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

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Introduction

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

Sheep and goat breeds that are resistant or resilient to endoparasites

Resistance to infections with endoparasites is defined as the initiation and maintenance of responses provoked in the host to suppress the establishment of parasites and/or eliminate parasite burdens. Resilience (or tolerance) is defined as the ability of the host to survive and be productive in the face of parasite challenge (Woolaston and Baker 1996). For livestock challenged with GI nematode parasites the degree of resistance has usually been assessed in terms of worm counts at necropsy or faecal egg counts (FEC) during an infection period in live animals. In lambs it is well documented that faecal egg counts are highly correlated with worm counts (Woolaston and Baker 1996). Resilience has been defined in terms of productivity (e.g. live-weight gain or wool production) under nematode challenge compared to productivity in non-infected animals (Albers et al. 1987). In New Zealand, resilience has been defined as the number of anthelmintic treatments needed over a given period of pasture challenge (usually several months) with nematode parasites (Bisset and Morris 1996). Packed red cell volume (PCV) and mortality rates have also been used as proxies for resilience (Baker et al. 2003). When sheep are infected with the blood-sucking parasite *Haemonchus contortus* they become anaemic and this is measured by PCV, which is a good indication of how the animal is managing to cope with the pathogenic effects of the parasite and to survive when infected. However, other studies (e.g. Albers et al. 1987) treated both FEC and PCV as two different measures of resistance.

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

However, there have been many reports since the mid-1930s of variation among breeds of sheep in resistance to GI nematodes, particularly to *Haemonchus contortus*, *Trichostrongylus* spp. and *Ostertagia* (*Teladorsagia*) spp. Gray's (1991) review summarised 23 publications on this subject and this was expanded to 34 publications in a review by Baker et al. (1992).

With a few exceptions most of these studies were carried out in temperate environments in North America, Europe and Australasia. Some of the important conclusions from reviewing these publications are the following:

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

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

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

In the past 10 years or so there has been increased interest in characterising a number of indigenous tropical sheep and goat breeds for resistance to endoparasites

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

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

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

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

continued over

Table 5.1 continued

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

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

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

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

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

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

Virtually all the research on genetic variation to endoparasites in sheep and goats has concentrated on the nematode parasites. In many areas of the tropics and temperate regions of the world liver fluke (trematode) infections (*Fasciola hepatica* and *Fasciola gigantica*) are also an important constraint to sheep and goat production (FAO 1992). While it is well documented that sheep can mount an effective immune response (self-cure) to nematode parasites, it has been demonstrated that they are unable to acquire resistance to liver flukes (e.g. Haroun and Hillyer 1986, Boyce et al. 1987). This may be why there has been little research on genetic resistance to liver fluke infections and few studies published. Boyce et al. (1987) found significant breed differences in faecal egg counts and fluke counts after five breeds of sheep were experimentally infected with *F. hepatica*. Barbados Blackbelly sheep were the most susceptible to infection while St. Croix and Florida Naïve sheep were the most resistant. While none of the breeds demonstrated an ability to resist re-infection with *F. hepatica*, clear breed differences were detected in response to the primary infection. Wiedosari and Copeman (1990) reported relatively high resistance to *F. gigantica* in Javanese Thin Tail sheep, although there was no contemporaneous breed comparison. Roberts et al. (1997a, 1997b) compared the resistance to *F. gigantica* of Indonesian Thin Tail sheep (sampled from Java and Sumatra) with St. Croix sheep and F2 and F3 crosses between these breeds (Table 5.1). They concluded that the Indonesian Thin Tail sheep were more resistant than St. Croix sheep and that resistance may be controlled by a major gene with incomplete dominance. In contrast, the Indonesian Thin Tail sheep were as susceptible to *F. hepatica* as the Merino sheep that they were compared with (Roberts et al. 1997a).

