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A 3-year field evaluation of pasture rotation and supplementary feeding to control parasite infection in first-season grazing cattle—Effects on animal performance

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Abstract

To evaluate non-chemical strategies to control pasture-borne parasites in first-season grazing (FSG) cattle, a 3-year grazing trial was conducted during 2002–2004 on naturally infected pastures on a commercial beef cattle farm in Sweden. A uniform pasture was divided in 4 equal 2 ha paddocks onto each of which 10, 5–9 months old dairy breed steer calves were allocated at turn-out in May each year. Two strategies were evaluated: (1) turn-out onto pasture which had been grazed the previous year by second-season grazing (SSG) steers, followed by a move to aftermath in mid-July (RT) and (2) supplementation with concentrate and roughage for 4 weeks from turn-out (FD). Comparisons were made with an untreated (UT), and an anthelmintic treated control group (DO). Animal parasitology and performance were monitored monthly throughout the 20 weeks grazing period. Additional sampling occasions were performed on day 9 (for coccidia) and 10 weeks after turn-out (mid-July). Due to clinical parasitic gastro-enteritis (PGE), salvage treatments were performed on all animals in group FD approximately 7 weeks after turn-out in 2003 and of three animals in group UT 5 weeks after turn-out in 2004. In 2003, the geometric mean oocyst excretion 9 days after turn-out was approximately 150,000 opg of mainly *Eimeria alabamensis* in group FD, and in 2004 approximately 180,000 opg in group UT. Apart from the DO group, geometric mean faecal egg counts (FEC) were between 80 and 400 epg 4 weeks after turn-out. Mean serum pepsinogen concentrations (SPC) of approximately 3.6 U tyrosine were recorded in the FD and UT groups from late August 2002. In 2003 and 2004, mean concentrations in these groups were between 4.1 and 7.2 U tyrosine 8 weeks after turn-out. By the end of the three grazing seasons the average weight gain difference compared to the DO group was for FD −29, −38 and −5 kg and for RT −4, −21 and +14 kg, and compared to the UT group −18, +2 and +22 for FD and +7, +19 and +41 kg for group RT. In conclusion, the rotation control strategy showed promising results, whereas the strategic feeding was poor from a parasite control standpoint.
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1. Introduction

The gastrointestinal (GI) nematodes *Ostertagia ostertagi* and *Cooperia oncophora* impose important constraints on the health and productivity of first-season grazing (FSG) cattle in temperate regions. Apart from sub-clinical infections and the accompanying performance penalties (Dimander et al., 2003; Shaw et al., 1998), heavy infections may cause severe clinical symptoms and should therefore be regarded as an animal welfare issue. Their control is often achieved by

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prophylactic use of anthelmintics (Nansen, 1993), but the trend towards 'sustainable' agriculture has created an interest for alternative methods of parasite control that can replace, or minimise, traditional chemotherapy. Generally, dependence on routine anthelmintic treatment is not accepted in organic livestock production in European countries and specifically in Sweden (KRAV, 2006). Consequently, refined grazing management techniques along with other alternatives to chemotherapy must be further developed and evaluated to provide farmers with reliable and practical solutions for the control of pasture-borne parasites of livestock.

In addition to the GI nematodes, the intestinal protozoan *Eimeria alabamensis* is an important pathogen in FSG cattle (Svensson, 1994; von Samson-Himmelstjerna et al., 2006). This parasite can cause severe diarrhoea, anorexia and weight loss within a week after experimental infection (Hooshmand-Rad et al., 1994), or following turn-out onto contaminated pastures (Svensson et al., 1994). Thus, both coccidia and nematodes are potential health hazards for young cattle turned out onto permanent pastures under temperate conditions.

The status of internal parasitism on organic dairy farms in Sweden and methods employed by these farmers for their control have been investigated by Höglund et al. (2001) and Svensson et al. (2000). They concluded that organic farmers in Sweden generally have an awareness of parasites, and apply a variety of methods for their control. A common non-chemical approach was grazing management, whereby approximately one third of the farmers utilized aftermath grazing. In addition, nearly 50% of the farmers provided nutritional supplementation following turn-out in spring with the intention to reduce parasite problems in FSG cattle (Svensson et al., 2000). The benefits of aftermath grazing have been demonstrated previously in Sweden (Dimander et al., 2000, 2003), but it needs to be combined with other measures to provide farmers with comprehensive strategies for parasite control in young cattle. In contrast, supplementary feeding of young animals following turn-out onto pasture has not been evaluated as a parasite control method under Swedish field conditions.

