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ARMOUR, J.

THE EPIDEMIOLOGY OF HELMINTH DISEASE IN FARM ANIMALS

Since the inaugural meeting of W.A.A.V.P. at Hannover in 1963, there has been a plethora of articles on the epidemiology of animal helminthiases culminating recently in several authoritative reviews (Michel, 1969, 1974; Gordon, 1973; Kelly, 1973). Despite these excellent reviews, no attempt has been made to classify the available knowledge in relation to epidemiological principles of disease; in this, helminthology is out of step with other microbiological sciences. The purpose of this summary is to arrange the published data on farm animal helminthiases in the form of general principles which will assist the field investigator; detailed examples will be provided in the full published text.

There are four basic reasons for the occurrence of helminth disease in farm animals.

The first and most common, is *an increase in the infecting mass in an already infected environment.* This involves helminthiases which occur seasonally, usually after at least one parasitic generation. They occur in both segregated young stock and where adults and young share a common environment; the severity and morbidity of disease is usually less under the latter management system. A multiplicity of causes are responsible for seasonal fluctuations in the numbers and availability of infective stages, and these may be grouped as factors affecting contamination and those controlling the development, dissemination and survival of free-living stages.

The stocking density and the immune status of the stock influence the level of contamination; if the total number of susceptibles or the ratio of susceptibles to immune stock per unit area is wide during the contamination phase, then the level increases. Segregated young with minimal previous exposure are regarded as classical susceptibles, but immune adults also become susceptible during late pregnancy and lactation due to a temporary relaxation of immunity. At this time, freshly acquired infections or larvae previously arrested within the host by acquired immunity, develop to patency and contaminate the environment with eggs or larvae; the degree of contamination may be exacerbated by stress factors, e.g. poor nutrition or inclement weather. In certain instances the development of arrested larval stages involves transmission to the young, either pre-natally or via colostrum.

The phenomenon of hypobiosis in nematodes makes a significant contribution to contamination; in this, larvae ingested during periods of environmental adversity, i.e. when conditions are

unsuitable for free-living phases, will arrest in their development and become dormant; several months later on receipt of signals, either via the endocrine system of the host or possibly intrinsically, the larvae resume development and on becoming adult contaminate the environment. Sometimes clinical helminthiasis occurs following maturation of arrested larvae.

In most areas of the world, under natural conditions, populations of the free-living stages of helminths or where appropriate their intermediate hosts, fluctuate seasonally; several environmental factors which affect the microclimate in which these stages live, are responsible for this fluctuation. Temperature and humidity are particularly important, moderate temperatures and a high humidity favouring the development and survival of most helminth eggs and larvae. However, microclimate humidity depends not only on rainfall but on factors influencing the amount of moisture which remains in the soil, e.g. the soil structure, drainage and vegetation type. Rainfall is also necessary for the dissemination of larval stages on pasture while herbage length can affect the availability of these larvae; since most larvae are concentrated in the lower quarter, short overgrazed herbage will increase their availability, but paradoxically will also increase their exposure to adverse factors such as freezing or dessication. Since the effect of many of these climatic factors can be measured precisely, mathematical models have been developed to accurately predict the seasonal increase in infective stages and these should be of considerable value to the field veterinarian.

The second reason, is *an alteration in the susceptibility of the existing stock.* This may occur as an altered susceptibility to the effects of an existing infection or to the acquisition of a new infection. The former occurs mainly in mature animals, often harbouring quite low helminth burdens, is insidious in onset and is reflected in poor levels of productivity, the so-called sub-clinical helminthiasis. It is provoked by poor levels of nutrition such as exists for grazing livestock during the winter in temperate zones and in the dry season in tropical areas. Deficiencies of certain mineral trace elements are also thought to influence susceptibility to helminths. In many countries the period of gestation in livestock coincides with that of inadequate nutrition and low helminth burdens can then have a detrimental effect on the food conversion of the dam; this influences foetal growth and subsequently that of the neonate through poor milk production by the dam. Curiously, if highly immune animals with negligible worm burdens are subject to reinfection, the productivity can be impaired, presumably due to the effects of an exaggerated immune response.

Increased susceptibility to new infections can result from immunosuppression and may affect all age groups. Apart from the pregnancy and lactation effect mentioned previously, other pathogens can also have an immunosuppressing effect and so enhance the establishment of fresh infections. In certain instances, immunity is dependent on the continuing presence of low infections, and the removal of these by an anthelmintic can precipitate reinfection; there is some evidence that the type of anthelmintic used may influence the degree of reinfection.

The third reason, is *the movement of susceptible stock into an already infected environment.* Clinical outbreaks with a high morbidity fall into this category, usually occuring within a few weeks of exposure, i.e. without a further parasitic generation. Since immunity to most helminths is slowly acquired, young stock are very susceptible, particularly following segregation and movement in the post-weaning phase; helminth-naive adults moved from non-endemic to endemic areas are also at risk as significant age immunity occurs in only a few helminth species. Another factor which contributes to this situation is the great longevity of many helminth infective stages which results in the maintenance of a highly infected environment between the introduction of successive batches of livestock.

A variation in innate susceptibility to some helminths is also known to occur both between and within host species, the latter being associated with breed differences and in some instances haemoglobin type. New stock are usually selected on performance criteria and not on susceptibility to infection; the introduction of animals which are genetically ultrasusceptible to certain strains of helminths could exacerbate existing problems or even create new ones.

Finally, helminthiasis may occur following *the movement of infected stock into a non-infected environment.* This situation is less common and will only happen when infected animals are moved into a non-endemic area with an environment suitable for the free-living development of the helminth involved. If the latter conditions exist and a further parasitic generation is completed, then the exposure of the susceptible indigenous stock to the newly infected environment could result in clinical helminthiasis.

Although some overlap exists in the above classification, it is possible to allocate most episodes of helminth disease to one of the above categories. By recourse to the special epidemiology within each category, the field investigator should be able to identify the source of the problem.

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BRUNSDON, R.V.

PRINCIPLES OF HELMINTH CONTROL

In this review of recent research on prophylactic control, the discussion primarily refers to gastro-intestinal nematodes of sheep and cattle. It will be appreciated that the principles also apply to other helminth infections.

Eradication of most helminth infections is not practical. Rather the aim of control is to ensure that parasite populations do not exceed levels compatible with economic production. The objective is achieved by three interrelated approaches: by grazing management, by the use of anthelmintics and by dependence on the acquisition of immunity. Potentially, the most efficient control requires the complete integration of all three facets. This is possible only on the basis of a full understanding of the epidemiology of infections.

Helminthosis is primarily the result of ecological imbalance and the first step in the development of satisfactory control procedures must be a search for the predisposing factors. Overall patterns of larval availability are governed by climate, but the sum of husbandry practices largely determines the level of parasite hazard of a particular production system.

