, or a delay in lambing date to avoid young lambs grazing during the peak *Nematodirus* period.

Decisions regarding the need to treat lambs during the course of the grazing season were based on a combination of regular faecal egg monitoring, lamb performance and the status of the pasture grazed. Monitoring faecal egg output indicated that lambs could reach high levels of faecal egg count in the autumn, and still appear to be performing adequately. For example, mean levels of over 1900 e.p.g. were recorded in a group of lambs that continued to finish satisfactorily. Evidence from elsewhere in the project, indicates a much more mixed population of nematodes existed in organically managed sheep than is generally encountered on conventional farms. In particular, large bowel species such as *Oesophagostomum* and *Chabertia* were present in greater numbers. While contributing to faecal egg output, these species are less pathogenic, and hence have fewer consequences for health and performance. The host:parasite relationship may also be modified by the fact that animals are exposed to an increasing challenge earlier in life. This apparent greater tolerance might therefore be explained by differences in parasite population profile (and relative fecundity), greater resilience in the stock due to genetic differences or previous exposure, or to the fact that organic farmers are harder to convince before making the decision to drench.

In terms of parasite monitoring, refinements were made during the project to improve mob sampling technique. Initially, farmers were asked to provide a bulked sample of fresh faeces, which was sent to Moredun to determine faecal egg count. However, the variation in the results suggested that improvements in sampling were required. For the second year of field sampling, participants sent individual faecal samples, which were then bulked on an equal volume basis at the laboratory. The resulting faecal egg counts had a much better correlation with the results of individual faecal samples.

During the project no attempt was made to ‘roll-out’ the use of novel crops onto the commercial farms studied. However, several farmers were interested in the possible effect of more diverse pastures on animal health and parasite control. On the mixed lowland farm, specific areas of chalk downland were thought to have some health benefits, arising from the greater herb content of the sward.

All four sheep flocks involved in the study operated closed flocks, and there was considerable interest in the genetics of parasite resistance. While rams were not purchased on the basis of an index for parasite resistance, on-farm selection of replacement stock tended to be on the basis of cleanliness (lack of scouring). There was some debate as to the merits of selection for resistance (ability to moderate parasite challenge) or resilience (ability to perform adequately under parasite challenge). The advice offered by Moredun was that an index based on faecal egg count is a useful tool to guide selection, however in an organic context the ability of an animal to perform much better than its peers under significant parasite challenge could be a good practical indicator. Farmers also thought it was important that stock were exposed to some level of parasite challenge in order to develop resistance. The mixed lowland farm had a deliberate policy of grazing ewe lambs for a period on contaminated pasture, to ensure exposure to parasites and encourage the development of acquired resistance.

It would be expected that the risk of developing anthelmintic resistance would be significantly reduced in organic systems, where anthelmintic input is much lower. However, evidence from the specialist lowland farm suggested that there was some anthelmintic resistance on the basis of parasite eggs present in faeces post drenching.

8.0 Conclusions and recommendations

The results from this study indicate the range in epidemiology, and disease risks present on organic farms. The individual nature of each farm, and the role of the farmer (and his advisers) in evolving a successful disease control policy are fundamental to reducing pharmaceutical anthelmintic inputs. With sufficient diversity of cropping and stocking, it is possible to virtually eliminate anthelmintic. However, many farms still face significant difficulties, particularly those systems dominated by sheep.

The extent to which control can be achieved by management alone, depends on the farming system, with the greatest opportunity for control in the more mixed, or very extensive production systems. A number of system limiting parasites were identified, notably *Nematodirus* in lambs. The greater incidence of species such as *Chabertia* and *Oesophagostomum* in organically managed sheep may also be significant. While they can produce substantial numbers of eggs, they are generally less pathogenic, which could have implications for the interpretation of raw FEC data.

Contrary to expectations at the start of the study, stomach worms appeared to be well controlled in young dairy-stock. Similarly, the perceived risk of winter parasitism in undrenched animals may also be overstated. Although this risk cannot be ruled out on an individual farm basis, little evidence was found in this study of significant parasite burdens in organic dairy or suckler-bred calves **.**The most significant potential parasite problem found in cattle was lungworm. For the UK as a whole, anecdotal evidence suggests that a significant proportion of organic dairy herds are using lungworm vaccine, including some monitored by this project. Lungworm was also detected in the upland suckler beef herd participating in the study, a result which would not have been predicted at the outset.

