

Comparison of Worm Control Strategies in Grazing Sheep in Denmark

By M.E. Boa¹, S.M. Thamsborg^{2,3}, A.A. Kassuku¹, and H.O. Bøgh³

¹Department of Veterinary Microbiology & Parasitology, Faculty of Veterinary Medicine, Sokoine University of Agriculture, Morogoro, Tanzania, ²Department of Animal Science and Animal Health, Organic Animal Health and Production, and ³Danish Centre for Experimental Parasitology, The Royal Veterinary and Agricultural University, Frederiksberg, Denmark.

Boa ME, Thamsborg SM, Kassuku AA, Bøgh HO: Comparison of worm control strategies in grazing sheep in Denmark. Acta vet. Scand. 2001, 42, 57-69. – Control of nematode parasites with reduced reliance on the use of anthelmintics was studied in 16 ewes with suckling twin lambs on contaminated pasture in Denmark. Ewes and lambs were treated with albendazole at turn-out 3 May. Ewes were removed from the groups on 26 July, and lambs were slaughtered on 11 October. The animals were allocated to 4 groups of 8 lambs and their 4 ewes. Group TS was treated with albendazole at weeks 3, 6 and 8 after turnout and set-stocked; group TM was similarly treated but moved to clean pasture in conjunction with the last drenching; group US was untreated and set-stocked, and group UM was left untreated but moved to clean pasture week 8 after turn-out. Supplementary feed was offered in June and August due to scarcity of pasture. Strategic treatments of ewes and lambs weeks 3, 6 and 8 after turn-out, with or without a move to clean pasture, were highly effective in controlling nematode infections for most of the season. This was reflected in better weight gains and carcass characteristics in the treated compared to untreated lambs, resulting in an average increase in the value of the product by 36%. The effect of moving without treatment (UM) on faecal egg counts was limited but peak pasture infectivity was reduced to less than 10% compared to the set-stocked group and weight gains of lambs were significantly better despite poor feed availability in late season. The study showed that under set-stocked conditions repeated anthelmintic treatments of both ewes and lambs in early season may ensure sufficient nematode control whereas moving animals to clean pasture without dosing was less efficient. The latter may, however, still be a viable option in organic and other production systems where routine use of anthelmintics is banned, particularly if weaning and moving are combined or a second move is performed.

gastrointestinal nematodes; parasite control; sheep; ruminants; grazing management.

Introduction

Gastrointestinal nematodes of sheep pose a major threat to welfare, good health and optimal growth of grazing lambs in most production systems. Control is essential and has for some decades relied entirely on the use of anthelmintics. However, routine and indiscriminate use of anthelmintics apart from being costly have re-

sulted in the development of strains of nematodes resistant to anthelmintics, causing severe problems with control in major sheep raising areas. Recently, anthelmintic resistance in sheep has been demonstrated in Scandinavia (Bjørn *et al.* 1991, Nilsson *et al.* 1993, Maingi *et al.* 1996a). The main objective of present day

control is to maintain parasite populations at levels that do not significantly affect health of the host animal or severely limit the production and maintain drugs of high efficacy. This must be accomplished by introducing control programmes based on sound knowledge of the epidemiology of the parasites and of the susceptibility of the hosts. Programmes under Danish conditions should be based on pasture management with minimal use of anthelmintics, and in the future perhaps biological control like nematophagous fungi (*Githigia* et al. 1996).

Pasture management specifically aiming at worm control includes clean-grazing systems (Rutter et al. 1984) and dose-and-move strategies (Coles & Roush 1992). Both options rely on efficacious anthelmintics. The farmers' adoption rate of these principles has been low in Denmark, probably due to practical problems and because grazing livestock traditionally is moved according to availability of feed (Maingi et al. 1996b). A major obstacle to clean-grazing in smaller enterprises and on farms having only permanent sheep pastures is provision of worm-free (clean) pastures at the time of turn-out. The rationale of the dose-and-move strategy is to extend the effectiveness of a single treatment by moving animals to a clean pasture in July to limit reinfection from the second wave of infection. Clean pastures at that time of the season can be achieved by refraining sheep from grazing the pastures the same year or by introducing other grazing livestock in spring. This may, however, also pose problems as most enterprises only have sheep, and facilities for hay or silage making may be lacking. Pasture spelling on its own would be uneconomical and perhaps not result in sufficient decline in number of infective larvae. The predominant species in northern temperate areas, *Trichostrongylus* and *Ostertagia* spp. have been shown to survive winter conditions in Denmark. This population of infective larvae gradually get killed by warm

weather in spring until almost complete extinction in July whereas *Nematodirus* spp. larvae are more resistant to weather conditions or eggs hatch later (Kerboeuf 1985, Rose 1990, Thamsborg & Schousboe unpubl. data 1996). In first year grazing heifers, a move to clean pasture without dosing has proved almost as effective as 'dose and move' (Foldager et al. 1981, Nansen et al. 1988) but repeated moves may be necessary under practical conditions (Eysker et al. 1998).