Adaptation and productivity of sheep and goats in the tropics

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

A study (summarised in Table 5.2) shows that under natural pasture challenge there was no difference in resistance to endoparasites between the indigenous

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

Menz and Horro sheep evaluated in the highlands of Ethiopia (Tembely et al. 1998, Rege et al. 2002). However, under artificial challenge there was some evidence that the Menz may be somewhat more resistant than Horro lambs (Haile et al. 2002). The most dramatic and most economically important breed effect in this study was for mortality rate for which the overall cumulative mortality from birth to 12 months of age was 37.3% for the Menz and 67.6% for the Horro lambs. Mukasa-Mugerwa et al. (2000) investigated the causes of lamb mortality and found that the most important cause of death for lambs from birth to 12 months of age was pneumonia, which accounted for 54% of all deaths. Endoparasite infections as a cause of mortality were of limited importance in both breeds (accounting for about 10% of deaths). Mukasa et al. (2002) reported the reproductive performance of the ewes in this experiment and overall flock productivity. Menz sheep had a significantly higher weaning rate (lambs weaned per ewe mated) than the Horro ewes

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

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

continued over

Table 5.2 continued

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

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

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

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

Table 5.3 Goat breed comparisonsa for resistance to internal parasites

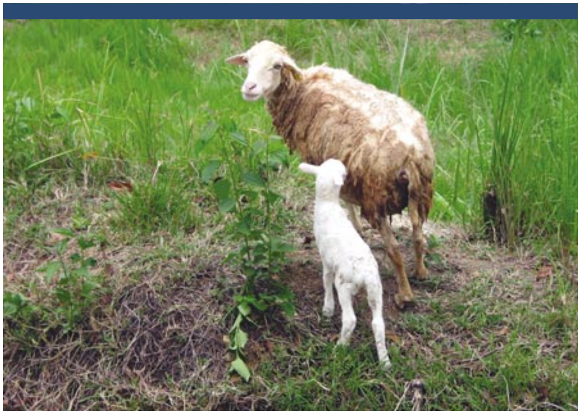
Resistant breed(s)[1] (no.)	Other breed(s)[1] (no.)	Traits[2]	Type of infect.[3]	Sp.[4]	Age-months (sex)[5]	Reference
Saanen (12)	SEA (12) Galla (12)	E, W, S	A	Hc	24–36	Preston & Allonby (1978)
Alpine	Saanen	E	N	Mixed		Cabaret & Anjorand (1984)
SEA (12)	Galla (9) Toggenburg x SEA (13)	E, P, W S, Bw	A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

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

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

superior adaptability in this environment of indigenous goats and the importance of assessing this adaptability, not just in terms of physical products (i.e. meat, milk and manure) but also accounting for socio-economic benefits.

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



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

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

Constraints to improving productivity in the tropics

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

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

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

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

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

Socio-economic constraints include:

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

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

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

Genetic improvement programs

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

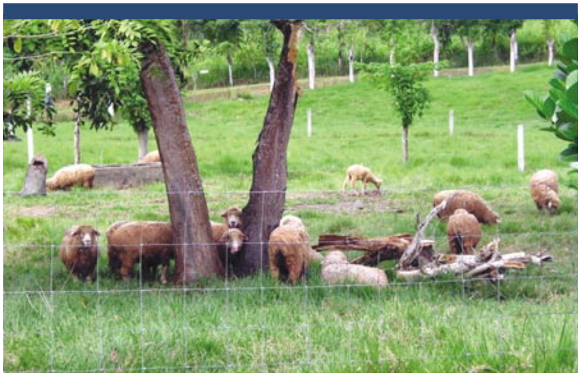
- defining the breeding objective (i.e. the improvement goal)
- choosing a breeding system and breed(s)
- deciding on population size and structure
- identifying the selection criteria and, if appropriate, deriving selection indexes
- obtaining (or estimating if not available) genetic parameters (e.g.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

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

During the process of quantifying constraints to production and developing integrated livestock development objectives it may become clear that development of breeding programs should not be attempted. For example, the small desert breeds of goats such as the Black Bedouin are exquisitely adapted to fragile desert environments after thousands of years of natural selection (Silanikove 2000), and the best breeding strategy now is to let natural selection continue without external interference with either their genetic potential or their desert environment.

Defining the breeding objective

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



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

objectives and REVs were refined as the data on input costs were obtained or derived (e.g. feed costs for grazing livestock) to allow the calculation of more comprehensive profit functions (Ponzoni 1986).