While the biggest impacts are likely to arise from the overall management system (stocking rate, species mix, lambing date, etc.), evidence from this work confirms that some novel crops can promote good lamb performance in the face of parasitic challenge. Of the crops tested, chicory offered the best agronomic potential, and despite a low dry matter content, consistently produced good growth rates and improved trace element status. However, it is difficult to see how the specific use of these crops can be widely recommended to organic farmers in the UK at the present time. A major problem with many novel crops is their tendency for poor establishment and persistency.

Most of these crops find it difficult to compete with ryegrass and clover in a sward. The costs of establishing a ‘pure stand’ also tend to be high - in terms of initial seed cost, quantity of forage dry matter produced, lack of persistency and increased risk of crop failure. Research on novel crops is being conducted elsewhere in the UK, for example at IGER to improve the agronomy of *Lotus*, and a programme investigating the anti-parasitic properties of secondary plant metabolites at SAC. Therefore the practical application of novel cropping systems may improve in the future, as more information becomes available on agronomic management and dietary thresholds and their effects on internal parasites. At the present time, a reasonable ‘half-way house’ might be the use of selected crops, such as chicory, forming part of a seeds mixture or sown in strips within a ryegrass/clover sward. This would reduce the overall cost and risk, while at the same time maintaining the possibility of improvements in parasite control, trace element nutrition, and overall mineral cycling on the pasture.

It is also apparent from this study that other characteristics of the crop – morphology, mineral and trace element content, or the micro-climate produced within the crop canopy, may also affect parasite burden in the grazing animal. There are many interacting factors involved, and insufficient information is currently available to make any judgements or recommendations on the effect of novel crops for parasite control, based on parasite pasture ecology. However, it is worth noting that while some attributes of a crop may be conducive to better parasite control, e.g. its chemical composition, these could theoretically be counterbalanced by other characteristics, e.g. sward conditions which favoured parasite development and survival. Understanding the wider pasture ‘eco-system’ may also be relevant to the performance of biological methods of parasite control, such as the potential role of the fungi *Duddingtonia spp***.**

The scientific evidence to support the role of nutrition in the control of internal parasites is strong, and entirely consistent with organic standards. Although the host:parasite responses to dietary manipulation were less in this study, than under very controlled housed conditions, the same principles were confirmed.

The results provide further impetus for organic farmers to optimise nutrition for their stock, and to prioritise available feed for the more susceptible classes of stock, such as first time lambers, leaner animals, and more prolific older sheep. In addition to the wider spectrum of parasites observed in organic sheep, nutritional status may be the other key factor in the apparently higher tolerance to parasites (as measured by faecal egg counts) in some organic animals. Nutritional benefits arising from the use of novel crops, may also be a contributory factor to the levels of animal performance observed, given that effects on total worm burden are not wholly consistent.

Organic livestock producers frequently face difficult judgements, balancing a desire to adhere to the spirit of organic production, whilst still ensuring high standards of health and welfare for their stock. It was clear from the study that decisions regarding anthelmintic input requires a more dynamic knowledge of the total epidemiological situation, rather than relying solely on faecal egg counts. This information includes:

- age and susceptibility of host animal
- status of current and future grazing pastures
- likely species of parasite involved
- growth, appearance and nutritional status of the host animal
- feedback from abattoir

Animal performance data was collected on organic farms in addition to parasitological measurements. However, without untreated control animals, it was not possible to measure any sub-clinical effects of parasites on animal performance. It is reasonable to assume that above a certain level of parasite burden, production losses will occur. By making very crude judgements from the weaning weights recorded on the sample of farms participating in this study, and allowing for breed and lambing date, it is possible to suggest that animal performance may be 5%-10% lower than that expected on comparable conventionally managed farms, where anthelmintic resistance is not a problem.

9.0 Implications for policy and the organic standards

The most immediate point for organic policy from this work is that there are some circumstances, particularly systems which are heavily dominated by sheep, where the aspiration of eliminating anthelmintic input may be very difficult, or impossible, to achieve. The extent to which these systems are capable of altering, will depend on the limits of resources available to the particular farmer, and the timescale allowed for any transitional period. As is the case on many sheep farms at present, it may be that a certain amount of anthelmintic input has to be tolerated. This at least has the advantage of safeguarding animal welfare, by using a product proven to have no immediate adverse effect on the host animal.