The objectives of this study were to investigate possible parasite control effects for FSG cattle through (1) turn-out on pastures grazed the previous season by second-season grazing (SSG) cattle, followed by one move to aftermath in mid-July and (2) nutritional supplementation during the four first weeks on pasture. These approaches were evaluated for three consecutive grazing seasons in comparison with one suppressive anthelmintic treated and one untreated control group of FSG cattle grazing permanent pasture. This paper concentrates on performance and parasitological variables in the host, whereas an additional article focuses on the dynamics of the free-living stages of parasites encountered in this study (Larsson et al., unpublished data).

2. Materials and methods

2.1. Experimental site, animals and pastures

A grazing trial was conducted during three consecutive grazing seasons (2002–2004) on a commercial beef cattle farm in south-central Sweden. Each year, male calves of the Swedish Red and White, and Holstein breeds with no experience of grazing, were purchased from various dairy farms, castrated and maintained indoors in pens with slatted floors (2002), or on deep litter straw (2003 and 2004), for at least 3 months before turn-out. During housing, these cattle were trough fed silage *ad libitum* plus approximately 2 kg concentrate per animal per day. At time of turn-out, the calves were between 5 and 9 months of age, weighing on average 189, 157 and 212 kg in 2002, 2003 and 2004, respectively.

An improved pasture, established for 12 years and previously grazed by anthelmintic treated FSG cattle, was used for the experiment. Thus, in spring 2002 the pasture was considered helminthologically 'safe'. Before the start of the trial the pasture was divided with electric fences into four contiguous experimental paddocks, each of approximately 2 ha. The stocking rate (SR) of approximately 5 animals/ha on improved pastures was decided on in agreement with the farmer. This SR was also applied in the study by Dimander et al. (2003). A similar sized paddock, which had never been grazed by cattle prior to the first year of this investigation, was used for aftermath grazing. From this paddock a silage cut was taken by early June each year, and the aftermath was then grazed from mid-July.

2.2. Experimental groups

Before turn-out each year, 40 FSG steers were sorted according to weight and randomly allocated in blocks of four to each treatment group of 10 animals (Table 1). After the mid-July move of the rotation group (RT) to the aftermath, their spring turn-out paddock was left ungrazed for approximately 2 weeks, until six (in 2002) or eight (in 2003 and 2004) SSG

Table 1
Experimental groups and management of the first-season grazing animals

Experimental group	Abbreviation	Management
Rotational grazing	RT	Spring turn-out onto pastures grazed the previous late season by SSG[a] cattle. Mid-July move of FSG[b] to aftermath (AM) after 10 weeks on pasture
Supplementary feeding	FD	Supplementary fed with concentrate 2 × 0.5 kg/calf and hay *ad libitum* daily for 4 weeks after turn-out, set stocked
Untreated control	UT	Untreated control group, set stocked
Treated control	DO	Treated with doramectin (Dectomax® vet, Pfizer, Amboise, France) given as subcutaneous injection (10 mg/50 kg live weight) from turn-out and every 4 weeks throughout the grazing season, set stocked

All groups consisted of 10 FSG animals that grazed in separate 2 ha paddocks for approximately 20 weeks during 3 consecutive years.
[a] Second-season grazing cattle.
[b] First-season grazing cattle.

cattle were assigned to graze this particular paddock until housing. The SSG animals were allocated from the same farm where the trial was conducted, and had been out grazing until they were recruited to the experiment. Before allocation to the RT paddock, these SSG animals were treated with fenbendazole 7.5 mg/kg BW (Axilur® susp 10%, Intervet, Igoville, France).

The supplementary fed group (FD) were trough fed on a group basis with both concentrate and hay. Dry matter (DM), energy and crude protein (CP) contents of the concentrate were approximately 87%, 13 MJ/kg DM and 167 g/kg DM. Fibre content (NDF) was 290, 330 and 340 g/kg DM in 2002, 2003 and 2004, respectively. DM of the hay for the 3 years was 84, 84 and 86%, the energy was 9.2, 9.2 and 8.3 MJ/kg DM and CP 81, 99 and 107 g/kg DM, respectively. NDF values for 2002 and 2004 were 661 and 640 g/kg DM, respectively. Data for NDF content of the hay in 2003 was not available. Animals in the untreated group (UT) were salvage treated when necessary due to animal welfare reasons. Animals in the anthelmintic treated group (DO) were given subcutaneous injections with doramectin 10 mg/50 kg BW (Dectomax® vet., Pfizer, Amboise, France) from turn-out and every 4 weeks throughout the grazing season. Group UT and DO were included as control groups.

