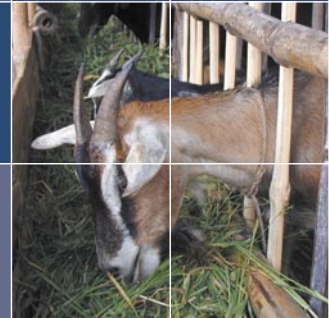




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# Worm Control in Small Ruminants in Tropical Asia



# Worm Control for Small Ruminants in Tropical Asia

Editors: R.A. Sani, G.D. Gray and R.L. Baker

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## Foreword

Sustainable technologies for the control of worm parasites of goats and sheep in the tropics have been developed through a series of international research projects, several of which have been supported by ACIAR.

ACIAR funded a collaborative project between research organisations in Southeast Asia for ILRI and regional partners to explore new ways to control helminth parasites in the tropics. The project aimed to increase small ruminant production in Southeast Asia by controlling internal parasites, which are one of the major constraints to sheep and goat production in the tropics. Control of internal parasites also provides an avenue for general improvement in husbandry methods.

The three objectives of the project were: to prevent the spread of resistance to anthelmintics (dewormers) used for control of nematode parasites of sheep and goats in Asia; to assess genetic variation in resistance to gastrointestinal nematode parasites in different breeds of sheep and goats; and to disseminate information about control of internal parasites in the tropics.

This publication and the accompanying CD draw together information from a number of sources to describe the state of research and development on worm control in sheep and goats in Asia and the Pacific.

This publication can also be downloaded from the ACIAR website: [www.aciar.gov.au](http://www.aciar.gov.au).



Peter Core  
Director  
Australian Centre for International Agricultural Research





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## Preface and Acknowledgments

The chapters in this volume were written originally between 1999 and 2001 to support the efforts of projects being implemented by the International Livestock Research Institute with partners in Asia and Australia. Now updated, and together with the accompanying CD, they describe information which, at the beginning of the projects, we believed was lacking or incomplete because much of the research on parasite control in small ruminants in our partner countries was not readily available. The difficulties of publishing applied research of local importance in international media are widely acknowledged. If published, it is often in national journals and, quite appropriately, in the national language of the country where the work has been carried out. However, local publication denies the authors the opportunity to have their work reviewed by peers in the international scientific and development community and denies regional and international readership access to the new research. When an international journal editor returns a well-written paper to its author commenting that 'the topic is not of sufficiently wide interest to our readership', that is often accurate and understandable as most paying subscribers will be in Europe or North America, but little comfort to millions of farmers, thousands of extension workers and hundreds of scientists whose livelihoods in the tropics are either constrained or occupied by the problems of worm control.

Supporting information was therefore a priority for the projects which funded this collection of 'grey' literature that is 'not cited internationally'. Our rationale has been

that efforts to develop new approaches to worm control, develop new technologies, and adapt existing technologies, would be strengthened by making this store of knowledge and experience available to the project partners and their research teams. This has been done within the project by publishing the early versions of these chapters and internal documents and circulating electronic versions on CD. As these initial projects drew to a close in 2003, it was timely to gather them in a single volume.

The chapters vary in style and content reflecting the different needs of the partner countries and the amount of information available. In a few cases, some original research is described briefly. Although being published formally here, the work is ongoing, and updates will be available electronically through the authors and the project website which can be accessed via ILRI at [www.ilri.org](http://www.ilri.org) or directly at [www.worminfo.org](http://www.worminfo.org).

The assessment of the the importance of small ruminants and the needs for parasite control in Nepal (Chapter 6) was undertaken against a background of substantial research of sheep and goats in Nepal, principally by scientists based at the Lumle and Pakhribas research centres. That research is reviewed in Chapter 15.

The accompanying CD contains all these chapters and many other tools and resources to assist those with an interest in worm control. The immediate beneficiaries will be researchers about to embark on a new research project, extension or development workers trying to solve immediate parasite problems or develop local





control strategies, and teachers of animal, veterinary and extension science who will benefit from a more complete approach to worm control than provided by the lists of chemicals and parasites which dominate the conventional literature. The final beneficiaries, of course, we expect to be the millions of poor livestock keepers who depend on sheep and goats, those who have no livestock but may use small ruminants as a pathway to build some assets and income, and subsistence farmers who may see the opportunity to expand their livestock farming to a more market-oriented enterprise.

The list of people and institutions to be acknowledged is long and reflects the breadth of the partnerships that have been developed and exploited to bring *Better Worm Control for Small Ruminants in Asia* to the press. The logos of their institutions alone would occupy several pages. Gathering and synthesising the information and development of the decision support tool *Goatflock* is a specific output of a project funded by the International Fund for Agricultural Development (TAG 443), where Ahmed Sidahmed has provided critical support and insights into our efforts. That project has been implemented in parallel with a project funded by the Australian Centre for International Agricultural Research (PN97133) where John Copland has been a staunch

advocate of applied research to benefit poor farmers. ACIAR contributed much to the earlier research being summarised here, notably in Indonesia, Malaysia and Fiji, and has contributed the funds to edit, publish and distribute this book and CD. Jenny Edwards provided critical interpretation and skilful editing of many chapters.

The names and institutions of those involved in these projects are reflected in the authorship and their affiliations listed in the following pages. Missing, however, are the hundreds of their collaborators and the thousands of farmers across the region who have given up their time to answer questions, record data and travel hundreds of thousands of kilometres to create this information and knowledge. That they have done so reflects the importance they give to small ruminants as a source of livelihood in their communities and the degree to which helminth infections reduce the many benefits that sheep and goats can provide. From this publication, we hope that these constraints are better understood and that more people will find better ways of overcoming them.

*Rehana A. Sani*  
*G. Douglas Gray*  
*R. Leyden Baker*



# 1. Worm control for small ruminants in Southeast Asia

R.A. Sani and G.D. Gray

## Introduction

Two-thirds of the world's poor live in Asia below nationally defined poverty lines and 479 million (65%) of them are poor livestock keepers who derive a large part of their household welfare from domesticated animals (IID 1999, Thornton et al. 2003). In Southeast Asia, the focus for this volume, the comparable figures are 161 m and 62 m (38%) with great variation between countries, between agroecological regions, and between communities with close or distant access to cities. Rural Southeast Asia is a group of countries with diverse cultures, economies and politics which is also characterised by mixed farming systems. These systems are often described by their staple crop, eg rice, yam or maize, which is significant for the farming culture. Nevertheless, with the possible exception of intensely irrigated farming systems, livestock are common to all systems: poultry, small and large ruminants and pigs are ubiquitous and an essential part of the management of economic and natural resources. For example, at the three project sites (described in Chapter 8) in the Philippines, livestock are a major part of the village economies, which are usually described as based on rice, coconuts or fishing. Thus, it is not appropriate,

in the context of rural poverty in Southeast Asia, to describe the vast majority of livestock keepers as being engaged in the livestock sector, but rather that the livestock sector is highly integrated into complex livelihoods based around multiple commodities and sources of income. Livestock are an essential part of existing systems and offer opportunities for high-value production (IFAD 2002). This contrasts with temperate farming systems where farmers are often dedicated to large-scale sheep or goat production. The parasites and hosts may be the same, but the nature of the problems caused by parasites and the options available for overcoming them are different and varied.

The rapidly changing patterns of demand for livestock and livestock products (dubbed the Livestock Revolution by Delgado et al. 1999, and others) point to livestock production being an increasing component (at least in value) of the agricultural economies of Southeast Asia. The extent to which the rural poor will benefit from these changes depends on how livestock can be integrated into developing markets, the potentially negative effects of industrialised production in rural areas and whether cheaper livestock products benefit the rural poor as



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consumers as well as producers. There is scope for small ruminants to play an important role for smallholder farmers in accessing these new markets.

In Southeast Asia the dominant livestock species are large ruminants (cattle and buffalo), pigs and poultry. With the exception of Indonesia, goats and sheep are relatively few. Their significance, however, which is now being exploited in several countries, is that they are small livestock in high demand and can thrive on low inputs and local resources. Their significance in South Asia is much greater and Chapters 6 and 15 on Nepal, with reference to India in Chapter 6, are useful points of reference.

The focus of this volume is on small ruminant production, the effects that nematode parasites have on their productivity and ways of overcoming these effects. In some chapters, 'avoidance' takes on more significance than 'direct confrontation'. There are many technical ways to remove worms from goats and sheep and make them grow better, the simplest being drug treatment, and in conventional economic terms, these treatments are cost effective with a high return on investment. Poor people, however, are not secure enough (Wood 2003) to make this type of investment: either they have higher priorities for cash-in-hand, they are uncertain if their animals will survive, or they have little confidence in when and how their animals will be sold, and their price. Thus, any attempt to increase goat and sheep production to benefit the poor must address the wider reasons for the failure of the poor to invest in technical solutions. This became increasingly obvious to the authors involved in the preparation of this volume and, as will be seen in several chapters, understanding and addressing social and market issues are highly significant.

This volume is arranged in two sections. The first section describes some advances in techniques and in the thinking behind worm control for smallholders in the humid tropics. Questions addressed include how to estimate the costs and benefits of control measures, how to make best use of genetic variation in resistance, how to use computerised tools in assessing control interventions, and how to use participatory approaches to help in devising sustainable control options.

The second section includes separate chapters on published, 'grey' and some previously unpublished information from Indonesia, Philippines, Nepal, Malaysia, Thailand, Fiji and Papua New Guinea. Vietnam, Lao and Cambodia are included in a single chapter as there has been little work on small ruminants in these countries.

The origins of this volume, and much of the work that is presented in it, lie in a workshop held in Bogor in 1996, the proceedings of which were published by ACIAR (Knox and LeJambre 1996). That workshop took a very wide look at all the potential options available for worm control in the region and it is essential reading for those who are interested in a more comprehensive account of all possibilities. How much progress has been made in the eight years since the Bogor workshop? There certainly have been some technical advances, but as predicted at the workshop, no miracle drugs or vaccines have appeared on the world market. A pessimistic view might be that the problems have worsened with increased resistance to anthelmintics. A more optimistic view is that there is wider understanding of all the elements that contribute to worm control: technical, social and economic, and

that these need to work in harmony for the end point of worm control to be realised: improved livelihoods for poor farmers from their sheep and goats.

A key objective of this volume, and the accompanying CD, is to bring to a wider audience the treasure trove of material in technical reports, in the so-called 'grey' literature, and in journals which are not widely circulated and in languages not widely understood. The most obvious example of this is in Indonesia where much research on parasite control is published in Bahasa Indonesia. Subandriyo and colleagues have tried to both summarise and translate many important publications (Chapter 9).

This overview chapter will take the same path, by singling out the control options and exploring their potential contribution to worm control, examining integrated approaches and finally considering the potential for worm control as an entry point for sustainable small ruminant production rather than an isolated problem. This is preceded by a review and discussion of the evidence for nematodes being an important problem for sheep and goats and, very briefly, a recap on the parasites and their hosts.

## The parasites and their hosts

A wide range of parasites are found in sheep and goats in Southeast Asia. They are mainly *Haemonchus contortus* and *Trichostrongylus* spp., followed in prevalence by *Strongyloides papillosus*, *Oesophagostomum* spp., *Moniezia* spp, *Trichuris* spp., *Cooperia*, the rumen and pancreatic flukes, *Bunostomum*, *Fasciola* spp. and also *Eimeria* spp. The cooler climates of Nepal and North Vietnam also host *Teladorsagia* and *Nematodirus*.

The breeds of sheep and goats available in the region are described in each of the country chapters. There are many, and their origins are diverse, leading to a conclusion that there is sufficient diversity of genetic resources in the region to satisfy the genetic needs of all possible small ruminant enterprises. The Indian subcontinent is the origin of most breeds but some, such as the Barbados Blackbelly and Santa Ines sheep, and Boer goats, have been imported recently from the Americas.



Goats and sheep are often kept for food security and emergency sources of cash. (G.D. Gray)

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## The null hypothesis: controlling worms is a waste of time and money

Given the investments in parasite control in the last century, is it worth stepping back and reconsidering the evidence for worms being a problem for sheep and goats in the tropics? Is it possible that investing resources in the control of worms in sheep and goats is not worth the effort, that these resources can be better invested elsewhere? Is it so obvious that parasites constrain production and that public and private funds should continue to be thrown at the problem? A premise of this entire volume and the basis of a significant section of the pharmaceutical industry and the scientific community is that the benefits of removing gastrointestinal nematode worms from sheep and goats outweigh the costs. In commercial large-scale production of small ruminants with well-defined markets at least, the short-term costs and benefits are well understood. In smallholder production systems, this is far from the case. In part, this is because the benefits of small ruminants are so many, for example, as assets, for weed control, and as sources of fertiliser and security. These benefits are very difficult to quantify. But also there are very little data on the effect on the more conventional parameters of value such as growth, mortality and offtake of meat, milk and fibre, which themselves are often hard to value because of informal and non-metric markets, especially in real farming systems outside the artificial confines of research stations. These data are reviewed below, less to provide an overall estimate of the effects of worms, than to discuss the various ways of doing so. Having reviewed this evidence, a case can be made for reducing the need for such estimates of loss, except as

a starting point for the design of options for intervention. The more critical cost and benefits, and those needed by the agencies who will pay for them, are those of the interventions themselves. The benefits of a single intervention, for example improved grazing management to reduce mortality from nematodes, may have a much wider benefit than simply 'worm control'.

## Effects of gastrointestinal nematodes on production

Data from Southeast Asia is sparse. Comparison between parasitised and non-parasitised goats in two villages in southern Luzon (Que et al. 1995) showed that they differed in growth by several kilos over a period of six months, representing a good return on investment from a single dose of anthelmintic.

