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Worm Control for Small Ruminants in Tropical Asia

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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 gastro-intestinal 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.

Peter Core.

Peter Core
Director
Australian Centre for International Agricultural Research

Contents

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 or directly at 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

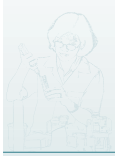
1. Worm control for small ruminants in Southeast Asia

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 (LID 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



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.

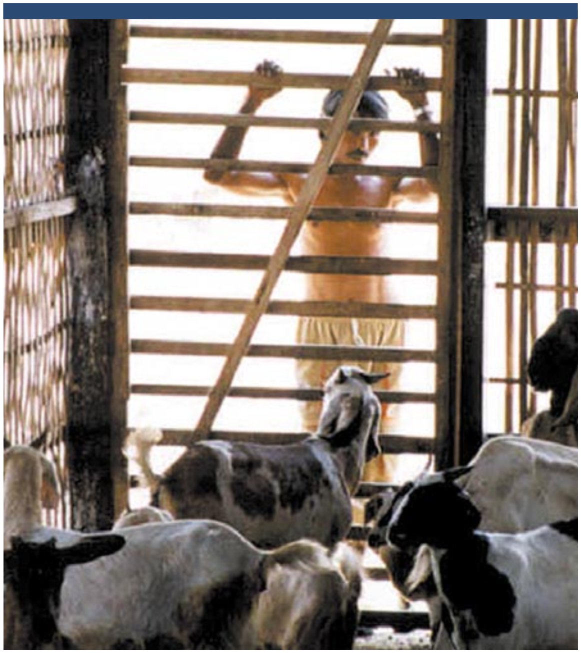
A key objective of this volume, and the accompanying CD, is to bring to a wider audience the treasure trove of material in technical reports, in the so-called 'grey' literature, and in journals which are not widely circulated and in languages not widely understood. The most obvious example of this is 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 climes 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)

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.

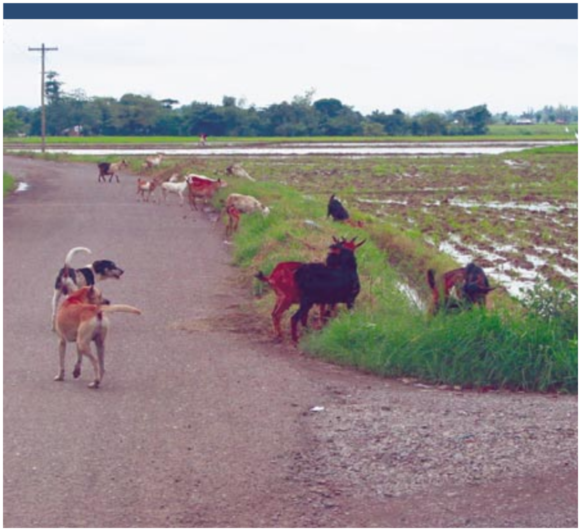
Beriajaya and Copeman (1996) studied goats and sheep on 50 farms in West Java, Indonesia to investigate the seasonal effect of nematode parasitism on weight gain of recently weaned sheep and goats. Weight gains of untreated animals were compared with those of an otherwise similar group treated each two 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.

Pralomkarn 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 short-acting, 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 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 form 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
Beriajaya and Copeman 1996	Sheep	3,842	127	50	Monthly	25%	None	
Beriajaya 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%

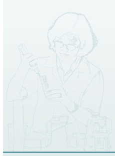
*N: Number of adult sheep in stud

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



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

	Control Option and Likely Contribution to Successful Control			
Disease	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), toxocariasis 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 amonts of clinical and epidemiological data. (G.D. Gray)

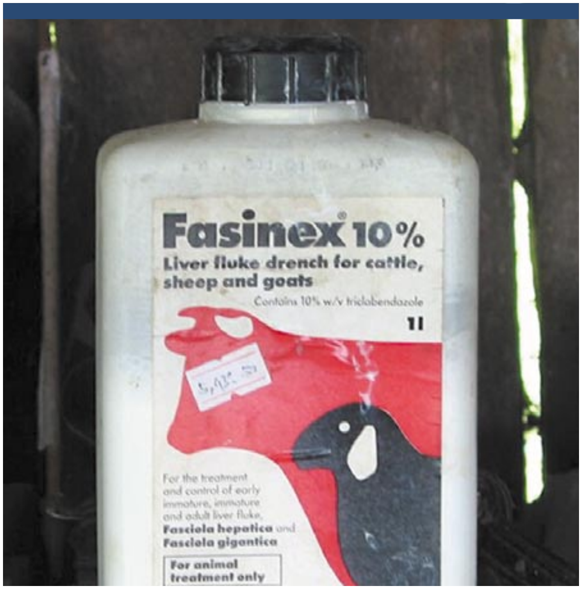
Control options

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.

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).



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

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 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).

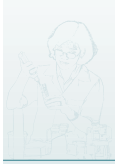
Comparative pharmacokinetics of albendazole in sheep and goats revealed that the systemic availability of the drug was the same in both species but peak levels were achieved earlier and fell off faster for goats, indicating a faster metabolic rate of albendazole in goats. Therefore, based on the disposition 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 responsibilty, 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.



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.

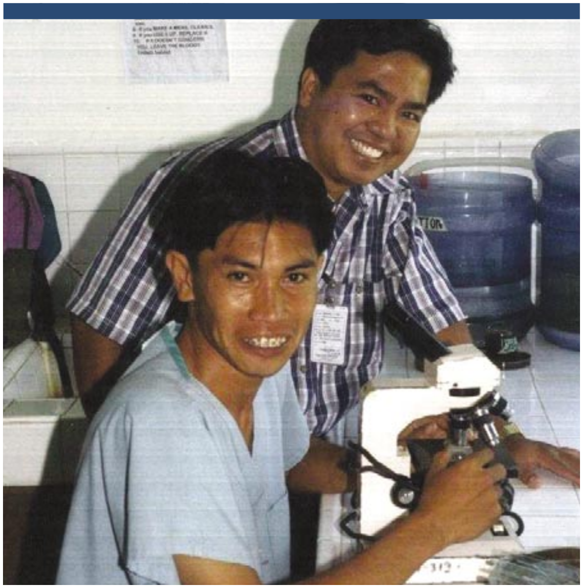
Beriajaya and Copeman (1996) suggest that as FEC were the same throughout the year it was the low levels of nutrition during the wet season that affected the pathogenicity of gastrointestinal nematodes. Farmers also realise the importance of supplementing their animals' diet. Dahlanuddin (2001) surveyed 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, 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*.



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

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 *Tinosphora rumphii* were highly effective against *Haemonchus* larvae *in vitro* and in reducing worm egg counts and worm numbers (Faelnar 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.

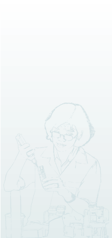
The immediate benefits of using worm measurements to select breeding stock come from the monitoring of disease levels and improved worm control. This usually means less use of expensive and increasingly unreliable chemicals. Genetic gains depend on the intensity of selection and the numbers of animals 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

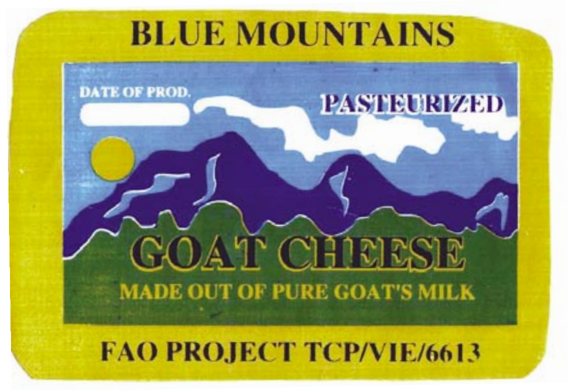
The foundation for any program on parasite control is based on a sound knowledge of epidemiology of parasite infection in a particular area. We now know that parasite control programs for smallholder farming systems in tropical Asia utilise strategic drenching, a combination of confined and grazing systems,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



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

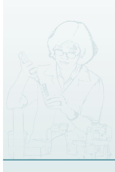
The above integrated approaches are limited to the technologies and are designed for application by a farmer on the recommendation of an advisor or other extension agent. Inclusion of the farmer in development of ideas and technical options and their evaluation, as well as the application of the technology, 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.



FAO networks and discussion groups

FAO has supported a Network for Helminthology in Africa which can be accessed at 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.

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 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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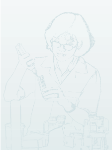


2. The economic impact of worm infections in small ruminants in Southeast Asia, India and Australia

R.S. McLeod

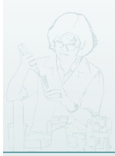
Introduction

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.

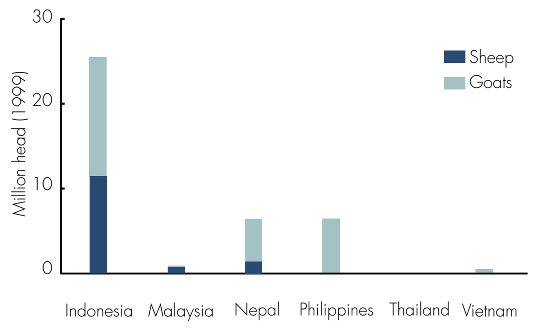


2. The economic impact of worm infections in small ruminants in Southeast Asia, India and Australia

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
Goats			
Liveweight of adult (kg)[a]	22	22	–
Liveweight of immature (kg)[b]	12	12	–
Adult composition of herd (%)[c]	71	71	–
Sheep			
Liveweight of adult (kg)[d]	22	22	36
Liveweight of immature (kg)[e]	12	12	25
Adult composition of herd (%)[f]	60	60	76
Wool production (kg/adult/year)[g]	–	–	4.5
Wool production (kg/immature/year)[g]	–	–	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

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

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

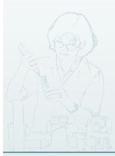
Selected studies of productivity in parasitised goats have been conducted in southern Luzon, Philippines. Que et al. (1995) showed that dewormed and parasitised goats differed in growth by 4 kg over a period of eight months. Howlader et al. (1997a, 1997b, 1997c) described the pathological, parasitological 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

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

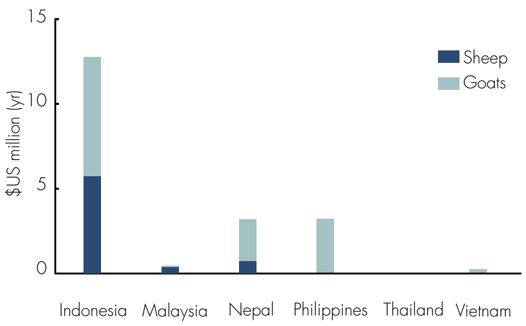
(a) Meat losses of 0.7 kg for adult goats and 0.4 kg in immature goats are consultant estimates derived from study by Que et al. (1995). In this study it was found that treated goats were 3.6 kg heavier than controls. It was assumed that 10% of this loss estimate would be experienced by average village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



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.

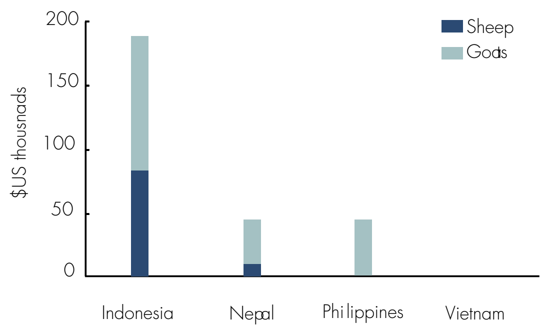
Potential economic benefits from SPC adoption

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



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

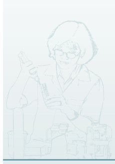
A.M.P. Alo

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 ILRI-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.



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).

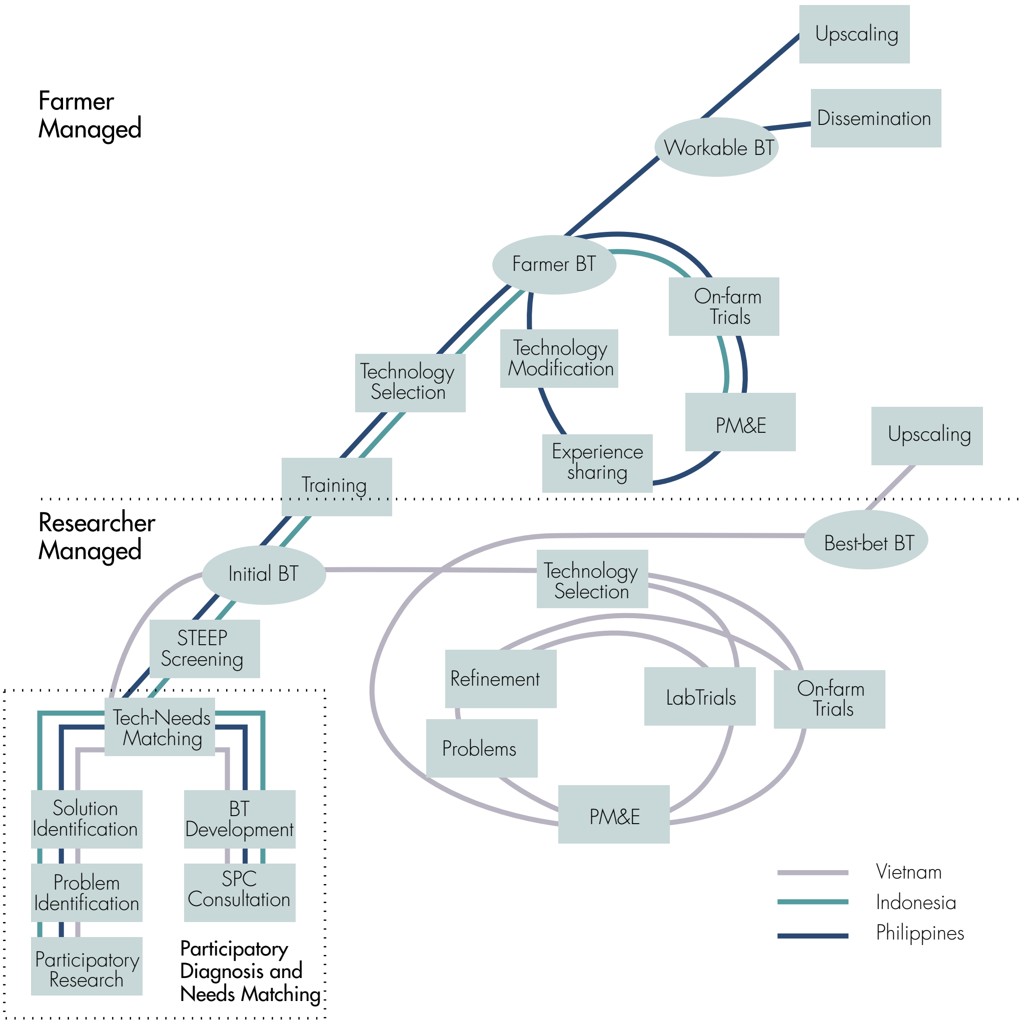
Indonesia and the Philippines

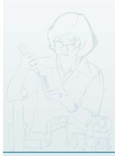
In contrast, in the Philippines and Indonesia, technology testing was farmer-planned, designed and managed. This meant that farmers, largely independent of the project team (Alo 2003, Subandriyo 2003):

- 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)





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.

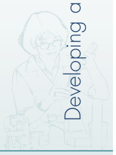
Baskets of technologies offered

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.

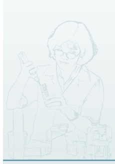
Local working groups, consisting of representatives from the Department of Agriculture-Regional Field Unit, Provincial Veterinary Office, the municipal/city agriculture office, municipal/city planning and development office, and the village council, were established in the provinces of Cebu and Pangasinan (the provinces with most goats). After some capacity building the groups identified a set of criteria to select farmer cooperators.

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

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



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 1m 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 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.

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

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.

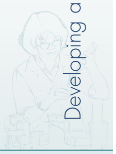
Table 3.1 Farmer-generated baskets of technologies (FBTs)

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.

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)

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	Dec 2002
	53.0%	
	2.0%	
% change	96.2%	58%
Decrease in mortality	Jan 2001	Dec 2002
	56.0%	
	2.0%	
% change	96.4%	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.

- *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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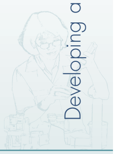

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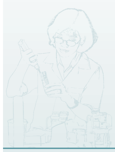

4. Anthelmintic resistance in small ruminant parasites: implications for smallholders in Southeast Asia

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). 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

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 essay (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 throughput 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).

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

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). Beriajaya 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 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).

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

- 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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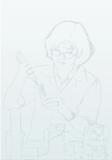

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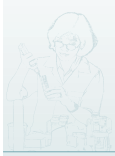


5. Appropriate breeds and breeding schemes for sheep and goats in the tropics

5. Appropriate breeds and breeding schemes for sheep and goats in the tropics

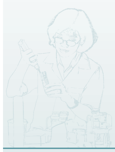
R.L. Baker and G.D. Gray

Introduction

The purpose of this chapter is two-fold. First, the information available on breeds of sheep and goats that are resistant or resilient to helminthiasis (mainly the GI nematodes) infections are reviewed. This is important information for inclusion of appropriate breeds in integrated endoparasite control programs, which may include resistant breeds or genotypes, improved nutrition, strategic drenching, improved management (e.g. housing animals in the wet season) and rotational grazing (Barger 1996, Waller 1997, Alo et al., this volume). However, most of the breeds of sheep and goats that have been identified as resistant or resilient are tropical indigenous ones. Many people, including smallholder farmers in the tropics, often perceive these relatively small indigenous breeds to be 'unimproved' with low genetic potential for increased production. Almost invariably, larger breeds with higher growth rates are assumed to be more productive and often the larger breeds are exotic breeds that are poorly adapted to tropical conditions. Therefore, the second part of this paper discusses how practical breeding programs in the tropics might be developed taking into account both adaptability (disease resistance is just one component of adaptability) and productivity. Particular emphasis is placed on the need to better understand different farming systems in the tropics, their production objectives and the different constraints to increasing productivity before embarking on genetic improvement programs.

Sheep and goat breeds that are resistant or resilient to endoparasites

Resistance to infections with endoparasites is defined as the initiation and maintenance of responses provoked in the host to suppress the establishment of parasites and/or eliminate parasite burdens. Resilience (or tolerance) is defined as the ability of the host to survive and be productive in the face of parasite challenge (Woolaston and Baker 1996). For livestock challenged with GI nematode parasites the degree of resistance has usually been assessed in terms of worm counts at necropsy or faecal egg counts (FEC) during an infection period in live animals. In lambs it is well documented that faecal egg counts are highly correlated with worm counts (Woolaston and Baker 1996). Resilience has



been defined in terms of productivity (e.g. live-weight gain or wool production) under nematode challenge compared to productivity in non-infected animals (Albers et al. 1987). In New Zealand, resilience has been defined as the number of anthelmintic treatments needed over a given period of pasture challenge (usually several months) with nematode parasites (Bisset and Morris 1996). Packed red cell volume (PCV) and mortality rates have also been used as proxies for resilience (Baker et al. 2003). When sheep are infected with the blood-sucking parasite *Haemonchus contortus* they become anaemic and this is measured by PCV, which is a good indication of how the animal is managing to cope with the pathogenic effects of the parasite and to survive when infected. However, other studies (e.g. Albers et al. 1987) treated both FEC and PCV as two different measures of resistance.

Much of the recent research on genetic resistance to GI nematode parasites (endoparasites) in sheep and goats has concentrated on quantifying within-breed genetic variation and selection of resistant (high responder) and susceptible (low responder) lines of sheep as reviewed by Gray (1991), Gray and Woolaston (1991), Gray et al. (1995), Woolaston and Baker (1996) and Baker et al. (2001, 2003).

However, there have been many reports since the mid-1930s of variation among breeds of sheep in resistance to GI nematodes, particularly to *Haemonchus contortus*, *Trichostrongylus* spp. and *Ostertagia* (*Teladorsagia*) spp. Gray's (1991) review summarised 23 publications on this subject and this was expanded to 34 publications in a review by Baker et al. (1992). With a few exceptions most of these studies were carried out in temperate environments in North America, Europe and Australasia. Some of the important conclusions from reviewing these publications are the following:

- Host resistance to *H. contortus* has been most commonly found. There is also evidence for resistance to *Ostertagia* spp. and *Trichostrongylus* spp.
- Resistance has been demonstrated both with artificial infection and natural pasture challenge. Usually with natural challenge animals are exposed to several parasite genera with one or two predominating.
- Faecal egg counts (FEC) have generally been used to measure resistance, but worm counts after necropsy have also been made. Resilience has usually not been assessed, but PCV has been commonly measured and can be used as a proxy for resilience when *H. contortus* is the predominant nematode parasite. Production traits and mortality rates have been recorded less frequently.
- Resistance has been demonstrated in both lambs and mature animals (ewes, rams and wethers).
- It appears unlikely in sheep that differences in feeding behaviour among breeds is a major cause of resistance since many breeds have been shown to be resistant both under natural pasture challenge and with indoor artificial challenge.
- The experimental design used in nearly all these breed comparisons was poor. In particular, the number of animals of each breed evaluated was

too small (commonly about 5–10), very few studies took account of variation among sires within breeds, and sampling method was not stated. Requirements for adequate experimental designs for breed evaluation experiments have been comprehensively reviewed and discussed by Dickerson (1969). How animals are sampled and the family structure (i.e. number of sires and progeny per sire) are critical factors.

- While the experimental design of many studies on breed variation for resistance to endoparasites can be criticised, it is reassuring to note that some breeds have been identified as resistant in a number of independent studies. This applies particularly to the Florida Native and Gulf Coast Native in the USA (Loggins et al. 1965, Bradley et al. 1973, Zajac et al. 1988, Amarante et al. 1999a, 1999b, Bahirathan et al. 1996, Miller et al. 1998, Li et al. 2001), the Barbados Blackbelly (Yazwinski et al. 1979, 1981, Goode et al. 1983) and the St. Croix (Courtney et al. 1984, 1985a, 1985b, Zajac et al. 1990, Gamble and Zajac 1992, Zajac 1995, Burke and Miller 2003) and for these breeds it can be concluded that they are relatively resistant to GI nematodes.
- Most of the breeds identified as being relatively resistant are indigenous or 'unimproved' breeds. This presumably reflects the fact that these breeds have been under natural selection for resistance for many centuries with no anthelmintic treatment.

In the past 10 years or so there has been increased interest in characterising a number of indigenous tropical sheep and goat breeds for resistance to endoparasites in tropical environments. While both the Barbados Blackbelly and St. Croix are tropical breeds that originated from the Caribbean, all the studies relating to them quoted above were carried out in the USA. However, there was anecdotal evidence in the Caribbean that the St. Croix may have been somewhat resistant to endoparasites (Hupp and Deller 1983). In Southeast Asia nearly all the recent breed comparison studies for sheep and goats (Table 5.1) suffer from the same deficiencies in experimental design noted in the earlier reviews. However it is pertinent to note that the St. Croix has been shown to be resistant in studies in both Indonesia and the Philippines under very different climatic (hot and humid) and management conditions than those used in the original studies carried out in the USA. Similarly, Barbados Blackbelly crosses were

Introduced breeds of goat and sheep need to be assessed for their ability to survive and reproduce in all conditions; Anglo-Nubian buck. (G.M. Hood)

Table 5.1 Sheep and goat breed comparisons for resistance to internal parasites in Southeast Asia

Resistant breed(s)[1] (no.)	Other breed(s)[1] (no.)	Traits[2]	Type of infect.[3]	Sp.[4]	Age-months (sex)[5]	Reference
SHEEP						
Sumatra(S) (90) St. Croix (22) 1/2S-1/2BB (65)	1/2S-1/2St. Croix(106) 1/2S-1/2JFT(117)	E	N	Hc	3 (M & F)	Subandriyo et al. (1996) Romjali (1995)
	Sumatra(S) (10) 1/2S–1/2St. Croix(10) 1/2S–1/2BB (10) 1/2S–1/2JFT(10)	E, P	A	Hc	18–24 (Rams)	Romjali et al. (1996) Romjali (1995)
1/2S–1/2BB (10)	Sumatra(S) (9) 1/2S–1/2St. Croix(9) 1/2S–1/2JFT(7)	PPR	N	Hc	24 (Ewes)	Romjali et al. (1997)
1/2Djallonke–1/2 Malin wool sheep	Malin wool sheep	E	N	Hc	3–12 (M & F)	Pandey (1995)
	1/4 Djallonke–3/4Malin 1/2 Dorset–1/2Malin	E	N	Hc	0–14 (M & F)	Sani (1994)
St. Croix (39)	Katahdin (27) Rambouillet (10) Philippine Native (30)	E, P	N	Hc	3–8 (M & F)	Suba et al (2002)
Indonesian Thin Tail–ITT (24)	St. Croix (12)	FC	A	Fg	6–12 (M & F)	Roberts et al. (1997a)
	ITT (20) Merino (12)	FC	A	Fh	6–12 (M & F)	Roberts et al. (1997a)
ITT (20)	ITTxSt. Croix (20) St. Croix (10)	FC	A	Fg	9–12 (M & F)	Roberts et al. (1997b)
1/2 Garole (G)–1/2 Deccani (D) or 1/2 Bannur (B) (75)	B, D, 1/2 B–1/2 D (192)	E	N	Hc (M&F)	3–7	Nimbkar et al. (2003)
1/2 Garole (G)–1/2 Deccani (D) or 1/2 Bannur (B) (65)	B, D, 1/2 B–1/2 D (171)	E, P	A	Hc	6–11 (M & F)	Nimbkar et al. (2003)

continued over

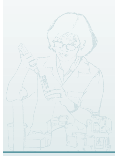
Table 5.1 continued

Resistant breed(s)[1] (no.)	Other breed(s)[1] (no.)	Traits[2]	Type of infect.[3]	Sp.[4]	Age-months (sex)[5]	Reference
GOATS						
Thai Native(12)	1/2TN–1/2AN(8) 3/4TN–1/4AN(8)	E, P, W	A	Hc	3–6 (M & F)	Pralomkarn et al. (1997)
Philippine Native (25)	Anglo-Nubian (25) Boer (25), Saanen (25)	E, P	N	Hc	20+ (Does)	Suba et al. (2000)
PN (41) Boer (50)	Anglo-Nubian (47) Saanen (14)	E, P	N	Hc	8 (M & F)	Suba et al. (2002)

(1) No. = number of records; BB = Barbados Blackbelly; JFT = Javanese Fat Tail; ITT = Indonesian Thin Tail (thin tail sheep from both Sumatra and Java); TN = Thai Native; AN = Anglo-Nubian; PN = Philippine Native. (2) E = eggs per gram; P = packed red cell volume; W = worm count; FC = fluke count. (3) N = natural infection from pasture; A = artificial infection. (4) Sp = parasite species; Hc = *Haemonchus contortus*; Fg = *Fasciola gigantica*; Fh = *Fasciola hepatica*. (5) M = males; F= females

shown to be resistant in Indonesia. Although there is no strong evidence from the studies summarised in Table 5.1 from Indonesia that the Indonesian Thin Tail sheep are resistant to *H. contortus*, some recent reviews (Subandriyo 2002, Raadsma et al. 2002) show that this breed is more resistant than susceptible Merino sheep, but not as resistant as the St. Croix. In two small studies in Thailand and the Philippines native indigenous goats were more resistant than Anglo-Nubian crosses or purebred Anglo-Nubian and Saanen goats (Table 5.1). There is also some preliminary evidence in the Philippines that Boer goats may be somewhat resistant to endoparasites.

Sheep-breed comparisons that have been carried out in Africa are summarised in Table 5.2. In the case of the Red Maasai breed from East Africa there is an interesting progression from the small studies originally undertaken by Preston and Allonby (1978, 1979) to the comprehensive studies carried out by the International Livestock Research Institute (ILCA 1991, Baker et al. 1999, 2002, 2003). We can now confidently conclude that the Red Maasai breed is both resistant and resilient to endoparasites and particularly to *H. contortus*. In addition to the sheep breeds that have been reasonably comprehensively characterised as resistant to GI nematodes there are other interesting tropical breeds that may be resistant. This is based almost entirely on the anecdotal evidence that these breeds survive and thrive in the stressful environments where they are found under severe disease challenge. These include the West African Djallonke sheep which may be resistant to both endoparasites and trypanosomiasis (Baker 1995, Osaer et al. 1999) and the Garole sheep in India (Ghalsasi et al. 1994). A study done in Maharashtra, India (summarised in Table 5.1), comparing the resistance to *H. contortus* of F1 Garole crossbred lambs with that of Bannur, Deccani and 1/2 Bannur–1/2



Deccani lambs, found that lambs with 50% Garole genes were significantly more resistant than the other breeds and crosses tested and lambs with 50% or more Bannur genes ranked second in resistance (Nimbkar et al. 2003). It is worthy of note that the Carribean St. Croix sheep originated from West Africa and are probably related to the West African Djallonke sheep (Bradford and Fitzhugh 1983). It is also interesting that the Javanese Thin Tail and the Garole might be related since they both carry the FecB (Booroola) gene for prolificacy (Davis et al. 2002).

The evidence for genetic variation for resistance to endoparasites among goat breeds is limited (Tables 5.1 and 5.3) and most of these studies suffer from the same shortcomings in experimental design noted for sheep. As for sheep, it is usually the indigenous goat breeds (e.g. the Alpine goats in France and the Small East African in Kenya) that are more resistant. It is possible that the mechanisms or level of resistance may be different in sheep and goats since, as goats are predominantly browsers, they are likely to have been under less intense natural selection for resistance (Baker et al. 2001). Indeed, it is known that goats are innately more susceptible to nematode parasites than sheep when they only have pasture available to graze (Pomroy et al. 1986), but the degree of susceptibility can differ for different parasite species (Gruner 1991). In those areas where browse is freely available it is often observed that the prevalence of endoparasites is higher in sheep than goats (Vercruysse 1983, Papadopoulos et al. 2003). This may not tell us anything about the relative resistance of sheep and goats to endoparasites, but could just reflect different feeding behaviour, i.e., sheep are predominantly grazers while goats are predominantly browsers. Hoste et al. (2001) also demonstrated that for goats, unlike sheep, different feeding behaviour can account for differences in resistance. Saanen goats were shown to have lower egg counts over a five-month period than Angora goats in an environment where both pasture and browse were available. This difference was mainly explained by the fact that Angora goats were predominantly grazers while Saanen goats were predominantly browsers.

Virtually all the research on genetic variation to endoparasites in sheep and goats has concentrated on the nematode parasites. In many areas of the tropics and temperate regions of the world liver fluke (trematode) infections (*Fasciola hepatica* and *Fasciola gigantica*) are also an important constraint to sheep and goat production (FAO 1992). While it is well documented that sheep can mount an effective immune response (self-cure) to nematode parasites, it has been demonstrated that they are unable to acquire resistance to liver flukes (e.g. Haroun and Hillyer 1986, Boyce et al. 1987). This may be why there has been little research on genetic resistance to liver fluke infections and few studies published. Boyce et al. (1987) found significant breed differences in faecal egg counts and fluke counts after five breeds of sheep were experimentally infected with *F. hepatica*. Barbados Blackbelly sheep were the most susceptible to infection while St. Croix and Florida Naṫive sheep were the most resistant. While none of the breeds demonstrated an ability to resist re-infection with *F. hepatica*, clear breed differences were detected in response to the primary infection. Wiedosari and Copeman (1990) reported relatively high resistance to *F. gigantica* in Javanese Thin Tail sheep, although there was no contemporaneous breed comparison. Roberts et al. (1997a, 1997b) compared the resistance to *F. gigantica* of Indonesian Thin Tail sheep (sampled from Java and Sumatra) with St. Croix sheep and F2

and F3 crosses between these breeds (Table 5.1). They concluded that the Indonesian Thin Tail sheep were more resistant than St. Croix sheep and that resistance may be controlled by a major gene with incomplete dominance. In contrast, the Indonesian Thin Tail sheep were as susceptible to *F. hepatica* as the Merino sheep that they were compared with (Roberts et al. 1997a).

Adaptation and productivity of sheep and goats in the tropics

It is now well documented that indigenous livestock that have evolved over the centuries in the diverse, often stressful tropical environments, have a range of unique adaptive traits (e.g. disease resistance, heat resistance, water tolerance, ability to cope with poor quality feed, etc) which enable them to survive and be productive in these environments (Fitzhugh and Bradford 1983, Devendra 1987, Baker and Rege 1994). In some cases the physiological basis of adaptation has been investigated in great detail, as illustrated by the detailed review of the physiological basis for the superior digestive capacity, efficient nitrogen economy and efficient use of water in desert goats (Silanikove 2000). However, more commonly this detailed assessment is not available, but it is still possible to infer 'adaptability' by measuring total flock productivity, efficiency or net benefits of different breeds (e.g. Fitzhugh and Bradford 1983, Bosman et al. 1997, Ayalew et al. 2003). Some recent studies will be described to illustrate this point.

A study (summarised in Table 5.2) shows that under natural pasture challenge there was no difference in resistance to endoparasites between the indigenous Menz and Horro sheep evaluated in the highlands of Ethiopia (Tembely et al. 1998, Rege et al. 2002). However, under artificial challenge there was some evidence that the Menz may be somewhat more resistant than Horro lambs (Haile et al. 2002). The most dramatic and most economically important breed effect in this study was for mortality rate for which the overall cumulative mortality from birth to 12 months of age was 37.3% for the Menz and 67.6% for the Horro lambs. Mukasa-Mugerwa et al. (2000) investigated the causes of lamb mortality and found that the most important cause of death for lambs from birth to 12 months of age was pneumonia, which accounted for 54% of all deaths. Endoparasite infections as a cause of mortality were of limited importance in both breeds (accounting for about 10% of deaths). Mukasa et al. (2002) reported the reproductive performance of the ewes in this experiment and overall flock productivity. Menz sheep had a significantly higher weaning rate (lambs weaned per ewe mated) than the Horro ewes

The Bach Thao goat in Vietnam is a synthetic breed created in the early 20th century. (G.D. Gray)

Table 5.2 Sheep breed comparisons for resistance to internal parasites in Africa

Resistant breed(s)[1] (no.)	Other breed(s)[1] (no.)	Traits[2]	Type of infect.[3]	Sp.[4]	Age-months (sex)[5]	Reference
Red Maasai (16)	Merino (16) Corriedale (16) Hampshire (16)	E, W	A	Hc	24–36 (wethers)	Preston & Allonby (1978)
Red Maasai (10)	BH Somali (10) Merino (10) Dorper (10) Corriedale (10) Hampshire (10)	E, W, S	N	Hc	wethers	Preston & Allonby (1979)
Red Maasai (10)	Dorper ewes (60)	E, W,S	N	Hc	wethers	Preston &Allonby (1979)
Horro (32) Arsi (32)	BH Somali (32) Adal (32)	E, P, W, S, Bw	N	Hc	6–12 (M & F)	Asegede (1990)
Red Maasai (17)	Dorper (17)	E, P, S, SP, Eos, WG	A	Hc	6–8 (entire males)	Mugambi et al. (1996)
Red Maasai (15)	BH Somali (15) Dorper (15) Romney (15)	E, P, S	N	Hc, Tsp	12–24 wethers	Mugambi et al. (1997)
Red Maasai (15)	BH Somali (10) Dorper (12)	E, P, W	A	Hc	24–26 wethers	Mugambi et al. (1997)
Red Maasai (28)	Dorper (15)	E. P	A, N	Hc	14+ ewes	Wanyangu et al. (1997)
	Menz (1439) Horro (1347)	E, P	N	Le, Tsp	20+ ewes	Tembely et al. (1998)
Red Maasai (463)	Dorper (442) RM x Dorper (786)	E, P, S Bw	N	Hc, Tsp	20+ ewes	Baker et al. (1999)
Red Maasai (1015)	Dorper (1055)	E, P, S Bw	N	Hc, Tsp	15+ ewes	Baker et al. (2002)

continued over

Table 5.2 continued

Resistant breed(s)[1] (no.)	Other breed(s)[1] (no.)	Traits[2]	Type of infect.[3]	Sp.[4]	Age-months (sex)[5]	Reference
Red Maasai (152)	Dorper (95)	E, P, S Bw	N	Hc, Tsp	3–6 (M&F)	Baker et al. (2002)
	Menz (2395) Horro (1966)	E, P, S Bw	N	Le, Tsp	0–12 (M&F)	Rege et al. (2002)
Menz (103)	Horro (49)	E, P, W Bw	A	Hc, Le Tc	4–12 (M&F)	Haile et al. (2002)
Red Maasai (212)	Dorper (318) RMxD crosses (1255)	E, P, S Bw	N	Hc, Tsp	0–12 (M&F)	Baker et al. (2003)
Sabi (1281)	Dorper (607)	E, P, S Bw	N	Hc, Tsp	24+ ewes	Matika et al. (2003)

(1) No. = number of records; BH Somali = Black-Head Somali; RM = Red Maasai; D = Dorper; SEA = Small East African. (2) E = eggs per gram; P = packed red cell volume; W = worm count; S = survival; Bw = body weight; SP = serum protein; Eos = peripheral blood eosinophil counts; WG = weight gain. (3) N = natural infection from pasture; A = artificial infection. (4) Hc = *Haemonchus contortus*; Tsp = *Trichostrongylus* species; Le = *Longistrongylus elongate*; Tc = *Trichostrongylus colubriformis;* Oe = *Oesophagostomum* species. (5) M = males; F= females.

(0.73 *vs* 0.57) and ewes which lambed in the wet season had a significantly higher (P<0.001) weaning rate than those that lambed in the dry season (0.76 *vs* 0.53). Menz ewes showed their superiority in weaning rate over the Horro ewes more clearly when lambing in the wet season (0.85 *vs* 0.67) than when lambing in the dry season (0.59 *vs* 0.47). Overall flock productivity was expressed in terms of potential offtake (number of sheep sold) of yearling sheep from flocks of Menz or Horro ewes lambing in either the wet or dry seasons. Both as number of yearling sheep and total liveweight for sale, the offtake of a flock of Menz sheep in this environment was about three times greater than a flock of Horro sheep when they lambed in the wet season, and about twice greater when they lambed in the dry. These results clearly demonstrate that, at least in this high altitude environment in Ethiopia, Menz sheep are better adapted than Horro sheep even though we are still unclear about the biological determinants of this adaptation. This study, and many others like it, was carried out on a research station, which may not necessarily reflect the situation that applies on smallholder farms.

Another recent study in Ethiopia, this time with goats, compared the productivity of an indigenous breed with that of Anglo-Nubian and indigenous goat crosses (Ayalew et al. 2003). This study was particularly

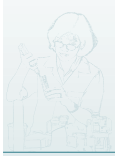


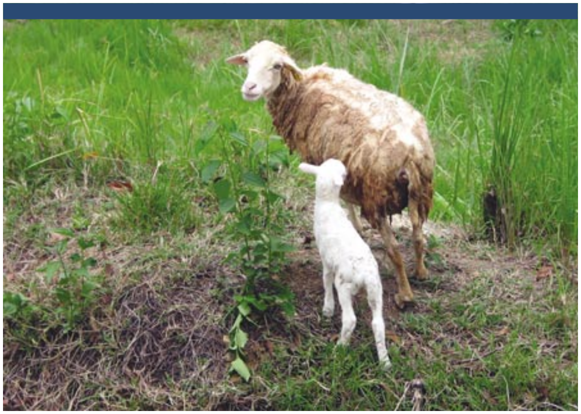
Table 5.3 Goat breed comparisonsa for resistance to internal parasites

Resistant breed(s)[1] (no.)	Other breed(s)[1] (no.)	Traits[2]	Type of infect.[3]	Sp.[4]	Age-months (sex)[5]	Reference
Saanen (12)	SEA (12) Galla (12)	E, W, S	A	Hc	24–36	Preston & Allonby (1978)
Alpine	Saanen	E	N	Mixed		Cabaret & Anjorand (1984)
SEA (12)	Galla (9) Toggenburg x SEA (13)	E, P, W S, Bw	A	Hc	10–14 (M)	Shavulimo et al. (1988)
Alpine	Saanen	E	N	Oc, Osp,	Does	Richard (1988)
Alpine (44)	Saannen (30) Crossbreds (26)	E	N	Tsp, Hc	Does	Richard et al. (1990)
SEA (8)	AN cross (8) Togg. cross (18) DPG (16)	E, P	N	Hc, Tsp	10–12 (M&F)	Rohrer et al. (1991)
SEA (228)	Galla (168)	E, P, Bw	N	Hc, Oe, Tsp	12+ does	Baker et al. (1998)
	Caninde (15) Bhuj (6) Angllo–Nubian (15)	E, P	N	Hc	12–16 (F)	Costa et al. (2000)
Saanen 10)	Angora (14)	E	N	Tsp, Tlsp,	Does	Hoste et al. (2001)
SEA (349)	Galla (204)	E, P, S Bw	N	Hc, Tsp	0–14 (M&F)	Baker et al. (2001)

(a) All published goat breed comparisons with the exception of those carried out in Southeast Asia which are shown in Table 5.1. (1) No. = number of records; SEA = Small East African. (2) E = eggs per gram; P = packed red cell volume; W = worm count; S = survival; Bw = body weight. (3) N = natural infection from pasture; A = artificial infection. (4) Hc = *Haemonchus contortus*; Tsp = *Trichostrongylus* species; Le = Longistrongylus elongate; Tc = Trichostronngylus colubriformis; Oe = Oesophagostomum species; Tlsp = *Teladorsagia* species. (5) M = males; F= females interesting because it was carried out with smallholder farmers who had previously been the beneficiaries of both crossbred goats and training in management of goats as part of a comprehensive livestock improvement package (FARM-Africa 1997). It also made a much more comprehensive study of productivity. The net benefits of goats to a household were calculated by aggregating the value added by physical products (meat, manure and milk) to socio-economic benefits (saved interest/premium on credit/insurance) and deducting purchased inputs. The result was then expressed as net benefit to each main limiting resource of a household: flock metabolic size, land and labour. There were increased net benefits per unit of land or labour from mixed flocks (i.e. those with both indigenous goats and Anglo-Nubian crosses) under improved management compared with indigenous goats under traditional management. This could be due to the crossbred goat, or the improved management or both. It was then shown unequivocally that in flocks using the improved management package the crossbreds did not produce more net benefits than indigenous goats either in mixed or separate flocks per unit of flock metabolic weight, per unit of land or per unit of labour. These findings explained the low adoption rate of the exotic crosses by the smallholder farmers. However, the improved management package was successful in improving the net benefits to farmers with indigenous goats. Therefore, it was concluded that household welfare could be improved in the crop-livestock, mixed smallholder production systems of the Ethiopian highlands by better management of indigenous goats without the extra organisational effort and cost of producing crossbreds. This study also demonstrated again the superior adaptability in this environment of indigenous goats and the importance of assessing this adaptability, not just in terms of physical products (i.e. meat, milk and manure) but also accounting for socio-economic benefits.