The control of helminthosis is rarely undertaken for other than economic motives. However, the measurement of loss due to helminths and of the benefits of control is far from simple. Frequently, parasitic disease is not recognised unless it represents a gross departure from the normal, and poor production due to helminthosis is often the normal situation. Furthermore, when the full economic consequences of subclinical infections are known, the levels of infection compatible with economic production may prove to be much lower than currently accepted. In the past, it seemed sufficient to evaluate the economics of a control programme simply in the broad terms of mortality prevention and meat and wool production. Now, with increasing intensification in farming enterprises, consideration must be given not only to "profit gained" but also to "loss avoided" and "opportunity cost". For this reason, decisions on the level of control desired and the assessment of the costs and benefits of various methods of control must be made in relation to the complete husbandry system.

Continuing extension of our understanding of the epidemiology of infections is leading to a new appreciation of the potential benefits which may accrue from the more rational use of anthelmintic treatment as one component of a comprehensive, preventive control programme. The results of

recent studies hopefully herald a return to the truly strategic use of anthelmintics, long advocated but largely ignored, in which the primary objective is to prevent or reduce pasture contamination rather than to remove worms which in many cases have a very short life expectancy.

At present most parasite control is "protective" in orientation and is based almost entirely on the regular use of anthelmintics. Whilst usually affording protection against serious disease and mortality, such treatments are frequently not effective in preventing the exposure of animals to high levels of pasture infestation. Consequently, production losses can still occur as a result of re-infection in the interval between treatments. In contrast, "preventive" control aims at:

(1) Preventing the build-up of dangerous numbers of larvae on pastures.
(2) Anticipating the periods during which large numbers of larvae are likely to occur and removing animals from heavily contaminated pastures before these periods.

These objectives can be achieved by the complete integration of the three facets of control mentioned earlier. In addition to its general applicability, this approach has a particular relevance to the control of disease resulting from the acquisition of large burdens of inhibited larvae (e.g., *Ostertagia ostertagi*) which may be unaffected by currently available anthelmintics.

Effective, integrated control is dependent upon a detailed understanding of the sequential interrelationships between the various sources of pasture contamination, the availability of infective larvae and the build-up and decline of infections; a knowledge of the time course of events is also of paramount importance. The interrelationships will differ according to variation in farm type and climate.

The essential requirement of integrated control is the provision of "safe" pasture for susceptible animals at appropriate times. Safe pasture is not parasite-free but has too few infective larvae on it to be directly damaging to susceptible animals. Such pasture can be produced by a variety of stock and pasture management manipulations (e.g., pasture spelling, fodder crops, hay or silage aftermaths, alternate grazing by another host species or alternate grazing by resistant animals of the same species) and maintained by the use of strategic anthelmintic treatments prior to the anticipated occurrence of conditions favourable for the free-living development of the parasites. In some climatic areas, an alternative to a change to safe pasture is the use of "critical", strategic anthelmintic treatments at times when re-infection is negligible.

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It is now appreciated that acceptable efficacy of such anthelmintic treatments, given for "hygienic" or "epidemiological" purposes, will require higher dose rates than those recommended for normal therapeutic use.

A different approach to preventive control has been the development of monitoring systems (e.g., faecal egg counts or pasture sampling on a regional basis) to indicate when pastures become dangerous. Similarly, the use of forecasting, on the basis of meteorological data, has been used to predict the likely occurrence of certain helminth diseases or the timing of a particular event such as a rapid rise in the availability of infective larvae on pasture. Computer simulation has also been attempted for the same purposes. Advocates suggest that such techniques allow the selection of appropriate treatment and management strategies. However, the practical value of such aids, in some circumstances, has been questioned.

As the specific objectives and requirements of preventive control become more clearly defined, questions arise as to the best form and method of implementation of control measures. It would seem practical and preferable to offer a number of "ready made" management systems rather than "made to measure" control procedures for each farming situation. Improved awareness, by farmers and their advisers, of the general principles, basis and aims of preventive control should allow broad strategies to be recommended. The means by which the objectives are achieved will necessarily vary because of differing management constraints.

In the face of increasing demands for complete production systems, decisions on parasite control can no longer be separated from other management considerations. It is essential that the methods of disease eradication, the costs and their benefits, be analysed in the broadest context and in relation to whole husbandry systems. This will involve a trans- or multi-disciplinary approach and will require the closest co-operation between helminthologists and various other specialists.

FALLIS, A.M.

EPIDEMIOLOGY AND ARTHROPOD PESTS AND VECTORS

The economic losses and disease caused by arthropod pests, and the pathogens they transmit amount to billions of dollars annually (Steelman, 1976). The losses are due to the constancy of the attack as well as to frank epizootics and are based especially on data from North America. Equivalent or more extensive damage almost certainly occurs in other parts of the world, especially in tropical countries for which statistics are not available. Such losses call for a redoubling of efforts to understand the causes, communication of this knowledge to those affected and concerned, and continuation or initiation of cooperative efforts to prevent or curtail the damage. Establishment of departments for epizootiological studies in universities and research institutes is recommended to assess the impact of various organisms on the live stock industry to assist with the coordination of control programs, and to conduct research in cooperation with other groups. Regional studies are often essential as the arthropod causing major damage in one locality may be absent or of minor importance in another. Moreover, the ecology may differ from place to place as well as the questions which require answers before control is feasible.

The review will summarize data pertaining to various groups of arthropods rather than attempt a comparison of epizootiology in one region with that in another. Indirectly arthropods have had, and still have, a profound effect on history and world development. The tsetse flies are in this category for they are limiting the use of 4½ million square miles in Africa or, as Swynnerton has suggested, holding it in trust until man learns to make proper use of it. In some parts effective control measures have led to an extension of grazing lands. This, together with expansion of herds, has resulted in over utilization of pasture. Omerod (1976) marshals evidence to support the hypothesis that overgrazing in places is responsible for climatic change. Klobe, too, (1974) stressed the necessity for correct land use and suggested establishment of game farms in some localities rather than attempting to make the land suitable for cattle. Basic and applied research involving several disciplines and the study of the epizootiology are desirable.

Mosquitoes are among the most widely distributed and annoying pests of man and beast and are of especial concern as vectors of several pathogens. Research has shown that some breeds of cattle are more resistant to attack by them than others. Similar conclusions have been reached by others concerning other arthropods such as ticks.

Continuation of such investigations, although time-consuming and costly, would seem in the best interests of all. Work on the transmission of viruses, such as Venezuelan encephalitis and western equine encephalitis, has demonstrated the necessity of understanding the feeding behaviour, host preference longevity and other aspects of the ecology of mosquitoes that serve as vectors of the viruses. Development of effective vaccines has facilitated control of some of these diseases.