On the positive side (from an organic perspective) many of the issues faced by the organic sector for some time, are increasingly relevant to conventional farmers. Anthelmintic resistance is becoming increasingly prevalent, with triple-resistant nematodes now confirmed in sheep (Yue et al., 2003). For sheep and goats, complete control of parasites through the use of anthelmintic appears to be no longer sustainable. There is increasing recognition of the importance of maintaining a proportion of the parasite population in refugia, either within relatively resilient host animals or on the pasture, in order to delay the proliferation of anthelmintic resistant roundworm parasites (Stubbings, 2003). More integrated strategies are required, not only for organic producers, but also to prolong the life of drenches currently used in conventional farming.

The advent of a Single Payment Scheme (SPS) under CAP reform, may well open new opportunities for further extensification of production systems and the development of alternative farm business arrangements. However, if SPS mitigates against the maintenance of cattle numbers, this could have a very significant impact on current parasite control measures, particularly in hill and upland areas.

To manage an integrated whole-farm strategy for parasite control, three elements should be promoted to organic farmers:

<u>Planning</u>
UK certifying bodies require the production of an animal health plan from the start of conversion, The value of a flock/herd health plan is to enable control principles to be used in context, identify key system-limiting parasites and combine the best options and approaches for the particular circumstances. In effect, it should form the basis of an agreement between farmer, vet and sector body to develop an acceptable parasite control strategy, pre-empt problems and agree circumstances in which intervention is appropriate. It should allow for (where possible) progressive improvements in disease status. However, the quality of the plans currently produced varies considerably (Hovi, 2003).

Monitoring

The value of monitoring is to provide regular information. Assessments done at single points in time are difficult to interpret, and are of limited value. In practice, faecal egg counts are the most common tool used - through a vet, commercial lab or, with appropriate training, using on-farm systems such as FECPAK. However, faecal egg counts are an indirect measure, an overall consequence of the total burden, physiological state and relative fecundity of the parasite species present. To arrive at a more robust conclusion, information should be drawn from a range of sources (current FEC, status of current and future grazings, weather conditions, age and animal performance) to provide a more rounded disease picture. *Post mortem* results, abattoir data, and any information fed back from the purchaser of livestock are all relevant. Another useful concept is 'contamination mapping' - a risk assessment based on likely previous contamination of the pasture by monitored animals. Over time, data and experience will build up to support some of the subjective judgements which have to be made. Following any treatment of organic sheep, a faecal egg reduction test is recommended to check the drug for continuing efficacy.

Biosecurity

Specific guidelines have been developed to counter the potential introduction of anthelmintic resistant nematodes on to farms (Stubbings, 2003), based on the quarantine of newly-introduced stock and sequential drenching with levamisole and avermectin-based products. These support earlier recommendations on drenching practice (e.g. dose rates, gun calibration, fasting and standing regimes) designed to increase the effectiveness of treatments given. The organic sector bodies need to take a pragmatic view when considering these inputs, on the basis of the benefit to the wider herd/flock from strategically treating a small number of individual animals. Additional benefits of a quarantine period and strategic treatment, may be realised for other important conditions, such as footrot and sheep scab, a preventive approach entirely consistent with organic ideology.

10.0 Technology transfer

Outputs from the project are listed below.

Papers

Williams, B, and Warren, J. (2004) Effects of spatial distribution on the decomposition of sheep faeces in different vegetation types. Agriculture, Ecosystems and Environment, 103: 237-243.

Keatinge, R., Kyriazakis, I. and Jackson, F. (2004) The effect of maternal body reserves at lambing on nematode faecal egg output in lactating, organically managed ewes. *Proceedings of the British Society of Animal Science*, 2004, p 8, University of York, March 2004.

Athanasiadou, S., Gray, D., Cowie, R., Tzamaloukas, O., Kyriazakis, I. and Jackson, F. (2004) The use of chicory to control parasitism in organic lactating ewes and their lambs. *Proceedings of the British Society of Animal Science*, 2004, p 54, University of York, March 2004.

Hyslop, J.J., Kennedy, F.A., Adamson, H.F. and Keatinge, R. (2004) Voluntary herbage intake and diet selection in organic Scottish Blackface ewes varying in body condition score, suckling twin lambs and grazing perennial ryegrass/white clover swards. *Proceedings of the British Society of Animal Science*, 2004, p 132, University of York, March 2004.

