Epidemiologically based control of *Haemonchus contortus* in small ruminants

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Abstract

Haemonchus contortus is a major pathogen of sheep and goats, frequently responsible for outbreaks of acute disease, death and is also notorious for the development of resistance to anthelmintic drugs. This nematode parasite is generally considered to be a problem specific to the tropics/subtropics, however *H. contortus* is becoming increasingly more common in small ruminant flocks in northern Europe. Sustainable, epidemiologically based, control strategies are urgently required. This report highlights two examples, where the author has had involvement, located at the extremes of the geographic range for this parasite. Firstly, in Malaysia, multiple anthelmintic resistant *H. contortus* is rampant and annual losses exceeding 25% attributed to this parasite are commonplace on government farms. Changes in management, based on epidemiological studies, showed that short-term rotational grazing provided good level of control against *H. contortus,* however this was improved by daily feed supplementation with the nematode destroying fungus, *Duddingtonia flagrans.* Secondly, *H. contortus* is becoming more prevalent in Sweden. Recent studies show that it has undergone unique epidemiological adaptations to survive in this country. Virtually complete inhibition of development occurs once infective larvae are acquired by sheep early in the grazing season and no survival occurs over-winter on pasture. Lambing ewes hold the key to between-year transmission, whereby high faecal egg counts at turn-out, leads to early contamination of pastures and continuation of infection. Thus eradication of *H. contortus,* on a farm-by-farm basis in Sweden is possible, by treating all ruminant livestock during the housing period with highly effective anthelmintics

Introduction

Among the diseases that constrain the survival and productivity of sheep and goats, gastrointestinal nematode infection ranks highest on a global index, with *Haemonchus contortus* being of overwhelming importance (Perry et al., 2002). This blood-sucking parasite is infamous throughout the humid tropics/ subtropics. Annual costs due to this parasite alone have been recently estimated to be $26m, $46m and $103m for Kenya (Anon., 1999), South Africa (I. Horak, pers. comm.) and India (McLeod, 2004), respectively.

H. contortus is probably the only nematode parasite of sheep and goats that can be accurately diagnosed without the aid of specific laboratory testing. Signs of acute anaemia are obvious. Past history and discounting other less common conditions causing anaemia, will strongly suggest clinical haemonchosis. On a worm-for-worm basis, *H. contortus* is considered to be the most pathogenic parasite of small ruminants. Although the free-living stages of *H. contortus* are not as tolerant to unfavourable climatic (cold, but particularly dry) conditions as the other important nematode parasites of sheep (Donald 1968; Waller and Donald 1970), the very high biotic potential and pathogenicity of this parasite ensure that it is a major problem in the humid tropics and subtropics (Anon. 1991; Waller et al. 1996; Chandrawathani et al. 1999; Anon. 2001; Perry et al. 2002). However, as Crofton et al (1965) postulated several decades ago, *H. contortus,* in common with other nematode parasites of livestock, exhibits considerable ecological and biological plasticity to overcome unfavourable conditions either in the external, or host, environment. Obvious examples in the latter are the ability of parasites to overcome extreme selective pressures within the host imposed by the use of anthelmintics. *H. contortus* is notorious for the development of anthelmintic resistance, which certainly would have emerged independently in this parasite species in many countries, if not regions within countries, of the world (Waller, 1997; Sangster, 1999, Kaplan, 2004).

Control of *H. contortus* in the Tropics, based on epidemiology

Government-owned sheep and goat breeding farms in Malaysia provide a source of animals to the small-holder farmers in the country. Despite the intensive use of anthelmintics on these farms, annual losses exceeding 25% of the total flock, attributed primarily to *H. contortus*, are commonplace. Recent investigations into the drug resistance status on several of these farms, showed total anthelmintic failure to all drugs (Chandrawathani et al. 2003; 2004a): see Table 1.