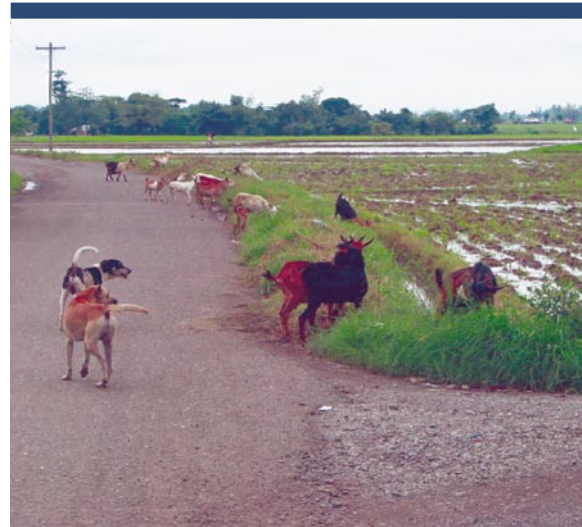
Berajaya and Copeman (1996) studied goats and sheep on 50 farms in West Java, Indonesia to investigate the seasonal effect of nematode parasitism on weight gain of recently weaned sheep and goats. Weight gains of untreated animals were compared with those of an otherwise similar group treated each two weeks with oxfendazole or albendazole to suppress nematode parasitism. During the dry season, animals grew much faster than in the wet season and anthelmintic treatment had no effect on weight gains. In the wet season, however, weight gains of both groups were lower and the effect of anthelmintic was to increase growth rates in treated sheep by 25 per cent.

Palomkarn et al. (1996) investigated the effects of internal parasites on growth rates of goats in village environments in southern Thailand in a humid tropical

climate and found the growth rates of goats drenched every three weeks were significantly higher than for those left undrenched and that drenching had most effect on animals on a lower plane of nutrition.

The effects of parasitism are more obvious in losses due to mortalities. In Malaysia, goat mortalities were monitored closely in two studies. Among a flock of grazing goats monitored from birth to 14 months of age and not given dewormers, postmortem examination showed deaths due to trichostrongyles were 32% (Daud et al. 1991). Symoens et al. (1993) studied 13 goat smallholdings over 15 months and found a mortality rate of 74% for animals up to one year old and 34% adult mortality. Postmortem examination confirmed the major causes of death as pneumonia and haemonchosis.

These first three studies illustrate several difficulties in arriving at good and meaningful estimates of the benefits of worm control. First, there is a need to establish populations of animals which are free from worm infection. In each of the studies this was done by anthelmintic treatment, which needs to be properly applied using a fully effective chemical. In all cases the chemical used was shortacting, lasting only a few days. The treated animals would therefore become infected with larvae from the grazing they shared with non-treated animals within a week. In the case of the Indonesian study, the chemical was given every fortnight which would probably never allow adult worms to develop. However, immature worms would certainly have been present. Thus, studies of this type will always underestimate the worm effect when the control groups are not free of infection. The second issue is timing.



Grazing sheep and goats are exposed to many threats including dog attack. (D. Yulistiani)

The study by Que lasted six months and we do not know what happened to the animals after observation ceased. Was there compensatory growth in the worm-affected groups, as is often observed in on-station experiments? Third, criteria used for 'effect' in all the experiments were growth rate and liveweight at the end of the trial. The implication drawn from the trials was that this liveweight difference could be translated into a financial loss by using a market price per kilo of liveweight. No account is made of the timing of sale (farmers often wait until an emergency or a particular season to sell animals) or the ability of the farmer to get market price for the exact weight of the animal. It is hard to know whether this over- or underestimates the effect of worms as the market value may be based

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on more qualitative traits such as 'condition' or 'colour'. Certainly, no account is taken of the other attributes of the animals, such as manure production (likely to be depressed along with appetite in infected animals), or the costs of tending and young animals with diarrhoea. At face value it makes economic sense to spend money on a simple anthelmintic. Que estimated a benefit-cost ratio of several hundred to one of doing so. But, by and large, smallholder farmers do not treat their animals. There must be more to this than simple economics.

In this volume the economics of parasite control are considered at the national (Chapter 2) and household (Chapter 4) levels.

In south and central Asia and Africa more detailed studies have been completed. In tropical Africa, two comprehensive studies have been undertaken in Nigeria (Osaer et al. 2000) and Senegal (Ankers 1998) that also use anthelmintics to keep as many worms as possible out of a control group of animals. These studies were more comprehensive because they measured many more animals (hundreds) over a longer period (years) and many more traits. As the trials lasted for more than one growing season, a key measurement could be made — offtake. The engine-room of any livestock production system is the female of reproductive age and, if the main product is meat, the critical measures of engine efficiency are reproductive rate and mortality rate. The more and heavier offspring weaned and the sooner she becomes pregnant after birth, the more efficient will be the herd or flock. Both Osaer et al. and Ankers et al. measured very large reductions (26 and 46% respectively) in offtake in the

groups not treated with dewormer. As noted above, it is likely that these effects are underestimates because of the short-term nature of the anthelmintic. Neither study recorded an effect of growth and only in goats was there a reduction in liveweight gain. Was this because of the different breeds used or the relatively low rainfall in the study areas? Of critical importance, had offtake not been measured in these two studies, it might have been concluded that worms had little or no effect on production.

In a similar type of long-term study, Thomson et al. (2000) measured offtake in Syrian sheep flocks and found such a small effect that it barely covered the cost of the dewormer. Presumably (but this is only speculation) this is because of the dry environment and low worm challenge. Indeed, a scan of Table 1.1 might suggest that, as annual rainfall increases over 10-fold from 300 mm in Syria to nearly 4 m in Java, both the magnitude of loss increases and the nature of loss changes: from offtake to reduced growth to high mortality. Had Pralomkarn, Que and Beriajaya and colleagues been able to measure offtake this hypothesis, perhaps, could have been strengthened.

Ghalsasi et al. (2002) addressed the difficulty of completely removing the worm population in a study on the sheep flock in Maharashtra, India by using an intraruminal capsule containing a macrocyclic lactone which prevents incoming larvae from establishing. By comparing these animals with others treated every three months with ABZ and others untreated they were able to show that the infrequent treatment had no effect, but by complete suppression of the worm population the

**Table 1.1 Summary of selected studies on the impact of gastrointestinal nematodes on production of sheep and goats**

Study	Host	Annual Rainfall (mm)	N*	No. Farms	Dewormer	Growth	Effect on Mortality	Offtake
Berajaya and Copeman 1996	Sheep	3,842	127	50	Monthly	25%	None	
Berajaya and Copeman 1996	Goat	3,842	96	50	Monthly	25%	None	
Que et al. 1995	Goat	2,100	39	2	4 x	23%	None	
Pralomkarn et al. 1995	Goat	1337	24	1	4 x	63%	None	
Ankers et al. 1998	Sheep	900	375	15	2 x	None	None	26%
Osaer et al. 2000	Sheep	650	233	5	3 x	None	None	24%
Osaer et al. 2000	Goat	650	385	5	3 x	None	6%	47%
Ghalsasi et al. 2002	Sheep	525	238	4	2 x	None	None	None
Ghalsasi et al. 2002	Sheep	525	238	4	Capsule	None	None	22%
Thomson et al. 2000	Sheep	300	432	10	2 x	None	None	2%

\*N: Number of adult sheep in stud

annual offtake per female in the flock increased by 22%. This raises a question for all the studies mentioned here; had the worm population been completely suppressed, would the effects have been even greater?

It is safe to conclude that worms do affect production in goats and sheep, that the effects are likely to vary for many reasons, including those associated with geography, that most of the costs and benefits to smallholder farmers have not been included in estimates and that the use of short-acting chemicals has led to underestimates of the true total impact of worm infections.

### Sickness and death are what matter most to smallholder farmers

In a series of, so far, unpublished studies in the Philippines, Indonesia and Vietnam, smallholder goat and sheep farmers participated in discussion groups which focused on the problems they faced. The leaders of the discussion groups were extensionists with backgrounds in animal health and production and the discussions were organized in such a way that the starting points were the most serious problems affecting the lives of the farmers and their families. Not surprisingly these were





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often lack of income and lack of savings to deal with medical emergencies and education expenses. None of the farmers milk their goats or sheep and they described the problems associated with them most often as 'mortality of young' and 'sickness and diarrhoea', especially during the wet season. While it may be possible to interpret some of this sickness and death to parasitism, it is impossible to quantify how much without the long-term and detailed studies. For the smallholder farmers there are two important needs. The first is to address the problem in their terms — reducing mortality and signs of sickness are obvious ways of doing this. Possibly more important, however, and hidden from the farmers, are the losses due to lost capacity to produce more lambs and kids. Addressing the second problem requires a more prolonged effort by scientists and extensionists to provide information to increase awareness of the potential gains. The initial outcomes of such an effort in the Philippines are presented in Chapter 3 and a tool for estimating the effects of reproduction using a computer model (*Goatflock*) is described in Chapter 7.

## Reduce focus on absolute losses and increase focus on benefits from interventions

The rationale of all these studies has been as a preliminary to designing effective options or control programs that minimise the impact of worms on 'production' however narrowly or widely that is defined. The options available to farmers now are: grazing management, improved nutrition, better housing and water supply, better control of breeding and use of chemical dewormers. With the exception of some dewormers, every one of these interventions has a much wider impact than just of worm infections. For example, using tree fodders to reduce intake of infective larvae also has an effect on the overall nutritional status of the animal, improving its resistance to infection and also its growth and resistance to other diseases. Thus, the overall benefits of any component of a control program should consider the total range of benefits for production and health. Likewise, removal of manure to prevent re-infection around housing creates opportunities for

Table 1.2 Control Options for Animal Diseases in Upland Villages of Lao PDR

Disease	Control Option and Likely Contribution to Successful Control			
	Vaccination	Improved Pens and Clean Water Supply	Movement Control	Chemical/Antibiotic Treatment
Classical Swine Fever (CSF)	**	*	**	—
Fowl Cholera (FC)	**	**	*	—
Toxocariasis	—	—	—	***
Haemorrhagic septicaemia (HS)	*	*	*	*

Source: ADB 2002; \*\*\*, complete control; —, no contribution to control.

applying the manure as fertiliser. Fodder trees can improve rice yields through leaf fall into paddies. Very quickly the estimate of benefits and attribution of a particular intervention becomes complex and beyond simple analysis of single factors and their short-term effects.

An example of this approach is illustrated in Table 1.2. The most important diseases among pigs and large ruminants in the uplands of Lao are classical swine fever (CSF), fowl cholera (FC), toxocarasis and haemorrhagic septicaemia (HS). While biologically these diseases are quite distinct, the range of control options that might be introduced for any one disease would have an effect on the others and lead to a decrease in the impact of related groups of diseases, eg neonatal enteritis and roundworms in pigs, roundworms of cattle and buffalo (other than *Toxocara*) and coccidiosis in poultry. This is quite apart from the increase in capacity required for the control of a single disease which would have flow-on effects across the extension service.

In summary, there remains the need for accurate definition of the parasites that infect sheep and goats and the direct impacts that they are having on easily measurable aspects of production. The more important effects, however, on reproduction rate, intermittent mortality and contribution to the farming systems and household economy are much more difficult to estimate. The most important question facing investors in livestock health and production is how to allocate their resources and some of the interventions that can help control small ruminant parasites have wider benefits which are not usually considered.



Counting worm eggs in faeces using flotation methods has provided large amounts of clinical and epidemiological data. (G.D. Gray)

## Control options

Details of these options are contained in the country chapters. This summary highlights the common practices and possibilities.

### Chemical control

Most countries in Southeast Asia have all three of the currently available broad-spectrum groups of anthelmintics, with benzimidazoles being the most widely used. Levamisole and macrocyclic lactones, in particular ivermectin, are used at levels directly related to the affluence of farmers, availability of government subsidies and ease of availability. The narrow-spectrum haemonchicide closantel is also available in a number of forms, as a single chemical and in combination. The extent of anthelmintic resistance has been estimated in a number of ways.

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Use of chemical dewormers is an important option for smallholders and other farmers. A study in East Africa (Nguti et al. (2002) – showed that under more extensive grazing in a humid tropical system, 25% of the mortality of young Red Maasai and Dorper sheep could be attributed to parasites. Effective chemicals need not be expensive and could be made widely available, but their use is increasingly constrained by the emergence of worms that are resistant to anthelmintic drugs, for example in Malaysia (Dorny et al. 1993, 1994; Sivaraj et al. 1994a, 1994b; Rahman 1993, 1994), Thailand (Kochapakdee et al. 1995) and Indonesia (Dorny et al. 1995). In the Philippines, benzimidazole resistance in a field population of *Haemonchus contortus* from sheep has been confirmed in Mindanao (Van Aken et al. 1994). Benzimidazoles have been in continuous widespread use for up to 20 years in the Philippines with little use of other chemical groups. Using an *in vitro* larval development assay (LDA) in the Philippines the mean benzimidazole efficacy for goats was 82% and for sheep was 62% (Ancheta et al. 2004).

In Vietnam, deworming of goats is not a common practice, with only 4–8% of farmers using chemical dewormers because the cost is prohibitive. In that country an anthelmintic trial with goats on smallholder farms and on an institutional farm showed benzimidazole efficacy of 70–80%, levamisole of 80–92% and ivermectin of 75%. In south Thailand, benzimidazoles failed to effectively reduce faecal egg counts while levamisole was relatively effective and ivermectin still effective. In Fiji, resistance to fenbendazole and levamisole has been detected. Resistant worm populations are emerging against the three main groups of anthelmintics in Malaysia, providing clear evidence



Deworming chemicals can be highly effective if used correctly at the right time. (K.C. Patawaran)

that anthelmintic resistance in parasites of small ruminants in that country is rapidly increasing. It is perhaps fortunate that most Asian countries with small ruminants have used mainly benzimidazoles. This has led to the fair conservation of the broad-spectrum anthelmintics such as levamisole and macrocyclic lactones, meaning they can still be drawn upon if required. However, the cost of such imported manufactured products can be the major limiting factor in their future usage. Chemical dewormers are mainly manufactured for cattle and sheep and the products or their dosages may not necessarily be extrapolated for use in goats. Albendazole sustained release capsules were not effective in goats but they are extremely effective in sheep in Fiji (Chapter 13).

