

The Dynamics, Prevalence and Impact of Nematode Infections in Organically Raised Sheep in Sweden

By Å. Lindqvist¹, B-L. Ljungström², O. Nilsson³ and P.J. Waller⁴

¹Swedish Animal Health Service (Sv DHV), Kalmar, ²Sv DHV, National Veterinary Institute, Uppsala, ³Sv DHV, Kristianstad, and ⁴Department of Parasitology (SWEPAR), National Veterinary Institute, Uppsala, Sweden.

Lindqvist Å, Ljungström B-L, Nilsson O, Waller PJ: The dynamics, prevalence and impact of nematode infections in organically raised sheep in Sweden: Acta vet. Scand. 2001, 42, 377-389. – A three-year survey (1997-99) was carried out on organically reared sheep flocks throughout Sweden. The aim was to determine the prevalence and intensity of nematode infections and to establish relationships between sheep management practices and parasite infections. Faecal samples from ewes and lambs were collected from 152 organic flocks around lambing-time and during the grazing-period for analysis. Results were compared with the different management practices that farmers use to prevent parasitism in their flocks. A high proportion of the flocks was infected with nematodes. The most prevalent species were *Haemonchus contortus*, *Teladorsagia circumcincta*, *Trichostrongylus axei*, *T. colubriformis* and *Chabertia ovina* and infections progressively increased during summer in lambs grazing on permanent pastures. Severity of parasitic infection in lambs was highly dependent on egg output from the ewes. *H. contortus* was found in 37% of the flocks, even at latitudes approximating the Polar Circle. *Nematodirus battus* was recorded for the first time in Sweden during the course of this study. Lambs turned out onto permanent pasture showed higher nematode faecal egg counts (epg) than lambs that had grazed on pastures, which had not carried sheep the previous year. This beneficial effect of lambs grazing non-infected pastures persisted if the ewes were treated with an anthelmintic before turn-out and if the lambs were kept on pastures of low infectivity after weaning. In lambs, the prevalence and the magnitude of their egg counts were higher during autumn in flocks where lambs were slaughtered after 8 months of age, compared with flocks where all lambs were slaughtered before this age. These results will be used in providing advice to farmers of ways to modify their flock management in order to minimise the use of anthelmintics, but at the same time efficiently produce prime lambs.

helminth; sheep; organic; production; Sweden.

Introduction

There is a trend towards increased organic, or ecological, production of agricultural products in Sweden. Not only is there an increased demand by consumers for organically produced food commodities, but much of this impetus is the result of government policy. For example in the sheep industry, the stated aim is that 10% of all lamb meat produced in Sweden by the year

2005 should be derived from organically reared animals. To assist farmers in achieving this objective, a national association (KRAV) has been established. This organisation provides guidelines and advice, monitors development and imposes regulations that conform with the statutes developed for organic farming both nationally by IFOAM (International Federation of

Organic Agriculture Movements) and by the European Union (EU Reg. 1804/1999, implemented August 2000). The latter regulations state that prophylactic use of anthelmintic treatments is prohibited, and animals are required to spend more time on pasture, which in turn, has to be organically prepared and maintained.

Currently the sheep population of Sweden is approximately 440 000 animals. These are mainly found in the southern half of the country, with the largest concentration of sheep on an area basis, being on the island of Gotland (SCB 2000). Farms with organically reared sheep are randomly distributed throughout the sheep raising areas of Sweden. The main enterprise is the production of prime lambs for the domestic market. Lambing is concentrated in the spring months (April-May) for the production of lambs with a target liveweight of approximately 40 kg in the autumn (August-October) of the same year. However, a significant number of lambs fail to reach this weight and are kept indoors throughout winter until the following early spring (generally referred to as "winter" lambs). In addition, there are some specialist sheep producers that gear their production to supply premium off-season lamb markets.

Nematode parasitic infection is recognised as the most important infectious disease problem of sheep in Sweden (Nilsson 1973), and this is likely to have become exacerbated with the recent trend towards organic systems of production throughout Scandinavia (Thamsborg et al. 1999). However, the increased problems with internal parasites in organic sheep flocks in Sweden are based largely on anecdotal evidence, such as farmers' impressions and from reports of clinical outbreaks of parasitic disease in particular flocks. Therefore, this comprehensive, 3-year investigation, involving representative sampling of organic sheep farms through-

