10. Worm control for small ruminants in Malaysia

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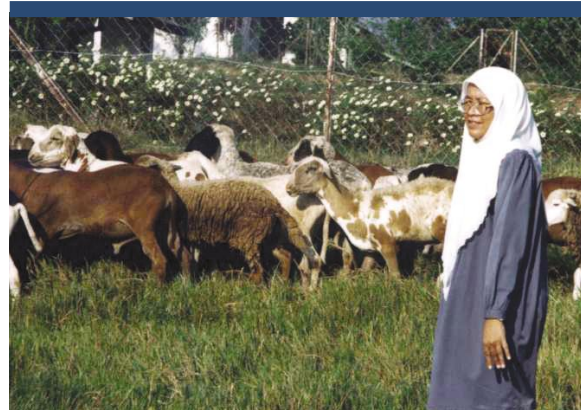
The Sanat Ines sheep from Brazil is one of several breeds imported to Malaysia for evaluation. (G.D. Gray)

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

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

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.

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

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

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.

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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11. Worm control for small ruminants in Thailand

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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

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)

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.

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.

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).

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)

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

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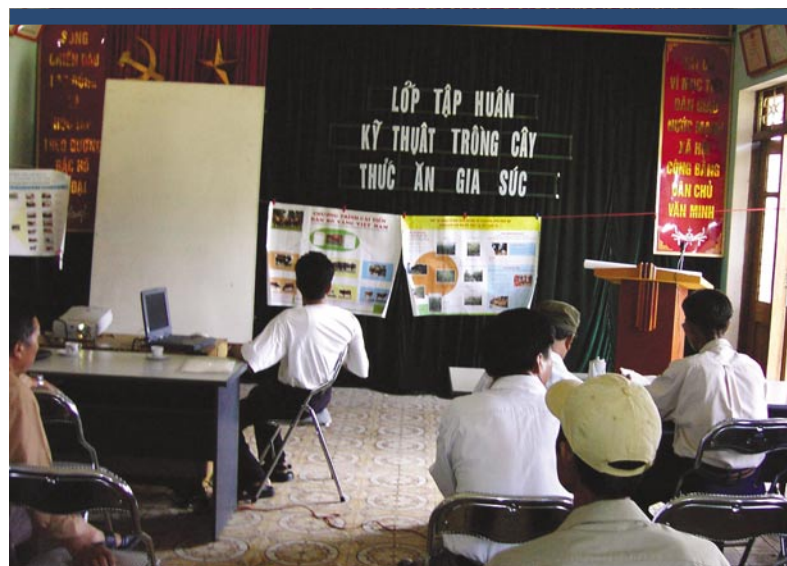
Formal training courses for extension students build capacity among agriculture graduates. (Dinh Van Binh)

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

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.

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

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

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.

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

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

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).

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,

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

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).

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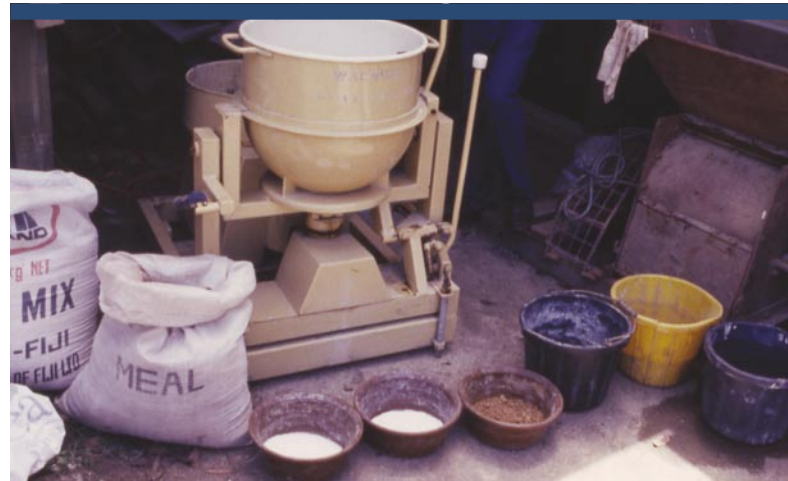
A wide range of ingredients can be incorporated into urea molasses blocks for manufacture on farm and in small enterprises. (ACIAR)

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).