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

The breeding system

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

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

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

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

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

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

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

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

Breed substitution

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

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

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

New breed formation

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

Specific and rotational crossing

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

Population size and structure

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

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

Selection criteria and breeding values

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

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

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

Some traits are expensive, impractical or impossible to measure and this includes some of the production traits (e.g. lifetime productivity, feed intake of grazing animals, carcass quality, behaviour) and many of the disease resistant and adaptability traits (e.g. metabolic efficiency, water tolerance, heat tolerance). In some cases indirect measures have been developed but in others measurable traits do not exist at present. However, where breeds or genotypes have been demonstrated to have the required attributes such as disease resistance or adaptability, then these genetic qualities can be harnessed by using those breeds or by crossbreeding with them without any need to resort to within-breed selection. It is also important to remember that the rate of genetic progress per generation in a breeding flock is proportional to the selection intensity (which is a constant for a given breeding structure), the degree of variability (i.e. the phenotypic variance) and the heritability (Falconer 1989). Some of the traits which are lowly heritable, such as reproduction rate, are also extremely variable and the expected rate of genetic progress of about 2% of the mean per year is similar to what is expected from traits such as growth or milk production which have moderate heritabilities but are less variable. FEC, which is commonly used as a predictor of resistance to endoparasites, is highly variable and usually has an over-dispersed skewed distribution. Even when transformations have been applied to FEC to normalise the variance (e.g. logarithms or square root), it still tends to be a fairly variable trait with a moderate heritability at least in susceptible breeds. It must also be remembered that while selecting for several different traits may be justified, the more traits that are included as selection criteria the less genetic progress that will be made for each one of them.

Industry structure and dissemination of genetically improved animals

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

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

Recently, plant breeders have been carrying out breeding programs in some tropical countries in collaboration with smallholder farmers (e.g. Eyzaguirre and Iwanaga 1995, Bellon and Reeves 2002). For example, farmers evaluate different crop varieties and give their views on what they consider are the important crop characteristics. FAO and ILRI are developing and testing 'breed survey guidelines' which, among other things, seek farmers' views on important livestock characteristics and their perceptions of the value of different breeds and strains of livestock (Rege and Rowlands, pers. comm.). Although it may be more difficult with livestock than plants to

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

develop farmer-assisted breeding programs, there is scope for some innovative research and development on this topic.This could take place in smallholder flocks, use modern participatory methods to gain insights into how smallholders make decisions about livestock and set breeding objectives, and use DNA technology to assist with identification of parentage.

Conclusions

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

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

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Introduction

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

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

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

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

Rainfall varies from as little as 500 mm per annum, in the rain shadow areas to the north of the high Himalayas, to over 5000 mm in areas to the south of some of the major Himalayan massifs. For most of the country, average rainfall lies between 900 and 1900 mm per annum, becoming progressively drier from east to west. The greater part of this rain falls during the monsoon, between the middle of June and the end of September. In general, there are four major and distinct seasons in Nepal: winter (December–February); spring (March–May); summer (June–August); and autumn (September–November).

Economy

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

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

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

Livelihoods analysis and poverty focus

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

Capital access

Table 6.1 provides a summary of some of the indicators examined and the proportion of districts in each region that are in the lowest third of the country's ranking. It is evident from Table 6.1 that, by most measures, the hill and mountain regions are ranked lower than the terai. In particular, access to natural resources is a constraint in the hill districts, while access to financial, social and physical capital, all highlight the problems of remoteness in the mountain districts.

Vulnerability context

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

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

Role of small ruminants

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

Table 6.1 Poverty indicators used in the study

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

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

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

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

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

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

Sedentary goat production in the hill districts

Farming systems

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

Livestock management

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

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

Animal health issues in small ruminants

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

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

Helminth problems

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

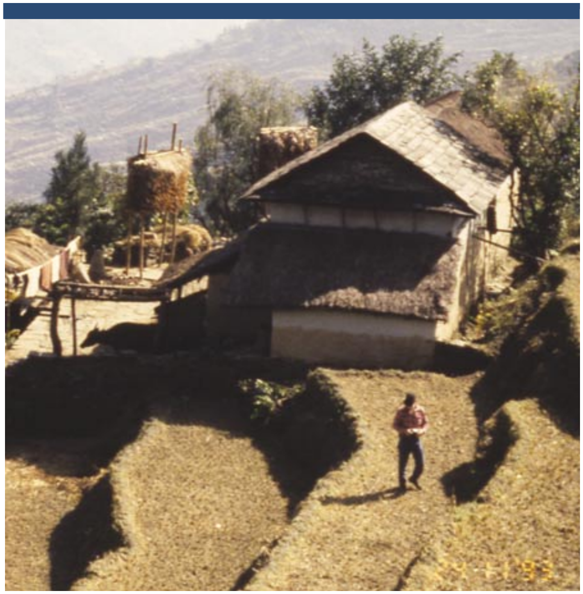
Trichostrongylus and *Oesophagostomum* may be the cause of the goat diarrhoea reported by farmers while *Haemonchus* on its own (or in combination with *Fasciola*) may be a significant cause of mortality or reduced productivity on these farms.