Periodically, attacks by blackflies cause morbidity and mortality among live stock in several countries. Some flies are vectors of protozoan and helminth parasites also. The severity of the attack and the occurrence of epizootics of diseases they transmit depends on the prevalence and abundance of particular species. Outbreaks are influenced also by other factors such as feeding preferences of flies, longevity, flight range, climate, weather, and the number and variety of hosts available to them. Ecological investigations and search for novel methods of curtailing populations and preventing their attacks should be welcomed in communities throughout the world where these are a nuisance.

Species of *Culicoides* are annoying pests of humans and of special economic importance in veterinary medicine because of their roles in transmitting the viruses of African horse sickness and blue tongue of sheep. The extent and severity of the diseases are affected by the feeding behaviour and preferences of the insects and the availability of different kinds of animals. Occurrence of the viruses in reservoir animals facilitate transmission and complicate control. Further research on various aspects of the biology of these midges is essential to an understanding of their roles in causing epizootics.

Deer, horse, stable and hornflies are pests in several places and some transmit pathogens. They are responsible for losses of millions of dollars annually. Research recently on hornflies has extended our knowledge of these flies. Continuation of such research should be encouraged and at the same time the information should be communicated to those who can use it to try to control the pest.

Non blood-suck flies, the ox-warble, face flies and nose-bot flies of sheep, are responsible for losses far in excess of that expected from the size of their respective populations. Improved methods of control for the warble flies and organized implementation of them have eradicated the pest in some places. Control of nose bots has been less successful and more information on their biology is required. Face flies have become troublesome in parts of North America since their accidental introduction several years ago. They illustrate

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the importance of preventing the introduction of pests to countries where they are not endemic.

Losses associated with lice tend to be local and vary with methods of husbandry, weather, and the extent to which preventive and control measures are practised. Infestations with fleas are likewise local; those on dogs and cats are brought to our attention most often. Association of the breeding cycles of fleas with those of their hosts is of particular interest.

Ticks and mites are especially important pests and vectors in several countries. Mites cause disease and are important economically even if disease is not obvious clinically as in bovine demodicosis in Finland. The subcutaneous nodules are responsible for defective leather. Seminal degeneration in rams has been associated with chorioptic mange.

Factors which favour large populations of ticks and their behaviour in relation to the presence of different kinds of domestic and wild animals are only partially understood. Resistance of different breeds of cattle to attack by ticks and the stimulation of resistance is assuming increasing importance. The tendency of ticks to be non-specific in their feeding enables them to be independent of domestic animals and complicates control. Relatively small populations are required to maintain transmission of a pathogen or to cause a disease such as tick paralysis. The report, a few months ago, that a species of *Ornithodorus* reacts to sounds raises questions concerning the behaviour of other species.

The review suggests the desirability of more emphasis on epizootiology, fostering cooperation, basic and applied research, and communicating the results to those who can use them to improve the livestock industry by eliminating or controlling pests.

FAYER, Ronald

EPIDEMIOLOGY OF PROTOZOAL INFECTIONS: THE COCCIDIA

In the recent past, Veterinary Parasitologists used the term "coccidia" to refer to only eimerian or isosporan parasites. Parasites of these genera are monoxenous, and generally quite host specific, and most parasitize the intestinal tract. In hosts harbouring several species, each species exhibits regional or cellular specificity within the intestinal tract. Infections are self-limiting in that each stage is succeeded by another until the life cycle is completed. Stages include one or more asexual schizogonic generations followed by the sexual microgamete (male) and macrogamete (female) that give rise to the oocyst. The only exogenous stage is the oocyst, which serves as the only source of infection for all potential hosts. The oocyst is also the best known and most widely recognized coccidian stage; in most cases it serves as the sole criterion for diagnosis and species identification.

For many years, several genera of protozoa, each identified in the vertebrate host by a characteristic extraintestinal cyst, were classified as protozoa of unknown taxonomic status. Many publications documented the host range, prevalence, and cyst morphology of these parasites. What little was known of their methods of transmission was mostly incorrect, and nothing was known of their life cycles except the cyst stage. Members of this group included *Toxoplasma*, *Sarcocystis*, *Besnoitia*, and *Frenkelia*.

A renaissance in coccidiology began in 1970 when coccidian stages were identified as part of the life cycle of one of these cyst forming protozoans - *Toxoplasma*. Subsequently, coccidian life cycles were discovered for *Sarcocystis*, *Besnoitia*, and *Frenkelia*; a new genus of cyst forming protozoan with a coccidian life cycle was discovered and named *Hammondia*; the life cycles of at least three isosporan species were re-examined, and additional (facultative) hosts were found; and other isosporan species which were known only by their exogenous stage are now known to be part of a *Sarcocystis* life cycle.

To understand the impact of this recently found data on the whole of coccidiology, we need to examine the newly discovered life cycles and compare them both with one another and with the classical life cycles of eimerians and isosporans. The easiest place to begin is with those parasites whose life cycles differ least from the classical monoxenous cycle. These parasites include *Isospora felis* and *I.rivolta* of cats and *I.canis* of dogs. We have long known that they develop typical asexual, sexual, and oocyst stages in the intestine; unsporulated oocysts are shed in the

faeces; and these oocysts sporulate and are infectious for other hosts of the same species. We now know that the oocysts are also infectious for additional hosts - rats, mice, and hamsters - in which extraintestinal monozoic cysts develop. Extraintestinal cysts also develop in cats that ingest *I.felis* oocysts; cats, therefore, are both final and intermediate hosts. As a consequence of these findings we must recognize that these species are fundamentally different from the classical monoxenous *Isospora*; they are facultatively heteroxenous. This difference may warrant separate generic status. However, reinvestigation of *Isospora* may show that others or all members of this genus also have this previously unrecognized parasitic potential.

Toxoplasma gondii, like *I.felis* and *I.rivolta*, has a feline final host and is a facultatively heteroxenous coccidium. *Toxoplasma gondii* has a much greater host range than other coccidia have, and has numerous modes of transmission. Classical asexual and sexual coccidian stages develop in the intestine of the final host and an unsporulated oocyst is shed in the faeces. Sporulated oocysts may be ingested by other felines, and the classical cycle may be repeated in the intestine or liberated sporozoites may invade extraintestinal tissues. In extraintestinal tissues tachyzoites develop rapidly by endodyogeny, a type of fission in which two daughter organisms form within the parent organism. Tachyzoites may then give rise to cysts containing more slowly developing bradyzoites. Of all the coccidia, *Toxoplasma* poses the most serious public health problems. If oocysts are ingested by humans or almost any other vertebrate, tachyzoites and bradyzoites develop in the same manner as in the estraintestinal tissues of the feline. Tachyzoites or bradyzoites may be horizontally transmitted from one host to another by carnivorism, through milk, by droplets from sneezing, by blood transfusion, or by organ transplants. If the host is pregnant at the time of acute infection, tachyzoites may be vertically transmitted to the foetus. The feline final host probably becomes infected most often through carnivorism of rodents or birds; the feline ingests cysts containing bradyzoites, which initiate intestinal stages that result in the shedding of oocysts.

