The role of epidemiological knowledge and grazing management for helminth control in small ruminants

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Abstract

There is no single requirement more crucial to the rational and sustainable control of helminth parasites in grazing animals than a comprehensive knowledge of the epidemiology of the parasite as it interacts with the host in a specific climatic, management and production environment. In its absence, anthelmintic treatment is either given suppressively, which provokes resistance, or therapeutically, which risks clinical disease and production losses. Sustainable parasite-control programmes require knowledge of seasonal larval availability, origin of larvae contributing to any peaks and climatic requirements for worm egg hatching, larval development and survival. Control measures based on this knowledge include strategic anthelmintic treatments and various forms of grazing management. While these measures can reduce the frequency of anthelmintic treatment required, their effect on selection for drench resistance is more problematical, unless they can be combined with other forms of control to reduce our current dependence on anthelmintics.

Keywords: Epidemiology; Grazing management; Anthelmintic; Control; Resistance

1. Introduction

There is no single requirement more crucial to the rational and sustainable control of helminth parasites in grazing animals than a comprehensive knowledge of the epidemiology of the parasite as it interacts with the host in a specific climatic, management and production environment. Because epidemiological studies typically extend over several years, tend to be conducted using simple “low-technology” methods, and rarely lead to patentable products or processes, they are frequently viewed with disfavour by funding agencies and hence by researchers. Alternatively, it is often considered that all of the necessary epidemiological work has already been done and that work conducted in one climatic region or production system can be extrapolated to another. Finally, in this trio of misconceptions, is the attitude that modern broad-spectrum anthelmintics render epidemiological knowledge superfluous, as all that is required to solve a parasite problem is to institute a regular programme of treatment with the latest product of the pharmaceutical industry.

In the absence of appropriate epidemiological knowledge, there are only two philosophical bases for anthelmintic administration. The first is to treat suppressively at intervals at or near the length of the pre-patent period of the parasite, or the effective persistence of the drug, whichever is greater; the second is to treat therapeutically, whenever clinical

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signs of excessive infection appear. Of these two approaches, the first is the most effective in the short term in minimising parasite populations and production losses, but has been repeatedly demonstrated both in the field and in computer models to select inexorably for drug resistance in the parasites [1–3]. The second certainly selects less strongly for resistance, but incurs significant risks of uncontrollable disease or production loss.

In this paper, I shall present a view of the epidemiological factors that I consider important in designing a parasite-control programme for sheep and goats, and give examples of how this knowledge can be used to minimise anthelmintic use, together with some observations on the probable outcomes for the evolution of drench resistance.

2. Epidemiological information required

2.1. Larval availability

The major epidemiological variable influencing worm burdens of grazing animals is the infection rate, or the number of infective larvae ingested from pasture each day. This is a difficult quantity to measure directly, so is usually estimated as the concentration of infective larvae per unit weight of the herbage on offer. As daily intake of pasture by ruminants is relatively constant on a day-to-day basis, daily intake of infective larvae will be proportional to the concentration of larvae on the herbage. Similarly, worm burdens of previously worm-free “tracer” animals grazed for short periods (2-3 weeks) also reflect current larval availability. When such measurements are made at regular intervals over at least a year, a pattern of the seasonal availability of infective larvae emerges. Such patterns show either a repeating seasonal picture of peaks and troughs, or, less commonly, a relatively constant level of larval availability throughout the year. So far, patterns of the second type have been observed only in wet tropical climates where temperatures and rainfall show little or no seasonal variation, and are indicative of favourable conditions for helminth egg hatching and larval development throughout the year [4]. The more commonly observed pattern of seasonal peaks and troughs is indicative of seasonal variation in egg-hatching, larval development and/or survival, induced by accompanying variation in temperatures or rainfall [5], or of seasonal variation in host susceptibility caused by population events such as parturition or lactation [6].

Clinical parasitic disease in small ruminants usually occurs at or shortly after times of peak larval availability. Regardless of the timing of, or even the existence of clinical disease, the timing of peak larval availability on pasture is of crucial importance in understanding the population dynamics of the parasite population, as this is when the largest worm burdens are acquired, and it is against these seasonal peaks that control strategies must be directed.

2.2. Origin of peaks in larval availability

It is useful to know the origin of larvae present during the peak. For example, do they arise from recent egg deposition induced to hatch and develop by recent weather events such as rainfall or favourable temperatures, or do they represent larvae derived from eggs deposited over many weeks or even months? The former is usually the case in outbreaks of *Haemonchus contortus* infection, while the latter is more typical of *Trichostrongylus colubriformis* or *Ostertagia circumcincta*.