Comparative pharmacokinetics of albendazole in sheep and goats revealed that the systemic availability of the drug was the same in both species but peak levels were achieved earlier and fell off faster for goats, indicating a faster metabolic rate of albendazole in goats. Therefore, based on the disposition of ABZ metabolites in plasma, equivalent activity of ABZ in sheep and goats might be obtained by increasing the dose rate for goats from 4.75 to 7.5 mg/kg, that is, 1.5 times the recommended dose for sheep (Hennessy et al. 1993). In relation to this, Dorny et. al (1994) demonstrated that closantel was active for a shorter time in Malaysian village goats than it is generally expected to be in sheep — at least 4 weeks at a dose of 7.5 mg/kg given orally. Thus, with a pre-patent period of 3 weeks for *H. contortus* FECs in sheep would appear, at the earliest, 7 weeks after closantel administration. The period when FECs reappeared after closantel administration (5 mg/kg subcutaneously or 10mg/kg orally) in the village goats was 6 weeks. However, taking advantage of the sustained activity of closantel, which not only prevents reinfection but also resulted in a 72.5–86.8% lower egg deposition on pasture during a 2-month period, it is recommended that in Malaysia closantel be used for strategic drenching alternately with broad-spectrum anthelmintics.

Given the opportunity, farmers would use anthelmintics as they perceive animals given these drugs to be fatter, healthier and to have better appetites. So, for these reasons farmers are willing to invest in parasite control. However, the reasons they don't use anthelmintics are: small flock sizes which makes purchasing large packets of anthelmintics unviable; the cost of the drugs; and their unavailability at the village level. In Indonesia

a system was proposed where farmers could form an association to make bulk purchases of anthelmintics, which could be dispensed in smaller quantities according to flock size and also bought at discounted prices (Misniwaty et al. 1996). The anthelmintic cost as percentage of total revenue from selling fattened sheep is only about 3%. Hence, making anthelmintics available to farmers on a non subsidised free market is viable (Scholz, 1992). Misniwaty et al. (1994) also suggested that the most effective method of anthelmintic distribution is an extension worker who is organized as a supplier in a certain area. Apart from being a job responsibility, through this delivery network a certain income would be a motivating drive. The improvement of the delivery arm for anthelmintics would have an overall general benefit in the distribution of other health tools such as antibiotics, vaccines and future approaches.

Given the pivotal role of anthelmintics in many worm control programs it is foreseen that their use will increase in Asia. Therefore, it is imperative that animal health workers be educated on the “do's and don'ts” of anthelmintic use for the sustainable conservation of present-day drugs.

### Improved nutrition

Animals which are better nourished are better able to withstand the effects of worm infection than those given a low plane of nutrition. Resistance of the animal to larval establishment can be enhanced by improved protein nutrition (Sykes & Coop, 2001). In tropical Asia, small ruminants rely mainly on grazing grass and forages which often have low nutritive value and are given little or no protein supplementation.



# 1. Worm control for small ruminants in Southeast Asia

Increasing protein quantity and quality for animals from commercial sources may be a costly option. Therefore, practices have focused on utilising locally available feed resources such as tree leaves, farm by-products and cut forages. However, under grazing conditions, there are no published studies which either directly or indirectly implicate nutritional status as having an impact on parasite levels in either sheep or goats.

However, a report by Handayani and Gatenby (1988) investigated the interaction between system of management (grazing versus stall-feeding), nutrition (legume supplementation versus no legume) and helminthiasis (with and without anthelmintic) in sheep in North Sumatra. They concluded that legume supplementation reduced the egg count of grazing lambs that were not given anthelmintic but the supplementation had no significant effect on mortality or growth rate. The non-significant effect was probably due to the small sample size (four lambs per group). However, a closer look at the raw data revealed that there was a 50% reduction in mortality in the groups given the higher levels of legume supplementation compared to unsupplemented lambs. Also, there was a trend of 5–10 fold increase in growth rates among the supplemented undrenched lambs. The existing worm burden that was not removed at the start of the trial had obliterated the benefits of legume supplementation in the untreated grazing group, which probably contributed to the high mortality rate of grazing lambs (38%). There was undisputably a very large effect of anthelmintic treatment on survival and growth rate of lambs that were given suppressive treatment.

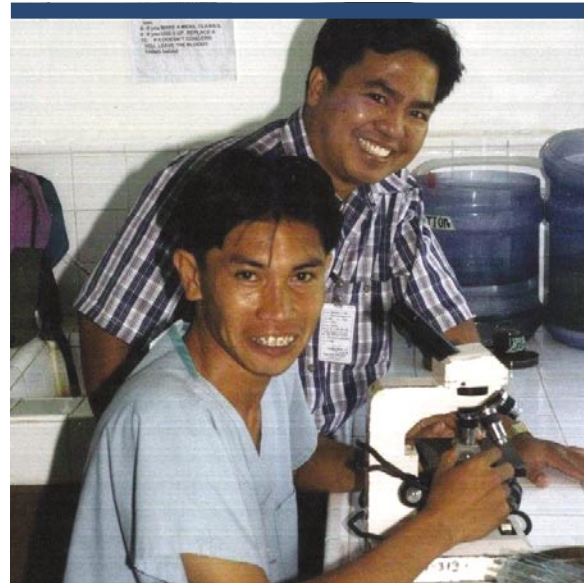
Berijaya and Copeman (1996) suggest that as FEC were the same throughout the year it was the low levels of nutrition during the wet season that affected the pathogenicity of gastrointestinal nematodes. Farmers also realise the importance of supplementing their animals' diet. Dahlanuddin (2001) surveyed farmers in Lombok, Indonesia and found that goats were offered a wide range of 30–40 different forages. Native grasses and *Sesbania grandiflora* were mostly offered, as single diets and, more often, as mixed diets. The latter, as well as other tree leaves and agricultural byproducts, were used even more during the dry season when native grasses were less available. The use of tree and shrub leaves reduces intake for ground-based and contaminated feeds. The highly nutritious *Leucaena leucocephala* was not used in some areas due to the temporary aversion by goats which farmers thought was permanent. Rice straw, although abundantly available, was not popular because goats rejected the straw. Preston's work in Cambodia showed that diets for growing goats containing cassava foliage supported better growth and feed conversion, and exhibited protective mechanisms (presumably due to the content of condensed tannins in the cassava) against nematode parasites than similar basal diets supplemented with freshly cut grass. Dry matter digestibility was apparently depressed on the cassava, compared with the grass diets, but this negative nutritional effect appeared to be more than compensated by the much higher protein intakes with cassava. Most goats in Vietnam grazed extensively on native grasses but only for about 2 hours daily, which means that the animals do not eat sufficiently. Only 12–23% of farms there supplemented with shrub and tree leaves such as *Leucaena*, jackfruit

and *Flemingia*. It is all very well to recommend supplementing the animal diet with nutritious forages but if these are not easily available, it is not an option for the farmer. So, in these cases a simple recommendation to allow the goats to graze for a longer period may be more appropriate. Symoens (pers. comm.) advised increasing the length of the grazing period for goats in smallholder systems from four to six hours, especially when the forage diet is mainly grasses. This allowed an increase in the quantity and quality of forages selected and ingested.

### Ethnoveterinary therapy

Locally produced oral dewormers are used for worm control by farmers and recommended by some animal health workers. Plant remedies are often practised by farmers not only as traditional panacea for good health but also because modern anthelmintics may not be available or are too expensive. However, the use of plant extracts as anthelmintics needs to be further investigated as there is a potential for their use in organic and conventional production systems. Caution needs to be exercised when comparing results from different studies using plants, as the origin and preparation form of the plant may have differing efficacies against worms.

Most reports on apparent success of plants in eliminating visible endoparasites such as ascarids and tapeworms need to be viewed with caution. They may well be acting as laxatives and not strictly related to an anthelmintic effect. Few references exist to those helminths which cannot be easily seen (Hammond et al. 1997). In Indonesia there is a wealth of information on the use of medicinal plants in small ruminants,



Spores from the free-living fungus *Duddingtonia* can prevent contamination of grass with worm larvae. (R.A. Sani)

particularly with less visible helminths. These refer to the economically important helminths which are the trichostrongyles. In particular, papaya seed suspension and papaya sap have been tried in several studies *in vivo* as well as *in vitro* with *Haemonchus contortus* infections and adult worms respectively and exhibited anthelmintic activity. However, two studies reported on the toxicity of papaya sap causing some pathology of the gastrointestinal tract mucosa. Other plant extracts were from nicotine, *Areca catechu*, *Curcuma aeruginosa*, *Zingiber purpureum*, *Monordica charantia* and *Morinda citrifolia*, all of which showed varying degrees of anthelmintic activity against *H. contortus*.



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Medicinal plants seem to be hugely popular with ruminant farmers in the Philippines (Mateo, 1996). Several plants have been tested for their efficacy as anthelmintics for goats in the Philippines. Crude extracts of *Mimosa pudica* and *Tinospora rumphii* were highly effective against *Haemonchus* larvae *in vitro* and in reducing worm egg counts and worm numbers (Faenar 1997; Fernandez 1995). In Malaysia fresh leaves of neem (*Azadirachta indica*) are provided to animals. Current studies in Vietnam on effects of plants on *Haemonchus* larvae *in vitro* showed promising results with extracts of some legumes, namely *Leucaena leucocephala*, *Acacia mangium* and *Calliandra* sp.

Farmers of small ruminants in rural Indonesia use traditional veterinary medicine extensively. Dano and Bogh (1999) rightly stated that herbal remedies have undergone many years of clinical trials and, as they prove reliable, are accepted by the users. It is only when scientists attempt to extract the 'active ingredient' from various parts of these plants in various ways in their experiments (which sometimes yield negative results) that the plants are deemed useless. However, scientific validation of such plants is crucial to be acceptable to mainstream veterinary practices. It is therefore an exciting yet challenging area of research to embark upon. A rigorous evaluation of some African herbal dewormers recently reached the same conclusion: that evaluation of these traditional remedies needs to be made with traditional healers, using standard guidelines, as controlled trials often show no or small effects on parasite burdens (Githiori 2003).

## Biological control

Research on biological control using nematophagous fungi as a new component for future integrated control of parasites of small ruminants has been ongoing for about five years (Larsen 2002). In many areas of Southeast Asia this novel tool is particularly useful as humidity and temperature are not limiting factors for the germination of fungal spores, which also applies to development of infective larvae. In India, Sri Lanka, Malaysia, Indonesia and China, nematophagous fungi have been isolated and/or results in experimental conditions have indicated the potential of using fungi in reducing nematode infections in ruminants (FAO 2002). Beriajaya and Ahmad (Indonesia, 1999) used *Arthrobotrys oligospora* for biological control of nematode parasites of sheep. They infected 20 young sheep free of helminth infection with 5000 L3 of *Haemonchus contortus*, and six weeks later all sheep were divided into two groups of 10. One group received a number of *A. oligospora* four times at two-weekly intervals, and the other group was a positive control. Examination was based on faecal worm egg counts and recovery of larvae after culturing of faecal samples. The results showed that the group receiving fungi produced fewer larvae than the control.

However, the two major obstacles that need to be addressed if this form of biological control is to be introduced in Asia, are the delivery system and the affordable large-scale manufacture of fungal spores.

## Genetics

Breeding approaches to decrease the impact of nematode worms on goats and sheep are increasingly important and many breeds of goats and sheep perform better in the presence of worm challenge than other breeds available to the farmer (see Chapter 5). These include the Red Maasai, Barbados Blackbelly, St Croix and Garole sheep and East African goats. The simplest breeding approach is to replace the currently used breed, which may have been introduced quite recently, with an adapted breed of proven productivity and reduced need for other inputs for worm treatment.

There is sufficient genetic variation in resistance to nematodes within breeds of sheep to allow selection for increased resistance but this would only be applicable in production systems where breeding can be controlled and there is systematic measurement of production. This has happened in the field in Merino, Romney, and Blackface sheep, and Cashmere and Guadeloupe goats. In Australia and New Zealand there are commercial breeding schemes which include resistance to nematodes in their breeding objectives.

Measurement of resistance is by collection of faeces from young sheep under challenge and counting the nematode eggs in the laboratory. This number, combined with production measurements, is used to select the next ram, buck or breeding female.

The greatest genetic change in modern time has been to decrease the resistance of indigenous breeds by the introduction of exotic breeds with greater dependence on chemicals for worm control.

The immediate benefits of using worm measurements to select breeding stock come from the monitoring of disease levels and improved worm control. This usually means less use of expensive and increasingly unreliable chemicals. Genetic gains depend on the intensity of selection and the numbers of animals measured. Genetic resistance can be used as part of an integrated health program, with adoption of rotational grazing systems, improved nutrition and management, confinement during risk periods and better use of chemicals.

## Vaccines

There are no commercially available vaccines for any gut nematode parasite of any host, including man and it is unlikely that a commercial vaccine will be produced for sheep or goats in the foreseeable future. Progress towards a vaccine against *Haemonchus* is most likely to come from a recombinant version of the hidden gut antigens which are known to be immunogenic and effective in suppressing infections in a variety of field conditions (Smith 2004XX). The research and development tasks for producing such a recombinant antigen in commercial quantities, finding an appropriate adjuvant and delivery systems and making the product available for relatively poor farmers are considerable.