Besnoitia besnoiti of cattle and *B.wallacei* of rodents have the cat as the final host. The more studied species, *B.wallacei*, is an obligatory heteroxenous coccidium; rats and mice are intermediate hosts. Classical asexual and sexual coccidian stages develop in the intestine of the final host, and unsporulated oocysts are shed in the faeces. After sporulating, oocysts infect only the intermediate hosts in which extra-intestinal cysts develop. Cyst-to-tachyzoite-to-

cyst transmission between intermediate hosts has been repeatedly documented for other *Besnoitia* species in the laboratory and could possibly occur in nature through carnivorism.

Some characteristics of *Hammondia hammondi* are similar to those of both *Toxoplasma* and *Sarcocystis*. The oocyst of *H.hammondi*, which is shed by the final host, the cat, is morphologically indistinguishable from that of *T.gondii*. However, *H.hammondi* is an obligatory heteroxenous coccidium and rats, mice, guinea pigs, hamsters, deermice, and dogs are the known intermediate hosts, whereas *T.gondii* is facultatively heteroxenous. Classical asexual and sexual coccidian stages of *H.hammondi* develop in the intestine of the final host; unsporulated are oocysts shed in the faeces. Ingestion of sporulated oocysts by intermediate hosts initiates development of tachyzoites in the intestinal wall and mesenteric lymph nodes followed by development of cysts in striated and cardiac muscle and, rarely, in the brain. Cysts resembling those of *Sarcocystis* lack metrocytes and bradyzoites are slender like those of *Toxoplasma*. Cysts are infectious, through carnivorism, for the final host only.

Many species of *Sarcocystis* have recently been identified each with a carnivore final host. Final hosts for various species include man, dogs, cats, wolves, foxes, coyotes, hyenas, racoons, and snakes. All *Sarcocystis* species are obligatory heteroxenous coccidia. Asexual coccidian stages have not been found in the final host; sexual stages develop in the intestine, and typical isosporan oocysts sporulate in the lamina propria of the small intestine. Most commonly, individual sporocysts are shed in the faeces. Sporocyst infectivity is quite specific for the intermediate host. Schizonts develop in vascular endothelium throughout the body; then cysts develop in striated and cardiac muscle and in neural tissue. Young cysts contain a noninfectious multiplicative stage, the metrocyte; as cysts mature infectious bradyzoites develop. Cysts are infectious, through carnivorism, for the final host only.

The life cycle of only one *Frenkelia* species is known. It is quite similar to that of the *Sarcocystis* species. A carnivorous bird is the final host of this obligatory heteroxenous coccidium. Sexual stages and unsporulated and sporulated oocysts develop in the lamina propria of the small intestine, and sporulated sporocysts are shed in the faeces of the bird. After sporocysts are ingested, schizonts develop in the liver of mice, followed by development of cysts in the brain. Young cysts contain metrocytes; mature cysts contain bradyzoites that are infectious, through carnivorism, for the final host.

From an epidemiologic viewpoint, the oocyst, as the only exogenous stage, is of central importance in the dissemination of all the genera

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discussed. It is a hardy, long lived, diapause phase. Numbers shed, factors affecting sporulation, survival, longevity and excystation, all bear on infectivity and thus on epidemiologic potential. Structurally, oocysts of *Tosoplasma, Besnoitia, Hammondia, Sarcocystis,* and *Frenkelia* are all the isosporan type and contain two sporocysts, each with four sporozoites. These genera appear to have evolutionarily added a cyst stage, which is essentially a second diapause phase, to the classical coccidial life cycle; thus, infectivity is further prolonged and completion of the life cycle is further ensured. Because of these cyst stages, much greater diversity in life histories are found amongst these genera than has been observed amongst parasites with eimerian oocyst morphology. Although life history diversity may be greater among the genera with isosporan oocyst morphology, the diversity in sizes and shapes of their oocysts and sporocysts is less. Now, the classical practice of naming and identifying species strictly on the basis of oocyst morphology apparently is no longer tenable. *Hammondia* oocysts cannot be distinguished from those of *Toxoplasma* or of *Isopora bigemina* and, most *Sarcocystis* cannot be distinguished from others of the same genus or from those of *Frenkelia*. Similar problems are encountered when we try to identify a species of *Sarcocystis* solely on the basis of cyst morphology. Considering the fact that a single intermediate host may harbour several species of *Sarcocystis* from various final hosts and that cysts of a single species change as they mature, identification of the species solely on the basis of the cyst stage is not always practical. Identification by serology also may be less accurate than it was once thought to be. When interpreting serologic tests for toxoplasmosis, one must now consider the fact that antibody to *Hammondia* in several intermediate hosts cross reacts with *Toxoplasma* antigen; this cross-reaction could lead to mistaken diagnosis of toxoplasmosis.

Thus, as we have learned more about the diversities in life histories, epidemiologic potentials, and interrelationships among the genera of coccidia, the certainty of proper identification of coccidian parasites has become more difficult.

MORLEY, F.H.W.

A.D. Donald

FARM MANAGEMENT AND SYSTEMS OF HELMINTH CONTROL

This paper examines relationships between farm management and gastro-intestinal helminthoses of grazing ruminants. Systems of grazing management and systems of treatment with anthelmintics are both considered.

Management decisions, perhaps made for reasons unrelated to helminth control, may modify the extent and severity of helminthoses. Helminthoses may render necessary, or desirable, modifications of management. Management decisions aimed at helminth control cannot be considered in isolation from their effects on other parts of the enterprise, since they compete for labour, finance, land, skills, and perhaps other resources.

The immediate effectiveness of integrated systems of parasite control is based on reducing infection rates by combining few anthelmintic treatments with the natural occurrence, or deliberate provision, of safe pastures. In the long-term, such systems may reduce the rate of selection for drug-resistant parasites by minimising drug use. Even if they do not, there is less dependence on the single factor of anthelmintic efficiency than if drugs are used alone.

The kinds of management decisions which may influence the extent and severity of helminthoses in grazing animals include:

1. Choice of stocking rate;
2. timing of reproductive events - especially parturition and weaning;
3. pasture resting, including rotational grazing;
4. alternate grazing by hosts of the same or of different species;
5. mixed grazing by hosts of the same or of different species;
6. production and use of fodder crops, new sowings, and aftermath of hay and silage;
7. variations in the proportions of young and adult livestock;
8. choice of pasture species.