All experimental paddocks were assigned a new set of experimental animals each year, although the treatments in each paddock remained the same throughout the trial. Turn-out was 7 May, 13 May and 11 May in 2002, 2003 and 2004, respectively, and the grazing period was 21 weeks in 2002 and 20 weeks in 2003 and 2004. To reduce rank pasture growth, all the paddocks (except the aftermath) were mown to a sward height of around 15–20 cm approximately 4 (in 2002 and 2003) or 7 (in 2004) weeks after spring turn-out, with the cut pasture material left on the paddock.

2.3. Sampling and laboratory procedures

During all 3 years of the study, individual rectal faecal samples were collected prior to turn-out, on day 9, and at weeks 4, 8, 10, 12, 16 and 20 (week 21 in 2002). The numbers of trichostrongyloid nematode eggs (epg) and *Eimeria* oocysts (opg) were determined by a modified McMaster method (Anonymous, 1986), based on 3 g of faeces and with a sensitivity of 50 epg/opg. Pooled faecal cultures from each group were prepared every 4 weeks by mixing 10–20 g faeces from each animal with vermiculite and then incubated for 2 weeks at 26–27 °C. Third stage infective larvae (L3) were harvested (Anonymous, 1986) and approximately 100 L3 were finally differentiated to genus level by morphological identification according to Borgsteede and Hendriks (1974). Blood samples were collected in plain vacutainer tubes prior to turn-out and at weeks 4, 8, 12, 16 and 20 or 21 (housing). Sera were prepared and stored at −20 °C until analysed for individual serum pepsinogen concentrations (SPC) using a micro method (Dorny and Vercruysse, 1998). Serum antibodies to *Dictyocaulus viviparus* infection were determined at housing each year using the lungworm Ceditest-ELISA (ID-DLO, Lelystad, The Netherlands) as described by Cornelissen et al. (1997). All calves were weighed prior to turn-out, on day 9, and at weeks 4, 8, 10, 12, 16 and 20 or 21 (housing).

Herbage availability (sward height) was estimated by using a Massey grass meter (Holmes, 1974). Recordings were made following a 'W' shaped path with at least 60 readings per paddock every 2–3 weeks starting 3 weeks after turn-out in 2002 and at turn-out in 2003 and 2004.

2.4. Weather data

Daily precipitation and temperatures were recorded at a meteorological station located 14 km from the experimental area. These data are presented as monthly means and expressed in relation to the long-term (1961–1990) average (LTA).

2.5. Statistical analysis

Data were summarised using Microsoft Excel® 2000, and analysed using the statistical analysis system (SAS) version 9.1. For analysis of epg, opg, weight gain and pepsinogen between groups, repeated measures analysis of variance was calculated, using the Mixed Model procedure (SAS, 2002–2003), with the individual animal as the experimental unit and the autoregressive covariance structure. The model included the effects of treatment, sampling week and animal, and the interaction between treatment and sampling week. The dependent variables opg and epg were log $(x + 1)$ transformed before analysis and are presented as geometric means, whereas pepsinogen and weight gain are presented as arithmetic means. Because of insignificant egg counts in the doramectin treated group (DO) this group was excluded from the epg analysis. The significance level was set to $P < 0.05$.

3. Results

3.1. Clinical observations, salvage treatments and feed consumption

Approximately, 1 month after turn-out in 2003, three animals in the FD group showed signs of parasitic gastro-enteritis (PGE) including diarrhoea and reduced weight gain. At week 7 all animals in the group were salvage treated with doramectin 10 mg/50 kg BW (Dectomax® vet., Pfizer, Amboise). Four weeks after turn-out in 2004, three animals in the UT group showed severe signs of PGE with weight loss of between 41 and 49 kg. These three animals were housed and treated with fenbendazole 7.5 mg/kg BW (Axilur® susp 10%, Intervet, Igoville) and rehydrated orally with a commercially available solution of electrolytes, citric acid, lactose and glycerol (Effydral, Fort Dodge, Vaals, The Netherlands). After 3 weeks of convalescence, the calves were returned to their original pasture.

The daily concentrate ration of 2 × 0.5 kg/calf was readily consumed on each feeding occasion, however with some individual differences as the feed was offered in a communal trough. Greater individual variations were observed for the hay consumption, but on a group basis the daily individual intake was estimated to between 0.5 and 0.75 kg/calf during all 3 years.