Table 1

Anthelmintic resistance status on Malaysian government small ruminant breeding farms (adapted from Chandrawathani et al. 2003; 2004a).

Govt. Farm	Percentage FEC reduction following anthelmintic treatment			
	Benzimidazole	Levamisole	Closantel	Ivermectin
Ranau	-122% (R*)	32% (R)	76% (R)	17% (R)
Purutan	17% (R)	22% (R)	-3% (R)	-54% (R)
Bongawan	2% (R)	82% (R)	35% (R)	41% (R)
Telupid	23% (R)	88% (R)	53% (R)	52% (R)
Lahad datu	40% (R)	85% (R)	25% (R)	67% (R)
Gajah mati	42% (R)	65% (R)	96% (SR^+)	73% (R)

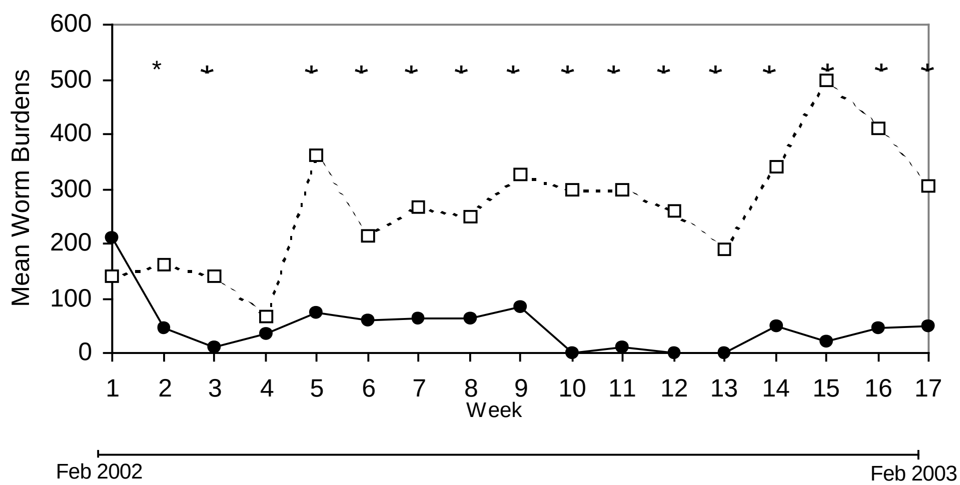
R*****: resistant; SR^+: suspected resistant. Based on Faecal Egg Count Reduction Test (FECRT) results

Clearly this situation is unsustainable – not only in maintaining viability of the government farms – but also because it facilitates the distribution of highly, multiple resistant parasites together with the animals to small holder farmers.

Changes in management are now being implemented on these government farms, based on short-term rotational grazing (only 2-3 days grazing on small pasture plots, returning to the original plot after 30 days spelling). The concept of rapid rotational grazing of sheep and goats in the humid tropics is based on previous epidemiological studies showing that contamination of pastures yields high numbers of infective larvae within one week (Banks et al. 1990), thus leading to auto-infestation of animals if they remain on the same pasture. However, the high numbers of infective larvae invariably decline to negligible levels within 4-6 weeks (Banks et al. 1990), apparently due to the fact that the actively moving larvae in water films rapidly exhaust their stored food reserves. Although this management system generally leads to excellent parasite control, the decline in the number of larvae can be more protracted particularly in unseasonably dry periods (Barger et al. 1994; Sani and Chandrawathani, 1996). This latter finding has led to further work aimed at improving *H. contortus* control, focused on the use of the nematophagous microfungus, *Duddingtonia flagrans,* in association with the rapid rotational grazing strategy. Spores of this fungus have been shown to survive passage through the gastro-intestinal tract of livestock, then germinate and spread on freshly deposited dung producing specialised nematode trapping structures. Thus, this fungus has the potential to break the life cycle of nematode parasites by capturing infective larval stages before they migrate from dung to pasture, where they would otherwise be acquired by grazing animals (Larsen 1999).