The number of free-living parasites per unit area of pasture, referred to here as the *pasture contamination status* (PCS), is distinguished from *pasture infectivity* (PIF), the number of infective stages ingested by a grazing animal.

1. Choice of stocking rate. The effects of stocking rate (SR) on production are well documented but very few studies have evaluated the effects of SR on helminths. Increased stocking rates reduce production per head, decrease pasture cover, and may increase the PCS but not necessarily the PIF depending on the effects of microclimate. Available evidence indicates little or no effect of

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SR on the productivity of grazing animals through parasites. The effects of higher SR on the PIF, through its effect on microclimate on development and survival, may balance any increase in rates of contamination. In the animal, varying levels of larval intake may affect asymptotically the development of resistance, worm burdens, the output of eggs by the worms, and animal performance. Evidence indicates that within broad limits variations in SR need not imply a need for variations in methods of helminth control.

2. Timing of reproductive events may be modified to facilitate the provision of safe pastures at parturition and weaning, without which anthelmintic treatment is likely to be ineffective.

3. Pasture spelling including rotational grazing. Ample evidence exists that feasible systems have little favourable impact on helminth control, largely because free-living forms can survive for periods much longer than the length of a grazing rotation.

4. Alternate grazing by hosts of the same or different species. Alternation of sheep and cattle may be especially effective against parasites such as *Ostertagia*, for which there is little cross transmission and which are difficult to control by other measures. Such management may even eliminate the need for anthelmintics. To contribute significantly to control in both host species, numbers of each must be sufficient to use effectively the land to be occupied by the alternate host. Preçautions must be taken that cattle are not unduly penalised, even allowing for compensatory gains, by being transferred to pastures which have been closely grazed by sheep. The possibility of evolution of cross-infective strains of parasite must be kept in mind.

Alternating older animals, with low egg outputs, with young susceptible animals could be useful, especially if conditions do not favour rapid turnover of generations of parasites. The adjustment of stocking rates to accommodate priorities in provision of feed may present problems.

5. Mixed grazing by hosts of the same or different species. The effect of this is to reduce the PCS and PIF for different hosts or for the more susceptible group of the same species. The grazing of dairy calves with the cows, rather than in a special calf paddock, could reduce PCS by a factor of 20 to 30 for the calves.

6. Fodder crops, new sowings, and aftermaths. Large areas of aftermaths from hay and silage crops are available in some countries, and may provide high quality grazing, relatively free from parasites, for young susceptible stock. These are unlikely to be available at parturition, but will often be useful for weaners. In countries such as Australia, Argentina, and New Zealand, the

substantial costs involved may cause the area to be restricted, especially if fodder cropping and conservation are of doubtful economic value. The area treated must be a substantial portion of the farm. Hence the SR on the untreated portion must be raised substantially for sufficient time for PCS to die out. Penalties in production incurred during the period of exclosure may be substantial unless this occurs during periods of feed surplus. The areas must also be sufficiently productive to carry susceptible livestock long enough for the untreated portion to lose most PCS and PIF. Such conditions may prevail in mediterranean or monsoonal climates.

7. Variations in the proportions of young and adult livestock. If control is relatively difficult and costly in younger animals the costs to the enterprise may be reduced by increasing the proportion of marketable products produced by older animals. Beef cattle may be marketed at greater ages and perhaps heavier weights, and wethers or yearlings may replace portion of the breeding ewes in wool producing and sheep-meat producing flocks.

8. Choice of pasture species. There are indications that helminthosis is less evident on pastures based on lucerne (*Medicago sativa*). The basis for this is not clear, nor is the extent of similar pasture factors known. Even were they to be widespread they would not have been detected in the majority of investigations.

Multiple dosing with anthelmintics

Major changes in well-established systems of production may incur substantial departures from the objectives of the farmer. Hence systems of parasite control which depend on frequent dosing with anthelmintics, and are relatively independent of production systems, have been advocated widely, and have certainly given good immediate results. In the long term such systems may prove to be unsatisfactory because they invite drug resistance, are costly in drugs and labour, and are unlikely to be adhered to. The epidemiology of the parasites considered here is such that effective control systems can be based on 2 or 3 dosings per year, combined with the provision of safe pastures, either through managerial manipulation or by timing of dosing to coincide with periods of rapidly diminishing or low PIF. Multiple dosing should be necessary only when, because of unusual environmental conditions, susceptible animals cannot be protected against massive reinfections from heavily infective pastures.

Summary Viewpoint

The effects of management in helminth control, and *vice-versa* seem insufficiently understood not only by farmers, but by their professional advisers. Recommendations based on helminthological information frequently fail to take into account

MORLEY, F.H.W.

the ecology of farm management. Although there are signs of improvement, the current failure to use information which is readily available in considering strategies such as rotational grazing, and the frequent advocacy of dosing at parturition emphasize the gaps between helminthology, ecology and farm management decisions. This paper is one attempt to reduce these gaps.

GIBSON, T.E.

THE APPLICATION OF ANTHELMINTICS IN THE FIELD

The pharmaceutical industry has made available to veterinarians a wide range of efficient, safe anthelmintics effective against a wide range of helminths which affect livestock. These drugs are available in a variety of preparations for administration as a drench, in the food, or by injection and the value of these preparations in various situations is discussed. The curative use of anthelmintics is only a minor part of their function and their application for prophylaxis is considered in relation to such phenomena as the spring rise, arrested development and the fluctuations of larval populations in the environment. The use made of forecasting for the timing of anthelmintic medication is described as well as possible future developments in this field. Some projections are made as to the direction in which future anthelmintic medication may develop.

REINECKE, R.K.

CHEMOTHERAPY IN THE CONTROL OF HELMINTHIASIS

Anthelmintic Tests

The faecal worm egg count test (Gordon, 1950); the critical anthelmintic test (Hall & Foster, 1918); the controlled anthelmintic test (Moskey & Harwood, 1941); the critical controlled test (Steward, 1955); the test of Banks & Michel (1960) and the improved controlled test (Gibson, 1964) were tested on an extensive scale in sheep.

From these findings the larval anthelmintic test was developed. Pure strains of various nematode species, worm-free lambs and calves; stables and pens that can be kept free of worms; feed that is worm-free and improved methods of worm recovery are essential in order to carry out these tests successfully.

Separate groups of sheep or calves are used and infective larvae of most species dosed every day until worms are present either
(a) as 3rd stage larvae and the 3rd moult or
(b) as 4th stage larvae and the 4th moult or as
(c) 5th stage and sexually adult worms.