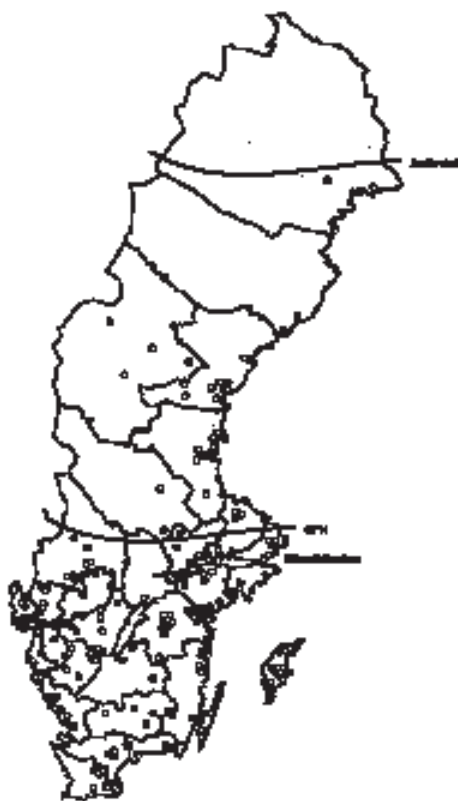


Figure 1. Distribution throughout Sweden of organic sheep farms involved in the study (1997-1999 incl.). Each circle represents one farm (closed circle – farms where *H. contortus* was detected; open circle – farms where no *H. contortus* was found).

out the entire country, was undertaken to obtain data on the status of nematode parasite infection in this livestock industry. Such information is essential for the development of rational advice, which can be used by farmers to manage nematode parasite infections in organically reared sheep flocks in Sweden.

Materials and methods

All organic sheep farmers registered with KRAV, (approx. 200), with a minimum of 20

ewes, were invited to participate in this three-year study. Altogether 152 producers participated and the distribution of these farms is shown in Fig. 1. This reflects closely the distribution of organic sheep farmers within the overall sheep farming industry in Sweden. The majority of farms ($\approx 70\%$) had between 20 and 60 ewes, with approximately a 150% turn-off of lambs each year.

Faecal sampling and monitoring

A comprehensive investigation (10 years of accumulated data) into the seasonal dynamics of nematode parasitic infections in Swedish sheep flocks has established that faecal samples taken at critical times of the year reflect the magnitude of worm infection derived from particular sources (*O. Nilsson* personal communication). Accordingly, the following sampling protocol was undertaken on each farm. Individual faecal samples from the rectum were taken from 8 ewes and/or 8 lambs in each flock. The selection of animals that were sampled was done initially at random, but these animals were identified, so the same animals were used for subsequent sampling. Samples were collected on each of the following occasions for the years 1997 to 1999 inclusive:

- Ewes – Spring: samples taken from lactating ewes in April – May, within one month after lambing. To assess the significance of the post-partum rise at this time and the importance of over-wintered infection in the ewes.
- Ewes – Autumn: samples taken in September – October. To assess the ability of ewes to "self-cure" with the onset of drying off.
- Lambs – Summer: samples collected after a minimum of 4 weeks on pasture, with most samples taken in June. To assess the magnitude of the first generation of parasites in the lamb crop, derived from larvae that had over-wintered on pasture.
- Lambs – Autumn: samples collected in

September – October, at the same time as the samples taken from the ewes. To assess the magnitude of infection mainly derived from nematode eggs passed by ewes and lambs earlier in the season.

- Lambs – Winter: samples collected during November 1998 and 1999 from lambs that were housed, because they did not reach the target slaughter weight on pasture. To assess the significance of worm infection in the "tail" of the lamb crop.

In addition to these sampling schedules, sampling was undertaken pre-lambing in 1998 and 1999 from 10 flocks where ewes lambed in mid-winter (January – February). In these flocks, comparisons between these post-parturient faecal egg counts and egg counts of the same ewes in April (spring-rise) were made to assess whether the season of lambing influenced the commonly reported phenomenon of post-parturient rise in ewe faecal egg counts.

Samples were consigned to the Swedish Animal Health Service laboratory, located at the National Veterinary Institute, Uppsala, within 24 h of collection. Individual nematode faecal egg counts were performed according to standard procedures (*Thienpont et al.* 1979), with the minimum level of detection being 50 epg, and composite faecal cultures for each class/group of 8 animals were made. Nematode egg counts were partitioned into trichostrongylids - excluding *Nematodirus* spp. *Nematodirus* spp, *Bunostomum*, *Chabertia ovina*, *Capillaria* and *Strongyloides* could be identified by egg morphology and were thus separately counted. In addition, a pooled sample of fresh faeces (≈ 20 gm) from each class/group of 8 animals was set up immediately in Baermann funnels for the specific recovery of lungworm larvae.

Following incubation for the composite faecal cultures for 10 days at 25°C, infective (3rd stage) trichostrongylid larvae were recovered by baermannization and differentiated (*Soulsby*

Table 1. Prevalence and seasonal abundance of trichostrongylid eggs (excl. *Nematodirus* spp) in faecal samples from ewes and lambs in organic sheep flocks in Sweden. Ewes were sampled in spring (April – May) and autumn (September – October) and lambs were sampled in summer (June) and autumn (September – October).