This information is obtained routinely by serial plot contamination studies [4, 5, 7]. Typically, clean plots or paddocks of pasture will be contaminated naturally or artificially with known numbers of eggs of known parasite species at specified intervals throughout the year, and the resulting populations of eggs and/or larvae monitored by direct recovery from soil or pasture samples, or by the use of “tracer” sheep. Once the origin of the peaks is determined, consideration can be given to either preventing or avoiding them as part of a control programme. Contrasting patterns are usually seen from temperate and tropical regions. In temperate areas, eggs deposited over prolonged periods in winter, spring or early summer may result in large numbers of larvae being available to grazing animals in spring, summer or autumn, respectively, depending on the temperature–rainfall relationships. Eggs deposited on wet tropical pastures hatch
and develop to infective larvae very rapidly, resulting in peak infectivity on pasture in a week or so.

2.3. Survival of infective larvae on pasture

The relative ability of infective larvae to survive on pasture at different times of the year is also relevant to successful formulation of a control programme, as it will determine how long a pasture can remain dangerous following high levels of larval concentration. Generally, cool, dry weather prolongs larval survival, and hot, wet weather shortens it. This is attributable to the fact that infective larvae do not feed, and must survive on stored energy. Low temperatures and dry conditions prevent active movement by larvae and thus minimise their energy expenditure. Larval survival times on pasture can also be inferred from serial plot studies, and range from a few weeks in the wet tropics [4, 7] to well over a year in temperate climates [8].

2.4. Climatic requirements for egg hatching and larval development

These can be deduced from detailed serial plot studies or from laboratory studies where eggs or larvae are exposed to varying temperature regimes. These studies can indicate the kinds of conditions required for egg hatching and development to the infective stage, and how long eggs or first- or second-stage larvae can survive while waiting for such conditions to occur.

3. Control measures using epidemiological knowledge

3.1. Strategic anthelmintic treatments

The aim of a strategic treatment is to remove a worm burden that, if untreated, would later produce sufficient eggs to lead to an escalation in pasture infestation with larvae. Its influence is intended to be long-term, and therefore precautions against rapid re-infection are usually taken. In some cases these precautions involve movement of animals to a relatively uncontaminated pasture immediately after treatment. In others, the timing of naturally occurring seasonal or immunological discontinuities in infection are exploited.

3.1.1. Before a move to clean pasture

The treatment of young animals at weaning, in conjunction with a move to a spelled pasture, is almost universal in commercial small ruminant production systems, even though the spelled pasture may be provided more for nutritional than parasitological reasons. Once the parasitological benefits of a move to clean pasture following weaning are appreciated, special efforts can be made to avoid excessive contamination prior to the spelling period. These efforts may be as simple as avoiding grazing such pastures with parasite-susceptible animals such as weaners or lambing ewes in the 6 months prior to weaning, or as complex as pre-grazing the pasture with animals given controlled-release anthelmintic capsules or persistent anthelmintics. Movement of animals to a feedlot is an extreme example of this strategy, as re-infection with helminth parasites does not occur in feedlots, nor do resistant survivors of treatment leave progeny. A strategic treatment with a broad-spectrum drug would usually be warranted in these circumstances.

3.1.2. Before seasonal discontinuity in infection

Extreme climatic conditions of either very high or very low temperatures or intense drought can virtually sterilise a pasture in some environments. Any anthelmintic treatment given early in such an event becomes strategic in nature, as re-infection rates following treatment are so low that the effect of the treatment on subsequent contamination is prolonged. An example of successful exploitation of a seasonal discontinuity in infection is provided by the various summer drenching programmes for sheep and goats in the winter-rainfall regions of southern Australia. Here, hot dry conditions over summer result in very low larval availability, so that anthelmintic treatment at this time is followed by very low rates of re-infection [9, 10]. A similar situation can arise with the larvae of cold-sensitive species such as H. contortus or Oesophagostomum columbianum. Larvae of H. contortus cannot survive extreme cold such as occurs in a northern continental winter, so treatment of housed sheep or goats in winter should be very effective in con-
trolling this species. *Oesophagostomum columbianum* is even more a tropical species, and its larvae cannot survive even the relatively benign cold of an Australian winter. The advent of modern broad-spectrum drugs and their use during winter have practically eradicated this species in recent years [11].

3.1.3. *After attainment of immunity*

For some parasite species, such as *H. contortus* and *T. colubriformis*, resistance to new infection can occur well before already resident infections are expelled [12, 13]. An anthelmintic treatment at this time to remove the resident worms results in an extended period of low egg production because of acquired immunity to new infection. The difficulty in making practical use of this phenomenon, particularly with young animals, is in being able to determine exactly when they have developed this immunity. This is somewhat easier with lactating ewes that have temporarily lost their immunity. It is rapidly regained by weaning, so treatment of lambing ewes at weaning is usually effective.