## Integrated control programs

The foundation for any program on parasite control is based on a sound knowledge of epidemiology of parasite infection in a particular area. We now know that parasite control programs for smallholder farming systems in tropical Asia utilise strategic drenching, a combination of confined and grazing systems, improved nutrition and controlled breeding. The countries



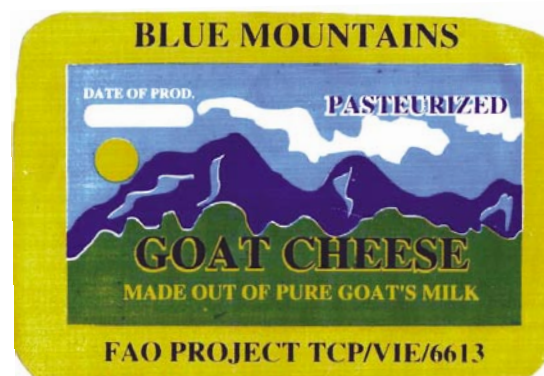


# 1. Worm control for small ruminants in Southeast Asia

which have epidemiological information on nematode infections in sheep and goats include Indonesia, Fiji, Philippines, Nepal, Malaysia and Thailand. These countries are thus in a stronger position to plan and implement parasite control programs.

The only practical option for reducing reliance on anthelmintics depends on enhancing resistance of the animal to larval establishment by improved protein nutrition and minimising exposure to parasites.

A substantial amount of information has been generated from Fiji to utilise these two broad approaches, utilising knowledge on epidemiology and integrating it with rotational grazing and use of medicated urea-molasses blocks (UMB). When medicated UMB was provided to pregnant does grazing on permanent pastures, the number of animals showing clinical signs of parasitism was reduced three-fold. So, the use of UMB reduced the frequency of treatments and suppressed the periparturient rise in FEC in pregnant ewes. In a 10 paddock, 35-day rotation system medicated UMB reduced the number of salvage drenches four-fold, provided pregnant does had access to the blocks for two cycles of the rotation in the six-cycle trial period. UMB provided to young and maiden ewes not only improved their reproductive performance at first lambing and reduced the number of salvage drenches based on FEC but, more importantly, nearly halved lamb mortality rates. The increase in milk yield and quality afforded by the blocks enhanced the survival of lambs at weaning. These findings have important implications in reducing treatment costs and lamb mortalities, both of which are vital considerations for the smallholder farmer.



Increased income from meat, milk products and fibre is one consequence of good management and worm control.

There is a vast amount of epidemiological information on helminth diseases from Indonesia. The effect of season, time of grazing and host age on gastrointestinal worm burden and carcass percentage of sheep in Java provides useful discussion (Kusumamihardja, 1988). Sheep grazing in the dry season have significantly lower worm burdens (average 1108 worms) than those grazing in the wet season (average 1928 worms). More interestingly, in the dry season sheep grazing in the mornings are at a higher risk of contracting heavier worm burdens (1969 worms) than those grazing in the afternoons (290 worms) whereas there was no difference grazing at any time of the day in the wet season. These worms were identified to belong to the strongyle group. These findings also corresponded with work by Sumartono (1985) who found a trend of highest egg production by *Haemonchus contortus* in the morning, which declined in the afternoon and was lowest in the early evening. These findings suggest that

during the wet season it is advisable to confine animals and stallfeed them to reduce exposure to infective stages of the parasite and to graze animals in the afternoons in the dry season. These grazing tactics may be adopted in areas which have distinct wet and dry seasons, such as some areas in Indonesia, Philippines, Cambodia and Vietnam.

### Participatory approaches

The above integrated approaches are limited to the technologies and are designed for application by a farmer on the recommendation of an advisor or other extension agent. Inclusion of the farmer in development of ideas and technical options and their evaluation, as well as the application of the technology, involves a different approach to the research and development process. The term 'participatory' is often applied to a process that involves farmers and other important people who influence them and are affected by their successes and failures. Their involvement is not just as recipients of technology but as active contributors to research and development. One such approach is described in this volume by Alo (Chapter 3). It is worthwhile commenting here on the technology options that were agreed to be feasible, available and affordable by some farmers in the Philippines. They were:

- **Use of effective chemicals** — incorporating knowledge on anthelmintic resistance and use of alternative delivery methods such as feed blocks. Quarantine drenching is an appropriate strategy for institutions and large commercial suppliers of stock.

- **Improved nutrition** — including the use of tree and shrub leaves to reduce intake for ground-based and contaminated feeds; plants with possible direct or indirect anthelmintic effect and cut-and-carry methods, especially during times of heavy rain or heavy pasture contamination.
- **Grazing management and housing** — improved housing to reduce stress through better ventilation, shelter, manure and feed management, rotational grazing and management of contaminated areas around housing.
- **Controlled breeding** — includes timing of breeding to produce young susceptible kids and lambs when worms can be best managed; considering possible increase or decrease in genetic resistance when deciding to use new genetics, especially 'upgraded' or 'improved' bucks and rams.

A participatory process of testing and evaluating these strategies alone and in combination has shown that controlled breeding has been the least successful. This outcome is location specific and other farmers working with other researchers in other farming systems may reach different conclusions.

### Forums for discussion

There are a number of ways in which scientists and others can informally discuss worm control and related issues and interact with other communities working on these problems. The following list will be useful as a starting point to accessing this increasingly electronic world of information sharing and debate.



# 1. Worm control for small ruminants in Southeast Asia

## FAO networks and discussion groups

FAO has supported a Network for Helminthology in Africa which can be accessed at [www.worms.org.za/](http://www.worms.org.za/). This group recently conducted an electronic conference on “Managing Worms Sustainably — we need to reconsider present recommendations”. The unedited contributions can be obtained from [/econf/manworm.doc](http://econf/manworm.doc).

## The ‘novel approaches’ series of meetings

Three meetings have been held — in Armidale, Australia; Baton Rouge, USA; and Edinburgh, Scotland. The fourth is in Merida, Mexico, with the theme: “Worm control or worm management: New paradigms in integrated control” indicating that some changes in thinking about worms and parasites are under way. The objectives of these meetings are to:

- 1) update the scientific community on the current state of knowledge of novel approaches for the control of helminths in livestock,
- 2) investigate the limitations affecting the application of this knowledge and
- 3) investigate what strategies can be adopted to overcome the limitations.

## The SParC newsletter and website

Originating from a project funded by ACIAR and IFAD in the Philippines and Southeast Asia, the SparC newsletter has been produced in paper and electronic format since 1998. The newsletter and a wide collection of resource material are available through the website associated with these projects, [www.worminfo.org](http://www.worminfo.org) and also included with this volume.

## Summary

In livestock smallholdings in Asia there is a need to change the emphasis from a disciplinary approach where studies are focused on chemical control, genetics or grazing management to a multidisciplinary approach where the integration of all disciplines is recognised as necessary. A further step, still being researched, is recognising that the full participation of farmers and other stakeholders is essential from the beginning of a research or control program if the results are to be useful and sustainable in the long term. Additionally, we speculate that gastrointestinal nematodes in small ruminants might be more usefully considered as indicators of poor management than as a problem in their own right.

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## 2. The economic impact of worm infections in small ruminants in Southeast Asia, India and Australia

R.S. McLeod

### Introduction

About 10% of the world's sheep population and 29% of the goat population are reared in Southeast Asia, mostly by smallholders. Haemonchosis, a disease caused by the blood-sucking stomach worm (*Haemonchus contortus*), has been identified as the most serious endoparasite problem of small ruminants in the region. Within sub-Saharan Africa, de Haan and Bekure (1991) estimated that endoparasites cause mortality and production losses in the order of \$2 billion per year. However, valuation of the economic impacts of roundworms in Asia is confounded by a lack of accurate estimates of disease prevalence and the differing characteristics of small ruminant production systems throughout the region.

This chapter will:

- characterise small-ruminant production systems in selected Asian countries and Australia, using sets of tables that describe flock structure and size
- estimate roundworm prevalence and livestock mortality in India, Indonesia, Thailand, Vietnam, Australia, Nepal and the Philippines
- calculate the annual economic impact of roundworm parasitism in each of the above countries
- quantify the economic benefits from sustainable endoparasite control (SPC) adoption in the target countries, which include Nepal, Indonesia, Vietnam and the Philippines.

The economic cost of roundworm parasitism alone does not justify allocating funds toward parasitological research and extension (Perry and Randolph 1999). The ability of research outcomes to reduce control and production-loss costs should guide funding decisions. Hence this attempt to quantify the potential economic benefits of reducing roundworm impact in the target countries. Decreasing the impact of roundworm parasitism is difficult, since conventional parasite control using anthelmintics has been adversely affected by increasing drug resistance in parasite populations. Gray (1999) noted that greater attention to the development of SPC strategies, which entail strategic anthelmintic treatment, genetically resistant hosts, improved management, vaccines, supplementary feeding and biological control, is needed.

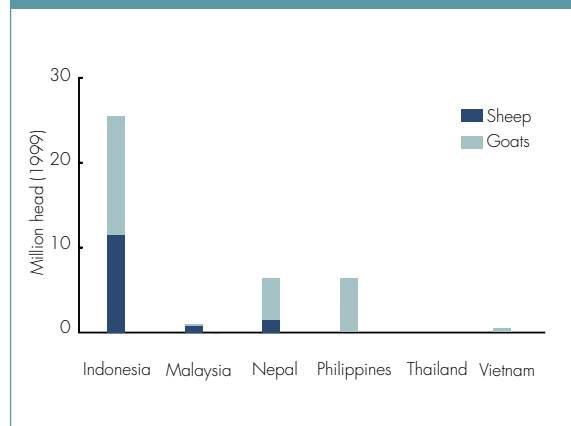


## 2. The economic impact of worm infections in small ruminants in Southeast Asia, India and Australia

### Small-ruminant production

Large flocks of small ruminants are found in Southeast Asia and Australia. The numbers of goats in target Southeast and southern Asian countries are illustrated in Figure 2.1. Asia and Australia differ in their agro-climatic conditions and livestock production practices and so the nature of small-ruminant production and the impacts of internal parasitism also vary. To systematically assess the economic impact of roundworm parasitism, national flocks are characterised into village (small-scale sedentary), commercial and transhumant systems. Parameters such as meat production and wool yield are detailed in Table 2.1 for each representative system. These parameters provide a baseline from which yield reductions, as a result of roundworm parasitism, can be estimated.

Figure 2.1 Small-ruminant flock sizes in Southeast Asia (FAO 1999)



Indonesia has the largest small-ruminant flock in Southeast Asia: about 15 million goats and eight million sheep. The national flock size has been increasing over the past 20 years in response to the growing demand for meat.

The Philippines and Nepal have the next largest flocks of small ruminants. Goats are widespread in the Philippines but sheep are uncommon, despite efforts to integrate sheep production within tree cropping systems.

Goat and sheep production is not widespread in Malaysia, Thailand and Vietnam. National flock sizes are small in these countries and large ruminant production is of greater economic importance. In Thailand and Malaysia small-ruminant production is becoming less important, perhaps because of increasing population pressure and greater urbanisation.

The smallholder village, or sedentary, production system is most commonly found in Thailand, Indonesia, Vietnam, the Nepalese hills and the Philippines. Traditionally, milk consumption has been low in Southeast Asia and small-ruminants are reared for supplementary income from meat production.

In India and Nepal, many sheep and goats are raised within transhumant systems. Madan (1996) indicated that 30% of sheep in arid areas form part of permanent, seasonal or temporary migratory flocks, with movement dictated by the timing of monsoon rains. In mountainous regions, sheep are also raised as part of migratory systems. Flocks are often maintained for four or five months under stall-fed production, then handed to a Chopan (professional shepherd) for grazing in alpine pastures from April to November (Madan 1996).

Table 2.1 Small-ruminant productivity for Asian and Australian livestock systems

Livestock system	Village	Transhumant	Commercial
<b>Goats</b>			
Liveweight of adult (kg) <sup>(a)</sup>	22	22	–
Liveweight of immature (kg) <sup>(b)</sup>	12	12	–
Adult composition of herd (%) <sup>(c)</sup>	71	71	–
<b>Sheep</b>			
Liveweight of adult (kg) <sup>(d)</sup>	22	22	36
Liveweight of immature (kg) <sup>(e)</sup>	12	12	25
Adult composition of herd (%) <sup>(f)</sup>	60	60	76
Wool production (kg/adult/year) <sup>(g)</sup>	–	–	4.5
Wool production (kg/immature/year) <sup>(g)</sup>	–	–	2.3

(a) Adult goat liveweights are derived from Ibrahim (1996) and Saithanoo et al. (1997). (b) Immature goat liveweight is derived from Saithanoo et al. (1997). (c) Adult composition is derived from Saithanoo et al. (1997). (d) Adult sheep liveweight is derived from Meat Research Corporation (1993) for commercial and Ibrahim (1996) for indigenous. (e) Immature sheep liveweight is derived from Meat Research Corporation (1993) for commercial and Ibrahim (1996) for indigenous. (f) Adult composition is derived from Meat Research Corporation (1993). (g) Commercial wool production is derived from ABARE (2000).

All sheep production in Australia is on a commercial basis. Spanish merino sheep are commonly raised for wool production, while crossbred sheep types (such as Merino cross-breeds) and British breeds are used in sheep-meat production. Merino sheep are typically more susceptible than British breeds to roundworm infection. Australian sheep numbers have been declining over the past 35 years, largely in response to the declining real price received for greasy wool. Statistics indicate that the national flock contracted from 158 million head in 1962 (FAO 1999) to 115 million in 2000 (ABARE 2000).