Indigenous breeds (such as the Philippine native goat), are well adapted to the highly variable and low input systems of most livestock keepers. (G.M. Hood)

Another important issue when assessing flock productivity is to recognise the potential importance of genotype by environment interactions. We concluded earlier from the studies summarised in Table 5.2 that Red Maasai sheep were more resistant to endoparasites than Dorper sheep. These studies were undertaken in many different locations in Kenya, ranging from the sub-humid coast to the semi-arid highlands. Therefore, we can safely conclude that there is no genotype by environment interaction for resistance as the Red Maasai were consistently the most



The Philippine native sheep has been bred from Merinos imported from Mexico. (G.M. Hood)

resistant breed in all the studies, although the magnitude of the difference in FEC between the Red Maasai and Dorper breed was quite variable in different studies. The productivity and efficiency of Red Maasai and Dorper sheep evaluated in experiments at the Kenya coast (humid environment) and the Kenya highlands (semi-arid environment) were compared by Baker et al. (2002). There were important breed by location interactions for growth, mortality rates and reproduction rates. When all these parameters were combined it was found that the indigenous Red Maasai sheep were three to five times more productive and efficient than Dorper sheep in the humid-coastal environment. In the semi-arid environment Dorper sheep were slightly more productive than the Red Maasai, but there was no significant difference in flock efficiency between the breeds. In this study efficiency was measured as kg of total meat offtake per megajoule of metabolisable energy per day, but this still ignores any differences between the breeds in input costs (e.g. health care costs will be lower in a Red Maasai flock than a Dorper flock) or socio-economic benefits. The reason for this interaction was that the Dorper sheep were very poorly adapted to hot humid conditions, which was reflected in their low growth rates, low reproductive rates and high mortality rates. The conclusion from this study is that breed of choice in a hot, humid environment is the Red Maasai, while in an arid or semi-arid environment there is little to choose between the two breeds. The Dorper breed was introduced to Kenya in the 1960s. It has gradually increased in popularity in the semi-arid Kenyan highlands mainly because of its size and growth potential and is popular with the Maasai herdsmen who cross it with their Red Maasai sheep. Judicious crossbreeding like this may be justified as long as the crosses include at least 50% Red Maasai blood to maintain at least some degree of endoparasite resistance (Baker et al. 2003, Nguti et al. 2003).

Constraints to improving productivity in the tropics

Despite the well documented fact that most indigenous sheep and goats in the tropics are well adapted to their stressful environments there is still a commonly held view that they are 'unproductive' because of, for example, their small size and high mortality rates. This has resulted in many misguided livestock improvement development programs importing exotic breeds, which are assumed to be more productive based on their performances in their benign temperate environments of origin. Often they cannot even survive in the tropical environments into which they are introduced. Although some development agencies are now appreciating the importance of an integrated systems approach to livestock improvement in the tropics (e.g. Ayalew et al. 2003) this has been the exception rather than the rule.

Before initiating any livestock improvement program it is important to have a good understanding of the production systems and the relative importance of the different constraints to production in these systems. The amount and distribution of rainfall are often principal determinants of system characteristics. For sheep and goat production in the tropics, two important systems are mixed crop/livestock farming systems in the medium to high potential agricultural areas and livestock-based grazing systems in the drier (arid and semi-arid) range or desert areas. Included in the crop/livestock farming systems are both small subsistence level farms, large commercial operations specialising in cropping with livestock usually playing a secondary role, and also commercial operations with reasonably large livestock enterprises. In all these systems sheep and goat production is often secondary in importance to crops and other livestock activities. In pastoral, transhumant and ranch farming systems ruminants graze rangelands to produce food and income. Cattle, sheep and goats are often managed in common herds under the care of owners, their family members or herders. During the day these herds may travel considerable distances in search of grazing and water. However, with few exceptions, they are closely confined at night as a safeguard against predators and theft. Confinement of livestock at night is also a feature of the crop/livestock farming systems.

Although the more detailed characteristics of tropical sheep and goat production vary from region to region around the world, some constraints are common to all tropical farming systems. The three broad categories of constraints are ecological, biological and socio-economic (Fitzhugh and Bradford 1983). Most production systems are affected by several of these and often there are important interactions among them.

Ecological constraints include land (area, topography, altitude, soil fertility) and climate (rainfall, temperature, humidity, growing season). Of these ecological constraints only soil fertility is readily amenable to human intervention and then only when improvements are economically justified, which is more likely to be the case in crop/livestock systems. In some large-scale, commercial farming systems, shelter (e.g. trees or buildings) can be provided to help lower heat stress. In smallholder systems in the high rainfall tropical environments, confinement of sheep and goats during the rainy seasons is an option, although this also means that labour must be available to provide feed in a cut and carry system.

Biological constraints include low quantity and quality of feed supplies, lack of drinking water (particularly in the arid and semi-arid grazing areas), high disease prevalence, theft and predation and perceived poor genetic potential.

Socio-economic constraints include:

- labour availability and animal husbandry skills
- taste preference and buying power of consumers
- cost and availability of credit

- marketing infrastructure
- government policies on prices of commodities, trade and land tenure.

It is commonly observed that traditional livestock management practices in the tropics, developed by trial and error through generations of experience, often make efficient use of available resources with minimal external inputs or risk to producers. For most indigenous sheep and goat breeds in the tropics natural selection has resulted in genetic potential for adaptation taking precedence over genetic potential for productivity. Therefore, in many tropical farming systems, genetic improvement for productivity (e.g. increased growth rate or milk production) often should only be attempted once nutritional, health, management and socio-economic constraints have been resolved. Alternatively, all the important constraints should be addressed simultaneously in an integrated improvement package. A more formal way of approaching integrated improvement has been suggested and called 'Livestock Development Objectives' (Djemali and Wrigley 2002).

Genetic improvement programs

Once the production systems and constraints to production have been characterised and quantified for a particular tropical environment or region then there are some logical steps that should be followed to implement a genetic improvement program. This would ideally include the following:

- defining the breeding objective (i.e. the improvement goal)
- choosing a breeding system and breed(s)
- deciding on population size and structure
- identifying the selection criteria and, if appropriate, deriving selection indexes
- obtaining (or estimating if not available) genetic parameters (e.g. heritabilities and genetic correlations)
- designing the animal recording system
- estimating breeding values for the selection criteria or an index
- designing a mating scheme for the selected animals
- designing a multiplication scheme to disseminate genetically superior animals or semen
- assessing genetic change and reviewing the breeding program regularly.

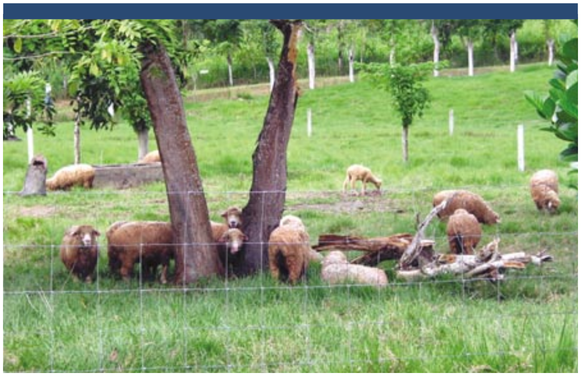
Descriptions of these steps have been published elsewhere (e.g. Ponzoni 1992, Harris and Newman 1994) and it is not within the scope of this paper to describe them in detail. Rather, we will discuss the steps in which breeding for adaptability and productivity in tropical sheep and goats requires special consideration, with particular attention to developing breeding programs for smallholder farmers. It is important to note that although the steps outlined above appear in a linear order, in fact there is interdependency between many of these steps, as will be illustrated later.

During the process of quantifying constraints to production and developing integrated livestock development objectives it may become clear that

development of breeding programs should not be attempted. For example, the small desert breeds of goats such as the Black Bedouin are exquisitely adapted to fragile desert environments after thousands of years of natural selection (Silanikove 2000), and the best breeding strategy now is to let natural selection continue without external interference with either their genetic potential or their desert environment.

Defining the breeding objective

At the outset of planning a breeding program the targeted livestock production and marketing system should be defined and then all traits that affect the profitability of that system should be identified. Decisions about which traits to target for genetic improvement should ideally be based on the extent to which each trait affects profitability (per head or per unit of labour or land), not on whether the trait is difficult or easy to measure or change genetically. This is of particular relevance to disease resistance or adaptation, which are not always easy to measure or change genetically and so are often ignored. Historically, breeding objectives and relative economic values (REV) of different traits in the breeding objective were first derived purely in terms of economic returns for different traits (e.g. the dollar values for an additional kilogram of meat, an additional kilogram of wool or an additional lamb weaned) without any attempt to take into account the costs of production and develop profit functions. Although these may not have been optimally designed breeding objectives they were still a good first step in getting breeding programs established and genetic progress was achieved. Over time the breeding objectives and REVs were refined as the data on input costs were obtained or derived (e.g. feed costs for grazing livestock) to allow the calculation of more comprehensive profit functions (Ponzoni 1986).



Crossing Philippine native sheep with St Croix and Katahdin has increased body size, litter size and reduced wool cover. (G.D. Gray)

In many tropical countries the economic data needed to develop comprehensive profit functions will be scarce. Efforts have been made to develop these functions for hair sheep in Cuba (Ponzoni 1992) and in Kenya (Kosgey et al. 2003, 2004). Solkner et al. (1998) argue strongly that 'The decisive but most frequently missing step in the design of village breeding programs is the definition of a breeding objective'. They also suggest that breeding objectives must be formulated in close collaboration with smallholder farmers with particular attention to the importance of risk avoidance, particularly in marginal environments. For many smallholder farmers in the tropics with hair sheep or goats, a simple and practical breeding objective may simply be increased financial returns from meat production per unit of limiting resource (e.g. per head, per unit of land, per unit of labour) or net income (which may include income from meat, milk and manure) from the sheep or goat unit. This is also the time when a rational decision can be made about whether a genetic improvement program is justified at all in terms of financial returns or increased profitability of the enterprise. Reports are conflicting about the profitability of small ruminants under traditional smallholder management in the tropics, with some indicating low or negative profitability (e.g. Soedjana 1996, Bosman et al. 1997, Seleka 2001, Kosgey et al. 2003) and others profitability (e.g. Upton 1985, Itty et al. 2001). However, there is strong evidence from several of the studies showing a lack of profitability that smallholder farmers often keep sheep or goats primarily as a ready source of cash income (e.g. acting as a bank), for socio-cultural reasons (e.g. for use in ceremonies such as weddings or funerals), as an insurance against crop failure and for manure rather than just for production of meat or milk. When these additional factors are included in the economic analyses then the production systems are profitable (e.g. Bosman 1997, Kosgey et al. 2004).

The breeding system

The three pathways of genetic improvement are selection among breeds or populations (e.g. strains within breeds), selection within breeds and crossbreeding designed to exploit heterosis and/or combine the merits of different breeds. These genetic improvement options are not incompatible, but once a particular crossbreeding system is chosen and it has stabilised, then any further genetic progress can only be achieved through selection within the new crossbred population. In many tropical sheep and goat production systems there is often scope to use both between- and within-breed genetic variation in breeding programs (Baker 1995, 1996, Woolaston and Baker 1996).

Choice of the most appropriate breed or breeds to use in a sheep or goat enterprise should be the logical first step when initiating a breeding program. However, this assumes that sufficient information is available on which to make rational breed choices, which very often is not the case. Historically, and especially during colonial times in Africa and Asia, it was assumed that the small local indigenous breeds of livestock in the tropics must be unproductive and many larger exotic temperate breeds of cattle, sheep and goats were imported to rectify this perceived problem. This was almost always a mistake and these exotic breeds did not survive unless they were given a level of care (e.g. management, feeding, disease control) that led to expenses far above anything smallholder farmers could afford. More recently, that is, within the past 10–20 years, there has been increased interest and awareness of the many unique attributes that the indigenous hair sheep breeds and indigenous goat breeds in the tropics have to offer. This is well illustrated by the studies summarised in Tables 1–3. For example, in Southeast Asia:

- St. Croix and Barbados Blackbelly sheep have been used in crossbreeding programs in Indonesia (Merkel et al. 1996, Subandriyo et al. 1996, Subandriyo 2002)

- Djallonke, Santa Ines, St. Croix, Barbados Blackbelly and Thai Long Tail have been evaluated in Malaysia (Ibrahim 1996)
- Vietnam has imported the Barbari, Jamunapari and Beetal goat breeds from India and the Boer, Saanen, Anglo-Nubian and Alpine goats from the USA (Binh 2003)
- In 1998 the Philippines imported the St. Croix, Katahdin (a St. Croix-Suffolk stabilised cross), and Rambouillet Merino sheep breeds, plus the Saanen, Anglo-Nubian and Boer goat breeds from the USA.


Shepherds in India are evaluating crosses between the highly prolific Garole, locally adapted Deccani and the high-carcase quality Bannur breeds. (G.D. Gray)

Often, even when the merits of different breeds have been compared, the decision should be made to utilise, and perhaps improve, the local indigenous breed. A good example is the Red Maasai sheep breed in the humid climatic zones of Kenya. The two most important biological constraints to production in this environment are endoparasite infections (predominantly *H. contortus*) and quantity and quality of feed. There is increasing evidence documenting the spread of anthelmintic resistance in Kenya (Wanyangu et al. 1996). So, it is important to use a breed that is resistant and/or resilient to endoparasites and that needs minimal or no treatment with anthelmintic drugs if kept on an adequate level of nutrition. Smallholder farmers almost invariably rank increased size and growth potential as important traits they would like to increase in their sheep and goat flocks (Kosgey, pers. comm., Jaitner et al. 2001). In this situation a simple and practical breeding program may be to select the heaviest purebred Red Maasai rams in a management system where they are exposed to endoparasites while grazing and not drenched. Those that survive under such a management regime should be those that are more resistant and/or resilient to endoparasites and there is no need to have to resort to recording FEC or PCV to ascertain this. Due consideration would have to be taken of animal welfare issues in such a management system to ensure that mortality rates were kept to a manageable level. Management strategies can also be developed to permit drenching of individual animals that are clearly suffering from the effects of endoparasites and will die if not treated. For infections with *H. contortus* the simple FAMACHA test developed in South Africa is a useful diagnostic tool (Vatta et al. 2001). This test is based on a colour chart with five colours depicting varying degrees of anaemia, which are compared with the colour of the mucous membranes of the eyes of sheep or goats. Those animals with the palest eye colour are severely anaemic and should be treated. Depending on the proportion of rams treated from birth until the age they are selected for breeding (e.g. commonly about 12–15 months of age) this can be included in the selection process as an independent culling level. For example, it may be possible to identify a reasonable number of rams that were never drenched over this period and then within this group the heaviest, functionally sound (i.e. no structural defects) animals could be selected. Such a breeding scheme would not result in a rapid rate of genetic change in growth. If a rate of 1% per year was achieved, this would mean that rams that averaged 30 kg at one year of age initially would be 33 kg after 10 years of selection. This is not a dramatic change and many farmers are looking for a quicker response. The easiest way to do this is to embark upon a crossbreeding program.

The benefits of crossbreeding schemes are (1) to combine the merits of different breeds and (2) to utilise heterosis (also commonly called 'hybrid vigour'). Heterosis is measured as the extra performance of the crossbred over the average of the parental breeds. The increase in performance ranges from 0 to 10% for growth traits and from 5 to 22% for fertility and mortality traits. These effects are additive, so for combined production traits, like weight of lamb weaned per ewe mated per year, heterosis commonly ranges from 15 to 25%. As a simple example, if a local breed has a mature weight of 30 kg and another breed (maybe an exotic imported breed) has a mature weight of 50 kg, then a first cross (F_1) animal is expected to have a mature weight of 40 kg (half 30 kg + 50 kg) if there is no heterosis. If there is 5% heterosis for this trait then the F_1 will have a mature weight of 42 kg. One can immediately see the large effect derived from combining the additive effect of two breeds even if there is no heterosis, and this increase will be achieved in one generation. However, it may not be as simple as this. If the local breed has an annual mortality rate of 20%, but the exotic breed in the new environment is not adapted and has a mortality rate of 50%, then the F1 cross with no heterosis is expected to have a mortality rate of 35%. It can easily be shown that this increase in mortality rate will often be of far greater importance in terms of its effect on total flock productivity or profitability than the increase in growth rate (e.g. Upton 1985).

Breeds can be used in crossbreeding programs in four main ways. These are substitution of an existing breed by a new breed, new breed formation based on crossing two or more breeds, specific crossbreeding in a stratified breeding system and rotational crossbreeding. Combinations of these different crossbreeding programs are also possible.

Breed substitution

If the new breed (B) is clearly more desirable than the original local breed (A), then one can just keep on 'backcrossing' with that breed until, after about four to five generations, breed A has effectively been replaced with breed B. For example, if the original sheep breed was an indigenous hair breed and there was a desire to establish a wool industry then backcrossing with a breed such as a Merino or a Corriedale would achieve that aim. This was exactly how the Merino and Corriedale breeds were originally established in the highlands of Kenya where they are reasonably well adapted.

When the same approach was followed in hot and humid environments the new breeds were not at all adapted and usually did not persist. It is also possible to introduce new breeds to a country or region by importing live animals, semen or frozen embryos although these are more expensive options. The recent importation of Rambouillet Merino sheep from the USA into the Philippines is a good example of importing a new breed that is poorly adapted to the hot humid environment. In contrast, the St Croix hair sheep imported from the USA into Indonesia, Malaysia and the Philippines (Table 5.1), have proved to be much better adapted to the hot, humid climates found in these countries both as purebreds and in crosses with indigenous breeds.

The Red Maasai sheep are resistant to worms and highly productive in areas of high parasite challenge. (R.L. Baker)

New breed formation

The simplest way to form a new breed is to cross breed B with breed A to form a first cross (F_1 = B x A), then mate B x A males with B x A females (inter-se mating) to form an F_2 population and then continue the process of interbreeding to the F_n generation (often called a composite or synthetic breed). This was the method used to produce the Coopworth (Border Leicester x Romney) and Perendale (Cheviot x Romney) breeds in New Zealand and the Dorper (Black-headed Somali x Dorset Horn) breed in South Africa. Usually breeds are chosen because they have attributes that breeders want to combine into the new synthetic breed. For example, the Dorper breed was produced to combine the adaptive merits of the Black-headed Somali hair sheep with the growth and milk production of Dorset sheep. The final result was a hardy meat breed that did not need shearing and was productive under harsh veldt conditions in South Africa (Milne 2000). Selection can take place during the interbreeding phase to ultimately produce a new breed with desired characteristics — for example, improved reproduction and fleece weight in the Coopworth (Coop 1974) and minimal wool production and certain colour patterns in the Dorper (Milne 2000). It is possible to combine more than two breeds to form a synthetic, which has the advantage of combining the attributes of more breeds but the disadvantage is that the logistics of breeding are more complicated. For example, the Kenyan Dual Purpose goat was produced by interbreeding the local Galla and Small East African breeds with the exotic Toggenburg and Anglo-Nubian breeds (Mwandotto et al. 1992).

Specific and rotational crossing

These crossbreeding schemes require a reasonable flock size (e.g. about 50 or more breeding females) so are not of interest to smallholders with small flocks. However, they can be employed by pastoralists who often have larger flock sizes. The simplest example of a specific crossing system is the use of a terminal sire breed (B) on a proportion of the flock (about 30–40%) to produce F_1 progeny (B x A) but with the rest of the flock being straight-bred (A x A) to supply female replacements. Often all F1 progeny are sold or slaughtered for home consumption. Many Maasai pastoralists in Kenya follow this sort of system by using the Dorper breed as a terminal sire over their Red Maasai flocks. However, the F_1 female progeny can be quite productive in the breeding flock when maintained under reasonable feeding and management conditions. Rotational crossbreeding may then be used to mate the F_1 females. For example, B x A F_1 females could then be crossed back to A sires and their progeny to B sires, etc. Alternatively, a new breed (C) could be introduced and mated with the B x A females to produce 3-way cross progeny [C x (B x A)]. These 3-way crosses may then all be sold or slaughtered or included back into the breeding program. Historically, this sort of trial and error crossing of different breeds is what has probably occurred and if productive progeny are the outcome then ultimately these can evolve into new breeds or strains.

Population size and structure

The important factors here include the number of males and females in the breeding nucleus which then affect the selection intensities that can be achieved and the inbreeding rate (Falconer 1989, Kinghorn 1995).

As a rule of thumb, a closed nucleus breeding flock should include a minimum of about 150 breeding females mated to at least five breeding males with breeding males being replaced annually with a male offspring and breeding females being kept in the flock for no longer than three to four matings. However, the larger the nucleus flock the better as this allows larger selection intensities and lower inbreeding rates to be achieved. Ponzoni (1992) recommended that a closed nucleus flock of 500 breeding females and seven new sires per year should be 'the absolute minimum below which the establishment of elite nucleus flocks should not be contemplated'.

Selection criteria and breeding values

It is important to make the clear distinction between the traits in the breeding objective which are identified solely on the basis of their economic importance to the enterprise and the selection criteria, which are the traits actually measured in the flock to predict the breeding objective. If, for example, the breeding objective was increased meat production, then possible selection criteria may be body weight taken at different ages (e.g. at weaning or at market age), female reproduction rate and mortality rates. In the temperate developed world there may also be measurements of carcass quality such as fatness or meatiness which can be estimated on the live animal using ultrasonic measurements. However, this is only justified if the market rewards the producer for improved carcass quality, which is rare in the temperate developed world and almost non-existent in the tropical developing world. However, in some markets (e.g. the Middle East) fat-tailed sheep command a considerable premium and this trait could therefore be a factor in deciding which breed to use.

Selection criteria need to be able to be measured, heritable, variable and correlated with the traits in the breeding objective. Heritability is the efficiency of transmission of parental phenotypic superiority to the next generation and, in theory, can vary from zero to one, but for animal production traits it varies from zero to about 0.60. It is possible that the traits in the breeding objective may also be selection criteria. If, for example, the breeding objective is increased milk production then the obvious selection criteria to measure is milk production of the does or ewes. However, it is not possible to measure milk production on the males in the population and they must be selected either on breeding values derived from milk records from their female progeny or from their female relatives (e.g. dam or grand-dam). The breeding value of a particular trait for an animal is a description of the value of that animal's genes to its progeny. The genes an animal carries are not known so we never know what the true breeding value is but it can be estimated from heritability estimates, the records of the individual (i.e the phenotype) and, if available, records of the individual's relatives (Falconer 1989, Kinghorn 1995).

Heritability estimates are low for fitness traits such as reproductive rate and mortality rates (0.01–0.10), moderate for growth and milk production (0.2–0.3) and high for carcass quality traits (0.4–0.5). In theory, genetic parameters such as heritabilities and genetic correlations are specific to a population and a given environment. In practice, estimates of these parameters for the production traits (e.g. reproduction, growth) have been found to be relatively robust across breeds and different environments and it is common to assume one set of parameters for a wide range of circumstances. For many disease resistance traits such assumptions are questionable as there is a physiological interaction between pathogen activity and production which may mask the underlying genetic relationships (see the review of Woolaston and Baker (1996) for a detailed discussion of this issue with regard to resistance to endoparasites). There is now good evidence for sheep in temperate climates that resistance to a number of diseases (e.g. endoparasites, footrot, blowfly strike) is moderately heritable (0.20–0.40), although heritability of resilience to endoparasites is lower (about 0.10). However, there is limited evidence for the heritability of disease resistance in tropical sheep and goats. It appears that resistance to endoparasites in resistant breeds like the Red Maasai may be very lowly heritable (Baker et al. 2003). Similarly, resistance to endoparasites in goats in the tropics has been reported to be very lowly heritable (e.g. Woolaston et al. 1992), but some recent studies have been more encouraging and suggest moderate estimates (Baker et al. 2001).

Some traits are expensive, impractical or impossible to measure and this includes some of the production traits (e.g. lifetime productivity, feed intake of grazing animals, carcass quality, behaviour) and many of the disease resistant and adaptability traits (e.g. metabolic efficiency, water tolerance, heat tolerance). In some cases indirect measures have been developed but in others measurable traits do not exist at present. However, where breeds or genotypes have been demonstrated to have the required attributes such as disease resistance or adaptability, then these genetic

qualities can be harnessed by using those breeds or by crossbreeding with them without any need to resort to within-breed selection. It is also important to remember that the rate of genetic progress per generation in a breeding flock is proportional to the selection intensity (which is a constant for a given breeding structure), the degree of variability (i.e. the phenotypic variance) and the heritability (Falconer 1989). Some of the traits which are lowly heritable, such as reproduction rate, are also extremely variable and the expected rate of genetic progress of about 2% of the mean per year is similar to what is expected from traits such as growth or milk production which have moderate heritabilities but are less variable. FEC, which is commonly used as a predictor of resistance to endoparasites, is highly variable and usually has an over-dispersed skewed distribution. Even when transformations have been applied to FEC to normalise the variance (e.g. logarithms or square root), it still tends to be a fairly variable trait with a moderate heritability at least in susceptible breeds. It must also be remembered that while selecting for several different traits may be justified, the more traits that are included as selection criteria the less genetic progress that will be made for each one of them.

Industry structure and dissemination of genetically improved animals

The developed world contains well documented breeding structures where genetic improvement takes place in a small proportion of the total industry (e.g. nucleus breeding flocks or the registered stud industry) and then genetic improvement is passed on to the commercial industry through sale of males (rams or bucks) or semen. This structure works well as long as the nucleus breeding flocks are achieving genetic improvement. This genetic improvement then flows through to the commercial sector. If, however, the nucleus flocks are not making any genetic improvement then no improvement will flow through to the commercial flocks. Historically, the registered stud industries in many developed countries put a lot of emphasis on traits not always closely related to productivity or profitability such as colour, type and body shape. In Australia and New Zealand open and closed group breeding schemes were established originally as a way of breeding livestock with emphasis on productivity and provided competition with the more traditional stud industry for provision of breeding stock. Today the registered stud industry displays a very different attitude, with many breed societies encouraging, or making mandatory, the recording of economically important traits (Hammond et al. 1992). Many tropical developing countries do not have breed societies and their existence is not essential to achieve genetic improvement. However, it is most unlikely in most tropical developing countries that performance recording will be logistically feasible in large numbers of smallholder or pastoralist flocks. For this reason, some form of open or closed nucleus breeding structure has been widely advocated so that the performance recording effort can be concentrated in one large nucleus flock or several reasonably large ones (Ponzoni 1992). Often the nucleus flocks have been established on government research stations and while this may have been successful initially when external funding was available, when this ceased these flocks were often disbanded (Madalena et al. 2002). There are also questions about whether the management systems that are adopted on well-funded government research stations are relevant to the environments under which the improved genotypes are expected to perform in low-cost, low-input smallholder systems.

Once nucleus breeding has been successfully implemented there is usually a need to establish a multiplication tier of farmers to ensure that reasonably large numbers of rams or bucks are available for the commercial industry. Jaitner et al. (2001) have discussed some of the constraints to doing this in relation to nucleus breeding schemes for Djallonke sheep and West African Dwarf goats which have been initiated by the International Trypanotolerance Centre in The Gambia. They highlighted, in particular, the constraint of individual farmers' small flock sizes (2–3 breeding females) and suggested that a possible solution was to establish village flocks as multipliers. This resulted in a combined flock size of about 30–50 ewes or does which would then be mated to improved rams or bucks from the nucleus once all the breeding males in the villages had been sold or castrated.

Recently, plant breeders have been carrying out breeding programs in some tropical countries in collaboration with smallholder farmers (e.g. Eyzaguirre and Iwanaga 1995, Bellon and Reeves 2002). For example, farmers evaluate different crop varieties and give their views on what they consider are the important crop characteristics. FAO and ILRI are developing and testing 'breed survey guidelines' which, among other things, seek farmers' views on important livestock characteristics and their perceptions of the value of different breeds and strains of livestock (Rege and Rowlands, pers. comm.). Although it may be more difficult with livestock than plants to develop farmer-assisted breeding programs, there is scope for some innovative research and development on this topic.This could take place in smallholder flocks, use modern participatory methods to gain insights into how smallholders make decisions about livestock and set breeding objectives, and use DNA technology to assist with identification of parentage.

Choice of buck and timing of mating can be controlled by keeping males and females separate for most of the year. (G.M. Hood)

Conclusions

- The experimental design used to evaluate sheep and goat breeds for resistance to endoparasites needs to be improved. In particular, attention needs to be paid to the number of sire families evaluated per breed with a minimum of 15 required and a minimum of five offspring per sire family. The 15 sires should also be as unrelated as possible. At least two breeds must be compared in each experiment.
- Despite the poor experimental design used in many published studies there is now good evidence from a number of independent studies that some tropical sheep breeds are resistant and/or resilient to endoparasites (predominantly Haemonchus contortus). These include the East African Red Maasai, the Florida Native and Gulf Native in the USA and the Barbados Blackbelly and the St Croix from the Caribbean. The Indonesian Thin Tail sheep have been shown to be resistant to the liver fluke Fasciola gigantica.
- There is much less evidence for breeds of goats that are resistant to endoparasites but the Small East African goat in Kenya and the Alpine goat in France have been shown to be resistant breeds.
- There is strong evidence that breeds of sheep and goats that are indigenous to the tropics have much more to offer for small-holder farmers than is often appreciated. There is an urgent need for more comprehensive breed evaluation studies that assess the total biological and economic productivity of these breeds with particular attention to their adaptation to stressful tropical environments. Adaptation in the tropics includes not only disease resistance but also heat resistance, tolerance of water shortages and the ability to cope with poor quality and quantity of feed.
- Prior to initiating any livestock improvement programme in the tropics it is important to have a good understanding of the production systems and the relative importance of the ecological, biological and socio-economic constraints to production in these systems. Genetic improvement programmes usually should only be attempted once the nutritional, health, management and socio-economic constraints have been resolved.
- Crossbreeding programmes with non-adapted imported breeds should be discouraged for low input smallholder systems in the tropics. However, crossbreeding among the indigenous tropically adapted may be an option in some farming systems.
- Within breed genetic improvement programmes is a feasible option for many tropically adapted breeds of sheep and goats.

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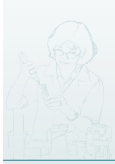

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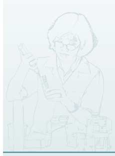

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6. Options to overcome worm infection in small ruminants for producers in Nepal

6. Options to overcome worm infection in small ruminants for producers in Nepal

R.K. Bain, B.R. Joshi, D. Gauchan and G.D. Gray

Introduction

The kingdom of Nepal is a landlocked country lying between India and China, on the southern slopes of the Himalayas. The country has a land area of 147,180 sq km. It is 800 km from east to west and varies from 144 to 240 km north to south, between longitudes 80–88°E and latitudes 26–31°N.

The three main physical regions of the country are based broadly on altitude. To the south of the country is the terai which is fertile, flat, low-lying land between 50–300 m and 25–32 km wide. Rising from the terai plains, at an altitude of 300–2500 m, and following an east/west alignment, are two ranges of hills collectively referred to as the mid-hills. Lower elevations of this region are known as the Siwalik (or Churia) Hills and higher elevations as the Mahabharat Lekh Range. Between the Mahabharat Lekh and the high Himalayas, covering elevations from 2500–5000 m, are another series of mountains commonly referred to as the high-hills. The high-hills ring a transitional zone and generally align north/south as a result of the rivers draining through them from the high Himalayas. To the north of these high-hills are the Himalayas proper at 5000–8800 m, aligned east/west and including the highest mountains in the world. These last two zones are either sparsely inhabited, or are uninhabited, with most land above 5500 m being permanently snowbound.

The climate and therefore the natural environment of the country are influenced by two factors. First, Nepal is in sub-tropical latitudes so that temperatures at low altitudes are warm to hot. Superimposed upon, and modifying, this potentially subtropical climate are the effects of altitude and aspect, which result in markedly diverse microclimatic temperature and rainfall conditions. Hence the natural environment can show great variation within a particular location.

The climate of the terai is subtropical, with the natural seasons being determined by the monsoon rains which affect the entire Indian subcontinent. In the low to mid-hills (300–2500 m), the climate is classified as warm temperate and above this, between 2500 and 4500 m, cool-temperate. The high hills (2500–5500 m), comprise an alpine zone, while above 5500 m, the temperature is almost always below freezing point.

Rainfall varies from as little as 500 mm per annum, in the rain shadow areas to the north of the high Himalayas, to over 5000 mm in areas to the south of some of the major Himalayan massifs. For most of the country,

average rainfall lies between 900 and 1900 mm per annum, becoming progressively drier from east to west. The greater part of this rain falls during the monsoon, between the middle of June and the end of September. In general, there are four major and distinct seasons in Nepal: winter (December–February); spring (March–May); summer (June–August); and autumn (September–November).

Economy

Annual per capita GDP in Nepal is about USD 220. With a human development index of 0.332, Nepal ranks 151st out of 174 countries (the average in South Asia is 0.444) (IFAD 1998). Life expectancy at birth is 54 years, infant mortality is estimated at 98 per thousand and only 31% of the adult population (only 13% of the women) are literate. The daily calorie intake is estimated at 1957 per capita.

With the present population growth rate of 2.3% per annum and a growth rate of less than 3% in the agricultural sector, Nepal faces an increasingly serious risk of food deficit and poverty. Marginal farmers, small farmers and the landless account for 89–96% of those living below the poverty line in rural areas. Just over half the population live in the hills and mountains and 60% of this group live below the poverty line (APP, 1995) compared with 42% in the terai. Holdings of less than 1 ha account for 82% of the total in the mountains and 77% in the hills, compared with only 59% in the terai (CBS 1998). Land holdings tend to be smaller in the hills (0.7 ha/household) and mountains (0.8 ha/household) compared with the terai (1.3 ha/household).

Reducing poverty and commercialising subsistence agriculture are key government goals. The Ninth Plan which started in 1997 emphasised poverty alleviation and aimed to reduce the proportion of those living below the poverty line from 42% to 32% by 2002–03. This was to be done largely through growth of the agricultural sector. The Agricultural Perspective Plan (APP 1995) placed increased emphasis on livestock development to generate national economic growth and improve the livelihood of the rural poor in the hills and mountains. The contribution of livestock is projected to increase, from the present level of 31%, to 45% by the end of the plan period (2015). Highest growth has been estimated for the hill and mountain regions of the country. Within the livestock sector, the contribution of small ruminants is 12% but this needs to be substantially increased in future to achieve the planned levels of growth and improvements in rural poor livelihoods.

Livelihoods analysis and poverty focus

Using a livelihoods analysis approach, a range of indicators pertaining to the five classes of capital, as defined by Carney (1998), were considered. On the basis of these indicators, it was apparent that poverty increases from the plains to the mountains. There is also a trend for the more remote districts in the west of Nepal to be poorer than their more accessible counterparts to the east.

Capital access

Table 6.1 provides a summary of some of the indicators examined and the proportion of districts in each region that are in the lowest third of the country's ranking. It is

evident from Table 6.1 that, by most measures, the hill and mountain regions are ranked lower than the terai. In particular, access to natural resources is a constraint in the hill districts, while access to financial, social and physical capital, all highlight the problems of remoteness in the mountain districts.

Vulnerability context

Population growth in Nepal is about 2.3% per annum, which is limiting access to natural resources in the hills. The population of the hill districts rose by 45.5% between the census of 1981 and that of 1991, while the mountain districts' population rose by only 7.8%. In part, population growth in the mountain districts is reduced by outward migration, although this appears to be a destabilising influence on the farming system and may further erode aspects of social capital.

There is a trend towards improved access and communication as roads and telecommunications permeate the more remote districts. Farmers in the hills and mountains are vulnerable to occasional natural disasters which, in the past, have brought famine to remote districts. Landslides are not unusual, while hailstorms, earthquakes, droughts and floods are all reported in the literature as being past causes of distress. Rinderpest has been present in the past and *peste des petites ruminantes* is a threat to the sheep and goat livestock system that has the potential to seriously threaten livelihoods.

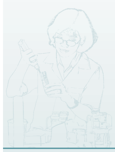
Role of small ruminants

Livestock contribute 31% of Nepal's GDP and small ruminants 12% (LMP 1993; APP 1995). Small ruminant production is an important component of mixed farming systems and an important source of cash generation and livelihood for resource poor farming communities (including women and marginal farmers) who are unable to invest in large ruminants. These animals are an important source of liquid assets for poor farm families and women during famine, illness and emergencies. Goat meat has wide acceptance in all the communities

Table 6.1 Poverty indicators used in the study

Type of capital	Terai	Hills	Mountain	Indicator
Human	8.6 million	8.4 million	1.4 million	Population
Natural[1]	0	62	6	Natural resource endowment index
Financial[1]	5	39	50	Agricultural credit uptake
Physical[1]	15	33	56	Socio-economic infrastructural development index
Social[1]	40	23	50	Women's empowerment index

[1] Percentage of districts in each region that fall in the lowest third of national ranking for each index.
Source: Districts of Nepal, Indicators of Development (ICIMOD 1997)



There is increasing conflict over lands used for grazing and forestry which can be reduced by confining goats. (G.D. Gray)

and ethnic groups in Nepal. The demand for both goat meat and live animals in rural and urban areas is increasing for consumption and religious sacrifices. The price of goat meat has more than doubled in the past five years compared with that of poultry and buffalo meat, indicating its importance and unfulfilled demand for it. Women contribute significantly to livestock raising, providing 70% of the work effort and are reported to be more knowledgeable than men about treating sick animals (APP 1995).

Mountain communities prefer to raise sheep for meat, wool and manure production. Sheep wool production also provides income and employment opportunities for rural women. Woollen products (hand-made carpets, blankets, Pashmina) produced from sheep and goat wool are major sources of rural income and livelihoods. Hand-made carpets and Pashmina shawls are the major export products of Nepal.

Small ruminants raised by poorer farmers do not attract the attention of the mainstream scientific establishment and little effort has been made to improve their economic prospects. Cash resources are limited and uptake of credit low. Together with poor access to technology and information, these constraints limit farmers' ability to use capital intensive techniques.

Sedentary goat production in the hill districts

Farming systems

Most farms in the hill districts are small-holder mixed enterprises. Cropping areas are mainly terraced, producing rice, wheat, barley, maize, potatoes and vegetables. Both rain-fed and irrigated systems are found and agro-forestry is practised. Livestock consist of cattle, buffalo, goats and poultry. Forests are used as a forage resource for grazing and browsing livestock. Livestock contribute manure and traction to the crop system and benefit from by-products and weeds from the cropping areas.

Livestock management

Small ruminants, particularly Khari goats, are managed in sedentary systems in the hill districts. Goat management practices are influenced by location, availability of pasture and communal grazing, availability of family labour, cropping pattern of the area and market prospects. Animals are kept in one area throughout the year and are penned at the homestead at night. Night pens are normally small sheds made of local materials, which may or may not be raised constructions with slatted floors. They may be semi-stall-fed or stall-fed (Ghimire 1992). However, grazing on waste or fallow land and browsing in bush or forest areas close to the village are more common. Because of limited availability of fodder and pastures in grazing land, in many places the animals are routinely supplemented at the stall with grasses, straw or fodder tree leaves. Food grains and salts may also be provided. Animals are watered during the day on the way to grazing.

With present management techniques, productivity is low, there is little selection or breeding control and some relatively unproductive animals may be maintained and compete for scarce feed resources. Throughout the year, goats must compete with cattle and buffalo and poor pasture quality forces animals to use forest resources. Continuous grazing of the same limited grazing areas may contribute to the build-up of heavy parasite burdens and contribute to low productivity.

Animal health issues in small ruminants

Diseases and parasites are regarded as major constraints to production in the sedentary production system. In fact, farmers ranked disease as the first constraint to increased productivity of sedentary goats. Various diseases (reported on a symptomatic basis) have been reported in goats and sheep under sedentary management. Among them, the prominent causes of losses are diarrhoea, fever, respiratory problems, skin infections, worm and fluke infections, foot and mouth disease, contagious ecthyma and coenuriasis. In addition to the common problems, *peste des petits ruminants* and setariasis have also been reported, in some parts of the country, during the past few years.

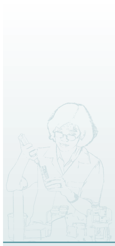
Sick animals are treated as and when is necessary, first by traditional methods and then by veterinary ones if the animal does not recover. Many ethnoveterinary practices are used, for example, leaves of *Cannabis indica* for the treatment of scour and garlic bulbs for plant poisoning. However, the effectiveness of these is uncertain.

Helminth problems

Parasitic diseases (including gastrointestinal nematodes, liver fluke and external parasites) of small ruminants are regarded as the most important cause of reduced productivity among goats in sedentary management systems in Nepal. Parasitic diseases were ranked first by farmers and this view has been further supported by studies showing superior response by animals treated with anthelmintics. Infection is mostly confined to the wet summer months, with low levels of infection during the winter and dry summer months. The main nematode genera found are *Haemonchus*, *Trichostrongylus* and *Oesophagostomum*, with *Cooperia*, *Strongyloides* and *Bunostomum* being found less often (Joshi 1997, 1999).

Trichostrongylus and *Oesophagostomum* may be the cause of the goat diarrhoea reported by farmers while *Haemonchus* on its own (or in combination with *Fasciola*) may be a significant cause of mortality or reduced productivity on these farms.