Year & season	Flock prevalence (%)	Mean EPG		Genera prevalence			
		AM	GM*	<i>H. contortus</i>	<i>Teladorsagia</i>	<i>Trichostrongylus</i>	<i>Cooperia</i>
EWES							
Spring							
1997 (72) 21*	93	652	393 ^a	24	93	74	3
1998 (101) 15	95	244	107 ^b	15	92	89	0
1999 (93) 18	98	373	195 ^c	18	85	83	5
Autumn							
1997 (60)	40	32	3 ^a	5	27	22	2
1998 (74)	78	53	8 ^b	4	31	37	0
1999 (66)	77	46	7 ^b	8	33	61	6
LAMBS							
Summer							
1997 (66) 7 [⊗]	88	180	85 ^a	2	88	55	3
1998 (81) 17	89	186	87 ^a	5	69	69	4
1999 (74) 9	80	122	66 ^b	9	52	39	0
Autumn							
1997 (60)	70	269	119 ^a	7	68	53	0
1998 (73)	93	384	189 ^a	11	63	77	18
1999 (66)	97	287	140 ^a	17	45	74	14

AM = Arithmetic mean; GM = Geometric Mean

* Comparisons between years. Means with the same superscript, within each subset, were not significantly different ($p > 0.05$)

⊗ Number of ewe flocks that were dosed with an anthelmintic, following the detection of *H. contortus*

⊙ Number of flocks where lambs were dosed with an anthelmintic

1965) in order to distribute the individual egg counts in accordance with the parasite genera present and estimate their prevalence.

Viscera were collected from lambs on farms in which *Nematodirus battus* was detected in faecal samples taken from lambs in autumn.

In accordance with the policy of the Swedish Animal Health Service, owners of any flocks that had a positive ewe faecal egg count for *H. contortus* at the spring sampling, were recommended to treat all their ewes with an anthelmintic. In addition, some producers who observed scouring in lambs, dosed them with

an anthelmintic without determining whether helminth parasitism was the cause of this condition.

Questionnaire surveys

Owners and/or managers of all farms involved in the study were asked to provide information on their properties, management of pastures, animals and the methods of parasite control that they practised for the duration of the study. An overall response rate of 68% was obtained from the 152 farms. Of the respondents, the majority provided information for one year (56), with

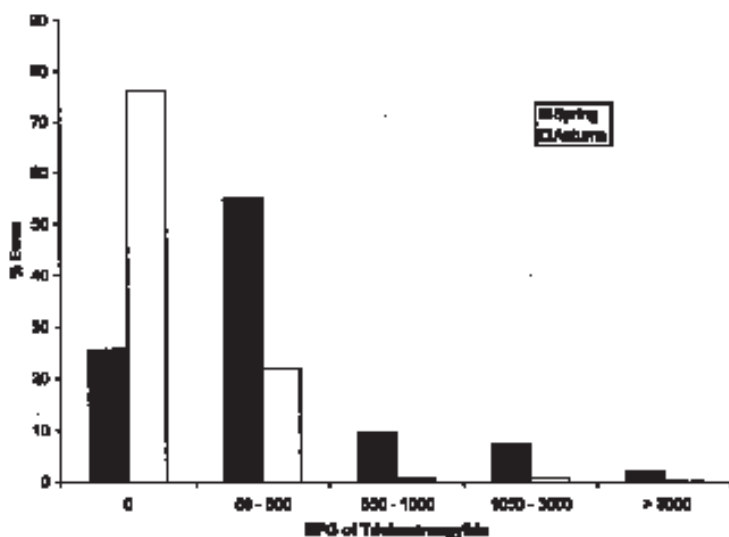


Figure 2. Frequency distribution of trichostrongylid (excl. *Nematodirus* spp) faecal egg counts of ewes soon after spring lambing and in autumn (1997-1999).

one-third (33) responding for 2 of the 3 years, whereas only 15 of the farmers responded for each of the 3 years of the study.

Statistical methods

All trichostrongylid egg count data were logarithmically transformed ($y = \log_{10} \text{egg count} + 1$) to stabilise variances and analysed by Student's t-Test, using a conventional statistical package (Stat View). The relative risk of infection (odd's ratio) was calculated for trichostrongylid egg positivity according to Schwabe *et al.* (1977).

Results

The proportion of flocks infected with trichostrongyle parasites, the mean faecal egg counts (arithmetic and geometric) and the prevalence of the 4 most abundant nematode species/genera (viz: *H. contortus*, *Teladorsagia*, *Trichostrongylus* and *Cooperia*) in ewes and lambs are shown in Table 1.

General prevalence and seasonal abundance of nematode species

A very high prevalence of infection (>90%) was found in flocks following sampling of the ewes in spring in each of the 3 years, with the mean egg count of ewes being significantly different between each year (Table 1). The prevalence ($\approx 65\%$ flocks infected) and mean number of eggs fell in the corresponding autumn sampling, with a substantial number of animals passing no eggs, thus accounting for the significant differences in the very low mean egg counts of ewes at this time. The distribution of faecal egg counts of ewes is shown in Fig. 2. Eggs of *Teladorsagia* spp., *Trichostrongylus* spp., *Haemonchus contortus* and *Nematodirus filicollis* were much more prevalent in ewe faecal samples taken in spring than in autumn. The prevalence of *Cooperia* spp. and *N. spathiger* was very low on both sampling occasions. Arithmetic mean trichostrongylid faecal egg counts were approximately 400 egg in samples