## Prevalence of roundworm parasitism

The most important nematode genera of Asia and Australia include *Haemonchus*, *Trichostrongylus*, *Strongyloides* and *Oesophagostomum*. Roundworm parasitism generally increases with the onset of the wet season in most tropical countries, however, there has been only limited examination of the seasonal trend in host worm burden and infectivity of pasture. To gain an appreciation for the seasonal prevalence of *Haemonchus* in countries where epidemiological data are limited, a simulation model (Barnes et al. 1988, Barnes and Dobson 1990 a, 1990b) was adapted for this



## 2. The economic impact of worm infections in small ruminants in Southeast Asia, India and Australia

nematode species. The model was further developed to assess worm control options. Results of the simulations are included in relevant country assessments.

It is difficult to quantify the extent to which internal parasites are constraining small-ruminant production in Asia as few field trials have been conducted to estimate the size of the problem. Goat flock productivity data from villages in Thailand (Saithanoo et al. 1997) indicate annual mortality rates of 39% for kids and immatures, and 7.2% for adults. For the purpose of this analysis, it is assumed that 1% of adult goats, and 5% of immature goats, suffer roundworm related mortality. Major assumptions relevant to the economic impact assessment are shown in Table 2.2.

Studies of sheep production in the tropics indicate that immature and adult mortality are generally high: 40% in perinatal lambs in Morocco (Idrissa et al. 1992); 19.3% in perinatal Menz sheep in Ethiopia (Mukasa-Mugerwa et al. 1994); 48 and 60% in immature and adult village sheep of northwest Cameroon (Ndamukong et al. 1989a); and 29% of sheep in Indonesia (Batubara 1997). Few studies have been carried out in the tropics to clearly identify the impact of roundworms on flock productivity, although Adeoye (1994) found that 27% of sheep deaths were related to helminth infection in village sheep of southwest Nigeria.

Table 2.2 Roundworm prevalence and mortality by production system

Livestock system	Village		Transhumant		Commercial	
	Adult	Immature	Adult	Immature	Adult	Immature
<b>Goats</b>						
Prevalence (%) <sup>(a)</sup>	–	–	90	90	60	60
Mortality (%) <sup>(b)</sup>	–	–	1	5	1	3
<b>Sheep</b>						
Prevalence (%) <sup>(c)</sup>	87	87	90	90	60	60
Mortality (%) <sup>(d)</sup>	1	3	1	5	1	3

(a) Disease prevalence estimates are the author's. Transhumant mortality losses are lower due to arid and mountain agro-climates. (b) Consultant estimates derived from overall flock productivity studies in Thailand by Saithanoo et al. (1997). (c) Disease prevalence estimates are the author's. Transhumant mortality losses are lower due to arid and mountain agro-climates. (d) Consultant estimates derived from experiments by Barger and Southcott (1978), Anderson (1972, 1973), Anderson et al. (1976), Thompson and Callinan (1981), and Brown et al. (1985) in the high rainfall areas of Australia.



Mortality data from Australian field trials using roundworm susceptible merino sheep (Barger and Southcott 1978, Anderson 1972, 1973, Anderson et al. 1976, Thompson and Callinan 1981, Brown et al. 1985) have been used to estimate sheep production losses within Asian production systems. Assumptions are included in Table 2.3. Roundworm parasites cause mortality as well as production losses in small ruminants that recover from the effects of infection. During the period of infection, milk production, growth and manure production are typically reduced. The severity of reduced productivity is a function of stock age, breed, physiological status and level of nutrition. A set of production-loss tables have been compiled (Table 3) to estimate the losses associated with roundworm infection.

Selected studies of productivity in parasitised goats have been conducted in southern Luzon, Philippines. Que et al. (1995) showed that dewormed and parasitised goats differed in growth by 4 kg over a period of eight months. Howlader et al. (1997a, 1997b, 1997c) described the pathological, parasitological and production changes in immature goats infected artificially with *H. contortus*. The growth of kids born of infected mothers was also affected.

Adult sheep are generally considered to have greater natural resistance to the impact of internal parasites and their production losses are assumed to be lower than those of immature animals.

Table 2.3 Annual production losses in disease-affected small-ruminants

Livestock system	Village		Transhumant		Commercial	
	Adult	Immature	Adult	Immature	Adult	Immature
<b>Goats</b>						
Liveweight loss (kg/hd/yr) <sup>(a)</sup>	0.7	0.4	0.7	0.4	0.7	0.4
<b>Sheep</b>						
Liveweight loss (kg/hd/yr) <sup>(b)</sup>	0.8	1.2	0.8	1.2	0.8	1.2
Wool loss (kg/hd/yr)	0.2	0.2	–	–	–	–

(a) Meat losses of 0.7 kg for adult goats and 0.4 kg in immature goats are consultant estimates derived from study by Que et al. (1995). In this study it was found that treated goats were 3.6 kg heavier than controls. It was assumed that 10% of this loss estimate would be experienced by average village goats.

(b) Meat losses of 0.8 kg for adult sheep and 1.2 kg in immature sheep are consultant estimates derived from studies by Barger and Southcott (1978) and winter rainfall trials by Anderson (1972, 1973), Anderson et al. (1976), Thompson and Callinan (1981) and Brown et al. (1985). (c) Wool losses of 0.2 kg for adult sheep and 0.2 kg in immature sheep are consultant estimates derived from studies by Barger and Southcott (1978) and winter rainfall trials by Anderson (1972, 1973), Anderson et al. (1976), Thompson and Callinan (1981) and Brown et al. (1985).

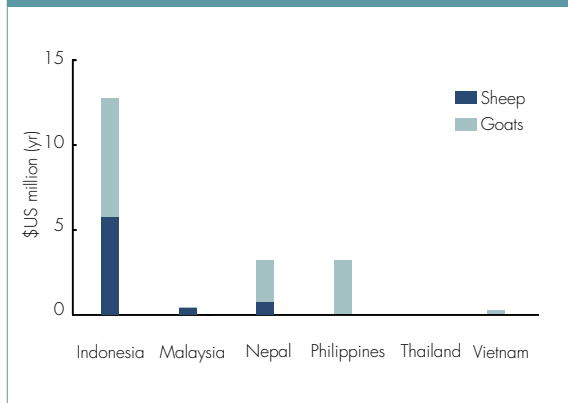


## 2. The economic impact of worm infections in small ruminants in Southeast Asia, India and Australia

### National economic loss and control costs

Production losses, estimated for each representative livestock system, are aggregated to country level using national small-ruminant flock size information (FAO 1999). National production losses are multiplied by livestock product prices to estimate the aggregate economic value of losses. The annual costs of roundworm parasites in selected Asian countries are shown in Figure 2.2. Of the target countries in the project, the aggregate costs of roundworm parasites are greatest for Indonesia, where it was estimated that the disease cost \$US 13 million in 1999.

Figure 2.2 Annual economic impact of roundworms in target countries



Small ruminant populations are especially high in Muslim countries where few pigs are raised.

Of the total roundworm-inflicted production loss estimated for Indonesia, \$7.1 million was attributable to goat production and \$5.6 million to sheep production. The estimated loss for sheep production is significantly larger than that calculated by Temaja in 1980. The increase may be a result of increased flock size and product prices over the past 20 years.

Small ruminant producers in Nepal and the Philippines were estimated to experience the next largest economic loss from roundworms. Economic loss estimates are largely proportional to numbers of small ruminants.

Roundworm-loss estimates have also been updated for India and Australia. These countries have large small-ruminant flocks and, hence, substantial annual economic losses: \$103 million and \$111 million, respectively. The Australian cost estimate is similar to that calculated by McLeod (1995), but has decreased with lower wool prices and a smaller flock. Strategic parasite control programs have been developed for both India and Australia. Lubulwa et al. (1996) quantified large

economic returns from the development and extension of improved roundworm control in western India, while Collins and Poulter (1990) and McLeod et al. (1992) estimated substantial economic benefits from the development of Wormkill and Drenchplan strategic roundworm control programs in the summer and winter rainfall areas of Australia.

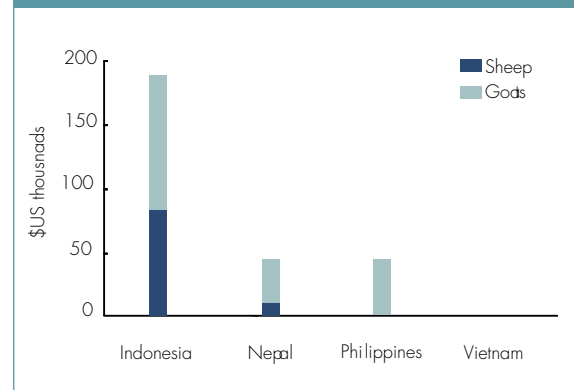
## Potential economic benefits from SPC adoption

Preliminary simulation analysis suggests that production losses associated with roundworm parasitism could be substantially reduced by adopting improved management recommendations. At this early stage of the SPC project it is counterproductive to suggest the most desirable combination of management practices, as this strategy is still to be formulated. However, if an SPC package could be devised that would reduce the effect of these parasites by 15% for adopting farmers, and 10% of sheep or goat owners were also to adopt the package, the economic benefits outlined in Figure 2.3 would be realised.

Indonesia would gain the largest economic benefits from 10% adoption of an SPC program that reduced productivity losses by 15%. Based on current prices and prevalence data included in the analysis, Indonesian farmers would capture \$0.2 million in annual benefits.

SPC adoption gains would also deliver substantial benefits for farmers in the Philippines and Nepal. Given that SPC recommendations will be formulated for Nepalese farmers in the mid-hills, transhumant producers are not likely to capture substantial benefits. Changes in SPC adoption level and flock size substantially affect estimated economic benefits. Consequently, on-farm research should be carried out at benchmark sites, representative of major agro-ecological zones, to develop SPC recommendations that maximise adoption. Studies have shown that improved parasite control generates financial benefits (Misniwaty et al. 1994) but adoption remains low. Constraints to the adoption of SPC need to be identified and innovative approaches to promote SPC practices investigated.

Figure 2.3 Annual potential benefit from SPC adoption



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### Spreadsheet model

A spreadsheet-based model, PBASE (Excel 97, Microsoft Corporation), has been developed to integrate flock size, disease prevalence and production loss components of the economic impact assessment procedure and evaluate total annual costs of roundworms within target countries. Preliminary data for Nepal, Australia, Thailand, Malaysia, Vietnam, India, Philippines, and Indonesia have been entered and up-to-date data for relevant systems need to be included. The model is supported by a help system that supplies operational and data background information to guide spreadsheet users.

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### 3. Developing and testing integrated approaches to sustainable parasite control in small ruminants with farmers in the Philippines, Vietnam, and Indonesia

A.M.P. Alo

#### Introduction

During the past 10 years there has been a big push to introduce or strengthen a user perspective in adaptive agricultural research. Technology development is said to be a complex, multi-stranded, and multi-directional process, involving many actors, other than scientists, in the formal research system (Cramb 2000). The evolution of a particular technology depends not only on its scientific merits but also on the actions of development coalitions — loose groupings of actors who combine their resources to push for a particular path of technical change (Biggs and Smith 1998). Thus there is a need for active participation of stakeholders to generate technologies that are not only ‘well-developed’ but also adopted in a sustained manner (Gabunada et al. 2003).

These factors were considered in the ILR/IFAD Technical Assistance Grant 443 (TAG 443) project entitled Development and Testing of an Integrated Approach to the Control of Gastrointestinal Parasites in Small Ruminants in Southeast Asia. A crucial component of TAG 443 was the Participatory Diagnosis of Small

Ruminant Gastrointestinal Parasites project, implemented in the Philippines, Indonesia, Vietnam, Lao-PDR and Cambodia. In this component project, farmers are offered the opportunity to conduct research on integrated worm control in goats. Specifically, technologies developed through the Sustainable Endoparasite Control (SPC) for Small Ruminants Project (ACIAR 97133) are offered as a basket of options for testing by farmers.

This chapter discusses how worm control technologies for small ruminants were developed and tested in three TAG 443 participating countries — Vietnam, Indonesia and the Philippines — with particular emphasis on the Philippines where project analysis is most advanced. Although the paths taken by the countries were different, common lessons point to one thing: it is extremely valuable to involve the beneficiaries of technology development in all phases of a project. In this case, not only did it accelerate the adaptation and advancement of new farming practices but it also improved the livelihoods of the participating small-ruminant keepers.





# 3. Developing and testing integrated approaches to sustainable parasite control in small ruminants

## The participatory technology development process

At each focal site in Vietnam, Indonesia and the Philippines the process began with participatory problem diagnosis and the matching of farmers' needs with existing technological options. At this point the Vietnamese project team took a different pathway as summarised in Figure 3.1.

### Vietnam

There was no ACIAR-SPC project implemented in Vietnam. So, using SPC literature from different countries, the Vietnamese project selected and evaluated specific approaches, both on-station and on-farm, to generate a basket of technologies to offer farmers. In essence, the Vietnamese project was initially researcher-managed although jointly planned and assessed by farmers and researchers.

Vietnamese farmers selected options that suited them from the initial basket of technologies and research plans were generated by combining farmers' local knowledge with the technical know-how of the researchers. Most research was done on farms but some, such as evaluating the effectiveness of medical plants on larvae, was done in the laboratory. A technical team helped farmers with their experiments by facilitating group discussions and helping collect and analyse data. Focus (treatment) and non-focus (control) farmers then came together with the technical team to jointly evaluate the experiments. Suitable technologies with

'good impact' were packaged as best-bet options for sustainable parasite control. Problems detected during the testing stage were also investigated. More problems emerged after each cycle, so the process of technology development (testing, monitoring and evaluating, modifying and refining) was repeated several times. The best-bet options were then offered to other farmers interested in replicating the experiments of focus farmers. These farmers, however, were not researcher-guided but allowed to decide how things best suited their conditions (Binh et al. 2003).