The effect of gastrointestinal nematodes on animal production was evident in studies in which the growth rate of the animals given regular anthelmintic treatment was higher relative to untreated animals reared alongside (Joshi 1998). The daily weight gain of anthelmintic-

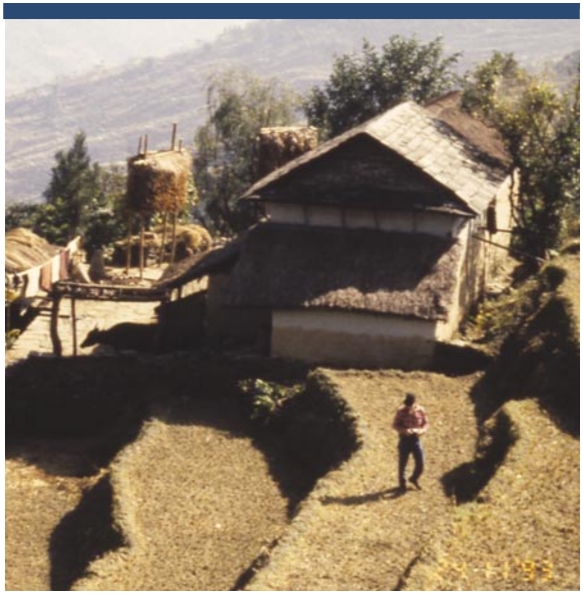


treated kids was up to 2.5 times that of untreated kids under sedentary conditions. These responses show that controlling parasites can greatly improve goat productivity in this system.

Options for helminth control

The following options, either alone or in combination, could help to reduce the effects of helminthiasis in sedentary flocks. These options might form a suitable list from which farmers could choose most-favoured options for further study, as part of participatory on-farm adaptive research. They are:

- controlling grazing to avoid the most heavily contaminated areas
- managing grazing to minimise build up of infection in grazing areas
- managing manure to prevent spread of eggs and larvae from housed animals
- increasing stall feeding to reduce pasture intake during risk periods
- avoiding grazing completely during the riskier wet months
- using cut and carry forage grasses and weeds to boost nutrition and enhance resilience
- using anti-parasitic tree forages such as mulberry to reduce parasite burden
- using nutritional supplementation purchased as by-products such as rice polish and mustard cake
- using non-conventional feeds for goats such as poultry manure and brewers grain
- treating kids strategically with anthelmintics to suppress build-up of infection during risk periods
- using supportive therapy for sick goats including symptomatic treatment to permit survival and recovery, for example, protein and energy supplementation and anti-scouring agents
- managing breeding to reduce the number of susceptible animals present during the risk periods.



Most farms in the hill districts are small-holder mixed enterprises. (ACIAR)

Based on currently available technology options a possible advisory note for people in sedentary systems appears in the Appendix to this chapter.

Sedentary system case study — Pyughar Village

Goat production is an important source of livelihood for the farming community in Pyughar village (Deurali VDC) of Tanahu district, in the western hill region of Nepal. It is a small village (55 households) located at an altitude of 400 m, on the bank of the Seti river and a one-hour walk from the Mugling–Narayangarh highway. The village is predominantly inhabited by people of the Gurung community with a few households of other ethnic groups such as Magar, Bahun, Chettri and occupational caste (Damai). Cereal food crops (rice, maize, wheat), goats, off-farm activities and vegetable production are the main sources of livelihood. After cereal food crops, goat raising is the next most important component of the mixed farming system. Most farmers are smallholders (<1 ha) with small marginal (upland) and low producing, cultivated lands. Since the majority of the farm households (>60%) have inadequate food production from their limited marginal farms, most of them suffer from food insecurity during some parts of the year (mostly during the pre-harvest period). Goat raising plays a critical role in meeting the food security and livelihood needs of these households.

Goats are grazed close to the village, in communal grazing lands and forests, during the day and kept in sheds close to the house overnight. Little supplementary feeding is provided to animals in the sheds. The number of animals kept by each household ranges from 1 to 18 with an average of 6–7 animals per household. Goats are of the indigenous hill breed (Khari) and are small.

Constraints to goat production

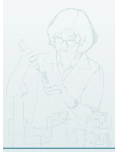
There are several critical constraints to smallholder goat production in the village. Farmer-perceived constraints were listed after group discussion with 14 farmers and then pair-wise ranked. In order of importance, these were: disease, lack of knowledge about goat raising, capital constraints and feed scarcity, and family labour constraints. Labour is a constraint in small families in which there is a shortage of adults to take care of the animals.

Symptoms and seasonality of disease

Diarrhoea was the most important disease symptom reported by the goat farmers. Other important symptoms mentioned were: watering from the nose, occurrence of fever and stomach swelling. The severity of disease is greatest in young animals during the rainy season (May–September).

Disease management

Goatkeepers use both traditional and chemical methods to control disease when animals develop diarrhoea. Some use cooked lemon extracts (chook), cannabis or garlic to control the initial stages of the disease symptoms. Farmers resort to the use of chemicals/anthelmintics only when traditional methods do not work well. Drugs and associated information are normally obtained from agroveterinary suppliers at Bharatpur (Chitwan district). Technical information and chemicals are rarely obtained from the local government livestock extension office. Farmers rarely receive relevant information from radio or other communication methods.



Transhumance sheep and goat production in the mountain districts

Farming system

Agro-pastoralism is the dominant form of farming in the mountain districts. Transhumance livestock production is integrated with limited cropping of barley, buckwheat and potatoes. Livestock contribute significantly to farmers' livelihoods and provide the soil fertility necessary for continued cropping.

Livestock management

Most of the sheep and goats in mountain districts are raised under the transhumance system of management. Animals are moved to different altitudes and climatic conditions throughout the year and are never penned or fed cut forage. This migratory movement is determined by the availability of fodder, the farming system and the climatic conditions. In the migratory flocks sheep and goats are raised together (sheep comprising the higher proportion). Baruwal sheep and Sinhal goats, well known for their flocking tendency and hardiness, are the principal breeds used in this system.

During early summer (May to early July) flocks migrate up to alpine pastures, grazing and browsing in the forests. From late July to early September animals feed on the alpine meadows and gain sufficient body weight before descending through the forests again in late September. From October through to April flocks graze in the fields and forests adjacent to the lower altitude villages.

Animal health issues in small ruminants

Shepherds of the transhumance flocks report disease and predation as important causes of animal loss. The most common ailments reported are 'six-month disease' (a disease of unknown etiology), diarrhoea, pneumonia, mange, contagious ecthyma and abortion. In addition, land leeches and nasal leeches are also reported as a serious nuisance to the animals. The main season for six-month disease is spring (April–May) and autumn (September–October), while diarrhoea is most common during the monsoon, and pneumonia and mange during winter. Most of the ailments are treated with available herbs and veterinary medicines are only used when the flocks are in accessible locations. The commonly used herbs are garlic, satuwa and kutki.

Helminth problems

Parasitic diseases (including gastrointestinal nematodes, liver fluke and external parasites) of small ruminants are regarded as an important cause of reduced productivity of sheep and goats under transhumance management in Nepal. Parasitic diseases are ranked second in importance after six-month disease and this view is further supported by the superior response of animals treated with anthelmintics in experimental studies (daily weight gains of treated kids were about double those of untreated kids) (Joshi and Joshi 1999, Joshi 1998).

The main nematode genera found are *Haemonchus*, *Ostertagia*, *Teladorsagia*, and *Trichostrongylus* and to a lesser extent *Oesophagostomum*, *Cooperia*, *Strongyloides* and *Bunostomum*. Studies indicate that *Ostertagia* and *Teladorsagia* are the main worm genera in the transhumance animals, although *Haemonchus* burdens increase when sheep and goats are in the low pastures in the winter (Joshi 1999).

Transhumance system case study — Ghandruk village

Ghandruk is a high mountain village (altitude 2000 m) located in the north-western part of Kaski district on a trekking route to the Annapurna Himalayan range. The village is predominantly inhabited by people of the Gurung community. Agriculture, tourism and off-farm activities are the main sources of livelihood for the local people.

Transhumance is the production system used for sheep and goat flocks in this mountain village. Farmers normally keep mixed flocks of sheep and goats (sheep comprising the higher proportion). Indigenous sheep (Baruwal) and goats (Sinhal) are raised in high mountain alpine pastures during the summer rainy season and grazed in the crop fields and forests/bush in the lower hills during winter. The number of animals per flock ranges from 250 to 500. Flocks are either owned by an individual or two to four owners. There is a declining trend in migratory sheep production in the village, with only five flocks currently in the community where formerly there had been 10.

Constraints to sheep and goat production

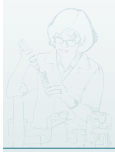
Semi-structured interviews and discussions with herders and owners revealed that the important constraints to migratory small ruminant production were: (i) diseases; (ii) predation from leopards and bears; and (iii) land leech nuisance to animals. An allergic reaction in sheep feeding on pastures containing a hairy caterpillar (which is a serious pest of *Alnus nepalensis*) was also reported as serious by one of the sheep owners.

Symptoms and seasonality of disease

Chhamase ('six-month') disease was perceived to be the most serious disease of sheep by the owners and shepherds. This disease kills young animals four to six months old causing significant economic losses to their owners. Fever and diarrhoea are the common symptoms of this disease, which occurs during migratory movement of the flocks (April–May and October). The other important disease reported by shepherds, which appears in some years, was blindness disease in sheep (probably a tapeworm cyst). Goats were reported to be relatively free from disease compared with sheep. However, sometimes diarrhoea from worm infection kills goats. Diarrhoea is severe in goats during the rainy season (June–September).

Disease management

Herders normally use herbal plants and also antibiotics (if available) to control *Chhamase* in sheep. For goat diarrhoea they use cooked lemon extracts (*chook*), garlic and other herbal remedies to control the initial stage of the disease. They obtain drugs and the information from agroveterinary suppliers in Pokhara and from the Agricultural Research Station at Lumle.



Discussion and observation with farmers in their own surroundings builds trust and yields better data. (G.D. Gray)

Options for helminth control

Few options for improving helminth control can be suggested for the transhumance system and none that could be readily or immediately implemented. Gaps in the understanding of the epidemiology of parasite species in this management system require further study. While such studies have the potential to contribute to the productivity of the system and the livelihoods of the shepherds and owners, there are many logistical problems to undertaking such work.

Conclusions

Because poverty and small ruminant production are clearly linked, the focus for any project activities should be the sedentary goat production system in the hill regions and the migratory sheep and goat production system in the mountain regions. The poverty focus of activities would be enhanced by paying greatest attention to the more remote areas in the west of the country.

The participatory exercises described here with farmers in the hill region highlighted that farmers recognise their lack of knowledge as a constraint to production. If farmers' demands for better knowledge were met and they were trained in simple skills associated with parasite control, there is a real chance that sustainable control practices might be adopted.

Allied to the above, the establishment and use of farmer research groups to undertake participatory testing of most-favoured options, chosen by farmers from the list of control options, might result in useful practical adaptation of these strategies. Such an exercise might provide valuable information on the process which could be extrapolated to the other countries in the project.

Further data are needed before valid control options for the migratory system in the mountains can be implemented. The logistical problems in undertaking this work should not be underestimated. However, the

Table 6.2 The significance and growth of livestock production per region

Region	Livestock GDP Proportion	Livestock Growth rate (91/92–94/95)
Terai	38%	2.8
Hills	53%	2.9
Mountain	9%	3.0

Source: Agriculture Perspective Plan (1995)

Table 6.3 The importance of ruminant livestock in different regions

	Terai	Hills	Mountains
Livestock cash income (% of total cash income)	9.7%	19.7%	21.2%
Labour utilisation for livestock (man days)	64	73	51
Goat numbers (000s)	1,828	3,396	855
Sheep numbers (000s)	122	386	361
Percentage of households keeping goats	46.8	54.2	55.5
Percentage of households keeping sheep	1.8	4.2	6.5

Data from: Livestock Master Plan (1993), Statistical Information on Nepalese Agriculture 1997/98 and Agriculture Perspective Plan (1995)

benefits from a greater understanding of the diseases present in this vulnerable and marginalised system would help increase its potential to meet the livelihood requirements of the region.

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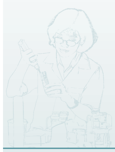

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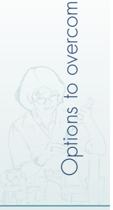


Appendix
Source material for an advisory note for sedentary system goat-keepers in Nepal

Internal parasites cause death and reduced production of meat, milk, fibre and manure from sheep and goats throughout Nepal. In the hill regions, problems are caused by nematode worms in the stomach and intestines and flukes in the liver. Options for better control include grazing control and management, stall-feeding and use of anthelmintics.

The problem

When does the problem occur?

While animals may be continuously infected and experience production losses all year round, clinically apparent signs are mainly found during the wet summer months of the monsoon period (July to September).

What are the causes?

Animals acquire burdens of *Haemonchus*, *Trichostrongylus* and *Oesophagostomum* causing a highly pathogenic multi-species parasitic gastroenteritis syndrome.
In addition, animals are frequently infected with *Fasciola* which increases the severity of the condition.

How the damage occurs

Trichostrongylus and *Oesophagostomum* cause a profuse diarrhoea, with a consequent failure to efficiently absorb nutrients in the intestine. *Haemonchus* and *Fasciola* cause a protein loss in the stomach and liver and reduced efficiency of stomach and liver function. In addition, *Haemonchus* is a blood feeder and leads to blood loss and anaemia.

Interaction with management

Under current management, animals tend to revisit the same grazing areas regularly during the wet season and it is presumed that high levels of infectivity build up on the pasture of these areas. In addition, since pasture is at its most abundant during this time, supplementation with cut fodder is reduced, encouraging animals to have higher intake of infected herbage and at the same time reducing the total quality of feed intake.

Grazing control and managment

Grazing control

- to avoid the most heavily contaminated areas

Grazing management

- to minimise build up of infection in grazing areas

Manure management

- to prevent spread of eggs and larvae from housed animals

Stall feeding

Increased stall feeding

- to reduce pasture intake during risk periods

Zero grazing during wet months

- to avoid grazing completely during risk periods

Table 6.4 Use the right drug for the right worms

Anthelmintic Group	Chemical	Roundworms	Flukes	Tapeworms
Group 1	Albendazole	YES	YES	YES
	Oxfendazole	YES		YES
	Fenbendazole	YES		YES
Group 2	Levamisole	YES		
	Tetramisole	YES		
Group 3	Ivermectin	YES		
Others	Rafoxanide	Haemonchus only	YES	
	Oxyclosanide		YES	
	Closantel	Haemonchus only	YES	
	Triclabendazole		YES	

Cut and carry forage grasses and weeds

- to boost nutrition and enhance resilience

Anti-parasitic tree forages

- use of forages such as mulberry to reduce parasite burden

Purchased by-products

- nutritional supplementation with rice polish, mustard cake,

Use of non-conventional feeds

- brewers grain, poultry manure etc.

Use of anthelmintics

Improved knowledge and use of anthelmintics

- to permit effective treatment and prevent the establishment of anthelmintic resistance

Strategic treatment of kids

- preventative use of anthelmintics to suppress build up of infection during risk periods

Supportive therapy for sick goats

- symptomatic treatment to permit survival and recovery e.g. protein and energy supplementation and anti-scouring agents

Breeding management

Better breeding management

- to reduce the number of susceptible animals present during risk periods

Best practice for drug use

- Use the correct drug
- Make sure you use the right dose of drug — don't underestimate an animal's weight
- Don't use anthelmintics too frequently or animals may develop resistance
- Use drugs before expiry
- Most drugs work best if given when the animal has an empty stomach
- If giving a drug by mouth, it should be given as far back in the mouth as possible
- Drug bottle contents should be well mixed before use
- Store drugs away from direct sunlight and children

7. The impact of parasitism on the development of small ruminant populations in Southeast Asia

7. The impact of parasitism on the development of small ruminant populations in Southeast Asia

G.M. Hood

Introduction

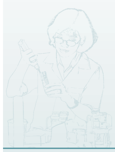
For smallholders to benefit from rising demand for livestock products, they need to increase herd and flock sizes so that livestock form a significant part of their farming income. With the notable exception of West Java — where sheep form a large component of the farming mix — small ruminant populations in Southeast Asia are small (FAO 2002). At the household level, this is reflected as small herd sizes. Figure 7.1, for example, shows the distribution of goat holdings in the municipality of Muñoz in the Central Luzon area of the Philippines. Most households have fewer than 10 goats, and the average holding in 2001 was just over three per household. Throughout much of Southeast Asia, herd sizes are small despite a strong market, rising prices for goat meat and recent demonstrations that raising goats for meat is profitable (e.g. Chapter 3).

Parasitism is one of many constraints that limits the creation and development of small ruminant enterprises. Parasitologists often report the effects of parasitism on physiological parameters, growth rates, reproduction and mortality, but it is relatively rare to see these effects translated to farming systems and the decisions made by smallholders.

Parasitism as a constraint to the development by smallholders of a medium-sized enterprise based on meat goats, and demographic models will be used in this chapter to assess the impact of mortality, reduced growth rates and delayed reproduction on both annual productivity and herd size. The set of models considered here includes a stochastic version that uses individual animals as the unit of study. It is therefore well suited to modelling smallholder systems in which the number of animals is small and the fate of individuals important. The observed mortality rate in tropical goats is one of the chief constraints to the growth of herd size, but opportunistic harvesting also prevents smallholders from developing medium-scale enterprises.

Model details

We use the Leslie matrix (Leslie 1945) as the basis for model development because of its close links to life tables and the availability of a large body of analytical theory (Caswell 2001). The model we consider, however, is an extension of that formalism which includes a group of classes to represent the stages of the breeding cycle, as illustrated in Figure 7.2.



7. The impact of parasitism on the development of small ruminant populations in Southeast Asia

Figure 7.1 Distribution of herd sizes among 1015 goat owners in Muñoz, Nueva Ecija, The Philippines in 2001. Source: Census by city veterinarian, Dr Jerry Rigoz.

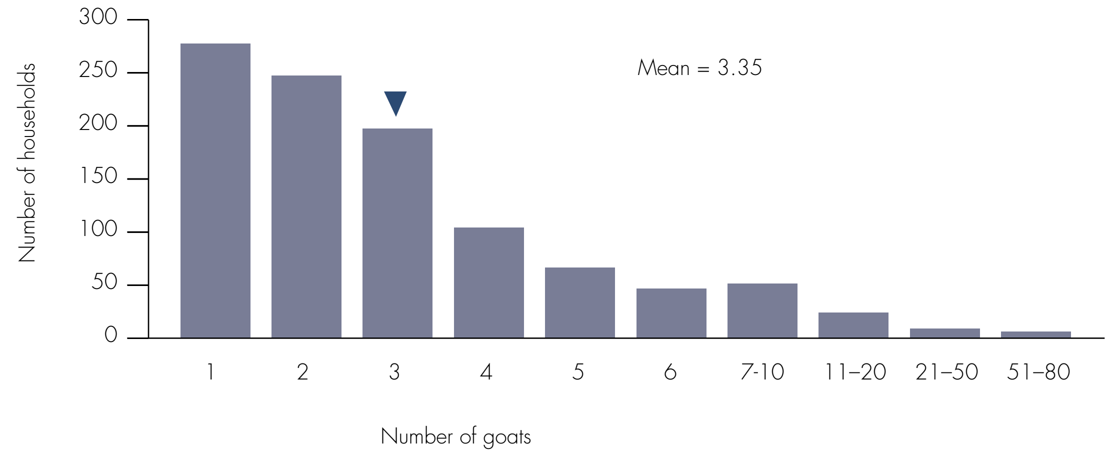
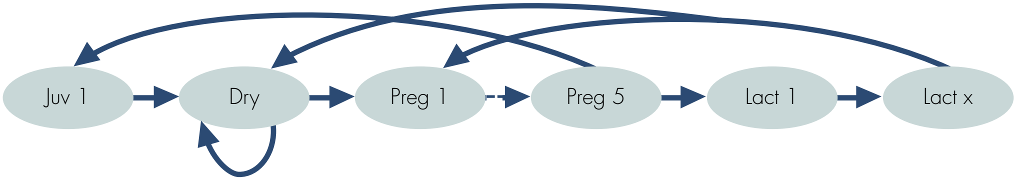


Figure 7.2 Lifecycle diagram showing stages of the goat's breeding cycle



Full details of the model are included in the help file that accompanies the GLORIA software package (available at www.worminfo.org/goatflock). In brief, 'Juv 1' represents female kids that have just attained the age of one month. Juveniles pass through several age classes (represented by the dotted arrow) until they are of reproductive age (Dry), whereupon they can fall pregnant (Preg 1), or stay dry. Newly conceived females go through five months of pregnancy (dotted arrow) before kidding. They then spend one or more months with kids at foot (Lact 1 to Lact x) before they can either conceive or return to the dry state after weaning of kids. Survival of male kids is modelled as a simple chain of age classes; the survival of adult males is not considered at all in the model. The availability of bucks for mating enters by proxy as a conception probability.

Each of the arrows in the life-cycle diagram represents a parameter, or set of related parameters, which must be estimated. Unfortunately, a complete set of survival and reproduction parameters is rare in field studies or surveys of smallholder populations. We therefore use an amalgam of published estimates and best guesses to parameterise the model. Specific suites of parameter estimates are available as scenarios in the ('GLORIA') software package.

The simplest version of the model treats the parameters as deterministic rates. Under these conditions, the life-cycle diagram can be mapped to a population projection matrix, which allows the dynamics of the model to be written:

$$N_{t+1} = AN_t$$

Where A is a square population projection matrix, and Nt is a column vector in which each element represents the number of animals in each class at time t. For this class of model, an array of analytical tools (Caswell 2001) can be employed to understand the relationship of demographic rates to the productivity of the population. In particular, the dominant eigenvalue, λ_1, of the projection matrix, A, gives the population growth rate. We will use the annualised population growth rate as an index of the potential rate of harvest for each scenario.

A more realistic version of the model treats the survival parameters in the model as probabilities and the reproductive parameters as the means of specified distributions. Although this stochastic version of the model has intractable mathematics, it can easily be simulated to estimate quantities like the population growth rate. The particular advantage of the stochastic model is that it allows us to consider the fate of a small herd of one or more females and to understand the risks that smallholders face due to parasitism-related mortality and other causes.

Analysis

We first consider model behaviour using a default set of key parameters. (Many other parameters are used in the model, but this is a key set likely to be affected by parasitism.) These have been estimated from field surveys in the Philippines, where goats are principally raised by tethering on crop residues and roadsides. Under these conditions, mortality from parasitism and other causes is high (Table 7.1).

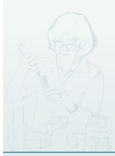


Table 7.1 Default parameter set

Parameter	Value	Explanation
Pre-weaning mortality	40%	Total mortality up to the age of weaning
Post-weaning mortality	20%	Total mortality after weaning but before attaining breeding age
Adult mortality	35%	Annual mortality of breeding females
Age at sale	9	Age at which surplus stock is sold
Breeding age	10	Age at which female kids are first mated
Conception rate	50%	Monthly probability that eligible females conceive
Weaning age	3	Age in months at which kids are weaned
Twinning rate	30%	Percentage of litters that yield twins

Given these parameters, analysis of the deterministic model yields a population growth rate of only 3% per annum, making it difficult to produce surplus stock for sale and increase herd sizes. An additional difficulty is illustrated in Figure 7.3, which shows two runs of the stochastic version of the model. Here, even though the stochastic growth rate (mean growth rate in 1000 simulations = 3%) is similar to the deterministic version, individual runs of the model are quite different. In Figure 7.3a, for example, the population has barely survived, producing only one kid for sale in three years; while in Figure 7.3b, the population has grown from four to nine goats in the same period and four kids have been produced for sale.

A second set of parameters illustrates the population growth rates achievable when parasites are controlled and mortality is low (Table 7.2). These parameters have been estimated using data collected in the Philippines (see Chapter 3) where, among other feeding and management options, wet season housing has been provided, and haemonchosis has been controlled by regular anthelmintic treatment. The principal change here is the reduction of mortality to rates similar to those found in temperate climates, together with a slight increase in the conception rate to reflect higher body weight and better condition score.

Analysis using the 'Housed' parameter set yields a population growth rate of 79% per annum for the deterministic model and 78% for the stochastic version (mean of 1000 runs), with almost two surplus kids produced per breeding female. There is also a profound decrease in the variability of the outcome. The GLORIA software package provides tools for investigating this variation in detail, but a simple indication of the magnitude of the change can be obtained by comparing the coefficient of variation (CV = standard deviation divided by the mean) in the size of various age classes at the end of a 36-month simulation. For the default parameter set, we obtain a CV in the final size of the breeding herd of 66%, while for the 'Housed' scenario we obtain a CV of 21% for the breeding herd. A similar decline in variation is observed in all age classes.

Figure 7.3 Two runs of the stochastic version of the model starting from a herd size of two adult and two juvenile females and running for three years (36 months). Lines show size of the female part of the herd and vertical bars show sales of surplus animals (usually kids).

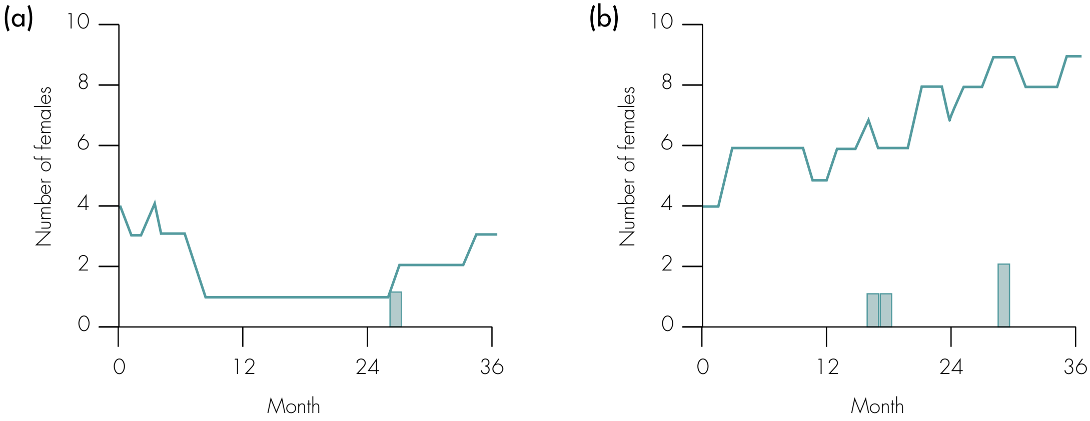


Table 7.2 'Housed' parameter set

Parameter	Value
Pre-weaning mortality	5%
Post-weaning mortality	5%
Adult mortality	5%
Age at sale	8
Breeding age	10
Conception rate	70%
Weaning age	3
Twinning rate	45%

Forage crops can provide a regular source of feed that allows more intensive production and reduces the labour required for feeding and herding. (G.M. Hood)

The unpredictability of the farming system with the default high mortality rates may help to explain the lack of development of small ruminant enterprises in Southeast Asia. Most goats in the region are kept as an easily liquidated asset for the purchase of medicines, payment of school fees and other needs. The demand for cash must often arise at times when surplus male kids are not available, so that owners are forced to sell breeding females. The combination of low inherent productivity and urgent cash requirements could, therefore, enforce a low ceiling on herd size. So, it is pertinent to consider the possible trajectories that a smallholder might follow in attempting to build a larger herd from a small initial holding.

Moving from a small to a medium-scale enterprise

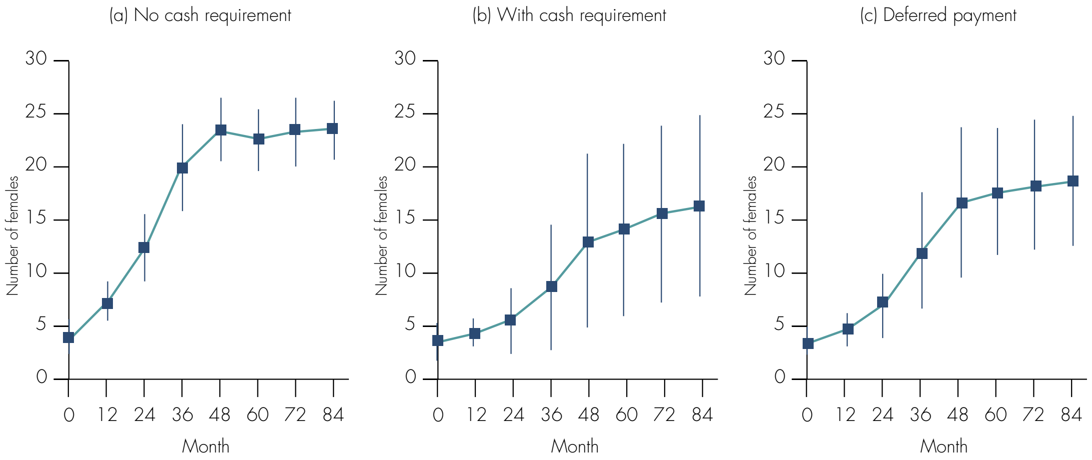
Consider the case in which parasitism and other major sources of mortality have been controlled, but in which there is an urgent need for cash on an annual basis that must be satisfied by selling goats — to pay school fees, for example. Using the model, scenarios will be considered with and without this cash requirement, and the rates at which a goat enterprise can develop will be contrasted. The endpoint will be a herd size of about 12 breeding females, starting from an initial herd of four animals two adult females (one of which is pregnant) and a six-month and eight-month-old female kid.

Figure 7.4 shows the mean of 100 trajectories using the 'Housed' parameter set, but with the imposition of a ceiling of 12 adult breeders (that is, breeders are culled to reduce herd size when the ceiling is exceeded). Each of the panels of the figure shows the result of simulations under a different set of financial circumstances. Figure 7.4a assumes that no urgent cash requirement exists, so that surplus kids and adults are simply sold as they become available. Under these conditions, mean herd size grows quite rapidly to reach a steady state capacity at about four years. In each of the 100 trajectories, the herd never died out.

Selling more young goats at better prices will allow youngsters to spend more time at school. (G.M. Hood)

In Figure 7.4b a 'cash requirement' has been imposed, forcing the owner to sell three goats in August every year. The rule imposed here is that surplus stock are sold first to meet the cash requirement, but breeders are also culled if necessary. Under these conditions,

Figure 7.4 Mean of 100 trajectories using the 'Housed' parameter set but with a ceiling of 12 imposed on the breeding population: (a) no cash requirement, (b) a requirement that three animals must be sold every 12 months to meet urgent cash needs, and (c) the cash requirement is spread over 3 months. Error bars show the standard deviation of herd size

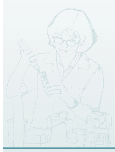

(a) No cash requirement

(b) With cash requirement

(c) Deferred payment

mean herd size grows relatively slowly and the final herd size is lower than that attainable without the cash requirement. The error bars of the figure show that the variation between trajectories when the cash requirement is imposed is extreme compared to the relatively predictable dynamics of the first scenario. The variation is partly driven by the extinction of some herds — in 18 of 100 simulations, the herd died out before six years had elapsed.

Figure 7.4c shows the result of simulations in which the cash requirement is spread over three months, as would occur if an interest-free loan were obtained. In this case, mean herd size grows somewhat faster than in Figure 7.4b to a slightly higher plateau. More importantly, herd size reached zero in only 8 of 100 simulations.



Conclusion

The differences between the scenarios of Figure 7.4 should not be surprising to development workers. The transition from bare subsistence to earning a modest income from any agricultural enterprise is difficult. Smallholders must cope with unpredictable changes in the weather and economic circumstances, which will drive managerial decisions, so that an optimum path for development of the enterprise cannot be followed. For small ruminants in the tropics, nutrition and the control of parasitism are key technological innovations that sustain viability, but appropriate markets and economic structures must be also in place to help smallholders succeed. As Figure 4c suggests, obtaining credit at a reasonable rate of interest, rather than the punitive rates prevalent under village conditions (e.g. Calara and Lapar 2001), may allow farmers to make better decisions.

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8. Worm control for small ruminants in the Philippines

8. Worm control for small ruminants in the Philippines

G.D. Gray, C.A.T. Yee and E.C. Villar

Introduction

The consensus which emerges from the literature published in the Philippines in the last 20 years is that there is a need to increase production of small ruminants in the country and that helminth parasites are a 'major constraint on production'. The greatest opportunity appeared to be the integration of sheep and possibly goats in plantation crops, especially coconuts but, at present, 'backyard' production is by far the dominant production system. A comprehensive review (Dar and Faylon 1996) identified the range of constraints on the substantial goat (2.63m head in 1996) and emerging sheep (30,000 head in 1996) industries and do not restrict these to animal health. That paper describes the medium term Philippine livestock R&D priorities 1995–2000 which included the aim of controlling and eradicating *economically important* diseases of swine, poultry and ruminants: The key phrase in this objective is 'economically important' and Ducusin and Faylon (1996a) [later published in the Philippines (Ducusin and Faylon, 1996b)] tackle the question of the importance of gastrointestinal helminths in Philippine sheep and goats and list the parasites present. Further, they agree with Manuel (1983a) and Parawan (1988) and many anecdotal reports, that nematode parasites limit small ruminant production. Parawan concludes his discussion on the integration of livestock with tree crops with:

> *The most important aspect of health and diseases on grazing livestock under tree crops is the problem of internal parasites. The problem is aggravated by the shading effect which favours parasite egg survival and persistency*

Typical of published observations is that of Villanueva and Soriano (1988) who concluded a report of a study of feeding water hyacinth meal to young sheep:

> *There was however an observed stunted growth in the experimental animals but this disturbance was due to external and internal parasites;*

or Bautista and Vaughan (1983), in explaining the lack of progress in their goat breeding program in Bagalupa, Mindanao,

> *high kid mortalities appear to have been due to pneumonia caused by a combination of inadequate shelter, poor nutrition and helminth parasitism,*

or Cruz et al. (1997) on the development of improved goats in Central Luzon,

> *"Parasitism is one of the causes of high mortality not only at the university goat project but especially under farm conditions. A broad spectrum dewormer is being used during [the] rainy season and once every three months during [the] dry season".*

The two main strategies that emerge from the literature for increasing small ruminant production are:

- The development of new industries integrated with tree crops including coconut, mango, oil palm, pepper, calamansi, coffee and rubber (Villar 1984, 1995; Tacio 1998; Alvarez et al. 1985; Subsuban et al. 1995; Faylon et al. 1989; Castillo 1994).
- Increased efficiency of existing extensive and intensive production systems (Villar 1984; Faylon and Villar 1988).

A national survey documented by Faylon and Villar (1988) characterised the current stock of sheep in the Philippines and determined the existing components of sheep production systems. Management, husbandry and herd health practices were identified with the aim of formulating a national framework for sheep research and development. Among their many findings, deworming and vaccination were the most commonly employed herd health practices. A very general account of ruminant development in developing countries was written from an international perspective by Madamba (1989).

No matter what national or international objectives are identified, the challenge remains, despite substantial research efforts, of how to achieve these objectives and to prevent parasitism from denying farmers their economic returns.

Host-parasite relationships and worm control options

Descriptions of parasites of small ruminants in the Philippines

A slaughter study of 40 goats from sale stands in Manila and Quezon City (Manuel and Madriaga, 1966) found four nematode species: *Trichostrongylus* sp., *Haemonchus contortus*, *Oesophagostomum columbianum* and *Trichuris ovis*. This was also the first Philippine description of *Eurytrema pancreaticum*, the pancreatic fluke.

The parasites (helminths and protozoa) of goats from a large number of provinces in the Philippines have been subjected to an extensive study (Tongson et al., 1981). 1230 faecal samples were examined and 39 goats necropsied. From the faecal examinations the four outstanding genera were *Trichostrongylus*, *Haemonchus*, *Oesophagostomum* and *Strongyloides* found in 1117, 1073, 1047 and 524 of the samples respectively. The actual counts are not presented. This was the first report of *Strongyloides papillosus* in the Philippines.

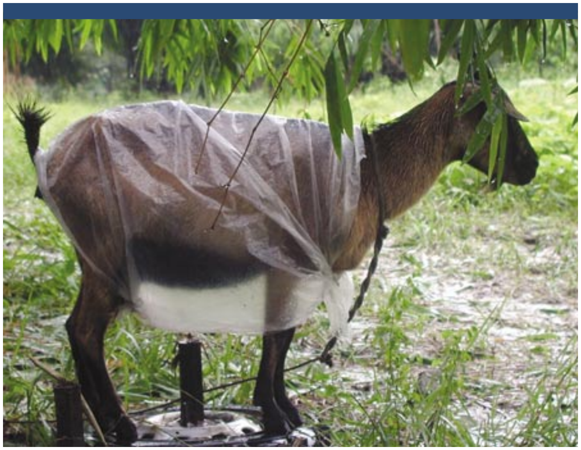
In a comprehensive account of the worldwide distribution of paramphistomes Eduardo (1988) lists *Cotylophoron cotylophorum* as a rumen fluke of sheep and goats in the Philippines, *Carmyerius synethes* and Fischoederius

cobboldi as rumen flukes of goats and the pancreatic fluke *Eurytrema pancreaticum* in goats. Tongson and Trovela (1980) found no correlation between faecal egg counts and worm burdens in 'grade Spanish Merino' sheep of various ages infected with *Haemonchus contortus*, *Oesophagostomum*, *Trichostrongylus* and *Cooperia*. Likewise there was no correlation between worm size and worm burden but there was a significant correlation between adult female numbers and faecal egg count. The ages of the sheep at slaughter were 3, 6, 12, 18 and 24 months with four animals killed at each age. In assessing the value of the lack of correlation the small number of animals in each class needs to be noted. Although not conclusive, this paper reinforces the warning that egg counts alone are not necessarily an indication of worm burden, although they are a direct measurement of pasture contamination.

Faeces from 60 sheep of varying ages were examined and larvae cultured (Matibag et al., 1991). *Trichostrongylus* and *Haemonchus* dominated the cultures, 'strongyles' dominated the egg counts with *Strongyloides* and five other nematode genera present.

Pajares (1986) described and elegantly photographed *Haemonchus* eggs and larvae as they develop from laying to hatching and moulting to infective larvae.

From the studies it can be summarised that using faecal samples alone for parasite identification is imprecise especially if only eggs are used for identification and are not allowed to develop to later free-living larval stages which can be more readily identified. Slaughter studies which permit identification of adult worms and parasitic larval forms are always preferable but not always practical.



Tethering exposes animals to extremes of weather. (G.D. Gray)

Worm control programs

One study strongly supports the concept of rapid rotational grazing systems in the Philippines (Barger 1996). [An interesting early reference to rapid rotational grazing systems in tropical conditions may be found in Spindler (1936) and Thomson and Carr (1957) who said that, in the tropics, small ruminants should be kept off pasture for 21–28 days.] Worm eggs from a native goat infected with several nematode species were maintained either under direct sunlight or in shade for several weeks, and at weekly intervals the viability of the eggs and larvae developing from them were estimated. Although the study was undertaken in Petri dishes and a direct comparison with pasture conditions cannot be made, the viability of deposited eggs to be recovered as larvae after 4 weeks was nil in the sunlight exposed

samples and very low in the shaded samples (Tongson and Dimaculangan, 1983). The humidity of the samples was maintained at >85% throughout. The recommendation from this study was that pastures should be rested for at least 4 weeks after grazing by infected goats and that this should be tested under field conditions.

Alvarez et al. (1991) showed that goats supplemented with ipil-ipil, but grazing in a rotational system rather than continuously, have a 'slight advantage' in terms of liveweight gain. This could be the result of diet quality, parasites or a combination of these.

A worm control program (Anon, 1981) for cattle describes the principles of strategic, tactical and offensive drenching for Philippine conditions. Drenching 2–3 weeks after the first heavy rains is suggested as a good strategy along with a mid-summer drench and one after soaking regular rains. It is not said if these strategies should also apply to small ruminants.

Manuel (1983b) provided the following worm control program for ruminants:

1. Calves should be treated against large ascarid and threadworms at the age of 1 month
2. Lambs and kids should be treated against Strongyloides at the age of 1 month.
3. Calves, kids and lambs should be treated against other gastrointestinal helminths at the age of 3 months.
4. Drench all animals (young and old) at least once a year preferably 1 month after the onset of heavy rain.
5. Pasture rotation should be practised.
6. Keep animals well nourished, supply vitamin and mineral supplements.

Feed supplementation (eg with urea molasses blocks) increases growth and reduces the impact of parasites. (G.D. Gray)

There is no evidence in this paper or later of these programs being tested experimentally against any other.

In an overview of livestock parasites in the Philippines, Manuel (1980) stated that "sheep and goats in this country are equally affected [by liver fluke, as buffaloes] but the condition is not considered a serious problem": the prevalence is the same but level of morbidity and mortality is less.

Several recent studies may reflect a change in approach to worm control as they describe seasonal variation on nematode infections in sheep and goats. Rosillo (1995) found that *H. contortus* and *S. papillosus* were present in ewes all year round when ewes were sampled regularly. Gemino (undated), Pangilinan (1998) Arrieta

(1998), Dilla (1998) and Gorospe (undated) examined faeces of goats of different age classes on a research farm in Neuva Ecija for a six month period from the dry to the rainy season. The dominant parasites were *Haemonchus* and *Trichostrongylus* with a distinct seasonal increase. Although limited in nature this trend towards longer term studies is encouraging. As part of these studies counts of parasitic and non-parasitic larva on pasture were also undertaken (Anon, 1998).

A more detailed study of the seasonal pattern of helminth infection of goats in La Union was reported by Barcelo and Camalig (1997). Although not a full report, the study extended over two complete years and, with the exception of April in the first year when *Trichostrongylus* made up more than 50% of the larvae which emerged from culture, the dominant species was *Haemonchus* which for all other months comprised more than 90% of the cultured larvae. This was reflected in the numbers of infective larvae in soil and herbage although only *Haemonchus* and *Trichuris* larvae were recovered (time of sampling not given).

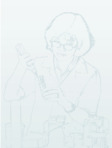
Marbella (1991) undertook some epidemiological studies which led to the establishment of a goat herd health program in the Bicol region of southern Luzon. The unit of measurement of a range of gastrointestinal parasites and *Dictyocaulus* was '*prevalent*'; simple flotation and sedimentation techniques being used to detect the presence and absence of nematode eggs and larvae, and trematode eggs. Twelve farms with at least 10 does were used across the region, representing three major climatic types. Four commercial dewormers (three BZs and tetramisole) were also tested for efficacy. Identification of nematode genera was made on the basis of egg morphology. Overall, there were no major differences between wet and dry seasons, between climate type and between worm genera in the two samples collected — one in the wet and one in the dry.