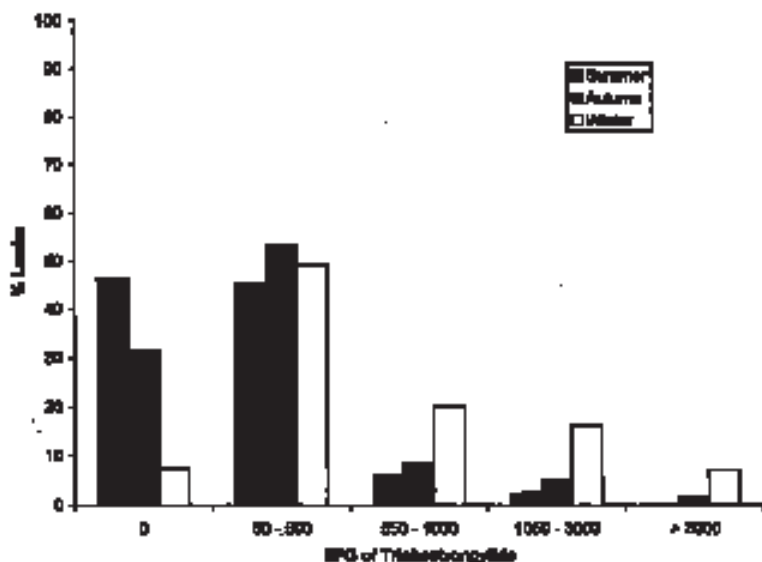


Figure 3. Frequency distribution of trichostrongylid (excl. *Nematodirus* spp) faecal egg counts of lambs after approximately 4 weeks on pasture (summer), in September-October (autumn) and November (winter lambs).

taken in spring and less than 50 epg in autumn. A comparison between farms in different regions showed that ewes had on average higher faecal egg counts in south-west Sweden [310 epg], than in other parts of the country [150 epg] ($p < 0.05$).

In a high percentage of the flocks (80%-90%), the lambs were infected at the first sampling occasion in summer in all 3 years (Table 1). The proportion of flocks with infected lambs remained similar the following autumn in all years, with the egg counts tending to increase. Overall, the prevalence of the different parasite species in the lamb faecal samples remained within the same order of magnitude. The average arithmetic trichostrongylid egg count in summer was approximately 160 epg and in autumn approximately 320 epg. Egg count patterns on farms in which lambs were sampled in winter, because they failed to reach market

weight, showed a distinct increase in abundance of parasite infection at this time (Fig. 3).

Other nematode genera were specifically recorded in faecal egg counts, viz. *Bunostomum*, *Strongyloides*, *Capillaria* and *Chabertia*. Only *Chabertia* was regularly present in lamb faecal samples, examined in autumn and winter. It occurred in about 80% of the flocks with a maximum individual prevalence of 56% and a relative intensity of 350 epg (maximum value 4200 epg). Likewise, tapeworm eggs (*Moniezia* spp.) were observed, particularly in lamb faecal samples in summer.

Specific cultures to recover lungworm larvae showed a low and irregular prevalence of *Muel-lerius capillaris* and *Protostrongylus rufescens* on a flock level, whereas *Dictyocaulus filaria* was not recorded at any time during the 3 years of this survey.

Table 2. Relative risk (odds ratio) for trichostrongyle infections and the quantitative egg output in relation to different variables. Single regression model on \pm trichostrongyle faecal egg positive animals. Differences between related figures are statistically significant ($p < 0.05$).

Categories, examined animals and variables	Relative risk of infection		EPG
	Odds ratio	95% CI	Geometric mean
Lambing time			
Ewes soon after lambing			
Winter	1	-	13
Spring	8.3	3.4 - 20.1	123
High EPG - values			
Ewes soon after lambing			
<i>Haemonchus</i> negative flocks	1	-	118
<i>Haemonchus</i> positive flocks	26	10 - 71	776
Different sampling times in the same flocks			
Lambs in Sept. - Oct.	1	-	37
Lambs in Nov.	5.0	2.8 - 8.7	213
Slaughtering time			
Lambs in Sept. - Oct.			
All lambs slaughtered before Dec. 1	1	-	10
$\geq 1\%$ of the lambs slaughtered after Dec 1.	3.9	2.5 - 6.1	83
Accommodation from birth to turn out in spring			
Lambs after appr. 4 weeks grazing			
Stable - new grazing area	1	-	3
Stable - old grazing area	3.8	2.4 - 5.9	22
Winter area - new grazing area	2.3	1.6 - 3.3	10
Winter area - old grazing area	9.1	5.6 - 14.6	63
Permanent outdoors	3.9	2.4 - 6.3	25
Pasture management			
Ewes not dewormed			
Lambs after appr. 4 weeks grazing			
New grazing area	1	-	4
Old grazing area	5.9	4.3 - 7.9	53
Ewes dewormed before turn out			
Lambs after appr. 4 weeks grazing			
New grazing area	1	-	4
Old grazing area	4.9	2.4 - 10.0	45
Lambs in Sept. - Oct.			
New spring grazing area + New autumn grazing area	1	-	8
New spring grazing area + Old autumn grazing area	7.4	2.9 - 19.3	156

Prevalence of *H. contortus*

The distribution of farms in which *H. contortus* was recorded is superimposed on the distribution of all sheep farms involved in this nationwide survey (Fig. 1). This species was randomly distributed over the entire country and

interestingly, positive flocks were found at latitudes higher than 65°N, approximately 200 km south of the Polar Circle. *H. contortus* was not found in sheep samples from the island of Gotland.