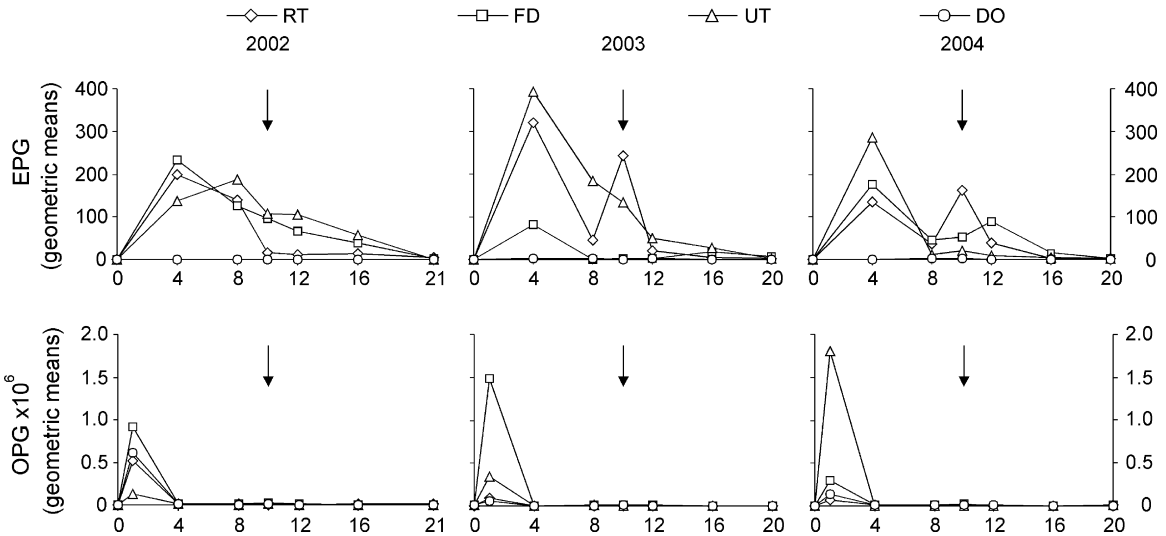

Fig. 1. Geometric mean faecal egg counts (epg) and oocyst counts (opg) for the experimental groups of cattle grazing the paddocks for 20–21 weeks between 2002 and 2004. Arrows indicate move of group RT in mid-July to aftermath. Anthelmintic salvage treatments of the FD group were performed 7 weeks after turn-out in 2003, and of three animals in group UT after 5 weeks in 2004 due to clinical PGE. Rotational grazing (RT), supplementary feeding (FD), untreated control (UT) and doramectin treated control (DO).

3.2. Nematode egg excretion

Geometric mean epg values are shown in Fig. 1. In 2002 and 2003, negative faecal samples were observed in all groups prior to turn-out and at the sampling occasion on day 9. In 2004, one animal in group UT had 50 epg prior to turn-out, and 9 days later also one animal in each of groups FD and DO, and two animals in group RT had 50 epg of trichostrongylid eggs. In all 3 years the majority of the calves in groups RT, FD and UT had positive faecal egg counts (FEC) 4 weeks after turn-out, with geometric group means ranging between 138 and 233 epg in 2002, 82 and 392 epg in 2003, and 134 and 286 epg in 2004. In general, FEC decreased following these early-season peaks and mean values <100 epg were recorded in early to late August. An exception to this was a second peak recorded in group RT in mid-July (prior to moving to aftermath) in both 2003 and 2004. Both the treatment effect and interaction between treatment and weeks on pasture were significant ($P < 0.001$) in year 2003. In 2002 and 2004, no significant differences were observed. In the DO group in 2002, a positive faecal egg count at the limit of detection (i.e. 50 epg) was observed in one animal in mid-July. However the following year (2003), this was observed in four animals between weeks 4 and 12, and in 2004 sporadic positive FEC of 50 epg was observed in five animals throughout the grazing season.

Differentiation of infective larvae from faecal cultures showed that the most abundant species were *Ostertagia* and *Cooperia* spp. followed by minor proportion of *Nematodirus* spp. (data not shown). In group RT, *Cooperia* spp. were the predominating species throughout all grazing seasons, except in late August in 2004, when *Ostertagia* spp. comprised >50% of the L3. In group FD, the proportion of *Ostertagia* spp. was higher than 50% in larval cultures at weeks 4 and 8 as well as by the time of housing in 2002, and it was <40% throughout grazing seasons 2003 and 2004. In group UT, *Ostertagia* spp. constituted <50% until the last sampling occasion at housing both in 2002 and 2003. In contrast, throughout the grazing season in 2004 the proportion of *Ostertagia* spp. in group FD was generally above 50%. The low numbers of L3 found in group DO were all identified as *Cooperia* spp. in 2002 and 2003, although in 2004 a few L3 of *Ostertagia* spp. were also observed.