Keatinge, R., Jackson, F., Coop, R., Kyriazakis, I. and Deane, J (2004) Controlling Internal Parasites in Organic Sheep and Cattle. Organic farming: Science and Practice for Profitable Livestock and Cropping. Occasional Symposium No. 37, British Grassland Society, 2004, pp73-82.

Keatinge, R., Houdijk, J.G.M., Jackson, F. and Kyriazakis,I. (2003) The effect of nutrition on nematode faecal egg output in lactating, organically managed ewes. *Proceedings of the British Society of Animal Science*, 2003, p 29, University of York, March 2003.

Hyslop, J.J., Kennedy, F.A., Adamson, H.F. and Keatinge, R. (2003) Voluntary herbage intake and diet selection in Scottish Blackface ewes suckling twin lambs and grazing perennial ryegrass/white clover swards with or without protein supplementation. *Proceedings of the British Society of Animal Science*, 2003, p 192, University of York, March 2003.

Warren J and Williams B (2003) Faecal breakdown rates and invertebrates in various forage types. Proceedings of the British Grassland Society, Seventh Research Conference. p 17-18.

Papers continued

Deane, J.C., Warren, J., Findlay, L., Dagleish, M., Cork, S., Jackson, F. & Keatinge R. (2002). The effect of *Chicorium intybus* and *Lotus corniculatus* on nematode burdens and production in grazed lambs. Proceedings of the UK Organic Research Conference, 26-28 March 2002, pp89-92.

Keatinge, R., Jackson, F., Kyriazakis, I. & Cork, S. (2002). Developing parasite control strategies in organic systems. Proceedings of the UK Organic Research Conference, 26-28 March 2002, pp341-344.

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Williams, B, and Warren, J. (2002) Pooh sticks and pasture ecology. Paper at the British Ecological Society Winter meeting. University of York 18-20 December 2002.

Keatinge, R. (2000). Parasite control in organic systems. ADAS Research Review 2000, p 52.

Keatinge, R., Gray, D., Marley, C. and Coop, R. (2000). Controlling internal parasites without the use of pharmaceutical anthelmintics. *Proceedings of the Network for Animal Health and Welfare in Organic Agriculture, Third NAHWOA Workshop, Clermont-Ferrand, 21-24 October 2000*

Conference and workshop presentations

- Organic Food and Farming Conference, Cirencester, 5-7 January 2001
- Soil Association, Farming and Food Conference, Cirencester, January 2003.
- British Ecological Society Winter Meeting, York, 18-20 December 2002
- Internal Parasite Control in Sheep, Short term strategies to slow the progress of anthelmintic resistant internal parasites of sheep, Kensington Close Hotel, London, March 2003.

Open Days/farm events

Preliminary results were presented at three meetings on parasite control in Wales during February 2001.

Results from the project were specifically promoted at a series of specific five farm events during 2003:
- Churchtown Farm, Cornwall, 25 July 2003.
- Rhug Estate, Denbighshire (Welsh Sheep Event), 28 May 2003.
- Pertwood Farm, Wiltshire, 8 July 2003
- Dowke Hill Farm, Shropshire, 10 July 2003
- ADAS Redesdale, Northumberland, 14 August 2003

Farming Press

Lessons for all from organic approach to worm control. The Sheep Farmer, May/June, 2004

Coverage of the research work in the general farming press included:
- Farmers Guardian, June 6 2003.
- Farmers Guardian, May 16 2003
- Farmers Weekly, 6 June 2003
- Farmers Guardian Supplement, August 1, 2003
- Farmers Weekly, 22 August, 2003

Technical leaflet

Results from the project have been extensively used in drafting a leaflet on parasite control within the Soil Association Producers Services series of technical leaflets providing information for organic farmers.

11.0 Future research requirements

Given the increasing cross-over between organic and conventional sectors in developing long-term approaches to parasite control, future research (management approaches to reduce parasite challenge, strategies to reduce the risk of anthelmintic resistance, population modelling, etc.) should consider incorporating the approaches and requirements of the organic livestock sector into conventional research programmes.

Better understanding of the mode of action, and improvements in agronomic performance, are required before the use of bioactive forages can be promoted to UK farmers.

The current project deliberately avoided research into genetic resistance to parasites, as this is potentially an area of work in its own right. The exploitation of genetic resistance/resilience to internal parasites is highly relevant to organic livestock production, and further funding should be considered for participative or LINK-based research.

12.0 Acknowledgements

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