Seasonal dynamics of Nematodirus spp.

Three species of *Nematodirus*, identified initially by egg morphology, were recorded in this survey, namely *N. filicollis*, *N. spathiger* and *N. battus*. Overall, the prevalence and magnitude of infection with these species were low. *N. filicollis* was the most abundant species, being recorded in both ewes (in very low numbers in spring only) and lambs, with egg counts significantly greater in samples taken in autumn. *N. battus* was recorded in faecal samples in autumn, a finding which was further supported by post-mortem examination of lamb viscera, from 3 farms in the south-west region. This is the first report of *N. battus* in Sweden.

Analysis of farmer responses to the questionnaires

An odds-ratio analysis was conducted on the compiled responses by the farmers to the questionnaire, which sought information on sheep management practices on each farm. From this, the relative risk of trichostrongylid infection, based on faecal egg positivity, for both ewes and lambs at the beginning and end of the grazing season, was assessed. The results of this analysis, where significant differences between various parameters were recorded, are shown in Table 2.

The seasonal cycle of infection was dependent on the magnitude of the nematode faecal egg output of ewes in the spring. In flocks with high faecal egg counts of ewes at this time, *H. contortus* was found to be a significant contributor to these counts. Based on these findings, 21%, 15% and 18% of farmers with spring-lambing flocks gave an anthelmintic treatment to ewes in the spring in 1997, 1998 and 1999, respectively. Early lactation faecal egg counts of ewes from flocks where lambing occurred in mid-winter (January - February) were on average 70 epg. In mid-April the corresponding value of the same individuals had increased to approximately 400

epg. Comparison between egg counts showed that the difference was highly significant ($p < 0.001$).

There was a high correlation between the magnitude of ewe egg output in spring and lamb egg output later in the season, indicating a direct relationship between the degree of pasture contamination and subsequent levels of larval availability. As a consequence, lambs that failed to reach the target market weight around mid-autumn and were kept on pasture after this time.

The type of housing and the early management of the lambing flock had a major impact on the effects of parasite infection in the lamb crop. Turn-out of lambs directly onto "clean" pasture in spring prevented infections from developing, whereas the use of winter pens and/or previously grazed pastures in spring resulted in higher egg counts, indicating more severe infections of lambs later in the grazing season.

There did not appear to be any beneficial effect on worm infection by grazing sheep together with horses and/or cattle, nor was there any correlation between stocking rate and severity of parasite infection. From experience it is well known that the Swedish pelt sheep is particularly susceptible to copper deficiency (Å Lindqvist, personal communication), thus provision of mineral supplements with copper on farms raising these sheep is necessary. In this study, there was a positive correlation between high faecal egg counts of Swedish pelt lambs in autumn and no access to minerals with copper supplementation.

Discussion

These results show that, in general, nematode parasite infections of sheep in Sweden are relatively well managed and controlled by current organic farming practices. This conclusion can be reached from the seasonal patterns of faecal egg counts of both ewes and lambs. These data

are presented as both geometric and arithmetic means in Table 1. The purpose of this is twofold. Using the geometric means for analysing parasitological data stabilises variances and provides the more correct "average" faecal egg count, or central tendency, for any group of animals at a particular point of time. However, the arithmetic mean is more suitable to assess the effect of the level of pasture contamination, and therefore predict future trends in larval availability and worm burdens (Dash *et al.* 1988). The arithmetic mean is probably more useful to the advisor, or farmer, because it can serve as an early warning of an impending worm control problem and evasive action can be taken. It is also more easily calculated.

The egg counts of post-parturient ewes were strongly influenced by the season of lambing. In flocks which lambed before the main lambing season in spring, the ewe egg counts remained very low (less than 100 epg) until the spring lambing period. Thus there is an important seasonal component, whereby the post-parturient rise in ewe faecal egg counts is indeed a "spring rise" phenomena in Sweden. However in comparison with observations made elsewhere, this rise is relatively low (O'Sullivan & Donald 1970). Recommendations as to whether or not, organic farmers should dose their flocks in spring, are based on the presence of infective larvae of *H. contortus* in faecal cultures. It is well known that *H. contortus* is a major sheep pathogen. Thus, it is the policy of the Swedish Animal Health Service to advise farmers to strategically treat their ewes if they pass eggs of this species in spring, in order to avoid parasitic disease, productivity losses and animal welfare concerns later in the season. However, *H. contortus* was recorded, albeit at low levels, in ewes and lambs sampled later in the season. These may be attributable to the acquisition of overwintered larvae from pasture, or more probably due to ineffective de-worming practices, as re-

sistance in *H. contortus* to the benzimidazole anthelmintics has been reported in Sweden (Nilsson *et al.* 1993). This latter conclusion is supported by a recent investigation on the presence of anthelmintic resistance, which involved 12 farms that had a history of *H. contortus* infections in their flocks. Benzimidazole resistance was detected on 50% of these farms, whereas there was no indication of resistance to other broad-spectrum anthelmintics (B-L. Ljungström personal communications).