The aim of this study was to compare under northern temperate conditions the effectiveness of different worm control strategies, related to pasture management: strategic treatments and setstocking (group TS), strategic treatments and move to clean pasture (TM), no treatments and setstocking (US) and finally, no treatment and move to clean pastures (UM).

Materials and methods

Study area and pasture management

The study was conducted at the field station of the Royal Veterinary and Agricultural University, 15 km west of Copenhagen, in 1993. A permanent pasture of 1.2 ha grazed by nematode infected sheep for the last 4 years was divided into 4 equal sized paddocks (A, B, C and D). The pasture consisting of predominantly grasses (*Lolium perenne*, *Festuca rubra*, *Poa pratensis*, *Festuca pratensis*) and little white clover (*Trifolium repens*) was fertilized with complete fertilizer (NPK 21-4-10) at the rate of 120 kg and 60 kg N/ha on 23 March and 28 June, respectively. Hay was cut and removed from paddocks B and D on 1 June. Due to a very dry period and expected scarcity of grass, the grass was cut at a level of 8 cm. The amount of herbage on offer to animals was estimated using a rising plate meter constructed with modifications according to Castle (1976). By lowering a circular aluminium plate (319 g, 0.42 g/cm²) sliding on a measuring stick, the

Table 1. Experimental design and distribution of lambs according to breed, age and live weight (mean \pm s.d.) at turn-out May 3.

Group	n	Strategic anthelmintic treatments (wks. 3+6-8)	Grazing management	Lambs at turn-out			
				Breed		Age (days)	Live weight (kg)
				(Lx F) x T ¹	L X F ²		
TS	8	+	Set-stocked (paddock A)	6	2	44 \pm 8	10.6 \pm 2.5
TM	8	+	Moved (paddock A to B)	4	4	43 \pm 9	9.6 \pm 2.1
US	8	-	Set-stocked (paddock C)	6	2	47 \pm 4	10.1 \pm 1.6
UM	8	-	Moved (paddock C to D)	4	4	45 \pm 4	9.5 \pm 2.1

¹ (Leicester \times Finn) \times Texel. ² Leicester \times Finn.

TS = treated and set-stocked. TM = treated and moved. US = untreated and set-stocked. UM = untreated and moved.

height of the slightly compressed grass was measured. In each paddock being grazed, measurements were made fortnightly in 50 places randomly selected by walking in a W-shape manner similar to the method used for herbage sampling. Weekly precipitation as well as daily maximum and minimum temperatures were obtained from a meteorological unit within 1 km of the experimental plot.

Experimental design

Sixteen Leicester or Leicester crossbred ewes (52-62 kg) with twin lambs were allocated to 4 groups (TS, TM, US and UM) according to weight, age, sex and sire of lambs (Table 1). Each group comprised 3 ram and 5 ewe lambs and their ewes. At turn-out on 3 May, all animals (ewes + lambs) were dosed with albendazole (Valbazen[®], Smith Kline) at the dose rate of 7.5 mg/kg body weight. Ewes and lambs in group TS and TM were further treated with albendazole at weeks 3, 6 and 8 after turnout, while group US and UM were left untreated. Two groups (TS and TM) were turned out onto paddock A while US and UM were put in pad-

dock C. Groups TM and UM were moved to paddock B and D, respectively, on 28 June and consequently the stocking rate (SR) was halved in all the groups; from 52 lambs/ha to 26 lambs/ha. Moving the animals coincided with deworming of groups TM and TS i.e. 8 weeks post turnout. Groups TS and US were thus set-stocked on contaminated pastures. Lambs were weaned on 26 July (age approx. 4½ mo.) by removing ewes from the paddocks. All lambs were slaughtered on 11 October at the end of study. Due to scarcity of grass in June and a marked decline in live weight of ewes, each group was fed 4 kg of whole barley per day from 14 June to 28 June. Lambs were supplemented post-weaning from 26 July to 6 September receiving 4 kg whole barley per group per day (0.5 kg/lamb/day).

Sampling and analyses

Rectal faecal samples and blood samples by jugular vein puncture together with live weights were obtained at 2 weeks intervals for each animal from turnout to the end of experiment (week 0-22). Animals were observed daily. Fae-

cal egg counts were determined using a modified McMaster method (Henriksen & Aagard 1976). Eggs were recorded as Other strongyles or Nematodirus spp. Eggs of *Trichuris*, *Capillaria*, and *Strongyloides* were disregarded in results presentation due to a very sporadic occurrence and expected low pathogenicity. Separate faecal cultures of ewes and lambs were set up. Faeces were pooled per group by mixing 1 g of faeces per animal with vermiculite and kept moist and aerated for 10-14 days (Henriksen & Korsholm 1983). Larvae were identified by morphological and morphometric features using keys of Anon (1986).