The experiments which led to the herd health program involved sampling of does 1–2 weeks, 1 month, 3 months and 6 months after treatment with a dewormer which was given to three different groups of does at monthly, 3-monthly or 6-monthly intervals in each of the three regions.

The results show albendazole used in Masbate was very poorly effective (measured by change in prevalence). Tetramisole in all regions was poorly effective. Confirmation of our interpretation of the experimental protocol with the study author is required. Goats drenched monthly gained most weight over a 6-month period. This is possibly the first circumstantial evidence of anthelmintic resistance in the Philippines and could become a focus for a future survey of resistance.

Impact of helminths on production

Kingscote (1968) estimated the impact of parasites in general on Philippine sheep and goats as 10% of the value of production and included 'unthriftiness, death and predisposition to other diseases' as the sources of that loss. Justification for this figure is not provided because none was available: economic estimates of the wide and long-term effects of helminth infections are difficult to obtain experimentally, especially under field conditions. However, comparison between parasitised and non-parasitised goats in two barangays in southern Luzon (Que et al., 1995) showed that they differed



in growth by several kilos over a period of 8 months representing a good return on investment from a single dose of anthelmintic. Such studies are often difficult to interpret (see Chapter 1) when the experimental and control (treated) animals are, as in this case, grazed separately on different farms. Nevertheless the result does point to a substantial impact of helminths on growing goats. A series of papers by Howlader et al. (1997a, 1997b, 1997c) describes the pathological, parasitological and production changes in young goats of different ages infected artificially with varying doses of *H. contortus*. Kids born of infected mothers had their growth affected by infection (about 70g/day over 5 weeks after birth compared with around 20g/day for the kids of uninfected dams) but this impact was not dependent on infective dose. Growing goats gained less weight than uninfected counterparts: about 4g/day in infected kids compared with about 19g/day in uninfected kids. Once again, the effect was not dependent of the level of infection given to the experimentally infected animals. In the same growing goats there was no effect of infection on circulating leukocyte numbers and a moderate effect on erythrocyte numbers. Related studies (Howlader et al., 1996a, 1996b) showed similar effects on growth and blood parameters as the result of *Haemonchus* infection. It is difficult to relate these results to field conditions but once again they point to a significant impact on the performance of young and old goats.

Anthelmintic plants and biological control

Medicinal plants as anthelmintics

Medicinal plants have attracted attention from various groups in the Philippines whose interests have been on, but not restricted to, their anthelmintic effects. Loculan and Mateo (1986) surveyed 22 barangays in Lipa City and identified the plants being used as medicines and their intended effect. The plants with purported anthelmintic effect for ruminants are shown in Table 8.1. Other publications by Mateo (1986 and 1996) contain similar information.

A more comprehensive list of anthelmintics for large animals (it is not stated which are for ruminants) was published by Mateo (1987) and is summarised in Table 8.2.

Claud and Mateo (1988) conducted interviews in Batangas province and found that in 100 responses from 18 barangays, 89% of respondents were using herbal medicine and 'obtained satisfactory results'. Nineteen medicinal plants were identified. These were prepared in a variety of ways and some were used to treat parasitism. Fernandez (1991) screened some local plants for their efficacy against *Haemonchus contortus* and found that eight were effective. Further studies on two of these have been published in abstract form: a 'crude extract' of *Mimosa pudica* was 93.6% effective against *Haemonchus* larvae *in vitro* and was 'as good as a commercial dewormer' in vivo in a dose response trial in terms of worm egg count reduction and reduction

Table 8.1 Plants with anthelmintic effect for ruminants

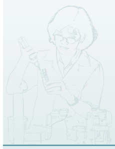
Common Name	Scientific Name	Parts Used	Method of Preparation and Administration	Approximate Dosage	Specific Ailments	Animals Treated
Niyog	*Cocos nucifera*	Oil/milk	Mixed with feeds	350ml, 2 x day for 2 days	Dewormer	Cattle
Makabuhay	*Tinosphora rumphii*	Vines and body of plants	Fresh plant, force fed	1–2 ft of vine, 2x day for 4 days	Dewormer	Cattle, carabao

Source: Loculan and Mateo, 1986

Table 8.2 Medicinal plants with anthelmintic effect

Common Ailment	Medicinal Plants	Direction for Use
Specific for tapeworms	Pakwan (*Citrullus vulgaris*)	Seeds fed *ad lib*
Common intestinal worms for large animals	Atis (*Anona squamosa*)	Raw leaves fed *ad lib*
	Makabuhay (*Tinosphora rumphii*)	One basket of fresh leaves orally
	Kamonsil or Kamanchili (*Pithecocobium duice*) (sic)	Raw leaves fed *ad lib*
	Kakawate (*Gliricidia sepium*)	Raw seeds fed *ad lib*
	Aludig (*Streblus asper*)	Boiled stem juice given as drench once a day
	Langka (*Artocarpus heterophilus*) (sic)	Decoction of leaves given orally Repeated after 1 week
Specific for liver fluke	Bunga (*Areca catechu*)	One whole nut in seven parts water per 50 kg body weight

Source: (Mateo, 1987)



in worm number post mortem (Faelnar, 1997). *Tinosphora rumphii* 'stem crude extract' was 85.6% effective *in vitro* and at a non-toxic dose level *in vivo* half of the experimental animals had their 'worm burdens significantly reduced' (Fernandez, 1995).

Salazar et al. (1986) report (in abstract form) 72 plant species used for livestock and poultry health but give no details of which plants were used for internal parasites.

Jovellanos (1997) dramatically demonstrated the efficacy of two out of three plant extracts in the treatment of gastrointestinal nematodes in cattle. The plant products were atis (custard apple: *Anona squamosa*), papaya (*Carica papaya*) and pineapple (*Ananas comosus*). The studies were conducted at Santa Barbara, Pangasinan. Forty cattle were selected with FECs over 400 epg. Albendazole was used as a control in one group of 10 cattle and the remainder were divided into three groups of 10 given a single treatment with dried powdered leaves of the three plants with molasses as a 'lick'. *Cooperia* and *Haemonchus* were the dominant species. The efficacies of the treatments were: albendazole 100%, *Ananas* 98.46%, *Anona* 95.53% and *Carica* 'no effect'. Efficacy was based on FEC. The cost of treatment with the plant extract was estimated to be the cost of molasses alone at P 9.5 per animal compared with P 37.33 per animal for albendazole treatment. Cost of collection and preparation of the extracts were not reported.

Nutritional supplementation

There have been few published studies which either directly or indirectly implicate nutritional status as having an impact on parasite levels in either sheep or goats under grazing conditions. Supplementation with concentrates fed as a replacement for 'grasses' in confined goats resulted in decreased FEC in 1-year-old native and Anglo-Nubian goats over a 6-month period while harbouring a nematode infection dominated by *Haemonchus* and *Trichostrongylus* (Barcelo and Camalig 1998).

Sevilla (1990a) reviewed approaches to feeding small ruminants and mentioned a range of supplementation strategies appropriate for high-fibre diets in the tropics. Sevilla rejects what he describes as 'traditional feeding standards' as a suitable approach to feeding small ruminants in the tropics where there are limited options for feed resources which can be highly variable. Studies such as that of Magay and Perez (1984) may fall into the 'traditional' category as they fed young native goats highly prepared diets, based on leguminous leaves and starch grains. Such feeds are not always available and the prescriptive recommendations from that study may apply only in certain circumstances and, we would argue, circumstances that are rarely found in real farming situations.

Boloron and Magadan (1982) made detailed recommendations for the improved nutrition of cattle and dairy goats using pasture and concentrates under backyard conditions. Castillo (1982) discussed fibrous agricultural residues and noted that winged bean residues had lower digestibility in goats (49%) than in cattle and carabao (63%).

High protein supplements such as *Azolla* (Sevilla et al., 1987) have been investigated and have been extensively reviewed (Sevilla, 1990b). In the case of *Azolla* the growth of animals with its leaf as a dietary component grew less well than those with comparable amounts of ipil-ipil (*Leucaena*) leaf.

A large number of supplementation trials have been undertaken using cassava leaves (*Manihot esculenta*) (Baquirquir and Coruña, 1989), ipil ipil (*Leucaena leucocephala*) (Faylon and Momongan, 1985; Aliling, 1980; Abilay et al., 1981; Patricio et al., 1990; Rasjid and Perez, 1982) and kakawate (*Gliricidia sepium*) (Siasico et al., 1990; Siasico and Coruña, 1990). If stated, all these trials cited were conducted in pens. In some cases the animals were dewormed before the start of the trial but in most cases no mention is made of parasites or treatment for parasite control. It is possible therefore that the effect of parasites may have influenced the outcome of these studies.

Other supplements that have been tried include biogas sludge (Cruz, 1981), urea-molasses (Gerona et al., 1984), urea-supplemented wheat straw (Ordoveza and Johnson, 1983), rice straw with urea-molasses (Lapuz, 1982; Trung et al., 1990), dried poultry manure (Bazar and Intong, 1991), water hyacinth meal (Villanueva and Soriano, 1988) and vegetable waste (Anon, 1982).

Lanting and Sevilla (1998) found that inclusion of the tanniniferous legume *Flemingia* improved growth and intake of sheep fed a *Stylosanthes* based diet. They did not investigate the impact on parasites.

There have been some grazing trials using supplementation. Gerona et al. (1984) compared the production of supplemented and non-supplemented castrated goats grazing at 20 head/ha. The supplement was molasses/urea at two ratios, 20:1 and 10:1. Both supplemented groups gained more weight than the control group but the conclusion, similar to studies with sheep under coconuts (Faylon et al., 1991), was that goats need additional supplementation if pastures are not to be degraded at these stocking rates.

Goat kids in the feed trough can defecate on feed, increasing chances of parasitism. Goats from Balungao, Philippines. (G.M. Hood)

Alvarez et al. (1991) showed that goats which were supplemented with ipil-ipil but grazing in a rotational system in Pampanga, Luzon, have a ‘slight advantage’ over goats given the same level of supplement but grazed continuously. Pastures were also in better condition under the rotational system.

A general pattern that may be emerging is that for agronomic reasons it is essential to supplement sheep and goats if they are to graze continuously in coconut plantations at the stocking levels used in these studies.

One future research application may be to investigate the timing and nature of nutrient supplementation to optimise animal production, pasture conservation and parasite control.

Genetic variation in production and resistance to disease

There are no published studies on genetic differences in resistance to helminths between sheep and goats, within breeds of sheep and goats and only one account of breed differences among goats but none for sheep. However it is likely that parasites have been present in all the studies described in this section and that they have contributed to some extent to the observed difference sin production. The extent of their effect is not known.

Genetic differences between sheep and goats

Interpretations of comparisons of any trait: disease, production and anatomical, between sheep and goat are notoriously difficult unless they are constrained to known diets and behaviours. Palo et al. (1995) elegantly demonstrated the comparative feed selectivity of sheep and goats using oesophageal fistulae. Goats were shown to be more selective and eat the forages of higher nutritive value. This may be important for intake of parasitic larvae that tend to be consumed from the low parts of more erect species rather than on the leaves of trailing or erect broadleaf plants.

Bato and Sevilla (1988) used oesophageal fistulae to investigate diet selection of goats on improved and unimproved pastures.

Production differences between and within breeds

Matias et al. (1997) list seven exotic and three local breeds of goats and 10 exotic and three local breeds of sheep (Table 8.3). The numbers of each breed have not been accurately estimated.

A number of studies have sought to compare native goats with varying levels of cross with Anglo-Nubians. These are summarised in Table 8.4.

There are several notable features. In none of the studies are sires identified or accounted for in the analysis of differences between 'breeds' and no attempt is made to account for heterosis in evaluation of the crosses. One intensively analysed study was by Karnuah et al. (1992) on 76 does of five genotypes which varied in their proportions of the two breeds, from 100% Anglo-Nubian to 50% Anglo Nubian and 50% Native. They concluded that crossbred animals were more productive across a range of parameters.

Aurelio et al. (1987) and Bautista and Vaughan (1983) studied crosses of Anglo-Nubian and Native (473 does) and Anglo-Nubian and Saanen crosses with Natives (number unknown) with mixed results which were heavily influenced by weather.

A substantial comparative study of milk production and kidding performance at two farms in Mindanao could not distinguish breed effects from management effects (Amonruji and Rigor, 1988) although on reading the methodology a comparison between Anglo-Nubian and Anglo-Nubian crosses should have been possible in at least one location. The data to support their conclusion that 'there were no differences in milk production on the basis of … breed' are not presented.

Table 8.3 Exotic and local breeds of goats and sheep in the Philippines

Goats		Sheep	
Exotic	Local	Exotic	Local
1. Anglo-Nubian	1. Cebu	1. Barbados Black Belly	1. Bukidnon
2. French Alpine	2. Dadiangas	2. Polled Dorset	2. Leyte
3. Toggenburg	3. Muñoz	3. Border Leicester	3. Bicol
4. Jumna Pari		4. Katahdin	
5. Boer		5. Rambouillet	
6. La Mancha		6. Merino	
7. Saanen		7. St. Croix	
		8. Suffolk	
		9. Wiltshire Horn	
		10. Southdown	

Source: Matias et al., 1997

Castillo (1983) and Villar et al. (1984) were able to analyse data from the Philippine Rural Life Centre from 1979 to 1981 and 1980 to 1982 respectively in which four breeds were represented. No breed or cross emerged with a clear productive advantage. Parawan et al. (1987) was able to study under village conditions the performance of Native and Anglo-Nubian crosses in a rainfed coconut system in Mindanao. The conclusion was that Native goats performed better when 3–5 were present in the production 'module' but not as well at lower numbers. It would be interesting to re-analyse that data on a 'weight of kid weaned per doe joined' basis.

Kharel and Lambio (1990) published an exhaustive study on morphological differences which showed that Native goats raised in villages are a different size and shape to Anglo-Nubian goats raised on research stations.

The Dadiangas goat breed (a hybrid of Native and several introduced breeds) found mostly in Mindanao has been advocated as a good 'prospect' (Anon, 1990, 1992; Villar, 1995). No comparative trials of their productivity have been published.

Future use of blood packed cell volume as a measure of anaemia resulting from Haemonchus infection, the baseline haematological study by Ducusin et al. (1995) in sheep grazing in coconut plantations may be useful.

Table 8.4 Studies which draw conclusions on production differences among 'Native','Anglo-Nubian' and 'Grades' Native and Anglo-Nubian

Author (Date)	Genotypes Compared[a]	No. of Animals per Breed	No. Sires per Breed	Traits Measured	Type of Statistical Analysis	Notes
Amonruji and Rigor (1988)	100% Anglo-Nubian 87.5% Anglo-Nubian 50% Anglo-Nubian	Varied with nature of observation	No information given	Mean age at first breeding and first kidding, milk production per day, lactation length and kidding interval and service pd.	Descriptive analysis, simple correlation coefficients, pooled correlations, ANOVA-CRD, split-plot analysis, t-test, multiple regression analysis	
Aurelio and Natural (1988)	100 % Anglo-Nubian 75% Anglo-Nubian 50% Anglo-Nubian	282 127 64	No information given	Birthweights, weaning weights, litter size, kidding intervals, occurrence of multiple simple births	T-test, ANOVA-CRD, multiple linear correlation analysis, linear regression analysis	
Maglunsod and Natural (1988)	100% Anglo-Nubian 75% Anglo-Nubian 50% Anglo-Nubian	230 kids (total)	5 AN (for all kids)	Birthweight, subsequent body weights, heritability of birthweights, correlation coefficient b/w birthweight and subsequent 6-, 8- and 12-month body weights	General linear model – CRD, paternal half-sib correlation, product moment correlation	Kids were produced from mating of pure Anglo-Nubian buck x Native and 50% Anglo-Nubian does.
Bautista and Vaughan (1983)	100% Anglo-Nubian Kids Anglo-Nubian x Native Kids Anglo-Nubian Native Goatlings Anglo-Nubian x Native Does Anglo-Nubian x Saanen x Native Goatlings	No information given	No information given	Growth rates, inter-kidding intervals	No information given	The proportion of each breed is not indicated in the publication

continued over

Table 8.4 continued

Author (Date)	Genotypes Compared[a]	No. of Animals per Breed	No. Sires per Breed	Traits Measured	Type of Statistical Analysis	Notes
Parawan et al. (1987)	50% Anglo-Nubian 25% Anglo-Nubian 100% Native	No information given	No information given	Kidding interval, occurrence of multiple births, age at first breeding, weight of females at 6 months, ADG values, kidding per year, number of kids per year	No information given	
Villar et al. (1984)	100% Anglo-Nubian 50% Anglo-Nubian 100% Native	4 4 4 (4 replicates per treatment group)	No information given	Age at first breeding, kidding interval, number of days open, kidding rate, kidding percent, post-partum oestrus, birthweight, incidence of twinning, litter size	ANOVA-CRD, Duncan's Multiple Range Test, descriptive analysis	
Karnuah et al. (1992)	100% Anglo-Nubian 93.75% Anglo-Nubian 87.5% Anglo-Nubian 75% Anglo-Nubian 50% Anglo-Nubian	31–76 (varied w/ the nature of observation	No information given	Oestrus manifestation, age and weight at first oestrus, age and weight at first breeding, conception rate, gestation period, kidding interval, incidence of multiple birth and post-partum oestrus	General Linear Model (GLM) of the canned package Statistical Analysis System (SAS), Least Squares Analysis	
Reyes and Abilay (1981)	100% Anglo-Nubian 100% Native	10 6	No information given	Oestrus cycle length, oestrus duration, services per conception, gestation period, kidding rate, birth and weaning weight, growth rates, daily milk yield, mortality rate at birth	No information given	
Yokota et al. (1991)	100% Anglo-Nubian 75% Anglo-Nubian	66 (total)	8*	Birthweight, growth rates	No information given	*8 bucks were kept on the farm but their use to generate the experimental animals is not stated

a The proportion of 'exotic' breed is indicated. Unless another breed is given then remaining proportion is 'native'.

Arboleda (1986, 1987) discusses the animal genetic resources available for livestock production in the Philippines. Although not entirely complimentary about the livestock of smallholders, describing them as '*nondescript mongrels with low performance potential*', Arboleda makes some telling points about the priorities of smallholders. He argues that smallholders have been using smaller carabao for breeding while using their larger animals for draught power, leading to a continual decrease in the size of the local animals. This raises the possibility that some similar effects may exist for sheep and goat populations with larger males and females being sold off for slaughter. Although enthusiastic about the upgrading of local stocks he has a cautionary message for poultry,

> *'Today, many small farmers still prefer to raise chickens based on their ability to survive and reproduce under minimal care and management'.*

Again, this may also be true for sheep and goat populations. In the 1986 paper Arboleda tabulated the comparative performance of four exotic goat breeds and the Philippine Native from several studies.

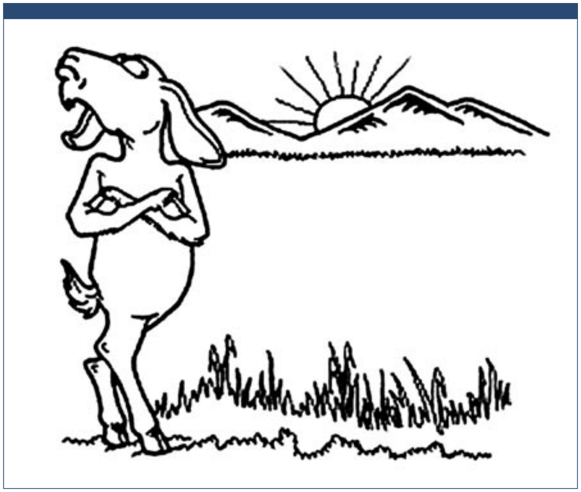
Like many authors, Arboleda uses the term 'Native' for sheep and goat populations which have been present in the Philippines for many years and which cannot be assigned to any distinct or recently imported breed. Because of the island nature of the Philippines, lack of a sophisticated breeding and marketing system for small ruminants and the occasional infusion of exotic genes, it is likely that populations of 'native' goat will be genetically heterogeneous. Lambio et al. (1992) used polymorphism of the enzymes transferrin and alkaline phosphatase in a population of 288 adult female indigenous goats from eight provinces (they were monomorphic for albumin, esterase and L2 macroglubulin) to construct a dendrogram based on genetic distance among the samples. Only the sample from Ilocos Norte differed genetically from the others which could not be distinguished from each other. Up to 20 polymorphic enzymes have been required to produce accurate dendrograms in other published studies. No studies of genetic distance have been conducted in sheep and no studies on sheep or goats have been reported using DNA polymorphisms. [Genetic polymorphism among goat and buffalo population in South and Southeast Asia has been the subject of two ACIAR projects. A sample of goats from Mindanao was included in one of these projects.]

Bondoc (1993) stated that it is important to conserve native breeds of livestock rather than to continue importing breeds, while ignoring improvement of native breeds that have special attributes such as greater resistance to disease. He stated that native breeds are:

- more adapted to the local environment
- more tolerant of poor nutrition and harsh environments
- a vital resource for scientific research and a cultural resource
- reservoirs for traits which, if lost, may never be recovered

Among the traits that could be used to identify the important genetic resources are 'alternate traits such as disease and parasite resistance'.

The technology to make sophisticated estimations of breeding values (EBVs) for livestock is available in the Philippines and has been applied to some sets of data from local livestock populations (Bondoc, 1995). The application of this 'Best Linear Unbiased Prediction' (BLUP) technology can only be made where accurate and, if possible, extensive pedigrees crossing several generations of large populations of animals are available. Equally critical is the need for performance data which can be manipulated in such a way that it can all be assessed as if it had been generated at a single time. This 'contemporary comparison' and use of complex pedigrees can be made possible using computers which today are commonplace. At the heart of the use of BLUP (or any breeding program) is the accuracy of the pedigrees, the quality of the performance data and the ability of livestock breeders to make decisions based on the numbers produced. In the study by Bondoc (1995) 324 weaning weights from the goat farm of UPLB covering 9 years, four sire breeds (10 sires), four dam breeds, two sexes, three types of birth and 87 dams were analysed. This analysis led to the conclusion that weaning weights were decreasing with time but not due to genetic effects. The study would also have produced estimated breeding values for weaning weight. If '*increased weaning weight*', '*decreased weaning weight*' or '*no change in weaning weight*' was part of a breeding objective for this flock then these EBVs would be valuable in making the correct selection decisions. The effect of this on liveweights at later ages could not be predicted.



Many tools such as this cartoon warning against grazing infected pastures can be used to make farmers and extension workers aware of technical innovations. (K.C. Patawaran)

A tantalising abstract from Maglunsod and Natural (1988) addressed this question of correlations among bodyweights of Anglo-Nubian and 'grade' kids at birth and 6, 8 and 12 months of age. The abstract refers to some 'breed' differences but the correlations are not given. In a related study, Aurelio and Natural (1988) report that purebred Anglo-Nubian does had shorter kidding intervals but 50% Anglo-Nubian 50% Native does had larger litter sizes.

Maglunsod (1987) estimated heritabilities of birth weight of 230 kids from 100%, 75% and 50% Anglo-Nubian:Native cross does which had been joined to five Anglo-Nubian bucks. The standard errors of the heritabilities ranged from 0.66 to 2.04. On this basis it was stated "birth weight is heritable, hence selection for the trait can help bring about improvement of productivity of goats". This bold statement contrasts with the more perceptive conclusion made that "overall [despite increased birth weight of kids from Anglo-Nubian does] improvement in meat productivity using 50% Anglo-Nubian grades is the most promising compared to the 75% and purebreeds in terms of overall performance". This conclusion is made in part because of the increased litter size of 2.09 seen in 50% crosses compared with 1.64 and 1.58 in 75% and purebreds respectively and equivalent kidding intervals of 326, 293 and 240 days.

A smaller study on 20 does joined to either a Saanen or Anglo-Nubian buck sought to measure breed effects but in fact was measuring sire differences (Udin, 1985). In that study all kids were wormed at 1 month of age.

A study of goats which were mostly imported (i.e. not born in the Philippines) was conducted by Beltran (1981). A total of five Saanen, eight La Mancha, nine Toggenbergs, six Anglo-Nubian and 13 locally-born 'crossbreds' were compared for milk quality and quantity. These genotypes were spread unequally and were unbalanced across three farms and little can be concluded about any breed effect.

Aurelio (1987) analysed a substantial set of data from 5 years of records from does at PGSC (Tables 8.5, 8.6 and 8.7). Anglo-Nubian (100%) and 75% and 50% crosses with Native animals were present. His results partly support those of Maglunsod (1987).

Table 8.5 No. of does of Anglo-Nubian/Native crosses at four experimental locations (Aurelio, 1987)

Location	AN	75%	50%
Pampanga	327	102	31
Bukidnon	36	36	
South Leyte	23		29
Zamboanga del Sur		42	50

Table 8.6 Litter sizes of does of Anglo-Nubian/Native crosses at four experimental locations (Aurelio, 1987)

Location	AN	75%	50%
Pampanga	1.41 ± 0.53	1.40 ± 0.54	1.59 ± 0.73
Bukidnon	1.70 ± 0.65	1.90 ± 0.55	
South Leyte	1.44 ± 0.63		1.53 ± 0.54
Zamboanga del Sur		1.15 ± 0.37	1.26 ± 0.44

Table 8.7 Kidding intervals of does of Anglo-Nubian/Native crosses at three experimental locations (Aurelio, 1987)

Location	AN	75%	50%
Pampanga	282 ± 55	320 ± 120	282 ± 84
Bukidnon	269 ± 62	347 ± 94	
South Leyte	233 ± 70		321 ± 39

The evidence for a systematic effect of breed on kidding interval is not so strong in this study and, although based on small numbers, the trend from South Leyte on a total of 23 does suggests that Anglo-Nubians have shorter kidding intervals.

Effect of breed on resistance to parasites

After a trickle *Haemonchus contortus* infection Native goats (aged 3–4 months) had a lower FEC, lower worm burden and higher PCV than Anglo-Nubian grade goats (Barcelo and Ancheta, unpublished data). This is the only evidence so far brought to the attention of the project which indicates a difference in resistance between any two 'breeds' in the Philippines. The group of Native and Anglo-Nubian does which produced the progeny used in that trial were joined in an uncontrolled way (i.e. pooled mating) to between three and five bucks of each breed.

Average faecal egg counts over the whole experimental period are given in Table 8.8.

Table 8.8 FEC (in eggs per gram of faeces) over the experimental period of 12 weeks

Breed	Mean	S.D.
Anglo-Nubian	108.50	47.98
Native	52.75	26.98

Source: Barcelo and Ancheta, unpublished data.

This is not a complete representation of the result. At week 9 there was a five-fold difference in FEC with Anglo-Nubian the higher of the two breeds. A trickle infection of *Haemonchus contortus* was given three times a week for 3 weeks (a total of about 7000 larvae) and there was little difference in the course of FEC trajectory until about week 8 of infection when the FEC of the Anglo-Nubian grades 'took off' to a five-fold difference. At week 12 some kids were slaughtered; the worm counts are given in Table 8.9.

Table 8.9 Worm counts at the end of the experimental period of 12 weeks

Breed	Mean	S.D.
Anglo-Nubian	100.50	58.63
Native	30.00	20.00

Source: Barcelo and Ancheta, unpublished data.

Caudilla (1983) measured FECs from August to February in 'confined' goats at the Dairy Training Research Institute at Los Banos and presented these results as comparisons between the three breeds represented in the nine animals in the study (three per breed). There were no significant differences between the average FECs of the Toggenburg, Alpine and Anglo-Nubian animals.

Use of anthelmintics and anthelmintic resistance

Johns (1983) describes albendazole as a useful broad spectrum anthelmintic. Campbell (1987) describes ivermectin as an even more useful anthelmintic and there is a study of ivermectin in sheep under coconuts (Barcelona, 1994) which shows that it works well against gastrointestinal nematodes.

Dajime (1982) undertook a dose response study of albendazole (Valbazen) in 48 male and female goats of mixed ages in four groups treated with 2.5 to 10 mg/kg and exposed to a natural infection. There was a 75% reduction in FEC in the group given the lowest dose and 100% in the others. From larval cultures *Strongyloides* was the most common genera, with counts as follows: (*Strongyloides* 2694, *Cooperia* 211, *Haemonchus* 115, *Oesophagostomum* 114, *Trichostrongylus* 53 and *Ostertagia* 27). The author concludes that 10mg/kg is required for complete clearance of *Strongyloides* (measured after 5 days).

Kimwell (1988) tested a single treatment with closantel (Parasitec Plus®) in 16 female sheep aged 3 years that were infected with *H. contortus*. Information on dose rate was not provided. Based on FEC it was completely effective.

Cabrera (1992) gave albendazole at the MRDR to does at the 10th and 20th days of pregnancy. One out of the eight does gave birth to a kid with forelimb abnormalities but cause could not be definitely attributed to the drug treatment as there was no comparable group of untreated does.

Benzimidazole resistance in a field population of *Haemonchus contortus* from sheep has been confirmed in Mindanao (Van Aken et al., 1994). More recently, methods have been developed for a larval development assay (LDA) to be used on farms in such circumstances (Venturina et al., 2002). Using the LDA the efficacy of BZ anthelmintics in the Philippines was estimated by an *in vitro* larval development assay using samples from over 200 farms representing areas of the country with high goat and sheep populations (Ancheta et al., 2004) The range of BZ efficacy estimated from the LDA results was 0–100% with mean efficacy of 82% and 64% for goats and sheep respectively. There were significant associations between efficacy and parameters measured to characterise the sampled farms: size of animal management group, FEC of sample, recent importation of stock and no access to common gazing were all correlated with decreased efficacy. Likewise, low efficacy was associated with reported frequency and number of years that BZ drenches had been used.

Measurement of production in grazing environments

As a guide to the stocking rates that might be used for different grazing systems in coconut plantations, Faylon et al. (1991) recommended a rate of five sheep/ha on the basis of the productivity per ewe and the overgrazing that took place at 10 head/ha. In that trial no impact on coconut yield was detected but it should be noted that no ungrazed areas were used for comparison. Soil structure and organic matter also improved at both stocking rates.

Sabutan and King (1993) investigated interactions between sheep and goat growth rates, forage types and stocking rates in a grazing trial in Kabacan, Cotobato over 5 months in 1989 and 1990. Of interest to this project is that the stocking rates ranged from 40 to 80 goats per ha. Elephant grass yielded more and the goats lost more weight than sheep during the trial, possibly due to declining pasture availability. *Leucaena* was available as browse to all animals.

Posas (1981) compared goat production and impact of soil, pasture and coconut production at stocking rates of 20, 40 and 60 goats [2, 4 and 6 Animal Units (AU)] per ha. Rotational grazing was practised and rotation was initiated by visual inspection of the pasture. Confined animals grew less well than grazing animals in terms of gain/ha.year. In discussing these results Posas says "*liveweight, however, is not very important economically since goats are mostly sold in the market per head*". This infers that mortality is a more important production parameter and in that study the overall mortality was around 27% in both confined and grazing animals. Neither parasites nor parasite control are mentioned in the study but it should be noted that the 'confined' animals were released for 1 hour per day for exercise when they could have been exposed to high levels of parasitism.

On a steeply sloping site (32% gradient) Mandal (1988) showed that goats caused significantly heavier run off and erosion when grazing density reached 3 AU/ha. year under coconuts.

Increased supply of goat and sheep meat provides opportunities for employment. (G.D. Gray)

A study on sheep grazing native vegetation under mangoes (Bejo, 1992) showed that 8–16 head/ha was the optimum stocking rate. The introduction to the thesis states "sheep are the most ideal ruminant to integrate with mango because of its less destructive feeding behaviour".

Under village conditions Parawan et al. (1986) measured the productivity of native sheep. Although the aim of their trial was to look at the growth of castrates vs. non-castrates they demonstrated that such trials are possible. The trial was based at the ASEAN Goat and Sheep Centre.

Domingo et al. (1991) measured the performance of 201 grazing ewes and pasture composition during a 12-month period finding that there was weight loss in the rainy season and weight gain in the dry. No supplements are mentioned in the abstract, nor any parasites, but lamb mortality was slightly higher in the rainy season (9.5% compared with 8.7%). Lambing interval of ewes which lambed in the wet was 22 days longer than for those which lambed in the dry.

Ramos (1981) compared tethered, confined and 'loosened' goats and found that loosened goats had the highest growth rates and provided the highest net economic return.

Finally, a very general paper by Guss (1983) argued that grazing goats in the tropics may not be successful and it may be necessary to resort to a totally confined system on raised slatted floors. He concludes

> *"In the Philippines … this simple inexpensive housing system has helped control internal parasitism and has resulted in much better milk production"*

Unless a sustainable system for the control of helminth parasites can be developed, Guss may yet prove to be correct.

Conclusions

These conclusions are based on an incomplete search of the Philippine literature. However we consider it unlikely that there have been any major published studies that the authors have not yet encountered in the sources investigated or as citations in individual articles.

- The range of helminth parasites in sheep and goats in the Philippines has been documented.
- There are worm control recommendations in place but these have not been tested against possible alternatives.
- There is little information on the economic impact of any helminth parasite of sheep and goats under farming conditions.
- There is no information available on the level and frequency of use of anthelmintics or the extent of anthelmintic resistance.
- Several studies indicate the potential for the use of plant extracts as anthelmintics.
- Although such an effect has not been described in the Philippines there is a wide range of nutritional options available for improving resistance to parasites. Ipil-ipil (Leucaena leucocephala) is the most widely tested proteinaceous supplement and there is ongoing research on a tanniniferous legume.
- There is little genetic information available to suggest that any one breed or genotype has superior resistance to endoparasites: the sole unpublished study suggests that Native goats are more resistant than Anglo-Nubian.

- There have been no detailed comparisons of any sheep or goat breeds for productivity under grazing or semi-confined conditions.
- There have been studies on grazing sheep and goats that can be used as guidelines for experimental design.

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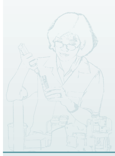

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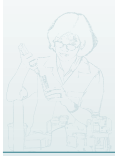

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9. Worm control for small ruminants in Indonesia

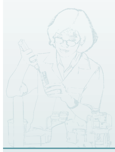
Subandriyo, T. Sartika, Suhardono and G.D. Gray

Introduction

In common with several Asian countries with large Muslim populations, small ruminants are important for farmers with small areas of land, or who are landless and can access only the forest, cropping or plantation land of others. Of the seven million sheep and 12 million goats in Indonesia (FAOSTAT 2002, available at http://apps.fao.org/default.htm) 53% of the sheep and 90% of the goats are on the island of Java with sheep being more common throughout the wetter areas of the country. Sheep and goats are raised for a variety of purposes including meat, milk and manure production, cultural and religious functions, and investment.

Indonesian sheep (Sumatra thin tail, Javanese thin and fat tail) and goat breeds (Kacang and Etawah Grade) are well adapted to the extreme tropical environment, temperature fluctuations, high humidity, low quality forages and high parasite infestation. The production system generally consists of confinement at night and grazing during the day. One of the major constraints of this production system is endoparasitic infection (Handayani and Gatenby 1988). Helminth diseases regarded as economically important for small ruminants in Indonesia are haemonchosis and fascioliasis (Soetedjo and Nari 1980, Ronohardjo et al. 1985, Ronohardjo and Wilson 1987). Ronohardjo et al. (1985) estimated the annual loss caused by fasciolosis and haemonchosis in large and small ruminants at 32 and 7 million USD, respectively. Thus, several institutions and large projects have devoted resources to basic and applied research in this area.

The focus of this work has been in Java but one large project — the Small Ruminant Coordinated Research Project (SR-CRSP) — invested heavily in addressing the major constraints to small ruminant production, including internal parasitism, throughout Indonesia. The SR-CRSP was a USAID funded collaborative research program carried out between the Research Institute for Animal Production (RIAP) of the Indonesian Agency for Agricultural Research and Development and US based institutions: the universities of California–Davis, North Carolina State and Missouri–Columbia, and Winrock International. The many working papers generated by this project can be found in the ILRI–Philippines library or in the Sustainable Parasite Control in Small Ruminants bibliographic database, available on CD or via the internet (see Preface for details).



9. Worm control for small ruminants in Indonesia

This chapter reviews the Indonesian literature on endoparasite control for small ruminants. Literature reported generally includes journal articles, papers from meetings and conferences, undergraduate, master and PhD dissertations, and abstracts and research reports published after 1980. Some relevant earlier articles have also been included.

Endoparasites of small ruminants in Indonesia

Building on the summary of Carmichael (1993), Table 9.1 lists the most important endoparasites of goats and sheep in Indonesia.

Several other endoparasites, of lesser economic importance, have also been described. They include the genera: *Bunostomum, Chabertia, Cooperia, Dicrocelium, Gongylonema, Moniezia, Ostertagia, Paramphistomum, Schistosoma, Strongyloides*, and *Trichuris* (Arifin et al. 1996, Atomowisastro and Kusumamihardja 1989, Beriajaya 1984, Carmichael et al. 1992, Dorny et al. 1996, Effendy and Sumiaty 1999, Firmansyah 1993, Mirza et al. 1996, Ridwan et al. 1996, Soetedjo and Nari 1980).

For studies of the biology and pathology of *Haemonchus contortus* and *Fasciola gigantica* in small ruminants in Indonesia, refer to the Sustainable Parasite Control in Small Ruminants bibliographic database (see Preface for details).

Worm control options

Grazing management

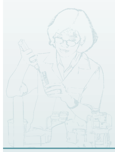
Endoparasitic infection is widespread and a major constraint to small ruminant production where continuous grazing is practised, particularly grazing associated with tree cropping (Carmichael 1990). The findings of Carmichael et al. (1992), from sheep grazing rubber plantations, suggest helminthiasis is a perennial, not a seasonal, problem in Indonesia. It is expected that reducing the time animals spend in a pasture by increasing the frequency of rotation or lengthening the rotational cycle can depress the population of parasites on pasture, and thus increase animal productivity.

Carmichael et al. (1992) showed that sheep grazing pasture under rubber plantations, 12–14 weeks after contamination with worms, had dramatically reduced faecal egg counts compared with sheep allowed to graze the pasture within 4–6 and 8–10 weeks. The total worm burdens of sheep allowed to graze 8–10 and 12–14 weeks after pasture contamination were reduced by 83% and 96% respectively, compared with the 4–6 weeks group. This is consistent with control measures based on rapid rotational grazing (Barger et al. 1994) which depends on relatively short survival of larvae on pasture in the tropics.

Similar results were reported by Batubara et al. (1995, 1996) in their studies of infectivity of pastures contaminated with *H. contortus*. The lowest mean number of abomasal worms was found in animals grazing pastures that had not been grazed for 12 weeks (average total worm count 29 worms) compared with

Table 9.1 The most important endoparasites of goats and sheep in Indonesia

Endoparasite	References	Comments
Nematodes		
Haemonchus contortus	Atomowisastro and Kusumamihardja 1989, Beriajaya 1984, Beriajaya 1986, Carmichael et al. 1992, Chotiah 1983, Darmono 1982, Dorny et al. 1996, Effendy and Sumiaty 1999, Mirza et al. 1996, Nasution 1988, Ridwan et al. 1996, Soetedjo and Nari 1980, Soetjedjo et al. 1980, Wilson et al. 1993	Anaemia, poor growth, low milk supply in ewes, weakness, death
Trichostrongylus colubriformis	Atomowisastro and Kusumamihardja 1989, Beriajaya 1984, Beriajaya 1986, Beriajaya and Stevenson 1986, Dorny et al. 1996, Ridwan et al. 1996	Appetite depression, poor growth, diarrhoea
Oesophagostomum columbianum	Arafin et al. 1996, Beriajaya 1984, Beriajaya 1986, Soetedjo and Nari 1980	Appetite depression, diarrhoea, dehydration, extensive nodule formation and abscesses in small intestine
Oesophagostomum asperum	Arafin et al. 1996, Beriajaya 1984, Beriajaya 1986, Carmichael et al. 1992, Soetedjo and Nari 1980	Appetite depression, diarrhoea, dehydration, severe nodule formation. Cases of *O. columbianum* may actually be *O. asperum*
Trematodes		
Fasciola gigantica	Beriajaya 1984, Boray 1985, Effendy and Sumiaty 1999, Soetedjo and Nari 1980	Evidence that primarily a problem of large ruminants and much less important in goats and sheep. Indigenous sheep breeds relatively resistant to infection (Wiedosari and Copeman 1990, Weidosari et al. 1991)
Eurytrema pancreaticum	Carmichael et al. 1992, Dorny et al. 1996, Graydon et al. 1992, Soetedjo and Nari 1980, Wilson et al. 1993	May be more important than currently recognised as cause of chronic, irreversible ill thrift leading to wasting and death in adult sheep, particularly in integrated plantation grazing



animals grazing pastures that had not been grazed for nine (37 worms) and 6 weeks (80 worms). Gatenby and Batabura (1994) recommend that pastures should be rested for at least 10 weeks before animals are returned.

In contrast, Ginting et al. (1996) found that 1-week grazing followed by a 6-week resting period had better worm control potential than both a 12-week grazing with 12-week resting period and 6-week grazing with 6-week resting period. Their study looked at the effects of grazing management and levels of concentrate supplementation on parasite establishment in two genotypes of lambs (Sumatra and crossbred St. Croix x Sumatra) infected with *Haemonchus contortus*. Improving the nutritional status of lambs by increasing the level of supplement offered may have depressed the establishment of *Haemonchus contortus* in the lambs. The two genotypes had similar faecal egg counts at a supplement level of 0.5% bodyweight, but at 1.6% bodyweight the crossbred lambs had a lower worm burden than the Sumatra ones.

Whatever the optimum period for larval numbers to decline on pasture, the decision to leave the pasture ungrazed must balance the conflicting needs of feed availability, feed quality, ability of sheep and goats to graze tall, regrown pasture, and the need to reduce infestation with infective nematode larvae.