Long-term trials on commercial farms showed that the level of *H. contortus* infection on pasture was consistently lower on the fungal supplemented pasture compared with the pastures grazed by sheep managed under the short-term rotation alone (see Figure 1). This was reflected in significantly heavier weight gains of lambs that received the combination of rapid pasture rotation and fungal supplement (Chandrawathani et al. 2004b).

Figure 1
Mean monthly *H. contortus* burdens from tracer lambs (n=2) grazing with Control [broken line] and Fungus [solid line] treatment groups in Malaysian field trials. (from Chandrawathani et al. 2004b)
* Significant difference between Control and Fungus at P<0.05



Control of *H. contortus* at the Polar Circle, based on epidemiology

Although *H. contortus* is particularly adapted to the warm, wet conditions of the tropics / subtropics, there is an apparent increasing prevalence of this parasite in the temperate climate countries of Europe (U.K: Jackson and Coop, 2000; France: Hoste et. al. 2002; Netherlands: M. Eysker, pers. comm.; Denmark: S. Thamsborg, pers. comm.). Recent studies in Sweden have shown this parasite occurs in sheep flocks located at latitudes as high as the Polar Circle (Lindqvist et. al. 2001). This may be attributed to several factors that could include the general trend of warmer and wetter grazing seasons, the greater time animals spend on pasture, ineffective de-worming practices, the development of anthelmintic resistance, or as a consequence of the adaptation of *H. contortus* to unfavourable, non-chemical conditions experienced either by the free-living, or the parasitic stages. *H. contortus* in Sweden could have either become more cold tolerant for the development and survival of the free-living stages, and /or developed special survival mechanisms of the parasitic stages within the host, to ensure between-year survival.
Although anthelmintic resistance to the benzimidazole anthelmintics has been reported in *H. contortus* in Sweden (Nilsson et al. 1993), it appears that this is the extent of the resistance problem. Thus the increased prevalence of this parasite is likely to be due to some other adaptive mechanism. A recent study in this country has shown that *H. contortus* has undergone some unique epidemiological adaptations (Waller et al. 2004). Virtually complete inhibition of development occurs once sheep acquire infective larvae early in the grazing season. Almost no survival occurs over-winter on pasture. The peri-parturient ewes hold the key to between year transmission, as they often show high *H. contortus* faecal egg counts at the time of turn-out in early spring. This leads to early contamination of pastures and continuation of infection for a further year, with only one parasite generation/year (see Table 2).

Table 2
Mean worm burdens of tracer lambs (n=4) grazing for monthly intervals in a field trial conducted in Sweden (adapted from Waller et al. 2004)

Test No. (date)	*H. contortus*	*T. circumcincta*
1 (13/5 – 2/6)	0	100
2 (2/6 – 23/6)	0	725 (22%)*
3 (23/6 – 8/7)	163 (60%)*	713 (54%)
4 (19/8 – 4/9)	850 (100%)	4300 (73%)
5 (4/9 – 23/9)	3213 (97%)	5563 (46%)
6 (23/9 – 9/10)	28800 (100%)	37838 (88%)
7 (9/10 – 28/10)	55450 (100%)	78938 (91%)
Year 2		
9 (13/5 – 10/6)	625 (100%)	157873 (64%)
10 (6/7 – 31/7)	13 (100%)	7263 (38%)

*Numbers in parenthesis represent the percentage of the population inhibited in development at the early fourth larval stage in the mucosa of the abomasum