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
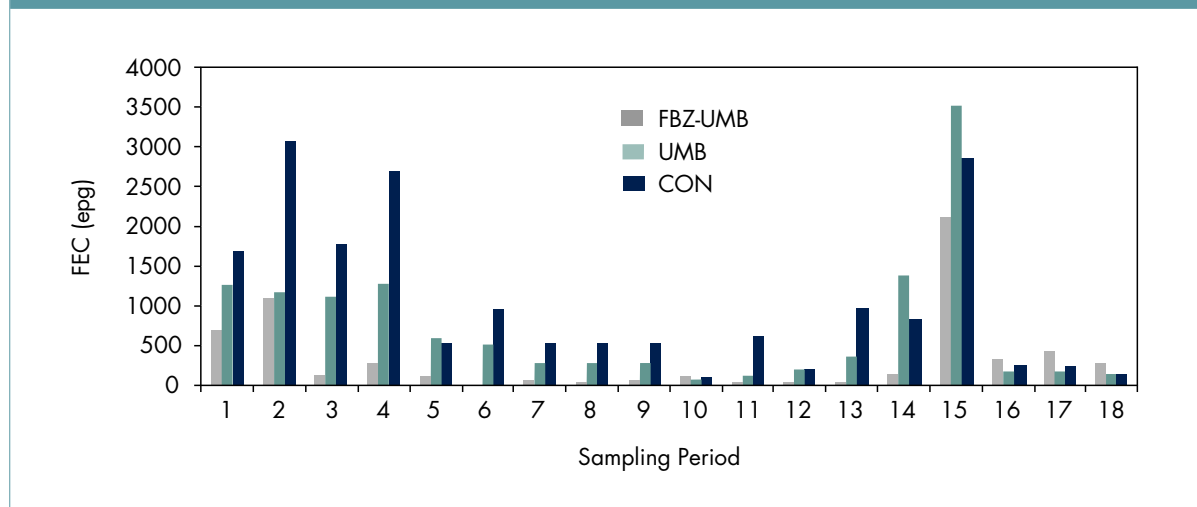
respectively). Ewe conception rates, lambing percentages and total weight of lambs weaned were increased by FBZ-UMB and UMB with the former providing a greater increase. The benefits in reproductive performance are thought to be caused by the higher mating liveweights of the FBZ-UMB and UMB groups. The 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
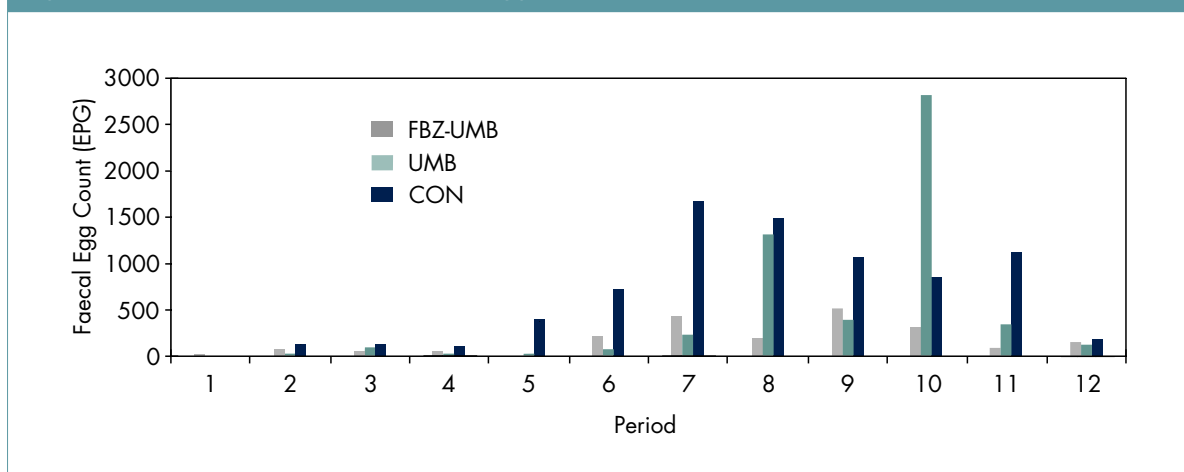
in the 1995 lambing season reveals no significant differences in pre-mating liveweights or their subsequent reproductive performance, indicating that there is no carryover effect of early suppressive anthelmintic control (FBZ-UMB) or nutritional supplementation (UMB) on ewe reproductive performance.

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

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

(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).

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.

- 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

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).

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

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		*

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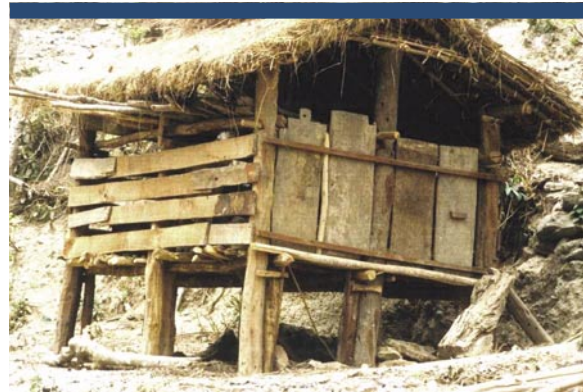
Goat housing with good ventilation, shelter and space for manure collection can be made out of local material. (G.D. Gray)

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).

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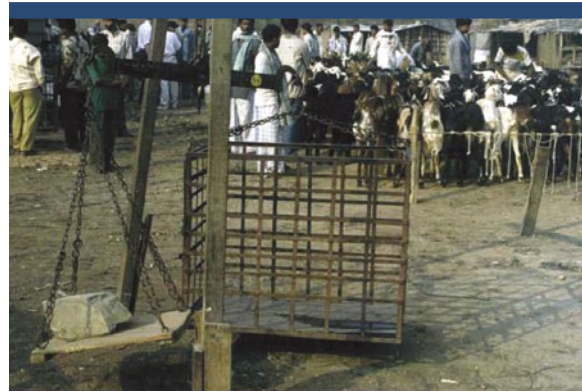
Accurate weighing scales at markets ensures farmers are rewarded for increased body size. (G.D. Gray)

■ 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).

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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