3.3. Oocyst excretion

The dynamics in faecal oocyst output are shown in Figure 1. Before turn-out each year, the geometric means in all groups were <1000 opg and the maximum number of *Eimeria* spp. oocysts found in individual faecal samples were 6200, 42,000 and 1100 opg in 2002, 2003 and 2004, respectively. Oocyst excretion increased by day 9 after turn-out, and individual samples up to 100,000 opg, with *E. alabamensis* being the predominant species, were seen in all groups in all 3 years. The highest mean numbers were observed in group FD in 2002 and 2003, and in group UT in 2004 (Fig. 1). The oocyst excretion was highly variable between and within groups, but also between years. In 2003, one animal in group FD excreted >500,000 opg, and the following year seven animals (two in group FD and five in group UT) had values between 500,000 and 2 million opg. In 2003 and 2004, the interaction between treatment and weeks on pasture were significant ($P < 0.01$). Faecal samples 4 weeks after turn-out showed geometric mean values of <1500 opg in all years.

3.4. Serology

In 2002, mean SPC were <2.1 U tyrosine in all groups until the end of July, when a slight increase was observed in groups FD and UT. By late August (week 16) mean values of approximately 3.6 U tyrosine were recorded in these two groups, and remained at these levels until housing (Fig. 2). In contrast, during grazing seasons 2003 and 2004, SPC increased earlier in the season for groups FD and UT (Fig. 2). In 2003, the highest values were observed 8 weeks after turn-out with mean values of 5.1 and 4.1 U tyrosine in groups FD and UT, respectively. In 2004, mean SPC increased to 5.1 and 7.2 U tyrosine after 4 and 8 weeks in groups FD and UT, followed by a decrease towards mid-July. The same pattern was observed all 3 years in group RT, however with only a slight increase in SPC during the first 8–10 weeks on pasture followed by a decline in mid-July. The highest mean concentrations observed in this group were 2.1, 2.9 and 3.5 U tyrosine in 2002, 2003 and 2004, respectively. SPC values in the anthelmintic treated control group DO never exceeded 1.6 U tyrosine in any of the grazing seasons. At housing in October, the maximum SPC values recorded during this 3-year trial were 2.3, 3.7, 3.7 and 0.9 U tyrosine in groups RT, FD, UT and DO, respectively. Both the treatment effect and interaction between treatment and weeks after turn-out were highly significant all 3 years ($P < 0.0001$). Antibodies to *D. viviparus* were not detected in any animal during the study.

3.5. Animal performance

The mean weight gains of the groups during 2002–2004 are shown in Fig. 2. The average daily weight gain