Winter housing of all small ruminants (sheep and goats) is virtually universally practiced throughout Sweden, and generally for a period of 4 - 5 months (December – April/May). Thus animals are not exposed to infection, and importantly there is no faecal contamination, on pastures. These results suggested that eradication of *H. contortus*, on a farm-by-farm basis in the first instance, to be a practical and realistic possibility for sheep (goat) flocks in Sweden. All ruminants on the farm (sheep, goats and cattle) need to be properly treated with highly effective anthelmintics during the winter housing period. This is because *H. contortus* is capable of infecting cattle, particularly young animals, and thus they could potentially act as a reservoir infection if not treated (Southcott and Barger, 1975). A 2-year pilot study on 2 farms was undertaken, where such a programme was followed. All ruminants on both farms were treated with anthelmintics during the winter of 2003/2004. Subsequent monitoring faecal egg counts and infective larval differentials of ewes and lambs for the following two grazing seasons were carried out, together with total abomasal worm counts of 10 lambs from each farm at the end of the 2004 grazing season, showed that this objective was achieved (Waller et al. 2006) – see Table 3.

Of course in any consideration of eradication of parasites, the potential importance of reservoir hosts needs to be considered. Sweden has large populations of wild cervids, notably roe deer (*Capreolus capreolus*) and moose (*Alces alces*). Moose favour browsing in woodlands and forests, whereas roe deer can be quite common in agricultural areas. Although *H. contortus* has been recorded in the viscera collected from hunted roe deer in Sweden, the prevalence was very low (<0.5%) in approximately 300 animals that were examined (Nilsson, 1971). Roe deer graze on pastures designated for ruminant livestock, but this is erratic and infrequent (rarely during the daylight hours). Additionally roe deer are by nature solitary, territorial animals. Even accepting that the occasional roe deer is infected with *H. contortus*, the expectation would be that the same epidemiological pattern, as described for sheep, would occur in these animals. That is, it is only the lactating female that is responsible for pasture contamination. The size of these animals is approximately that of sheep, thus one would expect that they would produce similar amounts of faeces. Thus on any given area of sheep pasture, where relatively large numbers of sheep graze, the contribution to faecal contamination of one, or even a small number, of roe deer make on the occasional short visit would seem to be totally insignificant and thus would not play a role in perpetuating *H. contortus* on sheep farms where eradication of this parasite is attempted.

Another very important point to consider before embarking on such an eradication plan for *H. contortus* is that if the anthelmintic(s) used do not have the efficacies expected in susceptible parasite populations (Benz et al. 1989), then the potential for rapid selection for resistance is a real threat as the whole parasite population is chemotherapeutically screened. Thus the best strategy would be to use a combination of all available broad spectrum anthelmintics on all ruminants on a farm during the winter housing period. The likelihood of multiple resistance in *H. contortus* populations in Sweden, where one broad spectrum drug class (the imidiothiazoles) has not been registered for use in sheep or goats, would be infinitesimally small.

Another important management issue on farms that have undertaken this strategy is to ensure that any ruminant livestock entering the farm are quarantine dosed with anthelmintic(s), to safeguard against the importation of *H. contortus* back onto the farm.

Table 3

Faecal egg counts of ewes and lambs and worm burdens of lambs on 2 farms in Sweden where eradication of *Haemonchus contortus* was achieved by dosing all sheep with anthelmintic during the winter of 2003/2004 (from Waller et al. 2005)**.**

Farm 1

Sampling Date	Mean Egg count (epg)	Infective Larval Differentiation				
		H. contortus	*T.circ.*	*Trich. spp.*	*Ch. ovina*	*Oesoph.*
2003						
Ewes 30 April	670	*36%*	*32%*	*8%*	*24%*	*0*
21 Aug.	25	*0*	*0*	*0*	*0*	*0*
25 Sept.	0	*0*	*0*	0	0	0
Lambs 21 Aug.	60	*0*	*0*	*0*	*0*	*0*
25 Sept.	240	*0*	*33%*	24%	17%	26%
2004						
Ewes 15 April	0	*0*	*0*	*0*	*0*	*0*
1 June	20	*0*	*23%*	*73%*	*4%*	*0*
Lambs 8 July	260	*0*	*63%*	*26%*	*11%*	*0*
31 Aug.	380	*0*	*7%*	*64%*	*16%*	*8%*
2005						
Ewes 19 April	200	0	25%	23%	50%	2%
Lambs 9 Aug	580	0	13%	8%	79%	0