3.1.4. *After a brief “window” of infection*

Perhaps the best example of a strategic anthelmintic treatment, albeit not one given to small ruminants, is the single treatment at 10 days of age with pyrantel to control *Toxocara vitulorum* in calves of buffalo and cattle [14]. Larvae of this highly pathogenic ascarid are transmitted only to calves within a few days of birth via the colostrum. Treatment with a drug active against immature parasites at this stage removes the pathogenic infection from the gut, and it is not replaced except by the non-pathogenic somatic stage of the parasite developing from eggs ingested from the environment. A single dose of an inexpensive anthelmintic thus prevents a parasitic disease effectively for the life of the animal.

3.2. *Grazing management*

The role of grazing management in worm control programmes based on epidemiological knowledge is simply to provide clean pastures on which stock may safely graze, usually, but not always, after a strategic anthelmintic treatment. The various forms of grazing management have recently been discussed and fully referenced elsewhere [15, 16], and only alternation of hosts and rotational grazing will be briefly discussed here.

3.2.1. *Alternation of host species*

To the extent that two or more host species in any given environment do not share common parasite species, alternation between the species can be a successful means of enhancing worm control. Small ruminants and cattle, small ruminants and horses, or horses and cattle would appear to be the most logical candidates for alternate grazing strategies, as long as *Trichostrongylus axei*, a species that can infect all host species, is not of major concern. The alternation of sheep and goats is unlikely to be of benefit as their parasite species are overwhelmingly shared. There have been occasional reports of *Ostertagia ostertagi* from cattle infecting sheep and goats, and of *H. contortus* from sheep cycling, but not causing disease, in young cattle when these host species have been alternated. In environments where *Haemonchus placei* infects cattle, great caution should be exercised if their pastures are used for grazing by sheep or goats, as this species is pathogenic in all hosts. In most temperate regions, however, each host species can be used to prepare clean pastures for the others, thus extending the interval required between anthelmintic treatments. Timing of pasture exchanges, lengths of rotations and measures required to deal with minor parasite species cannot be specified globally; they are matters for local experimentation illuminated by local knowledge of epidemiology and animal production systems. Little or no information is available on the place of some of the more recently fashionable host species, such as deer or alpaca, in alternations with traditional ruminant production animals.

3.2.2. *Rotational grazing*

This is a grazing management technique involving intensive subdivision of a pasture in which each constituent paddock is grazed for a short time and then spelled for a relatively much longer time. In a simple example, the total area for grazing might be subdivided into 15 paddocks, each of which could be grazed for 1 week and spelled for 14 weeks. The
grazing time in such a system is thus 1 week, and the rotation length is 15 weeks. Grazing times and rotation lengths for a given number of paddocks need not be constant all year round, but there are many conflicting demands in any rotational grazing scheme which will require that compromises be made in both agronomic and production objectives, let alone in any additional requirements for parasite control. For example, grazing time must not be so long that the survival of the pasture is threatened, but if too short, rotation length may not be sufficient for pasture re-growth. If rotation length is too long, ungrazed pastures may become rank and senescent, while grazed paddocks may be subjected to permanent damage. Too many paddocks imposes a severe burden in capital costs on the enterprise, while too few imply long grazing times and short rotations. The major requirement for parasite control, namely a long enough rotation length that most infective larvae originating from previous grazings have died off, is probably not achievable in temperate climates, given that substantial declines in pasture infectivity may take from 2 to 8 months to occur, depending on the climate and time of year. Certainly, there are no reports in the literature of successful deployment of rotational grazing for parasite control in temperate regions.

In contrast, rotational grazing may be useful on wet tropical pastures where larval survival times are short and can readily be incorporated within a practicable rotation length. The problem here tends to be in achieving a short enough grazing time to prevent auto-infection within a single grazing session, since development from egg to infective larvae can take as little as 4 or 5 days. A trial with a solar electric fenced 10-paddock system with a grazing time of 3.5 days and a rotation length of 35 days was conducted in Tonga in 1992 [7] and more recently in Malaysia (RA Sani, DT Chong, RA Haalim, P Chandrawathani, C Rajamanickam. Abstracts, Novel approaches to the control of helminth parasites of livestock. Armidale: University of New England, 1995;58), with encouraging results. This system is readily adaptable to more traditional husbandry methods, such as tethering and shepherding, used by smallholders in developing countries.