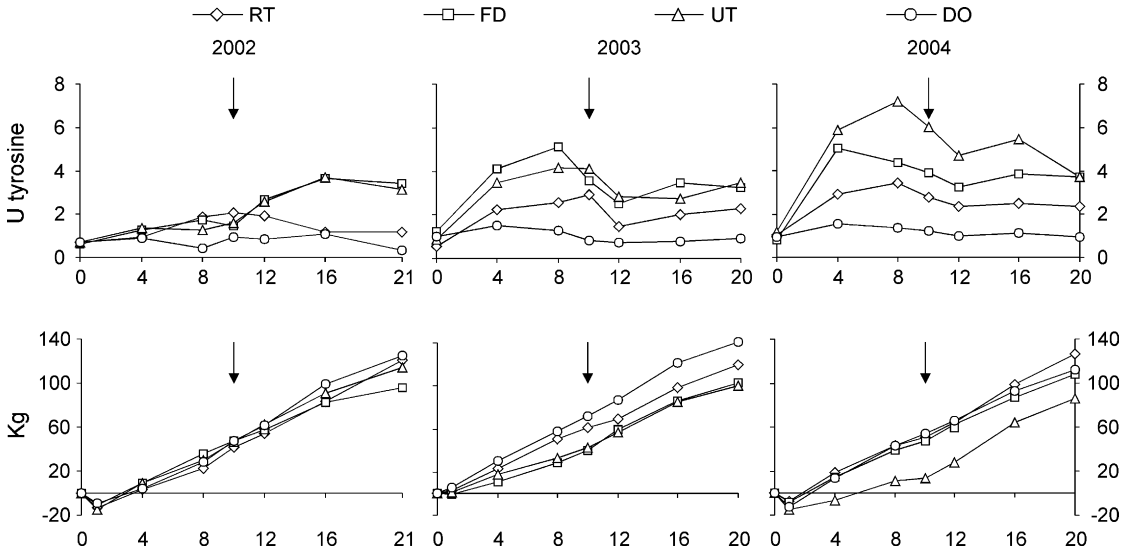

Fig. 2. Mean pepsinogen concentration (U tyrosine) and mean weight gains (kg) for the experimental groups of cattle grazing the paddocks during 20–21 weeks between 2002 and 2004. Arrows indicate move of group RT in mid-July to aftermath. Anthelmintic salvage treatments of the FD group were performed 7 weeks after turn-out in 2003, and of three animals in group UT after 5 weeks in 2004 due to clinical PGE. Rotational grazing (RT), supplementary feeding (FD), untreated control (UT) and doramectin treated control (DO).

of each group ranged between 0.82 and 0.91 kg for RT, 0.65 and 0.77 for FD, 0.62 and 0.78 for UT, and 0.80 and 1.0 for DO. The interaction between treatment and weeks on pasture were significant for all 3 years ($P < 0.0001$), showing that there was a difference in the weight gains between the various groups throughout the experiment. Nine days after turn-out in 2002 and 2004, mean weight losses of between 7 and 15 kg were observed in all experimental groups. In contrast, in 2003 group FD had lost an average of 1 kg by the first 9 days on pasture, whereas the other groups gained between 1 and 6 kg during the same period. From week 4 and onwards in 2003, the weight gains for both groups FD and UT were significantly lower compared to animals in group DO ($P < 0.01$). Also group RT showed a significantly lower weight gain compared to DO in the latter part of the grazing season this year ($P < 0.05$). In 2004, a significant reduction in weight gain was observed in group UT from week 4 compared to the other groups ($P < 0.05$). Eight weeks after turn-out, animals in group UT had gained on average 11 kg compared to approximately 41 kg for animals in the other groups.

3.6. Pasture availability

The average herbage availability is given in Fig. 3. Sward height declined on all paddocks from week 4, although in 2004 an increase at week 12 on paddock UT was recorded. At the time of housing for the first 2 years, pasture availability was comparable between paddocks FD, UT and DO, respectively. At housing in

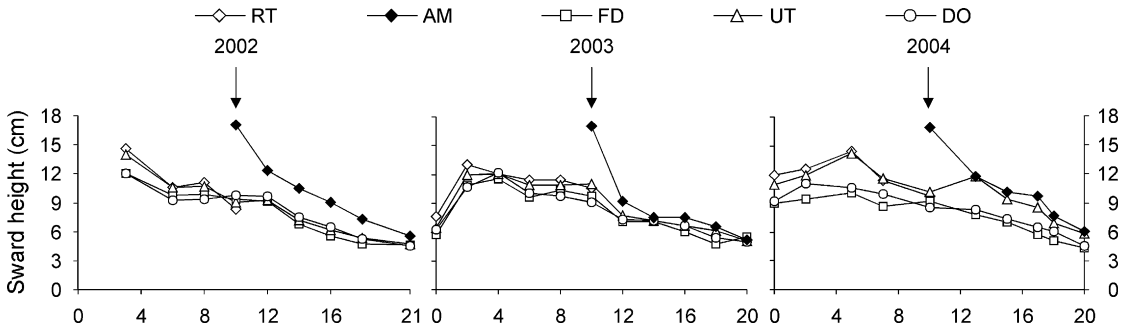

Fig. 3. Mean sward height estimations (cm), measured with a plate meter, on paddocks grazed by the experimental groups of cattle between 2002 and 2004. Arrows indicate move of group RT in mid-July to aftermath (AM). Rotational grazing (RT), aftermath grazing (AM), supplementary feeding (FD), untreated control (UT) and doramectin treated control (DO).

Table 2
Meterological data registered 14 km from the experimental site between 2002 and 2004

	Temperature (°C)				Precipitation (mm)			
	2002	2003	2004	LTA	2002	2003	2004	LTA
May	12	11	11	10	36	52	25	40
June	16	15	14	15	141	116	80	55
July	18	19	16	16	150	66	119	76
August	19	16	17	15	3	77	73	70
September	11	12	12	10	21	20	54	67

Comparisons between the trial period and the long-term (1961–1990) average (LTA) temperature and precipitation.