Mean Worm Burdens (10) Lambs - October 2004

Nil *1855* *75* *Nil* *Nil*

Farm 2

		H. contortus	*T.circ.*	*Trich. spp.*	*Ch. ovina*	*Oesoph.*
2003						
Ewes 9 May	1650	*44%*	*16%*	*32%*	*8%*	*0*
19 Aug.	165	+	+	+	-	-
29 Sept.	10	-	+	+	+	-
Lambs 19 Aug.	80	*20%*	*25%*	*20%*	*35%*	*0*
29 Sept.	390	*20%*	*29%*	*33%*	*18%*	-
2004						
Ewes 15 April	0	*0*	*0*	*0*	*0*	*0*
18 May	10	*0*	*0*	*0*	*0*	*0*
Lambs 13 July	425	*0*	*28%*	*23%*	*42%*	*9%*
16 Aug.	440	*0*	*25%*	*45%*	*30%*	*0%*
2005						
Ewes 12 April	215	*0*	*15%*	*50%*	*15%*	*20%*
Lambs 29 June	620	*0*	*45%*	*55%*	*0*	*0*

Mean Worm Burdens (10) Lambs - October 2004

Nil *6183* *600* *Nil* *Nil*

Conclusion

In the endemic *H. contortus* regions of the world, sheep and goat farmers have relied on the use of anthelmintics, often given frequently and empirically (ie. every 3 – 6 weeks). As a consequence, high levels of resistance to the range of anthelmintics used in control of this parasite, have emerged (Waller, 1997; Sangster, 1999, Kaplan, 2004). Using anthelmintics in a responsible way is essential, but maybe too late for many sheep and goat farmers in the humid tropics / subtropics throughout the world, because of magnitude of resistance as illustrated above for government managed farms in Malaysia. By definition, a responsible way usually means less often and to achieve this may well mean government intervention. This has happened in Scandinavia where anthelmintics for use in production animals are sold only on prescription from veterinarians who firstly must make a diagnosis of parasitism. However, this practice relies on a more therapeutic than prophylactic approach and often takes no account of subclinical losses, widely considered to be the source of greatest economic loss.

So it has now become a generally recognized fact by researchers, and to an increasing extent by producers, that the anthelmintic arsenal for production livestock is unlikely to be expanded in the foreseeable future. Those associated with the sheep and goat industries, particularly in Australia and South Africa have realized for some time that the only way that these industries can cope with parasites in the face of escalating, or existing high level, of anthelmintic resistance is to 'live with worms'. Recognizing the importance of maintaining a level of parasitism in the flock is a good thing from the standpoint of inducing and maintaining naturally acquired immunity in grazing animals, as well as preserving anthelmintic susceptibility by not exposing the entire worm population to drug selection. Towards this goal, Australian researchers have developed a web-based interactive program called *WormBoss* for farmers to use for managing parasites in their flocks in the face of high level of anthelmintic resistance (Le Feuvre et al. 2005). Also of particular relevance in the control of *H. contortus,* South African researchers have developed the FAMACHA system that is aimed at the identification of only those animals in a flock that need anthelmintic treatment (Malan et al. 2001).

Thus there is a paradigm shift in the way to deal with parasites in small ruminant livestock – away from hard control and the chemical 'big hit' approach, to something more akin to parasite management, ie. living with parasites. These novel control methods will assist in maintaining parasite infections below the economic threshold, related not only to efficiency of treatment, but to the epidemiology of parasite infection, animal management practices and other considerations (Ketzis et al. 2006). This paper reports on two examples of how very effective control of *H. contortus* can be achieved that exploits vulnerabilities of its life-cycle based on a thorough understanding of the epidemiology of *H. contortus* infection in sheep and goats.

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