The widespread and particularly the northerly occurrence of *H. contortus* in Swedish flocks is of considerable practical importance, as well as being of parasitological interest. This nematode is generally considered to be a parasite of the warmer regions of the world, particularly in the tropics/sub-tropics, where it causes one of the most severe infectious disease problems of small ruminants (Anon. 1991). Prior to the advent of the modern broad-spectrum anthelmintics, this parasite was recorded in more than 80% of lambs consigned to the regional abattoir of Luleå, which is located just south of the Polar Circle (O. Nilsson, personal communications 1966). Following the introduction of the benzimidazole anthelmintics, *H. contortus* became a rarity in sheep flocks in Sweden until recently (Nilsson *et al.* 1993). Thus, it is interesting to speculate as to how this parasite has been able to re-colonise, spread and even thrive in sheep flocks found in regions as far north as the Arctic Circle. Apart from the turn-off of lambs for slaughter, a "dead-end" for both sheep and parasites alike, the trading of sheep is not a widespread practice in Sweden. This has prevented *H. contortus* from re-entering the island of Gotland after it disappeared in the 1970's following several years of benzimidazole use. Initially, good luck rather than good management effected this control, but now care is taken to prevent re-introduction of this parasite to Gotland, by recommending that any sheep entering

the island receive a quarantine anthelmintic treatment (*O. Schwan*, pers. comm.). This parasite is particularly vulnerable to adverse environmental conditions experienced by the free-living stages (*Waller & Donald* 1970), which may largely explain the great biological plasticity of the parasitic stages (*Crofton et al.* 1965). Thus the process of inhibited, or arrested, development of the early fourth larval stage within the mucosa of the abomasum of sheep, has been well described in regions with long, cold winters (*Blitz & Gibbs* 1972, *Waller & Thomas* 1975), whereas inhibited development is not a characteristic of tropical isolates of this parasite (*Allonby & Urquhart* 1975). Therefore, we speculate that the population dynamics of *H. contortus* in Sweden is one where over-season survival occurs predominately as inhibited stages in the abomasal mucosa of ewes during housing. However, the cold-hardiness of Swedish isolates of *H. contortus*, as well as the role of wildlife (particularly roe deer and lagomorphs) as reservoir hosts need to be investigated, before any attempt of a farm-by-farm eradication of this parasite is contemplated.

It is of interest to note that autumn faecal egg counts of Swedish pelt lambs provided with a mineral supplement containing elemental copper, were less than those not fed the supplement. This observation supports work in New Zealand, where the use of capsules containing copper oxide wire particles provided extensive protection against *H. contortus* (*Bang et al.* 1990). Further work on this finding needs to be undertaken to establish whether copper/mineral supplementation could provide a useful adjunct in the control of this parasite species in sheep. This could be of particular benefit to organic flocks where the routine use of such supplements is permitted under current regulations. Nematode egg counts of ewes fell to negligible levels in summer, coinciding with the onset of drying-off, in accordance with the pattern typi-

cally observed in lambing flocks (*O'Sullivan & Donald* 1970). This coincided with relatively high faecal egg counts in lambs, which were on average 3 to 4 months of age. It is well known that there is a high correlation between faecal egg counts and worm infections in young lambs (*Barger* 1985). Thus it can be implied, based on the lamb faecal egg counts, that parasite infections tended to increase during autumn and were highest in lambs that remained on the farms at the end of the grazing season (winter lambs). This latter finding is not surprising, given that the winter lambs failed to reach market weight, largely due to poor constitution or stress. Twin or triplet lambs often constitute the winter lamb portion of the flock, due to the fact that they have a greater likelihood of nutritional stress (competing for milk from their dams) and have to graze sooner and more frequently than their contemporaries. Thus the risk of earlier and heavier worm infections are much greater in winter lambs, and these effects are generally long-term and are not abrogated by improved nutrition at a later period, such as during housing. This has been repeatedly observed in Sweden, where winter lambs fail to gain any weight even after several months of housing and hand feeding (*Schwan et al.* 1997).

It was surprising to establish in the farmer questionnaire survey that there appeared to be little parasitological benefit to sheep of grazing them together with cattle and/or horses. However, we believe that this lack of effect was almost certainly due to the fact that the number of these other herbivores were too few, or alternations between pastures were too short, to exert a demonstrable effect. Apart from the notable exception of *Trichostrongylus axei*, a parasite that can infect several herbivores, host specificity is a feature for many important nematode parasites of livestock. Thus a parasite species that is pathogenic in one host species either do not infect the alternative host, or are less pathogenic

and prolific. This feature has been exploited and there are many examples where high levels of parasite control have been achieved for both sheep and cattle by interchange grazing (Barger 1996). However, even where sheep and cattle are grazed together, there is evidence that improved parasite control can occur, particularly for sheep (Arundel & Hamilton 1975, Jordan *et al.* 1988). This is attributed to the "vacuum cleaner" effect of the alternative host, whether it is cattle or horses, on the number of infective larvae of sheep parasites on pasture.