2004, sward height was higher in paddock UT compared to those used by the other set-stocked groups.

3.7. Meteorological data

Monthly mean temperature and precipitation are presented in relation to the LTA in Table 2. Grazing season 2002 was characterised by warm weather with exceptionally wet conditions in June and July, followed by a dry August and September. Also 2003 was warm with June being wet compared to LTA. The last year of the study (2004) had normal temperatures until August when it became warmer compared to LTA. Again precipitation was above LTA in June and July 2004.

4. Discussion

Results from this grazing trial show that GI nematode infections in FSG cattle may be adequately controlled without the prophylactic use of anthelmintics. Animals in group RT that were turned out onto pastures which had been grazed by SSG cattle during the latter part of the previous grazing season, followed by a mid-July move to an aftermath pasture, performed almost as well as animals that were treated every fourth week with doramectin.

From late August 2002, elevated pepsinogen values indicated sub-clinical ostertagiosis (Hilderson et al., 1989) in groups FD and UT. Clearly this was a result from the build-up of pathogenic parasite exposure in these paddocks, whereas this was circumvented in group RT by their move to aftermath pasture in mid-July. The following grazing seasons (2003 and 2004) showed both elevated pepsinogen levels and signs of PGE in groups FD and UT within the first 2 months on pasture. High levels of overwintered infective larvae on pasture in May, as well as the early-season peak in FEC, are in accordance with earlier findings in Sweden (Dimander et al., 2003), yet without signs of clinical PGE. However, signs of early-season clinical PGE has been described from other experiments performed in Scandinavia such as Denmark (Nansen et al., 1989), Norway (Tharaldsen, 1976) and Sweden (Nilsson and Sorelius, 1973). In contrast, in central and western parts of Europe, the peak in FEC often occurs approximately 2 months after spring turn-out (Shaw et al., 1998). Thus, when providing Scandinavian farmers with alternative GI parasite control strategies for FSG cattle, the overwintering capacity of *Ostertagia* and *Cooperia* spp. should be emphasised, and monitoring of FEC after 1 month on pasture strongly advised, with the overall aim of preventing FSG cattle being exposed to detrimental levels of nematode infection when first allowed access to pasture.

There are at least two explanations to why the RT strategy was successful in this trial. Firstly, albeit that untreated FSG cattle had been grazing the RT spring pasture the previous year, animals in this group obviously were not exposed to high levels of over-wintered larvae at turn-out, as was indicated by their serum pepsinogen values, performance and clinical appearance throughout the trial. Apparently grazing by SSG cattle during late season effectively reduced a pasture contamination that otherwise would have overwintered and become exposed to FSG cattle the following season. The control effect of using dilutive grazing strategies has previously been demonstrated by mixed grazing of SSG cattle with FSG cattle (Nansen et al., 1990). However, this beneficial impact of grazing with SSG cattle may vary as the level of their immunity depends on the intensity and duration of previous exposure to infective larvae (Ploeger et al., 1995), and protective immunity develops earlier against *C. oncophora* compared to *O. ostertagi* (Armour, 1989; Hilderson et al., 1995). Thus, although the egg count of SSG or older cattle may be low (Agneessens et al., 2000; Borgsteede et al., 2000; Eysker et al., 2002; Höglund et al., 2001), the contamination that they generate may primarily be derived from more pathogenic *O. ostertagi*. Therefore, some caution needs to be used when this measure for control is advocated for consecutive years. As an illustration of this; in the last year of the present trial, mean pepsinogen concentration increased to a value close to sub-clinical levels in group RT 2 weeks before the move to the aftermath, indicating a possible build-up of pasture infectivity between years.

The other explanation to the benefits observed in the RT strategy would be that the FSG cattle at mid summer were moved to good quality pasture that was virtually parasite free. The aftermath paddock remained parasite safe throughout this trial and the low exposure levels

can be explained partly by the fact that the paddock was spelled until mid-July each year, and partly by the silage cut in June. This beneficial effect of using the same aftermath for consecutive years has been described earlier both in Sweden (Dimander et al., 2003) and in The Netherlands (Eysker et al., 1998) where the same aftermath was used for three and two consecutive grazing seasons, respectively. However, in the latter study reasonable control of GI nematode infections were only achieved when moves were performed at monthly intervals from mid-July until housing. Still, a single move in mid-July would be more practical from the farmer's standpoint.