The effect of gastrointestinal nematodes on animal production was evident in studies in which the growth rate of the animals given regular anthelmintic treatment was higher relative to untreated animals reared alongside (Joshi 1998). The daily weight gain of anthelmintic-treated kids was up to 2.5 times that of untreated kids under sedentary conditions. These responses show that controlling parasites can greatly improve goat productivity in this system.

Options for helminth control

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

- controlling grazing to avoid the most heavily contaminated areas
- managing grazing to minimise build up of infection in grazing areas
- managing manure to prevent spread of eggs and larvae from housed animals
- increasing stall feeding to reduce pasture intake during risk periods
- avoiding grazing completely during the riskier wet months
- using cut and carry forage grasses and weeds to boost nutrition and enhance resilience
- using anti-parasitic tree forages such as mulberry to reduce parasite burden
- using nutritional supplementation purchased as by-products such as rice polish and mustard cake
- using non-conventional feeds for goats such as poultry manure and brewers grain



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

- treating kids strategically with anthelmintics to suppress build-up of infection during risk periods
- using supportive therapy for sick goats including symptomatic treatment to permit survival and recovery, for example, protein and energy supplementation and anti-scouring agents
- managing breeding to reduce the number of susceptible animals present during the risk periods.

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

Sedentary system case study — Pyughar Village

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

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

Constraints to goat production

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

Symptoms and seasonality of disease

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

Disease management

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

Transhumance sheep and goat production in the mountain districts

Farming system

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

Livestock management

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

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

Animal health issues in small ruminants

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

Helminth problems

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

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

Transhumance system case study — Ghandruk village

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

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

Constraints to sheep and goat production

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

Symptoms and seasonality of disease

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

Disease management

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

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

Options for helminth control

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

Conclusions

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

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

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

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

Table 6.2 The significance and growth of livestock production per region

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

Source: Agriculture Perspective Plan (1995)

Table 6.3 The importance of ruminant livestock in different regions	Terai	Hills	Mountains
Livestock cash income (% of total cash income)	9.7%	19.7%	21.2%
Labour utilisation for livestock (man days)	64	73	51
Goat numbers (000s)	1,828	3,396	855
Sheep numbers (000s)	122	386	361
Percentage of households keeping goats	46.8	54.2	55.5
Percentage of households keeping sheep	1.8	4.2	6.5

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

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

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

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

The problem

When does the problem occur?

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

What are the causes?

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

How the damage occurs

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

Interaction with management

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

Grazing control and managment

Grazing control

- to avoid the most heavily contaminated areas

Grazing management

- to minimise build up of infection in grazing areas

Manure management

- to prevent spread of eggs and larvae from housed animals

Stall feeding

Increased stall feeding

- to reduce pasture intake during risk periods

Zero grazing during wet months

- to avoid grazing completely during risk periods

Table 6.4 Use the right drug for the right worms

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

Cut and carry forage grasses and weeds

- to boost nutrition and enhance resilience

Anti-parasitic tree forages

- use of forages such as mulberry to reduce parasite burden

Purchased by-products

- nutritional supplementation with rice polish, mustard cake,

Use of non-conventional feeds

- brewers grain, poultry manure etc.