3.3. New epidemiological knowledge

In the 3 years since the first conference in Armidale, little has been published on the epidemiology of helminths of small ruminants, probably because of the factors suggested in the Introduction. However, some novel and potentially useful findings have come from the Animal and Veterinary Sciences Group at Lincoln University, Canterbury, New Zealand.

3.3.1. Nutrition and the periparturient loss of immunity in ewes

This loss of previously acquired immunity to gastrointestinal nematodes in ewes following parturition and lactation has long been investigated, but its mechanisms remain obscure [17]. Its significance in the epidemiology of helminthoses in ewes and lambs is beyond dispute, however, with the periparturient ewe responsible for much of the larval contamination of pasture to which her naive lamb is subsequently exposed. In a series of experiments with penned pregnant ewes exposed to trickle infections with *T. colubriformis* and *O. circumcincta*, Donaldson [18] has shown that a high quality protein supplement, but not an energy supplement, will abrogate the periparturient rise in egg counts and worm counts. This finding would make it technically feasible to discard at least one traditional anthelmintic treatment for lambing ewes. Further work will be required to make it economically attractive.

3.3.2. Winter contamination by ewes

Familton and McAnulty [19] and other New Zealand workers have described elevated faecal egg counts in ewes, and particularly in young ewes, during autumn and winter, well before lambing in spring. The production impact of this extended period of pasture contamination was shown by comparison of ewes given albendazole controlled-release capsules after mating with ewes given the traditional post-lambing drench. The capsule-treated ewes weaned around 50% greater total weight of lambs under both dryland and irrigated conditions, and the lambs from such ewes produced up to 20% more wool. The relevance of these results
to other climatic and production environments would be worth establishing.

3.3.3. Egg hatching and larval development under extreme climatic conditions

The same authors also reported epidemiologically significant development of *T. colubriformis* and *O. circumcincta* eggs and larvae on pasture during winter months, and some fascinating measurements of temperatures inside faecal pellets on pasture [20]. Some of these results are nothing short of astonishing. For example, over a couple of mild Canterbury summer days, in which air temperatures varied between 6°C and 16°C, temperatures within the faecal pellet varied between 6°C and 55°C. The upper temperature is almost certainly lethal and raises many questions about larval survival over summer in the temperate New Zealand climate, let alone in warmer regions.

3.4. Influence on selection for drench resistance

There is a popular view, certainly among farmers and extension workers, that treatment frequency is the best measure of the propensity of a control programme to select for drug resistance. This view probably arises from the fact that frequent treatment almost always results in rapid development of resistance. However, its converse is not necessarily true, and it cannot be assumed that control programmes based on epidemiological knowledge and/or grazing management are less likely to select for resistance because they employ fewer treatments [15, 21–24]. Nearly all examples of the successful use of epidemiological knowledge and/or grazing management to reduce treatment frequency involve treatment of the host during a “bottleneck” in the size of the free-living parasite population on pasture, such as before a move to clean pasture or an environmental discontinuity in infection. Under these circumstances, the parasitic population resident in the hosts at the time of treatment makes up almost the entire parasite population. This means that treatment can be extraordinarily effective, but can equally be extraordinarily selective, as resistant survivors can then contribute enormously to the next generation of parasites. Of the examples given in this paper, only the treatment of animals before going into a feedlot could be predicted as unlikely to intensify the evolution of anthelmintic resistance.

A better indicator of the propensity of a control programme to select for drug resistance, albeit much more difficult to estimate, is the genetic contribution that resistant survivors make to the next generation of worms [21]. This contribution is greater, all else being equal, when animals are treated frequently, but may be as great or even greater in animals treated only once and moved to a perfectly clean pasture. Some cases of frequent treatment, such as those based on the therapeutic approach described in the Introduction, involve treatment of animals grazing heavily-infected pastures. Resistant survivors of such treatments are immediately diluted by incoming larvae that have not been exposed to selection, thus diminishing their opportunity to contribute to the genetic basis of future worm populations on that pasture. Epidemiological knowledge and grazing management can certainly offer opportunities to reduce the number of treatments required, but cannot guarantee a commensurate reduction in selection for drug resistance. That can only come when our current reliance on anthelmintics, even at low frequency, has been replaced by a fully integrated approach involving epidemiology and management, together with additional components such as biological control, vaccines and resistant hosts. In my vision of a truly sustainable approach to worm control, anthelmintics would be used in support of other control measures, rather than in substituting for them as they do at present. Only if we can reduce our current complete dependence on these valuable compounds can we continue to enjoy their many benefits indefinitely.

References