Every 2 weeks, 2 samples of herbage per paddock were analysed for infective larvae. In the morning (9-12 a.m.) a wisp of grass was plucked by hand or cut every 5 m, irrespective of any faecal deposit, when crossing the paddock in a W-shaped manner. The grass was soaked overnight in tap water and examined for the presence of infective larvae using the method of Mwegoha & Jørgensen (1977) without addition of bile. Infective larvae were counted and identified as above, although, larvae of *Ostertagia* spp. and *Trichostrongylus* spp. were not differentiated.

At slaughter, worm counts of the abomasum and small intestine were carried out according to Thamsborg et al. (1996). Lamb carcasses were weighed and graded for body conformation (0-10, where 10 is prime quality and 5 medium) and fat layer (1-5, where 3 is normal fat layer and 5 too much fat) by experienced meat officers. Price per kg was determined according to market price.

Statistical analysis

Group means of lambs' weight gains, weight of carcass, conformation, fatness, carcass value and log-transformed worm counts were analysed by analysis of variance using GLM procedure of SAS (SAS, 1990) with the main factors

moving (MOVE, +/-) and strategic treatments (TRT, +/-) and their interaction (MOVE*TRT). Sex, breed and age were included. Factors other than main factors were stepwise excluded from the model if $p > 0.20$.

Results

Meteorology and pasture availability

In early summer there was a severe shortage of rain followed by heavy rains from mid July to mid August. A short dry spell was observed in the second half of August. September and October were very wet (Fig. 1). The mean grass heights of paddocks A and C declined gradually from turnout to mid July due to the very dry weather and high stocking rate (Fig. 2). Thereafter, coinciding with weaning and supplementation of lambs and rainfall in late July, a gradual rise was observed in both paddocks up to late August and early September. From mid September to the end, mean grass height declined, probably due to cessation of growth. In paddocks B and D, the height was rising after cutting in June before grazing took place. In July, mean heights declined gradually followed by a small increase in August similar to paddock A and C. Paddocks B and D had consistently higher mean grass heights than in A and C, but wilted straw material constituted a much larger proportion from mid September to early October.

Clinical observations

Diarrhoea was noted amongst ewes on 26 July in groups US and UM. Two cases of mild diarrhoea were seen in group TS, while no case in group TM. In lambs, diarrhoea was first noted on 26 July with 6 and 5 lambs in groups US and UM, respectively being affected. Mild cases of diarrhoea were observed in few lambs of groups TS and TM in August while most of the lambs in groups US and UM started to recover. At the end of September, the majority of lambs

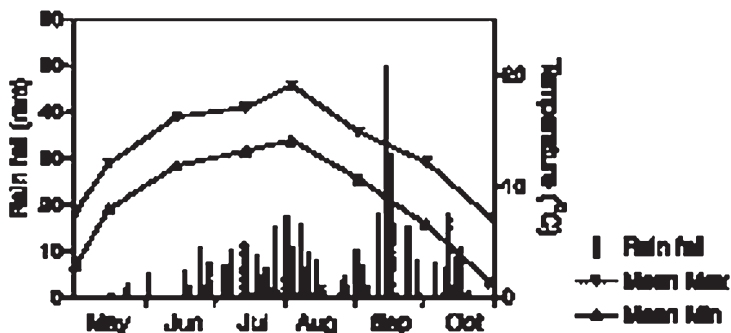


Figure 1. Meteorological observations made near experimental plot in 1993 (Courtesy of Dr. S. Jensen, Dept. of Agricultural Sciences, Section of Soil and Water and Plant Nutrition, The Royal Vet. and Agric. University, Copenhagen)

in all the groups had severe diarrhoea. Tape-worm (*Moniezia expansa*) segments in faeces of lambs were first observed at the end of July and by the end of the study, all lambs were infected.

Faecal egg counts of ewes

Mean faecal egg counts (FECs) of ewes in groups TS and TM were nil in May and below 100 epg for the rest of the study, apart from a brief rise to 250 epg in group TM in late July at the time of weaning. FECs of untreated groups (US+UM) rose to a peak of 375 epg in mid June and gradually decreased to nil at weaning in late

July. In May and June approximately 60% of the larvae from cultures were *Ostertagia* spp., while 30% were *Trichostrongylus* spp. In July, *Trichostrongylus* spp. were predominant in all the groups (approx. 60%).