Use of anthelmintics

Improved knowledge and use of anthelmintics

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

Strategic treatment of kids

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

Supportive therapy for sick goats

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

Breeding management

Better breeding management

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

Best practice for drug use

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

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

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

G.M. Hood

Introduction

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

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

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

Model details

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

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

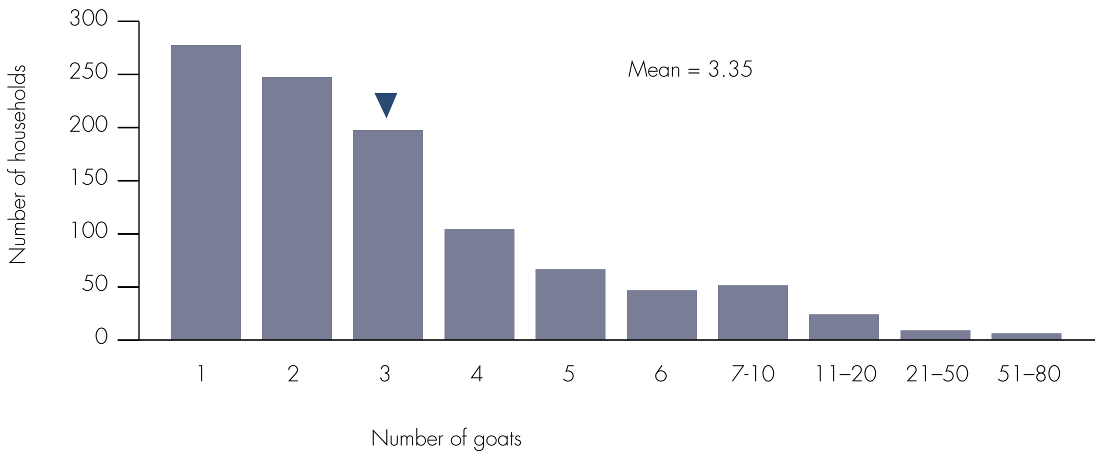
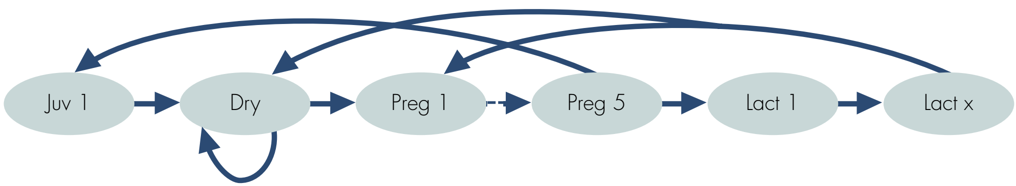


Figure 7.2 Lifecycle diagram showing stages of the goat's breeding cycle



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

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

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

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

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

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

Analysis

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

Table 7.1 Default parameter set

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

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

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

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

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

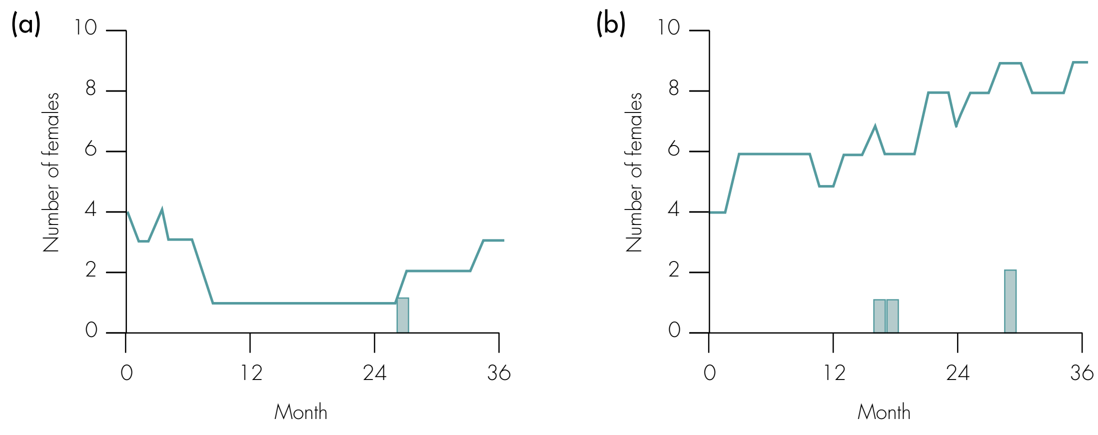


Table 7.2 'Housed' parameter set	
Parameter	Value
Pre-weaning mortality	5%
Post-weaning mortality	5%
Adult mortality	5%
Age at sale	8
Breeding age	10
Conception rate	70%
Weaning age	3
Twinning rate	45%