Supplementary feeding for 4 weeks from turn-out (group FD) proved unsuccessful for parasite control since all animals in this group had to be treated for PGE within 2 months of grazing the second year (2003). The rationale behind supplementary feeding at the time of turn-out was to provide a smooth transfer from pen feeding to a sole pasture diet for young cattle unaccustomed to grazing, as well as to improve their level of nutrition when first exposed to parasitism. The positive effect of good host nutrition in ruminants on their ability to withstand GI nematode infections has been the subject for numerous reviews (i.e. Coop and Holmes, 1996; van Houtert and Sykes, 1996). Although many trials have been conducted under pen conditions, few studies have focused on this matter in grazing cattle managed under practical farm conditions. However, positive results have been reported on the clinical condition (Jørgensen et al., 1992) and weight gains (Jørgensen et al., 1992; Magaya et al., 2000) of supplementary fed grazing cattle. An additional benefit with supplementary feeding on pasture would be the indirect reduction of exposure to infective larvae on pasture by replacing herbage intake with supplement. This 'substitution effect' is well known in adult dairy cows (Bargo et al., 2003), and was suggested as an explanation for improvements in clinical conditions and weight gain observed in a Danish trial where set stocked grazing heifers were offered lucerne pellets *ad libitum* for 1 month in the middle of the grazing season (Jørgensen et al., 1992).

The reasons for the poor result of supplementary feeding in the present study remain unclear, but the period of feeding, as well as the quantity and nutritional composition of the supplement, are factors that require further investigation. The same batch of concentrate used during the preceding housing period was offered after the turn-out, which would facilitate practical farm management, but the daily ration of concentrate was halved. Although the concentrate was readily consumed, hay given *ad libitum* was mostly rejected in favour of the lush spring grass. Thus, while the quantity in the present trial may have been too low to obtain enough substitution effect, the costs and feasibility involved in a more comprehensive supplementary feeding scheme have to be taken into consideration.

Early-season coccidiosis in combination with GI nematodes was the most likely explanation to the negative performance of the animals in group FD the second year (2003). The coccidium *E. alabamensis* has been described as an important cause of diarrhoea and weight loss in FSG cattle soon after turn-out on permanent pastures (Svensson, 1998; Svensson et al., 1994) and the appearance of *E. alabamensis* in this study was no surprise since problems with this parasite had previously been encountered on the farm. It may be speculated that the permanent location of the supplementary feeding trough predisposed to a local accumulation of *E. alabamensis* oocysts around this area that exacerbated this condition in the FD group in 2003. The fact that oocysts of *E. alabamensis* successfully overwinter on pasture (Svensson, 1995) is important as early infection with high levels of overwintered oocysts in young FSG cattle may obliterate any benefits from early-season feed supplementation. However, as with other pasture-borne parasites, the incidence and severity of *E. alabamensis* infections seem to be highly variable and difficult to predict. During the last year of our study the faecal oocyst excretion was considerably lower in the FD group, and these animals performed as well as the DO group. Notably, the doramectin salvage treatment of group FD in 2003 obviously reduced contamination and thus the otherwise expected numbers of overwintered larvae at spring turn-out in 2004. This of course compromised a thorough evaluation of the FD group the last year of the study, however it was an essential intervention from an animal welfare standpoint.

An interesting observation in this trial was that the groups with the highest mean opg values on day 9 also developed PGE early in the grazing season 2003 (group FD) and 2004 (group UT). The hypothesis of a possible synergism between *E. alabamensis* and GI nematodes was examined in a previous study with experimentally infected FSG cattle (Larsson et al., 2006). Although no evidence of synergism was observed in that trial, *E. alabamensis* had a devastating effect on the weight gains of FSG cattle, and affected animals were unable to compensate for the lost weight gain for up to 9 weeks after infection. Consequently, it seems reasonable to assume that grazing cattle recovering from a preceding coccidial infection might be more susceptible to an infection with GI nematodes at levels higher than those

used in the study by Larsson et al. (2006). More studies are therefore needed on the consequences of concurrent *E. alabamensis* and other GI parasite infections.

In conclusion, this experiment has demonstrated that practical and effective GI nematode parasite control may be achieved by turn-out of FSG cattle onto pasture that had been grazed the previous year by SSG animals, followed by a single move of the FSG cattle to aftermath in mid-July. On the other hand, strategic nutritional supplementation, as used in this trial, failed to control PGE. Whether or not this was a result of an unresolved *E. alabamensis* infection, or an exacerbation from subsequently acquired GI nematode infections, remains unclear. Further studies are required to investigate such interactions in more detail, both experimentally and under practical farming conditions.

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