Faecal egg counts of lambs: Other strongyles and Nematodirus spp.

A very pronounced rise in mean FEC of group UM observed in June-July was due to 3 animals only out of 8 lambs in the group (Fig. 3a). The 3 animals had FECs of 3000-4000 epg, while the FECs of the rest of the lambs were within the range 120-520 epg. During this period strategically treated groups (TS and TM) had lower FECs than untreated groups, whereas they rose in September to FEC levels comparable in all the 4 groups. In May and June, the eggs were predominantly *Ostertagia* spp. (approximately 60%) in groups US and UM but later in July, *Trichostrongylus* spp. were the predominant species in all 4 groups.

Very low mean *Nematodirus* spp. FECs were observed in groups TS and TM from early May to late July (Fig. 3 b), but counts rose subsequently. Groups US and UM rose in mid June from negligible levels to levels around 150 epg in July/August. In late August group UM had a

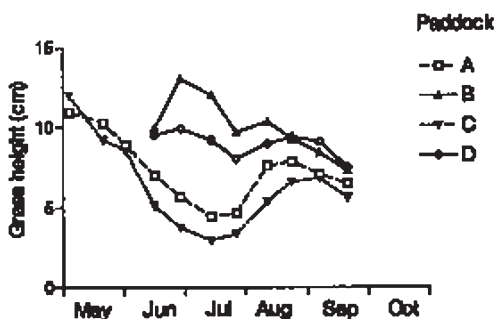


Figure 2. Mean grass heights of paddocks grazed by experimental animals.

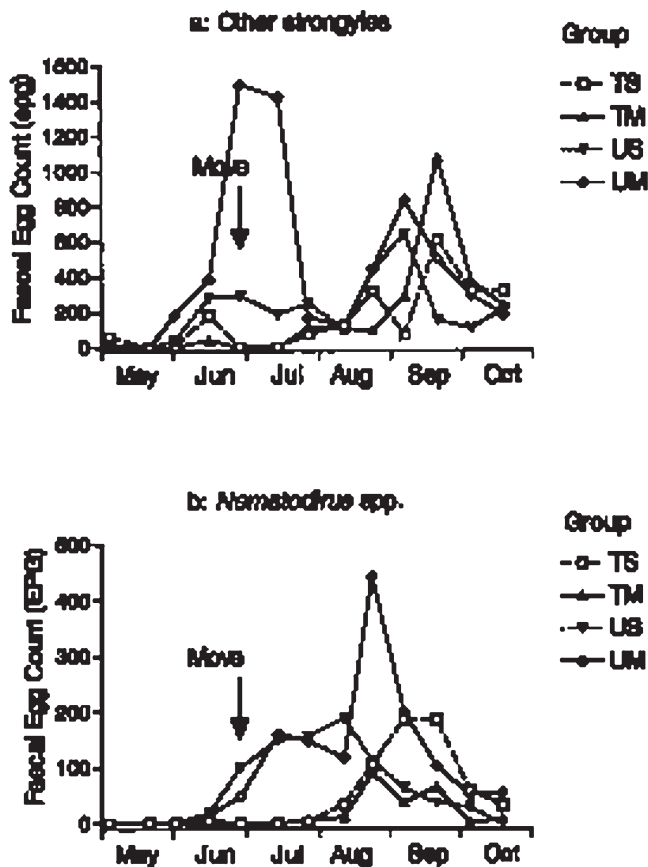


Figure 3. Mean faecal egg counts of lambs: (a) other strongyles; (b) *Nematodirus* spp. The moving of TM and UM on June 28 indicated by an arrow.

pronounced second rise, 3 animals only contributing with FECs of 1120, 820 and 820 epg. FECs for the rest of the lambs ranged between 120 and 340.

Pasture larval counts: Ostertagia/Trichostrongylus spp. and Nematodirus spp.

Pasture contamination remained low in all 4 paddocks until late June, and there was no notable differences at the time of the move between paddocks whether grazed or cut for hay (Fig. 4a). Paddock B being grazed by group TM con-

tinued with very low counts (<500 L3/kg) until the end of the experiment. In paddock D, a minor rise was observed in late July, 4 weeks after introduction of infected animals (group UM). In paddock A which was grazed for the entire season by group TS, an increase occurred in mid July, 2 weeks after cessation of the strategic treatments. In paddock C grazed for the entire season by group US, a pronounced rise (maximum 65,000 L3/kg) was observed in July coinciding with rains on 23-26 July.