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

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

Moving from a small to a medium-scale enterprise

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

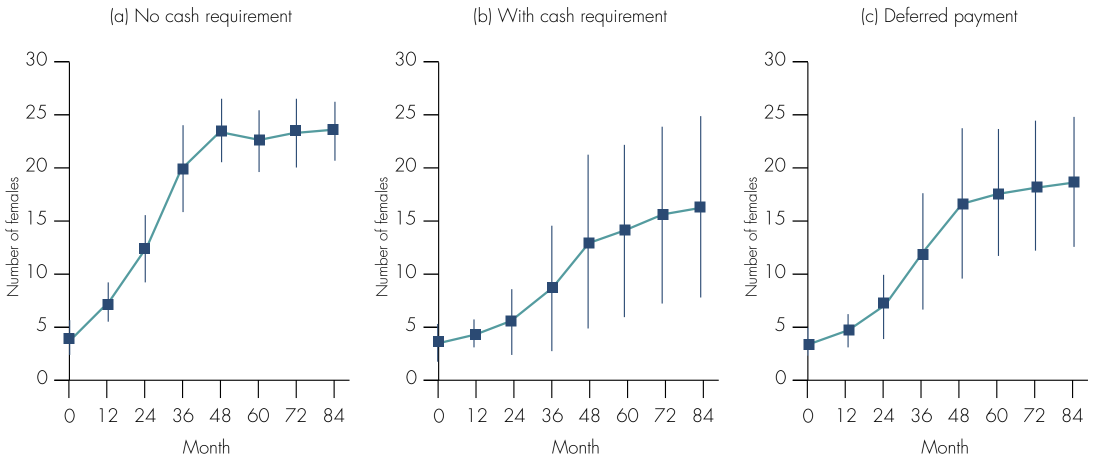
Figure 7.4 shows the mean of 100 trajectories using the 'Housed' parameter set, but with the imposition of a ceiling of 12 adult breeders (that is, breeders are culled to reduce herd size when the ceiling is

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

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

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

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



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

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

Conclusion

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

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8. Worm control for small ruminants in the Philippines

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

Introduction

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

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

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

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

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

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

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

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

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

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

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

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

Host-parasite relationships and worm control options

Descriptions of parasites of small ruminants in the Philippines

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

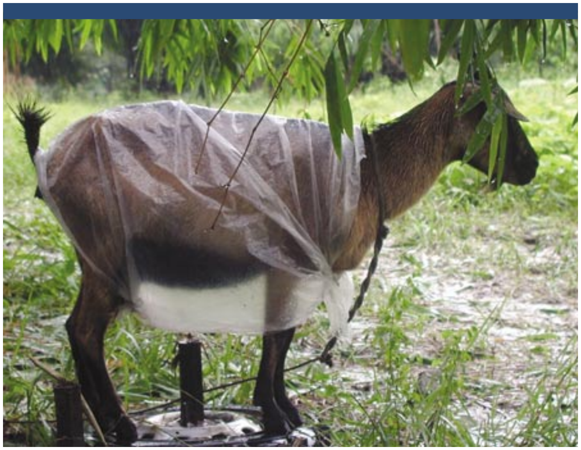
The parasites (helminths and protozoa) of goats from a large number of provinces in the Philippines have been subjected to an extensive study (Tongson et al., 1981). 1230 faecal samples were examined and 39 goats necropsied. From the faecal examinations the four outstanding genera were *Trichostrongylus,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

In a comprehensive account of the worldwide distribution of paramphistomes Eduardo (1988) lists *Cotylophoron cotylophorum* as a rumen fluke of sheep and goats in the Philippines, *Carmyerius synethes* and Fischoederius cobboldi as rumen flukes of goats and the pancreatic fluke *Eurytrema pancreaticum* in goats. Tongson and Trovela (1980) found no correlation between faecal egg counts and worm burdens in 'grade Spanish Merino' sheep of various ages infected with *Haemonchus contortus*, *Oesophagostomum*, *Trichostrongylus* and *Cooperia*. Likewise there was no correlation between worm size and worm burden but there was a significant correlation between adult female numbers and faecal egg count. The ages of the sheep at slaughter were 3, 6, 12, 18 and 24 months with four animals killed at each age. In assessing the value of the lack of correlation the small number of animals in each class needs to be noted. Although not conclusive, this paper reinforces the warning that egg counts alone are not necessarily an indication of worm burden, although they are a direct measurement of pasture contamination.

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

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

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



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

Worm control programs

One study strongly supports the concept of rapid rotational grazing systems in the Philippines (Barger 1996). [An interesting early reference to rapid rotational grazing systems in tropical conditions may be found in Spindler (1936) and Thomson and Carr (1957) who said that, in the tropics, small ruminants should be kept off pasture for 21–28 days.] Worm eggs from a native goat infected with several nematode species were maintained either under direct sunlight or in shade for several weeks, and at weekly intervals the viability of the eggs and larvae developing from them were estimated. Although the study was undertaken in Petri dishes and a direct comparison with pasture conditions cannot be made, the viability of deposited eggs to be recovered as larvae after 4 weeks was nil in the sunlight exposed samples and very low in the shaded samples (Tongson and Dimaculangan, 1983). The humidity of the samples was maintained at >85% throughout. The recommendation from this study was that pastures should be rested for at least 4 weeks after grazing by infected goats and that this should be tested under field conditions.