Time of grazing has also been shown to affect worm burden (Mirza and Gatenby 1993a, 1993b). Groups of four lambs were grazed in the morning (0800–1200h), at midday (1100–1500h) or in the afternoon (1400–1800h) while a control group was stall-fed with grass cut in an ungrazed area. The stall-fed control group maintained few worm eggs per gram of faeces (epg) (geometric mean 0.5). Lambs grazed in the morning, midday and afternoon, had geometric mean epg values of 48, 15 and 31, respectively. The lower worm burden of the midday group is attributed to the dryness of the pasture at midday. Although the stall-fed group had the lowest epg, their weight gain was not as high as the midday-grazed group, presumably because the nutrition of the grazed pasture was superior. In 1982 Kusumamihardja studied the effect of season and time of day on the presence of nematode larvae on grass. Larvae numbers were higher in the wet season than in the dry and the number on leaf blades was highest in the morning. Another study by Kusumamihardja (1988) also reported that the degree of nematode infestation during the rainy season was significantly higher than in the dry season but found no age group (lambs, young, and adult) effect. In the dry season, worm burdens were significantly higher in the group grazed in the morning than in the group that grazed in the afternoon. However, there was no significant difference between morning and afternoon grazing during the wet season. Carcass dressing percentage was affected by season, age of sheep and period of grazing. Higher carcass percentages were recorded:

- during the dry than the wet season
- in adult sheep than in lambs
- in animals grazing in the afternoon than in the morning.

The benefits of reduced grazing time, therefore, like the resting of pasture for many weeks, need to be balanced against possible reduced intake and nutritional status.

Zabell et al. (1992) reported that washing forage, using forage from ungrazed areas and allowing animals to graze in rotational systems all resulted in lower transmission of strongyles than if contaminated forage or dried contaminated forage were fed.

To control *Fasciola* infections, Suhardono et al. (1998) recommended that animals be fed fresh rice straw that had not been immersed in water. This was based on the observation that sheep fed on the bottom wet 10 cm of the rice stalks, which harbour 98% of the flukes, become much more heavily infected than those fed on stalks cut above 10 cm.

Anthelmintics

Plants and plant products as anthelmintics

Traditional veterinary medicine is used extensively by smallholders in rural Indonesia and has significant potential to solve sheep health problems (Adjid 1990). The Small Ruminant Collaborative Research Support Program conducted a workshop at the Central Research Institute for Animal Science in Bogor in 1990 to collect information on this topic. Diseases of the digestive tract (worms, diarrhoea and bloat) were the ones most frequently treated with traditional medicine. Parts of plants used to prepare veterinary remedies include seeds, leaves, fruits, tubers, roots and rhizomes, or, for herbs, whole plants. Medicinal plants are fed to animals alone or mixed with other ingredients such as eggs, honey, shrimp paste, salt, soy sauce or sugar. Table 9.2, which builds on the work of Mathias-Mundy and Murdiati (1991), Sangat-Roemantyo and Riswan (1991), Murdiati (1991), Gultom et al. (1991), and Murdiati and Muhajan (1991), lists the most common medicinal plants used to treat worm-infected ruminants in Indonesia. The most common medicinal plants used for worms in Bogor, West Java, are the leaves of *Antidesma bunius* (huni) and *Cyclophorus nummularifolius* (deduitan) (Adjid 1990, Mathias-Mundy 1992, Wahyuni et al. 1992).

Children often care for small ruminants and benefit most from increased family income. (G.D. Gray)

Table 9.2 Medicinal plants used to treat ruminants with worms in Indonesia

Scientific name	Family	Local name	Part used
Allium sativum L.	Amaryllidaceae	Bawang putih	Bulb
Anacardium occidentale (cashew)	Anacardiaceae	Gajus	Skin of fruit
Ananas comosus L. Merr (pineapple)	Bromoliaceae	Nanas	Fruit/juice of fruit
Antidesma bunius L.	Euphorbiaceae	Huni	Leaves
Areca catechu L.	Arecaceae	Pinang	Seeds
Artemisia vulgaris	Asteraceae	Sidomolo	Leaves
Bamubusa (bamboo)?	Gramineae	Buluh	Shoots
Carica papaya L.	Caricaceae	Papaya	Leaves, latex
Codiaeum variegatum (L.) Bl	Euphorbiaceae	Puring	Leaves
Cucurbita domestica Val	Cucurbitaceae	Kunyit	Rhizome
Cucurbita moschata (Duck) Poir	Cucurbitaceae	Labu merah	Fruit
Curcuma aeruginosa	Zingiberaceae	Temu hitam/ireng	Rhizome
Curcuma heyneana Val. and v. Zijp.	Zingiberaceae	Temu giring	Rhizome
Curcuma xanthorrhiza Roxb.	Zingiberaceae	Temulawak	Rhizome
Cyclophorus nummulariforus	Polypodiaceae	Deduitan	Leaves
Hibiscus tiliaceus	Malvaceae	Waru	Leaves
Languas galanga	Zingiberaceae	Lengkuas	Rhizome
Leucaena leucocephala	Fabaceae	Lamtoro	Seeds
Monordica charantia L	Cucurbitaceae	Paria/Pare fruit	Leaves
Morinda citrifolia L.	Rubiaceae	Pace, Mengkudu	Fruit
Musa (banana)	Musaceae	Pisang	Blossoms
Nicotiana tabacum L.	Solanaceae	Tembakau	Leaves
Piper nigrum L.	Piperaceae	Merica	Seeds
Terminalia catappa	Combretaceae	Ketapang	Leaves
Zingiber purpureum	Zingiberaceae	Bangle	Tuber

Use of these plants by farmers does not necessarily mean they are effective as dewormers. Many plants and their products have been tested *in vitro* and *in vivo* for efficacy and such studies are described here.

The anthelmintic properties of both the seed and sap of *Carica papaya* (papaya) have been studied *in vitro* and *in vivo* in sheep. Beriajaya et al. (1997) reported that 1.5% solutions of ground papaya seed killed adult *H. contortus in vitro* within two hours and 1% solutions of papaya sap had the same effect within 4.5 hours. Subsequently, Beriajaya et al. (1998) used papaya seed as anthelmintic on sheep infected with 10,000 larvae. In this study papaya seed was oven-dried at 37°C for 24 hours and ground into a powder. The powder was given to three groups of experimental animals at 0.75 g/kg, 1.5 g/kg and 3.0 g/kg body weight, daily for one week. The numbers of adult worms present were not significantly different among the three treatments and the control group, but egg counts were. It was concluded that papaya seed could be used as anthelmintic in sheep if given for a long time. Gunawan (1992) gave young worm-infected Javanese fat tail rams suspensions of papaya seed at several dosages (3.6, 7.2, and 10.8 g per 100 ml) and compared the animals' egg counts with those of infected rams treated with levamisole at 8 mg/kg body weight and infected controls. Results showed that papaya seed effectively reduced the egg count of sheep, but was less effective than levamisole. Murdiati (1997) showed that sheep artificially infected with *H. contortus* given 0.75 g/kg body weight of papaya sap had significantly reduced worm egg counts compared with controls.

Confinement of goats offers employment opportunities in the cutting and carrying of feed. (G.D. Gray)

The effect of papaya sap on sheep artificially infected with *H. contortus* was reported by Kusnadi (1999). Four weeks after infection, the animals were divided into five groups: three groups were given papaya sap orally at 0.5, 0.6 or 0.7 g/kg for three days; one group was treated with albendazole (Valbazen) at 5 mg/kg for three days; and the control group was not treated. Faecal and blood samples were collected weekly from zero to 6 weeks. At the end of the study period the animals were slaughtered to obtain worm counts. Papaya sap at the given dosages had low efficacy in reducing *H. contortus* infection and the 0.7 g/kg dosage was toxic. Satrija et al. (1999) also did not recommend using papaya sap for controlling gastrointestinal nematodes in sheep due to high toxicity. Post-mortem examination showed that papaya sap seemed to cause haemorrhage as a result of erosion in the gastrointestinal mucosa possibly due to proteolytic activity of enzymes in the sap. There is no information on an increased use of papaya products as a routine deworming treatment.

Karo-Karo (1990) reported the effect of nicotine extract. Extract from chopped tobacco leaves (0.94%) at dosages of 27–207 mg per animal was found to enhance *H. contortus* egg production in goats, however, a dosage of 311 mg depressed egg production by 78%. Nicotine extract was able to reduce egg numbers but not the number of adult worms.

Beriajaya et al. (1998) studied the effect of *Areca catechu* (pinang) seed extracts on adult *H. contortus in vitro*. *A. catechu* seeds were sliced, oven-dried at 40°C for four days, ground and then sieved with a 75 μm mesh. Solutions of *A. catechu* were made at concentrations of 0.1, 0.2, 0.3, 0.4, and 0.5 g/ml. All worms were killed when incubated with any of the *A. catechu* solutions. The solutions had a similar effect on larvae with more larvae being killed as the concentration increased. The results of this trial indicated that *A. catechu*, which contains the alkaloid arecholine, may have anthelmintic effects *in vivo*.

The efficacy of *Curcuma aeruginosa* (temu hitam) tuber was compared with 15 mg/kg of mebendazole in sheep infected with digestive tract worms (Agustin 1994). *C. aeruginosa* and mebendazole both reduced egg counts but the commercial product was more effective. *C. aeruginosa* tuber at dosages of 3, 6 and 9 g reduced egg counts by 83%, 90.5% and 91%, respectively. Bendryman et al. (2000) reported that urea molasses mineral block (MUMMB) containing *Curcuma xanthorrhiza* (temulawak) or *C. aeruginosa* (temu hitam) roots only, or a combination of the two, can reduce the egg count of sheep infected with *H. contortus* by 97.20%, 94.81% and 95.68%, respectively. The use of the two plants in MUMMB was proved safe by liver function tests (SGOT and SGPT) and kidney function tests (blood urea nitrogen and creatinine).

Zingiber purpureum (bangle) tuber was used in the form of infusion and extract against larvae and adult *H. contortus* in vitro (Herawaty 1998, Murdiati et al. 1998). Murdiati et al. (1998) concluded that extract and infusion of *Zingiber purpureum* both have anthelmintic effects.

Mahfoed (1995) reported on the anthelmintic properties of pressed *Monordica charantia* (pare fruit) at concentrations of 100%, 50% and 25% with adult *H. contortus in vitro*. Levamisole solution at 0.0032% was used for comparison. At a concentration of 100% the efficacy of *M. charantia* did not differ significantly from that of levamisole with both killing more than 50% of the worms after seven hours.

Mulyaningsih (1995) studied the anthelmintic activity of *Morinda citrifolia* (mengkudu) fruit juice in sheep. *M. citrifolia* juice was administered orally once a week for nine weeks. The juice reduced the worm numbers, increased body weight and influenced the haematology of infected sheep. Extraction studies to trace the active ingredient in the *M. citrifolia* fruit were reported by Hildasari (1998) and Murdiati (2000). The chloroform fraction, containing alkaloid and anthraquinone, was the most effective against adult worms (100% death after two hours) and worm eggs. However, Nurhayati (2000) used the chloroform extract of *M. citrifolia* fruit on sheep infected with *H. contortus* and found that it did not significantly reduce the number of worms and egg production of the sheep.

Commercial anthelmintic products

Several studies of the effectiveness of commercial deworming products have been conducted. The cost, activity spectrum, effectiveness, and toxicity of commercial anthelmintics vary significantly.

Soetedjo et al. (1980) found that, despite the presence of large populations of infective *H. contortus* larvae on pasture and herbage grasses, a single injection of disophenol in smallholder sheep suppressed the numbers of *H. contortus* to low levels for up to 3 months.

Comparing the broad-spectrum anthelmintic, levamisole-phosphate, with the long-acting narrow-spectrum product, closantel, in naturally infected village sheep showed that levamisole could significantly improve the weight gain of animals (Beriajaya and Stevenson 1985a, 1985b). Based on the slaughter value of the treated animals and the cost of the drug used, there was a clear financial benefit from treating the sheep. Beriajaya and Stevenson (1986), comparing four anthelmintics in sheep and goats, found that broad-spectrum anthelmintic significantly increased weight gain. Closantel treatment, which was effective in removing *Haemonchus* but had little effect on the other nematode species, did not result in significant improvement in weight gain. Similarly, no weight gain was seen using disophenol, a long-acting narrow spectrum anthelmintic given as a single injection. These results suggest that nematodes other than *Haemonchus* are the cause of reduced weight gain.

Butchers, abattoir workers and associated labourers benefit from increased supply of animals. (G.D. Gray)

In a study on albendazole in naturally infected local sheep in Cirebon, Beriajaya (1986a) reported that the group treated with albendazole at a dose rate of 3.8 mg/kg every month for six months had a significantly lower average egg count than the control group. However, in Garut (Beriajaya, 1986b), differences in growth rate were not significant between treated and untreated groups. This is probably because sheep in Garut were confined and so the egg count was too low to have a marked effect on growth rate. Hartati (1989) reported that sheep naturally infected with gastrointestinal nematodes and then treated with albendazole at 4 mg/kg grew significantly better than untreated sheep. However, red blood count, haemoglobin, PCV and total plasma protein were only slightly higher than those of the control group.

Noviyanti (1992) used ivermectin dosages of 50, 100 and 200 µg/kg in goats and reported that the levels of erythrocytes, haemoglobin, PCV, lymphocytes, monocytes and neutrophils did not significantly differ between treated and control animals. Eosinophil count was the only blood parameter that showed a significant change. A comparison of ivermectin and doramectin, at a dosage of 200 µg/kg in sheep infected with gastrointestinal nematodes, found no significant difference between the two products in reducing egg count or improving growth rate (Pariyadi 1997).

Tetramisole treatment, combined with farm management practices, controlled gastrointestinal helminth infections in sheep (He et al. 1990). However, helminthiasis in this group of sheep was found statistically to be 20% associated with reduced mean live weight, indicating the need for more effective, broad-spectrum anthelmintics to improve animal productivity.

Thiophanate at 70 mg/kg, albendazole at 5 mg/kg, pyrantel-pamoate at 20 mg/kg and levamisole HCl at 8 mg/kg were all effective against strongyle infection in sheep (Sudarmadi 1989). Thiophanate and pyrantel-pamoate significantly increased the erythrocyte count, haemoglobin concentration and percentage PCV. Albendazole significantly increased the erythrocyte count and haemoglobin concentration but not PCV, while levamisole significantly increased PCV, but not erythrocyte count and haemoglobin concentration.

Dorny et al. (1995) studied anthelmintic efficacy in sheep on a breeding farm and on seven smallholder farms in North Sumatra, Indonesia. Albendazole was tested on all farms and febantel, levamisole and ivermectin just on the breeding farm. On the large breeding farm the efficacy of albendazole, febantel, ivermectin and levamisole was 99%, 100%, 99% and 95%, respectively. The efficacy of albendazole was 100% on the seven smallholder farms. The results indicate that there was no anthelmintic resistance at the study sites.

The use of anthelmintics to control *Fasciola* was studied by Brotowidjojo (1975, 1983) and Kusumamihardja (1978). Brotowidjojo (1975) looked at the efficacy of clioxanide and rafoxanide on *F. hepatica* in sheep, 6 and 12 weeks post-infection with 100 viable metacercariae. It was concluded that rafoxanide at 3.75 mg/kg could be recommended for treating immature infections of *F. hepatica* and that 7.5 mg/kg was appropriate for adults. Clioxanide, because of its substantially reduced efficiency intra-abomasally, was not recommended for use against immature flukes but was found to provide a variably moderate to high efficiency against adult infections at the recommended dose rate of 20 mg/kg. Furthermore, it was suggested fasciolicides that do not contain a nitro-group, such as clioxanide and rafoxanide, were effective when given orally (preferably by drenching) without previous oral administration of copper sulphate solution.

Kusumamihardja (1978) used Dovenix (active ingredient nitroxinil) against natural gastrointestinal nematodes and *Fasciola* infections in five sheep and reported that one died a day after treatment. Post-mortem examination showed that Dovenix was very effective against *Fasciola* spp., but killed nematodes relatively slowly.

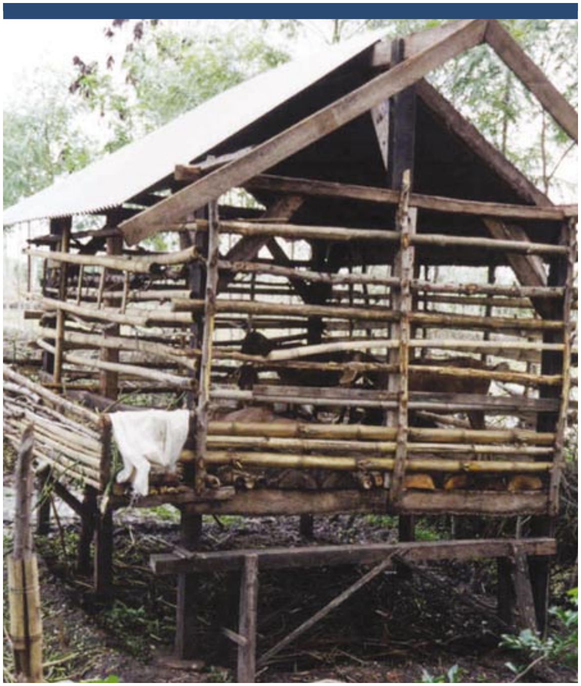
Gatenby et al. (1992a, 1992b) studied the effectivenes of nitroxynil, praziquantel and albendazole against pancreatic fluke (*Eurytrema pancreaticum*). Results showed that albendazole and praziquantel significantly reduced the level of pancreatic fluke infection, but neither drug reduced it to a negligible level. More frequent or higher doses of the drugs may be more effective, but would almost certainly not be economical. Nitroxynil appeared to be ineffective in controlling pancreatic flukes, but it reduced nematode egg counts.

Resistance

Currently, internal parasites are controlled by regular administration of anthelmintics, but resistance to these drugs is emerging in Indonesia and other parts of Southeast Asia (Venturina et al. 2003, Beriajaya et al. 2003; and described in detail in Chapter 4).

Delivering commercial anthelmintics to farmers

Cost–benefit analyses of parasite control in sheep using commercial anthelmintics show good returns on the health care investment. Marginal return using parasite control amounts to Rp 42,000 revenue for Rp 4200 treatment expenses. This suggests that making anti-parasite treatment available to farmers on a non-subsidised free-market basis is viable. The rapid improvements in animal condition from just one treatment, and the provision of practical information, are likely to make farmers willing to invest in parasite control (Scholz 1992). Misniwaty et al. (1994) reported that anthelmintic cost was only 1.8–3.0% of the total revenue received from selling fattened sheep.



Theft can be prevented by total confinement while kids and lambs are fattened for market. (G.D. Gray)

Possible anthelmintic distribution schemes, via livestock traders, local poultry shops and extension workers, were discussed by van Schie et al. (1992). The livestock traders cover a large area and are able to visit farmers, but farmers do not trust them as much as extension workers. Extension officers only visit a limited number of farms. The disadvantage of local poultry shops is that farmers have to go to the shop to buy the product but the advantage is that they no longer depend on another person to deliver the medicines.

Kartamulia et al. (1993) stated that there is an urgent need to redefine the respective roles of government and the private sector in the delivery of livestock services. In particular, the animal health sector offers attractive opportunities for greater private involvement. Reasons why farmers do not use animal health care products include: small flock sizes, the expense of products due to the large sizes sold (e.g. 1 L bottles of anthelmintic) and the difficulty in obtaining products at the village level. To overcome these problems, an animal health delivery network for distributing anthelmintics was developed by the Small Ruminant Coordinated Research Project and Research Institute of Animal Production Station at Sungai Putih, North Sumatra together with local livestock services and wholesalers of animal medicine. This study, reported by Misniwaty and Kartamulia (1993), Kartamulia et al. (1993), Misniwaty et al. (1994) and reviewed by Misniwaty et al. (1996), indicated that the most effective way to distribute animal health care is via an extension worker who is organized as a supplier in a specific area.

Biological control

Beriajaya and Ahmad (1999) investigated the use of nematophagous fungi, *Arthrobotrys oligospora*, as a biological control for *H. contortus*. Twenty young sheep, free of helminth infection, were orally infected with 5000 *H. contortus* L3 larvae. After 6 weeks, half of the sheep were treated with the fungi (four times over the following period of 6 weeks). Egg counts and faecal cultures indicated that the group that received fungus produced fewer larvae than the control animals. This preliminary study shows that nematophagous fungus can reduce live L3 *H. contortus* larvae numbers.

Biological control for fasciolosis can be targeted at the intermediate host of *Fasciola*, the snail (*Lymnaea* spp), or at the larvae of *Fasciola* that still lives in the snail. Studies of *Echinostoma revolutum* larvae as an agent for biological control of *F. gigantica* have been conducted by the Research Institute for Veterinary Science (Balitvet) and reported by Estuningsih (1991, 1998a,b). Estuningsih concluded that the dominant antagonism of *E. revolutum* over *F. gigantica* in L. *rubiginosa* and the reduction of fecundity and longevity of snails infected with *E. revolutum* could be useful for biological control of *F. gigantica* (1991, 1998a).

The competitive interaction of snails with *Lymnaea rubiginosa*, the intermediate host of *F. gigantica* has also been studied. After 8 months the population of *L. rubiginosa* decreased and the population of snails *Thiara scabra* and *Physa doopi* increased. The competitive interaction does not seem to be due to competition for food but to chemical factors, possibly water-soluble pheromones (Estuningsih, 1998b).

Table 9.3 Summary of *H. contortus* vaccination studies in Indonesia

Host	Vaccination/infection type	Summary of findings	References
Sheep	Exsheathed larvae	No response	Beriajaya et al. (1995)
	Irradiated larvae	Some serological response using range of techniques	Partodihardjo, (1996), Setiawati (1996), Suryastuti (1996), Syah (1994)
	Irradiated larvae	Reduced pathogenicity	Henriana (1997)
	Irradiated larvae	No effect on egg counts but serum proteins elevated	Beriajaya and Partodihardjo (2000)
	Irradiated larvae (double dose)	Positive results	Partodihardjo et al. (2000), Partodihardjo et al. (1998)
	Extract with range of adjuvants	No effect	Berliana (1998), Heryani (1998)
	Extract	No effect on egg count	Beriajaya and Suhardono (2000)
Goats	Infective larvae	No solid immune response	Maryani (1997)

Table 9.4 Summary of *Fasciola* vaccination studies in Indonesia

Host	Nature of study/vaccination	Summary of findings	References
	Protein antigen characterisation	2 antigenic proteins identified	Estuningsih and Widjajanti (1999)
Sheep	Extract + adjuvant	Immune response greater with adjuvant	Widjajanti (1999a,b)
	Irradiated	Significant resistance	Wiedosari et al. (1996)
	Irradiated	Decreased infective capability	Tuasikal et al. (1996)
	Irradiated	Good immune response and decreased infectivity	Arafin and Tuasikal (1998)
in vitro	Antisera from sheep	No cross protection against *F. hepatica*	Estuningsih et al. (1999)
Sheep & Goats	Infective metacercariae	Goats more resistant to infection	Arafin (2000)
Goats	Irradiated	45 Gy irradiation optimal for decreased infectivity	Arafin et al. (2000)

Suhardono (1998) proposed biological control of *F. gigantica* in rice fields by means of competition between trematode larvae in the snail *L. rubiginosa*. Ducks naturally infected with trematodes, were used as the source of competitive larvae. The study showed that *Fasciola* infection in *L. rubiginosa* was depressed by other trematodes which were more dominant in infecting the snail intermediate host.

Vaccination

Several immunological studies to find candidate vaccines for haemonchosis and fasciolosis have been conducted (Tables 9.3 and 9.4). Research on irradiated and non-irradiated parasites has been performed mostly at the Research Institute for Veterinary Sciences (Balai Penelitian Veteriner) in collaboration with the Central Research and Development for Isotope and Radiation Technology, National Atomic Energy Agency (PAIR, BATAN). The development of an effective vaccine remains an important challenge.

Nutritional supplementation

While publications about the effect of nutritional supplementation on small ruminant production are readily available (Subandriyo 1993), research on the effect of nutritional supplementation on their endoparasite infestations is limited.

Handayani and Gatenby (1986, 1988) studied the effect of four levels of legume supplementation in conjunction with two grazing management schemes and anthelmintic treatment or non-treatment. They found that sheep on low levels of nutrition are more susceptible to helminthiasis than well-fed animals.

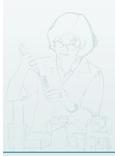
In 1988, Ginting reported that supplementation of concentrate feed (high plane nutrition) in lambs infected with *H. contortus*, reduces worm burdens and can reduce the need for anthelmintics to control endoparasites. Although feed supplementation can reduce susceptibility to parasite infection, the response varies according to breed and level of infection. This indicates that interaction between genotype and environment affects susceptibility to parasite infection (Ginting et al. 1996).

Beriajaya and Copeman (1996) studied the effect of season on gastrointestinal nematodes and weight gain in recently weaned sheep and goats. The effect of parasitism was assessed by comparing weight gain of untreated animals with that of animals treated with oxfendazole or albendazole every 2 weeks. There was no difference in weight gain between treated and untreated sheep and goats during the dry season. During the wet season weight gain dropped by half in untreated animals and by about 20% in treated animals. As faecal egg counts for each group were the same throughout the year the low level of nutrition during the wet season was the main determinant of pathogenicity of worms. Improved nutrition during the wet season, particularly for the first 10 weeks after weaning, may remove the need for anthelmintic therapy.

Beriajaya et al. (1995) tested feeding blocks containing 3% phenothiazine in solidified molasses (Wormolas, Animeal Australia Ltd) for their ability to control gastrointestinal nematode infections, and their effect on mineral status, in village sheep in Cirebon. The mean egg count of the treated group decreased from 576 epg to 123 epg and the percentage of sheep

Table 9.5 Studies of genotypic differences in resistance to *H. contortus* in sheep

Genotypes compared	Findings	References
Sumatera thin-tail St. Croix St. Croix x Sumatera thin-tail F1 Javanese fat-tail x Sumtera thin-tail F1 Barbados Blackbelly x Sumatera thin-tail F1 St. Croix x Sumatera thin-tail F2	Javanese fat-tail x Sumatera thin-tail and St. Croix x Sumatera thin-tail most susceptible. Barbados Blackbelly x Sumatera thin-tail most resistant	Dorny et al. (1994), Romjali et al. (1994), Romjali (1995), Romjali et al. (1997)
Sumatera thin-tail Virgin Island and 90% Virgin Island Virgin Island x Sumatera thin-tail F1 Barbados Blackbelly x Sumatera thin-tail F1 Virgin Island x East Java fat-tail F1 Virgin Island x Sumatera thin-tail F2	Faecal egg counts similar for all breeds, excluding, Virgin Island ewes which had lower egg counts Time of sample and individual animals within breeds had significant effect on counts	Batubara et al. (1994)
Sumatera thin-tail St. Croix x Sumatera thin-tail 25% Barbados Blackbelly, 25% St. Croix, 50% Sumatera thin-tail	At high levels feed supplementation St. Croix crosses better able to withstand parasitism Sumatera thin-tail more susceptible to internal parasites than composite genotype	Ginting et al. (1996) Ginting et al. (1999)
Sumatera thin-tail Barbados Blackbelly x Sumatera thin-tail F1 Javanese fat-tail x Sumatera thin-tail F1 St. Croix x Sumatera thin-tail F1 St. Croix x Sumatera thin-tail F2	Barbados Blackbelly x Sumatera F1 and St. Croix x Sumatera F2 had lowest egg counts No substantial differences between genotypes in terms of worm counts	Mirza et al. (1994)
Sumatera thin-tail Javanese fat-tail x Sumatera thin-tail F1 St. Croix and Sumatera thin-tail F1 St. Croix and Sumatera thin-tail F2	Javanese fat-tail x Sumatera thin-tail much more susceptible to parasitic infection	Gatenby et al. (1995)
Javanese thin-tail Sumatera thin-tail Barbados x Sumatera F1 Javanese fat-tail x Sumatera F1 St. Croix x Sumatera F1	Observed variation of resistance within genotypes	Gatenby et al. (1991) Carmichael et al. (1992) Romjali (1995)
Sumatera thin-tail St. Croix x Sumatera F1 Barbados x Sumatera F1 25% Barbados, 25% St. Croix, 50% Sumatera	No variation in resistance within genotypes	Batubara et al. (1995)
Sumatera thin-tail St. Croix x Sumatera Javanese fat-tail x Sumatera Barbados x Sumatera 25% Barbados, 25% St. Croix, 50% Sumatera	No significantly difference in susceptibility or resistance between genotypes but large variation within each genotype Hair sheep cross breeds similar to Sumatera in terms of *H. contortus* infection	Batubara (1997)



producing viable larvae decreased from 50% to 24%. In contrast, egg counts of the control group increased from 768 epg to 4840 epg and the percentage of sheep producing viable larvae increased from 65% to 84% over the same period. In the treated group the number of *Haemonchus* larvae declined significantly (36% to <6%) and at the end of the trial *Trichostrongylus* larvae predominated in larval cultures (>80%). Mineral analysis of untreated sheep revealed deficiencies in sodium and copper, low levels of zinc and normal levels of potassium, calcium, magnesium and phosphorus. The feeding block significantly affected sodium and zinc status but not copper although sufficient levels of this element were available. Comparison of bodyweight gains showed a significantly higher rate of increase in the treated animals

Genetic variation in resistance to parasites

Genetic variation in resistance to parasites has been reported in a series of studies conducted by the Small Ruminant CRSP in collaboration with the Research Institute of Animal Production and Research Station of Central Research Institute for Animal Sciences at Sungai Putih, North Sumatra. Results were reviewed by Subandriyo et al. (1996) and Subandriyo and Widjajanti (1999).

Genetic research on differences in resistance to *H. contortus* among sheep breeds is summarised in Table 9.5.

Studies of the resistance of sheep to the liver fluke, *F. gigantica*, have been mostly conducted by the Research Institute for Veterinary Science (RIVS, Balitvet) in collaboration with ACIAR. Research shows that Indonesian thin-tail sheep are relatively resistant to the liver fluke. Wiedosari (1988) and Wiedosari and Copeman (1990) first showed that Indonesian thin-tail sheep, in this case Javanese thin-tail, expressed high innate resistance to challenge with metacercariae from *F. gigantica* when compared with an equivalent challenge in buffalo and cattle. Rumantiningsih (2000) showed that Javanese fat-tail sheep were more susceptible to *F. gigantica* than Javanese thin-tail ones. Spithill and colleagues confirmed the resistance expressed by Indonesian thin-tail sheep in comparison with Javanese fat-tail and Merino sheep (Wiedosari et al. 1994, Roberts et al. 1995 1996a 1966b 1997a 1997b 1997c, Estuningsih et al. 1996, Spithill 1996).

Roberts et al. (1997a) deemed the basis of the acquired resistance in Indonesian thin-tail sheep to be an exceptional immunological capacity to respond to an antigen, or an immunological suppressant, peculiar to *F. gigantica*. That molecule, produced by juvenile parasites, warrants further study, as a candidate for a vaccine.

A series of studies by Roberts et al. (1995, 1996a, I997c) showed that a dominant gene may induce the mechanism of resistance in Indonesian thin-tail sheep. They also found indications that IgG2 acts as blocking antibody that interferes with the mechanism of resistance. Hansen et al. (1999) postulated that IgG2 could act as a blocking antibody for protective effector responses against *F. gigantica* in sheep and that the Indonesian thin-tail sheep, by downregulating IgG2 responses, have an enhanced capacity for killing *F. gigantica in vivo*.

A worm control program in Indonesia

In developing health control strategies at least three non-veterinary factors must be considered: farmer needs, production systems and climatic factors (Wilson et al. 1996). The priority given to solving problems identified by farmers has led to a farmer-first approach using participatory methods such as those described in Chapter 3. Strategies to minimise disease problems include intervening in animal and pasture management, using chemical agents, and developing host resistance though breeding and nutrition. These strategies and their delivery must be developed as part of an integrated approach to disease control incorporating research, extension, government and private sectors, suitable technology, training and recognising the needs of farmers. The farmer-first approach implies that research and extension must at least include farmers and ideally be led by them.

The problems of farmers, however, are rarely simple and, even if identified as being caused principally by parasites, will often include several genera of nematodes and flukes. According to Brotowidjoyo (1990) parasitic infections in domestic animals are generally polyparasitic rather than monoparasitic and are dependent upon a myriad of hosts, parasites and environmental factors. Currently, parasite control is usually based on chemical treatments that have disadvantages such as drug resistance (Beriajaya and Batubara 1996). This has proven to be the case in recent studies (Venturina et al. 2003, Beriajaya et al. 2003) on farms that use anthelmintics intensively.

The support of diagnostic services is essential to make good decisions about deworming. (G.D. Gray)

During the Small Ruminant Collaborative Research Support Program, researchers designed training materials to teach farmers improved strategies for animal raising. This information became the basis for a manual titled the Sheep and Goat Production Handbook for Southeast Asia (Merkel and Subandriyo 1997). The book contains a wealth of information relevant to the development of an integrated approach to worm control. The third edition was developed to be used by:

- farmers as an information source
- extension personnel as a reference and storehouse of training materials
- scientists as a starting point in their quest to improve village sheep and goat production.

As Merkel states, 'The greatest impact and benefit will occur when all three: farmers, extensionists and scientists, work together' (Merkel and Subandriyo 1997).

Conclusions

- Small ruminant endoparasites in Indonesia, and their intermediate hosts, have been well-documented.
- Grazing management studies show that rotational grazing, cutting forage at midday and/or at 10 cm above the ground, and washing forage, all reduce levels of worm infection.
- Smallholder farmers, particularly in Java, use traditional veterinary medicine against worms. The efficacy of the medicinal plants must be confirmed scientifically.
- Several studies of the effectiveness of commercial deworming products have been conducted. However, information on the level and frequency of anthelmintic use and the extent of anthelmintic resistance is limited.
- An animal health delivery network for distributing anthelmintics and treatment information has been developed. It needs to be further tested and extended to other locations.
- Preliminary information on biological control options for fasciolosis and haemonchosis has been reported.
- Several immunological studies to find candidate vaccines for haemonchosis and fasciolosis have been conducted but the development of an effective vaccine remains an important challenge.
- A wide range of information on the use of nutritional supplementation to improve production exists. However, there is little data about the effect of nutritional supplements on parasite infestation.
- There is little or no difference in susceptibility or resistance to *H. contortus* between sheep genotypes but large variation within each genotype. Indonesian thin-tail sheep appear to have innate resistance to *F. gigantica*.
- There is little data on worm control for goats in Indonesia.

Despite the extensive basic and applied research on parasite control in Indonesia, worms remain a constraint to small ruminant production. There has been little evaluation of the benefits of this research. The impact upon communities may be difficult to measure, for example, the spillover benefits of using appropriate chemicals at correct dosages, and greater numbers of better-trained extension workers, are hard to quantify. Many of the technologies work well in controlled settings but have had low levels of adoption by farmers. Hence, the need for a new approach to improving the control of worms in sheep and goats, using a model like that described in Chapter 3.

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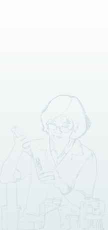

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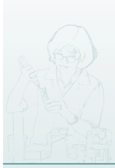

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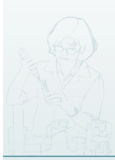

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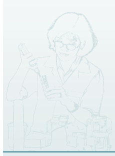

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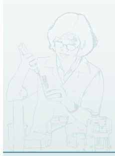

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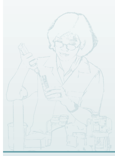

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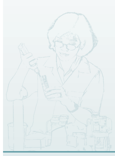

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10. Worm control for small ruminants in Malaysia

R.A. Sani, M. Adnan, T.S. Cheah and P. Chandrawathani

Introduction

Although small ruminant production has been an important part of Malaysian agriculture for many years it is relatively minor compared with other sectors of the livestock industry. Since the mid 1980s efforts to expand the industry have focused on integrating sheep into the more than four million hectares of oil and rubber plantations (Ibrahim 1996).

The 2000–01 figures from the Department of Veterinary Services, Malaysia, estimate the goat and sheep populations to be about 235,000 and 131,000, respectively.

Only one study, by Fadzil in 1977, has attempted to measure the cost-effects of parasitism in small ruminants in Malaysia. Losses (deaths, treatment costs and condemnation in abattoirs) in goats due to parasitism were estimated at RM 44,400 (now USD 11.7). This is considered a gross underestimate because it was extrapolated from a 5-year record of the Central Animal Husbandry Station, Kluang, which recorded that only one in 937 goats died of parasitism each year. Other more recent studies, which record mortality, quote much higher figures.

This review covers work reported after 1980 on small ruminants pertaining to control of gastrointestinal parasitism in Malaysia. The details of some studies that could contribute to formulating control measures are included. Significant recommendations of some reports are also included.

The endoparasites found in goats and sheep in Malaysia were described by Shanta (1982), Sani et al. (1985, 1986), Amin et al. (1990) and Wahab and Adanan (1993). Common endoparasites include:

- *Haemonchus contortus*
- *Trichostrongylus* spp.
- *Oesophagostomum* spp.
- *Cooperia curticei*
- *Strongyloides papillosus*
- rumen flukes
- pancreatic flukes

Ostertagia spp. and the lungworm *Dictyocaulus* spp. were reported by Shanta (1982) as rare and were not found in the later studies. Perhaps these parasites were from imported goats and sheep.

To assess the natural resistance of goats to parasitism, 46 goats, monitored from birth to 14 months, were not given any dewormer (Daud et al. 1991). Post-mortem examinations revealed that 32% of deaths were due to worms (mean *H. contortus* count 808, *T. colibriformis* 1177) and 30% of deaths to pasteurellosis pneumonia. The goats that died of pneumonia also harboured worms (mean *H. contortus* count 236, *T. colubriformis* 203). It was postulated that the worm burden, representing mild haemonchosis, weakened the goats so they subsequently succumbed to infection by *Pasteurella* sp., leading to pneumonia.

Pasteurella haemolytica is part of the normal flora of the nasopharynx of various animals and causes pneumonia when animals are stressed. Zamri-Saad et al. (1994) demonstrated that sub-clinical haemonchiasis (dosing with 4000–5000 infective larvae), without significant reductions in total serum protein or packed cell volume, stressed goats enough to induce sufficient immunosuppression and allow the development of experimentally induced pneumonic pasteurellosis.

In a 15-month study on 13 goat smallholdings in the state of Selangor, the mortality rate for animals up to 1-year-old was high at 74% (Symoens et al. 1993). Adult mortality was 34%. Pneumonia, mainly caused by *Pasteurella* sp., and haemonchosis were found to be the major causes of deaths in all age classes. Sam-Mohan et al. (1995) noted a mortality of 16% from clinical haemonchosis in lambs and ewes that grazed on vegetation under oil palm trees.

Epidemiological studies in goats suggest that grazing goats ingest many infective *H. contortus*, *T. colubriformis* and *O. columbianum* larvae at all times of the year in Malaysia (Sani et al. 1985, Dorny et al. 1995, Ikeme et al. 1986, Cheah and Rajamanickam 1997).

Further studies of the biology and pathology of endoparasites in Malaysia have been conducted (Sani et al. 1994, Sam-Mohan et al. 1995, Cheah and Rajamanickam 1997, Daud et al. 1991, Dorny et al. 1995, Sam et al. 1995, Israf et al. 1996a, 1996b).

Worm control options

Grazing management

Studies of trichostrongyles on open pasture and on vegetation under tree crops found that eggs developed to infective larvae in a minimum time of 3.5–4 days after faecal deposition and most larvae developed within 7 days. Infective larvae on open pasture survived for 5–6 weeks, on vegetation under rubber trees for 6–7 weeks and on vegetation under oil-palm trees for 5–8 weeks (Sani et al. 1994, Sam-Mohan et al. 1995, Cheah and Rajamanickam 1997). Earlier it was thought that larvae survived much longer in the microenvironment under the canopy of tree crops (Sani and Rajamanickam 1990). The relatively short larval survival times observed allows for the integration of grazing management with worm control. Small ruminants can safely graze for 3–4 days in an area which is ‘rested’ for 5–6 weeks.

During a 5-month trial, sheep grazing in a rotation system, with 3–4 days on and 31 days off each paddock, had significantly lower mean egg counts compared with sheep permanently grazing the same pasture and receiving a monthly drench of closantel (Chandrawathani et al. 1995). A three and a half-month study showed that sheep perpetually grazing the same area under mature rubber trees had higher egg counts compared with ones rotationally grazing in a hedgerow planting system—3–4 days on and 35 days off each area (Sani et al. 1996).

Anthelmintics

Commercial products

The control of worms in small ruminants in Malaysia, like elsewhere, relies heavily on chemical de-wormers or anthelmintic drugs. Shanta et. al (1978, 1980, 1981a, 1981b) published a series of reports on the use of benzimidazole compounds against gastro-intestinal worms of goat. These trials report a high level of efficacy. However, in the 1980s and 1990s, other anthelmintics were also used. Avermectin derivatives were noted as being highly successful in numerous reports (Sani and Siti-Suri 1989, Rajamanickam et al. 1990, Wahab et al. 1993, Wahab 1997, Chandrawathani et al. 1998a). Closantel was also reported to be effective (Dorny et al. 1994a, Chandrawathani and Adnan 1995, Chandrawathani et al. 1996a). A postal survey on the use of anthelmintics suggested that most farmers used the four major classes of drugs (Chandrawathani et al. 1994).

The Sanat Ines sheep from Brazil is one of several breeds imported to Malaysia for evaluation. (G.D. Gray)

Resistance to anthelmintics

Anthelmintic resistance has been suspected in Malaysia since the 1980s with unofficial reports of drug failures. In the early 1990s unpublished reports, particularly from institution farms, noted the ineffectiveness of anthelmintics. Dorny et al. (1991) in an investigation of the efficacy of currently available anthelmintics in Malaysia in 10 smallholder goat farms, reported suspected benzimidazole resistance of *H. contortus* on two of the farms, using the faecal egg count reduction (FECR) test. Levamisole resistance was also detected on two of the farms investigated.