From early May to mid June pasture larval

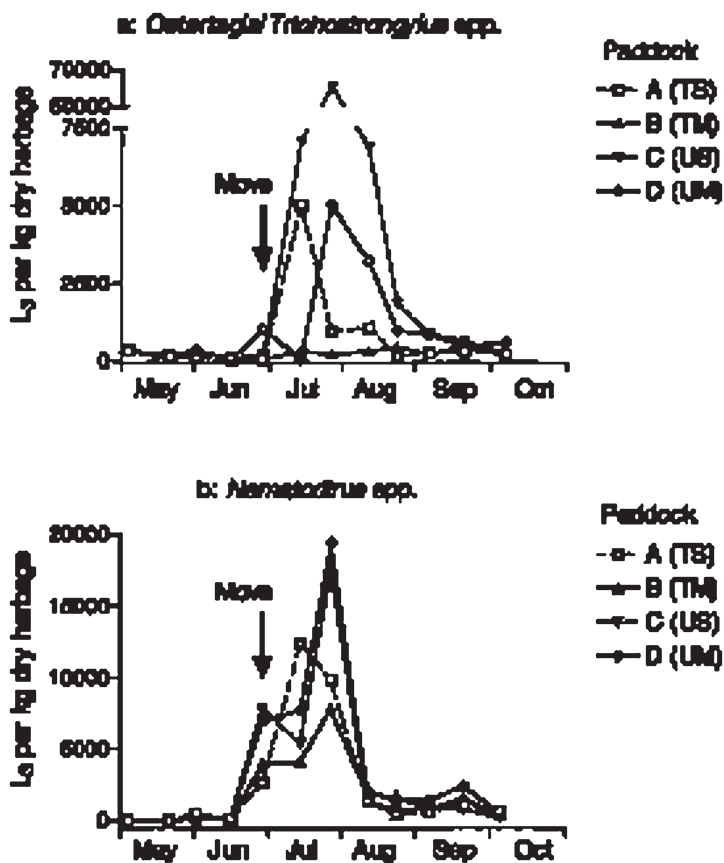


Figure 4. Herbage larval counts of the four paddocks: (a) *Ostertagia/Trichostrongylus* spp. (b) *Nematodirus* spp. Paddock A and C co-grazed by TS/TM and US/UM, respectively, before moving TM and UM on June 28.

counts of *Nematodirus* spp. were very low (Fig. 4b) followed by a sharp rise in late June in all the paddocks, including previously ungrazed paddocks (B and D). A dramatic synchronous decrease was seen in early August. Peak values were higher on paddocks C and D being grazed earlier in the same year.

Worm counts

O. circumcincta was the dominant species encountered with lesser numbers of *O. trifurcata*, *T. vitrinus*, *N. spathiger*, and *N. filicollis* en-

countered. Insignificant numbers of *T. axei*, *N. helveticus*, *Trichuris ovis* and *Chabertia ovina* were found. The heaviest mean worm burdens were seen in untreated groups (US and UM) (Table 2). The ANOVA on log-transformed counts showed significant effects of strategic treatments on immature *Ostertagia* ($p < 0.05$), *Trichostrongylus* ($p < 0.0001$) and total counts (back-transformed least square (LS) means of treated: 4358 and untreated: 8102; $p < 0.05$). Higher *Trichostrongylus* numbers ($p < 0.05$) and marginally significant higher total worm counts

Table 2. Worm counts of lambs at end of study (arithmetic means \pm s.d.).

Group	n	Abomasum		Small intestine			Immatures	Total
		<i>Ostertagia</i> spp.	Digestion	<i>T. vitrinus</i>	<i>N. spathiger</i>	<i>N. filicollis</i>		
TS	8	1095 \pm 565	1437 \pm 801	37 \pm 74	121 \pm 159	38 \pm 63	885 \pm 2343	3615 \pm 2759
TM	8	2690 \pm 2650	2546 \pm 2074	161 \pm 162	296 \pm 466	464 \pm 556	735 \pm 1017	6893 \pm 4860
US	8	2328 \pm 1909	4275 \pm 3556	540 \pm 260	83 \pm 233	217 \pm 382	1585 \pm 1871	9028 \pm 6524
UM	8	2828 \pm 1320	4473 \pm 3214	727 \pm 426	166 \pm 186	640 \pm 1140	1343 \pm 2179	10175 \pm 4891

TS = treated and set-stocked. TM = treated and moved. US = untreated and set-stocked. UM = untreated and moved.

(LS-means: 7375 vs. 4783; $p = 0.09$) were noted in the groups being moved. Ram lambs had more worms than ewe lambs (+63%; $p = 0.06$). The interaction between treatment and moving was not significant in any species.