In *Dictyocaulus filaria*, the 3rd stage 3rd moult 4th stage 4th moult take place in the mesenteric lymph nodes and therefore these stages and moults are combined in one group.

Species that infest percutaneously do not lend themselves to repeated infestation, e.g. *B.phlebotomum*, *G.pachyscelis* and *S.papillosus*, and therefore the improved controlled test of Gibson (1964) is used for these species.

Data are analysed by the non-parametric method (NPM) of Groeneveld and Reinecke (1969) as modified by Clark (1969). The following appears on the label of the container of the anthelmintic

Class A: More than 80% effective in more than 80% of treated animals
Class B: More than 60% effective in more than 60% of treated animals
Class C: More than 50% effective in more than 50% of treated animals
Class X: Ineffective

The NPM is also suitable for analysing data of controlled tests of young and adult trematodes.

Critical tests on naturally acquired cestode infestations are done and in order to estimate the percentage of the treated animals that are affected by the compound, 30 animals should be treated. Cestodes are usually present as single worms or in low numbers of 2 or 3 and therefore the binomial method is used to test the results which are expressed in numerals in order not to confuse them with the results on nematodes, which then reads:

Class 1: 100% effective in more than 80% of treated sheep

Class 2: 100% effective in more than 60% of treated sheep
Class 3: 100% effective in more than 50% of treated sheep
Class X: Ineffective

Epizootiology

An attempt has been made to correlate data of critical worm surveys carried out in the Southern Hemisphere, by workers in the Republic of South Africa, New Zealand and Australia, in four climatic zones depending on the rainfall.

Non seasonal rainfall. Data are derived from Muller (1968), Brunsdon (1970, 1973) and Southcott, Major and Barger (1976). Intestinal *Trichostrongylus* spp. are rife from February until September: *Trichostrongylus axei* from March to September and *Ostertagia* spp. reach a peak in New Zealand from April to May, in Australia from June to September and in the RSA from August to September.

Haemonchus contortus - these worms are plentiful from January right through to September in some areas and in all countries hypobiosis starts in March or April and continues until spring.

Nematodirus spp. are prevalent in October and November and again from January to June while *Cooperia* spp. are more prevalent from March to August. Treatment will have maximum effect in October and November when most larvae are at a low ebb.

Summer rainfall (Rossiter, 1964; Barrow, 1964; Horak, 1977b; Horak and Louw, 1977a,b).

H.contortus - total worm burdens reach peaks from December to April or May, adults dominating until January or February and hypobiotic larvae increasing from March to a peak in June.

Trichostrongylus spp. - in some areas heavy infestations occur from March to August and *Ostertagia* spp. from February to June and near the coast may rise in spring from October to November.

Oesophagostomum columbianum finds suitable conditions in the grazing from January to May.

Treat in September with a broad spectrum anthelmintic and with disophenol in December and March to control adult *H.contortus*.

Winter rainfall (Anderson, 1972, 1973). *Ostertagia* spp. and *T.vitrinus* occur from June to September while *T.axei* persists until October and *Nematodirus* spp. are always present on the grazing. Flock treatments are advocated in October and January by Anderson (1973).

Semi arid (Viljoen, 1964, 1969). The example chosen is the Karoo in the RSA. *N.spathiger* and *T.falculatus* increase from March to a peak in July or August possibly boosted by more than 60 mm of rain in March because only 1-9 mm per month occurred in the winters that followed.

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Treatment any time in summer with a benzimidazole, morantel or levimisole would have maximum effect.

The classification of anthelmintics by Gordon (1973) and Kelly, Gordon and Whitlock (1976) is briefly summarized and integrated worm control advocated. Ewes are drenched prior to lambing, placed on pastures that have been rested and lambs treated in spring with mebendazole or cambendazole, effective against cestodes and nematodes. Autumn lambs are also treated with these compounds in winter and non seasonal rainfall areas in May and July or with niclosamide or resorantel in summer rainfall areas in these months.

Weaners are treated at weaning and all sheep injected with disophenol in December and in March wherever *H.contortus* is rife.

Grazing with an alternate host, e.g. cattle, advocated by Southcott and Barger (1975) has proved a good method of removing sheep parasites from pastures.

For maximum production the advantages of low-level dosing with thiabendazole is discussed. A plea is made for an integrated approach to research on worms using the talents of workers in the state, universities and the pharmaceutical industry.

URQUHART, G.M.

APPLICATIONS OF IMMUNITY IN THE CONTROL OF PARASITIC DISEASES

Over the past two decades, interest in the immune responses associated with helminth and protozoal infections has increased enormously. The stimulus has been essentially three-pronged.

First, the increasing awareness that the parasitic infections of man such as malaria and schistosomiasis are still a major cause of suffering and death. For example, malaria, which the layman tends to regard as a disease which has been largely solved, still kills on average one million annually, and causes severe illness in many times that number. Studies of the epidemiology of many of these diseases have shown that the natural development of acquired immunity plays an essential role in containing their effects, and considerable effort is being expended, in the face of immense theoretical and practical difficulties, in attempts to induce artificially a substantial degree of immunity.

In the veterinary field, the practical success of the irradiated larval vaccine against the bovine lungworm *Dictyocaulus viviparus* stimulated a great deal of similar work with other important helminth infections. For a variety of reasons these have been largely unsuccessful to date, although the knowledge obtained has played a valuable role in the exploitation of new anthelmintics in the development of prophylactic regimens.

The third prong of the stimulus has been the interest aroused in immunologists by the astonishing variety and complexity of host parasite interactions. Antigenic variation, immune unresponsiveness and immaturity, immunosuppression, the production of blocking antigens, the potentiation of IgA and IgM responses and other phenomena all occur to provide a satisfying field of scientific effort which is both intellectually challenging and of potential practical significance.

In this review it is not intended to catalogue every aspect of the applications of immunity in the control of parasitic diseases of animals; rather it will discuss in some detail the potential of immunological control in a number of important animal diseases of helminth and protozoal aetiology, with most of which the author has some personal experience.

Among others, it is hoped to discuss the application of immunological procedures in the control of trypanosomiasis, East Coast Fever and babesiosis.

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The first two of these diseases, of primary importance in the African continent, traditionally present two sides of the immunological spectrum, in that in trypanosomiasis the apparently repeated susceptibility of domestic stock in endemic areas contrasts with the life-long immunity of cattle which have survived a single attack of East Coast Fever. The real situation is rather more complex, and it is intended to examine this in some detail with regard to the development of practical methods of immunisation.

One of the most successful achievements in veterinary protozoology is that vaccination against bovine babesiosis has recently been achieved on a large scale in Australia, and the way now seems open for the application of this technique to the many areas of the world where babesiosis presents problems in the maintenance and translocation of cattle.