A nationwide survey reported the presence of benzimidazole resistance in 33 out of 96 smallholder goat farms by means of an egg-hatch assay (Dorny et al. 1994b). Correlation was found between drenching frequency in the previous 2 years and the presence of benzimidazole resistant worms. Wahab (1994) also reported resistance to benzimidazole by *H. contortus* on eight out of 10 commercial goat farms in the northern region of the country.

Chandrawathani et al. (1996b) successfully used a netobimin-levamisole combination drench in goats with a benzimidazole resistant strain of *H. contortus*. However, 40 days after treatment, as a result of re-infection, the FEC reached pre-treatment values. Hence, a drug-dependent method of control is only a short-term solution.

Ivermectin and benzimidazole-resistant strains of *H. contortus* were isolated on an institution sheep farm that served as the source of breeding stock to farmers in Malaysia (Sivaraj and Pandey 1994). Simultaneous resistance of *H. contortus* to benzimidazoles and ivermectin and of *T. colubriformis* to benzimidazoles and levamisole was found in sheep on another institution farm (Sivaraj et al. 1994). Moxidectin was found to be effective against both worm species present on the particular farm, however, the authors do not recommend using moxidectin when ivermectin resistance is known. Resistance to three anthelmintic classes on the same farm is particularly serious when the farm supplies breeding stock to smallholder farmers, and is hence ‘exporting’ animals with drug-resistant worms.

The investigation by Chandrawathani et al. (1999) of 39 sheep and nine goat farms showed that most had worm populations resistant to all classes of anthelmintics, providing clear evidence that anthelmintic resistance in parasites of small ruminants in Malaysia is rapidly increasing. On a large government farm that served as a sheep breeding centre, anthelmintic resistance increased in 3 years from being a moderate problem to one where total chemotherapeutic failure has occurred (Chandrawathani et al. 2003).

Medicated feed blocks

Rajamanickam et al. (1992) tested an imported commercial anthelmintic feed block on a group of sheep and found relative success in reducing the FEC below levels in conventionally drenched sheep and untreated controls. This is particularly significant as all three groups grazed together with other sheep that had no access to the block and that were not drenched.

In a study of sheep grazing under rubber trees, (Sani et al. 1995) animals were given locally made urea molasses block with: no anthelmintic, 0.5g/kg fenbendazole, or supplemented with palm kernel cake meal. There was little difference between egg counts of animals receiving fenbendazole and those getting the unmedicated blocks. Even the supplemented animals were able to minimise the incidence of new infections. It is assumed that, provided the larval challenge is ‘light’, the improved nutrition provided by the blocks, irrespective of incorporation of anthelmintic, as well as the supplementation, is sufficient to effectively reduce the incidence of new infections. Further work by Maria et al. (1996), where urea molasses blocks, medicated or not, were effective in reducing new infections, lends support to this assumption. Hence, it is recommended that unmedicated blocks be given when supplementation is needed, so reducing the likelihood of anthelmintic resistance.

Chandrawathani et al. (1997) gave medicated urea molasses blocks to all animals in a smallholder sheep farm at a restricted economical intake of 60g/day/animal. The animals grazed permanently on heavily contaminated vegetation (indicated by egg count >7000 epg) under oil palm trees. After an initial moxidectin drench and access to the blocks, egg counts remained below 300 epg over 3 months.

Plants as anthelmintics

This aspect of ethnoveterinary medicine is at a fledgling stage in Malaysia although there are undocumented reports of the use of tamarind juice and legumes to treat worms in goats.

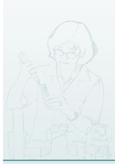
When fresh leaves of the neem tree (*Azadirachta indica*) were fed to a group of trichostrongyle-infected sheep, faecal egg counts and larval recoveries were reduced. The number of worms recovered in the neem-fed sheep was only 5–15% that of the control sheep (Chandrawathani et al. 2002c). Neem leaves were acceptable to the animals and there was no indication of toxicity. Clearly, there is potential for more investigation into the anthelmintic properties of the plant.

Breeding

There are few reports in Malaysia on genetic resistance to parasites. Over a period of 9 months, worm egg counts were monitored in weaned lambs of the local long-tail wool sheep and compared with those of the imported 'Cameroon' (Djallonke) hair sheep crosses (Pandey 1995). This study found that the crossbreeds were more resistant to *H. contortus* than the local wool sheep. However, a later study on the same farm of 42 female 50% Poll Dorset x Malin (Malaysian indigenous breed) wool sheep and 20 female 25% Cameroon hair sheep grazing together, showed no difference in egg counts from birth to 13.5 months (Sani 1994). It is important to note that the wool sheep on this particular farm have been selected for improved production and hence, inadvertently, possibly also for worm resistance, for more than 15 years.

Large-scale sheep and goat production is commercially viable where there is strong demand and efficient marketing. (R.A. Sani)

A newly imported hair breed from Brazil, the Santa Ines, was studied for worm resistance purely because there were many animals available from which nucleus flocks of resistant and susceptible animals could be created. Selection of this breed, based on field and challenge infections, showed 20–30% resistant individuals. Mating of the resistant individuals produced resistant offspring (Sani et al. 2000).

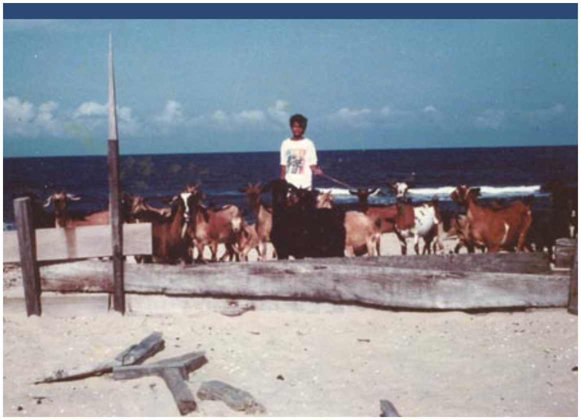


Biological control

Initial bio-control research in Malaysia used the fungus, *Arthrobotrys oligospora,* found in cattle dung, on *Strongyloides papillosus* larvae (Chandrawathani et al. 1998b).

Investigations of the more robust *Duddingtonia flagrans,* as a nematophagous inclusion in animal feed are continuing. Studies of *D. flagrans* began with a faecal survey for naturally occurring nematode-trapping fungi (Chandrawathani et al. 2002a). The fungus was grown on local media such as wheat grains, padi and millet, prepared for feeding to small ruminants and also incorporated into urea molasses blocks. These two delivery methods (feed granule supplement and nutrient block) were found to be suitable for feeding sheep and goats. Studies of an isolate of *D. flagrans,* identified by the Veterinary Research Institute, showed that it could reduce larval development by nearly 95% in worm-infected animals fed six million spores each (Chandrawathani et al. 2002b). When spores were incorporated into feed blocks, the spores were less effective. Furthermore, how blocks containing fungal spores are stored affects the efficacy of the fungus. It is ideal to store them in cold room facilities as this can extend the shelf life of the spores.

Further trials were conducted on penned animals artificially infected with *H. contortus*, using dose rates of 125,000 and 250,000 spores per kg as a feed supplement, as well as via blocks. The spores were able to reduce larvae by 80–90% within 48 hours and the effect was seen at least 3–4 days post treatment. In another trial on grazing sheep fed with 500,000 spores/kg, spores tended to reduce pasture contamination, thereby lowering the rate of re-infection of sheep, over a period of 3 months. Untreated controls had higher faecal egg counts as a result of continuously grazing contaminated pastures. The total worm counts of tracers indicated a higher level of larval contamination in the pastures grazed by the untreated control sheep.



Goats kept on coastal fringes of eastern Malaysia eat only shrubs and have no worm burdens. (P. Dorny)

In the final trials on large-scale sheep farms in Infoternak and Calok, fungal spores were fed at a dose rate of 500,000 spores/kg. Results clearly showed that simultaneous use of spores and a 10-paddock, rapid, rotational-grazing strategy was an effective way to reduce pasture contamination to a minimum, such that anthelmintics need not be used. This demonstrates the ultimate use of nematode-trapping fungi in systems for which anthelmintics are ineffective because of resistance.

Conclusions

The worm profile of small ruminants in Malaysia, and the nature of infection in traditional smallholdings, on open pastures and under plantation crop management have been documented. This provides for a sound foundation to formulate control programs for worms in the various animal management systems. The wide availability of the major groups of anthelmintics coupled with government subsidies for ruminant health has led to the emergence of widespread anthelmintic resistance. However, chemical dewormers remain the most used form of control. Strategic treatment based on faecal egg count (FEC) appears to be well adopted on government and commercial farms. The animal health worker monitors the FEC of the farm by sending samples to the nearest government laboratory. The managers are advised to treat if 30–40% of the flock has FEC>1500. When treating animals it is recommended that drugs are rotated (ie, two drugs per year) and that strict precautions, such as fasting animals before treatment and calculating dosage based on the heaviest animal, be adopted.

Grazing management using rotational systems based on epidemiological knowledge is a success on government farms that use the practice consistently. Rotational grazing has not been well adopted in plantations because plantation managers are not convinced of the benefits. Moreover, plantations currently prefer rearing cattle, rather than small ruminants, as cattle appear to be less problematic and provide better returns.

Feed blocks are very popular but their cost is a constraint. Their popularity stems from improved productivity from increased nutrition, rather than the medication in the block. This has been clearly demonstrated by comparing the performance of non-medicated and medicated blocks.

Breeding for resistance works well in the hands of researchers but as there is no organized breeding plan for worm resistance on government farms this approach to worm control has not been adopted by government breeders and multiplier farms. Selection of breeding animals is based on body weight and breed conformation. Sheep breeding farms are now using only hair breeds which were imported because of their reputation for resistance to worms.

Biological control using nematophagous fungi is in the developmental research stage.

When animal rearing is a secondary source of income, farmers are less willing to experiment with, or commit to, techniques to improve their husbandry. Smallholder farmers usually depend solely on chemical control. The farmers who succeed in making small ruminants a primary enterprise are those who have invested heavily in their farms and are open to suggestions.

Entrepreneurial producers use a worm control program. They ensure good sanitation, apply principles of good nutrition and provide proper housing with raised, slatted flooring. They do this in the name of good management rather than consciously thinking of sustainable parasite control. After their considerable investment in the small ruminant enterprise these farmers will adopt other practices instead of depending on chemical dewormers. Farmers who face anthelmintic resistance confine their animals and feed them cut-and-carry forages.

The future for work on worm control in small ruminants in Malaysia, apart from exploring medicinal plants, is to expose farmers to the available options. The continuing education process of animal health workers who are closest to the farmers therefore cannot be overemphasised.

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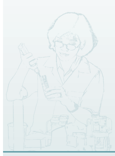

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11. Worm control for small ruminants in Thailand

S. Kochapakdee and S. Saithanoo

Introduction

Thailand has about 150,000 goats and 43,000 sheep (FAOSTAT 2003). Almost 90% of the total goat population is found in southern Thailand, mainly in the five provinces close to the Thai–Malaysian border where Thai Muslims are concentrated. In contrast, sheep occur across the country. Gastrointestinal parasites increase mortality in small ruminants, slow growth of young animals and affect the performance of adult animals. They are likely to be a significant constraint to sheep and goat productivity in Thailand (Kochapakdee et al. 1993a, 1993b, Pralomkarn et al. 1994).

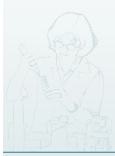
There are fewer goats and sheep than large ruminants, such as cattle and buffalo, and they are less important economically. However, most small ruminants are owned by smallholder farmers, and are therefore economically important to the rural people. The government has been trying to increase goat numbers in the country by providing loans to farmers to buy breeding goats from government farms. Farmers have formed cooperative groups to raise goats to sell as breeding stock to other farmers. In recent years, goats have attracted the attention of private companies because of the high price they command at market. In 2000, the CP Hybrid Co Ltd imported a large number of Boer and Saanen goats from South Africa and Australia.

This chapter compiles the results of research relevant to the control of internal parasites in small ruminants in Thailand. As little research has been conducted in sheep, the chapter focuses on worms in goats and discusses best control options for this species.

Prevalence of worms

Sheep

Only two publications on the prevalence of endoparasites in sheep in Thailand have been located (Sukapasana 1987, Churnnanpood et al. 1988). The following endoparasites were found in the faeces of lambs grazing at a research station: *Strongyloides papillosus*, *Cooperia*, *Haemonchus*, *Oesophagostomum*, *Trichostrongylus* spp. and *Moniezia benedeni* (Sukapasana, 1987). Oocysts of coccidia were also found. *S. papillosus* and *M. benedeni* were only found in 20 and 60% of the sampled sheep, respectively. All of the other endoparasites were found in 100% of samples. Moreover, the first eggs/oocysts



were found in the faeces 3–5 weeks after birth, which suggests that lambs were ingesting parasite eggs/oocysts immediately after lambing.

Churnnanpood et al. (1988) reported a case of paramphistomiasis in sheep from 40 herds in Nakomswan Province, central Thailand with morbidity and mortality rates of 50–90%. Sick animals did not respond to broad-spectrum antibiotics and sulfa drugs, or to anthelminthic drugs such as Trodax and Citarin-L. Post-mortem and histological examinations were done and many immature flukes of *Paramphistostomum* spp. were found in the upper part of the small intestine.

Recently, Chatchawal et al. (unpublished data) reported the prevalence of endoparasites in sheep flocks belonging to the Department of Livestock Development in southern Thailand and found that gastrointestinal parasites, particularly *Haemonchus contortus*, are a major constraint to sheep production in the area.

Chatchawan (unpublished data) reported the prevalence of worms in female sheep raised at Thepa Livestock Breeding Station in southern Thailand. He found that in November (season of heavy rain) the average egg count for Longtail sheep was 2041 while the average for Longtail-Barbados crossbred sheep was 1502. Moreover, 58.1% of Longtail sheep had egg counts greater than 1000, but only 43.1% of Longtail-Barbados crossbred sheep had egg counts at that level.

Goats

Endoparasites found in goats in Thailand are stomach roundworms (*H. contortus* and *Trichostrongylus* spp.), threadworm (*Strongyloides* spp.), whipworm (*Trichuris* spp.), tapeworm (*Moniezia* spp.) and coccidia (*Eimeria* spp.) (Suttiyotin 1987, Kochapakdee et al. 1991). However, the degree of infestation of these parasites should be compared in terms of percentage of infection and numbers of eggs per gram of faeces (epg), both mean and range. Suttiyotin (1988) found that the frequency of animals infected with gastrointestinal nematodes, coccidia, *Strongyloides*, *Trichuris* and *Moniezia* were 92, 83, 55, 11 and 0%, respectively. Kochapakdee et al. (1991) also found the infection with coccidia (96%), stomach roundworm (95%), *Strongyloides* (62%), *Trichuris* (19%) and *Moniezia* (4%).

Counting the number of eggs (or oocysts) in faeces is a simple way to quantify the degree of infection with parasites. In a study by Kochapakdee et al. (1991) in village goats, the average egg count of stomach roundworm was 1264, with 33% of sampled animals having counts above 1000. The average oocyst count of coccidia was 2293 and 58% of the animals had counts greater than 1000. The counts for *Strongyloides* eggs were low (295 eggs/g) and 88% of the sampled animals had counts less than 500. The findings suggest that only stomach roundworm, coccidia and *Strongyloides* are commonly found in goats in Thailand and, based on count data, that only stomach roundworms and coccidia may affect the productivity of goats.

Several factors affect prevalence of endoparasite in goats, including: season, type of management, genotype and age of the animals. Suttiyotin (1987) found that worm egg counts were higher during the monsoon months (October–December) than in the dry period. However, Kochapakdee et al. (1993a) did not find differences in counts of gastrointestinal nematodes when sampling monthly from October to January but this was probably due to higher than average rainfall occurring in January of the year of study.

The type of management system employed affects the prevalence of endoparasites. Kochapakdee et al. (1991) found that egg counts for stomach roundworms were greater for goats raised in fishing villages than for those raised in rice/rubber villages (1415 vs 1149). In fishing villages, goats typically graze together in lowland areas where conditions are well suited to parasite infestation. In contrast, most goats in rice and rubber villages are raised by tethering, with four to six per family, so the spread of parasites is low. In another study, Kochapakdee et al. (1993b) compared worm egg counts of weaned goats raised on two different research farms belonging to the university. Egg counts were much higher at the farm with wet, tall and dense pasture, ideal for larval survival and ingestion, than at the site with dry and sparse pasture.

Research suggests that animals may gain some form of immunity to worms as they get older or have a more prolonged exposure to infection. Suttiyotin (1987) reported that pre-weaned kids had higher egg counts than weaned ones (370 vs 208). Kochapakdee et al. (1991) also found that young goats with milk teeth had higher egg counts than mature goats (1523 vs 1004).

Studies of the effect of genotype on egg count had varying results. No difference in egg count was found between Thai-native goats and Thai-native x Anglo-Nubian crosses grazing together under village conditions (Kochapakdee et al. 1994). However, Kochapakdee et al. (1993b) found that egg counts of weaned goats raised under research farm conditions were 491, 1982 and 2320 for Thai-native, 25% Anglo-Nubian cross and 50% Anglo-Nubian cross, respectively. Choldumrongkul et al. (1997) and Pralomkarn et al. (1997) also found that Thai-native kids had much lower egg counts than Anglo-Nubian cross kids suggesting they have some form of genetic resistance.

Research in stations, such as the KHK research station pictured here, can provide understanding of the epidemiology and production characteristics of local and imported breeds. (S.Saithanoo)

Effects on production and blood constituents

Kids at Hat Yai farm had higher pre-weaning growth rates and weaning weights than those raised at Klong Hoi Kong farm (Kochapakdee et al. 1993b). One reason for this difference is the effect of gastrointestinal nematodes with egg counts at Klong Hoi Kong farm being higher than those at Hat Yai farm (3655 vs 117).

The effect of gastrointestinal parasites on the growth rate of Thai-native and Anglo-Nubian cross goats was studied in a village environment in southern Thailand (Kochapakdee et al. 1995b). Goats were grazed on native pasture without supplementation from 0 to 9 weeks and then provided with a concentrate supplement from 9 to 18 weeks. They were also divided into three groups according to anthelmintic treatment (untreated, 3-week interval treatment or 9-week interval treatment). The egg count of goats in the untreated group reached 1250 and remained at this level throughout the experiment. Goats treated every 3 weeks had higher growth rates than those in the untreated group or the 9-week-treated group. However, without concentrate supplementation, treated goats only gained slightly. In contrast, goats grew faster with concentrate supplementation, even the untreated ones (Table 11.1). There was no significant difference in growth rate among the genotypes during the period of no supplementation. However, when fed a concentrate supplement, the Thai-native goats had significantly lower growth rate than the 25% Anglo-Nubian or 50% Anglo-Nubian crosses (Table 11.1). Kochapakdee et al. (1993a) and Pralomkarn et al. (1994) also found that 50% Anglo-Nubian male weaners grazed on native pasture without supplement only maintained their weight, while they gained weight substantially when supplemented with concentrate. These findings suggested that without adequate nutrition, crossbred goats do not outperform the natives and that anthelmintic treatment alone does not result in increased weight gain unless the nutritional status is also improved.

Under improved management, however, no significant difference was found in the growth rate of treated and untreated female weaners (Pralornkam et al. 1994) and the average egg count was lower. The lower egg count may be due to rotational grazing every 4 weeks. This suggests that, in addition to nutrition, improved management could be a way to control parasite infestation.

Table 11.1 Least-square means for growth rate (g/kg$^{0.75}$/day) of goats with different anthelmintic treatments and genotypes

	Period of study[1]		
	0–9 weeks	9–18 weeks	0–18 weeks
Treatment			
Control	0.4^{ab}	5.4^{b}	2.9^{b}
3-week interval	1.1^{a}	11.5^{a}	6.3^{a}
9-week interval	-0.9^{b}	7.9^{b}	3.5^{b}
Genotype			
Thai-native	3.5^{b}	5.6^{a}	5.6^{a}
25% Anglo-Nubian cross	1.1	10.2^{b}	5.6^{b}
50% Anglo-Nubian cross	0.2	9.0^{b}	4.6^{b}

(1) 0–9 week: without concentrate supplement; 9–18 week: with concentrate supplement. (a, b) factors in same row with different superscripts differ significantly ($P<0.05$). Source: Kochapakdee et al. (1995b)

Four studies investigating the association between parasite infestation and blood constituents in goats have been conducted in Thailand, one in village conditions (Kochapakdee et al. 1995) and three under improved management systems (Pralornkarn et al. 1994, Pralornkarn et al. 1997, Choldumrongkul et al. 1997).

In a village where goats were continuously grazed in one paddock, Kochapakdee et al. (1995b) found that after 9 weeks of grazing, the average egg count of untreated goats was 2289 while the average for goats treated with anthelmintics every 3 weeks was only 46. Packed cell volume and haemoglobin concentration were lower in the untreated group. These findings contrast with those from goats rotationally grazed at the university farm (Pralornkarn et al. 1994) where treated and untreated goats had similar blood constituent levels. The difference between the two studies is probably due to the severity of infestation with the egg count of the untreated group in the study of Pralornkarn et al. being only 600. Under continuous gazing at the university farm, Choldurnrongkul et al (1997) did not find differences in blood constituents between treated and untreated kids either.

Pralornkarn et al. (1997) found that artificially infected weaner kids had decreased packed cell volume, haemoglobin, total protein and albumin, compared with non-infected goats. This decrease occurred between week 4 and week 9 of infection, which relates to the maturity of the worms. Moreover, weight gain of kids in this study was 36–64% lower than in control kids.

Worm control options

Anthelmintics

Anthelmintics are used extensively to control gastrointestinal nematodes in goats, especially on research/institutional farms. Fenbendazole, albendazole, ivermectin and levamisole have been used sequentially at the Prince of Songkla University farm since 1985.

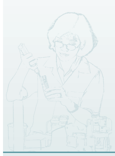
Table 11.2 Efficacy of anthelmintics used in goats, expressed as faecal egg count percentage

Anthelmintic	Study 1[a]	Study 2[b]	Study 3[c]
Albendazole	58.2	88.0	24.8
Fenbendazole	54.7	–	25.1
Ivermectin	–	93.0	98.9
Levamisole	–	98.0	94.1
Oxfendazole	63.4	–	–

Sources: a Kochapakdee et al. (1993a): b Choldumrongkul et al. (1994); c Kochapakdee et al (1995b)

Kochapakdee et al. (1993a) compared the efficacies of three anthelmintics — fenbendazole, oxfendazole and albendazole — in a village, using 24 Thai-native x Anglo-Nubian cross, weaner bucks. Choldumrongkul et al. (1994) reported a study conducted on the university farm using 24 Thai-native x Anglo-Nubian cross female weaners which compared the anthelmintics fenbendazole, albendazole and ivermectin. In another experiment 84 goats raised on the university farm were treated with albendazole, fenbendazole, levamisole or ivermectin (Kochapakdee et al. 1995). In all three studies faecal samples were collected from individual animals on day 0 and then once again 2 or 4 weeks later: on day 14 (study 2 and 3) and day 28 (study 1). The efficacies of the anthelmintics were calculated by faecal egg count reduction test (Table 11.2).

The lower efficacy of anthelmintics in study 1 may be due to the time of faecal sampling rather than to the drugs themselves. Anthelmintics had not been used in



the village previously so resistance is not likely to occur. Reinfestation of parasites may have occurred by day 28 and resulted in higher counts. In study 2, all anthelmintics were effective at reducing egg counts. However, in study three, only ivermectin was highly effective and worms showed resistance to albendazole and fenbendazole.

Both the Department of Livestock Development and Prince of Songkla University agreed that farmers should deworm their goats for the first time at the age of 8–10 weeks. After that, treatment should depend upon the severity of infestation. If animals are severely infested, they should be treated again at weaning (aged 3–4 months). Adult goats should be treated every 2–3 months during the rainy season and every 4–6 months in the dry season.

Genetic resistance

There is evidence of genetic variation in resistance to helminths between and within breeds (Gray et al. 1995). Therefore, breeding of animals resistant to internal parasites is an alternative method, complementary to other methods of control. The effect of trickle infection with a sheep strain of *H. contortus* in Thai-native, 25% Anglo-Nubian cross and 50% Anglo-Nubian cross was evaluated (Pralomkarn et al. 1997). Thai-native goats were more resistant to *H. contortus* in terms of parasitological and blood parameters compared with the Anglo-Nubian crosses. This may be due to the evolution of Thai native goats in an environment where *H. contortus* is an important parasite. In this study, a large variation among goats within and between genotypes in parasitological variables was observed. During the course of infection, Thai native goats exhibited less change in blood parameters than their crosses with Anglo-Nubian goats.

Choldurnrongkul et al (1997) also found a difference in egg count between genotypes: Thai-native kids had much lower egg counts than the Anglo-Nubian crosses.

Best-bet options in Thailand

Based on our experience in Thailand we have proposed eight best-bet options for controlling worms in sheep and goats. The best choice for individual farmers will depend upon their objectives in raising small ruminants and their available resources or the level of resources they are prepared to invest. The proposed methods are listed below.

1) Stall feeding: this option has already been adopted among farmers who raise goats for live sale, meat or milk. Many farmers already know the benefits of this option and are willing to invest the necessary resources.

2) Stall feeding and tethering: tethering alone, even when they are moved frequently, cannot supply all the nutrients animals need. Therefore, goats should be provided with extra feed, minerals or supplements during the night in the form of stall feeding.

3) Proper housing: good quality housing with an elevated slatted floor is commonly used and farmers appreciate the benefits it provides. The roof and walls should be designed to protect goats from drafts, strong winds and rain. Steps should not be too steep or slippery and ideally should have something to prevent the animals from falling down. Feed and

water troughs should be built so that animals cannot soil the feed. Some farmers light a fire under the house to keep it warm. Smoke from the fire can also repel insects and other external parasites. Fire also keeps the ground and faeces underneath dry. Mineral blocks are cheap, easily available and contain all the minerals which the animals need, so they can replace salt containers.

4) Shrub/tree leaf supplementation: plants such as leucaena (*Leucaena leucocephala*) jackfruit (*Artocarpus heterophyllus*) and *Streblus asper* have been used as fodder for goats. Many farmers believe that goats that eat grass plus tree leaves grow better and are healthier than those that eat grass alone. They believe goats obtain extra nutrients and medical compounds from the alternative forage. However, fast-growing trees like *Gliricidia sepium*, *Sesbania* (*S. sesban*; *S. grandiflora*) can also be used as a buffer for leucaena or in areas unsuitable for growing leucaena. If this option is to be adopted, it needs adequate numbers of trees to meet the amount of feed that the animals need. Trees also need to be lopped regularly and have fertiliser applied to obtain maximum production.

5) By-product supplementation: in southern Thailand, where oil palm is one of the major industries, by-products, especially palm kernel cake (PKC) or palm kernel meal (PKM), are a good source of energy and protein. These can be used as feed supplements.

Evaluation of control options under village conditions is essential. (S. Saithanoo)

6) Controlled breeding has the following objectives:
   - prevent in-breeding
   - prevent mating when breeding animals are not ready
   - mate the best males and females
   - plan on lambing or kidding at times suited to the farmers.

   For this option to succeed, good records need to be kept and an appropriate method used to keep males and females apart.

7) Medicated urea mineral molasses blocks: these are not used in Thailand although urea mineral molasses blocks have already been used for large ruminants and therefore could easily be introduced to small ruminants.

8) Rotational grazing: is one of the best options. It not only minimises parasitic infection, but also enhances pasture utilisation. However, this option needs a large area and/or more fencing. Smallholder farmers do not seem to adopt it.

Conclusions

- Endoparasites found in sheep are *Strongyloides papillosas*, *Cooperia*, *Haemonchus*, *Oesophagostomum*, *Trichostrongylus* spp., *Moniezia benedeni*, *Paramphistostomum* spp. and coccidia.
- There is no information available on prevalence, impact on production, economic impact or methods of control of endoparasites in sheep.
- Most published results on endoparasites in goats are derived from research at the Small Ruminant Research and Development Research Centre, Prince of Songkla University. The studies covered prevalence of gastrointestinal parasites, their impacts on growth as well as on blood constituents and use of anthelmintic control.
- There is evidence of nematode resistance to benzimidazole in goats raised on institutional farms.
- A study under village conditions showed that anthelmintic treatment alone did not improve performance of crossbred goats unless the nutritional status was also improved.
- One study suggests that Thai native goats are more resistant to gastrointestinal parasites than Anglo-Nubian crosses.

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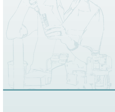


12. Goat production, parasites and testing of control options in Lao, Cambodia and Vietnam

12. Goat production, parasites and testing of control options in Lao, Cambodia and Vietnam

R.A. Sani, Dinh Van Binh, Nguyen Duy Ly, Sorn San and Viengsavanh Phimphachanhvongsod

Introduction

There is very little documentation on small ruminants in Lao, Cambodia and Vietnam. This chapter comprises information available from annual reports of these three countries which were produced according to the objectives of the IFAD TAG 443 project. The information from Lao is basically on goat production, its constraints, technical training needs and ongoing research. Cambodia had conducted a survey of goat distribution and prevalence of parasites as well as a series of trials to study the effect of nutrition on parasitism. Vietnam tested several technologies for worm control at the farmer level and assessed the impact. This chapter is devoted to describing the goat situation in these three countries as well as the related research that was conducted.

Goat production

The population of small ruminants in Lao, Cambodia and Vietnam is 150 000, 5000 and 550 000 respectively, comprising almost exclusively meat-type goats. The goat population in Cambodia was estimated very recently but the figure is likely to be only 60% of the actual population. Goats are mainly kept by village farmers with 3–10 head, 10–49 head and 6–20 head per farmer in Lao, Cambodia and Vietnam respectively. There is constant demand for goats at relatively stable prices. The price for goat and sheep in liveweight is higher than for pigs and cattle. Goat rearing requires a low labour input compared to cropping. Hence, many poor families show interest in participating in goat projects because they have available labour, the necessary feed resources and it is easy to develop as part of the traditional farming system. Goat production has a significant impact on farmer households and so goats can be a first step out of poverty.

Health problems

Diseases were the main cause of small animal mortality but the diseases were not identified in Lao. However, goat owners complained of footrot, orf (facial eczema) and worms in their stock. A survey conducted in six villages in Luang Prabang province indicated that the highest mortality of goats was in two upland villages with an average of 2.0–2.5 head per household annually. Goat mortality also appeared in two villages in the mountainous agroecosystem with an average of 1.5–2.0 head per household annually. There was

no goat mortality reported in the lowland. There are no reports on epidemiological studies of nematode infections in goats in Lao.

Foot and Mouth Disease (FMD) was the most reported disease in goats in Cambodia. There is no vaccination available for FMD. Farmers also reported deaths of goats but the causes were not known as there is no diagnostic facility in the provinces. Farmers report diarrhoea and skinny goats which may be linked to parasitic diseases. The common complaints or constraints in rearing goats were skinny goats and not enough feed which, again, may be linked to parasitic diseases and poor nutrition.

Flock productivity data from village production systems in Vietnam indicated that mortality rate of kids and immature goats was 35–45% and of adults was 8.5%. Although the exact contribution of roundworm parasitism to annual flock mortality is unknown, it was estimated that about 15% adult mortality and 51% kid mortality were closely related to gastrointestinal parasitism.

Table 12.1 Identified internal parasites of goats in Cambodia and Vietnam

Cambodia	Vietnam
Haemonchus contortus	*Haemonchus contortus*
Trichostrongylus spp.	*Fasciola sp.*
Fasciola sp.	*Trichostrongylus*
Oesophagostomum spp.	*Moniezia spp.*
Strongyloides papillosus	*Nematodirus sp.*
	Oesophagostomum spp.
	Ostertagia sp.

Cambodia and Vietnam identified the internal parasites commonly found in goats (Table 12.1). The worms are listed according to importance.

Technology options tested in Cambodia

Three trials were conducted at the University of Tropical Agriculture attached to the Royal University of Agriculture in Phnom Penh as follows:

- Effect of cassava foliage, legume foliage, banana leaves or grass on growth and nematode infestation in goats fed a high protein diet
- Effect of cassava foliage or grass on growth and nematode infestation in goats fed a high protein diet
- Effect of cassava foliage or grass on growth and nematode infestation in goats fed a low protein diet

The goats in all three trials were confined individually in raised floor wooden pens with slatted floors. Water was always available.

In Trial 1, the basal diet was fresh brewer's grains (high protein) offered at 20% above observed intakes and supplemented with the foliages fed at approximately 10% (fresh basis) of the liveweight of the Bach Thao goats. Foliage from cassava supported the highest growth rate in the goats and the lowest faecal worm egg counts. Worm egg counts were highest in goats fed the natural grasses and growth rates were 30% lower compared to cassava. Very low growth rates were observed when the legume, *Flemingia*, was fed. It was concluded that cassava has a high potential as a protein-rich feed for goats kept in confinement.

In Trial 2, a basal diet of fresh brewer's grains at a restricted level of 50% of the expected *ad libitum* intake was provided to Bach Thao goats. The supplements were foliage from cassava, cut natural grasses or a mixture of the two on a 50:50 basis given *ad libitum*. The feeds were offered twice a day. All animals were treated with ivermectin before starting the experiment. With foliage supplementations using cassava only, cassava + grass, and grass only, the average daily weight gains were 91.7g/day, 115 g/day and 80 g/day respectively and faecal egg counts were 67, 63 and 466 epg. The high growth rates and good feed conversion in this trial probably relate to the breed and higher protein content of the diet. The lower egg counts in goats supplemented with cassava suggest there is a possible direct anthelmintic effect on parasites, or an indirect effect though additional protein or condensed tannins in cassava.

In Trial 3, native goats were fed a basal diet of wheat bran (low protein) supplemented with foliage from cassava, cut natural grasses or a mixture of the two on a 50:50 basis given *ad libitum*. The animals were not dewormed except for a fourth group given grass alone, which was dewormed with ivermectin. The average daily gains were modest, mainly because the goats were slow to adapt to the cassava foliage. Worm egg counts declined steadily from initial high values in the cassava groups. However, egg counts in the grass group remained low throughout the experiment.

Considering the results of the three experiments, it would appear that cassava foliage could contain compounds — possibly condensed tannins — that are useful in preventing parasitism in goats.

Banana stems are a good feed resource but require family labour. (G.D. Gray)

On-farm technology testing in Vietnam

In Vietnam, the process of selecting technologies to be tested was to fully discuss all available options with farmer groups and, once agreed, the farmers took part in trials which were designed and run by the project team with the farmers fully cooperating and benefiting from the results. The researchers led the process and provided the technical and, in some cases, financial support. This process has resulted in some very promising and practical options which are being carried forward to participatory farmer evaluation.

Grazing compared to confinement. These two systems of managing goats were compared to study the effect of confining goats in order to prevent access to worm larval stages. All goats were treated with an anthelmintic at the beginning of the trial; one group of goats grazed freely without supplementation and the other group was confined and fed foliages. At the end of the 4-month trial period the average daily weight gain of the confined goats was 10 g more and the FEC was 40–60% less than their grazing cohorts. Although the results of the trial appeared promising, the farmers considered that confining goats was too tedious as it meant having to cut grass or foliage. They prefer goats to graze, which minimises labour.

Biological control. This option of worm control used two approaches; one was to use ducks to kill snails, which are an intermediate host of trematodes, and the other was the mechanical dragging of soil to kill pasture mites which serve as intermediate hosts of cestodes. Using ducks to kill snails reduced *Fasciola* infections by 60%. When goats were raised on farms which turned over their soil the incidence of cestode infection was lessened by 57% compared to the farms which did not practise soil turnover. This option was found to be suitable for the farmers in Vietnam because it also improves crop cultivation.

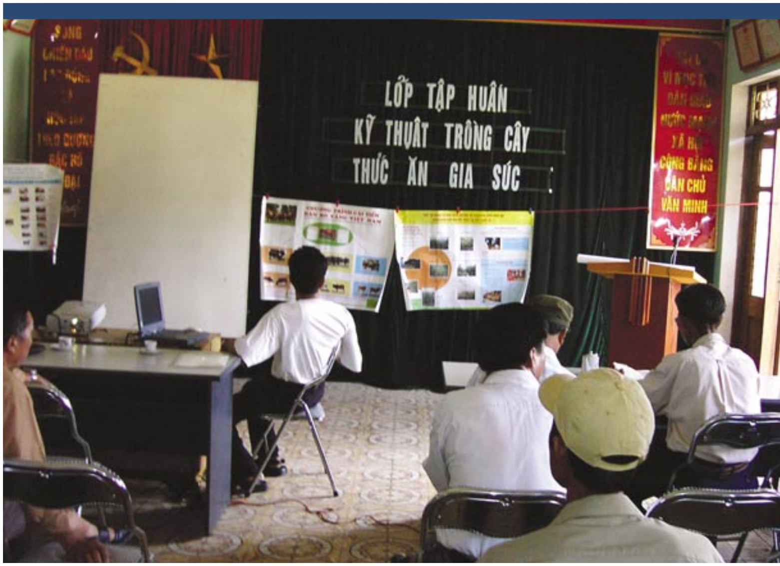
Improved nutrition. This control option was selected to study the effect of improved nutrition on the worm burden of growing goats. Six three-month-old weaner goats each on 10 farms were fed with foliage and given concentrates at 1% bodyweight. The concentrates were given twice a day; in the morning before grazing and in the afternoon after grazing. After 5 months they attained an average daily bodyweight gain of 62 g/day compared to the unsupplemented goats at 33 g/day, an improvement of over 87%. Although there was no significant difference in FEC between the two groups of animals, during the trial period the FEC in the control goats was 10–27% higher compared to the FEC of supplemented goats. Farmers understand that improved nutrition increases animal productivity and health. However, this requires investing in feeds and building of sheds. Some farmers have applied this option especially in dairy weaner goats to increase bodyweight before selling.

Sanitation. In Vietnam bad hygiene is common in traditional animal management. It is closely related to the transmission of disease and parasites. This procedure aimed to show farmers the benefits of good hygiene practices. On nine goat farms manure was disposed of daily and clean water provided while another nine farms maintained their traditional management. All goats were dewormed before the start of the trial. During the trial period of 6 months the FEC on the `clean' farms was 20% lower than on the farms not practising good sanitation. Differences in the first 3 months of the trial were much higher suggesting that the sanitation had delayed the re-infection of the animals. Bodyweight gains of the goats over the trial period were also 20% higher on the `clean' farms (60 g/day) compared to those in the traditional system (50 g/day). This study clearly demonstrated that good sanitation and the provision of clean drinking water reduced infections with worms and increased weight gains in goats under village conditions.

Improving on-farm hygiene as a measure to control internal parasites is simple to apply and maintain and will probably be adopted easily by farmers. Farmers see the benefits — diarrhoea decreases, weight gain increases and there is organic fertiliser for crops.

Chemical deworming. Farmers in Vietnam do not often use chemical drenching. The purpose of this trial was to study the efficacy and impact of conventional dewormers. The following efficacies against nematodes were found: levamisole, 80–92%; mebendazole and fenbendazole, 70–80%; and ivermectin, 75%. These results are a combination of results from 50 goats on five village farms and 50 goats from the Goat and Rabbit Research Center (GRRC). When goats were kept on farms practising good hygiene and with sufficient nutrition, deworming could be done at 7–9 month intervals; 50% of such goats had FECs of 0–1250 epg and diarrhoea was not frequently sighted, while 42% of goats kept in the traditional system had FEC of 1000–2500 epg.

Farmers in the trial obtained knowledge about chemical dewormers and on how and when to deworm. Where anthelmintics were provided to four sites to control parasites; goat production increased by about 15–20%. The technical team was also educated on the sensible use of anthelminthics and warned that frequent use of chemicals can lead to drug-resistant parasites.



Formal training courses for extension students build capacity among agriculture graduates. (Dinh Van Binh)

Breeding management. Good bucks were provided to farmers to improve breeding on the focus farms. Farmers were informed of the negative effects of inbreeding and introduced to animal management and controlled breeding. For this, they needed to build housing. Farmers were supplied 30% of the total value of a buck, while very poor farmers were supplied 100%. After 2 years, bucks were transferred to other farms. From 5 months onwards, all male kids were managed and grazed in separate areas.

After 2 years the results of using improved goat breeding showed in increased production.

Medicinal plants. Initial results indicated that mimosa, papaya and leucaena have detrimental effects on larvae of *Haemonchus in vitro*. Some plants used in the treatment of diseased animals were identified to contain anti-parasitic activity.

This option is easily available to control parasites, especially in rural areas. However more research is needed.

Applying technology options on farm

After testing and evaluating technology options for control of gastrointestinal parasites on farms, best bet options were packaged by discussion and ranking with participant farmers. Meetings with farmers were held in the villages to introduce technology options for controlling parasites that farmers could select to apply on their farms. Farmers selected options to suit their situation. To evaluate the impact of the various options, participatory assessment was done with focus and other farmers in villages with the participation of extension officers to compare between the new and old (traditional) systems. After 1 year, results are good (Table 12.2). On these farms mortality was reduced by 51%, production increased by about 69% and there was an income benefit of 56% (Table 12.3). In the new system 42% of goats had low FEC of ≤500 epg and 58% had medium to high FEC of 500 to > 3000 epg while in the old system only 11% of goats had low FEC and 89% had medium to high FEC. Therefore, in the new system 35% fewer goats had medium to high FEC. Other non-participating farmers are beginning to show interest in applying these new technologies on their farms to improve production and reap benefits.

Table 12.2 Results of goat production in Vietnam

Parameters	Old system (125 goat farms)	New system (80 goat farms)	Change (%)
Number of goats (head/farm)	13	22	69
Mortality (%)	35	17	-51
Diseases (Diarrhoea) (%)	24	10	-58
Weight gain (g/day)	37.5	46.3	23.5
Goats with FEC of 500–>3000 epg (%)	89	58	35
Level of infection (epg)	2270	1560	-32
Sanitation (%)	10	100	900
Supplement concentrate (%)	10	100	900
Supply clean water (%)	5	35	600
Deworming (%)	10	100	900
Breeding management (%)	6	75	1150

Table 12.3 Results of socio-economic change

Parameters	Old system (125 goat farms)	New system (80 goat farms)
Income (average/person/year, million VND)	2.55	3.99
Knowledge of goat husbandry (%)	30	100
Knowledge of goat health (%)	20	100
Innovative farmers (%)	20	60
Attitude change (%)	20	60
Change of habit (%)	—	60

Note: Income was measured by identifying total income (from cultivation, husbandry and other sources) and dividing by the total number of people in the household.