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

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

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

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

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

6. Keep animals well nourished, supply vitamin and mineral supplements.

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

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

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

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

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

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

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

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

Impact of helminths on production

Kingscote (1968) estimated the impact of parasites in general on Philippine sheep and goats as 10% of the value of production and included 'unthriftiness, death and predisposition to other diseases' as the sources of that loss. Justification for this figure is not provided because none was available: economic estimates of the wide and long-term effects of helminth infections are difficult to obtain experimentally, especially under field conditions. However, comparison between parasitised and non-parasitised goats in two barangays in southern Luzon (Que et al., 1995) showed that they differed in growth by several kilos over a period of 8 months representing a good return on investment from a single dose of anthelmintic. Such studies are often difficult to interpret (see Chapter 1) when the experimental and control (treated) animals are, as in this case, grazed separately on different farms. Nevertheless the result does point to a substantial impact of helminths on growing goats. A series of papers by Howlader et al. (1997a, 1997b, 1997c) describes the pathological, parasitological and production changes in young goats of different ages infected artificially with varying doses of *H. contortus*. Kids born of infected mothers had their growth affected by infection (about 70g/day over 5 weeks after birth compared with around 20g/day for the kids of uninfected dams) but this impact was not dependent on infective dose. Growing goats gained less weight than uninfected counterparts: about 4g/day in infected kids compared with about 19g/day in uninfected kids. Once again, the effect was not dependent of the level of infection given to the experimentally infected animals. In the same growing goats there was no effect of infection on circulating leukocyte numbers and a moderate effect on erythrocyte numbers. Related studies (Howlader et al., 1996a, 1996b) showed similar effects on growth and blood parameters as the result of *Haemonchus* infection. It is difficult to relate these results to field conditions but once again they point to a significant impact on the performance of young and old goats.

Anthelmintic plants and biological control

Medicinal plants as anthelmintics

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

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

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

Table 8.1 Plants with anthelmintic effect for ruminants

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

Source: Loculan and Mateo, 1986

Table 8.2 Medicinal plants with anthelmintic effect

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

Source: (Mateo, 1987)

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

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

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

Nutritional supplementation

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

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

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

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

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

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

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

There have been some grazing trials using supplementation. Gerona et al. (1984) compared the production of supplemented and non-supplemented

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

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

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

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

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

Genetic variation in production and resistance to disease

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

Genetic differences between sheep and goats

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

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

Production differences between and within breeds

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

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

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

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

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

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

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

Source: Matias et al., 1997

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

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

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

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

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

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

continued over

Table 8.4 continued

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

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

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

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

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

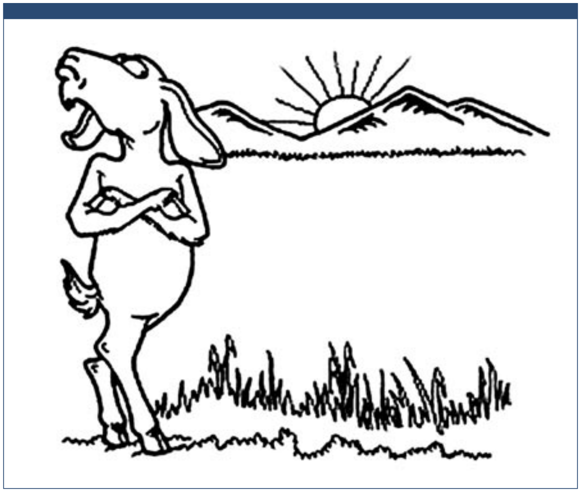
Like many authors, Arboleda uses the term 'Native' for sheep and goat populations which have been present in the Philippines for many years and which cannot be assigned to any distinct or recently imported breed. Because of the island nature of the Philippines, lack of a sophisticated breeding and marketing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

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

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

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

Effect of breed on resistance to parasites

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

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

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

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

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

Source: Barcelo and Ancheta, unpublished data.

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

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

Source: Barcelo and Ancheta, unpublished data.