Weight gains of lambs

All groups showed a markedly reduced growth rate after 6 weeks on pasture (Fig. 5), probably related to the low availability of herbage and thus reduced lactation. The move to clean pastures of groups TM and UM was accompanied by a dramatic increase in mean daily weight gains compared to the set-stocked groups (week 8-12; 221 g/day vs. 102 g/day; $p < 0.0001$), irrespective of treatments. After

weaning in week 12 and until the end of the study, the moved groups had significantly lower growth rates compared to the set-stocked groups (149 g/day vs. 191 g/day; $p < 0.001$). Thus, in the whole period from moving until end of study (week 8-22), the effect of moving was not significant but treated lambs performed better than untreated ($p < 0.01$) (Table 3). Two lambs in groups TS and UM, respectively, showed signs of ill thrift 2-4 weeks after turnout and never exceeded a body weight of 27 kg. These lambs were probably mismothered and were excluded from the analysis. Over the entire grazing season (week 0-22), the treated lambs grew 13% better than untreated lambs ($p < 0.001$) but the effect of moving was not significant. Although moving to clean pasture had only a temporary effect on weight gains in treated lambs, untreated and moved lambs (UM) had 15% higher mean weight gain than untreated and set-stocked lambs (US) (comparison from week 8 to 22; repeated measures ANOVA; $p < 0.05$). Viewed over the entire season, the difference in weight gain between UM and US was 9%. In accordance with these findings, the interaction between treatment and moving was marginally significant (Table 3). Ram lambs performed generally better than ewe lambs ($p < 0.01$) whereas breed and age at turnout did not influence the weight gains apart from initial 8 weeks.

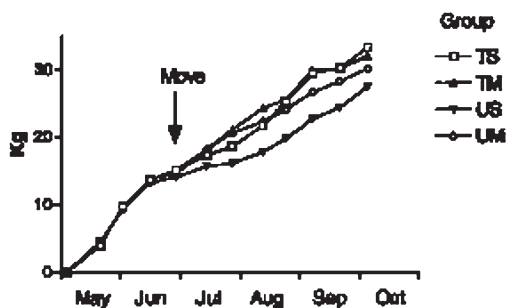


Figure 5. Mean accumulated weight gains of lambs. The moving of TM and UM on June 28 indicated by an arrow.

Table 3. Summary of results of analysis of variance on lambs' performance in relation to moving and treatment: least square means for daily weight gains in different periods of the grazing season.

		Turn-out to move (week 0-8) g/day		Move to slaughter (week 8-22) g/day		Entire season (week 0-22) g/day		
	Move	Yes	n.a.	170	NS	204	NS	
		No	n.a.	165		201		
	Treat	Yes	262	185	p<0.01	215	p<0.001	
		No	257	150		190		
Treat	Yes	Move	Yes	n.a.	181	Treatment x move	212	Treatment x move
			No	n.a.	190		219	
	No	Move	Yes	n.a.	160	p = 0.13	198	p = 0.09
			No	n.a.	140		182	

NS = not significant. n.a.= not applicable

Lambs' carcass weight and classification

The analysis of variance showed that strategic treatments resulted in higher mean carcass weight (LS-means: +16%; $p<0.001$), better fatness score (+22%; $p=0.05$) and a 36% better market value of the carcasses ($p<0.01$) compared to the untreated groups, irrespective of moving (Table 4). Moving resulted in poorer conformation (-17%; $p<0.05$) which may be attributed to less Texel halfbreeds in moved groups. The interaction between treatment and moving was not significant in any of the parameters whereas sex influenced carcass weight ($p<0.01$) and breed strongly influenced confor-

mation ($p<0.001$) and market value ($p<0.001$). In general, the ANOVA-models explained a considerable part of the variation (R^2 : 0.37-0.63).

Discussion

Strategic treatments of ewes and lambs weeks 3, 6 and 8 after turn-out, with or without a move to clean pasture, were highly effective in controlling strongyle infections for most of the season. Faecal egg counts of weaned lambs were low until August. Herbage infectivity of *Ostertagia/Trichostrongylus* remained very low in the paddocks of both treated groups throughout

Table 4. Carcass characteristics of lambs slaughtered at the end of the experiment (mean \pm s.d. (least square means)).

Group	n	Carcass weight (kg)	Conformation (0-10)	Fatness (1-5)	Market value (DKK)
TS	7 ^a	19.4 \pm 2.4 (19.0)	6.1 \pm 1.5 (5.8)	2.9 \pm 0.4 (2.8)	329 \pm 83 (304)
TM	8	18.4 \pm 2.9 (18.6)	4.5 \pm 1.4 (4.5)	2.6 \pm 0.5 (2.6)	266 \pm 113 (266)
US	8	15.8 \pm 2.0 (15.4)	5.0 \pm 0.8 (4.6)	2.5 \pm 0.5 (2.4)	237 \pm 60 (207)
UM	7 ^a	16.7 \pm 1.8 (17.0)	4.0 \pm 1.4 (4.1)	2.0 \pm 0.6 (2.0)	203 \pm 81 (212)