Another parasite that is the exception to the host-specificity rule, with regards to sheep and cattle is *Nematodirus battus*. This parasite is considered the most pathogenic of the *Nematodirus* genus (incl. *N. spathiger*, *N. filicollis*), and it causes the clinical condition, termed nematodiriasis (or more correctly nematodiriosis), the most important parasitic disease affecting young lambs in the Northern British Isles (Coop 1989). Although this parasite has been recorded previously in Scandinavia (Helle 1969), this is the first report of *N. battus* in Sweden. The severity of nematodiriosis is linked very closely to the management of the lambing flock. Young lambs are particularly vulnerable to early and often massive levels of larval intake from pasture, particularly if the same fields are used as lambing pastures for successive years. To break this cycle, it has been recommended that either several effective anthelmintic treatments should be given to lambs early in the grazing season, or pasture management should be used to avoid grazing lambs on pastures that carried lambs the previous season (Boag & Thomas 1975). The latter is the most appropriate option for the organic farmer and many such farmers in the United Kingdom have implemented a "clean" grazing system, which has involved an annual alternation between sheep and cattle. However, a number of farms employing this "clean" grazing strategy have continued to

report outbreaks of clinical nematodiriosis in their lambs. Studies by Coop *et al.* (1991), identified this as being due to the fact that *N. battus* is capable of not only surviving for 2 years on pasture, ie. during the intervening year with cattle grazing, but also being able to cycle in young calves. These are important points for the organic sheep farmer to consider in Sweden and freedom of this parasite in both sheep and cattle should be ascertained prior to the implementation of grazing strategies that are aimed at controlling parasites.

One of the most important conclusions that emerged from this study, is that although parasite infections in organically reared lambing ewes in Sweden can be considered as moderate, they certainly prime the process of parasite population build-up in the forthcoming grazing season, which has significant productivity penalties on their progeny. This will inevitably be exacerbated by the increasing trend of the sheep industry in Sweden to move towards organic systems of production. The problem of controlling parasite infections on organic farms also implies a serious animal welfare issue, because even relatively low infection levels can cause such distress that it results in loss of appetite in infected animals (Coop & Kyriazakis 1999). Thus the challenge facing researchers and extension workers in Sweden is to develop control systems that are compatible with the principles of organic farming of livestock.

Acknowledgements

The authors would like to thank the technical staff of the Department of Parasitology, National Veterinary Institute, Uppsala, Sweden, for generous co-operation. We also wish to thank all collaborating sheep farmers for their invaluable help with the practical field work.

We also thank the Swedish Board of Agriculture (Jordbruksverket) for financial support.