Constraints in goat production

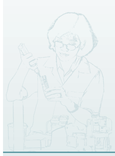
There were four main constraints according to farmers who responded to a survey in Lao and these were similar to constraints identified from discussions held with farmers in Cambodia, which were:

- Lack of knowledge about goat husbandry, health and sanitation — the problems identified were internal and external parasites, ignorance of deworming practices and not recognising disease symptoms
- Lack of feed — a shortage of animal feed during the dry season while available crop residues, fodder trees or pasture grasses as part of the livestock system were underutilised
- Lack of extension capability — to promote improved animal nutrition and husbandry
- Lack of capital — access to credit by smallholders was generally difficult and expensive

Training needs

A workshop was conducted as part of the TAG 443 project entitled `Goat Production and Management in Lao PDR' and held on 16–20 December 2002 for 24 technical and extension livestock officers from four provinces in Lao. Comments and suggestions from the workshop participants for further training were:

- practical sessions on feed formulation, faecal egg counts, slaughtering, GoatFlock computer model, making silage and mineral blocks
- information on animal drugs (including antibiotics), the use of herbal medicines and traditional treatments for animal health
- techniques on goat breeding, mating and A.I.
- improved extension and communication techniques with farmers



- information about integration of goats and crops
- information and discussion on investment for goat production, cost-benefit and goat marketing
- a specific training workshop on livestock research

The 80 goat farms in the new system are from the initial 125 farms investigated. They were monitored for 1 year applying different technology options. Data were compared using percentage change between the two systems. Gastrointestinal parasite infection was animals with worm eggs present.

13. Worm control for small ruminants in Fiji

P. Manueli

Introduction

This chapter brings together the results of small ruminant worm control research in Fiji. Where the results have not been published in the scientific literature, an attempt is made to provide as much information as possible on the research trials. If the research has been previously published, only a brief description is provided. It is hoped that the information will be useful in the design of best-bet worm control options and that, through the sharing of these results, costly duplication of research activities can be avoided.

Gastrointestinal parasites have been a constraint to small ruminant production in Fiji ever since small ruminants were introduced into the country in the 1850s. It is of interest that much of the early literature on livestock production in Fiji does not mention worms as a constraint to goat production. It is thought this is because goats tended to be reared in small herds under close supervision. However, early attempts at sheep farming in Fiji were modeled on the extensive systems of Australia and New Zealand with the aim of producing wool for export and mutton for local consumption. Under this management system worms were found to be a major constraint to the establishment of a local sheep industry. Table 13.1 contains a list of the important parasites of small ruminants found in Fiji.

Table 13.1 The important parasites of small ruminants in Fiji

Species	Site	Frequency observation[a]
Haemonchus contortus	Abomasum	+++
Trichostrongylus axei	Abomasum	+++
Trichostrongylus colubriformis	Small intestine	+++
Strongyloides papillosus	Small intestine	+++
Moniezia expansa	Small intestine	+++
Oesophagostomum columbianum	Large intestine	++
Trichuris spp.	Large intestine	+
Haemonchus similis	Abomasum	*
Haemonchus placei	Abomasum	*
Mecistocirrus digitatus	Abomasum	*

[a] +, Occasional; ++, Common; +++, Very Common; * Present in cattle and potentially infectious

13. Worm control for small ruminants in Fiji

Importance of gastrointestinal parasites

Despeissis (1922) in a paper in the Agricultural Circular entitled 'Sheep in Fiji' stated that: 'Of all pests, worms are probably the most serious'. This view was supported by Turbett (1929) who wrote: 'Worm infestation probably causes a greater loss than is recognised as, where the inspection of flocks and pastures is not carried out regularly, sheep which die are not missed until the counting of the flock at the general muster…'. By 1940 (Turbett 1940) it was apparent that of all reasons given for the failure of the sheep industry in Fiji to prosper:

> *… infestation with worm parasites was the most important.*

This view is still current today and it is generally acknowledged that worms comprise the major animal health problem limiting small ruminant production in Fiji (Walkden-Brown and Banks 1986, Manueli 1996) with *Haemonchus contortus* and *Trichostrongylus colubriformis* being the most common. Effects of worms on small ruminant production include stock mortalities, reduced animal productivity and increased production costs from preventative treatments.

The development of anthelmintic resistance in some small ruminant herds and flocks in Fiji (Banks et al. 1987) has made the importance of the development of sustainable parasite control methods imperative for the survival of small ruminant industries in Fiji.

A recent participatory survey of 34 progressive small ruminant farmers (Manueli unpublished data) indicated that worms remain a major constraint to the expansion of the small ruminant industries in Fiji. During the survey the farmers identified three dimensions of the worm problem that need to be addressed. These were:

- availability of anthelmintics
- cost of anthelmintics
- effect of worms on production.

These areas will now form the basis for worm control research and extension initiatives by the Division of Animal Health and Production.

Early research into worm epidemiology and control

The first documented report of research into helminth control in Fiji is that of Baker (1970). This report documents 5 years of research work carried out from 1965 to 1969 on the newly established Government Sheep Farm at Nawaicoba. Trials into gastrointestinal parasitism during this period include a comparison of locally available anthelmintics and the use of a rotational grazing system.

A study was conducted comparing the effects of the anthelmintics phenothiazine, thiobendazole and minitic on growth rates of yearling sheep transferred to the Animal Quarantine Station on the wet side of the island. Lamb liveweight gains did not increase greatly after treatment with any of the specified drugs nor was there any retardation in weight gain in animals in the period before the next anthelmintic treatment. No information is available on the total worm burdens or faecal egg counts of animals in the trial although it is reported

that larvae of all of the normal species of bowel worms were cultured and that eggs of *Dicrocoelium dendriticum* were seen in one faeces sample. The results of the trial indicated that worms were not a major problem with yearling stock in the wet zone.

The development of a rotational grazing system was also studied during this period. Unfortunately there is little available information on the design of the trials and no parasitologcal data are presented in the report.

The results of the research indicated that the adoption of a system of grazing paddocks for 4 days followed by a 28-day spell was effective for controlling parasites in adult stock, and that only two to three drenches a year are needed to maintain health.

At the conclusion of the research program recommendations on parasite control made to farmers were to:

- rotationally graze all stock as far as possible given economic constraints on building fences
- drench adult stock as necessary and definitely once before the start of the wet season, once during the wet season and once again after the wet season
- drench growing stock fortnightly during the wet season and monthly during the dry season
- alternate anthelmintics used for successive drenches.

Soil erosion from overgrazing can be prevented by providing supplementary forages in the dry season. (ACIAR)

Singh et al. (1972) compared suppressive fortnightly anthelmintic treatment as recommended by Baker (1970) for growing stock with a 30-day rotational grazing system using five paddocks. The 9-month trial used four groups of animals: set stocked undrenched (SU), set stocked drenched (SD), rotationally grazed undrenched (RU) and rotationally grazed drenched (RD). The mean liveweights of the RD and SD groups were found to be higher at the completion of the trial than those of the SU and RU groups. Egg counts of all groups were recorded at 4-weekly intervals. Egg counts of the SU and RU groups were higher than those of the RD and SD groups at all stages of the trial, and eggs were recovered from the faeces of animals in SU and RU groups more frequently than in the SD and RD groups. Some sheep in the undrenched groups needed to be drenched three or four times during the trial to prevent deaths. From these results Singh et al. (1972) concluded that helminth control was absolutely necessary for sheep rearing in Fiji, that it would be feasible to drench animals less frequently than fortnightly, and that rotation with a 4-weekly resting period was useless.

13. Worm control for small ruminants in Fiji

With the initiation of a series of ACIAR-funded collaborative research programs between the Ministry of Agriculture (Fiji) and CSIRO (Australia) in 1984 the level of parasitology research in Fiji increased. The series of four projects, starting in1984, covered a wide range of topics and were titled as follows:

- ACIAR PN8418: The epidemiology and control of gastrointestinal nematodes of small ruminants in the Pacific Islands
- ACIAR PN8913: Ecological and host-genetic control of internal parasites of small ruminants in the Pacific Islands
- ACIAR PN8523: Self-medication of ruminants in tethered husbandry systems
- ACIAR PN9132: Nutritional and chemotherapeutic strategies for sustainable control of gastrointestinal parasites of ruminants

ACIAR PN8418: The epidemiology and control of gastrointestinal nematodes of small ruminants in the Pacific Islands

Survey for anthelmintic resistance

Twenty-four herds were surveyed for anthelmintic resistance. Management practices varied from tethering through uncontrolled grazing to fenced commercial farms. A random selection of 40 goats or sheep on each farm were used to evaluate the effects of anthelmintic treatment on faecal egg counts. Ivermectin was the only drug to which no parasite resistance was found with 54% of the farms carrying strains of parasites resistant to either fenbendazole, levamisole or a combination of both levamisole and fenbendazole (Banks et al. 1987).

Seasonal fluctuations of larvae on pasture

The research trial investigated the survival and seasonal pattern of egg hatching of *H. contortus* and *T. colubriformis* on pasture at two sites, wet zone and dry zone (Banks et al. 1990). Each month, a separate pasture plot at each site was contaminated at weekly intervals with *H. contortus* and *T. colubriformis* eggs. The plots were sampled at regular intervals and the infective larvae identified and counted.

Infective larvae numbers on pasture were highest 7 days after the last contamination and there was considerable seasonal variation in the survival of larvae on pastures. In the wet zone, survival was shorter in the wet season (5–9 weeks) than the dry season (13–17 weeks). Larval survival on the dry zone plots was found to be much more variable. *T. colubriformis* larvae were found on pasture in all months except the 2 driest (August and September). The survival of *H. contortus* larvae on pasture appeared to be more sporadic possibly in response to changes in available moisture.

Effect of season on egg hatching on pasture

The development of worm eggs and larvae on pasture was investigated. Pasture plots were contaminated with known numbers of parasite eggs in the faecal pellets of naturally infected does. Recovery of eggs and larvae from faecal pellets on pasture at 12-hour intervals was carried out in July, October, January and April.

By 72 hours after exposure to parasites 97% of eggs had developed to the first larval stage, with the first third-stage larvae (L3) appearing by 96 hours after contamination. Development to the L3 stage appeared to occur faster in January and April (96 h) than in July and October (144 and 108 h respectively) (ACIAR, 1990a).

Natural history of trichostrongylidosis in goats

The experiment investigated seasonal patterns of worm burdens and the effects of physiological status in grazing goats in the wet and dry zones of Fiji over a 12-month period. Groups of 20 does were set stocked on paddocks in the dry (five does/acre) and wet (10 does/acre) zones of Fiji and drenched at 6 and 4-weekly intervals, respectively, to maintain health. Every 2 months, four young worm-free tracer animals were introduced to the herds for 2 months and then slaughtered. In May and June worm-free dry (four) and lactating (four) does were introduced into the herds for 2 months and also slaughtered.

H. contortus and *T. colubriformis* were the dominant parasite species but *Oesophagostomum columbianum* and *Taenia ovis* were also sometimes found. Tracers became infected throughout the year although worm burdens were higher in the wet zone. Mean worm counts varied considerably from month to month at both sites and no reliable pattern of infection was detected, although it appeared that *H. contortus* and *T. colubriformis* burdens were highest during the cool months (July and August) in the dry zone. Worm counts of mature dry does appeared to be similar to those of young growing animals indicating that there was little development of age resistance. Differences in worm counts between lactating and dry does were small, which was indicative of an absence of immunity. There was no evidence of arrested development in *H. contortus* indicating that development to adult stages occurred throughout the year (ACIAR 1994).

In larger sheds, pregnant, non-pregnant and young animals can be fed separately. (ACIAR)

Simulation model of parasites on pasture

Data collected from epidemiological studies was used to develop a simulation model of parasites on pasture. Development of the simulation model was then continued in a following project, ACIAR 8913 (ACIAR 1988).

Testing potential worm control measures in goats — Phase 1

Trials were carried out in the wet and dry zones to compare the following three treatment regimes:

1. NORM — normal control measures of 4-weekly (wet zone) and 6-weekly (dry zone) drenching in set-stocked goats
2. RG — rotational grazing where animals grazed a paddock for a period (4 weeks in the wet zone, 6 weeks in the dry zone) before being drenched and moved to a second paddock while the first was spelled for an equivalent period of time
3. SD — strategic drenching using 6 fortnightly drenches of ivermectin, with a dose of closantel administered with the last dose of ivermectin.

In the wet zone, faecal egg counts and larval cultures showed no differences between the RG and NORM treatments with larval cultures indicating that *H. contortus* and *T. colubriformis* were present. Egg counts of the SD animals were low (but never falling to zero) during the drenching period, and increased as soon as drenching had ceased, necessitating the termination of the SD treatment 7 months later. In the dry zone both the NORM and RG treatments had low egg counts over the duration of the trial and this may have been due to low levels of pasture contamination resulting from the drought before the start of the experiment. There were no differences between either the NORM and RG treatments in egg counts, although liveweight gains were slightly lower in the RG group (ACIAR 1988).

Testing potential worm control measures in goats — Phase 2

The following three treatment regimes were compared in the wet and dry zones:

1. NORM — as above
2. RRG — rapid rotational grazing of eight paddocks with animals grazing a paddock for 4 days before resting the paddock for 28 days
3. SD — as above.

Individual animals in NORM and RRG groups were drenched when their egg counts exceeded 1000 epg.

In the wet zone, egg counts of NORM animals exceeded 1000 epg three and five times, respectively, in the two replicates. In the dry zone animals in the NORM replicates required 10 and seven drenches, respectively. Egg counts of SD animals remained low until 25 weeks after the start of the trial (13 weeks after the last closantel dose). They then rose to levels similar to those in the NORM group. Animals in the RRG group needed less frequent drenching than the NORM animals with replicates in the dry zone needing four and six treatments, and replicates in the wet zone needing two and nil treatments, respectively (ACIAR 1990a).

Sustained release capsules for worm control

Goats

Two groups of 10 does were grazed on pastures naturally infected with *H. contortus* and *T. colubriformis*. Five does in one group received ewe-strength albendazole capsules containing 3.85 g of albendazole (ET) and five were maintained as controls (EC). Five does in the second

group received lamb strength capsules containing 2.1 g of albendazole (LT) and five does were maintained as controls (LC). The capsules were designed to release the anthelmintic over 3 months. Forty-eight hours after capsules were inserted all does were drenched with a double dose of ivermectin (400 ug/kg) to remove adult worms.

The use of both lamb and ewe albendazole capsules appeared to delay the establishment of patent infections by 2 weeks in comparison to controls, however, after 6 weeks the egg counts of treated animals were equal to or greater than those of control animals. The experiment was terminated after 8 weeks as the capsules were clearly unsuitable for use in goats (ACIAR 1988).

Sheep

Forty ewe hoggets naturally infected with *H. contortus* and *T. colubriformis* were drenched with ivermectin and allocated to one of two paddocks. One group of 20 ewes received ewe strength albendazole capsules containing 3.83 g of albendazole (ET). The other group acted as a control and was drenched every 8 weeks. The albendazole capsules totally suppressed the production of parasite eggs in the faeces of treated animals for 120 days. This suppression occurred in spite of the fact that capsules used were '90 day' (ACIAR 1990).

Minimal drenching program for sheep

The entire sheep flock at the Nawaicoba Station was converted to a minimal drenching program. This involved drenching lactating ewes three times during lactation, lambs and hoggets monthly, and dry ewes only when they had signs of infection. After a year, only 19 of the 600 ewes had required anthelmintic treatment over and above the treatments allocated to lactating ewes (ACIAR 1990a).

The gums of sheep and goats made anaemic by Haemonchus are pale and can be examined quickly. (ACIAR)

Transmission and identification of *Mecistocirrus digitatus* in goats

Mecistocirrus digitatus had previously been identified in cattle in Fiji but not in goats. Eggs were recovered from female worms from the abomasum of cattle at slaughter and incubated for 8 days in a sterile culture medium. Infective larvae were recovered and used to infect two goats (200 larvae/goat). The *M. digitatus* larvae exhibited only a low ability to establish in goats (ACIAR 1990).

Night yard trials in goats

Sixty mature does were drenched with a double dose of ivermectin (400 ug/kg) at the beginning of the dry season and allocated to one of two treatment groups: night yarding (N) or shedding at night (S). The animals grazed the same pastures but were separated at night when they were either locked in a shed (S) or a night yard (N). Does in both groups had similar worm burdens, despite the fact that infective larvae numbers were much higher in the night yard than in the pasture ones (ACIAR 1988).

Faecal egg count heritability pilot study

A pilot study was done to estimate the heritability of faecal egg count in goats. Blood and faecal samples were taken from 129 kids, 3–4 months old and sired by six bucks on a government goat station, 6 weeks after they had been drenched with ivermectin. Significant effects of sire were seen on egg counts and haemoglobin, but not packed cell volume. The heritability of egg count was estimated at 0.45. Investigations into the heritability of faecal egg count were continued in ACIAR Project 8913 (ACIAR 1988).

Age resistance of sheep to internal parasites

Twenty weaner lambs, 20 dry ewes and 20 lactating ewes were drenched with ivermectin and grazed together on a 15 ha paddock naturally infected with *H. contortus* and *T. colubriformis*. Ten dry ewes, 10 wet ewes and 10 weaners were slaughtered after 2 months to obtain worm counts. After slaughter, 10 additional weaners were added to the group (lactating ewes had since dried off) leaving the group composition at 20 dry ewes and 20 weaners. Faecal egg counts were monitored.

At slaughter, total worm counts for weaners differed significantly from those of dry ewes. Egg counts of weaners gradually decreased over time. At the termination of the experiment weaner egg counts had not yet fallen to the same levels as those of the ewes. By this time weaners were 14-months old indicating that age resistance had not yet developed (ACIAR 1990a).

ACIAR PN 8913: Ecological and host-genetic control of internal parasites of small ruminants in the Pacific Islands

Project 8913 was designed to build on the results of the epidemiological studies of ACIAR project 8418. In addition, the project investigated the heritability of faecal egg count in goat and sheep populations in Fiji to examine the feasibility of breeding for parasite resistance.

Pharmacokinetics of albendazole in small ruminants

Six goats and six sheep were maintained under controlled conditions and fed a complete ration for a period of 2 weeks. Each animal received a single intra-ruminal dose of 7.5 mg/kg albendazole directly into the rumen and 10 ml blood samples were collected at 0, 2, 4, 8, 12, 24, 30, 36, 48, 72, 96 and 120 hours after dosing. Two of the sheep were not included

in the analysis as no anthelminitic was detectable in their plasma samples. The systemic availability of albendazole metabolites was the same in both goats and sheep. Peak albendazole sulphone levels occurred earlier, and fell off faster, in goats than in sheep, indicating a faster rate of albendazole metabolism in goats (ACIAR 1994).

Host genetic control of internal parasites

The results of investigations into host genetic controls have previously been published in the scientific literature (Woolaston et al. 1995, Woolaston et al. 1996, Woolaston et al. 1992) and so will only be discussed briefly.

Goats

Faecal egg count data were collected from 1513 weaner goats (<365 days old) and 951 adult (>365 days old) goats on government research stations from 1988 to 1992. During 1988 and 1989 animals were carrying naturally acquired, mixed parasite infections, but in 1991 and 1992 animals were treated with closantel 1 month before sampling. Goats were treated to remove *H. contortus* from their worm burdens in an attempt to minimise between animal variation in the ratios of *H. contortus* and *T. colubriformis*.

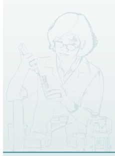
There appeared to be an effect of age on egg count (adult: 508 epg, weaner: 1385 epg) indicative of a possible age-acquired immunity to parasites. Birth status appeared to affect egg counts with twins and triplets having higher values than singles. Heritability estimates of faecal egg count obtained in both weaners and adult goats did not differ significantly from zero.

A good quality ram with little wool cover and good conformation. (ACIAR)

Haematological data collected in 1988 and 1989 when *H. contortus* was present in the worm burden indicated that neither packed cell volume nor haemoglobin measures were of use as indicators for resistance. It was concluded that there was very little scope for within-herd genetic improvement.

Sheep

Egg-count data were collected from a total of 1826 weaner sheep from 1988 to 1993. During 1988 and 1989 the sheep were carrying naturally acquired mixed parasite infections, but from 1991 to 1993 *H. contortus* was removed by drenching with closantel 4–6 weeks before sampling.



Age (younger<older), sex (female<male) and year affected egg counts. Heritability estimates for the pooled data were 0.23 ± 0.07. The results indicate that there is a good chance of selecting for reduced faecal egg count. Faecal egg count has since become a criterion for the selection of replacement rams on government sheep stations.

Haematological data from the 1988 and 1989 samplings showed that the 'Fiji Sheep' had higher PCV values than pure-bred Barbados Blackbelly sheep, but there were no breed effects on haemoglobin values or faecal egg counts.

Haematological data from the 1991–93 weaners showed significant sex (male>female) and age (older>younger) effects on circulating eosinophil counts, however neither breed nor sire effects could be detected. There was a negative phenotypic correlation between faecal egg count and eosinophil count suggesting that eosinophil counts would be of little value as indicators of resistance.

ACIAR Project 8523: Self medication of ruminants in tethered husbandry systems

Several experiments investigated the use of urea molasses blocks as a delivery mechanism for fenbendazole in small ruminants in goats and sheep over the duration of the project. As resistance to fenbendazole had already been detected on some goat farms in Fiji, the research program hoped to increase the efficacy of the fenbendazole by delivering it in a feed block. This was seen as a potential way to maintain high blood levels of fenbendazole metabolites to increase its effectiveness against worms that had already developed some levels of resistance to the drug.

Fenbendazole dose-rate trial in goats

The initial trial carried out during the program was aimed at determining appropriate daily fenbendazole (FBZ) dose rates to control worms in goats as a simulation of the delivery of FBZ using a medicated block. The trial was carried out using dry adult does (mean liveweight 35 kg) which were divided into four groups of 5, 5, 5 and 4 animals and treated daily with doses of 0, 0.75, 1.5 or 5 mg/kg liveweight of FBZ, respectively, for 6 weeks. Faecal egg counts were monitored weekly and group larval cultures grown to determine the species composition. The results indicated that at a dose rate of 3.0 mg/kg FBZ was able to reduce egg counts and the production of viable larvae to zero (ACIAR 1990b). From the dose-rate trial, urea molasses blocks were formulated and FBZ powder incorporated at a rate of 0.75 g/kg of block. The blocks were then used in field trials in goats and sheep to test their efficacy.

Fenbendazole-medicated feed blocks in goats

A 36-week experiment compared three treatment groups of 20 animals each. Group 1 was given unrestricted access to FBZ medicated urea molasses blocks (FBZ-UMB); group 2 was given unrestricted access to unmedicated urea molasses blocks (UMB); and group 3 was kept under normal station management (NORM), which included supplementation with 250 g/head/day

of a 50:50 coconut meal to mill mix ration. Individual animals whose egg counts exceeded 1000 epg were drenched to maintain good health.

Results indicated that the medicated blocks were efficacious in controlling egg counts: on average, animals in the FBZ-UMB group required only 1.9 treatments per animal to maintain health as compared with 7.25 for the UMB and 7.35 for the NORM groups. FBZ-UMB and NORM groups exhibited similar and significantly higher liveweight gains than those of the UMB group. For the NORM group this is thought to be due to nutritional supplementation. Analysis of plasma fenbendazole levels in the FBZ-UMB varied between individual animals, which indicated variations in block intakes (ACIAR 1991).

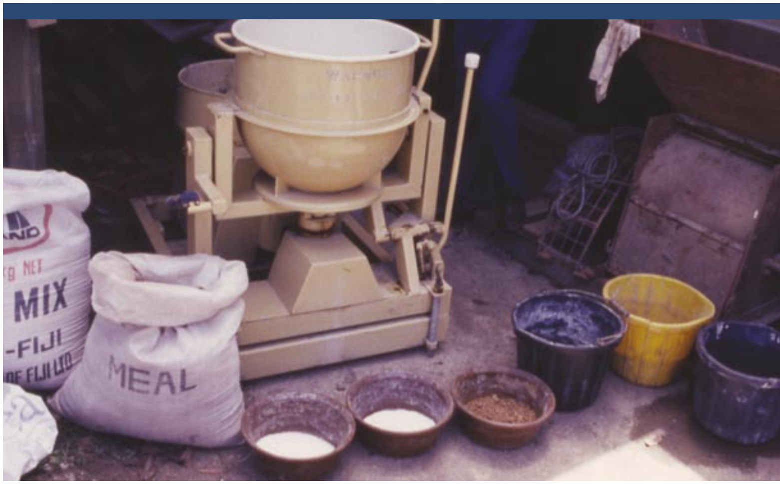
Alternate strategies for fenbendzole-medicated feed blocks in goats (A)

Sixty yearling does from the previous experiment were dosed with ivermectin and allocated to one of the following three treatment groups (two replicates/treatment):

1. FBZ-UMBAUR — unrestricted access medicated blocks
2. FBZ1-UMB2 — access to medicated block for 1 week, then unmedicated block for 2 weeks
3. FBZ1-UMB3 — access to medicated block for 1 week, then unmedicated block for 3 weeks.

Individual animals were drenched when their egg counts exceeded 1000 epg.

FBZ-UMBUR animals had lower egg counts than other animals on most occasions. Numbers of animals requiring drenching over the 22 weeks of the trial were 12, 36 and 26 per respective group. Average body weight gains for the period were 6.3 kg, 5.0 kg, and 4.5 kg, respectively and average medicated block intakes were 4.0 g/head/day, 31.9 g/head/day, and 13.4 g/head/day (ACIAR 1992).



A wide range of ingredients can be incorporated into urea molasses blocks for manufacture on farm and in small enterprises. (ACIAR)

Alternate strategies for fenbendazole-medicated feed blocks in goats (B)

This experiment was similar in design to the previous experiment but a fourth group, managed as per normal station practices (4–6 weekly drenching and daily supplementation 150 g/head/day of a 50:50 coconut meal to mill-mix ration), was included (NORM). FBZ-UMBUR, FBZ1-MB2 and FBZ1-UMB3 treatments had lower egg counts than the NORM treatment throughout the trial. Drenching of animals was done on 30, 24, and 26 occasions for the FBZ-UMBUR, FBZ1-MB2 and FBZ1-UMB3 treatments, respectively, compared with 81 for the NORM treatment. *H. contortus* and *T. colubriformis* dominated larval cultures. Body weight gains were 3.0 kg, 3.1 kg, 3.6 kg and 6.6 kg, respectively (ACIAR 1992).

Fenbendazole-medicated feed blocks in periparturient goats

Sixty-four pregnant does were divided into two even groups and allocated to separate 7 ha pasture plots. The experiment began mid-May and the does were expected to kid in the last week of June. Does in one group (FBZ-UMB) were given access to unmedicated blocks until one month before their expected kidding date, when they were drenched with ivermectin and their blocks were changed to medicated. No does were drenched unless they showed clinical signs of infection. The second group was subjected to normal station management including regular drenching (NORM).

Egg counts of the FBZ-UMB group were lower than those of the NORM group on all occasions. They also needed fewer drenches than the NORM group (25 and 78, respectively). *H. contortus* and *T. colubriformis* dominated larval cultures. Average doe liveweights and kid birthweights were similar for the two treatments. Weaning weights of the NORM group were higher as a result of their access to coconut meal supplements from birth; kids of the FBZ-UMB group were not supplemented during the trial (ACIAR 1992).

Urea molasses blocks can be mixed by hand in a drum or in a small concrete mixer. (ACIAR)

Fenbendazole-medicated feed blocks in periparturient sheep (A)

Sixty pregnant female sheep were allocated to the following three groups:

1. FBZ-UMB — medicated blocks
2. UMB — unmedicated blocks
3. CON — no blocks.

All animals were grazed during the day and housed at night. The FBZ-UMB and UMB had access to their blocks at night. A fourth group was later selected from the general herd for comparison. They were not housed at all but subjected to normal station management (NORM). The trial was run for 18 weeks.

Animals in the FBZ-UMB group tended to have lower egg counts throughout the trial. The UMB group had lower egg counts than the CON and NORM, though it was necessary to drench all UMB animals in week 12 to prevent mortalities.

Block intakes in the UMB group over the duration of the trial were much higher than in the FBZ-UMB groups. There was no significant effect of treatment on ewe body weights, but there was a major difference in the weight of lambs at weaning. Lambs of the UMB group were 5 kg heavier than those of the FBZ-UMB and CON groups. The weaning weights of the lambs of the NORM group were a further 2 kg behind the FBZ-UMB and CON groups. There appeared to be a benefit from improved nutrition in both egg count and weaning weights in the UMB treatment. Low block consumption appears to have limited the effectiveness of the FBZ-UMB in this trial. At weaning the ewes were removed from the trial and the lambs retained in their treatment groups for experimentation (ACIAR 1991).

Fenbendazole-medicated feed blocks in lambs after weaning (A)

Lambs weaned from ewes in the previous experiment remained in their respective treatment groups (FBZ-UMB, UMB, CON and NORM). If group sizes were not even, additional lambs of similar weights and ages were added. Animals not receiving blocks were supplemented with a 50:50 coconut meal to mill-mix ration as per normal station management.

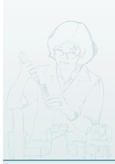
Animals in the NORM treatment exhibited high egg counts and needed to be drenched monthly. Over the trial period egg counts were lowest in the UMB group followed by the FBZ-UMB, CON and NORM treatments. The lower egg counts in the UMB group appear to be due to improved nutrition as a result of access to the blocks. During the trial, block intakes in the UMB group were much higher than the FBZ-UMB group. Liveweight of UMB lambs was higher than those of other groups at the completion of the trial but this appeared to be due to their higher initial liveweights (ACIAR 1992).

Fenbendazole-medicated feed blocks in periparturient sheep (B)

Sixty pregnant ewes were dosed with Ivomec and then allocated to one of two treatment groups and grazed in separate 2 ha paddocks. One group had access to medicated blocks (FBZ-UMB) in its night shed, the other to unmedicated blocks (UMB). Egg counts were significantly lower in the FBZ-UMB group on all occasions. It was not necessary to treat any of the ewes and the FBZ-UMB effectively suppressed the periparturient rise in egg count.

Ewes in the UMB group all needed to be treated in the third month of the trial. FBZ-UMB block intakes were higher than for UMB (38.8 g/head/day vs 1.4 g/head/day). *H. contortus* and *T. colubriformis* dominated larval cultures, *Oesphagostomum* spp. was also present in small numbers.

Ewe liveweights and lamb birth weights were not significantly affected by treatment, but lamb weaning weight at 3 months of age was significantly higher in the FBZ-UMB treatment than the UMB treatment (17.2 kg vs 14.6 kg). At weaning, the ewes were removed from the trial and the lambs retained in their treatment groups for further experimentation (ACIAR 1992).



Fenbendazole-medicated feed blocks in lambs after weaning (B)

Lambs born in the previous experiment were retained in their respective treatment groups (FBZ-UMB and UMB). If group sizes were not even, additional lambs of similar weights and ages were added. All animals were drenched with ivermectin at the start of the trial. Individual animals with egg counts above 4000 epg received salvage treatments. A breakdown of the block mixer meant that blocks were not available for the FBZ-UMB and UMB groups for 55 and 38 days, respectively, though average daily block consumption was similar for both treatments (40.3 g/head/day and 47.4 g/head/day).

Egg counts were significantly lower in the FBZ-UMB group than the UMB group. *H. contortus* and *T. colubriformis* dominated larval cultures. At the completion of the trial the initial 2.6 kg weaning weight advantage of the FBZ-UMB group had increased to 4.3 kg with the FBZ-UMB group weighing 30.1 kg and the UMB group weighing 25.8 kg (ACIAR 1993).

ACIAR PN9132: Nutritional and chemo-therapeutic strategies for sustainable control of gastrointestinal parasites of ruminants

Project 9132 was an extension of project 8523. A trial was carried out to investigate the possibilities of using medicated and unmedicated blocks to control worms in goats managed in a rapid rotational grazing program.

Fenbendazole-medicated feed blocks in conjunction with rapid rotational grazing

This experiment was designed to test the use of medicated blocks in conjunction with rapid rotational grazing in a 10-paddock, 35-day rotation scheme. Sixty pregnant does were allocated to one of three treatment groups each with two replicates of 10 does per group:

1. FBZ-UMB35 — rotational grazing with medicated blocks for the first cycle of rotation
2. FBZ-UMB70 — rotational grazing with medicated blocks for the first two cycles
3. UMB — unlimited access to unmedicated blocks.

A separate group of 20 does, maintained under normal station management (NORM), were kept nearby. NORM does were fed a ration of 250 g/head/day of a 50:50 coconut meal to mill-mix ration from 28 days before their expected kidding date, until the end of the trial, which ran for 30 weeks. Animals with egg counts above 1000 epg were drenched to maintain good health.

Does in the FBZ-UMB70 treatment had significantly lower egg counts over the period of the trial. During periods when the FBZ-UMB70 and FBZ-UMB35 treatments had access to medicated blocks no parasite eggs were detected in their faeces. Goats in the NORM treatment had the highest egg counts at all times, followed by the UMB treatment. Numbers of animals requiring anthelmintic treatment to maintain health were 6, 25, 38, and 25 for the respective treatment groups. Doe liveweights at the completion of the trial in the FBZ-UMB70, FBZ-UMB35 and NORM treatments were

similar, but liveweights of does in the UMB treatment were lower. A similar pattern was seen in the liveweights of kids at weaning.

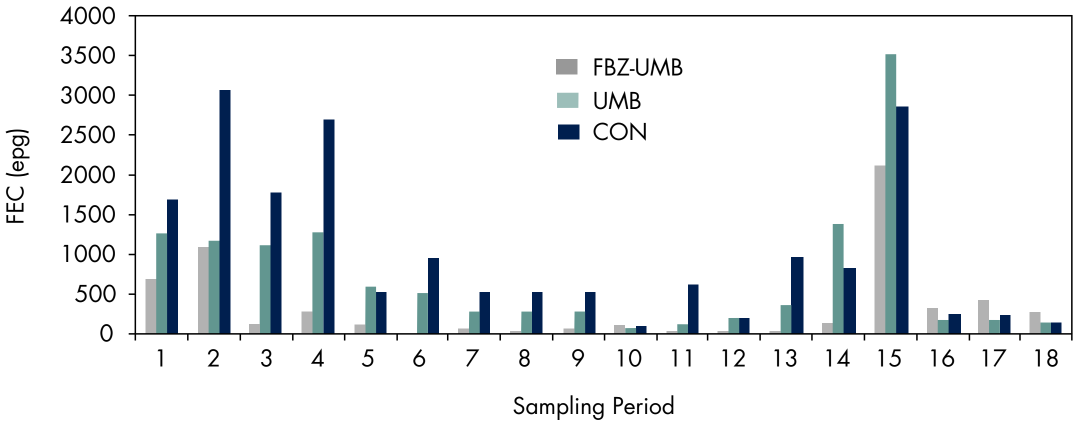
Nutritional supplementation given to the NORM group appears to have been sufficient to compensate for the losses in production seen in the UMB treatment. This resulted in final doe liveweight and mean kid weaning weight being similar to those of the FBZ-UMB70 and FBZ-UMB35 treatments.

Effect of worm control and nutrition on development of young ewes (9132 A)

Manueli et al. (1995) investigated the effects of worms and nutrition on young Fiji sheep at pasture. Six groups of 30 ewes (11 months old) were each placed into 2 ha paddocks. Two groups were allowed unlimited access to medicated blocks (FBZ-UMB at 0.75g FBZ/kg), two groups to unmedicated blocks (UMB) and two received no supplementation (CON). Animals with egg counts above 3000 epg were drenched with anthelmintic to avoid unnecessary mortalities. Egg counts were lowest for the FBZ-UMB group and highest for the CON group, while the UMB group was intermediate (Figure 13.1).

During the experiment it was necessary to salvage treat FBZ-UMB, UMB and CON ewes 13, 55 and 92 times, respectively. Larval cultures indicated that *Haemonchus* spp. and *Trichostrongylus* spp. were dominant. *Oesophagostomum* spp. were also present but in low numbers. At mating, after 7 months of experimentation, the FBZ-UMB and UMB groups had gained more weight than the CON group (10.5 kg, 10.0 kg, and 5.8 kg,

Figure 13.1 Trends in Faecal Egg Counts 9132A



respectively). Ewe conception rates, lambing percentages and total weight of lambs weaned were increased by FBZ-UMB and UMB with the former providing a greater increase. The benefits in reproductive performance are thought to be caused by the higher mating liveweights of the FBZ-UMB and UMB groups. The large benefits in total weights of lambs weaned per treatment are caused by nutritional benefits from UMB and the benefits of worm control and nutrition in the FBZ-UMB treatment (Table 13.2). In comparison with unsupplemented controls, weight of lambs weaned per treatment was increased by 82% and 138% for the UMB and FBZ-UMB treatments, respectively.

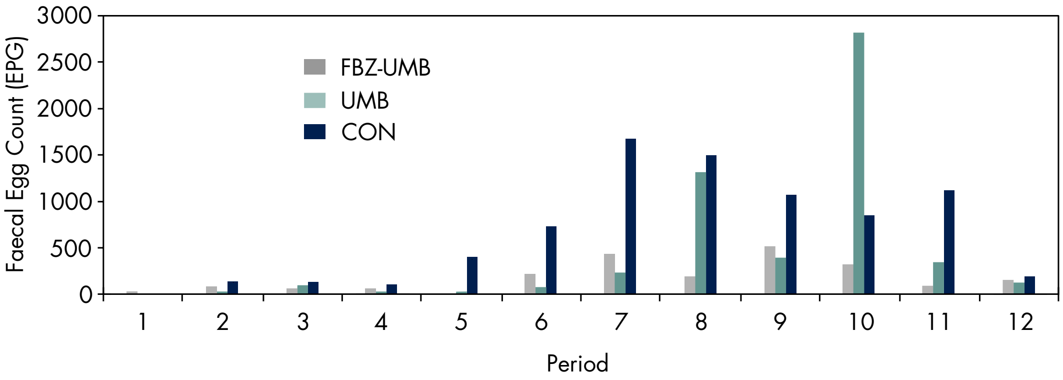
At the completion of the trial the ewes were returned to the main flock and subjected to normal station management. An investigation of their performance

Table 13.2 Effect of Fenbendazole-medicated and unmedicated feed blocks on reproductive and lambing performance

	FBZ-UMB	UMB	CON
Ewes lambing	40	34	22
Lambs born	44	40	24
Total weight born (kg)	144	126	66
Lambs weaned	40	39	20
Lamb weaning weight (kg)	13.2	10.4	11.1
Total weight weaned (kg)	528	405	222
Lamb mortality rate (%)	9.1	2.5	16.6

FBZ-UMB = urea molasses feed block containing fenbendazole, UMB = urea molasses feed block with no anthelmintic added, CON = control, no block

Figure 13.2 Treatment Effects on Faecal Egg Counts 9132B



in the 1995 lambing season reveals no significant differences in pre-mating liveweights or their subsequent reproductive performance, indicating that there is no carryover effect of early suppressive anthelmintic control (FBZ-UMB) or nutritional supplementation (UMB) on ewe reproductive performance.

Effect of worm control and nutrition on lambing performance of maiden ewes (9132 B)

The results of the previous experiment demonstrated the benefit of the continuous use of the medicated blocks. A second trial was designed to investigate the effects of strategic use of the fenbendazole medicated blocks (FBZ-UMB) to reduce usage of the anthelmintic and costs and to avoid possible problems of drug resistance that could develop with the extended use of the fenbendazole blocks. Manueli et al. (unpublished) tested a program of short-term use of FBZ-UMB in conjunction with unmedicated blocks (UMB) to determine the optimal time for their prophylactic use. A group of 150 ewes (15-months old) were divided into six even groups according to bodyweight and allocated to 2 ha paddocks. The two groups were given:

- unlimited access to UMB for 8 weeks
- substitution of UMB with FBZ-UMB (0.75g FBZ/kg) 4 weeks before, and 7 weeks during, mating
- return to UMB until 4 weeks before parturition, and then
- access to FBZ-UMB again until lambs were weaned.

Another two groups had unlimited access to UMB and the remaining two groups received no supplementation (CON). Animals whose egg counts exceeded 3000 epg were drenched with anthelmintic to avoid unnecessary mortalities. Egg counts were lowest for the FBZ-UMB group and highest for the CON group while the UMB group was intermediate (Figure 13.2).

Table 13.3 Effect of fenbendazole-medicated and unmedicated feed blocks on lambing performance

	FBZ-UMB	UMB	CON
Lambs born	46	43	41
Total weight born (kg)	173	146	134
Lambs weaned	36	31	19
Total weight weaned (kg)	537	382	206
Lamb mortality rate (%)	21.7	28	53.6

FBZ-UMB = urea molasses feed block containing fenbendazole, UMB = urea molasses feed block with no anthelmintic added, CON = control, no block

During the experiment it was necessary to salvage treat individual FBZ-UMB, UMB and CON ewes 4, 14 and 32 times respectively. Larval cultures indicated that *Haemonchus* spp. and *Trichostrongylus* spp. were dominant and that *Oesophagostomum* spp. were also present but in low numbers. Treatment differences in ewe reproductive performances and liveweights during the experiment were not significant. Treatment had a substantially positive effect on numbers of lambs weaned and the total weight of lambs weaned (Table 13.3).

Effect of worm control and nutrition on performance of periparturient maiden ewes

The results of trials 9132A and 9132B clearly demonstrated beneficial increases in weight gain by using FBZ-UMB and UMB compared with unsupplemented controls. However, the experiments failed to clearly identify the mechanisms by which the benefits accrued. In an attempt to identify the mechanism by which this occurred, Manueli et al. (unpublished) investigated the effects of FBZ-UMB on the growth of lambs and the milk production of ewes. Seventy-two pregnant, 21-month old, Fiji ewes were divided into six even groups according to bodyweight and allocated to 1 ha paddocks. Two groups had unlimited access to FBZ-UMB (0.75g FBZ/kg), two to UMB and two received no supplementation (CON). Animals with egg counts above 3000 epg were drenched with anthelmintic to avoid unnecessary mortalities. Ewe milk production was estimated three times at monthly intervals using the oxytocin injection (1 ml oxytocin) and hand milking method and the milk fat and milk protein contents were determined. Mean 63-day milk yield was estimated by multiplying mean daily milk yield by the number of days between the three milk-production estimates.