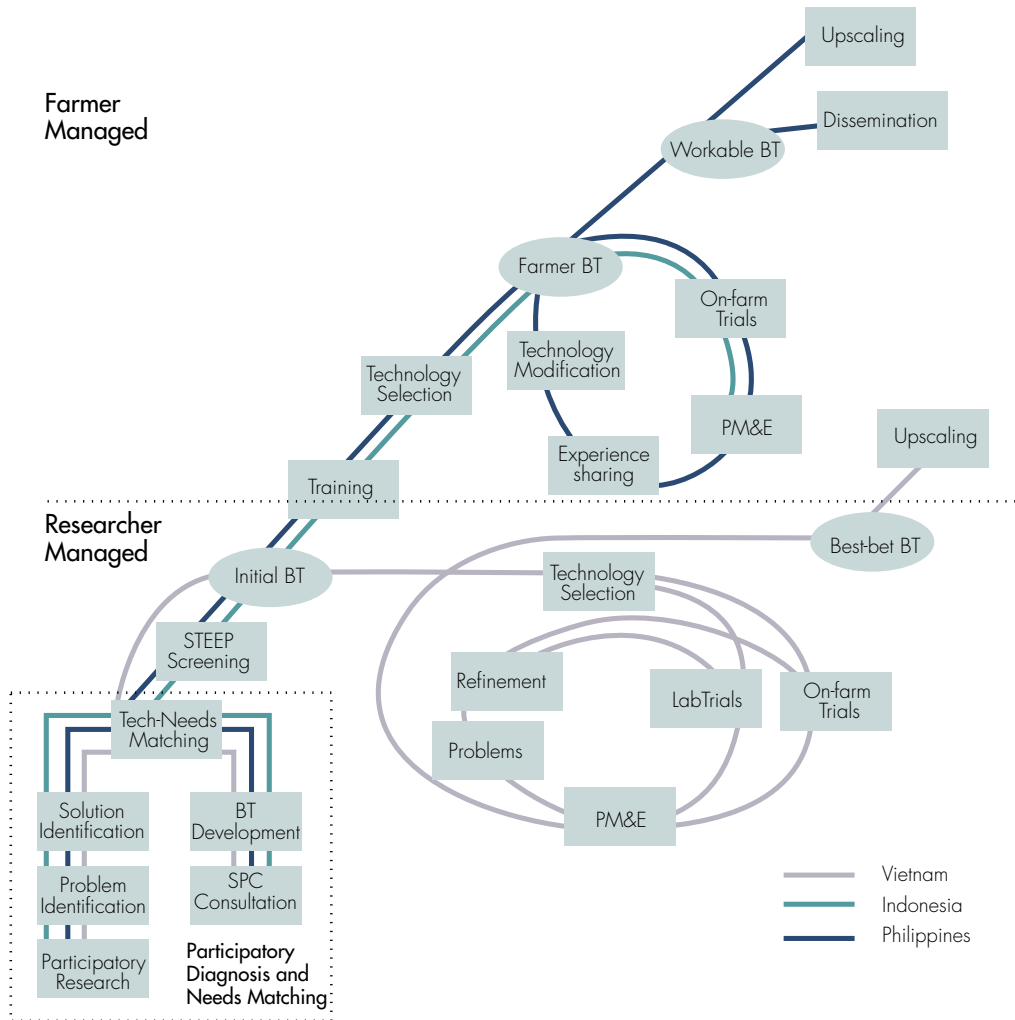
### Indonesia and the Philippines

In contrast, in the Philippines and Indonesia, technology testing was farmer-planned, designed and managed. This meant that farmers, largely independent of the project team (Alo 2003, Subandriyo 2003):

- designed their projects and mixed and matched options to address their needs
- managed their own on-farm trials
- found needed resources
- modified the technologies to fit their resources and capabilities.

Participatory site appraisal was the first stage of the process. A series of consultations was conducted with various local government units, SPC experts and farmers. These meetings ensured that key stakeholders were aware of the realities surrounding goat production in the focal villages and the potentials of each SPC technological intervention identified.

Figure 3.1 Technology development paths taken by TAG 443-Philippines, Indonesia and Vietnam (BT = basket of technologies)



### 3. Developing and testing integrated approaches to sustainable parasite control in small ruminants

Once the initial basket of technology options was developed, it was subjected to STEEP screening for:

- Social acceptability
- Technical feasibility
- Economic viability
- Environmental soundness
- Political acceptability

Field-based training courses were then held to inform farmers about the options available to help solve their problems. Farmers were invited to select any technology option they wanted to try on their farm. It was made clear to them that along with this opportunity came the responsibility of finding the needed resources and of managing their chosen project. Farmers were not forced to try approaches that did not match their beliefs, resources or capabilities.

Participatory monitoring and evaluation were used to assess the dynamic process with farmers choosing an initial technology-mix, testing the options on-farm and adapting them until they arrived at the mix of options that best suited their circumstances. Results were used to select a group of technologies that farmers felt were best suited to them and that could be scaled up or disseminated to other farmers and communities — a farmer-generated basket of technologies.

#### Baskets of technologies offered

The main aim of the project is to control worms but the technology baskets developed were holistic and considered all aspects of goat management. The baskets

of options generated in Vietnam, Indonesia and the Philippines were almost the same, including strategies for improved management of:

- disease — strategic deworming using commercial anthelmintics (with or without medicated feed supplement mineral block); biological control of endoparasites using ducks, fungi and earthworms
- grazing — rapid rotational grazing
- nutrition and feeding — establishment of forage gardens, tree and shrub leaf supplementation, concentrate supplementation, stall-feeding
- breeding — introduction of exotic upgrades, use of large local breeds, controlled breeding
- housing and confinement — well-designed housing with partitions, elevated slatted flooring, waste pits, year round or rainy season confinement
- sanitation — effective waste management.

The options offered provided potential solutions to the major goat production problems of farmers, the foremost being mortality from poor management (Alo 2003; Subandriyo 2003; Binh et al. 2003).

The project teams in Vietnam and Indonesia are still at the participatory monitoring and evaluation stage. Although some preliminary results from Vietnam have been collected, no detailed assessment has been conducted. The Philippine project has completed this stage and their results have been analysed.

## Participatory technology development in TAG 443-Philippines

### Community-based approach

The problem of parasitism among small ruminants markedly constrains farm productivity in the Philippines. The challenge is to empower farmers with knowledge about goat production and health, to improve productivity, minimise worm infestation and ensure farmers receive the economic returns due to them. This is best achieved through the active participation of farmers in planning, field validation and evaluation, thus the Philippine team supported the central role of the farmers in the TAG 443 project.

A community-based integrated approach to goat worm control was employed. The project's activities can be classified into:

- selecting focal sites
- identifying farmer cooperators
- mobilising the community socially
- creating and evaluating baskets of options.

Focal site selection involved three levels of screening: regional, followed by provincial and then municipal or village level. Once focal sites were identified, the project started to be institutionalised at each location.

Local working groups, consisting of representatives from the Department of Agriculture-Regional Field Unit, Provincial Veterinary Office, the municipal/city agriculture office, municipal/city planning and development office, and the village council, were



Farmers, extensionists and researchers can work together to plan and conduct experiments. (A.M. Alo)

established in the provinces of Cebu and Pangasinan (the provinces with most goats). After some capacity building the groups identified a set of criteria to select farmer cooperators.

After farmer cooperators were selected social mobilisation (field trips, on-farm training, and technology workshops) began. This led to the development of baskets of technology options from which farmer cooperators selected technologies for testing. Farmers' experiences and evaluation were the basis for adoption, rejection or modification of technologies.

### Process of technology testing

Field trials in the Philippines were not all conducted at once. Preceding the testing was a week-long, hands-on workshop on SPC technologies. This technology training occurred during the rice-planting season in the village of Tobor (one of the three focal sites) so farmers there deferred testing until cropping chores



### 3. Developing and testing integrated approaches to sustainable parasite control in small ruminants

were finished. One cooperator even deferred adoption of rapid rotational grazing to October 2001 as he did not have the budget for the divisional fences required.

Testing was deferred at most sites because most farmers were not immediately able to construct a pen, the primary prerequisite of all the baskets. Hence, on-farm trials across sites officially started in July 2001, or two months after the last farmers' training workshop.

Initially, farmers were asked to construct a pen or remodel their existing shed to meet the project's recommendations of:

- an elevation of at least 1 m from the ground
- walls and roof
- feeders, salt lick tubes and brooder boxes
- a separate kidding pen
- a well-drained position with a share of the morning and afternoon sun.

Each farmer was given the freedom to design his own pen or to modify other designs. Each pen was then evaluated by all project participants using a score sheet. Everyone benefited from the exchange of ideas and ultimately constructed the pen most appropriate to their circumstance.

After constructing the pen, farmers were asked to confine their animals either all day long (complete confinement) or just at specific times of the day or night (partial confinement), depending on the chosen technology mix. About a month before the rainy season started, the local government technician dewormed all the ruminants in the community to ensure that they were clean before testing started. To monitor the feeding activities, farmers

were required to note, during the initial month, the length of time they spent on each activity, the kind of feed they collected and an estimate of the weight of forage per feeding. The farmers had the freedom to choose the forages they wanted to use for their animals.

To avoid inbreeding, the farmers were asked to exchange bucks or upgrade their breed by using an Anglo Nubian buck lent by the local government unit to the site.

Each month, the local working group (i.e. representatives from local government agencies in the concerned region) recorded animals' weights and collected faecal and blood samples. Samples from Cebu were analysed in the diagnostic laboratory of the regional Department of Agriculture and those from Pangasinan at Central Luzon State University. For accurate identification, all animals were eartagged. Larval development assays were performed at the diagnostic laboratories, as required and when the facilities and expertise were available.

Results, including faecal egg count (FEC), blood packed cell volume (PCV) and recommendations from the project's veterinarian, were provided to farmers after every analysis. Part of the agreed participatory monitoring and evaluation protocol was the regular sharing of experience by the farmers with the secondary stakeholders (i.e. the local government unit representatives) and the team. During these sessions, the project researchers interpreted the worm profile per farm as the farmers narrated their experiences, experiments and lessons learned. These sessions doubled as in-course assessment periods.

## Subsidies/incentives given to farmers for testing

Unlike traditional government programs, this project did not give any incentives to farmers for testing the technology options. From the start, it was emphasised that this was not a goat dispersal project and that loans would not be provided. The only benefit that the project promised was knowledge empowerment through the conduct of technology-based learning workshops. However, to ease the financial burden on the farmers, the local government units provided inputs such as dewormers and forage seeds at the start of the project. In Liloan, a focal site in the Visayas, the local government units even constructed animal housing for four of the six cooperators, with the agreement that costs be repaid after a set period of time.

Although farmers initially found it difficult to operate independently (especially in Liloan), after almost two years they have demonstrated that they no longer need to rely on the local government units.

## Farmer-generated technology baskets

Free grazing or tethering of goats was the traditional practice used by cooperators at the three project sites. Goats were allowed to graze freely or were tethered in available communal pasture during the day and placed under a tree in the backyard or makeshift shelter at night. Housing for goats, although provided by a few, was still considered an innovation at all the sites. Hence, worm infestation in goats was generally high. Worm-related disease was the primary cause of mortality and to cope with this farmers were forced to



Researchers and farmers both make important contributions to developing new ideas and technologies. (G.D. Gray)

immediately sell or slaughter affected animals to prevent further losses. Farmers made little attempt to consult veterinarians or seek advice from livestock experts, primarily because goats were not a priority commodity or a significant program of the local government.

TAG 443-Philippines introduced baskets of technology options revolving around worm control but including strategies for all aspects of goat production management. Rather than choosing a single technology, farmers mixed and matched options to best fit their needs. Since each combination was chosen to suit individual conditions they were identified as farmer-generated baskets of technologies. This differs significantly from the traditional approach of experts coming to a village with ready-made technology plans. The project's strategy gave researchers opportunities to understand each farm and gave the clients freedom to choose options based on their perceptions and needs.



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Table 3.1 Farmer-generated baskets of technologies (FBTs)

FBT 1: Complete confinement + strategic deworming	Complete confinement is the banner technology of this basket. Specifically, animals were completely confined during the rainy season but were allowed to graze freely in summer. Animals were housed and fed grasses in stalls. Leaves of local trees and shrubs were given as supplement. Goats were strategically dewormed a month before the onset of the rainy season and the second dose, if necessary, followed at the peak of the rainy months. A medicated urea molasses mineral block (MUMMB) was supplied within two months of the rainy season and an improved buck was introduced in the herd to further upgrade their stocks.
FBT 2: Rapid rotational grazing + strategic deworming	Rapid rotational grazing is the primary component of this basket. However, for another farmer who tested this on their pasture land, rotational herding was done (that is, continual movement of a herd over a large area). For rapid rotational grazing, the pasture was divided into 10 paddocks and animals transferred from one paddock to another after 3.5 days. They were housed at night and during inclement weather. Just as in FBT 1, grasses were cut and carried to the stalls, tree leaves used as supplement, MUMMB supplied for two months of the rainy season, strategic deworming employed, and an improved buck introduced.
FBT 3: Partial confinement + strategic deworming	This basket is the closest to the farmers' traditional practice. Partial confinement and strategic deworming are its main components. Animals were confined at night and during inclement weather. However, when the weather was good, they were either tethered and transferred from one site to another predetermined non-grazed site every 3.5 days, or allowed to graze freely. Even during rainy months, animals were allowed out of the pen so long as it was not raining and the ground was dry. Animals were supplemented with tree leaves and shrubs upon return to the pen, strategically dewormed, MUMMB-supplemented and mated to an improved buck to further upgrade the stocks.

Ultimately, after months of testing, farmers came up with three baskets of technologies (Table 3.1). These were generated through a dynamic process with farmers choosing an initial technology mix, testing it on their farms and making modifications or refinements until they arrived at the one that best suited their circumstances.