^a) one lamb excluded due to ill thrift from turn-out, probably mismothering

the season, apart from a brief increase in July on the set-stocked paddock (A), probably derived from the ewes' egg output in May-June. Lower worm counts were found at slaughter compared to untreated lambs. The effect on *Nematodirus* spp. infections was less pronounced but similarly, faecal egg counts rose later and were generally lower. The effect on nematode infections was reflected in better weight gains post-weaning and better carcass weights and fat cover in the treated compared to untreated lambs, resulting in an average increase in the value of the product by 36%. However, it did not result in improved weight gains in the suckling lambs up till moving i.e. the first 8 weeks on pasture. It thus emerged from the study that a move to clean pasture combined with a single anthelmintic treatment would be as good as a strategic programme on set-stocked pastures. Despite the favourable responses, diarrhoea, most likely related to nematode infections, was prevalent in both groups (and in the untreated groups) at the end of the study.

It was, however, surprising to find that moving to clean pasture week 8 did not further enhance the favourable response to treatment. On the contrary, moving to clean pasture led to higher worm burdens at slaughter, although levels still were generally low, and lamb performance was similar or lower. There may be several reasons for this finding. Firstly, ewes and lambs were re-infected because the 'clean' pasture (paddock B) was not totally without infective larvae of *Ostertagia/Trichostrongylus* (61 L3/kg dry herbage) at the time of the move in week 8. Mitchell & Fitzsimons (1983) and Mitchell et al. (1984) made similar observations on farms practicing 'clean' grazing, where very low initial pasture larval counts (less than 200 L3/kg) resulted in high worm burdens in tracer lambs grazing those fields in August and in pasture larval counts in excess of 8000 L3/kg, emphasizing the dangers inherent to building-up of in-

fections. In the present study, the level of 8 cm instead of 4 cm for cutting of hay, chosen because of risk of shortage of feed due to prevailing drought, did not leave the herbage sufficiently exposed to facilitate killing of infective larvae on pasture (Kerboeuf 1985). Also the contamination with *Nematodirus* was substantial. Secondly, the nutritional quality of forages in the paddocks may have been an important limiting factor in the moved groups. The move in early July from approx. 6 cm in paddock A to 13 cm sward height in paddock B immediately resulted in a doubling of lambs' growth rate (and ewes'!) (data not shown). However, in August with new rains and reduced grazing due to supplementation of lambs, the regrowth was substantial in paddock A with set-stocked lambs. The height increased dramatically and most likely the feed value of the juvenile sward was higher compared to paddock B where the sward height was generally decreasing and consisted mainly of senile, wilted material. The reason for this being lack of stocking in early season, the high cutting level, and that the paddock was never grazed down properly.

It is an intriguing question as to why animals moved to clean paddocks (groups TM and UM) were generally having high worm burdens at slaughter compared to the ones remaining on contaminated pastures (groups TS and US). A study by Whitelaw & Fawcett (1982) suggested that lambs reared on 'clean' pasture up to weaning did not develop a significant level of acquired immunity to helminth infections, and when challenged by appreciable numbers of infective larvae for the first time will develop higher worm burdens than lambs which have been previously exposed to infection, having been reared on permanent pastures. The latter may indeed be the case in group US being exposed to high levels of pasture contamination for the whole season and building up immunity. Waller & Thomas (1981) showed that lambs ex-

posed to high levels of larval intake from pastures were able to express immunity by resisting establishment and later to expel adult worm burdens of *T. axei* and *T. vitrinus* by 5 months of age, while lambs exposed to lower larval intake were still accumulating burdens of both species at 7 months of age.

It may be regarded as coincidental that lambs of group UM when moved had significantly higher strongyle FECs compared to co-grazed group US. As already mentioned, the elevated mean FEC came from only 3 individual lambs, and the FECs fell within one month. It is thus difficult to judge whether moving of ewes and lambs without dosing does in fact result in lower faecal egg counts. It is, however, evident that peak herbage infectivity (in July/August) was reduced to less than 10% compared to the set-stocked group where the egg output of lambs and not least ewes in May and June caused very high levels of herbage infectivity. The lower level of exposure to nematode infections in group UM was reflected in significantly better weight gains and carcass weight, although the effect on performance was severely limited by the poor feed availability in the clean paddock (D) for reasons summarized above. From weaning to the time of slaughter, the moved lambs failed to maintain the impressive weight gains seen in July. In the present study, moving took place in early July and lambs were weaned a month later. If moving and weaning coincide or lambs at weaning are moved a second time to clean pasture, the ewes' egg output will not contribute to the increase in pasture contamination in late season and better control is likely to be achieved to avoid the late cases of diarrhoea and high numbers of immature nematodes. A second move may also be advisable under a 'dose and move' strategy, as suggested by *Herd et al.* (1984) who observed a dramatic increase in pasture larval counts and weight loss in late season (September) after an initially

favourable parasitological response to 'dose and move' of weaners on July 2. In regions where *Haemonchus contortus* is prevalent, this may indeed be the case due to the notoriously rapid build-up of this infection. A 'dose and move' at weaning followed by two moves without treatments in a sheep-cattle rotation system proved to be as effective as combining all three moves with anthelmintic treatments (*Donald et al.* 1987). *Brunsdon* (1976) demonstrated that a change to clean pasture at weaning resulted in a production response similar to, or better than, an anthelmintic treatment without moving the lambs.