Log transformed (Log(FEC+1)) egg counts were lowest for the FBZ-UMB group (370 ± 288 epg) and highest for the CON group (2878 ± 290), while the UMB group (2790 ± 291) was intermediate. Despite the use of salvage treatments some ewes died (FBZ-UMB: 2, UMB: 6, CON: 10) from an outbreak of haemonchosis during the latter part of the trial. Ewes that died were replaced with animals that had been drenched before entering the trial and this may have affected mean treatment egg counts and milk yields. Four, 12 and 39 salvage treatments were required for the FBZ-UMB, UMB and control groups, respectively.

The mean daily milk production of ewes from the FBZ-UMB group was significantly higher than production from the UMB and CON groups. Milk composition (as a percentage) was not affected by treatment, however, there was a significant effect of treatment on mean daily milk yield, mean daily milk fat production and mean daily milk protein production (Table 13.4). The differences in milk production were reflected in numbers of lambs weaned and total weights of lambs weaned in the various treatment groups (Table 13.5).

Research into biological control of gastro-intestinal parasites in Fiji

Research into the use of nematophagous fungi to control worms in small rumiannts in Fiji began in 1996. The first investigations, in conjunction with the CSIRO and under the aegis of ACIAR, involved conducting a survey to try to collect the nematophagous fungus *Duddingtonia flagrans* from local small ruminant farms (Manueli et al. 1999).

Some 2712 faecal samples were collected and cultured from a total of 26 sheep and goat farms in Fiji. The survey yielded 23 nematophagous fungi isolates. Eleven of these were lost and a further 12 were identified as belonging to one of four species of the genus *Arthrobotrys*.

Table 13.4 Effect of fenbendazole-medicated and unmedicated feed blocks on ewe milk production

	FBZ-UMB	UMB	CON
Mean daily milk yield (ml/day) (se ±)	607 (45.4)	418 (46.8)	381 (50.5)
Mean daily milk fat production (se ±)	29.8 (2.7)	21.4 (2.8)	17.59 (3.2)
Mean daily milk protein production (se ±)	44.2 (5.1)	29.1 (5.2)	25.4 (5.6)
63 day milk yield (l)	38.2	26.3	24.0

FBZ-UMB = urea molasses feed block containing fenbendazole,
UMB = urea molasses feed block with no anthelmintic added,
CON = control, no block

Table 13.5 Effects of fenbendazole-medicated and unmedicated feed blocks on lambing performance

	FBZ-UMB	UMB	CON
Lambs born	23	24	21
Total weight born (kg)	78	76	62
Lambs weaned	18	15	8
Total weight weaned (kg)	318	196	118
Lamb mortality rate (%)	21.7	37.5	62

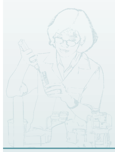
FBZ-UMB = urea molasses feed block containing fenbendazole,
UMB = urea molasses feed block with no anthelmintic added,
CON = control, no block

Subsequently, an isolate of *D. flagrans* was imported from CSIRO in Australia and a series of pen and field trials conducted. *D. flagrans* chlamydospores were fed to animals carrying naturally acquired worm infections, and the percentage of their faecal egg counts recovered as infective larvae was monitored.

D. flagrans was effective in trapping infective larvae in faecal cultures at a range of dose rates (Manueli unpublished data). The trapping of infective larvae resulted in reductions of up to 90% in the numbers of larvae recovered from larval cultures. Replicated field trials aimed at investigating the use of *D. flagrans* under grazing conditions are on-going. Initial results are variable with larval recoveries from grazing animals fed *D. flagrans* daily, ranging from 0 to 60% of those from control animals without access to *D. flagrans*.

Conclusions

- Anthelmintic resistance means that it is necessary to develop sustainable parasite control measures.
- The most important worms of small ruminants in Fiji are *H. contortus* and *T. colubriformis*; *M. digitatus* does not readily infect goats.
- Larvae survive on pastures all year round. Infective larval stages are generally available on pasture by 4 days after faecal contamination with parasite eggs.
- Rotational grazing using eight paddocks over 28 days or 10 paddocks over 35 days can be effective for the control of worms in small ruminants. Reducing the number of paddocks in a 28-day rotational grazing system makes it ineffective.



13. Worm control for small ruminants in Fiji

- It is not necessary to drench young stock fortnightly.
- Albendazole sustained-release capsules are not effective in goats but are extremely effective in sheep. Albendazole is metabolised faster in goats than it is in sheep.
- Night yarding has no effect on faecal egg counts in goats.
- Evidence for the development of age immunity in goats is equivocal. Epidemiological studies indicate that little age resistance occurs, though the genetic studies found evidence of an age effect.
- Faecal egg count is not heritable in goats in Fiji. However, it is heritable in sheep and can therefore be used in selection programs. Eosiniphil count is not a good predictor of faecal egg count in sheep.
- Fenbendazole administered at a dose rate of 3.0 g/kg liveweight can reduce egg counts and larval hatch rates to zero. Fenbendazole medicated blocks (FBZ-UMB) can be used to control worms in sheep and goats provided block intakes are adequate. There is much variation within flocks and herds in FBZ-UMB intakes.
- FBZ-UMBs can reduce the need for drenching in small ruminants. The strategic use of FBZ-UMBs with unmedicated blocks can be effective in controlling worms in small ruminants. FBZ-UMBs can be used in conjunction with RRG to control worm infections in small ruminants.
- Improved nutrition can be beneficial in helping worm-infected small ruminants overcome and/or withstand the effects of infection.
- In young ewes worms can affect reproduction by delaying the attainment of oestrous, resulting in fewer lambs. This is exacerbated by sub-optimal nutrition. This effect does not carry over. These effects on reproduction do not occur in well-grown ewe hoggets.
- Worms cause reductions in ewe total milk yields, total fat yields and total protein yields. Worms affect the growth rates of lambs from birth to weaning.
- Nematophagous fungi surveys were unable to identify *D. flagrans* in Fiji.
- Biological control using *D. flagrans* has potential but problems of delivery and fungal culture methods need to be addressed. Pen trials have been successful though results in field trials have been variable.

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14. Internal parasites of small ruminants in Papua New Guinea

14. Internal parasites of small ruminants in Papua New Guinea

A.R. Quartermain

Introduction

Internal parasites are seen as a primary threat to the expansion and improvement of smallholder production of sheep and goats in the humid tropics. This chapter reviews the literature on internal parasitism of small ruminants in Papua New Guinea (PNG). Documentation is limited because, in the past, small ruminants in PNG have been perceived to be less important than pigs, poultry and cattle. Accordingly, human and financial resources available for research have been limited.

PNG has extremely variable agro-ecological conditions. Although it is entirely in the wet tropics, altitude ranges from sea level to above 4000 m and annual rainfall varies from 1000 mm to more than 6000 mm. For the purposes of the present review, it is possible to restrict discussion to the following three broad climatic zones.

1. Permanently wet lowlands and mid-altitude areas up to 1200 m, with rainfall from 2000 to 5000 mm.
2. Dry or seasonally dry lowlands with rainfall less than 2000 mm and pronounced dry periods of up to six months of the year.
3. Highlands from 1200 m up to the limit of cultivation, about 2700 m. The highlands are cooler with an even temperate climate. There are occasional frosts above 1800 m, and rainfall is between 2000 and 3500 mm, with slight seasonality.

Essentially there are two types of sheep and one type of goat in PNG, as discussed by Quartermain (2002). Tropical PNG Priangan sheep predominate in zones 1 and 2 while sheep now called Highlands Halfbred, derived from crossbreeding temperate wooled sheep (mainly Corriedale and Perendale from New Zealand) with Priangans, are found in zone 3. Priangan sheep comprise around 2000 of the total sheep population of 15,000. The goat population is estimated at 20,000 and there appears to be no genetic differentiation by zone. Although derived from early introductions of mainly dairy animals, goats are now kept almost exclusively for meat production (Quartermain 2002). Smallholder sheep and goat owners generally keep fewer than 10 animals which they allow to range freely during the day, and house at night.

Endoparasites present in small ruminants of PNG

The first recorded list of parasites of sheep and goats was derived from a government veterinary laboratory and field reports by Anderson (1960). Egerton and Rothwell (1964) updated Anderson's list with confirmed diagnoses. At that time they estimated there were only 500 sheep and 6500 goats in PNG, mainly in the highlands (i.e. above 1200 m). The list is shown in Table 14.1.

Subsequently, Asiba (1987) added *Mecistocirrus* sp., previously reported in cattle, to the list for sheep, while Owen (1988,1998a), identified *Trichostrongylus axei*, *Cooperia curticei*, *Trichuris ovis* and possibly *Trichuris skrijabini* in sheep. It appears, from the few studies with larval culture, that the dominant genera are *Haemonchus*, *Cooperia*, *Trichostrongylus* and *Oesophagostomum*. *Fasciola hepatica* is economically important, but geographically restricted, while cestodes are thought to be unimportant (Asiba 1987).

Table 14.1 Worm species identified in sheep and goats of PNG

Worm	Sheep	Goats
Trematoda		
Fasciola hepatica	*	*
Cestoda		
Cysticercus tenuicollis	*	
Moniezia expansa	*	*
Nematoda		
Bunostomum trigonocephalum	*	*
Cooperia sp.	*	*
Haemonchus contortus	*	*
Nematodirus sp.	*	*
Nematodirus spathiger		*
Oesophagostomum columbianum	*	*
Oesophagostomum asperum		*
Oesophagostomum venulosum		*
Strongyloides *papillosus*	*	*
Trichostrongylus colubriformis	*	*
Trichuris globulosa	*	*
Trichuris ovis		*

Studies of internal parasitism in small ruminants of PNG

Other than lists of identified species, there are no published studies of internal parasitism in goats in PNG. It might be expected that parasitism would be less of a problem for goats, which browse more, than for sheep, but this has yet to be verified. The findings and comments made in this chapter for sheep, generally also apply to goats. In the mixed-species, institutional flocks that are managed with intensive daytime grazing in paddocks, both species are treated alike in receiving regular (usually monthly) dosing with anthelmintics. Manua (1994) reported a study of smallholder sheep and goat farms in the highlands and stated that, although

animals were not drenched, they were found to be healthy and losses from gastro-intestinal parasites to be small. However, no data are included to support this statement.

Dry lowlands

Studies on Priangan sheep in the dry lowlands have been carried out in three locations. The first was the National Veterinary Laboratory, where a small flock (established in the 1950s) grazes on a small area of pasture with supplementary feeding as necessary. The area has an annual rainfall varying from 500 to 1500 mm and a seasonal dry period from May to November. From 1980 to 1994 the flock, ranging in size over the years from nine to 35 ewes, was monitored weekly for faecal egg counts (Owen and Awui 2000). No anthelmintics were used up to 1984 but thereafter sheep were treated when egg counts (eggs per gram) were higher than 5000 or sheep showed symptoms. Pre-weaning mortality to 12 weeks averaged 20.2%. Over all years, only 0.06% of rams and 0.36% of ewes had egg counts higher than 10,000, with most high counts in ewes coinciding with lambing. This lambing rise occurred in 64.2% of births, usually peaked at 5000 and returned to normal within 4–8 weeks without treatment. Counts in lambs were more variable with 14–76% of yearly average egg counts lower than 500 and 0–6% higher than 10,000. Most lambs showed a rise between 7 weeks and 3 months of age. *Haemonchus contortus* was the most prevalent parasite in egg counts over 3000 but otherwise *Trichostrongylus* species prevailed. The former could cause death with egg counts over 10,000 but the latter was not lethal even with egg counts up to 36,000. *Strongyloides papillosus* was frequently seen in lambs, constituting up to 50% of the larvae with egg counts over 3000. *Oesophagostomum columbianum* and *C. curticei* were present at low levels. Pastures remain infective all year round and more so in the wet season. There was little variation from year to year. Parasitism, generally due to lack of timely treatment, was linked to the deaths of only five ewes and five lambs over the 15 years. Five Corriedale ewes present during the first few years showed little resistance to parasites and had consistently higher egg counts than the Priangans. It was concluded, overall, that the majority of the Priangan animals showed a level of either resistance or tolerance that enabled them to survive and produce under poor nutritional and high parasite challenge conditions.

Another study, carried out with the Priangan flock at the National Veterinary Laboratory (Owen 1988), was designed to evaluate closantel as an anthelmintic with residual activity and high efficacy against *H. contortus*. Sheep with egg counts above 500 were treated with either 7.5 or 15.0 mg/kg. After treatment, egg counts dropped markedly within 3 days and remained low for 7–10 weeks, depending on the dose rate. *Haemonchus* eggs vanished from the faeces of the treated sheep but gradually increased during weeks 5–8 and reached pre-treatment levels by weeks 12–13. *Haemonchus* remained at 69% of the larval population in untreated cohorts. When all sheep were dosed with 15 mg, control continued for 21 weeks and egg counts were only half of the pre-treatment levels at 26 weeks. The proportion of *Haemonchus* larvae dropped from

51% to nil within 3 days, began to re-appear in week 9 and gradually increased back to 50% in week 23. *Trichostrongylus* larvae dominated when *Haemonchus* was absent and declined as the latter reappeared. It was concluded that the benefits of closantel are only realised when all sheep are dosed, with benefits lasting up to 5–6 months.

The other two dry lowland locations where sheep were studied were Erap in the Markham Valley, and Urimo on the Sepik Plains. The former has an average annual rainfall of 1250 mm with a little seasonal variation, while the latter has a similar climate but with a higher rainfall (1850 mm). The government Priangan flock at Erap was derived from the sheep of Southeast Asian origin accumulated in 1971 from scattered remnants and, subsequently, was used to establish the other main institutional flocks and the Highlands Halfbred sheep. Holmes and Absolum (1985) reported the results of a trial where, at each site, a total of 20 wethers aged 6–18 months were divided into groups and treated with levamisole (Nilverm). The sheep were drenched at 0, 4, 8 or 12–week intervals over a period of 12 months at Erap and 9 months at Urimo. Erap sheep were set-stocked at five sheep/ha on pasture while those at Urimo grazed over a large area during the day and were housed at night. Egg counts were measured every 4 weeks. The treated wethers out-performed the controls at both sites but only marginally at Urimo. The highest monthly average egg count in the untreated sheep was only 3060 at Erap and 856 at Urimo. Drenching reduced egg counts but there were no differences among drenching intervals. The response was greater in the younger sheep but there were no correlations between growth rates and counts within or across sites. Larval cultures showed *Haemonchus* and *Cooperia* to be dominant at Erap and *Trichostrongylus* at Urimo. It appears that parasitism is a minor problem for these sheep, under these conditions, at low stocking rates. Observations at Erap also suggest that housing sheep on slatted floors at night did not reduce parasitism.

Wet lowlands

The only formal study in the wet lowlands was at another treatment site used in the levamisole study by Holmes and Absolum (1985). The site was on the coast and had an annual rainfall higher than 4000 mm. Twenty sheep grazed freely over about 40 ha of swampy pasture during the day and were housed at night on a slatted floor. Egg counts were low in all groups, the monthly average ranging from 8 to 270 in the untreated sheep. Treatment reduced counts but differences among drenching intervals were inconsistent. Although drenched wethers grew faster than untreated animals, this was only significant for the smaller, younger sheep. Across all three sites in the Holmes and Absolum (1985) study, small drenched wethers grew at 0.54 kg/week compared with 0.32 for untreated sheep. In spite of this response, it was concluded that even under these very wet conditions, with a low stocking rate, internal parasitism is a minor problem.

In the two larger institutional flocks of goats and Priangan sheep in the wet lowlands — at the PNG University of Technology and the National Agricultural Research Institute — all animals are currently drenched monthly with benzimidazole (Panacur), as a safeguard against mortality. Both flocks graze pasture at a high stocking rate and are housed at night on slatted floors.

Highlands

Most of the data for the highlands zone come from the government sheep-breeding flock held at Menifo in the Eastern Highlands Province. The Menifo station, at 1608 m, was the site for the introduction of sheep from New Zealand under the Sheep Development Project which started in 1975. The average annual rainfall varies from 1000 to 1500 mm with a drier period between June and September. It has a drier climate than most of the highland zone. Owen (1998a) monitored Corriedale sheep on intensive grazing over 2 years from July 1997 and used worm-free tracer lambs to monitor parasite species. Of the nine species of worms found (all previously listed) the most prevalent were *H. contortus* and *Trichostrongylus colubriformis*. The latter became dominant when the former was controlled. Natural seasonal availability of larvae on the pasture could not be determined because anthelmintic treatment was started in December 1977, when egg counts were high, and became a regular program from May 1978. Nevertheless, larvae were plentiful on the pasture at all times (although at lower levels in the second year, probably because of the treatments). High egg counts could occur at any time and *Haemonchus* could dominate at any time. The longevity of free-living stages of *Haemonchus* after hatching, as evidenced by the tracer lambs after specific dosing of the other sheep, ranged from less than 12 days, at the end of the wetter season, to about 3 weeks. This short survival time would appear to be the key for control of *Haemonchus* with the strategic use of closantel or rafoxanide, together with a broad spectrum drench, before any expected rainy season build-up of parasites.

Priangan sheep with some locally adapted meat goats. (A.R. Quartermain)

Owen (1998b) studied the possible role of mixed grazing of sheep and cattle as a management option for parasite control in areas where the climate allows year-round development and survival of parasites on pasture. Priangan X Corriedale and Corriedale sheep were grazed together with Brahman X steers and monitored in two separate one-year trials at Aiyura, in the Eastern Highlands, which had rainfall of 1860 and 1877 mm in the two respective trial years. Egg counts were measured every 4 weeks in the first year and every 2 weeks in the second. Sheep grazing with cattle had lower overall egg counts than sheep grazing alone but this reduction was not enough to prevent haemonchosis and the need for drenching. *Haemonchus* and *Trichostrongylus* dominated in sheep, with the latter dominant during the drier months of the second year. Corriedale sheep had consistently higher egg counts than crossbreds. Steers had negligible egg counts for about 8 months each year after being dosed with levamisole or rafoxanide. Mixed grazing resulted in a 50% increase in weight gain for the wether hoggets but much of this could be attributed to better pasture growth and utilisation. Mixed grazing with sheep and cattle is not a practical option for most smallholder farmers in PNG.

Asiba (1987) drew attention to the lack of information about basic health and production of smallholder sheep flocks but stated that gastrointestinal nematodes cause significant losses in flocks set-stocked for any length of time. Subsequently, he elaborated on the situation in the highlands by drawing on his own experiences as a regional veterinarian, and on National Veterinary Laboratory reports from 1977 to 1994 (Asiba 1995). However, much of this information again came from Menifo. Supported by evidence from autopsies, the majority of deaths could be attributed to parasitism. Pneumonia commonly showed up in post mortems and this could be secondary to stress caused by parasitism. Evidence from a prolonged dry spell in 1993 suggests poor nutrition as a predisposing factor. Fifteen sheep monitored in successive weeks in February 1994 had egg counts ranging from 120 to 11,740. The author suggests that eggs persist on the pasture in the Eastern Highlands for up to 5–6 months and hence egg counts remain high even after dosing with benzimidasole or levamisole drugs. The suggestions for institutional flocks in the highlands are controlled grazing, improved nutrition, and monitoring of egg counts so treatment can be applied as needed. Strategic drenching immediately after weaning, at the onset of the rainy season if one exists, and before lambing could be useful. Sheep of the National Agricultural Research Institute at the Tambul highlands station (2,240 m) are grazed on pasture and all sheep are drenched monthly. However, drenching is not practised by 10 smallholder keepers of sheep and goats in the Tambul area (F. Dua, pers. comm.).

The only trematode of concern is *F. hepatica* which was inadvertently introduced from Australia with early sheep introductions and established itself in the highlands where its intermediate host, the snail *Lymnaea viridis*, thrives, given suitable environments. Distribution of the snail is limited by temperature to areas above 600 m and is uneven. Fasciolosis is a particular problem at Menifo. Owen (1989) has described the epidemiology, using fluke-free weaner lambs over a period of 22 months at Aiyura. Metacercariae can be found on pasture throughout the year if sheep have access to snail-contaminated sites. The presence of swampy areas, drainage lines or ponds gives persistent snail populations which can spread onto pasture whenever prolonged heavy rain saturates pastures and soils. It appears that 125 mm of rain in a 4-week period is necessary for infected snails to move onto saturated pasture and liberate cercariae. There was considerable variation between lambs with one weaner having 446 flukes in its liver after only 2 months of grazing exposure while another had only one fluke. Sheep are liable to acquire low level infection leading to chronic fasciolosis at any time when continuous contamination of pasture occurs. However, acute fasciolosis may occur with heavy grazing under wet conditions when snails migrate onto flooded pastures or when sheep have access to areas that remain permanently wet.

Conclusions

- Parasite species identified include one trematode, two cestodes and 14 nematodes.
- No work has been done specifically on goats.
- In the lowlands, *H. contortus* and species of *Trichostrongylus*, *Strongyloides*, *Oesophagostomum* and *Cooperia* appear to dominate.
- Parasitism is only a problem, even under very high rainfall conditions, with intensive grazing or set-stocking.
- Control can be achieved with strategic drenching, especially if targeted at *Haemonchus*.
- Local Priangan sheep appear to have some tolerance or resistance to endoparasites.
- In the cooler highlands, *H. contortus* and *T. colubriformis* dominate. Eggs and larvae are available at all times on intensively grazed pastures although *Haemonchus* larvae have a short survival time.
- Although mixed grazing of sheep and cattle has proven beneficial it is not a practical option for most smallholders.
- *F. hepatica* is locally important in the highlands and infestation requires management solutions.
- In general, under conditions in which parasite problems exist, solutions depend on grazing management and strategic drenching.
- Smallholder farmers seem to manage adequately without treating their stock with drugs.

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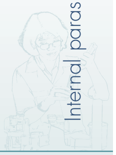


15. Internal parasites of small ruminants in Nepal

B.R. Joshi

Introduction

Small ruminants are an important source of cash generation and livelihood for resource-poor farming communities in Nepal. The livestock sector contributes about 31% of Nepal's gross domestic product and small ruminants alone comprise roughly 12% (LMP 1993, APP 1995). The 6.61 million goats and 0.84 million sheep in the country (FAOSTAT 2002) are reared under either sedentary or migratory management systems. Migratory management is used for about 65% of sheep and about 35% of goats (LMP 1993) in the northern districts of Nepal, adjoining the southern flank of the Himalayas, while sedentary management is used in the rest of the country. Goats are primarily reared for meat and manure and are regarded by farmers as the second most important animal species for generating cash income (Gatenby et al. 1990). Sheep are kept for wool, meat and manure. In the eastern region of the country about 80–85% of farming families are involved in sedentary goat management (Gatenby et al. 1990). However, on average, the percentage of households involved in sheep and goat rearing varied between 46 and 55%, depending upon the region of the country, increasing from the low terai regions to the mountain regions (Table 15.1).

The national small ruminant population is mainly comprised of indigenous sheep and goat breeds, each found in a particular region of the country (Table 15.2). Management and production systems for small ruminants in Nepal have been described in detail by Ghimire (1992).

Diseases and parasites are regarded by farmers as the most important constraints to small ruminant productivity in Nepal and this view has been supported by various studies. Lohani and Rasali (1993/95) calculated the economic loss caused by animal diseases, based on

Table 15.1 Distribution and importance of small ruminants in different regions of Nepal

Population distribution	Terai	Hills	Mountains
Goat population (in '000)	1828	3396	855
Sheep population (in '000)	122	385	361
Percentage of households keeping goats	46.8	54.2	55.5
Percentage of households keeping sheep	1.8	4.2	6.5

Data from: Livestock Master Plan (1993), Statistical Information on Nepalese Agriculture 1997/98 and Agriculture Perspective Plan (1995).

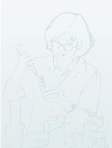


Table 15.2 Distribution and management of sheep and goat breeds in Nepal

Species	Breed	% Total	Region	Altitude (m)	Climate	Management
Goat	Chyangra	6	Mountain	>2500	Cool temperate	Sedentary/migratory
	Sinhal	35	Mountain	>2500	Cool temperate	Migratory
	Khari	50	Hills	300–2500	Warm temperate	Sedentary
	Terai	9	Terai	<300	Subtropical/tropical	Sedentary
Sheep	Bhyanglung	4	Mountain	>2500	Cool temperate	Sedentary/migratory
	Baruwal	41	Mountain	>2500	Cool temperate	Migratory
	Kage	43	Hills	300–2500	Warm temperate	Sedentary
	Lampuchhre	12	Terai	<300	Subtropical/tropical	Migratory

(Adapted from: Wilson 1995)

survey data from six districts, to be about 885 million rupees annually, equivalent to 17.7 million USD in 1995. In sheep and goats, losses from parasitic diseases (including flukes, gastrointestinal worms and tapeworms) have been estimated at 80% of the total losses from disease; roughly 1.5 million USD (sheep) and 0.25 million USD (goats). A later study reported that the annual loss from parasitic gastroenteritis alone would be about 9.2 million USD (Joshi 1996). These estimates may vary but together they indicate the national importance of this problem.

This chapter collates information on gastrointestinal nematode infection of small ruminants in Nepal. Relevant production research is also included. It attempts to include not only the published literature but also unpublished information presented in annual reports and similar documents.

Worm species

A detailed survey of the worms of small ruminants in Nepal (Joshi 1997) gave similar findings (Table 15.3) to earlier studies at the generic level (Singh et al. 1973, Morel 1985, Thakur and Thakuri 1992, Jha et al. 1993) except that *Nematodirus* was not recorded in this study.

As well as the worms listed in Table 15.3, some uncommon parasites have also been recorded in sheep and goats in Nepal, namely *Eurytrema cladorchis* (Mahato 1987) and *Dinobdella ferox* (Mahato et al. 1989). The presence of *Fasciola gigantica*, *Fasciola hepatica* and the intermediate form of *Fasciola* species from the goats of Palpa district was reported by Lohani and Jaeckle (1981/82). *Moniezia*, *Stilesia*, *Coenurus cerebralis*, *Echinococcus granulosus*, *Fasciola gigantica* and *Paramphistomum* and lung worms were also recorded in the study by Singh et al. (1973).

Table 15.3 Gastrointestinal parasite species of small ruminants rared under sedentary and migratory management systems in Nepal

Worm	Sedentary	Migratory
Haemonchus contortus	*	*
Trichostrongylus axei	*	*
T. colubriformis	*	*
T. vitrinus	*	*
T. orientalis	*	*
Bunostomum trigonocephalum	*	*
Cooperia curteici	*	*
C. punctata	*	*
Oesophagostomum asperum	*	*
O. venulosum	*	*
Trichuris ovis	*	*
Strongyloides papillosus	*	*
Teladorsagia circumcincta	*	*
T. davtiani		*
T. trifurcata		*
Ostertagia leptospicularis		*
O. nianquingtanggulaensis		*
Grossospiculagia occidentalis		*
Chabertia ovina		*
Skrjabinema ovis		*

Prevalence and impact of worms

Jha et al. (1993) analysed the autopsy records of 266 goats from Pakhribas Agricultural Centre, Dhankuta and attributed 6.4% of mortality in goats to gastrointestinal nematodes and 3.7% and 1.9% mortality to fasciolosis and paramphistomosis, respectively. In a retrospective analysis of eight years data with 41,944 clinical cases also from the Pakhribas Agricultural Centre and seven hill districts in the eastern region, Chand Thakuri et al. (1994) found that the major clinical problems in goats were caused by parasitic diseases which accounted for 74% of the total treated cases. These workers concluded that infection by helminth parasites was a pressing constraint for improving the productivity of goats. Of the 20,449 cases of helminth parasites recorded in the hill districts, the proportions infected by liverfluke, gastrointestinal nematodes and tapeworm were 34, 65 and 1%, respectively.

Later, a more detailed study was carried out in the western hills of Nepal by Joshi (1995, 1998, 1999). Dung samples from sheep and goats of the village flocks reared under migratory and sedentary management systems were analysed at monthly intervals with more than 4090 faecal samples collected over 12 months. Prevalence of worm infection ranged between 60–100% in ewes, 7–97% in lambs, 15–100% in adult goats and 6–100% in goat kids. Faecal egg counts were higher in sheep (in both adult and young age groups) than in goats. Similarly, the faecal egg counts were higher in sheep and goats raised under the sedentary system than in those raised under the migratory one.

Epidemiology

Thakur and Chand Thakuri (1992) reported that June–August was the main season for worm infection in goats in the eastern hills of Nepal and that there was 100% infection during the month of July. Further, Joshi (1995) studied various aspects of the epidemiology of worms in sheep and goats from sedentary and migratory management systems in the western hills of Nepal. The rate of pasture infection was determined by grazing naïve (born and reared indoor) tracer lambs with the flocks for successive months of the year and then rearing them indoors before slaughter. It was recorded that the peak of pasture infection was during the wet summer months (June–September), and that it gradually declined during the drier winter months. The highest level of infection was acquired by the tracer lambs during the month of June in both management systems. Thus infection of animals was closely related to the development of larvae on the pasture and their intake by grazing animals. The proportion of hypobiotic larvae in the lambs grazed with the sedentary flocks was low (5% during January and February) but high in the lambs grazed with migratory flocks (60 and 70% during September and August).

In the same study, evaluation of the grazing pasture for its infectivity showed that high altitude pastures were heavily contaminated with nematode larvae. Larvae were recovered up to 4170 m above sea level. There were distinct trends according to the altitude range. At the lower altitudes (below 2300 m), *Trichostrongylus* spp., *Ostertagia* spp. and *Haemonchus contortus* were all present, at 2300–4000 m, *Trichostrongylus* spp. and *Ostertagia* spp., and above 4000 m, only *Ostertagia* spp. (Joshi 1996).

Joshi (unpublished) studied the development and survival of *H. contortus* larvae at different altitudes in the hill region and recorded that eggs and larvae survived considerably longer at the lower altitudes and during the cold winter months. Eggs became larvae within one week from May to October at both altitudes but needed six to eight weeks during January and February. The longest survival was recorded for the larvae put on the pasture during the month of May at the lower altitudes (26 weeks) and during April at the higher altitudes (24 weeks).

Joshi (unpublished) also studied the development of *H. contortus* derived from sheep and goats in the corresponding and alternate host species. It was recorded that fecundity of an isolate of *H. contortus* derived from goats was higher in both sheep and goats (Table 15.4). In particular, the percentage of gravid female worms at 28 days post-infection was higher with the goat strain in both sheep and goat species (68 and 90%). However, with the sheep strain, the percentage of gravid female worms was higher in goats than sheep (82 and 36%, respectively).

Table 15.4 Mean faecal egg counts (eggs per gram) at 28 days post-infection in lambs and kids infected with sheep and goat strains of *H. contortus*

Strain	Lambs	Kids
Sheep	400 ± 200	700 ± 100
Goat	2166 ± 548	2000 ± 1250

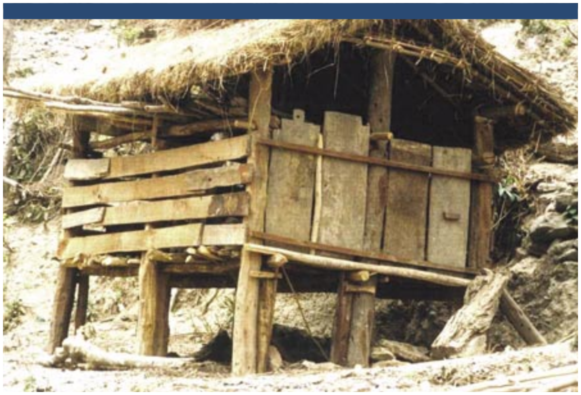
Peri-parturient egg rise had different trends in sedentary and migratory management systems (Joshi, unpublished). Sedentary ewes had a steady rise in egg count two weeks post parturition, whereas the peri-parturient egg rise trend was erratic in the migratory ewes. There was no peri-parturient egg rise in the sedentary nannies (in fact a decline was observed) but an increase was observed in the migratory nannies. These trends are difficult to explain, but might have been influenced by the grazing management. The other factor might be that all lambing and kidding were during the winter months when it was dry and cold with low or no possibility of infection from the pastures. These studies indicated that peri-parturient egg rise might be of epidemiological significance in sheep kept under migratory management.

Feeding of rice straw, which plays such an important role in the transmission of *Fasciola* to stall-fed buffaloes (Joshi 1987), does not seem to have any role in the epidemiology of gastrointestinal nematode infection of small ruminants.

Controlling worms and improving productivity

Commercial anthelmintic treatment

Joshi (1996a, 1996b, 1999) monitored the effect of worms on small ruminant productivity managed under sedentary and migratory management.
A group of animals was maintained worm free by regular anthelmintic treatment and managed together with untreated pair-matched control animals (under normal farming management). No supplementation was provided. Weight gain and faecal egg counts were monitored for six months (in sedentary animals) to one year (in migratory animals). The results of the study show a significant effect of worms on the weight gain of the animals (Table 15.5).



Goat housing with good ventilation, shelter and space for manure collection can be made out of local material. (G.D. Gray)

The performance of migratory animals after a single drenching was studied by Joshi and Joshi (1999). Weight gain was encouraging but the study was conducted for only a short period (up to May).

Shrestha et al. (1990) demonstrated significant improvement in the growth rate of goats treated with anthelmintics and supplemented with maize grain (@10 g/kg body weight) over the untreated controls. A single anthelmintic treatment increased the daily weight gain from 28 g/day to 47 g/ day in the yearling male goats and was profitable, whereas supplementation without anthelmintic was not economically profitable.

Table 15.5 Weight gain responses of migratory and sedentary sheep and goats following worm control using anthelmintics.

System	Species	Groups	Total weight gain (kg)	Weight gain/day (g)
Migratory	Sheep	Treated	11.0	30
		Control	5.1	14
	Goats	Treated	9.1	25
		Control	5.0	14
Sedentary	Sheep (during summer)	Treated	3.5	19
		Control	1.6	9
	Sheep (during winter)	Treated	5.5	30
		Control	3.4	19
	Goats	Treated	9.0	43
		Control	3.7	18

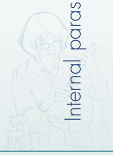
This study, however, did not indicate the level of infection, management system or the time and duration of the study.

Nutrition

The effect of anthelmintic treatment during the summer monsoon months and/or nutrition was studied in village goat flocks (Kadariya and Joshi 1994). Anthelmintic treatment and better nutrition significantly improved mean weight gain per day as follows:

- controls, 26 g/day
- anthelmintic only, 30 g/day
- anthelmintic and concentrate fed, 37 g/day
- anthelmintic plus concentrate and mineral supplement, 43 g/day.

It was interesting to note that, in addition to body weight gain, the age of first kidding, kidding–conception interval, kidding interval and kidding percentage were also significantly reduced in the treated and supplemented groups. However, there was no effect on twinning percentage. Among the untreated animals about 10% mortality was attributed to parasitic gastroenteritis.



In a similar study, Gurung et al. (1994) supplemented feed with mustard cake and maize and compared the weight gain of anthelmintic treated, and untreated, castrated male goat kids. In the anthelmintic treated goats, growth rate was 59% higher than in the untreated groups. Mustard cake alone also significantly improved growth: 'Despite infection of gastrointestinal nematodes, supplementation of mustard cake as a protein source increased the growth rate of fattening goats in the undrenched group'. There was no consideration of the level of infection and its dynamics after the interventions.

McTaggart and Wilkinson (1981, 1982) studied the growth response of terai goats with ad lib berseem (leguminous forage) feeding and reported a daily weight gain of 98 g. This dropped to 29 g/day with grazing on natural pasture only. Anthelmintic treatment contributed marginally to weight gain, but it was also shown that berseem feeding resulted in self-cure among untreated kids.

The effect of experimental infection with *Fasciola gigantica* and different levels of nutrition on Nepalese hill goats was studied by Pakhrin et al. (2000). Although the recovery of flukes was higher (55 flukes) in the concentrate-fed goats than those grazing on fodder trees (1 fluke), the concentrate-fed ones had a higher daily weight gain (61 g/day compared to 39 g/day) and the condition of the liver was normal. Thus, improved nutrition reduced the pathogenicity of the parasites. Though not conclusive, fodder trees appear to reduce fluke establishment in goats and it may be possible that some tree fodder has similar effects on the establishment of gastrointestinal nematodes. This needs to be further investigated.

Making compost from manure provides fertiliser and prevents contamination of pasture with worm eggs and larvae. (D. Pezo)

Plants as anthelmintics

Some plant products have been evaluated for their anthelmintic properties in Nepal, for example, *Euphorbia roulina* has been tested against *Ascaris suum* of pigs and has been recorded to be very effective (Mahato and Rai 1988). Other plants (roots of *Imparata cylindrica* and *Morus indica roxburgii*, bulb of *Allium satirum*, seeds of *Litsea cubeba*) were evaluated against buffalo ascariasis (*Neoascaris vitulorum*) and found to expel adult worms but were not comparable to commercial anthelmintics (LAC Annual Report 1987/88). These studies (and those mentioned at the end of the previous section) indicate the potential of some plant products to be used as anthelmintics but more detailed studies are needed.

The only study on goat worms used a commercially available Indian herbal product — Krimos Powder (Bharatiya Booti Bhawan). This was found to be ineffective compared with fenbendazole and mebendazole (Thakuri et al. 1994). Farmers have reported the use of various plants (bark of *Melia azedarach*, buds of Dhurteli, buds of Ainselu and juice of ginger) against worm infection of farm animals (Joshi et al. 1997) but the anthelmintic efficacy of these plants has not been scientifically evaluated.

Genetic resistance

The resistance of three indigenous sheep breeds (Kage, Baruwal and Lampuchhre) to artificial *H. contortus* infection was evaluated by measuring faecal egg counts and recovering worms (Joshi 1995). Kage sheep were most resistant to the challenge infection of *H. contortus* and Baruwal were most susceptible.

Production performance of different breeds

The performance of several indigenous sheep and goat breeds in different regions of Nepal has been studied as follows:

- migratory Baruwal sheep in the Gandaki zone (Karki 1985)
- migratory Baruwal sheep and Sinhal goats in the eastern region of Nepal (Shrestha 1997)
- migratory Sinhal goats in the Larnali region (Upreti and Mahato 1995)
- sedentary Chyangra goats at the Pakhribas Agricultural Centre (Shrestha et al. 1992)
- Kage sheep and local goats at the Institute of Agricultural and Animal Science farm in Chitwan (Dhakal et al. 1985).

Accurate weighing scales at markets ensures farmers are rewarded for increased body size. (G.D. Gray)

When the performance of migratory Baruwal sheep was compared with that of their crosses with Polwarth and Border Leicester it was found that most reproduction parameters were comparable between the native sheep and the exotic crossbreeds. However, wool production in the crossbreeds was significantly higher than in the native animals. Notably though, survival of native sheep in the migratory management system was considerably higher than for the cross-breeds, probably because of the better flocking behaviour of native sheep (Dhaubadel and Karki 1996, Rasali 1995).

When the performance of sedentary native Khari goats was compared with that of their crosses with exotic breeds Jamunapari, Beetal and Barbari in the eastern region of the country, the native goats were found to be more profitable (Oli 1987). Later, at Bandipur goat farm, the performance of seven breeds — two native (Sinhal and Khari), two exotic (Jamunapari and Barbari) and three crosses between local and exotic breeds (Khari x Jamunapari, Khari x Barbari and Khari x Kiko) — was compared (Upreti and Khanal 1997). Results clearly showed that both native breeds were more profitable than the exotic breeds or their crosses.

Worm control strategy

The epidemiological studies in the mid-1990s were helpful in designing control strategies for both sedentary and migratory systems of small ruminant management in Nepal. Until then, methods of parasite control were based on anthelmintic drenching without any consideration of season. Drenching was usually conducted during the winter months or when the animals were clinically sick. Joshi (1995) recommended the strategic use of anthelmintics for better control of endoparasites. Pasture management techniques for worm control are not applicable under Nepalese conditions.

The strategy suggested required:

1) protecting vulnerable animals, particularly young animals, from heavy challenge during the peak transmission period (wet monsoon months)

Grazing fallow rice paddies makes effective use of stubble and weeds and provides manure. (G.D. Gray)

2) treating adult animals, especially lactating ewes, at the beginning of dry winter to avoid winter weight loss
3) using anthelmintics in a feed-based formulation for sedentary sheep
4) treating goats, both young and adults, during wet summer months
5) studying and evaluating plant products with anthelmintic properties and using them at the field level
6) stall feeding, particularly during the wet season

Conclusions

This review will need to be updated as further information becomes available. Although it is difficult to draw conclusions, the findings of many of the papers reviewed can be summarised as:

- goat and sheep rearing is an important aspect of the Nepali farming system and provides an important source of cash income for most households in Nepal

- animals are reared under traditional management systems — sedentary or migratory —without many external inputs
- gastrointestinal nematodes are an important constraint to increased sheep and goat productivity under both sedentary and migratory management systems
- infection of small ruminants with worms is confined to the wet summer months
- increased productivity response to anthelmintic treatment is encouraging
- there is a considerable potential to improve animal productivity by improving management of health and nutrition
- some plants have been shown to possess anthelmintic properties but their efficacy is not well evaluated
- native goats have better productivity than the exotic breeds or their crosses
- the exotic sheep breeds and their crosses are not well adapted under migratory management despite their higher productivity
- the native Kage breed of goat was found to have greater resistance to *Haemonchus* infection than the other two breeds
- goat breeds have not been evaluated for their genetic resistance to helminth infection
- a worm control program has not been well developed and poses considerable problems
- the availability of chemical anthelmintics could be a problem in remote areas
- no information on anthelmintic resistance is available.

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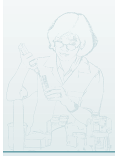

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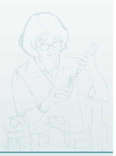

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