#### Resource requirements of the farmer-generated baskets of technologies

Housing, as explicitly detailed by Brown et al. (2003), was a requirement of all of the baskets. Most cooperators adopted a housing design introduced by the project with some farmers adapting and improving an adopted design. Houses were made from cheap local materials:

wood, bamboo and used galvanised iron. Many cooperators could obtain some of these materials at no cost, however, for purposes of analysis, these were assigned an estimated value to arrive at a more accurate picture of the cost of the technology mix. Some cooperators and members of their families supplied the labour in the construction while others hired labour to help. Whether family or hired labour was used, a value was assigned to represent the opportunity cost of labour.

Stall-feeding is a component technology common to all farmer-generated baskets of technologies. However, this practice is most intensive in FBT 1 with animals being completely confined and thus entirely dependent on gathered feeds. Labour for gathering grasses and tree leaves and shrubs is the most important resource required for this practice. Feed was abundantly available at the focal sites and could be freely gathered.

All of the farmer-generated baskets of technologies included chemical deworming. Initially, cooperators followed strategic deworming, which consisted of providing the animals with chemical dewormer a month before onset and during the peak of the rainy season. However, cooperators later decided to deworm only before the rainy season, primarily because animals were confined and tree leaves (stall fed) with anthelmintic action were available. Chemical dewormers were provided to farmers at no cost through the local government units but a value was assigned to determine the costs incurred by farmers if they were required to pay. The three technology mixes also used MUMMB as a dewormer, but only during the initial stage of the project.



Identifying market prices, trends and the demands of consumers is essential for good technology development. (K.C. Patawaran)

All cooperators opted to improve their stock using improved bucks of the Anglo Nubian bloodline. Anglo Nubian stock grows faster than traditional stock and marketable size can be achieved after a much shorter growing period. In addition, it has better reproductive performance. Improved breeding could be done by purchasing an improved buck and making it part of the herd, by hiring a buck for natural insemination or by using artificial insemination.

### Baskets tested and criteria for adoption

Of the 16 cooperators, only three were willing to test FBT 1 (complete confinement) at the start of the process. Most farmers (11 out of 16) initially chose FBT 3 (partial confinement), as this was most similar to their traditional way of raising goats. However, eight of the original 11 farmers who opted for FBT 3 eventually shifted to FBT 1.





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Reasons cited for rejecting partial confinement and opting for complete confinement were as follows:

- Better time management — complete confinement allows more time for other chores and commercial enterprises.
- Better disease management — as reflected in their monthly FEC-PCV monitoring sheets, fewer incidences of morbidities (worm and respiratory-related) were recorded, as goats were prevented from feeding in contaminated pastures and protected by the pens from the harsh weather. Fewer deaths were also observed.
- Ease of operation — farmers do not have to bring goats to grazing areas four times a day, run to secure them when it rains and haul them back when the rain stops. Farmers are no longer exhausted from looking after grazing goats and looking for pastures with enough green grasses.
- Pastureland need not be available — farmers without much land can run a goat enterprise through complete confinement; available land can be used for other crops throughout the year, hence can contribute to higher farm productivity.
- Not labour intensive — when goats are confined, only one person is needed to gather feed, clean the pen, give water and perform other minor chores. When animals are allowed to graze, at least three people are needed to ensure that the herd is in one place and to bring them home without loss.
- Better social relationships — once goats are confined, there is less conflict with neighbours as the goats are prevented from trampling on other people's crops and gardens.
- Better nutrition management — farmers who tried FBT 1 believed that they were better able to choose appropriate forages and balance the nutrition for their goats with stall-feeding than with tethering. Moreover, once they had learned about the use of tree leaves and shrubs, they were able to establish forage gardens near their goat sheds, reducing the need to transport forages from field to shed.

Two of the three farmers who began with, and stayed with, FBT 3 also wanted to shift to FBT 1, but neither had the resources to do so. One was a widow tending a store, without any house help and the other did not have enough money to expand his animal pen. Only one farmer was completely happy with FBT 3 and had no plans to shift. This farmer had almost 40 goats in December 2002 and unlimited access to 5 ha of pasture land near his homestead. Although he has occasional problems with parasitism, he feels that his animals are better nourished through his practice of rotational tethering in the field.

Only two farmers were willing to try FBT 2 — rapid rotational grazing. Both had access to vast lands that could be divided, if not with fences, by stakes. They also had surplus manpower to help transfer animals from paddock to shed and back to paddock. Moreover, since their stock sizes were quite large, totally confining all the animals and stall feeding them one by one was seen as impractical.

Resource endowment (e.g. labour, capital, land) served as the primary consideration for farmers when choosing a particular technology mix. This was followed by ease of operation, the effect of the technologies on the animals and the effect on social relations.

### Modifications made by farmers

After testing technologies in the field, some farmers were keen to adapt the options to better suit their needs and situation. Pen design and operation, in particular, were critically assessed and adapted by farmers. Some modifications are listed in Table 3.2 and shown in the photos below.

**Table 3.2** Problems identified by technology testing and corresponding modifications made by farmers

Emerging problem	Modifications made
Difficulty in collecting dung beneath pen	Increased elevation of pen 1–1.2 m Installation of catching net
Difficulty in controlling breeding	Construction of more 'goat rooms' or partitions
Mineral block eaten by goats	Reshaping of block to simulate salt lick
Difficulty in hardening mineral block	Rolling of block on hot cemented floor for three consecutive days and every other day thereafter



Increasing pen elevation makes it easier to collect dung.



Farmers can easily modify technologies if they see increased survival of kids and increased income; urea mineral blocks (above). (K.C. Patawaran)



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#### Benefits to farmers from participatory technology development

##### Decreased morbidity and mortality and increased stocks

In the Philippines and Vietnam, stock sizes increased as farmers tested the FBTs. The increase in stocks can be attributed to a decrease in worm-related diseases and mortalities (Table 3.3), which, in turn, was due to improved competence in goat management. The data imply that adoption of FBTs was effective in controlling worm-related production losses.

##### Cost-benefit

The FBTs had a positive financial impact as indicated by the net incremental income figures listed in Table 3.4. These figures consider both the benefits and costs associated with the technology mixes. As stock numbers increase, and the initial costs of establishing the enterprise are reduced, income continues to rise.

These improvements are large considering that most cooperators started with a small number of stock (some with just three animals). The number of females in the initial herd determined, to a large extent, the net benefit derived from the project. As discussed earlier, the primary benefit derived from the FBTs was a reduction in mortality rate. Therefore, as female stocks multiplied it became possible to engage in breeding (Brown et al. 2003).

Table 3.3 Biological benefits from technology testing

	Philippines	Vietnam
Increase in stocks	192%	69%
Decrease in morbidity	Jan 2001 53.0%	Dec 2002
% change	2.0%	58%
Decrease in mortality	Jan 2001 56.0%	Dec 2002
% change	2.0%	51%

(Alo et al. 2003, Binh et al. 2003, Venturina et al. 2002)

Table 3.4 Cost-benefit of technology testing

Farmer-developed basket of technologies	Net incremental income 2001–02
FBT 1 complete confinement	4, 872 (\$97.44)
FBT 2 rapid rotational grazing	16, 840 (\$336.80)
FBT 3 partial confinement	3, 702 (\$14.04)

## Increased personal competence

The human and social dimensions also showed rewarding improvements. Knowledge levels improved by 548% and attitude by 75%. Farmers also developed their skills in managing and increasing their stock, establishing forage gardens, designing animal pens, experimenting (testing, observing, and deducing) with different options, detecting parasitism and administering proper deworming protocols (Alo et al. 2002).

## Improved social competence

Farmer participation in technology testing also affected the way farmers dealt with people outside their households and the way their social environment treated them. Specifically, there were marked improvements in the following:

- *Farmer-to-farmer extension activities* — other farmers who saw the improvements on participating farms sought advice and the farmer cooperators were able to teach them what they had learned. Of the 284 people who visited the 16 cooperators, 99 pursued similar goat enterprises in their villages. This can be expressed as a 35% influence on the cooperators' social environment and 450% increase in technology testers.
- *Departure from local government unit dependency syndrome* — initially, some farmers at one site depended largely on their local government unit for support for de-wormers, detection of parasites, forage garden materials and even housing materials. As their competence improved, there was marked departure from this dependency (Table 3.5).

Table 3.5. Farmer knowledge improvements from technology testing

	Mean knowledge		
	Tobor	Danao	Liloan
Jan 2001	11.2	3.5	2.2
Dec 2002	24.7	22.75	23.6
(%) rate of change	120.0	550.0	972.7
Mean change	547.6%		

- *Commercial visibility* — participating farmers have also gained recognition as commercial sources of good stock. The farmers take pride in having established a better price for goat meat. In Tobor, the farmers united to peg the price to P100/kg liveweight during lean months and P150/kg during peak season. As they have been known to produce good quality stock, buyers now accept the price that they set.
- *Community strength* — the common experience generated a strong bond between the participants. In Tobor, farmers felt that they could now mobilise each other for support. In establishing their forage garden, for instance, they were able to get seeds from the local government unit, from the project and even from one of the cooperators who had established a Napier garden (i.e. *Pennisetum purpureum*, a large grass that grows in bamboo like clumps and is used for forage and windbreaks). They are now united by the common goal of making their individual village a respected source of goats.



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- *Personal confidence and wealth* — the confidence levels of all cooperators have increased from the lowest to the highest rating: they believe they can make their goat enterprises booming businesses in the near future. Farmers felt extremely wealthy after two years with the project, not just because they were able to sell goats, but primarily because they were able to reduce mortality. Above increase in income, they valued the experiences, knowledge, contacts and skill that they gained and the opportunities all these initial gains might bring them. Moreover, they were enormously proud to have helped pull 35% of their community out of poverty.

## Conclusions

- Within the participating communities there was a transformation from individual to group empowerment. Personally and socially the farmer cooperators increased their capacity and strength to do things for themselves. They were able to influence 35% of their community (99 other farmers) and help them to try the new technologies.
- With the development of the right mix of technologies by the actual technology-users, researchers need not push for their adoption. The technologies will spontaneously diffuse, from farmer to farmer, throughout the entire community, pulling more and more families out of poverty (Alo et al. 2002).
- This project clearly demonstrates that farmers can be active participants who can bring intellectual contributions to the development process.

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## 4. Anthelmintic resistance in small ruminant parasites: implications for smallholders in Southeast Asia

G.M. Hood

### Introduction

In developed countries where anthelmintics have been continuously used for the past 30 years, resistance to broad-spectrum anthelmintics is now widespread, and threatens the viability of sheep and goat enterprises (Waller 1997a). In many parts of Southeast Asia, small ruminants are raised in backyards by resource-poor farmers. Broad-spectrum anthelmintics are considered expensive and used infrequently, except by relatively wealthy farmers and on government farms. As a result, although anthelmintic resistance has been found in many countries in the region, it has not yet reached the alarming prevalence reported in the major sheep-raising countries of the southern hemisphere (Waller 1997a). Rising global demand for livestock products (Delgado et al. 1999), however, makes intensive and semi-intensive production of small ruminants an increasingly attractive enterprise for smallholders in Southeast Asia. This development is likely to increase stocking rates, with a concomitant rise in the intensity of parasitism. Anthelmintics comprise a powerful tool in the suite available for controlling gastrointestinal parasites, and so conservation of their efficacy is an important goal for livestock development agencies in Southeast Asia.

This chapter reviews the current status of anthelmintic resistance in Southeast Asia, and examines the implications for smallholders, for whom anthelmintics offer one key to the control of parasitism and the development of enterprises based on small ruminants. Alternatives to the use of anthelmintics — such as nutritional strategies and grazing management — are also considered, since these have significant potential for reducing the selection pressure for anthelmintic resistance.

### Anthelmintics used in Southeast Asia

Almost all of the anthelmintic groups used in developing countries are also available in Southeast Asia (see [www.worminfo.org/anthelbase](http://www.worminfo.org/anthelbase)). However, their availability to smallholders depends on the wealth of the local community, proximity to drug stores, and the whims of local government units, which sometimes provide free or subsidised anthelmintics for smallholders. In the Philippines, benzimidazoles are widely available, levamisole/tetramisole products are harder to find, and macrocyclic lactones are available primarily from



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veterinarians or drug stores in large towns. For example, a recent survey of 19 drug stores (Patawaran et al. 2003) found that benzimidazoles were available and recommended in 95% of stores, levamisole/tetramisole products in 63%, and the macrocyclic lactone group sold in smaller quantities (16% of stores). Narrow spectrum drugs and piperazine and its derivatives were also available. There seems to be a bias among veterinarians and other experts toward benzimidazoles: 106 of 119 Philippine experts surveyed by Ancheta et al (2004) recommended the use of benzimidazole products, while only one recommended levamisole/tetramisole, even though the most popular benzimidazole product (albendazole) can be toxic to pregnant goats. In other countries, levamisole and tetramisole, which are comparable in price to the benzimidazoles, are both recommended and readily available.

Most poor livestock keepers do not buy anthelmintics for strategic drenching programs. Instead they use ad hoc treatments for sick animals or locally grown herbal remedies. When anthelmintics are used, it is likely to be at sub-optimal doses. Drug stores in Southeast Asia usually stock broad-spectrum anthelmintics in small, often single dose, packages because smallholders can rarely afford to treat more than one or two animals. Single-dose preparations can lead to under-dosing if used for heavy animals. For example, 220 mg mebendazole capsules are only sufficient for 18 kg animals, and 2 g sachets of levamisole hydrochloride for 20 kg animals. The availability and high price of these products, in combination with low levels of literacy and poor understanding of dose rates, means that under-dosing is probably frequent in Southeast Asia. Under-dosing

is also likely to occur through the use of poor quality generic products. The quality of anthelmintics used in Southeast Asia has not been assessed, but studies in Africa (van Wyk et al. 1997, Wanyangu et al. 1996) indicate that some generic products have sub-optimal concentrations of the active ingredient.