An interesting finding was the uniform pattern in pasture contamination with *Nematodirus* spp. in all paddocks from mid June to mid July irrespective of whether they were grazed in spring or left ungrazed until 28 June. This indicates that at least part of the pasture contamination is derived from hatching of overwintered eggs or less likely, from a reservoir of larvae (*Rose* 1990). The rapid decline in pasture strongyle larval counts in paddock C and D in late August can partly be explained by a substantial pasture regrowth and thus dilution. Whether a secondary peak would appear later in October, as a result of lambs' egg output in September, is likely but remains speculative. A secondary peak following a decline in August/September has been observed in other studies (*Thamsborg et al.* 1996).

The present study confirmed that under set-stocked conditions, where other strategies for nematode control are not available, repeated anthelmintic treatments of both ewes and lambs in early season - often termed 'poor man's clean grazing' - will probably ensure sufficient nematode control. The use of this strategy may, however, be questionable due to the risk of developing anthelmintic resistance in the nematode population, although the evidence is conflicting (*Coles & Roush* 1992). In the present

study, a 'dose and move' approach was likely to provide a similar level of control with a reduced number of treatments. In organic production systems prophylactic use of anthelmintics is banned (Thamsborg et al. 1999). Despite the lack of control of worm burdens, the present and earlier studies suggest that moving animals to clean pasture without anthelmintic treatment may also be an option for control, particularly if weaning and moving are combined or a second or more moves are performed. However, care must be exercised to have plenty of nutritive sward available at all times and farmers should be aware of the potential build-up of infections. The study emphasizes the need for including carcass quality at slaughter in studies of impact of parasitic infections.

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Sammendrag

Strategier til forebyggelse af indvoldsorm hos græssende får i Danmark.

Forebyggelse af indvoldsorm med reduceret anvendelse af ormemediciner blev undersøgt under danske forhold. Moderfår med tvillingelam blev behandlet med albendazol og udbundet på smittet mark 3. maj. Dyrene blev fordelt på 4 hold bestående af 8 lam og deres 4 moderfår. Hold TS og TM blev behandlet med albendazol 3, 6 og 8 uger efter udbinding. Hold TS forblev på samme mark hele græsningsæsonen, mens hold TM blev flyttet til ren mark i forbindelse med sidste behandling (uge 8). Hold US og UM var ubehandlede. Hold US forblev på samme mark, mens hold UM blev flyttet til ren mark i uge 8. Moderfårene blev fjernet fra grupperne 26. juli, og alle lam blev slaget 11. oktober. Tilskudsfoder blev tildelt i juni og august på grund af græsmangel. De strategiske ormebehandlinger af moderfår og lam uge 3, 6 og 8 efter udbinding, med eller uden flytning til ren mark, medførte en effektiv kontrol med indvoldsorm bedømt ud fra ægudskillelse og græsmarkssmitte. Dette afspejledes i statistisk signifikant bedre tilvækster og bedre slagte kvalitet sammenlignet med ubehandlede lam og dermed 36% bedre afregning af slagtekroppene. Flytning til ren mark uden behandling af moderfår og lam (hold UM) havde begrænset effekt på dyrenes ægudskillelse, men græsmanglen var reduceret, og trods græsmangel sidst på sæsonen var lammenes tilvækster signifikant bedre end på det ikke flyttede hold (US). Forsøget viste, at flytning til ren mark uden ormebehandling ikke er så effektivt til kontrol med indvoldsorm som gentagne ormebehandlinger i forsørgeren. Strategien "flytning uden behandling" (evt. gentagne flytninger) bør dog fortsat betragtes som et alternativ i økologiske og andre produktionssystemer, hvor anvendelse af ormemediciner ønskes begrænset.

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Reprints may be obtained from S.M. Thamsborg, Department of Animal Science and Animal Health, The Royal Veterinary and Agricultural University, Grønnegaardsvej 2, DK-1870 Frederiksberg C, Denmark. E-mail: smt@kvl.dk, tel: +45 35 28 30 28, fax: +45 35 28 30 55.