References

- Allonby EW, Urquhart GM: The epidemiology and pathogenic significance of haemonchosis in a merino flock in east Africa. *Vet. Parasitol.* 1975, *1*, 129-143.
- Anonymous: Report of the FAO Expert Consultation on the Helminth Infections of Livestock in Developing Countries. 1991. AGA-815. Rome, 23-27 September 1991. Food and Agriculture Organisation of the United Nations, Rome.
- Arundel JH, Hamilton D: The effect of mixed grazing of sheep and cattle on worm burdens in lambs. *Aust. Vet. J.* 1975, *51*, 436-439.
- Bang KS, Familton AS, Sykes AR: Effect of copper oxide wire particle treatment on establishment of major gastrointestinal nematodes in lambs. *Res. Vet. Sci.* 1990, *49*, 132-137.
- Barger IA. The statistical distribution of Trichostrongylid nematodes in grazing lambs. *Int. J. Parasitol.* 1985, *15*, 645-649.
- Barger IA. Prospects for integration of novel parasite control options into grazing systems. *Int. J. Parasitol.* 1996, *26*, 1001-1007.
- Blitz NM, Gibbs HC: Studies on the arrested development of *Haemonchus contortus* in sheep. 1. The induction of arrested development. *Int. J. Parasit.* 1972, *2*, 5-12.
- Boag B, Thomas RJ: Epidemiological studies on *Nematodirus* species in sheep. *Res. Vet. Sci.* 1975, *19*, 263-268.
- Coop RL: Nematodirus infection of lambs: A re-emerging problem. A.D.R.A. Newsheet No. 18. 1989.
- Coop RL, Jackson F, Jackson E: Relative contribution of cattle to contamination of pasture with *Nematodirus battus* under an alternate grazing system of husbandry. *Res. Vet. Sci.* 1991, *50*, 211-215.
- Coop RL, Kyriazakis I: Nutrition-parasite interaction. *Vet. Parasitol.* 1999, *84*, 187-204.
- Crofton HD, Whitlock JH, Glazer RA: Ecological and biological plasticity of sheep nematodes. 2 Genetic and environmental plasticity in *Haemonchus contortus* (Rud. 1803). *Cornell Vet.* 1965, *55*, 251-258.
- Dash KM, Hall E, Barger IA: The role of arithmetic and geometric mean worm egg counts in faecal egg count reduction tests and in monitoring strategic drenching programs in sheep. *Aust. Vet. J.* 1988, *65*, 66-67.
- Helle O: The introduction of *Nematodirus battus* (Crofton & Thomas, 1951) into a new environment. *Vet. Record* 1969, *84*, 159-160.
- Jordan HE, Phillips WA, Morrison RD, Doyle JJ, McKenzie K: A 3-year study of continuous mixed grazing of cattle and sheep: parasitism of offspring. *Int. J. Parasitol.* 1988, *18*, 779-784.
- Nilsson O: Helminthological problems in Sweden. In: Helminth Diseases of Cattle, Sheep and Horses in Europe (GM. Urquhart and J. Armour - editors). Robert MacLehose and Co. Ltd. Glasgow, UK. 1973. pp 163-167.
- Nilsson O, Rudby-Martin L, Schwan O: Benzimidazol-resistenta *Haemonchus contortus* påvisade hos får i Sverige (Benzimidazole resistance demonstrated in *Haemonchus contortus* infections of sheep in Sweden). *Sv. Vet. Tid.* 1993, *45*, 303-307.
- O'Sullivan BM, Donald AD: A field study of nematode parasite populations in the lactating ewe. *Parasitol.* 1970, *61*, 301-315.
- SCB: Jordbruksstatistisk årsbok. 2000 (Agricultural Statistics Yearbook 2000).
- Schwabe CW, Riemann HP, Franti CE: Epidemiology in Veterinary Practice. Lea & Febiger. Philadelphia 1977.
- Schwan O, Nilsson O, Lundeheim N: Produktion av vinterlamm. Hälsa och produktivitet Rapport till Stiftelsen Lantbruksforskning. 1997 (Production of winter lamb. Health and Productivity Report to the Agricultural Research Foundation 1997).
- Soulsby EJJ: Textbook of Veterinary Clinical Parasitology. Vol 1: Helminths. 1965. Blackwell Scientific Publications. Oxford. United Kingdom.
- Thamsborg SM, Roepstorff A, Larsen M: Integrated and biological control of parasites in organic and conventional production systems. *Vet. Parasitol.* 1999, *84*, 169-186.
- Thienpont D, Rochette F, Vanparijs OFJ: Diagnosing helminthiasis through coprological examination. 1979. Janssen Research Foundation (pub). Beerse, Belgium
- Waller PJ, Donald AD: The response to desiccation of eggs of *Trichostrongylus colubriformis* and *Haemonchus contortus* (Nematoda: Trichostrongylidae). *Parasitol.* 1970, *61*, 195-204.
- Waller PJ, Thomas RJ: Field studies on inhibition of *Haemonchus contortus* in sheep. *Parasitol.* 1975, *71*, 285-291.

Sammanfattning

Förekomst och betydelse av nematodinfektioner hos ekologiskt uppfödda får i Sverige.

1997-1999 utfördes en undersökning som omfattade 152 fårbesättningar med ekologisk uppfödning spridda över hela landet. Syftet var att kartlägga nematodinfektionernas dynamik, prevalens och intensitet. Olika samband mellan skötseltekniska faktorer och förekomsten av parasiter studerades. Totalt undersöktes ca 7000 träckprov från tackor och lamm. Drygt 90% av besättningarna var infekterade med nematoder dominerade av familjen Trichostrongylidae. Infektioner med *Haemonchus contortus*, *Trichostrongylus axei*, *T. colubriformis* och *Chabertia ovina* ökade successivt under betessäsongen hos lamm på permanenta beten. Störande infektioner hos lammen initierades främst av tackorna, vars äggutskiljning

ökade starkt efter vårlamningen, sk "spring – rise". Stora magmasken *H. contortus*, påvisades i 37% av besättningarna. *Nematodirus battus* påvisades för första gången i Sverige. Lamm som släpptes på permanenta beten hade högre äggutskiljning under sommaren än lamm som släpptes på rena "välkomstbeten". Den positiva effekten kvarstod under hösten om tackorna avmaskades före betessläppningen och om lammen släpptes på låginfekterade beten efter avvänjningen. Prevalensen och äggutskiljningens storlek hos lamm var högre under hösten i besättningar där lamm slaktades efter 1 december (vinterlamm) jämfört med besättningar där alla lamm var slaktmogna före 1 december. Undersökningsresultaten kommer att ligga till grund för framtida rådgivning om parasitförebyggande åtgärder i ekologiska fårbesättningar.

(Received november 27, 2000; accepted March 26, 2001).

Reprints may be obtained from: Åsa Lindqvist, Svenska Djurhälsovården, Box 932, 391 29 Kalmar, Sweden. E-mail: asa.lindqvist@svdhr.org, tel: +46 48 05 73 40, fax: +46 48 05 73 45.