### Tests for anthelmintic resistance

Most investigators in Southeast Asia have used the *in vivo* faecal egg count reduction test (Coles et al. 1992) to detect anthelmintic resistance. This intuitive test is readily applied in large flocks and herds (more than 15 animals) but needs a follow-up visit for the second sample, and can overestimate the prevalence of levamisole resistance (Grimshaw et al. 1996, Maingi et al. 1998). It is also less precise than *in vitro* methods (Le Jambre 1996). The *in vitro* egg hatch assay (Le Jambre 1976) is useful for detecting benzimidazole resistance, and has been used in peninsular Malaysia (Rahman 1993). A new *in vitro* test, the larval development assay (Hubert and Kerbouef 1992, Lacey et al. 1990), has been used in recent work in Indonesia and the Philippines (Ancheta et al. 2004, Beriajaya et al. 2003, Venturina et al. 2003). It has two principal advantages over other methods: first, it provides quantitative results for levamisole and benzimidazoles, and a qualitative result for the macrocyclic lactones; second, it needs just a single sample — no follow-up visit is required. The second feature means it can be used in smallholders' flocks and herds or at markets and abattoirs (Venturina et al. 2003). It should therefore now be possible to obtain accurate estimates of the prevalence of anthelmintic resistance.



## Prevalence of anthelmintic resistance

Most of the sheep and goat producing countries of Southeast Asia have reported some degree of anthelmintic resistance. In Indonesia, which has the largest population of small ruminants, low levels of resistance to benzimidazoles have been detected on the island of Java (Beriajaya et al. 2003), but no resistance was detected to benzimidazoles, levamisole or ivermectin in surveys conducted in Sumatra (Dorny et al. 1994b). In the Philippines, benzimidazole resistance was first reported in *Haemonchus contortus* in Mindanao (Van Aken et al. 1994), and has since been reported from many locations throughout the Philippine islands (Ancheta and Dumilon 2000, Venturina et al. 2003). Resistance to levamisole is apparently less common, probably reflecting usage patterns (Ancheta et al. 2003).

Farmers in Malaysia and Thailand are relatively wealthy compared with those in other countries of the region, and anthelmintics are therefore used more often. Studies on small numbers of goats in Thailand (reviewed in Kochapakdee et al. 2002) indicate that benzimidazole resistance is present, but that resistance has not yet emerged to levamisole or the macrocyclic lactones. In nearby peninsular Malaysia, however, suspicions of resistance to benzimidazoles and levamisole were first reported by Dorny et al (1991), benzimidazole resistance was confirmed in 1991 (Dorny et al. 1993) and levamisole and ivermectin resistance were reported by Sivaraj and Pandey (1994). Subsequently, national surveys found 50% of sheep farms and 75% of goat farms had benzimidazole resistance, and resistance to levamisole, closantel and ivermectin was also detected (Dorny et al. 1994a).



Faecal egg count reduction tests, egg hatch and larval development assays can be used to identify resistant worms. (G.D. Gray)

The study of Dorny et al (1994a) is one of the few in Southeast Asia to yield an estimate of prevalence based on a random sampling procedure. The survey included a substantial proportion of the national goat population (2.3%) and is therefore likely to have yielded a good estimate of prevalence — albeit using a selection procedure that is not convincingly random. Other estimates of prevalence in Southeast Asian countries depend on purposive sampling (i.e. targeted, non-random sampling) schemes, and have almost certainly yielded biased estimates. In particular, government and large commercial farms, which notoriously use suppressive treatments, are over-represented in almost all surveys (e.g., Ancheta et al. 2003, Chandrawathani et al. 1999). There is, therefore, a clear need for active surveillance of anthelmintic resistance using statistical sampling procedures (Cochran 1977).



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Introducing anthelmintic resistance by transfer of stock is a potentially significant threat to smallholders.

### Risk factors and transmission of anthelmintic resistance

Worldwide, two factors have emerged as having the greatest predictive value for anthelmintic resistance: frequency of treatment and transfer of stock. Of these, high frequency of treatment is of overwhelming importance (Martin et al. 1984) and has also been most consistently associated with anthelmintic resistance in Southeast Asia (Ancheta et al. 2003, Chandrawathani et al. 1999, Dorny et al. 1994a).

Importation of anthelmintic resistance by transfer of stock is a potentially significant threat to smallholders because government and commercial farms, which serve as sources of stock for the larger smallholder sector, use anthelmintics intensively to reduce parasite burdens and maintain high productivity of grazing sheep and goats. Recent evidence shows that importing of stock and restricting access to shared grazing

(a potential larval refuge) is correlated with decreased efficacy (Ancheta et al. 2004). Beriqajaya et al (2003) have shown that resistance is easily transferred to smallholders by dispersal of stock from government farms. The quantitative importance of stock transfer remains unknown. Refugia — locations where eggs and larval nematodes escape exposure to anthelmintics — are more common in the humid tropics than in major sheep producing regions of the world, and so dilution of emergent resistance alleles should be expected. It would nevertheless be prudent for managers of government farms to apply quarantine drenching treatments before dispersing stock to smallholders. Quarantine treatment with several efficacious anthelmintics, either serially or as a mixture, should minimise the risks of transfer of worms carrying alleles for anthelmintic resistance.

Other risk factors such as farm size and size of animal management group have also been identified (Ancheta et al. 2004, Venturina et al. 2004), but such factors are invariably colinear with drenching frequency and are therefore difficult to interpret.

### Implications for development of small ruminant enterprises

Gastrointestinal parasitism is widely regarded as the most serious constraint to the development of small ruminant enterprises in the humid tropics (Carmichael 1993). Indeed, it can be argued that the tiny populations of sheep and goats in most Southeast Asian countries have already reached a carrying capacity dictated, not by feed resources, culture or markets, but by intense challenge from gastrointestinal parasites.

To assess the impact of resistance on smallholders we need to consider the three main farming systems under which small ruminants are raised in Southeast Asia: traditional tethering, stall-feeding, and extensive grazing systems.

### Traditional tethering

Tethering, mainly of goats, in backyards, on wastelands, on crop residues and on roadsides is practised throughout Southeast Asia. It is the dominant method used for goats in the Philippines, and seems designed to maximise the impact of coccidiosis and helminthosis by ensuring close contact with faeces. Faecal egg counts are higher in tethered animals than in grazed animals (Magona and Musisi 2002). Also, the inability of tethered animals to select forages probably decreases nutrient supply (Muir et al. 1995), which is known to enhance the pathogenicity of gastrointestinal parasites (Coop and Kyriazakis 1999).

Tethered goats and sheep are primarily raised by the poorest smallholders. They are usually raised as a sideline to cropping and receive little care. The owners cannot afford the suppressive anthelmintic regimes needed to minimise parasitism and have limited access to livestock extension services (and furthermore do not actively seek such services). Anthelmintic resistance is consequently of negligible importance in this system.

### Stall-feeding

Stall-feeding systems are dominant in the uplands of Java where most of Southeast Asia's small ruminants are raised. The houses used in these systems have a raised, slatted floor to allow faeces and urine to drain away.



Laboratory procedures need to be standardised and well managed. (G.D. Gray)

The collected manure is composted with rejected feed and used in a tightly integrated crop–livestock system (Tanner et al. 2001). If grazing is precluded and houses are well designed, it is possible to reduce exposure to parasites under stall-feeding conditions (see Chapter 3), but increases in parasitism and faecal egg counts in stall-fed systems frequently occur. For example, Knox (1990) reports higher worm burdens in stall-fed sheep in West Java (Garut) than in grazed lowland sheep near Cirebon. Likewise, in Tanzania, diarrhoea and gastrointestinal parasitism were significantly higher in stall-fed than grazed goats (Kusiluka et al. 1998). Exposure to helminth larvae in stall-fed animals probably occurs through faecal contamination of floors and feeding troughs (Kusiluka et al. 1998). Larvae are also introduced via forages, especially grasses, that are cut low to the ground (Nguyen Kim Lin et al. 2003).



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The area around houses is likely to be rich in helminth larvae and provides another source of infection for stock that are allowed to graze occasionally.

Javanese smallholders who practise stall-feeding do not commonly use anthelmintics (Beriajaya, pers. comm.), but the combination of stall-feeding and anthelmintic treatment can significantly improve productivity (see Chapter 3). A suppressive anthelmintic regime is used in one of the most productive stall-feeding systems for goats — the SALT 2 demonstration maintained by the Mindanao Baptist Rural Life Center in the Philippines — in which more than a dozen milking goats and their offspring are raised on less than a hectare of forages (Laquihon and Pagbilao 1998, Partap and Watson 1994).

The value of anthelmintics in stall-feeding systems, and consequently the likely impact of resistance, is an open question. Much research on helminths and the use of anthelmintics in the humid tropics has used grazing stock; the portals by which housed stock acquire infection and the interaction with control and treatment methods has been little studied. With good housing design, rigorous enforcement of zero-grazing, and attention to the height at which forages are cut, it seems likely that stall-fed animals could be maintained with limited or no recourse to anthelmintics. It is also relatively simple to provide housed stock with strategic nutritional supplements to improve resistance to parasites, or with biological control agents such as nematophagous fungi (Waller and Faedo 1996). Including tree leaves in the diet — and perhaps those with high levels of condensed tannins — could also help control parasitism and provide smallholders with a sustainable means of income generation.

Holistic research is sorely needed for stall-feeding systems. Such research should, at the very least, model the interactions between parasites, forages, livestock and soil properties. As an example of the need for such research, consider the current upsurge in applied research on the use of plants containing condensed tannins to reduce parasitism in goats (e.g. Kahiya et al. 2003, Nguyen Kim Lin et al. 2003). Cassava is one such plant with high levels of condensed tannins. It can sustain high growth rates in goats (Nguyen Kim Lin et al. 2003), but also rapidly depletes soil nutrients. Leguminous forages, on the other hand, replenish soil nitrogen and have high levels of condensed tannins but, on fertile soils, produce less biomass per hectare than grasses or cassava. The optimum choice of forages in any particular situation will depend on complex interactions among soils, livestock and parasites, and the economic factors that drive decision making.

### Extensive grazing systems

Large-scale grazing of small ruminants is not commonly practised in Southeast Asia. For many years, intensive research by the Small Ruminant Collaborative Research and Support Program (SR-CRSP) in Indonesia explored possibilities for increasing the productivity of grazing sheep and goats under plantation conditions in Sumatra and elsewhere (Horne et al. 1995, Iniguez et al. 1991). SR-CRSP research showed that — with effective anthelmintics and suppressive drenching programs — it is indeed possible to graze small ruminants in the humid tropics and achieve high productivity (Horne et al. 1995). But adherence to the required drenching

programs is difficult to maintain, and the growth of small ruminant enterprises in Sumatra has occurred primarily using stall-feeding systems (Sinulinga et al. 1995). In nearby Malaysia, some plantation owners have turned to cattle, rather than small ruminants, to avoid crippling losses from pneumonia and helminthosis (Ibrahim 1996).

The emergence of anthelmintic resistance dims prospects for unmanaged grazing of small ruminants in the humid tropics. Resistance has yet to be reported from Sumatra, but surveys of smallholder farms are being conducted in South Sumatra in 2003 (Beriajaya, personal communication), and experience elsewhere suggests that the regimes used, for example, at Sungai Putih (Horne et al. 1995), will inevitably lead to resistance.

Grazing management could help reduce dependence on anthelmintics in the humid tropics. A drench and move policy was used in the SR-CRSP research to minimise dependence on anthelmintics, although reinfestation with worms to pre-treatment levels is reported to have occurred within four to six weeks (Horne et al. 1995). A particularly promising grazing strategy is rapid rotational grazing (Barger et al. 1994) in which ten plots are grazed in sequence for three and a half days at a time. This schedule ensures that stock are moved before eggs mature to the L3 stage, and do not return to the same plot for more than a month. Owners of large flocks and herds might have the necessary discipline and fencing to adhere to such a rigorous grazing schedule. For smallholders, however, the technique has generally proved impractical (see Chapter 3).



Training of extensionists and veterinarians increases their awareness of the resistance problems and the tests available. (K.C. Patawaran)

## Conclusions

The population of small ruminants in Southeast Asia is unlikely to increase without major changes in current practices to control worms. Improved practices are discussed in this volume and have been amply reviewed elsewhere (eg, Waller 1997b). For immediate practical implementation by smallholders, however, the strategy that stands out is wider adoption of stall-feeding systems. Stall-feeding is growing in popularity in the Philippines (see Chapter 3), Malaysia (Chandrawathani, personal communication), and Sumatra (Sinulinga et al. 1995). For smallholders, stall-feeding has many advantages over grazing systems including:

- a ready collection point for manure and urine which is recycled as fertiliser for crops
- parasitism and mortality rates being minimised



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- grazing damage to crops and fragile soils being eliminated (Thorne and Tanner 2002).

Moreover, meeting the feed requirements of small ruminants encourages the development of forage plantings which can be used to reduce soil erosion in upland agroecosystems (Stur et al. 2002).

It seems likely, therefore, that the legacy of anthelmintic resistance will be a general reduction in grazing by small ruminants and a move toward intensive production using forages. In some areas, this is actually a welcome development. The poorest people in Southeast Asia often live in upland communities, where they are heavily dependent on unsustainable cropping methods (Coxhead and Buenavista 2001). Integration of stall-fed small ruminants within these upland systems would minimise grazing damage and create incentives for planting perennial forages as hedgerows and along farm borders to minimise soil erosion. The challenge for parasitologists is to develop sustainable methods to control parasites so that livestock can be integrated into agroecosystems that are currently dominated by cropping.

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