Of all the possible vaccines against helminth infections of farm animals, one against haemonchosis in sheep would be of undoubted value both in areas of sophisticated husbandry and in developing areas where regular chemoprophylaxis is not practised. This has not proved possible due to a number of factors; some of these are poorly understood and perhaps this field of investigation has been rather neglected considering the worldwide importance of the disease. The role of a number of these factors, such as the age and breed of the host and the effect of anthelmintic therapy on the development of the immune response, will be reviewed together with relevant results from comparative studies on small laboratory animals.

Finally, it is proposed to discuss some recent advances in the immunology of infections such as bovine ostertagiasis and cysticercosis. Although very effective anthelmintics are available for the control of the former, the natural development of an effective immune response normally plays a highly significant role in maintaining a sustained level of protection. The problem, perhaps still unresolved, is how to get the best of both worlds.

In bovine cysticercosis, recent reports of effective techniques of immunisation have reawakened interest in this subject. It is hoped to discuss the opportunities and problems associated with immunological control of this infection, which continues to plague many ranching endeavours in developing countries.

MORRIS, R.S.

MEASUREMENT AND EVALUATION OF THE ECONOMIC EFFECTS OF PARASITIC DISEASE

The Value of Economic Analysis

Although veterinary parasitologists were among the earliest research workers to relate the severity of disease to its financial consequences, most of the early reports were concerned with estimating the "cost" of parasitic diseases to an individual or a nation. This approach is undesirable, because it incorrectly infers that this cost is completely recoverable, a situation which would only be true if perfect control of the disease could be achieved at no cost! Much greater value is obtained from studies on the economic benefits of control procedures.

In recent years soundly based economic analyses have been used to an increasing extent in veterinary parasitology, and considerable experience has been accumulated in the application of economic techniques in research on parasitic disease. This paper will review both economic and parasitological aspects of such investigations.

Components of an Economic Study of Parasitic Disease

The principal value of an economic analysis is that it permits the livestock producer to make soundly based decisions on what action to take with respect to a particular disease. Studies should therefore compare a number of alternative strategies within a single experiment. The control procedures selected for evaluation should cover as wide a range as possible, from nil (or minimal action) through a number of strategies grouped around the anticipated optimum level of control, to a strategy which achieves maximum control of the disease, irrespective of cost.

If the study is designed in this way, it becomes possible to produce a response surface for increasing intensity of control (known to economists as a production function), and the results can then be applied much more effectively than would be possible for a less comprehensive study.

Experiments should be designed so that adequate physical measurements can be made, both of productivity of the animals and also of activities required to achieve each level of control. This permits re-evaluation of the experimental data in the light of altered circumstances, whereas a study which solely records financial data rapidly becomes outdated, and cannot be updated.

In essence, a well designed economic experiment consists almost entirely of careful physical measurement, and interpretation of the results. Actual financial calculations are only required in the final stage, and are totally dependent on the quality and appropriateness of the physical results. Most errors in economic studies result from inappropriate or incomplete measurements being taken in the experimental phase of the study.

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Physical Measurement of Benefits and Costs

The economic effects of a parasitic disease in animals can be characterised as falling in one or more of the following categories:-

(i) Reduction of quantity of product through depression of feed intake.
(ii) Reduction of quantity of product through depression of feed digestibility.
(iii) Reduction of quantity of product through depression of feed conversion efficiency.
(iv) Reduction of product quality, or aesthetic acceptability of the product to consumers.

If possible, experiments should endeavour to estimate the importance of these four mechanisms in a disease, and to quantitate their contribution at various levels of severity of the disease. This in turn requires special precautions to be taken in developing the experimental design, so that all appropriate components of both benefits and costs can be included.

Economic Interpretation of Experimental Results

The simplest and most widely applicable analytical procedure is partial farm budgeting. Only those components of farm income and expenses which are influenced by the control programme are measured, so considerable care is required to ensure that all relevant items are included, and that items are not unintentionally "double counted" (one of the most common errors). This technique, and its application will be described in detail in the paper.

Gross margins analysis is a technique which permits economic comparisons to be made between farms, using defined components of farm returns and expenses. While this produces a figure which appears to be closely related to the "actual" benefit of a control programme applied to a group of farms, there are a number of serious limitations of the technique, when applied to actual field studies.

Benefit-cost analysis is the most appropriate analytical tool when a control programme involves capital expenditure, and/or large contributions from public funds, and when implementation of the programme and achievement of the benefits will occur over a period of years.

For all economic analyses, the expected financial return is not the only criterion on which results should be assessed. Sensitivity of the results to variation in climatic or management circumstances, product prices and experimental results must also be taken into account. These are characterised by economists as the "riskiness" of a decision, and can be included in the consideration of results through a technique known as decision analysis. This combines economic and statistical components, and is more appropriate for economic studies than traditional statistical procedures.

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Design of Economic Experiments

Economic studies are intended to provide information for decision-making, so it is essential that experiments replicate field conditions as closely as possible. Abnormal management systems (such as pen studies for grazing animals) should only be used when absolutely necessary, and experiments should be designed to ensure that equal quantities of feed are available to all experimental groups, and that confounding between effects of disease and other factors (such as changes in effective stocking density) are avoided.

In order to make experiments applicable under a range of circumstances, replication of grazing experiments at a number of geographical locations deserves serious consideration.

The biggest difficulty in field experiments is to provide appropriate valuations for the end-products of the experiment, particularly since it is frequently inappropriate to market the animals in the usual fashion. Economic procedures which can be used to minimise this difficulty will be discussed in the paper.

Synthesis of Information

Economic experiments are inherently very demanding of resources and staff, so it is necessa necessary to minimise the number of experiments undertaken, and to obtain maximum value from each study.

The technique of computer modelling provides a valuable adjunct to such efforts, since it permits the experimenter to extrapolate his conclusions to circumstances beyond those of the field studies, and strengthens the foundations on which advice is given. Computer modelling also permits the findings from a number of studies to be drawn together, and recommendations made on control options and future research. The way in which this can be done will be described in the paper.

WHARTON, R.H.

K.R. Norris

CONTROL OF DISEASES DUE TO PARASITIC ARTHROPODS

Parasitic arthropods cause diseases of varying degrees of severity in domestic animals, in addition to acting as vectors of pathogens. They may be directly responsible for production losses due to (a) irritation, as from non-biting flies, (b) "worry", compounded of irritation, allergic responses and blood losses from feeding by fleas, lice, keds, biting flies, mites and ticks, (c) deaths or debilitating effects, with possible damage to carcass, fleece or skin, from the attacks of myiasis flies, and (d) paralysis or toxicosis produced by the feeding of certain ticks.