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

Use of anthelmintics and anthelmintic resistance

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

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

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

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

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

Measurement of production in grazing environments

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

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

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

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

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

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

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

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

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

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

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

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

Conclusions

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

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

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

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9. Worm control for small ruminants in Indonesia

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

Introduction

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

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

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

9. Worm control for small ruminants in Indonesia

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

Endoparasites of small ruminants in Indonesia

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

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

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

Worm control options

Grazing management

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

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

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

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

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

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

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

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

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

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

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

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

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

Anthelmintics

Plants and plant products as anthelmintics

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Commercial anthelmintic products

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

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

Comparing the broad-spectrum anthelmintic, levamisole-phosphate, with the long-acting narrow-spectrum product, closantel, in naturally infected village sheep showed that levamisole could significantly improve the weight gain of animals (Beriajaya and Stevenson 1985a, 1985b). Based on the slaughter value of the treated animals and the cost of the drug used, there was a clear financial benefit from treating the sheep. Beriajaya and Stevenson (1986), comparing four anthelmintics in

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

sheep and goats, found that broad-spectrum anthelmintic significantly increased weight gain. Closantel treatment, which was effective in removing *Haemonchus* but had little effect on the other nematode species, did not result in significant improvement in weight gain. Similarly, no weight gain was seen using disophenol, a long-acting narrow spectrum anthelmintic given as a single injection. These results suggest that nematodes other than *Haemonchus* are the cause of reduced weight gain.

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

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

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

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

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

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

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

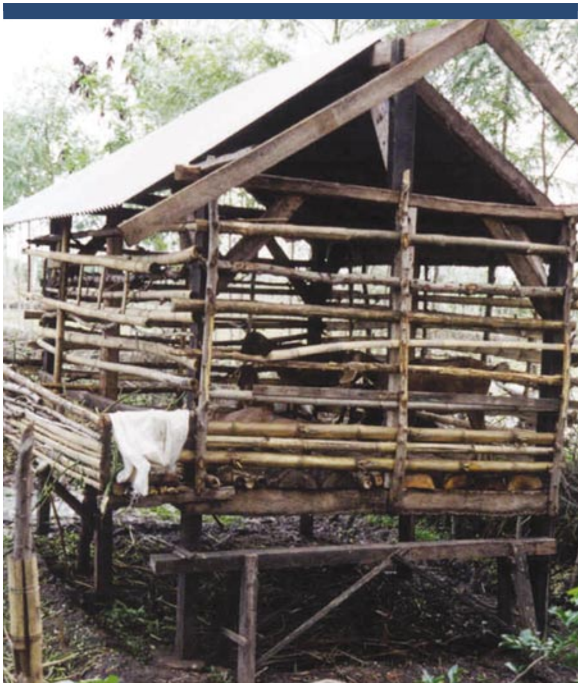
Gatenby et al. (1992a, 1992b) studied the effectivenes of nitroxynil, praziquantel and albendazole against pancreatic fluke (*Eurytrema pancreaticum*). Results showed that albendazole and praziquantel significantly reduced the level of pancreatic fluke infection, but neither drug reduced it to a negligible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

Resistance

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

Delivering commercial anthelmintics to farmers

Cost–benefit analyses of parasite control in sheep using commercial anthelmintics show good returns on the health care investment. Marginal return using parasite control amounts to Rp 42,000 revenue for Rp 4200 treatment



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

expenses. This suggests that making anti-parasite treatment available to farmers on a non-subsidised free-market basis is viable. The rapid improvements in animal condition from just one treatment, and the provision of practical information, are likely to make farmers willing to invest in parasite control (Scholz 1992). Misniwaty et al. (1994) reported that anthelmintic cost was only 1.8–3.0% of the total revenue received from selling fattened sheep.

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

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

Biological control

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

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

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

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

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

Table 9.4 Summary of *Fasciola* vaccination studies in Indonesia

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

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

Vaccination

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

Nutritional supplementation

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

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

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

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

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

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

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

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

Genetic variation in resistance to parasites

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

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

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

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

A series of studies by Roberts et al. (1995, 1996a, l997c) showed that a dominant gene may induce the mechanism of resistance in Indonesian thin-tail sheep. They also found indications that IgG2 acts as blocking antibody that interferes with the mechanism of resistance. Hansen et al. (1999) postulated that IgG2 could act as a blocking antibody for protective effector responses against *F. gigantica* in sheep and that the Indonesian thin-tail sheep, by downregulating IgG2 responses, have an enhanced capacity for killing *F. gigantica in vivo*.

A worm control program in Indonesia

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

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

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

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

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

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

Conclusions

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

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

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