Production losses and costs associated with the control of parasitic arthropods are immense. In the U.S.A., in addition to losses from screw-worm, annual production losses were estimated to be nearly $900 million in the 1951-60 period. In Australia, the cattle tick was estimated to cost the cattle industry A$42 million per year in 1972-73, about $4-5 per head while the sheep blowfly was estimated to cost the sheep industry A$28 million per year in 1969-70, about 20c per head. These problems, like the screw-worm before eradication in U.S.A. and ticks in Africa, have dictated livestock management practices for many years.

Assessments of the effects of parasitic arthropods on production and costs associated with their control are important for decisions on the action to be taken against them at the individual, community or national level.

Past Approaches to Control

Approaches to the alleviation or elimination of parasitic arthropod problems have involved eradication or attempted eradication (sheep scab, *Boophilus* cattle ticks, screw-worm and warble flies), planned suppression to minimal levels by compulsory or voluntary chemical treatments of host animals (ticks in Africa, Australia, Argentina) and temporary, often haphazard, suppression by various methods, mainly chemical, for humanitarian or cosmetic reasons, or to reduce populations to levels at which no obvious production losses occur.

Eradication is the desirable objective for any major parasitic arthropod pest as the benefits are permanent, provided future exclusion by quarantine is practicable. Traditional eradication measures are adequate for one-host *Boophilus* cattle ticks but have been impractical in many areas because of sociological, economic and management problems including in some areas the presence of alternate hosts. The eradication of the non-specific screw-worm fly in U.S.A. by release of sterile males is the most dramatic achievement in parasitic arthropod control, but the eradication of sheep

scab in Australia in the 1863-96 period illustrates that major achievements were possible prior to the modern era of highly efficient pesticides and sophisticated technology.

The post-war period of highly efficient pesticides led to improved control of many parasitic arthropods. However the routine use of pesticides has brought problems of pesticide resistance, particularly in Australia in the cattle tick *Boophilus microplus* and the sheep blowfly *Lucilia cuprina*. Resistance has caused instability in control because of the necessity to change chemicals and increasing difficulties in the development and marketing of alternative chemicals that are efficient and environmentally acceptable. Reliance on highly efficient pesticides has resulted in the failure to use, or delayed the development of alternative approaches to control such as resistant hosts, pasture rotation and Mules' operation.

Many parasitic arthropods are exotic to the countries where they occur as pests, but biological control through the introduction of natural enemies from their native geographical range, has had no success. This technique seems to be poorly applicable to most arthropod parasites of vertebrates but a promising approach is the introduction of dung beetles to control dung-breeding flies.

Prospects for Future Control

Problems associated with complete reliance on pesticides for the control of agricultural pests are a major stimulus for the development of pest management (integrated control) philosophies. These philosophies have received little recognition in discussions on the control of animal parasites. They have no role in eradication programmes except for pre-eradication evaluation of the benefits/risks/costs associated with eradication compared with "living with the pest" and managing it at or below an economic threshold level. The recent breaching of the Mexico/U.S.A. quarantine by *Boophilus* ticks raises the question of whether eradication for the national benefit warrants the disruption of the local economy.

Pest management involves the definition of a pest. In agriculture a pest has been described as a species which affects or conflicts with man's profit, convenience or welfare. In livestock industries social, humanitarian and cosmetic values have to be added, not only for the owner, but also for the market. Thus Zebu (*Bos indicus*) cattle that control *B.microplus* may be less acceptable because of traditional beliefs, real or imagined, that their beef is of poor quality. For arthropods that are vectors of animal disease, e.g. East Coast Fever in Africa, an additional parameter is needed before pest management can be considered -

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a method for elimination of the disease from economic consideration. This stage has been reached for the *Babesia* parasites transmitted by *Boophilus* ticks. Pest management strategies, based on the use of resistant cattle are needed to control these ticks not only in Australia where the chemical resistance problem is most severe, but also in numerous tropical countries where cattle industries are developing and non-resistant European breeds of cattle are being imported.

Pesticides will be an integral part of most pest management strategies but a paradox is developing where new pesticides are needed to control resistant pests. Resistance has developed because of over-dependence on the pesticide, high selective pressure and the emergency of resistant individuals. To avoid or delay the emergence of resistance, it is realistic to press for its use to be restricted and this is incompatible with the interests of manufacturers who are already faced with increased costs of developing and marketing new pesticides.

Many new approaches to pest control have been explored in recent years - new types of chemicals such as analogues of juvenile hormones, exploitation of sex and aggregation pheromones, resistant varieties and genetic manipulation of the pest population as in the release of sterile males. All need to be considered in the context of the pest's biology, the economics and sociology of the industry affected by the pest and whether major pest problems will remain the responsibility of individuals or become the responsibility of the community.

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CAMPBELL, N.J.

J.K. Dineen & J.D. Kelly

THE STIMULATION OF RESISTANCE IN SHEEP TO *FASCIOLA HEPATICA* BY INFECTION WITH *CYSTICERCUS TENUICOLLIS* 1

Infection of sheep with *Cysticercus tenuicollis* for 12 weeks generated a high level of protection (> 95 per cent) against intra-ruminal challenge with metacercariae of *Fasciola hepatica* as measured by recovery of flukes from liver and bile ducts and counts of fluke eggs in faeces. The animals were resistant to *Fasciola* whether challenge was superimposed upon the cestode infection or after removal of the cestode with mebendazole.

Previous infection with *C.tenuicollis* also protected against the pathogenic effects of challenge infection with *F.hepatica*. Liver fibrosis was much less extensive in resistant sheep than controls and PCV's were not affected although these were reduced during fluke infection in the control animals.

BARGER, I.A.

W.H. Southcott

CONTROL OF NEMATODE INFECTIONS IN WEANER SHEEP BY ALTERNATE GRAZING WITH CATTLE 2

Three systems for the post-weaning management of Merino wethers were compared over two years. In all systems, all sheep were given two anthelmintic treatments per year: at weaning in January, and in July. In the first system (SS) the same paddock was used as a weaning paddock each year in succession. In the second system (SC 6) sheep and cattle grazed the paddock alternately for 6 month periods from January and July; the third system (SC 12) comprised sheep and cattle grazing alternately for 12 month periods from July of each year.

Compared with the SS treatment weaners from the SC 6 treatment had significantly lower faecal egg counts and lower burdens of *Haemonchus contortus, Trichostrongylus axei, Trichostrongylus colubriformis* and *Nematodirus* spp. They had significantly higher numbers of *Cooperia oncophora* and similar numbers of *Ostertagia circumcincta*. SC 6 sheep made greater liveweight gains, produced heavier fleeces, and suffered lower mortalities than their SS counterparts. Results for the SC 12 system were generally intermediate.